TVA 10752 (OE 6-85)

CEB REPORT

TITLE		REPORT NO.
Sequoyah Nuclear Plant - Concrete Nondestructive Testing	ENCLOSURE 2	CEB 87-02
		PLANT/UNIT
		SAR SECTIONS

VENDOR	CONTRACT NO.	KEY NOUNS	UNID SYSTEM(S)
		Concrete, Nondestructive Testing	

	REV	(FOR RIMS USE)	RIMS ACCESSION NUMBER
VENDOR	R0		B41 '870127 003
APPLICABLE DESIGN DOCUMENTS	R1		
	R2		
REFERENCES	R3		
	R4		

TENNESSEE VALLEY AUTHORITY
OFFICE OF ENGINEERING
CIVIL ENGINEERING BRANCH

	REVISION 0	R1	R2	R3	R4
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CEB REPORT

SEQUOYAH NUCLEAR PLANT

CONCRETE NONDESTRUCTIVE TESTING

Introduction

A review of the computer printout of the "Concrete Cylinder Data" (CSG-87-005), which is the data base of the strength tests of standard cured concrete cylinders from Sequoyah Nuclear Plant, revealed periods of time when the results did not meet the requirements of General Construction Specification No G-2 for Plain and Reinforced Concrete. This specification required that no more than 10 percent of the strength test results be below the specified strength for specified strengths equal to or greater than 3000 psi and no more than 20 percent for specified strengths less than 3000 psi. The effect of this deficiency on the Category I structures was investigated using estimated in-place strengths which were developed using the results of a test program reported in CEB 86-12 "Study of Long Term Concrete Strength of Sequoyah and Watts Bar Nuclear Plants." It was later verified that the equivalent specified strengths based on 90 days standard cured cylinders also satisfy design requirements. Nondestructive concrete testing was performed to provide additional verification of the adequacy of the inplace concrete. This report documents the results of those tests.

Procedure

Six mixes which had time periods when more than 10 percent of the strength test results were less than the specified strength were investigated. These mixes were: 300.75 AFW, 301.5AFW, 401.5AFW, 500.75 AFWG, 500.75 AFW, and 800.75 BFW. (The 401.5AFWR mix had been previously evaluated). Using a computer printout of the "Concrete Pour Card Data Base" (CSG-87-004) an attempt was made to randomly select a number of pours that were placed during acceptable strength periods and a number of pours that were placed during low strength periods but which contained only one mix. If the selected pours were accessible they were tested per ASTM C803 for penetration resistance and per ASTM C805 for rebound number.

Test Results

Test results are listed in Table I. When initial selections were made from the pour data base it was not noted that some pours were split. Three pours, 0-A2CPABAB15B, 20D and 21A (OBs. 1, 12 and 13) which required 301.5BFW concrete were split and were completed using 401.5 AFW concrete during a low strength period. Initial selection was to represent low strength 4000 psi concrete but since the pours incorporate substantial quantities of other mixes, the test results were attributed to the lower strength mixes.

Two pours 0-A2CPABAB24-13 and-16 were split and both partial pours were tested. The lower portion of -13 (Obs 15) was placed with 4000 psi concrete during an acceptable strength period whereas the upper portion (Obs 5) was placed with 3000 psi concrete during a low strength period. The lower portion of -16 (Obs 17) was also placed with 4000 psi concrete during an acceptable strength period whereas the upper portion (Obs 18) was placed with the same mix during a low strength period.

Strength test results for both 28 and 90 days are provided when samples were attributable to specific pours. The pours randomly selected during low strength periods were selected without regard to such test results. The test results indicate that even though the pours were made in low strength periods, the specific tests attributable to the pours were not low in strength.

The column headed ESS provides the equivalent specified strength (approximately the strength below which no more than 10 percent of the strength test results would occur) for the time period in which the pour was made. The column headed PE provides the average probe extension and the column headed RN the average rebound number for the tested pour. All slabs were tested from the underside. Five units[1] were subtracted from the rebound numbers determined vertically upward before listing here and comparing them to the other rebound numbers determined horizontally.

Discussion

Only the 3000A and 5000A mixes have sufficient data for independent analysis. Table 2 contains the statistical analysis of the 3000A rebound numbers. Sample 1 contains the pours made during time periods with acceptable strengths and sample 2 those made during time periods when there was an excessive number of low strength test results. Note that the average and the median of rebound numbers is higher for sample 2 than for sample 1. Table 3 contains similar information for probe extensions. Differences between sample 1 and 2 are not statistically significant.

Tables 4 and 5 contain the analyses of rebound numbers and probe extensions for 5000A concrete. Again, differences between sample 1 and 2 are not statistically significant.

Table 6 contains the regression analysis for the 90 day strength of standard cured cylinders as a function of the rebound numbers. The data is plotted on figure 1 together with the 95 percent confidence limits for the mean and for individual test results. Table 7 and figure 2 contain similar information for probe extension data. The fit of the regression equations for both test methods is not good. The probe and rebound hammer regression equations have correlation coefficients of 0.19 and 0.55, respectively, (1.0 equals perfect fit). The lowest rebound number obtained, 34 (Obs 1), appears to indicate a concrete with a standard cured 90 day cylinder strength of 4900 psi.

Conclusions

The following conclusions are made.

1. The test data does not indicate any unacceptable concrete.

2. The test data does not indicate a statistically significant difference between the concrete placed during low strength periods and that placed during acceptable strength periods.

Reference:

[1]Malhotra, V. M., "Testing Hardened Concrete: Nondestructive Methods," Monograph No. 9, American Concrete Institute, Detroit, Mich.

TABLE 1

OBS	MIX	DAY28	DAY90	ESS	PE	RN	POUR	FEATURE
1	3000A			3000	1.66	34	0-A2CPABAB15B	WALL
2	3000A	3890	6615	3000	2.13	42	0-A2CPABAB09-06A	WALL
3	3000A	3165	5580	2600	2.17	49	0-A2CPABAB10-17H	SLAB
4	3000A	3390	4990	3000	1.83	39	0-A2CPABAB22-02A	SLAB
5	3000A	4960	7075	2600	2.01	51	0-A2CPABAB24-13	WALL
6	3000A	3470	5130	2700	2.05	40	0-A2CPABPT-B-14C	WALL
7	3000A			3000	2.09	44	0-C2CPCBCB1-05E	WALL
8	3000A	4280		3000	2.19	56	0-C2CPCBCB1-12A	SLAB
9	3000A	3570	5240	3000	1.90	39	05D-CPDADGB-4-3E	WALL
10	3000A	3550		3000	2.11	51	1-R2COR1RB1-3-10D	SLAB
11	3000A	4045	6190	3000	2.12	44	2-R2CPR2RB2-3-10D	SLAB
12	3000B	2670	3890	3000	1.96	43	0-A2CPABAB20D	WALL
13	3000B	2370	3575	3000	2.18	49	0-A2CPABAB21A	WALL
14	4000A			4000	1.99	41	0-A2CPABAB18A	WALL
15	4000A	5080	8490	4000	1.99	51	0-A2CPABAB24-13	WALL
16	4000A	4910	6580	3300	2.23	47	0-A2CPABAB24-14	SLAB
17	4000A	4840	7470	4000	2.15	52	0-A2CPABAB24-16	WALL
18	4000A	4980	7215	3300	2.24	57	0-A2CPABAB24-16	WALL
19	5000A			4800	2.22	53	0-A2CPABAB25-01P	WALL
20	5000A	6795	8595	4800	2.09	52	0-A2CPABAB25-1U	WALL
21	5000A			4800	2.25	55	0-A2CPABAB25-1Y	WALL
22	5000A	5465	7520	5000	1.93	55	1-R2CPR1RB1-15A	WALL
23	5000A			4800		49	1-R2CPR1RB1-23A	WALL
24	5000A	5005	6510	4800		48	1-R2CPR1RB1-24A	WALL
25	5000A	5625	7305	5000	1.99	58	1-R2CPR1RB1-4-23C	WALL
26	5000A	6350	9550	5000	2.09	45	1-R2CPR1RB1-8A	WALL
27	5000A	6010	8390	5000	2.06	42	1-R2CPR1RB1-9A	WALL
28	5000A	5400	7995	4600	2.10	57	1-R2CPT1RB1-4-23B	WALL
29	5000A	6100	8630	4800	2.10	53	2-R2CPR2RB2-11A	WALL
30	5000A	6385	8210	5000	2.05	56	2-R2CPR2RB2-15A	WALL
31	5000A	5990	7340	4600	2.00	52	2-R2CPR2RB2-4-16E	SLAB
32	5000A			4800	1.93	43	2-R2CPR2RB2-4-17E	BEAM
33	5000A	6380	9090	4800	2.09	49	2-R2CPR2RB2-4-18E	WALL
34	5000A	5270	7500	5000	2.03	49	2-R2CPR2RB2-8A	WALL
35	8000B	7690	9975	8000	2.13	56	1-R2CPR1RB1-16A	COL
36	8000B	6400	9055	8000	2.12	57	2-R2CPR2RB2-16A	COL

Day 28 = Strength test result at 28 days
Day 90 = Strength test result at 90 days
ESS = Equivalent specified strength
PE = Average probe extension
RN = Average Rebound Number

TABLE 2 - TWO-SAMPLE ANALYSIS RESULTS - 3000A REBOUND NO.

		Sample 1	Sample 2	Pooled
Sample Statistics:	Number of Obs.	8	3	11
	Average	43.625	46.6667	44.4545
	Variance	49.4107	34.3333	46.0602
	Std. Deviation	7.02928	5.85947	6.78677
	Median	43	49	44

Conf. Interval For Diff. in Means: 95 Percent

(Equal Vars.) Sample 1 - Sample 2 -13.4383 7.35501 9 D.F.

(Unequal Vars.) Sample 1 - Sample 2 -14.3148 8.23147 4.4 D.F.

Conf. Interval for Ratio of Variances: 0 Percent

Sample 1 ÷ Sample 2

Hypothesis Test for HO: Diff = 0 Computed t statistic = -0.662

vs Alt: NE Sig. Level = 0.524559

at Alpha = 0.05 so do not reject HO.

TABLE 3 - TWO-SAMPLE ANALYSIS RESULTS - 3000A PROBE EXTENSION

		Sample 1	Sample 2	Pooled
Sample Statistics:	Number of Obs.	8	3	11
	Average	2.00375	2.07667	2.02364
	Variance	0.0345696	6.93333E-3	0.0284232
	Std. Deviation	0.185929	0.0832666	0.168607
	Median	2.1	2.05	2.09

Conf. Interval For Diff. in Means: 95 Percent

(Equal Vars.) Sample 1 - Sample 2 -0.331206 0.185373 9 D.F.

(Unequal Vars.) Sample 1 - Sample 2 -0.259819 0.113985 8.2 D.F.

Conf. Interval for Ratio of Variances: 0 Percent

Sample 1 ÷ Sample 2

Hypothesis Test for HO: Diff = 0 Computed t statistic = -0.638794

vs Alt: NE Sig. Level = 0.538871

at Alpha = 0.05 so do not reject HO.

TABLE 4 - TWO-SAMPLE ANALYSIS RESULTS - 5000A REBOUND NO.

		Sample 1	Sample 2	Pooled
Sample Statistics:	Number of Obs.	6	10	16
	Average	50.8333	51.1	51
	Variance	42.1667	15.8778	25.2667
	Std. Deviation	6.49359	3.98469	5.0266
	Median	52	52	52

Conf. Interval For Diff. in Means:		95 Percent	
(Equal Vars.)	Sample 1 - Sample 2	-5.33534 5.30201	14 D.F.
(Unequal Vars.)	Sample 1 - Sample 2	-7.15061 6.61728	7.3 D.F.

Conf. Interval for Ratio of Variances: 0 Percent
Sample 1 ÷ Sample 2

Hypothesis Test for H0: Diff = 0	Computed t statistic = -0.102733
vs Alt: NE	Sig. Level = 0.919632
at Alpha = 0.05	so do not reject H0.

TABLE 5 - TWO-SAMPLE ANALYSIS RESULTS - 5000A PROBE EXTENSION

		Sample 1	Sample 2	Pooled
Sample Statistics:	Number of Obs.	6	8	14
	Average	2.025	2.0975	2.06643
	Variance	3.27E-3	0.01085	7.69167E-3
	Std. Deviation	0.0571839	0.104163	0.0877021
	Median	2.04	2.095	2.075

Conf. Interval For Diff. in Means:		95 Percent	
(Equal Vars.)	Sample 1 - Sample 2	-0.175725 0.0307252	12 D.F.
(Unequal Vars.)	Sample 1 - Sample 2	-0.168266 0.0232665	11.2 D.F.

Conf. Interval for Ratio of Variances: 0 Percent
Sample 1 ÷ Sample 2

Hypothesis Test for H0: Diff = 0	Computed t statistic = -1.53068
vs Alt: NE	Sig. Level = 0.151775
at Alpha = 0.05	so do not reject H0.

TABLE 6 - REGRESSION ANALYSIS - LINEAR MODEL : Y = a + bX

Dependent variable: DAY90 Independent variable: RN

Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	-387.155	2266.65	-0.170805	0.865752
Slope	152.9	45.6296	3.35097	2.5608E-3

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	Prob. Level
Model	21414705	1	21414705	11	.00256
Error	47677197	25	1907088		
Total (Corr.)	69091902	26			

Correlation Coefficient = 0.556727 R-squared = 30.99 percent
Stnd. Error of Est. = 1380.97

TABLE 7 - REGRESSION ANALYSIS - LINEAR MODEL : Y = a + bX

Dependent variable: DAY90 Independent variable: PE

Parameter	Estimate	Standard Error	T Value	Prob. Level
Intercept	529.496	7014.01	0.0754912	0.94045
Slope	3217.96	3389.8	0.949307	0.351927

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	Prob. Level
Model	2484783.8	1	2484783.8	.9	.35193
Error	66173851	24	2757244		
Total (Corr.)	68658635	25			

Correlation Coefficient = 0.190238 R-squared = 3.62 percent
Stnd. Error of Est. = 1660.5

FIGURE 1

(X 100) REGRESSION OF STRENGTH ON REBOUND NUMBER

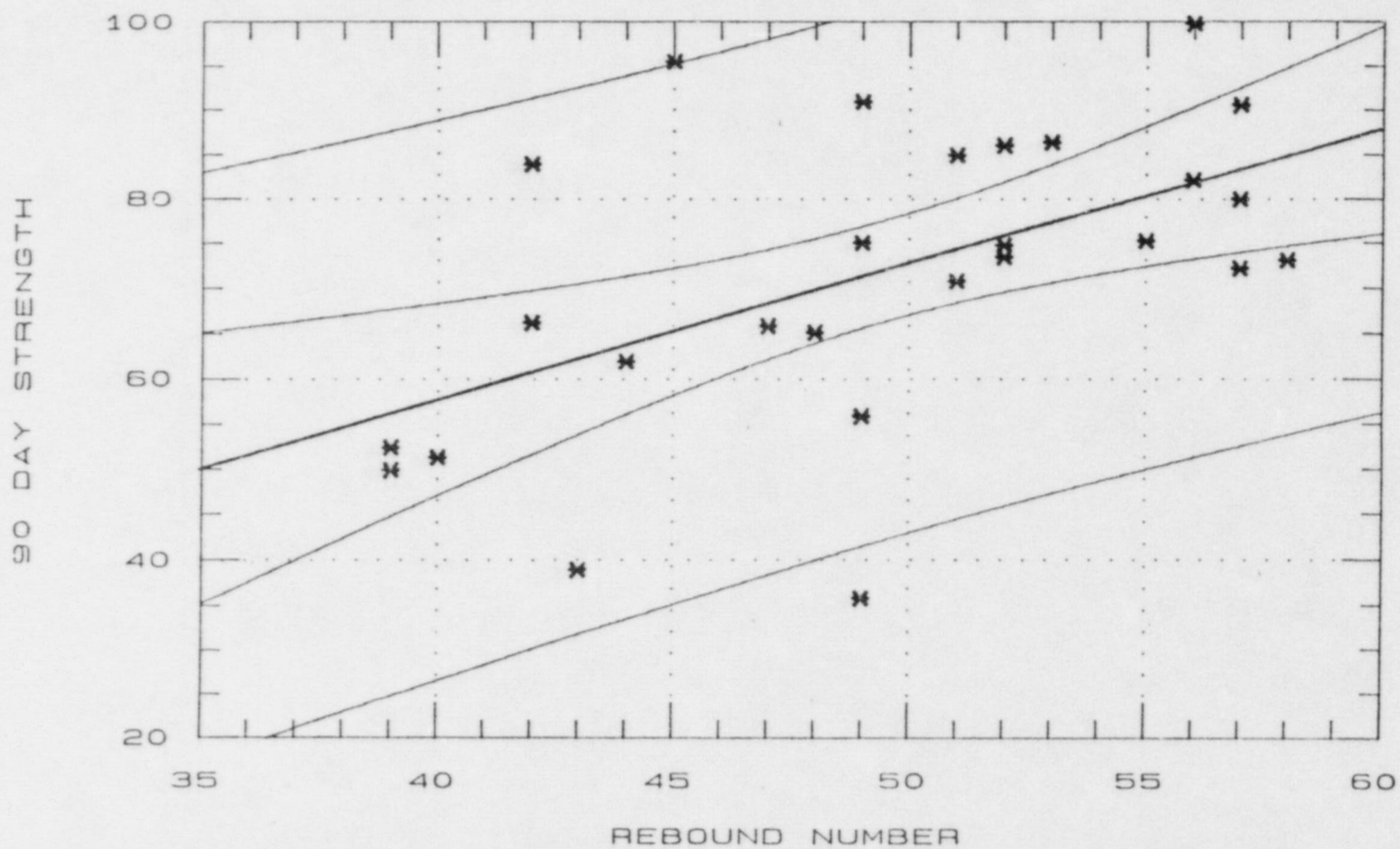

FIGURE 2

REGRESSION OF STR ON PROBE EXTENSION