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M. P. Gillen
Portland Cement Association

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STRENGTH AND ELASTIC PROPERTIES TESTS OF HANFORD CONCRETE CORES - 241-SX-115 TANK AND 202-A PUREX CANYON BUILDING

Prepared for Rockwell Hanford Operations

by

Michael P. Gillen

CONSTRUCTION TECHNOLOGY LABORATORIES
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February 1982

Prepared for United States
Department of Energy
Under Contract DE-AC06-77RL01030

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EXECUTIVE SUMMARY

This report, prepared by the Portland Cement Association in support of the Long-Term High-Level Defense Program, Tank Evaluation Methods Task (H2-42) documents part of an investigation to evaluate methods for assuring long-term performance of waste storage tanks at the Hanford Site. Results of material properties tests of concrete cores from the haunch and wall of 241-SX-115 tank and the 202-A Purex Canyon Building are given. These are the first material properties tests performed on load supporting (haunch and wall) concrete from a waste tank. As the wall concrete experienced higher temperatures, resultant material properties were expected to be lower than those determined from previous samples taken from a tank dome. The results are also compared to controlled laboratory tests performed on new samples made using the Hanford mix. The Purex concrete was tested as a "base line" as the 202-A Building and the 241-SX tanks were built at the same time (1953-54) using the same concrete mix design. The 202-A Building concrete was not exposed to elevated temperatures.

Average values from the 241-SX-115 concrete samples were: compression strength = 3825 to 6960 psi; splitting tensile strength = 494 to 933 psi; modules of elasticity = 2.84 to 5.88 million psi; and Poisson's ratio = 0.15 to 0.26. These values were somewhat less than measured for dome concrete and about the same as earlier controlled laboratory samples. A pattern of possible decreasing strength with depth was observed, but all samples were above design values.

The Purex cores were tested under 3 temperature conditions: unheated, 200°F, and heated to 200°F then cooled to ambient. In the past, concrete specimens had been heated at a rate of 3.6°F/minute or faster; in this test the concrete was heated at a rate of 75°F/day to determine if the heat-up rate was significant. The final test was to determine if strength is recovered upon cooling. Earlier tests assumed no strength recovery. For the 72°F test, the 202-A Building concrete compressive strength ranged from 3440 to 6340 psi. These values, as well as modulus of elasticity, splitting tensile strength and Poisson's ratio, are significantly less than values from previous Purex cores tested and are less than the 241-SX samples. After heating to 200°F, compressive strength ranged from 3770 to 4370 psi, indicating that any decreases would be screened by variations of the basic concrete mix. Samples heated to 200°F and then cooled had a compressive strength ranging from 3825 to 6960 psi, indicating some strength recovery upon cooling.

It is concluded that there is a greater variation than previously realized between concrete batches made to the same mix design indicating temperature effects may not be as crucial as earlier thought. It is also noted that assuming higher concrete strengths based on a few samples would not be prudent.

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STRENGTH AND ELASTIC PROPERTIES TESTS OF HANFORD CONCRETE CORES - 241-SX-115 TANK AND 202-A PUREX CANYON BUILDING

ABSTRACT

Specimens fabricated from concrete cores obtained from the Tank 241-SX-115 and the 202-A Purex Canyon Building located at Hanford, Washington, were tested to determine compressive strength, splitting tensile strength, modulus of elasticity, and Poisson's ratio. Average values obtained from 18 Tank Farm cores were: compressive strength = 5550 psi; splitting tensile strength = 765 psi; modulus of elasticity = 4.98 million psi; and Poisson's ratio = 0.21.

Tests were conducted on 17 specimens from the 202-A Purex Building under three temperature conditions: unheated, heated to 200°F, and heated to 200°F and then cooled to ambient. Average values for unheated concrete were: compressive strength = 4810 psi; splitting tensile strength = 428 psi; modulus of elasticity = 3.53 million psi; and Poisson's ratio = 0.18. For specimens heated to 200°F, average values were: compressive strength = 4040 psi; modulus of elasticity = 2.37 million psi; and Poisson's ratio = 0.14. For Purex Building specimens heated to 200°F and subsequently tested at 72°F, average values were: compressive strength = 4720 psi; modulus of elasticity = 2.83 million psi; and Poisson's ratio = 0.18.

In addition to physical tests, a visual examination was made of all core materials as received. Six specimens were found to have visible cracks varying from 2 to 10 in. in length. Also, several pieces of large aggregate in two core samples were found to have cracks; however, no other signs of deterioration of cement matrix or aggregates were visible.

This report has been prepared for Rockwell Hanford Operations (Rockwell) as part of an investigation to evaluate long-term performance of waste storage tanks at the Hanford Site and was funded by the Long-Term High-Level Defense Waste Program (AR-05-15-20).

INTRODUCTION

Thirty-seven core sections were received at the Construction Technology Laboratories of the Portland Cement Association in August 1981. These samples were obtained from the haunch, wall, and footing of single-shell Tank 241-SX-115. Samples consisted of approximately 32 ft of 2.7-in. nominal diameter core in different lengths.

Also in August 1981, an additional shipment of 17 concrete core samples was received. These were identified as being taken from the N and M Cell areas of 202-A Purex Canyon Building. Specimens labeled No. 1 to No. 10 were approximately 5.5 in. in diameter, and 8 to 12 in. in length. Specimens labeled No. 11 to No. 16 were about 7.5 in. in diameter, and 7 to 11.5 in. long. Specimen labeled No. 17 was 3.5 in. in diameter, and 10

in. long. All core samples were obtained and shipped by Rockwell Hanford Operations, Richland, Washington.

The test program consisted of a visual inspection of all core samples, and the determination of compressive strength, splitting tensile strength, modulus of elasticity, and Poisson's ratio from concrete specimens cut from core sections. A total of 18 241-SX-115 Tank specimens were used for strength and elastic properties determinations at room temperature. Specimens were cut from core sections such that three test specimens were obtained for each 5 ft of core depth.

Seventeen concrete cores from the 202-A Purex Building were also fabricated into specimens for strength and elastic properties determinations. Sixteen of these cores were re-cored to provide test specimens of uniform diameter. Eleven Purex Building specimens were tested at ambient conditions. Three specimens were tested at 200°F. The remaining three specimens were tested after being heated to 200°F and then cooled to room temperature.

VISUAL INSPECTION

All core materials were visually examined when received to determine the presence of cracks, voids, aggregate segregation, discoloration, or any signs of concrete deterioration. Results of this inspection are given in Table A1 of Appendix A for Tank Farm cores and Table A2 of Appendix A for Purex Building cores.

Four Tank Farm cores and two Purex Building cores were found to have visible cracks, ranging from approximately 2 to 10 in. in length. Also several large aggregate pieces in one core sample from each structure were found to have cracks. No other visible signs of concrete deterioration were observed.

STRENGTH AND ELASTIC PROPERTIES TESTS

After visual inspection, core materials were fabricated into cylindrical test specimens, heated if required, and subjected to elastic properties and strength tests. Details of each phase of specimen preparation and testing are given in the following sections.

Specimen Fabrication

The Hanford 241-SX-115 Tank specimens were cut from 2.7-in. nominal diameter cores. Specimens were cylinders approximately 2.7 in. diameter by 5.4 in. long. Tank Farm specimen dimensions are listed in Table B1 of Appendix B. Three test specimens were prepared from each 5-ft increment of core depth (total depth was approximately 32 ft). Eighteen Tank Farm specimens were fabricated for strength and elastic properties testing.

Because cores from the 202-A Purex Building were of differing diameters, it was decided to re-core these samples to provide specimens of uniform cross-sectional area. This was done by casting Core Samples No. 1 to No. 16 into a concrete slab and taking one 3.7-in. diameter core from each original core sample. The re-cored cylindrical samples were then cut to provide test

specimens with nominal dimensions of 3.7 in. diameter by 7.4 in. length. Core Sample No. 17 was 3.5 in. in diameter as received, and therefore, it was unnecessary to re-core this sample. Dimensions of the 17 Purex Building test specimens are listed in Table C1 of Appendix C.

Ends of all concrete test cylinders were lapped plane to assure uniform distribution of load during elastic properties and strength tests.

Test Equipment and Procedures

Equipment and methods used for mechanical testing of specimens are described below.

Modulus of Elasticity and Poisson's Ratio. Elastic constants for 2.7 by 5.4-in. and 3.7 by 7.4-in. test cylinders were determined using compressometers similar to that described in American Society for Testing and Materials (ASTM) Designation: C469 "Standard Method of Test for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression."[1] The compressometers utilized linear variable differential transformers to measure axial and lateral strains. A third differential transformer in the testing machine was used to indicate load.

A cylinder with compressometer in place ready for testing is shown in Figure 1. Axial strain, lateral strain, and load were recorded simultaneously on an X-Y-Y plotter. Elastic constants were obtained from slopes of the plotted curves.

Specimens were loaded four times to approximately 40 percent of their strength. The first loading was to seat the

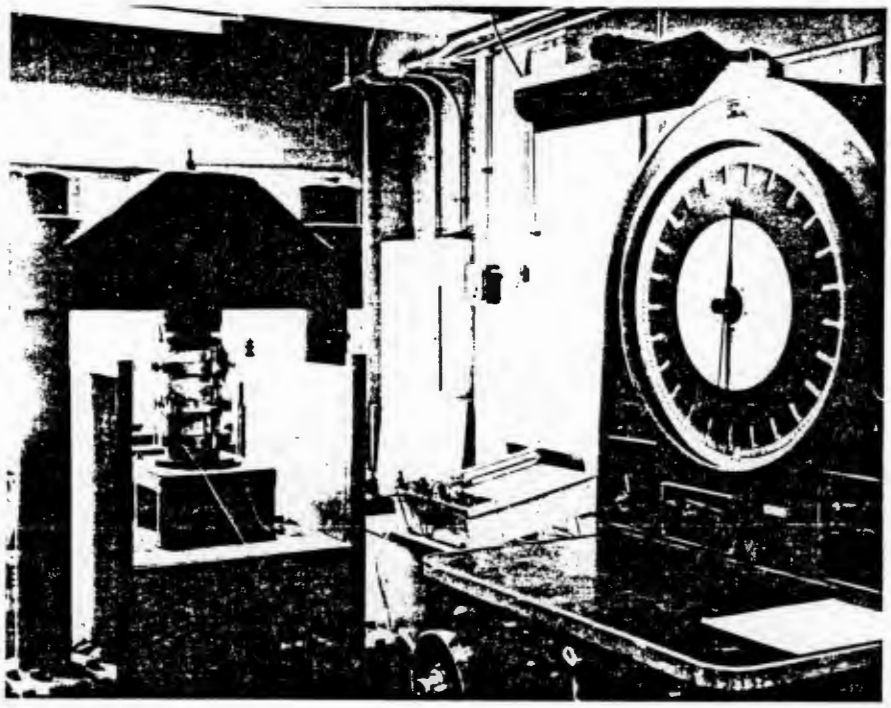

Fig. 1 - Static Test Method For Determining Elastic Constants and Compressive Strength

specimen in the test apparatus. No data were recorded. The final three loads were recorded. Elastic constants were calculated from the slopes of the three sets of curves and then averaged.

Compressive Strength - After determination of elastic constants, the compressometer was removed. Specimens designated for compressive strength determination were then loaded in compression to failure. Test procedures followed guidelines in ASTM Designation: C39, "Standard Method of Test for Compressive Strength of Cylindrical Concrete Specimens."[2]

Splitting Tensile Strength. Specimens not used for compressive strength determination were designated for splitting tensile strength testing. Test procedures followed guidelines in ASTM Designation: C496, "Standard Method of Test for Splitting Tensile Strength of Cylindrical Concrete Specimens."[3]

Heat Treatment (Purex Building Concrete)

Strength and elastic properties tests were conducted on Tank Farm specimens at 72°F with no prior heat treatment. Specimens from 202-A Purex Canyon Building were tested under three different temperature conditions: unheated, heated to 200°F, and heated to 200°F and then cooled to ambient temperature prior to testing.

Unheated Purex Building specimens were treated in the same manner as the Tank Farm specimens before and during testing. Six Purex Building specimens designated for heat treatment were placed in an oven initially at room temperature. These six

cylinders were then heated to 200°F at a rate of 75F/day. Specimens were maintained at 200°F for 2 days.

At this point, three Purex cylinders were removed from the oven and immediately subjected to elastic properties and compressive strength tests. The three cylinders remaining in the oven were cooled back to room temperature at a rate of 75°F/day. These three cylinders were subjected to elastic properties and compressive strength tests 24 hr after the oven reached room temperature.

TEST RESULTS

Results of elastic properties and strength tests of the Hanford 241-SX-115 Tank and of the 202-A Purex Building core materials are described in the following sections.

241-SX-115 Tank Concrete

Results of tests to determine modulus of elasticity, Poisson's ratio, and compressive or splitting tensile strengths of Hanford 241-SX-115 Tank cores are listed in Table 3 of Appendix B. Values of properties measured varied over the following ranges: modulus of elasticity = 2.84 to 5.88 million psi; Poisson's ratio* = 0.15 to 0.26; compressive strength = 3825 to 6960 psi; and splitting tensile strength = 494 to 933 psi. Average values and statistical distribution of the data are given in Table B2 of Appendix B.

*Excluding data from cracked specimens.

Variations in properties along the length of the core are shown in Figures 2 and 3. In Figure 2, elastic constants are plotted as a function of approximate core depth as indicated by markings on the sides of the cores received from Hanford. If values measured at the extreme ends of the core are ignored, there appears to be a trend of decreasing modulus values with increasing core depth. Linear regression analysis of these data indicates that the modulus decreases about 7800 psi per foot of core depth. This is shown in Table B3, of Appendix B. Poisson's ratio values, however, appeared to increase by about 0.002 per foot of core depth.

Similar analysis of compressive and splitting tensile strength data indicate that compressive strength decreased about 60 psi/ft and splitting tensile strength decreased about 3 psi/ft of increasing core depth. These results are summarized in Table 6. Plots of these data, shown in Figure 3, display a general decreasing trend in strength with increasing depth, particularly for compressive strength.

There are several factors that may account for the general decrease in values of mechanical properties with increasing core depth. One reason may be variations in initial strength from batch to batch during construction of the tank. Such variations have been suspected of being responsible for wide scatter in strength data of tank farm concrete cores measured in an earlier study.[4]

A second cause may be the variations in temperature experienced along the height of the wall as the waste solutions heat

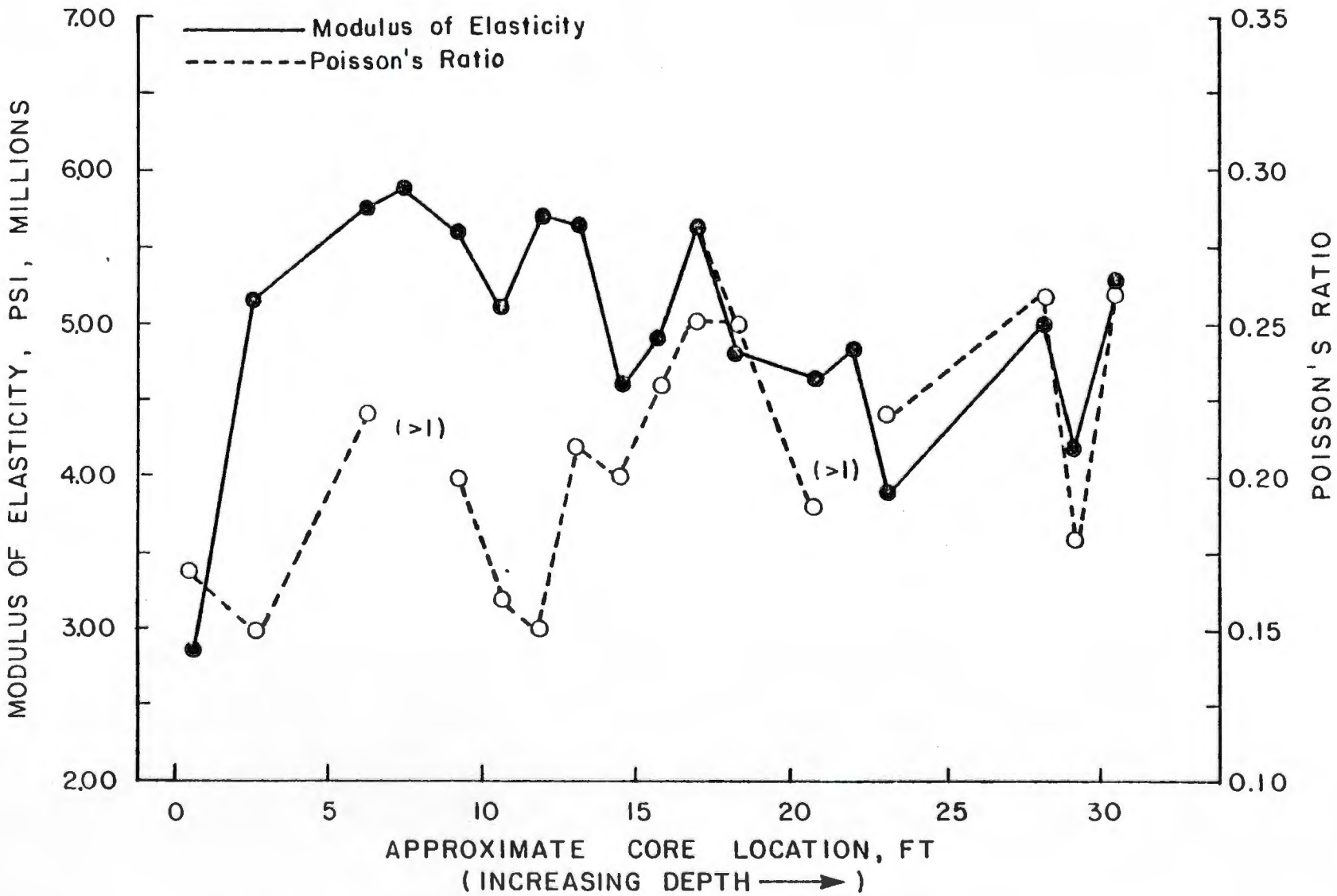

FIG. 2 VARIATION IN ELASTIC PROPERTIES ALONG CORE LENGTH

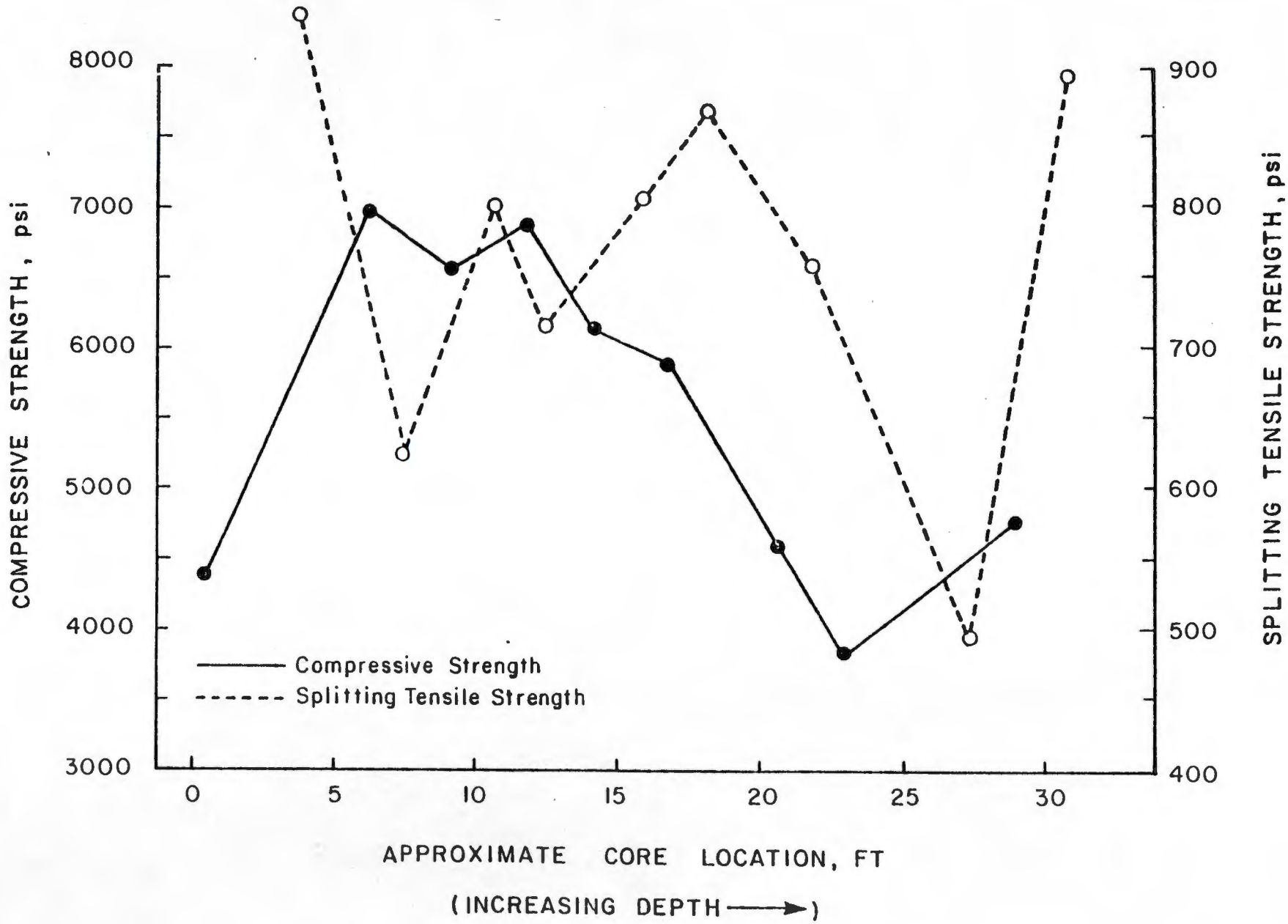

FIG. 3 VARIATION IN STRENGTHS ALONG CORE LENGTH

and cool. Those areas of the wall near the bottom of tank presumably would be heated to higher temperatures, owing to proximity of waste solutions. In this case, the higher temperatures presumably produce greater properties losses in the concrete. Cooler areas in the upper portions of the wall would, thus, suffer less properties degradation. A third cause might be penetration of waste solutions into the concrete. However, no signs of chemical attack were visible during inspection of 241-SX-115 cores.

Information on the construction and thermal histories of the waste tanks have been published by Rockwell.[5,6,7] Concerning tank construction, it is stated that concrete was placed in 6 separate 5-ft high pours, each allowed to set at least 24 hours prior to the next pour, in the 30-ft high tank wall. The tank was built during 1953-54, but was not put into operation until 1958.

Regarding operation of the 241-SX-115 tank, the following information is given:

> "The waste level in the tank gradually increased from 6 feet (as measured from the bottom of the tank) in 1958 to about 20 ft in 1960. It remained at about 20 ft (700,000 gallons) until 1965, when the tank was emptied. The air above the waste quickly rose to 210°F and then gradually increased to 280°F in 1960. The temperature then gradually decreased to 220°F in

1964. The water temperature would be higher than the air temperature. A 3/8 inch carbon steel liner separates the waste and the concrete."

Without information on the initial strengths of the concrete batches used in construction of the 241-SX-115 tank, it is not possible to determine whether strength variations along the wall are due to temperature or inherent strength differences in the concrete batches. Also, since the data reported in the present study are from one core taken from one tank, results from the regression analysis should not be assumed to be representative of all tanks. Additional core tests would be needed to verify that the strength loss with increasing depth is a general trend in the walls of operational tanks.

202-A Purex Canyon Building Concrete

Results of tests to determine modulus of elasticity, Poisson's ratio, and compressive or splitting tensile strengths of Hanford 202-A Purex Canyon Building core materials are listed in Table C1 of Appendix C. These data include tests on concrete in the unheated condition, heated to 200°F, and heated to 200°F and then cooled to ambient prior to test.

Properties of unheated concrete varied as follows: modulus of elasticity = 2.88 to 4.91 million psi; Poisson's ratio* = 0.11 to 0.28; compressive strength = 3440 to 6340 psi; and splitting tensile strength = 320 to 535 psi. The range of

*Excluding data from cracked specimen.

values for specimens tested at 200°F was: modulus of elasticity = 2.21 to 2.48 million psi; Poisson's ratio = 0.11 to 0.19; and compressive strength = 3770 to 4370 psi. Data on specimens heated to 200°F and then cooled and tested at ambient varied as follows: modulus of elasticity - 2.74 to 2.93 million psi; Poisson's ratio = 0.14 to 0.21; and compressive strength = 280 to 5210 psi. No splitting tensile strength tests were scheduled for heated specimens.

Information on statistical distribution of Purex concrete data is given in Table C2 in Appendix C.

EVALUATION OF RESULTS AND COMPARISON WITH DATA FROM PREVIOUS TESTS

A number of test programs have been conducted at the Construction Technology Laboratories (CTL) on concrete core materials from the Hanford tank farms and Purex facilities, as well as on concrete cast in-house using mix designs and materials similar to those from Hanford concrete structures. Data from the current test program are compared to results from previous studies in the following sections.

241-SX-115 Tank Concrete

In an earlier test program conducted at CTL, strength and elastic properties of Hanford Tank Farm concrete core materials were determined at 72° and 250°F.[4] These tests were conducted on 3-in. by 6-in. cylinders fabricated from core materials from the 241-A, 241-S, 241-T, and 241-U Tank Farms.

Average properties for 241-A Tank Farm specimens at 72°F were as follows: compressive strength = 7970 psi; splitting tensile strength = 1137 psi; modulus of elasticity = 5.075 million psi; and Poisson's ratio = 0.21. It should be noted that all of the previous tank farm cores were taken from center one third of tank domes. This concrete was subjected to temperatures less than or equal to 212°F. Hence, they were never heated as high as the samples taken from 241-SX-115 tank wall.

In this same study, tests were also conducted on specimens made from concrete cast at CTL using materials and mix designs similar to those used for concrete in Hanford structures. The average of the results of these tests on the "in-house" concrete specimens were: compressive strength = 5110 psi; splitting tensile strength = 810 psi; modulus of elasticity = 3.93 million psi; and Poisson's ratio = 0.19.

When comparing the results of tests on Tank Farm concrete in the present study to the data cited above, it would appear that concrete from the 241-SX-115 Tank is comparable in compressive and tensile strength to concrete cast "in-house" at CTL. Differences in values of compressive strength, tensile strength, and Poisson's ratio of 241-SX-115 Tank concrete and CTL concrete are less than 10%. Differences in values for elastic modulus are approximately 20%.

Differences between strength values of 241-SX-115 and 241-A tanks were relatively large. 241-A Tank Farm concrete compressive and tensile strengths were about 45 percent greater

than those values obtained from 241-SX-115 Tank concrete. However, elastic properties of both Tank Farm concretes were essentially equal. This could be due to variations between concrete batches or the fact that the 241-SX-115 tank wall concrete was subjected to higher temperatures during tank farm operation than the dome concrete in the 241-A tank farm. In no case did compressive strength of any 241-SX-115 Tank specimen fall below 3000 psi. The lowest strength measured was 3825 psi.

202-A Purex Canyon Building Concrete

In an earlier study at CTL, strength and elastic properties were determined for approximately 60 concrete cores taken from the Hanford 202-A Purex Facility Building.[8] These cores were taken from the interior wall in the Sample Gallery between Column Nos. 8 to 20. Mean property values obtained in this earlier program were: compressive strength = 7840 psi; splitting tensile strength = 780 psi; modulus of elasticity = 4.82 million psi; and Poisson's ratio = 0.21. These values were determined on concrete at ambient conditions - no tests were performed on heated concrete.

A comparison of data on concrete from the 202-A Purex Building at ambient conditions shows that for all properties, values obtained in the current study were lower than those determined in the earlier study. The magnitude of differences between current and earlier determined values is as follows: compressive strength = 3030 psi lower; splitting tensile strength = 350 psi lower; modulus of elasticity = 1.29 million

psi lower; and Poisson's ratio = 0.03 lower. However, in no case did compressive strength of Purex Building specimens in the present study fall below 3000 psi. The lowest strength measured was 3440 psi.

The effects of temperature on the strength and elastic properties of the 202-A Purex Building concrete cores are difficult to assess. The reason for this difficulty is the wide range of strength values measured with unheated cores, from 3440 psi to 6340 psi. Strengths of heated concrete cylinders fell well within this range. Thus, effects of temperature on concrete properties are masked by the considerable variation in properties of concrete in situ.

Since the area in the 202-A Building where these cores were removed was reportedly not exposed to elevated temperatures,[9] the large scatter in strength values may be attributed to batch to batch variations in concrete mixes used in construction. Such batch variations may also be responsible for variations in the strength of tank farm concretes observed in the present study and in an earlier investigation.[8]

Regardless of the cause, the scatter in the above Purex Building concrete data precludes determination of the effects of temperature on material properties.

SUMMARY

In this study, the mechanical properties of concrete core materials from the Hanford 241-SX-115 Tank and 202-A Purex

Canyon Building were determined. Strength and elastic constants were obtained from 18 unheated Tank Farm specimens and 11 unheated Purex Building specimens. Property determinations were also made on six Purex Building specimens heated to 200°F. Three of these six specimens were tested at 200°F; the remaining three were tested after cooling back to room temperature. In addition, a visual inspection was made of all core materials in their "as-received" condition.

Major results of the current study were:

(a) Visual Examination. Four Tank Farm cores and two Purex Building cores were found to have cracks ranging from 2 to 10 in. in length. Internal cracks in large aggregate pieces were observed in one Tank Farm core and one Purex Building core. No other signs of concrete deterioration were visible.

(b) 241-SX-115 Tank Concrete Properties at 72°F. Compressive strength ranged from 3825 to 6960 psi; splitting tensile strength from 494 to 933 psi; modulus of elasticity from 2.84 to 5.88 million psi; and Poisson's ratio* from 0.15 to 0.26.

These properties are lower than values obtained from testing concrete samples taken from the domes of other tanks.[4] This, combined with an apparent decrease in strength with depth, would appear to confirm the observation that sustained temperatures

*Excluding data from cracked specimens.

above 212°F decrease concrete properties. However, it all cases strength exceeds the 3000 psi design strength.

(c) 202-A Purex Building Concrete Properties:

At 72°F. Compressive strength ranged from 3440 to 6340 psi; splitting tensile strength from 320 to 535 psi; modulus of elasticity from 2.88 to 4.91 million psi; and Poisson's ratio** from 0.11 to 0.28.

These values are significantly less than values from previous Purex cores tested.[8] Given the large scatter in both sets of strength data for concrete *in situ*, there appears to be a wide variation caused by differences between concrete batches made to the same mix design.

After Heating to 200°F. Compressive strength ranged from 3770 to 4370 psi; modulus of elasticity from 2.21 to 2.48 million psi; and Poisson's ratio from 0.11 to 0.19.

After Heating to 200°F/Then Cooled to Ambient. Compressive strength ranged from 4280 to 5210 psi; modulus of elasticity from 2.74 to 2.93 million psi; and Poisson's ratio from 0.14 to 0.21.

The above data suggests a strength loss on heating, followed by some recovery on subsequent

**Excluding data from cracked specimen.

cooling. However, the strengths of heated concrete fell well within the range of strengths measured for unheated concrete. Because of the large scatter in strength data for unheated concrete, it is not possible to determine with any certainty the variation in strength due to heating from results of this study.

It should be noted that compressive strengths of the Tank Farm and Purex Building concrete specimens were in excess of 3000 psi in all cases.

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APPENDIX A

VISUAL EXAMINATION OF CORES

TABLE A1 - VISUAL EXAMINATION OF HANFORD CONCRETE CORES

TANK 241-SX-115

Core I.D.	Tested	Minimum Usable Length, in.	Crack	Honeycomb	Agg.[a] Seg.	Discolor	Other
Box 0'0" to 8'0"							
#1	X	11.0	No	No	No	No	
#2		8.7	No	No	No	No	
#3	X	8.6	No	some air voids 1/4" to 1" length	No	No	
#4		6.3	No	several voids 1/2" length	No	No	
#5		10.4	2" crack near top; 3-1/2" crack near midpoint	No	No	No	rebar near top
#6	X	9.0	No	several air voids 1/2" length	No	No	
#7	X	8.8	2" and 3-1/2" crack along length	several air voids 1/2" length	No	No	
#8		10.5	5" crack along length	some air voids 1/4" to 3/4" length	No	No	rebar near midpoint

a - Aggregate Segregation

TABLE A1 - VISUAL EXAMINATION OF HANFORD CONCRETE CORES

TANK 241-SX-115 (Continued)

Core I.D.	Tested	Minimum Usable Length, in.	Crack	Honeycomb	Agg. Seg.	Discolor	Other
Box 8'0" to 16'4"							
8'0" to 9'8"	X	18.7	No	some air voids 1/8" to 3/8" length	No	No	only small aggregate (3/4") visible on core surface
9'8" to 11'	X	13.0	some cracks, pores in aggregate	No	No	No	rebar near midpoint
11'0" to 12'+	X	10.2	No	some air voids 1/8" to 3/8" length	No	No	
12'+ to 13'0"	X	8.0	No	some air voids 1/8" to 3/8" length	No	No	
13'0" to 13'5"		4.5	No	some air voids 1/8" to 3/8" length	No	No	some pores in aggregate
13'5" to 15'0"	X	13.0	No	some air voids 1/8" to 3/8" length	No	No	
15'0" to 16'0"	X	10.3	No	No	No	No	cold joint near bottom of core?
16' mark		4.0	No	No	No	No	some pores in aggregate

TABLE A1 - VISUAL EXAMINATION OF HANFORD CONCRETE CORES

TANK 241-SX-115 (Continued)

Core I.D.	Tested	Minimum Usable Length, in.	Crack	Honeycomb	Agg. Seg.	Discolor	Other
Box 16'4" to 28'							
16'4" to 16'6"		1.0	No	No	No	No	some pores in aggregate
16'6" to 16'10"		3.0	No	No	No	No	
16'10" to 17'4"	X	5.0	No	some air voids 1/8" to 1/4"			
17'4" to 17'8"		1.0	No	No	No	No	broken irregularly
rubble		-	-	-	-	-	
17'8" to 18'10"	X	6.0	broken near bottom of core	several small air voids	No	No	
18'10" to 19'4"		2.0	broken near top of core	several small air voids	No	No	
19'4" to 19'6"		1.0	-	-	-	-	irregular shape
19'6" to 20'0"		3.5	No	No	No	No	
20'0" to 21'4"	X	7.2		air voids near large aggregate 1/8" to 1/2"	No	No	
rubble		-	-	-	-	-	

TABLE A1 - VISUAL EXAMINATION OF HANFORD CONCRETE CORES

TANK 241-SX-115 (Continued)

Core I.D.	Tested	Minimum Usable Length, in.	Crack	Honeycomb	Agg. Seg.	Discolor	Other
Box 16'4" to 28' (Cont'd)							
21'4" to 22'	X	5.0	3-1/2" crack from top	air voids 1/8" in length	No	No	
22' to 22'9"	X	6.0	No	many small air voids 1/8" to 3/8"	No	paste appears lighter in color	surface of core rough; as through paste lost on coring
rubble		-	-	-	-	-	
27' to 28'	X	10.0	No	some air voids 1/8" to 3/8"	No	No	
Box 28'0" to 32'4"							
27'	X	6.0	No	small air voids in concrete	No	No	small pores (1/8") in aggregate
28'6"		4.0	No	small air voids in concrete	No	No	small pores (1/8") in aggregate
28'		1.0	No	small air voids in concrete	No	No	irregular shape

TABLE A1 - VISUAL EXAMINATION OF HANFORD CONCRETE CORES

TANK 241-SX-115 (Continued)

Core I.D.	Tested	Minimum Usable Length, in.	Crack	Honeycomb	Agg. Seg.	Discolor	Other
Box 28'0" to 32'4" (Cont'd)							
29'		4.5	No	small air voids in concrete	No	No	
		4.0	No	small air voids in concrete	No	No	
30'	X	5.5	No	small air voids in concrete	No	No	
		1.0	fractured irregular piece				
31'		3.0	No	some small air voids	No	No	
32'		2.0	No	some small air voids	No	No	
rubble		-	-	-	-	-	

TABLE A2 - VISUAL EXAMINATION OF HANFORD CONCRETE CORES

202-A PUREX CANYON BUILDING

Core No.	Diameter, in.	Minimum Usable Length, in.	Crack	Honeycomb	Agg. Seg.	Discolor	Other
#1	5.6	8-1/2	No	No	No	No	minor air voids (1/8" to 1/4")
#2	5.6	8	8" crack from steel insert down (also bad spot on core surface)	No	No	No	minor air voids (1/8" to 1/4")
#3	5.6	8	2" crack from top 10" crack from top	No	No	No	also steel insert in top of specimen and rebar (2)
						No	small air voids rebar (3)
#4	5.6	8	No	No	No	No	small air voids rebar
#5	5.6	11	heavy gouge on surface from anchor pullout (3/4" deep)	No	No	No	widely distributed air voids (1/8" to 1/2")
#6	5.6	8	No	No	No	No	small air voids rebar (2), anchor
#7	5.6	8-1/2	several aggregates have cracks	No	No	No	air voids (1/8" to 3/4") rebar (2)
#8	5.6	11	No	some widely distributed voids up to 1" diameter	No	No	-

TABLE A2 - VISUAL EXAMINATION OF HANFORD CONCRETE CORES

202-A PUREX CANYON BUILDING (Continued)

Core No.	Diameter, in.	Minimum Usable Length, in.	Crack	Honeycomb	Agg. Seg.	Discolor	Other
#9	5.6	8-1/2	No	No	No	No	small air voids, rebar
#10	5.6	7-1/2	No	No	No	No	2-1/2" hole in top of specimen rebar, air voids (1/8" to 3/4")
#11	7.6	7	No	No	No	No	numerous rebar, cable (?)
#12	7.6	11-1/2	No	No	No	No	some small voids (1/8") some aggregate with voids
#13	7.6	7	No	Yes	No	No	rebar pullout gouge along side, irregular shape
#14	7.6	11	No	Yes	No	No	rebar pullout gouge along side, irregular shape, also air voids
#15	7.6	11-1/2	No	Yes	No	No	some air voids, some pores in aggregates
#16	7.6	9	No	Yes	No	No	some small voids (1/8" to 1/4")
#17	3.5	9-1/2	No	Yes	No	No	some small voids (1/8" to 1/4")

APPENDIX B

ELASTIC PROPERTIES AND STRENGTH DATA - HANFORD 241-SX-115 TANK

TABLE B1 - STRENGTH AND ELASTIC PROPERTIES OF HANFORD CONCRETE CORES

TANK 241-SX-115 (AT 73°F)

Core I.D.	Date of Test, mo-day-yr	Weight at Test, lb	Length, in.	Diameter, in.	Modulus of Elasticity, Million, psi	Poisson's Ratio	Compressive Strength, psi	Splitting Tensile Strength, psi
Box 0'0" to 8'0"								
#1	9-15-81	2.68	5.25	2.65	2.84	0.17	4350	-
#3	9-14-81	2.61	5.30	2.65	5.16	0.15	-	933
#6	9-14-81	2.64	5.31	2.63	5.75	0.22	6960	-
#7	9-14-81	2.62	5.40	2.65	5.88	1.06*	-	623
Box 8'0" to 16'4"								
8'0" to 9'8"	9-14-81	2.58	5.40	2.63	5.61	0.20	6565	-
9'8" to 11'0"	9-14-81	2.64	5.42	2.65	5.10	0.16	-	798
11'0" to 12'+	9-14-81	2.69	5.50	2.63	5.69	0.15	6870	-
12'+ to 13'0"	9-14-81	2.66	5.45	2.65	5.63	0.21	-	714
13'5" to 15'0"	9-14-81	2.64	5.40	2.65	4.58	0.20	6145	-
15'0" to 16'0"	9-14-81	2.65	5.30	2.65	4.91	0.23	-	802
Box 16'4" to 28' & Box 28'0" to 32'4"								
16'10" to 17'4"	9-14-81	2.32	4.60	2.65	5.82	0.25	5880**	-
17'8" to 18'10"	9-14-81	2.65	5.30	2.65	4.79	0.25	-	870
20'0" to 21'4"	9-15-81	2.68	5.35	2.65	4.63	0.19	4590	-
21'4" to 22'	9-15-81	2.23	4.50	2.65	4.86	1.42*	-	758
22' to 22'9"	9-15-81	2.60	5.45	2.65	3.89	0.22	3825	-
27' to 28'	9-15-81	2.68	5.35	2.65	4.99	0.26	-	494
27'	9-15-81	2.68	5.45	2.65	4.20	0.18	4770	-
30'	9-15-81	2.71	5.30	2.65	5.28	0.26	-	893

*Visible crack running length of specimen. Poisson's ratio influenced by crack opening displacement.
**Strength value corrected for L/D ratio per ASTM C42.

TABLE B2 - STATISTICAL DISTRIBUTION OF

PROPERTIES DATA FOR TANK 241-SX-115

	Compressive Strength (psi)	Splitting Tensile Strength (psi)	Modulus of Elasticity (million psi)	Poisson's Ratio
Number of Tests, n	9	9	18	16
Mean Value, $\bar{x}$	5550	765	4.98	0.21
Standard Deviation, s	1182	139	0.78	0.04

TABLE B3 - LINEAR REGRESSION - PROPERTIES VARIATION

WITH DEPTH OF CORE FOR TANK 241-SX-115

Best-fit Analysis: Property = A X Depth + B

	Compressive Strength	Splitting Tensile Strength	Modulus of Elasticity	Poisson's Ratio
A	-58.4 psi/ft	-2.86 psi/ft	-7800 psi/ft	0.0024/ft
B	6398 psi	812 psi	5.098 million psi	0.169
r*	-0.432	-0.190	-0.088	0.574

*r = correlation coefficient

APPENDIX C

ELASTIC PROPERTIES AND STRENGTH DATA - HANFORD 202-A PUREX CANYON BUILDING

TABLE C1 - STRENGTH AND ELASTIC PROPERTIES OF HANFORD CONCRETE CORES

202-A PUREX CANYON BUILDING

Core No.	Date of Test, mo-day-yr	Weight at Test, lb	Length, in.	Diameter, in.	Temperature at test, °F	Modulus of Elasticity, Million psi	Poisson's Ratio	Compressive Strength, psi	Splitting Tensile Strength, psi
#1	10-1-81	7.80	7.45	3.70	72	3.48	0.28	4010	-
#2	10-1-81	6.54	7.03	3.70	72	4.46	0.25	-	446
#3	10-1-81	7.50	7.53	3.70	72	3.25	0.37*	4200	-
#4	10-1-81	7.92	7.63	3.70	72	2.89	0.16	-	320
#5	10-1-81	7.90	7.61	3.70	72	3.32	0.19	3440	-
#6	10-5-81	6.97	7.67	3.70	72**	2.81	0.18	5210	-
#7	10-2-81	6.85	7.59	3.70	200	2.43	0.11	4370	-
#8	10-1-81	7.20	7.50	3.70	72	3.14	0.17	-	473
#9	10-1-81	7.15	7.57	3.70	72	3.40	0.17	4620	-
#10	10-5-81	6.92	7.52	3.70	72**	2.93	0.21	4280	-
#11	10-2-81	6.78	7.52	3.70	200	2.48	0.11	3770	-
#12	10-1-81	7.24	7.57	3.70	72	2.99	0.13	-	364
#13	10-1-81	7.70	7.51	3.70	72	4.91	0.16	6240	-
#14	10-5-81	6.82	7.50	3.70	72**	2.74	0.14	4660	-
#15	10-2-81	6.97	7.60	3.70	200	2.21	0.19	3980	-
#16	10-1-81	7.12	7.52	3.70	72	4.13	0.19	-	535
#17	10-1-81	6.81	7.45	3.50	72	2.88	0.11	6340	-

*Crack visible along length of specimen prior to test.
**Heated to 200F at 75F/day, held at 200F for 2 days, cooled to ambient at 75F/day - then tested at 72F.

TABLE C2 - STATISTICAL DISTRIBUTION OF PROPERTIES DATA FOR 202-A PUREX CANYON BUILDING

	Compressive Strength (psi)	Splitting Tensile Strength (psi)	Modulus of Elasticity (million psi)	Poisson's Ratio
Unheated, 72°F				
Number of Tests, n	6	5	11	10
Mean Value, $\bar{x}$	4808	428	3.53	0.18
Standard Deviation, s	1209	86	0.68	0.05
Heated, 200°F				
Number of Tests, n	3	-	3	3
Mean Value, $\bar{x}$	4040	-	2.37	0.14
Standard Deviation, s	305	-	0.14	0.05
Heated, 200°F/Cooled, 72°F				
Number of Tests, n	3	-	3	3
Mean Value, $\bar{x}$	4717	-	2.83	0.18
Standard Deviation, s	468	-	0.10	0.04