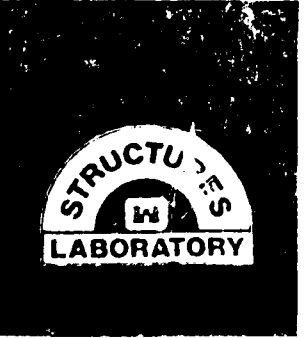
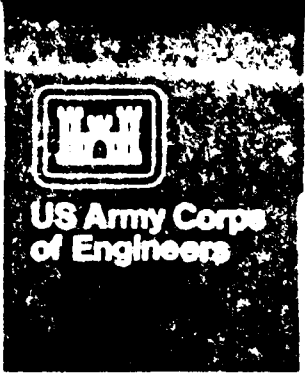


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

13



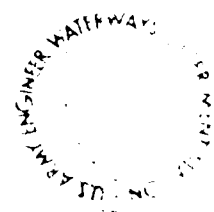
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COMPUTER-AIDED ANALYSIS OF CONCRETE STRENGTH TEST RESULTS

Roy L. Campbell
Structures Laboratory
U.S. Army Engineer Waterways Experiment Station
P.O. Box 637, Vicksburg, Mississippi 39180



Contract No. W81-001-001-001
Final Report

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report documents a computer-aided statistical analysis program that is primarily designed to (1) process laboratory strength test results and generate regression data for accelerated versus design-age strengths and (2) process field strength test results using laboratory regression data and generate predicted design-age and required average strengths in accordance with EM 1110-2-2000, "Standard Practice for Concrete." The statistical portions of the (Continued)		

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20. ABSTRACT (Continued)

program were written to comply with "Recommended Practice for Evaluation of Strength Test Results of Concrete, ACI 214-77" and "Use of Accelerated Strength Testing, ACI 214.1R-81."

The program is an interactive time-sharing program written in Honeywell Level 66 Fortran language. The program is accessible through the CORPS Computer Library System as program X0064. A graphics terminal such as the Tektronic 4014 is required to take full advantage of the capabilities of the program. Output data are presented in tabular or graph form or both.

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PREFACE

This report was prepared at the Structures Laboratory (SL) of the U. S. Army Engineer Waterways Experiment Station (WES) under the sponsorship of the Headquarters, U. S. Army Corps of Engineers (HQ USACE) as a part of Civil Works Investigation Studies Work Unit 31138, "New Technologies for Testing and Evaluating Concrete." Mr. Joseph L. Lamond and Mr. Fred Anderson (DAEN-CWE-DC) served as HQ USACE Technical Monitors.

The study was conducted under the general supervision of Mr. Bryant Mather, Chief, SL, and Mr. John Scanlon, Chief, Concrete Technology Division (CTD), SL; and under the direct supervision of Mr. Kenneth L. Saucier, Chief, Concrete and Grout Group, CTD, Mr. James E. McDonald, and Mr. Henry T. Thornton, Acting Chief, Evaluation and Monitoring Group, CTD. This report was prepared by Mr. Roy L. Campbell, Sr.

The Commander and Director of WES during this study and the preparation and publication of this report was COL Tilford C. Creel, CE. Mr. F. R. Brown was Technical Director.

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CONVERSION FACTORS, NON-SI TO SI (METRIC)
UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>
inches	2.540	centimetres
pounds (force) per square inch (psi)	6.894757	kilopascals
Fahrenheit degrees	5/9	Celsius degrees or Kelvins*

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$. To obtain Kelvins (K) readings, use: $K = (5/9)(F - 32) + 273.15$.

COMPUTER-AIDED ANALYSIS OF CONCRETE
STRENGTH TEST RESULTS

PART I: INTRODUCTION

1. This report contains the basic information needed by a user to execute a computer program called "CONEVAL." The program provides computer-aided statistical analysis and report-form output of concrete strength test specimen results. The program is primarily designed to (a) process laboratory test results and generate regression data for accelerated versus design-age strengths and (b) process field strength test results using laboratory regression data and generate predicted design-age and required average strengths. The statistical portions of this program are written to comply with ACI 214-77 and ACI 214.1R-81. The program is accessible through the CORPS Computer Library System as program X0064.

2. In retrospect, the concrete specimens should be made according to ASTM Designations: C 31-69 and C 192-81 or according to C 684-81 for accelerated testing and tested in accordance with ASTM: C 39-81.

PART II: PROGRAM FEATURES

Features Applicable to Analysis of Both Laboratory and Field Data

3. The program is written for time-sharing system use and is interactively executed. A restart option is available that allows the user to process up to 480 concrete test samples. The user has the option to display or not to display input and output values in either tabular or graph form or both. The displayed tables and graphs can be automatically copied by the program. Graphs can be redisplayed using scales selected by user.

Features Applicable to Analysis of Laboratory Data

4. For analysis of laboratory strength test results, the program performs a linear regression for accelerated versus design-age strengths. The series of individual points that are graphically displayed with the regression curve are selected by the user. At this point in the program, the selection of points and the replotting of the graph can be repeated as many times as needed. Field data can be processed as laboratory data to generate a regression curve by simply giving a 'N' response for the field analysis query.

Features Applicable to Analysis of Field Data

5. For analysis of field strength test results, strength data are processed according to age of test specimen at time of testing. The program uses interactively entered laboratory regression data (slope, Y-intercept, number of points on curve, and 95 percent confidence interval) to generate predicted strengths for design-age group and required average strengths for both accelerated and design-age groups. The program computes averages of the sample input. It statistically analyzes the strength test results for standard deviations, coefficients of variation,

and ranges. The test-age group(s) for which data are to be displayed is selected by user.

6. For structural concrete an average of the last three consecutive tests is maintained by the program while for nonstructural concrete an average of the last five tests is maintained. The program flags design-age strengths for structural concrete in which (a) the average of a set of three consecutive tests is less than the specified strength, f'_c , (ACI 318-77, para 4.8.2.3(a)) and (b) an individual test is more than 500 psi below f'_c (ACI 318-77, para 4.8.2.3(b)). This procedure will allow calculations to be made to determine compliance with the provisions of Section 7-2.e. of EM 1110-2-2000.

PART III: DEVICE

7. A graphics terminal* is required to take full advantage of the capabilities of this program. For a user who only has access to a line-printer terminal,** tables can be listed by giving the following question responses:

- a. Entering 'ALP' for device.
- b. '0' (zero) for number of copies.
- c. A carriage return at the end of each table.
- d. Entering 'N' for the plot option.

* For example, the Tektronix 4014.

** For example, Texas Instruments Silent 700.

PART IV: INPUT

Units

8. Input units are selected and interactively entered into the program by the user. Units can be either non-SI or SI (metric). Units most compatible with output formats are (a) inches (in.), Fahrenheit degrees (F), and pounds per square inch (psi) or (b) centimetres (cm), Celsius degrees (C) or Kelvins (K), and kilopascals (kPa).

Format

9. Alpha data are read by the program using an A30 character format. Numeric data are read using a free-field format. The order of values contained in a file of either laboratory or field data is the same, except that the design water:cement ratio is not included with the laboratory data. The input file containing either laboratory or field data is structured in either initial or restart file forms. The order and description of values contained in the initial and restart file forms are presented in Figure 1.

Initial File

10. An initial file is used to start the analysis. It can contain up to 60 samples with a maximum of 7 tests per sample and 2 tests per age group. Note that in order to comply with the provisions of Section 7-2.e.(3) of EM 1110-2-2000 each sample should consist of two tests each for both the accelerated and design-age groups and one test for each informational age group. The number of tests per sample and the number of tests for a given age group are constants for the analysis. The order and description of values contained in an initial file are defined by lines identified as 1 through 6 and 7 through 9 in Figure 1. An example of an initial file is presented in Figure 2.

```

INPUT
-----
LINE 1: LINE NO.,NO. TESTS VALUES PER LINE INPUT(MAX. 7)
LINE 2: LINE NO.,TEST AGES(MAX. 7)
LINE 3: LINE NO.,PROJECT NAME(A45)
LINE 4: LINE NO.,CONTRACT NUMBER(A45)
LINE 5: LINE NO.,MIX IDENTIFIER(A45)
LINE 6: LINE NO,DESIGN AGE,DESIGN STRENGTH,T-DISTRIBUTION FACTOR,
        MAXIMUM SIZE AGGREGATE AND DESIGN WATER-CEMENT RATIO<

*****
* LINES 6A THRU 6H FOR RESTART FILE ONLY
*
LINE 6A: LINE NO.,NO. WATER-CEMENT RATIOS,CUMULATIVE SUM OF
        WATER-CEMENT RATIOS,NO. SLUMPS,CUMULATIVE SUM OF
        SLUMP,NO. AIR CONTENTS,CUMULATIVE SUM OF AIR CONTENTS
* REPEAT LINES 6B AND 6C FOR EACH SET OF 2-CYLINDER DATA
LINE 6B: LINE NO.,NO. RANGES,CUMULATIVE SUM OF RANGES
LINE 6C: LINE NO.,LAST 10 RANGE VALUES
* REPEAT LINE 6D FOR EACH AGE GROUP ENTERED
LINE 6D: LINE NO.,NO. TEST,CUMULATIVE SUM OF TEST VALUES,
        CUMULATIVE SUM OF SQUARES OF TEST VALUES, LAST 3 TESTS
        FOR STRUCTURAL CONCRETE OR LAST 5 TEST FOR NONSTRUCTURAL
        CONCRETE
LINE 6E: LINE NO.,MINIMUM WATER-CEMENT RATIO,MAXIMUM
        WATER-CEMENT RATIO,PAIR OF MINIMUM AND MAXIMUM
        STRENGTH VALUES FOR EACH AGE GROUP
LINE 6F: LINE NO.,NO. REGRESSION POINTS,SUM OF ACCELERATED
        STRENGTHS,SUM OF SQUARES OF ACCELERATED STRENGTHS
LINE 6G: LINE NO.,SUM OF DESIGN-AGE STRENGTHS,SUM OF SQUARES
        OF DESIGN-AGE STRENGTHS,SUM OF PRODUCT OF ACCELERATED
        AND DESIGN-AGE STRENGTHS
LINE 6H: LINE NO.,PAIRS OF ACCELERATED AND DESIGN-AGE STRENGTHS

```

Figure 1. Order and description of input data (Sheet 1 of 2)

```
*****  
*REPEAT LINE 7 FOR EACH SAMPLE(MAX. 60)  
LINE 7 : LINE NO.,YEAR(I2)$,MONTH(I2)$,DAY(I2)$,SAMPLE  
IDENTIFIER(A8)$,WATER-CEMENT RATIO,SLUMP,AIR CONTENT  
AIR TEMPERATURE,CONCRETE TEMPERATURE,STRENGTH VALUES  
ORDERED BY AGE,REMARKS(A35)$
```

```
< ENTER FOR FIELD ANALYSIS ONLY  
$ OUTPUT FIELD LIMITS
```

Figure 1. (Sheet 2 of 2)

Restart File

11. The program limits the number of samples that can be processed in the initial run to 60. However, the restart option of the program permits the user to process a total of 480 samples. When the user requests that a restart file be generated, the program writes the cumulative sums and other information needed to continue the analysis to a restart file in accordance with lines 1 through 6 and 6A through 6H of Figure 1. An example showing the contents of a restart file as written by the program is presented in Figure 3. New sample data (maximum of 59 samples) are added to the end of the restart file in accordance with lines 7 through 9 of Figure 1. An example of the updated restart file is presented in Figure 4.

12. During the execution of the program, the statistical output is displayed for only the values contained in the present restart file. However, data for predicted strengths are displayed for all samples. Graphs of the restart data can be scaled by the user to overlap with graphs from previous runs. As many restart files as needed can be processed so long as no more than 480 total samples are entered. It is important to note that the values for the required average strength are computed exclusively from the strength results contained in the restart file being processed and not from previous test results.

Undefined Values

13. Certain input values that are not defined and are to be omitted in the statistical analysis can be processed by the program when entered as follows:

<u>Input Description</u>	<u>Entry for Undefined Value</u>
Air content	0
Sample slump	0
Sample water:cement ratio	0
Test specimen strength	0
Temperature of air	-100
Temperature of concrete	-100

All other values associated with the undefined input are designated as undefined by the program. The undefined values appear as '****' in the tabular displays. These values are omitted from the graph displays.

14. Some age groups contain two test specimens. When one of these test values is undefined, the number of tests for the overall-sample data is increased by one; however, the number of tests for the within-sample data is not. For each such occurrence, this results in the difference for the number of tests between overall-sample and within-sample data being increased by one. This is reflected in the plots for (a) "Standard Deviation and Range Versus Number of Tests" and (b) "Coefficient of Variation Versus Number of Tests."

Data Entry

15. Data can be entered into the program in one of three ways: (1) from an existing file, (2) from the terminal, and (3) part from an existing file and part from the terminal. Data from the terminal are entered through a series of interactive question/answer responses as illustrated in Figure 5. Additional lines of data can be added to data from an existing data file through the same series of question/answer responses as illustrated in Figure 6. Data entered through this interactive option of the program are automatically written to an output file. An Edit system such as the one on the Honeywell computer at WES can be used to correct the contents of a data file as illustrated in Figure 7.

```

ENTER DEVICE SPEED(30 OR 120) - 120
DO YOU WISH TO ENTER DATA FROM TERMINAL(Y OR N) - Y
ENTER NAME OF OUTPUT FILE - EXAMPLE1
IS PART OF DATA TO BE ENTERED FROM A FILE(Y OR N) - N
IS INPUT DATA FROM A RESTART FILE(Y OR N) - N
DO YOU WISH TO ANALYZE FIELD DATA(Y OR N) - Y
IS STRUCTURAL CONCRETE TO BE ANALYZED(Y OR N) - N
-----
TO TERMINATE INTERACTIVE BUILD MODE ENTER 'DONE'
-----
ENTER NUMBER OF TESTS PER SAMPLE(MAX VALUE OF 7)
- 7
ENTER TEST AGES
- 1 1 7 28 90 90 365
ENTER PROJECT
- RICHARD B RUSSELL
ENTER CONTRACT NUMBER
- DACU78-21-C0084
ENTER MIX NUMBER
- T012
ENTER 1)DESIGN AGE, 2)DESIGN STRENGTH, 3)7-DISTRIBUTION FACTOR,
4)MAXIMUM SIZE AGGREGATE, 5)DESIGN WATER-CEMENT RATIO
- 90 2000 1.282 6 .67
FOR SAMPLE 1
-----
ENTER 1)YEAR(12), 2)MONTH(12), 3)DAY(12), 4)SAMPLE ID NO.(AB),
5)WATER-CEMENT RATIO, 6)SLUMP, 7)AIR CONTENT,
8)AIR TEMPERATURE, 9)CONCRETE TEMPERATURE
- DONE
DO YOU WISH TO MAKE ANOTHER RUN(Y OR N) - N
ELIST EXAMPLE:
1 7 1 1 7 28 90 90 365
2 1 RICHARD B RUSSELL
3 DACU78-21-C0084
4 T012
5 90 2000. 1.282 6.00 0.67
6

```

Figure 5. Example of program being used to build a new data file

```

ENTER DEVICE SPEED(30 OR 120) - 120
DO YOU WISH TO ENTER DATA FROM TERMINAL(Y OR N) - Y
ENTER NAME OF OUTPUT FILE - EXAMPLE2
IS PART OF DATA TO BE ENTERED FROM A FILE(Y OR N) - Y
ENTER NAME OF INPUT FILE - EXAMPLE1
IS INPUT DATA FROM A RESTART FILE(Y OR N) - N
DO YOU WISH TO ANALYZE FIELD DATA(Y OR N) - Y
IS STRUCTURAL CONCRETE TO BE ANALYZED(Y OR N) - N
-----
TO TERMINATE INTERACTIVE BUILD MODE ENTER 'DONE'
-----
FOR SAMPLE 1
-----
ENTER 1)YEAR(12), 2)MONTH(12), 3)DAY(12), 4)SAMPLE ID NO.(AB),
5)WATER-CEMENT RATIO, 6)SLUMP, 7)AIR CONTENT,
8)AIR TEMPERATURE, 9)CONCRETE TEMPERATURE
- 79 3 19 1 .3 2 6.5 -100 67
ENTER STRENGTH VALUES ORDERED BY TEST AGE
- 265 269 495 9999 1786 1786 0
ENTER SAMPLE REMARKS(NO BLANKS ALLOWED)
- G-02-23A
FOR SAMPLE 2
-----
ENTER 1)YEAR(12), 2)MONTH(12), 3)DAY(12), 4)SAMPLE ID NO.(AB),
5)WATER-CEMENT RATIO, 6)SLUMP, 7)AIR CONTENT,
8)AIR TEMPERATURE, 9)CONCRETE TEMPERATURE
- DONE
DO YOU WISH TO MAKE ANOTHER RUN(Y OR N) - N
*LIST EXAMPLE2
1 7 1 1 7 28 90 90 365
2 1 RICHARD B RUSSELL
3 DACU78-21-C0084
4 70712
5 90 1.282 6.00 6.67
6 90 2000. 0.30 2.00 6.5-100. 67. 265. 269. 495. 9999. 1786. 1786. 0. 0-02-23A
11 79 3 19 1

```

Figure 6. Example of program being used to add new data to an existing file

```

LIST EXAMPLE2
1 7 1 7 28 90 90 365
2 RICHARD B RUSSELL
3 DACU78-21-C0084
4 70712
5 90 2000. 1.282 6.00 0.67
6 11 79 3 19 1 0.30 2.00 6.5 -100. 67. 265. 269. 495. 9999. 1785. 1785. 0. 0-02-23A

EDIT 0 EXAMPLE2
-F1/11/ RUS1/99/1/ 9/

11 79 3 19 1 0.30 2.00 6.5 -100. 67. 265. 269. 495. 999. 1785. 1785. 0. 0-02-23A

-DONE
PRESS EXAMPLE2
DATA SAVED-EXAMPLE2

```

Figure 7. Example of Edit system being used to correct contents of an existing file

PART V: EQUATIONS

16. Equations used by the program to compute the displayed output data are as follows:

For Linear Regression of Accelerated Versus Design-Age Strengths

<u>Description of Output</u>	<u>Equation Used by Program</u>
Slope	$b = \frac{\sum X_i Y_i - \frac{\sum X_i \sum Y_i}{n}}{\sum X_i^2 - \frac{(\sum X_i)^2}{n}}$
Y-intercept	$a = \frac{\sum Y_i - b \sum X_i}{n}$
Correlation coefficient	$cc = b \frac{\sqrt{\sum X_i^2 - \frac{(\sum X_i)^2}{n}}}{\sqrt{\sum Y_i^2 - \frac{(\sum Y_i)^2}{n}}}$
95% confidence interval	$ci = t \sqrt{\frac{1}{n-2} \left[\sum Y_i^2 - \frac{(\sum Y_i)^2}{n} - b^2 \left(\sum X_i^2 - \frac{(\sum X_i)^2}{n} \right) \right]}$

where a = Y-intercept

b = Slope

cc = Correlation coefficient

ci = 95% confidence interval (see Appendix B for derivation)

n = Number of points

t = t-distribution factor for 95% confidence interval; for n = 1 to 29, t-distribution factor is 12.706, 4.303, 3.182, 2.776, 2.571, 2.447, 2.365, 2.306, 2.262, 2.228, 2.201, 2.179, 2.160, 2.145, 2.131, 2.120, 2.110, 2.101, 2.093, 2.086, 2.080, 2.074, 2.069, 2.064, 2.060, 2.056, 2.052, 2.048, and 2.045, respectively; for n ≥ 30, t-distribution factor is 1.960.

X_i = An individual accelerated strength

Y_i = An individual design-age strength

For Predicted Design-Age Strengths

<u>Description of Output</u>	<u>Equation Used by Programs</u>
Predicted design-age strength	$Y_p = a + b X_i$
Average strength	$\bar{X} = \frac{X_1 + X_2 + X_3 \dots + X_n}{n}$
Standard error of estimate	$S = \sqrt{\frac{\sum d^2}{n}}$

where a = Y-intercept from laboratory regression curve
 b = Slope from laboratory regression curve
 d = Difference between accelerated and predicted strengths
 n = Number of pairs of actual and predicted design-age strengths
 S = Standard error of estimate
 X_i = An individual accelerated strength
 \bar{X} = Average strength
 Y_p = Predicted design-age strength

For Required Strengths

<u>Description of Output</u>	<u>Equation Used by Program</u>
Required average strength for design-age test specimens	$f_{cr} = f'_c + t * \sigma_d$
Required accelerated strength	$f_{ca} = \frac{f'_c - a}{b}$
Required average accelerated strength when $n \geq 30$	$f_{cra} = f_{ca} + t * \sigma_a$
Required average accelerated strength when $10 \leq n < 30$	$f_{cra} = f_{ca} + t * \sigma_a + t' * S_{y \cdot x}$

where a = Y-intercept from laboratory regression curve
 b = Slope from laboratory regression curve

- f'_c = Specified strength
- f'_{ca} = Required accelerated strength
- f'_{cr} = Required average strength
- f'_{cra} = Required average accelerated strength
- n = Number of pairs of accelerated and design-age strengths on laboratory regression curve
- σ_a = Standard deviation of accelerated-age strengths contained in current file only
- σ_d = Standard deviation of design-age strengths contained in current file only
- $S_{y \cdot x}$ = The standard error of estimate of Y values for a given X value using $n - 2$ degrees of freedom (See Appendix B for derivation)
- t = A constant multiplier for standard deviation (σ) that depends on the number of tests expected to fall below f'_c (ACI 214-77, Table 4.1)
- t' = A constant multiplier for standard error of estimate when $10 < n < 30$ (ACI 214-77, Table 4.2)

For Statistical Analysis of Strength Test Results

<u>Description of Output</u>	<u>Equation Used by Program</u>
Average of test results	$\bar{X} = \frac{X_1 + X_2 + X_3 + \dots + X_n}{n}$
Average of last- m tests	$X_{lm} = \frac{X_{n-m+1} + X_{n-m+2} + \dots + X_n}{m}$
Standard deviation	$\sigma = \sqrt{\frac{\sum X_i^2 - \frac{(\sum X_i)^2}{n}}{n-1}}$
Coefficient of variation	$V = 100 \frac{\sigma}{\bar{X}}$
Within-sample, 2-test specimen average	$X_{iAB} = \frac{X_{iA} + X_{iB}}{2}$
Actual range	$R_i = X_{iA} - X_{iB} $

Average range $\bar{R} = \frac{R_1 + R_2 + R_3 + \dots + R_n}{n}$

Average of last-10 ranges $R_{L10} = \frac{R_{n-9} + R_{n-8} + \dots + R_n}{10}$

Within-sample coefficient of variation $VW = \frac{100 \left(\frac{1}{d_2}\right) \bar{R}}{\bar{X}}$

Actual within-sample coefficient of variation $VW_{act} = \frac{100 \left(\frac{1}{d_2}\right) R_i}{\bar{X}}$

where $\frac{1}{d_2} = 0.8865$; 2-test specimen value for computing within-sample standard deviation (ACI 214-77, Table 3.4.1)

f'_c = Specified strength

$m = 3$ for analysis of structural concrete
 $= 5$ for analysis of nonstructural concrete

n = Number of tests

R_i = Actual range

R_{L10} = Average of last 10 ranges

σ = Standard deviation

V = Coefficient of variation

VW = Within-sample coefficient of variation

VW_{act} = Actual within-sample coefficient of variation

X_i = An individual test result

X_{iA} = One of two within-sample strengths

X_{iB} = Second of two within-sample strengths

X_{iAB} = Within-sample, 2-test specimen average

X_{Lm} = Average of last- m tests

\bar{X} = Average strength

PART VI: EXECUTION

17. The program is executed through a series of interactive question and answer responses between the computer and the user, respectively. For processing laboratory strength test results, Figure 8 can be used as a guide for a step-by-step execution of the program. In this example, the data are being read from an initial file (Figure 2).

18. The slope, Y-intercept, number of points on curve, and 95 percent confidence interval for the regression curve produced from the analysis of laboratory data are required as input in processing field strength test results. If regression data are based on 30 or more data points, the 95 percent confidence interval is not required as input. Figure 9 and Figure 10 can be used as guides for a step-by-step execution of the program in processing field data. In Figure 9, the analysis is being made using an initial data file (Figure 2). In Figure 10, the analysis is being continued using a restart file (Figure 4). In Figures 8-10, nonstructural concrete is being analyzed.

For WES or MACON systems:

*RUN WESLIB/CORPS/X0064,R

For BOEING system:

C->OLD, CORPS/UN=CECEL.B
C->CALL, CORPS, X0064

ENTER DEVICE SPEED(30 OR 120) - 120
DO YOU WISH TO ENTER DATA FROM TERMINAL(Y OR N) - N
ENTER NAME OF INPUT FILE - L1
IS INPUT DATA FROM A RESTART FILE(Y OR N) - N
DO YOU WISH TO ANALYZE FIELD DATA(Y OR N) - N
ENTER UNITS FOR SLUMP(A2), STRENGTH(A3) AND TEMPERATURE(A1) - IN PSI F
ENTER NUMBER OF COPIES OF OUTPUT TO BE MADE - 3
DO YOU WISH TO LIST TABLES(Y OR N) - Y
DO YOU WISH TO LIST SUMMARY TABLE(Y OR N) - Y

Figure 8. Example showing a step-by-step execution of program using an initial file that contains laboratory test results (Sheet 1 of 8)

U.S. ARMY CORPS OF ENGINEERS
EVALUATION OF CONCRETE STRENGTH DATA

PAGE: 1
DATE: 02/24/83
TIME: 16129

PROJECT: RICHARD B RUSSELL
CONTRACT: DACJ78-81-0084
F CI 2000. 1.282

MIX: TC12
DESIGN AGE: 90-DAY
MAX SIZE AGGR: 6.00

SUMMARY TABLE

RANGE OF WATER/CEMENT RATIO : 0.30 TO 0.65
RANGE OF 90-DAY COMPRESSIVE STRENGTHS, PSI : 1786. TO 5535.

LINEAR REGRESSION OF 1-DAY AND DESIGN AGE(90-DAY) LAB DATA

EQUATION FOR LAB DATA IS : $Y(90-DAY) = 1822. + 4.9538X(1-DAY)$
NO. OF POINTS ON CURVE IS : 30
95% CONFIDENCE INTERVAL IS : 958.36
CORRELATION COEFFICIENT IS : 0.7519

Figure 8. (Sheet 2 of 8)

DO YOU WISH TO LIST INPUT DATA(Y OR N) - Y

PAGE: 2
 DATE: 02/24/83
 TIME: 16120

U.S. ARMY CORPS OF ENGINEERS
 EVALUATION OF CONCRETE STRENGTH DATA

PROJECT: RICHARD B RUSSELL
 CONTRACT: DAC-78-21-C0084
 S.C. 2000.

NIXI: TOT12
 DESIGN AGE: 90-DAY
 MAX SIZE AGGR: 6.00

BATCH INPUT

MIX DATE YR NO DA	SAMPLE NUMBER	U/C	SLUMP (IN)	AIR (%)	TEMP F		REMARKS
					AIR	CONC	
79	3 19 1	0.30	2.00	6.5	XXXX	67.	0-02-23A
79	4 10 55	0.65	2.75	7.0	XXXX	53.	0-04-23C
79	4 17 68	XXXX	2.50	4.8	XXXX	54.	0-02-23A
79	4 18 76	XXXX	2.25	5.8	XXXX	45.	0-02-23A
79	4 19 98	XXXX	2.25	4.8	XXXX	54.	0-06-24
79	4 19 107	XXXX	1.00	4.0	XXXX	50.	0-05-24
79	4 20 115	XXXX	1.50	4.0	XXXX	55.	0-05-24
79	4 30 146	XXXX	2.00	7.0	XXXX	49.	0-04-22
79	5 1 154	XXXX	2.50	5.1	XXXX	53.	0-04-22
79	5 2 178	XXXX	2.25	5.4	XXXX	50.	0-02-22
79	5 4 202	XXXX	2.00	4.6	XXXX	54.	0-04-22
79	5 14 227	XXXX	2.00	4.4	XXXX	55.	0-03-23
79	5 16 242	XXXX	2.00	4.0	XXXX	46.	0-04-21
79	5 16 250	XXXX	2.00	5.7	XXXX	48.	0-04-21
79	5 18 274	XXXX	2.25	7.0	XXXX	XXXX	0-02-21
79	5 18 282	XXXX	1.75	6.8	XXXX	55.	0-03-21
79	5 19 298	XXXX	1.25	4.2	XXXX	50.	0-03-23
79	5 23 332	XXXX	3.00	7.2	XXXX	53.	0-04-22
79	5 23 340	XXXX	2.00	4.4	XXXX	50.	0-04-21
79	5 25 364	XXXX	1.50	5.4	XXXX	42.	0-05-24
79	5 29 372	XXXX	2.75	5.0	XXXX	48.	0-04-20
79	5 30 380	XXXX	1.50	5.4	XXXX	50.	0-04-20
79	6 6 458	XXXX	1.75	5.2	XXXX	50.	0-03-22
79	6 6 466	XXXX	3.00	7.0	XXXX	XXXX	0-03-22
79	6 8 498	XXXX	2.75	4.0	XXXX	53.	0-05-23
79	6 11 522	XXXX	2.50	5.8	XXXX	46.	0-04-19
79	6 13 554	XXXX	2.75	4.3	XXXX	50.	0-01-20
79	6 14 570	XXXX	2.00	5.3	XXXX	38.	0-06-21
79	6 15 600	XXXX	2.75	6.6	XXXX	52.	0-02-19
79	6 18 616	XXXX	2.00	5.4	XXXX	55.	0-03-21

Figure 8. (Sheet 4 of 8)

J.S. ARMY CORPS OF ENGINEERS
 EVALUATION OF CONCRETE STRENGTH DATA

PAGE: 3
 DATE: 10/24/83
 TIME: 16129

PROJECT: RICHARD B RUSSELL
 CONTRACT: DACL78-21-C0084
 FCI: 2000. T1 1.282

MIX: TOT12
 DESIGN AGE: 90-DAY
 MAX SIZE AGGR: 6.00

TEST RESULTS

MIX DATE	SAMPLE VR NO DA NUMBER	CYLINDER STRENGTH (PSI)						
		1-D	7-D	28-D	90-D	90-D	365-D	
78 3 19 1	265	260	495	999	1786	1786	1786	XXXX
78 4 10 55	265	XXXX	796	2036	3342	3289	3289	XXXX
78 4 17 68	329	325	770	2335	4667	3749	3749	XXXX
78 4 18 76	301	308	803	2280	3837	3944	3944	XXXX
78 4 19 99	354	318	868	2326	3872	3856	3856	XXXX
78 4 19 107	371	389	831	2341	3767	XXXX	XXXX	XXXX
78 4 20 115	361	364	833	2414	3979	3873	3873	XXXX
78 4 20 146	347	364	870	1760	3185	3201	3201	XXXX
78 5 1 154	622	622	1478	3334	5822	4863	4863	XXXX
78 5 2 178	637	637	1381	8741	4183	3988	3988	XXXX
78 5 4 208	376	376	1008	2538	4882	4421	4421	XXXX
78 5 14 227	673	668	1309	3537	5368	5368	5368	XXXX
78 5 16 242	424	436	1041	2888	3878	4403	4403	XXXX
78 5 16 250	516	546	1026	3033	4680	4481	4481	XXXX
78 5 18 274	474	508	1186	2812	4888	4481	4481	XXXX
78 5 18 282	477	463	1061	2706	4244	4158	4158	XXXX
78 5 19 298	584	591	1114	2900	4881	4527	4527	XXXX
78 5 23 322	531	541	1086	2370	3961	3784	3784	XXXX
78 5 23 340	580	592	982	2440	3749	3802	3802	XXXX
78 5 25 364	424	416	1619	2866	3944	3767	3767	XXXX
78 5 29 372	417	427	1008	2794	3767	3979	3979	XXXX
78 5 30 380	531	534	1406	3484	5352	4969	4969	XXXX
78 6 6 458	371	392	1028	2706	3802	4509	4509	XXXX
78 6 8 466	340	360	716	1692	2769	2971	2971	XXXX
78 6 8 498	368	378	973	2440	3443	3468	3468	XXXX
78 6 11 522	460	460	1008	2600	4103	4067	4067	XXXX
78 6 13 554	407	424	946	2228	3501	3501	3501	XXXX
78 6 14 570	538	552	1265	2776	4863	4863	4863	XXXX
78 6 15 600	403	400	982	2281	4050	4050	4050	XXXX
78 6 15 616	651	665	1657	3431	5323	5128	5128	XXXX

Figure 8. (Sheet 5 of 8)

DO YOU WISH TO PLOT DATA(Y OR N) - Y

DO YOU WANT REPLOT CABILITIES(Y OR N) - N

DO YOU WISH TO PLOT REGRESSION CURVES(Y OR N) - Y

REGRESSION PLOT

ENTER BEGINNING AND ENDING TEST NUMBERS TO BE PLOTTED - 1 30

Figure 8. (Sheet 6 of 8)

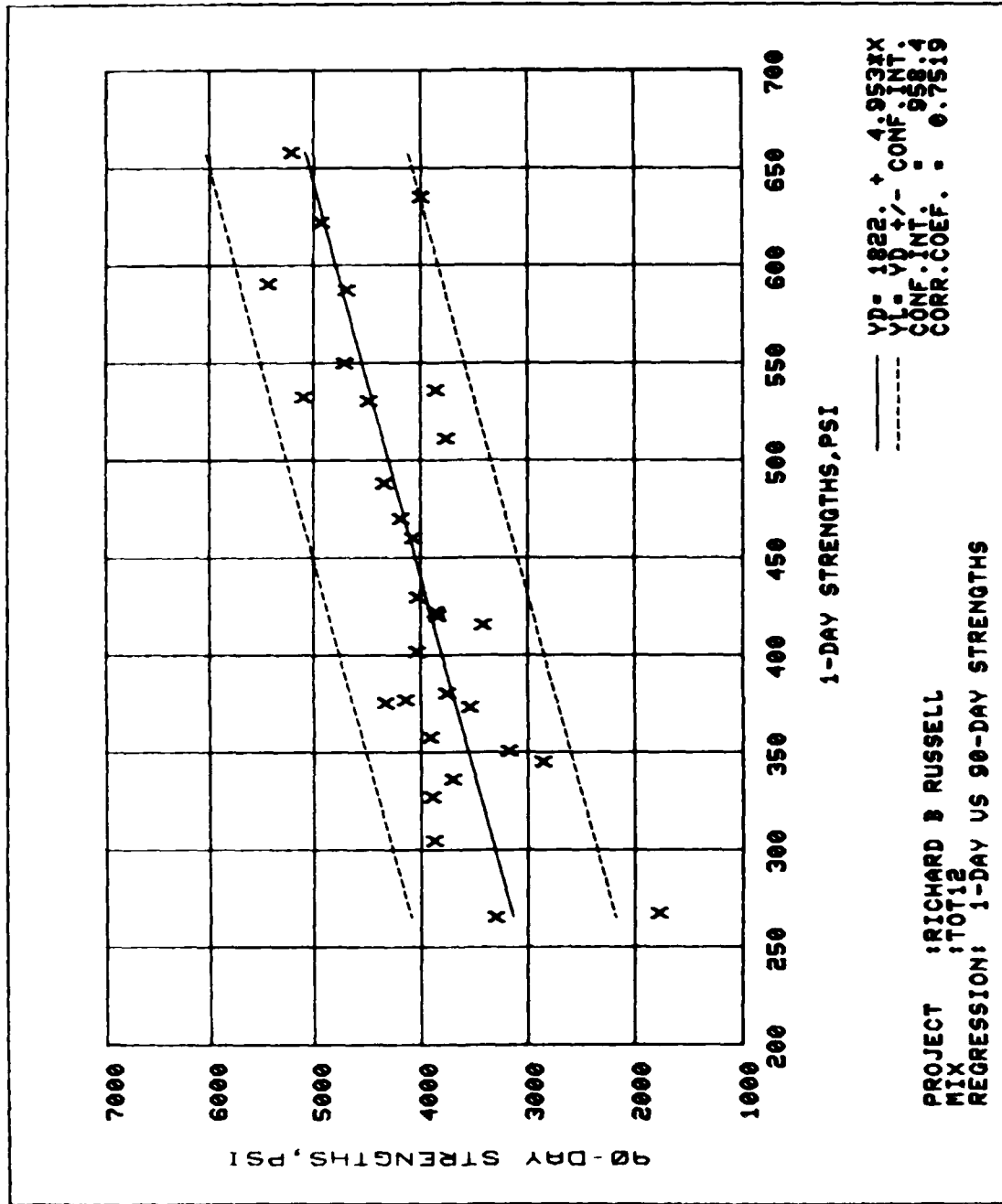


Figure 8. (Sheet 7 of 8)

DO YOU WISH TO REPLOT REGRESSION CURVE(Y OR N) - N
DO YOU WISH TO RETURN TO TABLE OPTION(Y OR N) - N
DO YOU WISH TO RETURN TO PLOT OPTION(Y OR N) - N
IS RESTART FILE TO BE GENERATED(Y OR N) - N
DO YOU WISH TO MAKE ANOTHER RUN(Y OR N) - N

*

For WES or MACON systems:

*RUN WESLIB/CORPS/X0064,R

For BOEING systems:

C>OLD,CORPS/LN=CEGELB
C>CALL,CORPS,X0064

ENTER DEVICE SPEED(30 OR 120) - 120

DO YOU WISH TO ENTER DATA FROM TERMINAL(Y OR N) - N

ENTER NAME OF INPUT FILE - F1

IS INPUT DATA FROM A RESTART FILE(Y OR N) - N

DO YOU WISH TO ANALYZE FIELD DATA(Y OR N) - Y

IS STRUCTURAL CONCRETE TO BE ANALYZED(Y OR N) - N

ENTER SLOPE,Y-INTERCEPT, AND NO. POINTS
FOR LABORATORY REGRESSION CURVE - 4.953 1822 30

ENTER UNITS FOR SLUMP(A2),STRENGTH(A3) AND TEMPERATURE(A1) - IN PSI F

ENTER NUMBER OF COPIES OF OUTPUT TO BE MADE - 3

DO YOU WISH TO LIST TABLES(Y OR N) - Y

DO YOU WISH TO LIST SUMMARY TABLE(Y OR N) - Y

Figure 9. Example showing a step-by-step execution of program using an initial file that contains field test results (Sheet 1 of 27)

U.S. ARMY CORPS OF ENGINEERS
 EVALUATION OF CONCRETE STRENGTH DATA

PAGE: 1
 DATE: 02/24/83
 TIME: 17:10

PROJECT: RICHARD B. RUSSELL
 CONTRACT: DACU78-2-C0084
 F/C: 2000. T: 1.282 MAX SIZE AGGR: 6.00 W/C: 0.57

MIX: 7CT12
 DESIGN AGE: 90-DAY

SUMMARY TABLE

AVERAGE LATER/CEMENT RATIO 0.48
 AVERAGE SLUMP, IN 2.18
 AVERAGE AIR CONTENT, % 5.4
 REQUIRED 1-DAY ACCELERATED STRENGTH, PSI 36
 REQUIRED AVERAGE 1-DAY ACCELERATED STRENGTH, PSI 178
 SPECIFIED STRENGTH FOR 90-DAY STRENGTHS, PSI 2000
 REQUIRED AVERAGE 90-DAY STRENGTH, PSI 2934

AGE TEST	NO.	SUP OF TEST	SQUARED	TEST AVERAGE	RANGE	COEFF. OF VARIATION			STD DEV
						PSI	WITHIN SAMPLE	WITHIN GROUP	
1	30	13317.	6265911.	444.	12.	2.4	24.0	111.	
7	30	31128.	34314802.	1038.	XXXX	XXXX	25.4	264.	
28	30	76884.	20659332.	2553.	XXXX	XXXX	21.3	546.	
90	30	126605.	50024848.	4020.	196.	4.3	18.1	729.	
305	0	0.	0.	0.	XXXX	XXXX	0.	0.	

LINEAR REGRESSION OF 1-DAY AND DESIGN AGE (90-DAY) LAB DATA

EQUATION FOR LAB DATA IS : $y(90-DAY) = 1822 + 4.9538x(1-DAY)$
 NO. OF POINTS ON CURVE IS : 30

Figure 9. (Sheet 2 of 27)

DO YOU WISH TO LIST PREDICTED STRENGTHS(Y OR N) - Y

Figure 9. (Sheet 3 of 27)

U.S. ARMY CORPS OF ENGINEERS
EVALUATION OF CONCRETE STRENGTH DATA

PAGE 1 2
DATE 10/24/83
TIME 16138

PROJECT: RICHARD B RUSSELL
CONTRACT: DACJ78-21-C0084
F.C.: 2000
SIZE AGGR: 6.00
J/C: 0.67

TEST TOTAL
DESIGN AGE: 90-DAY

PREDICTED STRENGTHS

N	PREDICTED STRENGTHS		STRENGTH		DIFFERENCE		DIFFERENCE	
	ACCELERATED 1-DAY (PSI)	PREDICTED 90-DAY (PSI)	ACTUAL 90-DAY (PSI)	90-DAY (PSI)	90-DAY (PSI)	90-DAY (K)	90-DAY (K)	90-DAY (K)
1	267	3144	1786		-1358.5		-76.1	
2	285	3135	3316		181.0		5.5	
3	327	3442	3908		466.4		11.9	
4	305	3330	3891		560.3		14.4	
5	336	3486	3714		227.3		6.1	
6	380	3704	3767		62.0		1.7	
7	358	3593	3828		333.3		0.5	
8	351	3558	3183		-375.0		-11.0	
9	622	4903	4943		30.7		0.8	
10	635	4967	4015		-952.7		-23.7	
11	376	3679	4342		662.1		15.3	
12	591	4747	5447		699.8		12.8	
13	430	3949	4041		81.2		2.3	
14	531	4450	4501		50.0		1.1	
15	488	4230	4351		111.4		2.6	
16	470	4160	4200		50.1		1.2	
17	588	4732	4704		-27.9		-0.6	
18	536	4477	3873		-604.3		-15.8	
19	511	4353	3776		-577.5		-15.3	
20	420	3082	3855		46.8		1.2	
21	422	3012	3873		39.2		1.0	
22	533	4469	5111		651.0		12.7	
23	377	3687	4166		488.7		11.3	
24	345	3531	2865		-665.8		-23.2	
25	373	3669	3555		-115.0		-3.2	
26	460	4100	4085		-15.4		-0.4	
27	418	3880	3431		-449.5		-13.1	
28	550	4546	4722		175.3		3.7	
29	402	3811	4050		239.4		5.0	
30	658	5081	6226		144.4		2.8	
AVERAGE	444.	4021.	4020.		XXXXXXXX		XXXXXXXX	
STD ERROR OF EST.	XXXXXXXX	XXXXXXXX	XXXXXXXX		472.4		17.3	

Figure 9. (Sheet 4 of 27)

DO YOU WISH TO LIST INPUT DATA(Y OR N) - Y

Figure 9. (Sheet 5 of 27)

U.S. ARMY CORPS OF ENGINEERS
EVALUATION OF CONCRETE STRENGTH DATA

PROJECT: RICHARD B ALSSELL
CONTRACT: DACW78-21-C0084
P.C. 2000

DESIGN AGENT: 90-DAY
DATE: 02/24/83
TIME: 16138

TEST: TOTAL
DESIGN AGENT: 90-DAY
DATE: 02/24/83
TIME: 16138

TEST: TOTAL
DESIGN AGENT: 90-DAY
DATE: 02/24/83
TIME: 16138

BATCH INPUT

MIX DATE	YEAR	MO	DA	SAMPLE NUMBER	W/C	SLUMP (IN)	AIR (%)	CONC	REMARKS
79	3	19	1	0.30	2.00	6.5	xxxx	67	G-02-23A
79	4	10	55	0.65	2.75	7.0	xxxx	53	G-04-23C
79	4	17	68	xxxx	2.50	4.8	xxxx	54	G-02-23A
79	4	18	76	xxxx	2.25	5.8	xxxx	45	G-02-23A
79	4	19	99	xxxx	2.25	4.8	xxxx	54	G-06-24
79	4	19	107	xxxx	1.00	4.0	xxxx	50	G-06-24
79	4	20	115	xxxx	1.50	4.0	xxxx	55	G-06-24
79	4	30	146	xxxx	2.00	7.0	xxxx	49	G-04-22
79	5	1	154	xxxx	2.50	5.1	xxxx	53	G-04-22
79	5	2	178	xxxx	2.25	5.4	xxxx	50	G-02-22
79	5	4	202	xxxx	2.00	4.6	xxxx	54	G-06-22
79	5	14	227	xxxx	2.00	4.4	xxxx	55	G-03-23
79	5	16	242	xxxx	3.00	4.9	xxxx	46	G-04-21
79	5	18	250	xxxx	2.00	5.7	xxxx	49	G-04-21
79	5	18	274	xxxx	2.25	7.0	xxxx	xxxx	G-02-21
79	5	18	282	xxxx	1.75	6.8	xxxx	55	G-02-21
79	5	19	298	xxxx	1.25	4.2	xxxx	50	G-03-23
79	5	23	332	xxxx	3.00	7.2	xxxx	53	G-06-22
79	5	23	340	xxxx	2.00	4.4	xxxx	60	G-06-21
79	5	25	364	xxxx	1.50	5.4	xxxx	42	G-06-24
79	5	29	372	xxxx	2.75	5.0	xxxx	48	G-04-20
79	5	30	380	xxxx	1.50	5.4	xxxx	50	G-04-20
79	6	6	438	xxxx	1.75	5.2	xxxx	50	G-03-22
79	6	6	486	xxxx	3.00	7.0	xxxx	xxxx	G-03-22
79	6	8	498	xxxx	2.75	4.0	xxxx	53	G-05-23
79	6	11	522	xxxx	2.50	5.6	xxxx	46	G-04-19
79	6	13	554	xxxx	2.75	4.3	xxxx	50	G-01-20
79	6	14	570	xxxx	2.00	5.3	xxxx	38	G-06-21
79	6	15	600	xxxx	2.75	6.6	xxxx	52	G-02-19
79	6	18	616	xxxx	2.00	5.4	xxxx	55	G-03-21

Figure 9. (Sheet 6 of 27)

PROJECT: RICHARD B RUSSELL
 CONTRACT: DACU78-21-00084
 F.C.: 2000. 71 1.282 MAX SIZE AGGR: 6.00 W/C: 0.67

MIX: 70-12
 DESIGN AGE: 90-DAY
 W/C: 0.67

TEST RESULTS

MIX DATE	SAMPLE NO	CYLINDER STRENGTH (PSI)				
		1-D	7-D	28-D	90-D	365-D
79 3 19 1	265		495	989	1786	1786
79 4 10 55	265	2222	796	2936	3342	3289
79 4 17 68	329		770	2335	4067	3749
79 4 18 76	301		893	2890	3837	3944
79 4 19 99	354		318	2325	3572	3855
79 4 19 107	371		389	2341	3767	3888
79 4 20 115	361		354	2114	3979	3873
79 4 30 146	347		679	1760	3165	3201
79 5 1 154	622		1472	3334	5022	4863
79 5 2 178	637		1221	2741	4193	3926
79 5 4 202	375		1008	2538	4282	4421
79 5 14 227	573		1309	3537	5535	5358
79 5 16 242	424		1061	3088	3878	4493
79 5 16 250	516		1028	3033	4589	4421
79 5 18 274	474		592	2812	4280	4421
79 5 18 282	477		1185	2812	4280	4156
79 5 19 298	584		1114	2900	4881	4627
79 5 23 332	531		1026	2370	3961	3784
79 5 23 340	520		982	2440	3749	3892
79 5 25 364	424		1010	2885	3844	3767
79 6 29 372	417		1009	2784	3787	3979
79 6 30 380	531		1486	3484	5252	4969
79 6 6 468	371		1028	2766	3802	4509
79 6 8 488	340		716	1592	2759	2971
79 6 11 522	480		1008	2440	3643	3465
79 6 13 564	487		946	2828	4103	4067
79 6 14 570	538		1265	2776	3360	3501
79 6 15 600	493		902	2281	4050	4863
79 6 18 616	551		1557	3431	4050	4850
					5323	5128
					6323	6128

Figure 9. (Sheet 7 of 27)

ENTER NUMBER OF AGE GROUPS FOR WHICH
STATISTICAL TABLES ARE TO BE LISTED - 3

ENTER TEST AGES OF GROUPS TO BE VIEWED - 1 28 90

PAGE: 5
 DATE: 02/24/83
 TIME: 16:38

U.S. ARMY CORPS OF ENGINEERS
 EVALUATION OF CONCRETE STRENGTH DATA

PROJECT: RICHARD B RUSSELL
 CONTRACT: DACW78-81-C0084
 F.C. 2000. 1.1.282 MAX SIZE AGGR: 5.00 W/C: 0.67
 M: M: TOT: 12
 DESIGN AGE: 90-DAY
 U/C: 0.67

BATCH STATISTICS

MIX DATA		SAMPLE NUMBER	SEQUENCE NUMBER	CUMULATIVE AVERAGES		
VR	MO DA			U/C	SLUMP	AIR
79	3 19	1	0.30	2.00	6.5	
79	4 10	55	0.48	2.38	6.0	
79	4 17	68	0.48	2.42	6.1	
79	4 18	76	0.48	2.38	6.0	
79	4 19	99	0.48	2.36	6.8	
79	4 19	107	0.48	2.13	5.5	
79	4 20	115	0.48	2.04	6.3	
79	4 30	146	0.48	2.03	5.5	
79	5 1	154	0.48	2.08	5.4	
79	5 2	178	0.48	2.10	5.4	
79	5 4	202	0.48	2.09	5.4	
79	5 14	227	0.48	2.08	6.3	
79	5 16	242	0.48	2.15	6.3	
79	5 16	250	0.48	2.14	6.3	
79	5 18	274	0.48	2.15	5.4	
79	5 18	282	0.48	2.13	5.5	
79	5 19	298	0.48	2.07	5.4	
79	5 23	338	0.48	2.13	5.5	
79	5 23	340	0.48	2.12	5.5	
79	5 25	364	0.48	2.09	5.4	
79	5 30	372	0.48	2.12	5.4	
79	6 8	388	0.48	2.09	5.4	
79	6 8	458	0.48	2.08	5.4	
79	6 8	486	0.48	2.11	5.5	
79	6 11	522	0.48	2.14	5.4	
79	6 13	554	0.48	2.15	5.4	
79	6 14	570	0.48	2.18	5.4	
79	6 16	600	0.48	2.17	5.4	
79	6 18	616	0.48	2.18	5.4	

Figure 9. (Sheet 9 of 27)

PAGE 1 6
DATE: 10/22/83
TIME: 16138

U.S. ARMY CORPS OF ENGINEERS
EVALUATION OF CONCRETE STRENGTH DATA

PROJECT: RICHARD B RUSSELL MIX: 7012
CONTRACT: DACU78-21-C0084 DESIGN AGE: 90-DAY
F.C.I. 2000. T: 1.282 MAX SIZE AGGR: 6.00 W/C: 0.67

REPORT FOR 1 DAY STRENGTHS

SAMPLE NUMBER	CYCL AVE	PSI	CUM AVE	PSI	RANGE			COEF OF VAR			STD DEV
					L-S AVE	ACT	PSI	L-10	ACT	UN	
1	267	267	267	267	4	4	XXXX	1.3	1.3	0.	0
55	265	XXXX	XXXX	XXXX	XXXX	4	XXXX	XXXX	XXXX	0.5	1
68	327	286	XXXX	XXXX	4	4	XXXX	1.2	1.2	12.3	35
76	305	291	XXXX	XXXX	7	5	XXXX	2.1	1.5	10.4	30
99	336	300	XXXX	XXXX	36	13	XXXX	10.6	3.0	11.0	33
107	380	313	XXXX	XXXX	18	14	XXXX	5.1	3.9	14.1	44
115	358	320	XXXX	XXXX	7	13	XXXX	1.9	3.5	13.6	44
146	361	346	XXXX	XXXX	7	12	XXXX	1.9	3.2	12.9	42
154	622	367	XXXX	XXXX	0	10	XXXX	0.	8.0	30.0	107
178	635	384	XXXX	XXXX	4	10	XXXX	0.9	2.2	34.8	134
202	375	384	XXXX	XXXX	0	9	XXXX	0.	2.0	33.1	187
227	591	401	XXXX	XXXX	36	11	XXXX	7.7	2.5	33.7	136
242	430	402	XXXX	XXXX	11	11	XXXX	2.4	2.4	32.1	130
250	531	412	XXXX	XXXX	29	12	XXXX	6.2	2.7	31.3	129
274	488	417	XXXX	XXXX	28	14	XXXX	5.9	2.9	30.2	126
282	470	481	XXXX	XXXX	14	14	XXXX	3.0	2.9	29.1	122
298	588	430	XXXX	XXXX	17	13	XXXX	1.4	2.7	29.1	125
312	536	436	XXXX	XXXX	10	13	XXXX	2.0	2.6	28.4	124
340	511	440	XXXX	XXXX	18	13	XXXX	3.6	2.7	27.6	122
364	420	439	XXXX	XXXX	8	13	XXXX	1.6	2.6	27.6	119
372	422	438	XXXX	XXXX	10	13	XXXX	2.0	2.6	26.4	116
380	533	443	XXXX	XXXX	3	12	XXXX	0.6	2.5	25.9	115
458	377	440	XXXX	XXXX	11	12	XXXX	2.2	2.5	25.6	113
466	345	436	XXXX	XXXX	10	12	XXXX	2.0	2.5	25.7	112
488	373	433	XXXX	XXXX	10	12	XXXX	2.0	2.5	25.5	110
522	460	434	XXXX	XXXX	0	12	XXXX	0.	2.4	24.9	108
554	416	434	XXXX	XXXX	17	12	XXXX	3.5	2.4	24.6	106
570	550	438	XXXX	XXXX	24	12	XXXX	4.9	2.5	24.3	107
600	402	437	XXXX	XXXX	3	12	XXXX	0.6	2.4	24.0	105
616	658	444	XXXX	XXXX	14	12	XXXX	2.8	2.4	24.9	111

REQUIRED AVERAGE STRENGTH FOR ABOVE DATA = 178. PSI

Figure 9. (Sheet 10 of 27)

PAGE 1 7
 DATE 10/24/83
 TIME 16138

L.S. ARMY CORPS OF ENGINEERS
 EVALUATION OF CONCRETE STRENGTH DATA

PROJECT: RICHARD B RUSSELL
 CONTRACT: DACU78-21-C0084
 F.C.I. 2000. T: 1.282 MAX SIZE AGGR: 6.00 U/C: 0.67
 MIXI DESIGN AGE1 90-DAY
 TOT:2

REPORT FOR 28 DAY STRENGTHS

SAMPLE NUMBER	CUM		L-S		COEF		STD	
	AVE	PSI	AVE	PSI	JAR	N	DEV	PSI
1	999		XXXX		0		0	
55	1518		XXXX		48.3		733	
68	1790		XXXX		38.2		781	
76	1915		XXXX		32.6		825	
99	1997		XXXX		28.6		871	
107	2054		XXXX		25.8		920	
115	2106		XXXX		23.9		962	
146	2063		XXXX		23.2		1011	
154	2204		XXXX		22.0		1061	
178	2258		XXXX		20.9		1111	
202	2283		XXXX		20.5		1161	
227	2388		XXXX		17.8		1211	
242	2411		XXXX		16.5		1261	
260	2455		XXXX		15.9		1311	
274	2479		XXXX		15.4		1361	
282	2493		XXXX		14.2		1411	
298	2517		XXXX		13.5		1461	
332	2509		XXXX		12.9		1511	
340	2505		XXXX		12.3		1561	
364	2523		XXXX		11.8		1611	
372	2536		XXXX		11.3		1661	
380	2570		XXXX		11.0		1711	
458	2585		XXXX		11.0		1761	
466	2543		XXXX		10.6		1811	
498	2539		XXXX		10.2		1861	
528	2545		XXXX		9.8		1911	
564	2533		XXXX		9.4		1961	
570	2542		XXXX		9.0		2011	
600	2533		XXXX		8.6		2061	
616	2583		XXXX		8.2		2111	

Figure 9. (Sheet 11 of 27)

PROJECT: RICHARD B RUSSELL MIXI 7012
CONTRACT: DACW78-81-C0084 DESIGN AGE: 90-DAY
F.C.I. 2000. T1 1.282 MAX SIZE AGGR: 6.00 U/O: 0.87

REPORT FOR 90 DAY STRENGTHS

SAMPLE NUMBER	20 YL AVE PSI	CUM AVE PSI	L-5 AVE PSI	RANGE		COEF OF VAR		STD DEV PSI
				ACT	AVE L-10	ACT	UJ	
1	1786	1786	1786	0	0	0.0	0.0	0
55	3216	2551	3216	57	27	1.8	0.9	1082
68	3808	3003	3808	318	124	8.4	3.7	1085
76	3891	3225	3891	107	120	2.9	3.3	988
99	3714	3323	3323	283	152	7.6	4.1	892
107	3767	3397	3710	388	152	8.8	4.0	818
115	3926	3472	3841	106	145	2.7	3.7	773
146	3183	3436	3506	36	129	0.9	3.3	723
154	4843	2694	3906	159	133	3.9	3.3	842
178	4815	3645	3967	177	138	4.3	3.3	805
202	4342	3708	4088	159	140	3.8	3.3	792
227	5447	3853	4386	177	143	4.1	3.3	906
242	4641	3857	4567	726	192	16.6	4.4	860
250	4591	3913	4489	159	189	3.6	4.2	852
274	4351	3942	4528	141	186	3.2	4.2	820
282	4500	3958	4588	88	179	2.6	4.0	804
288	4784	4062	4369	354	190	7.8	4.2	799
322	3873	3996	4326	177	189	3.9	4.2	776
340	3776	3983	4181	53	182	1.2	4.0	755
372	3856	3972	4082	177	182	3.9	4.0	739
389	5111	4024	4097	212	183	4.7	4.1	741
438	4356	4029	4154	203	188	6.2	4.1	741
466	2865	3981	4154	707	211	15.6	4.7	726
498	3555	3914	3972	212	211	4.7	4.7	747
522	4085	3968	3954	36	203	0.8	4.7	737
554	3431	3948	3818	141	201	3.2	4.5	716
570	4722	3976	3731	293	204	6.3	4.5	717
600	4650	3979	3968	0	196	0.0	4.4	705
616	5226	4020	4303	195	196	4.3	4.3	729

REQUIRED AVERAGE STRENGTH FOR ABOVE DATA = 2934. PSI

Figure 9. (Sheet 12 of 27)

DO YOU WISH TO PLOT DATA(Y OR N) - Y

DO YOU WANT REPLOT CABILITIES(Y OR N) - N

ARE AIR CONTENTS AND SLUMPS TO BE PLOTTED(Y OR N) - Y

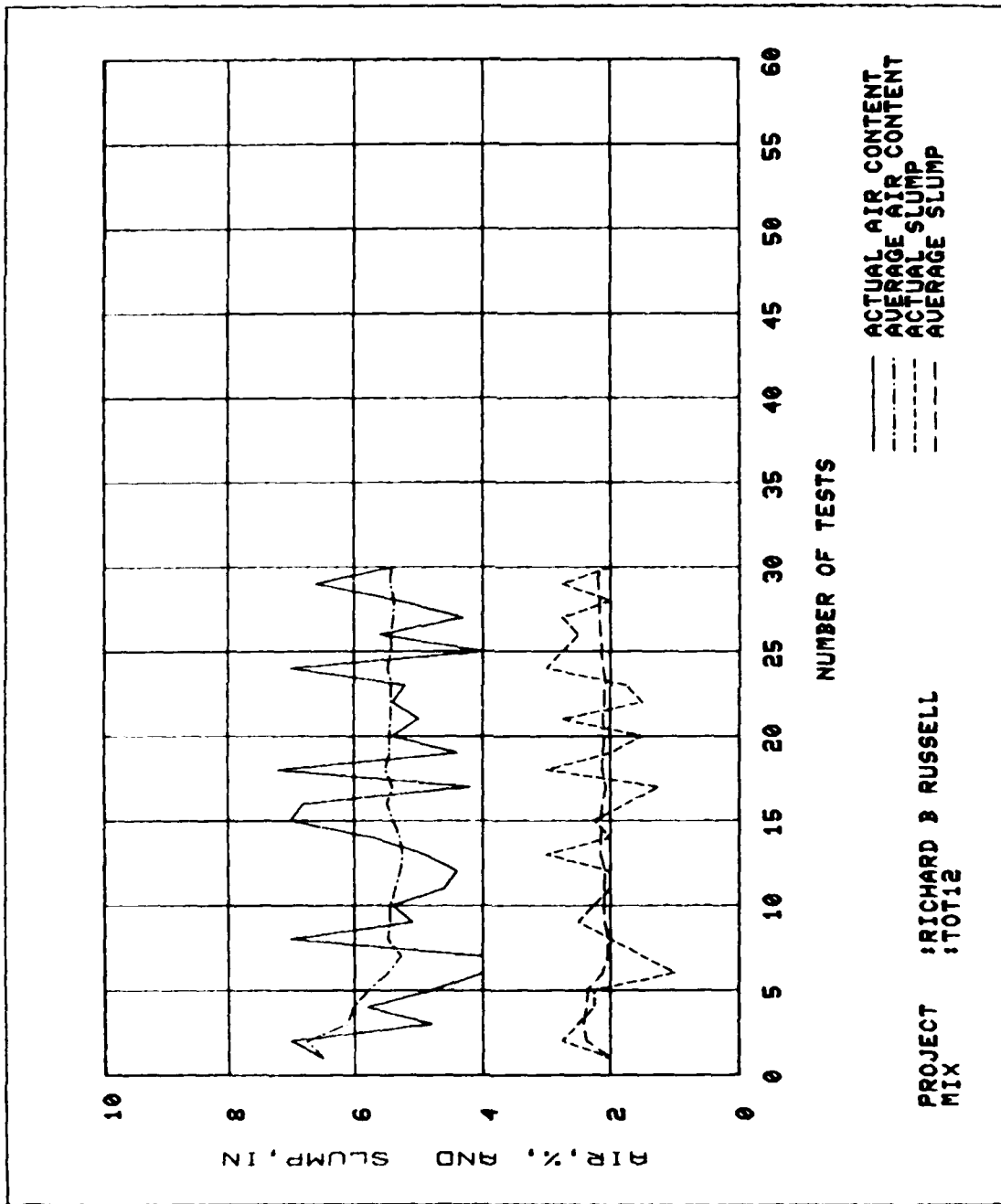


Figure 9. (Sheet 14 of 27)

DO YOU WISH TO PLOT PREDICTED STRENGTHS(Y OR N) - Y

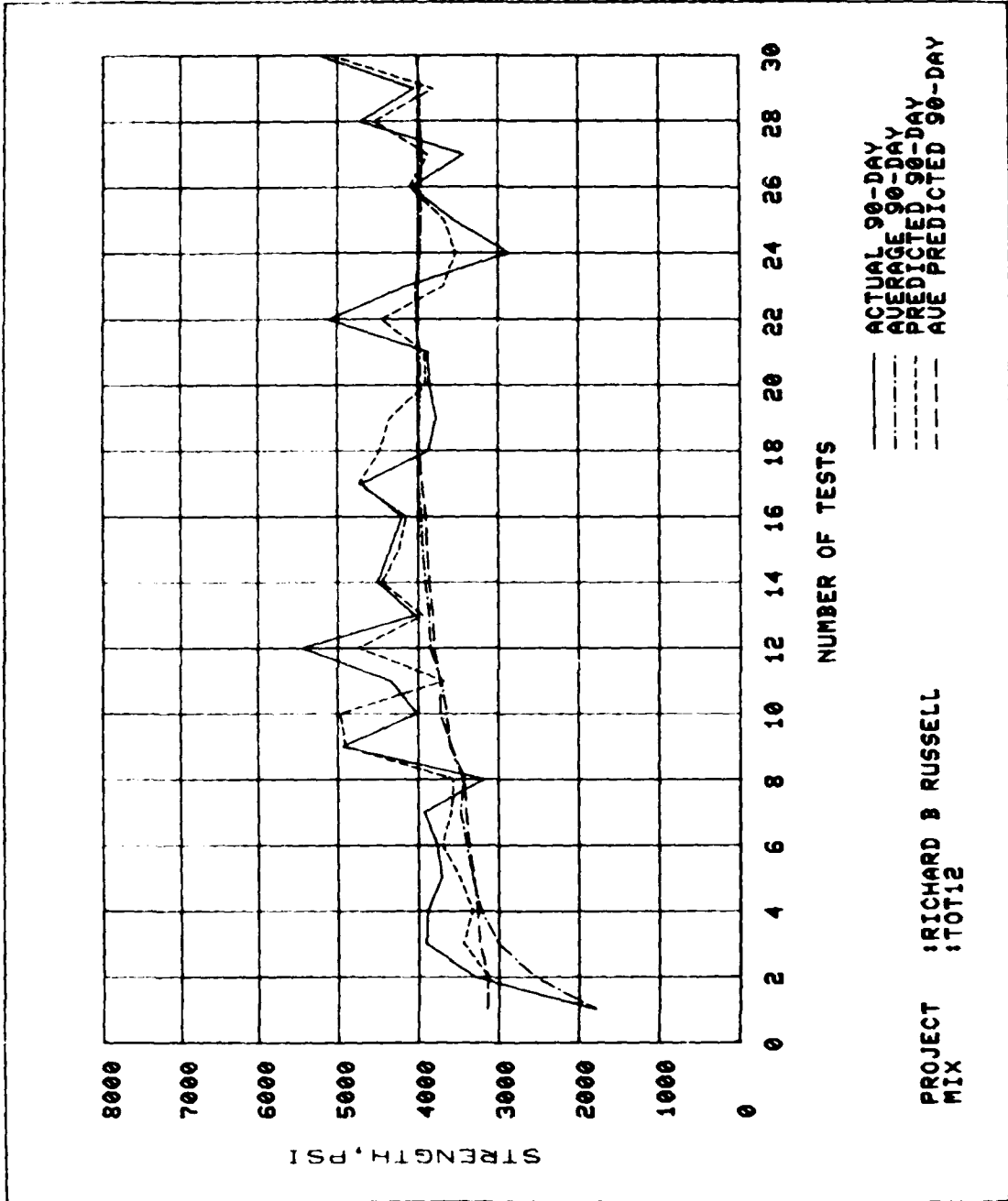


Figure 9. (Sheet 16 of 27)

ENTER NUMBER OF AGE GROUPS FOR WHICH
STATISTICAL TABLES ARE TO BE PLOTTED - 3

ENTER TEST AGES OF GROUPS TO BE VIEWED - 1 28 90

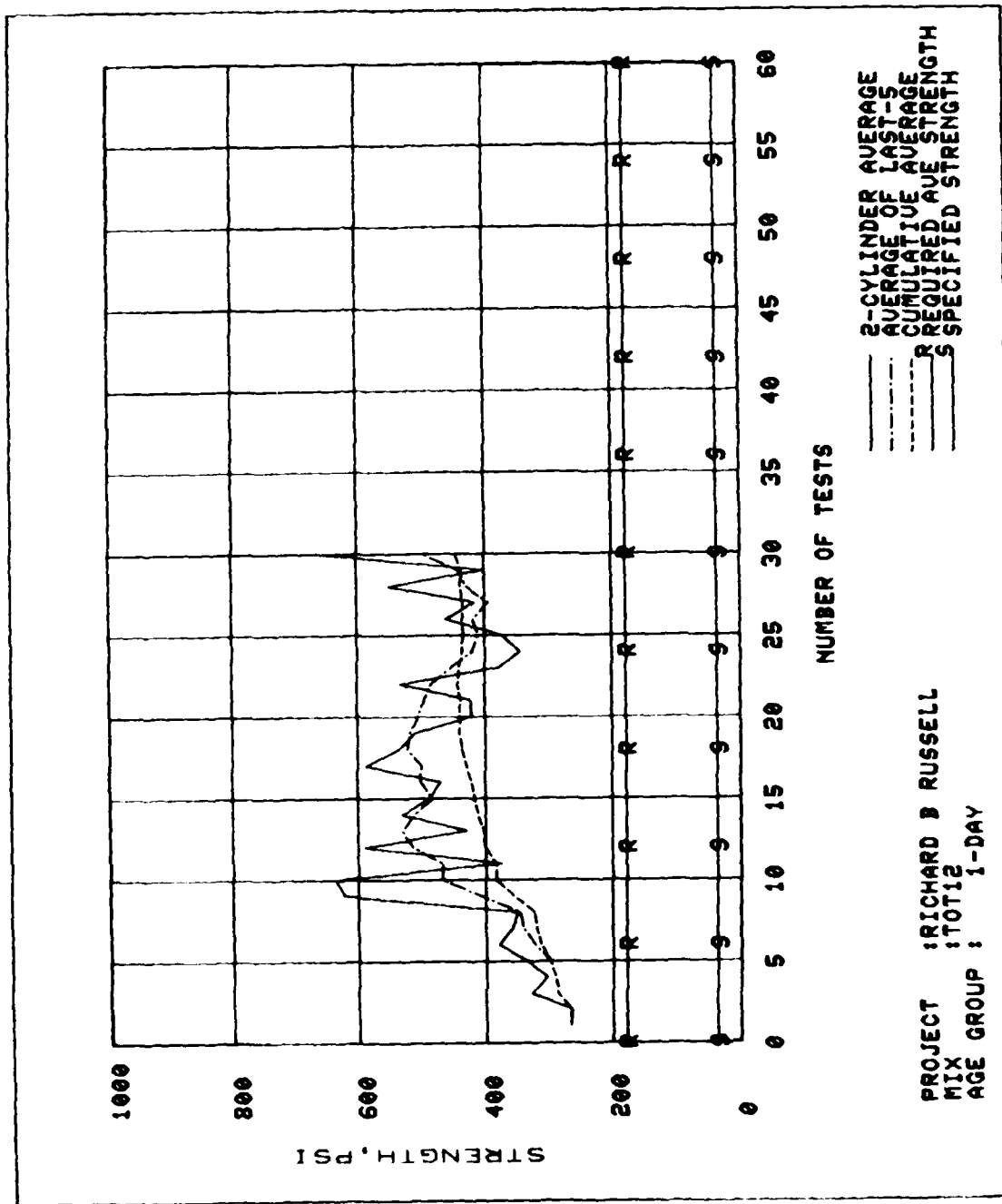


Figure 9. (Sheet 18 of 27)

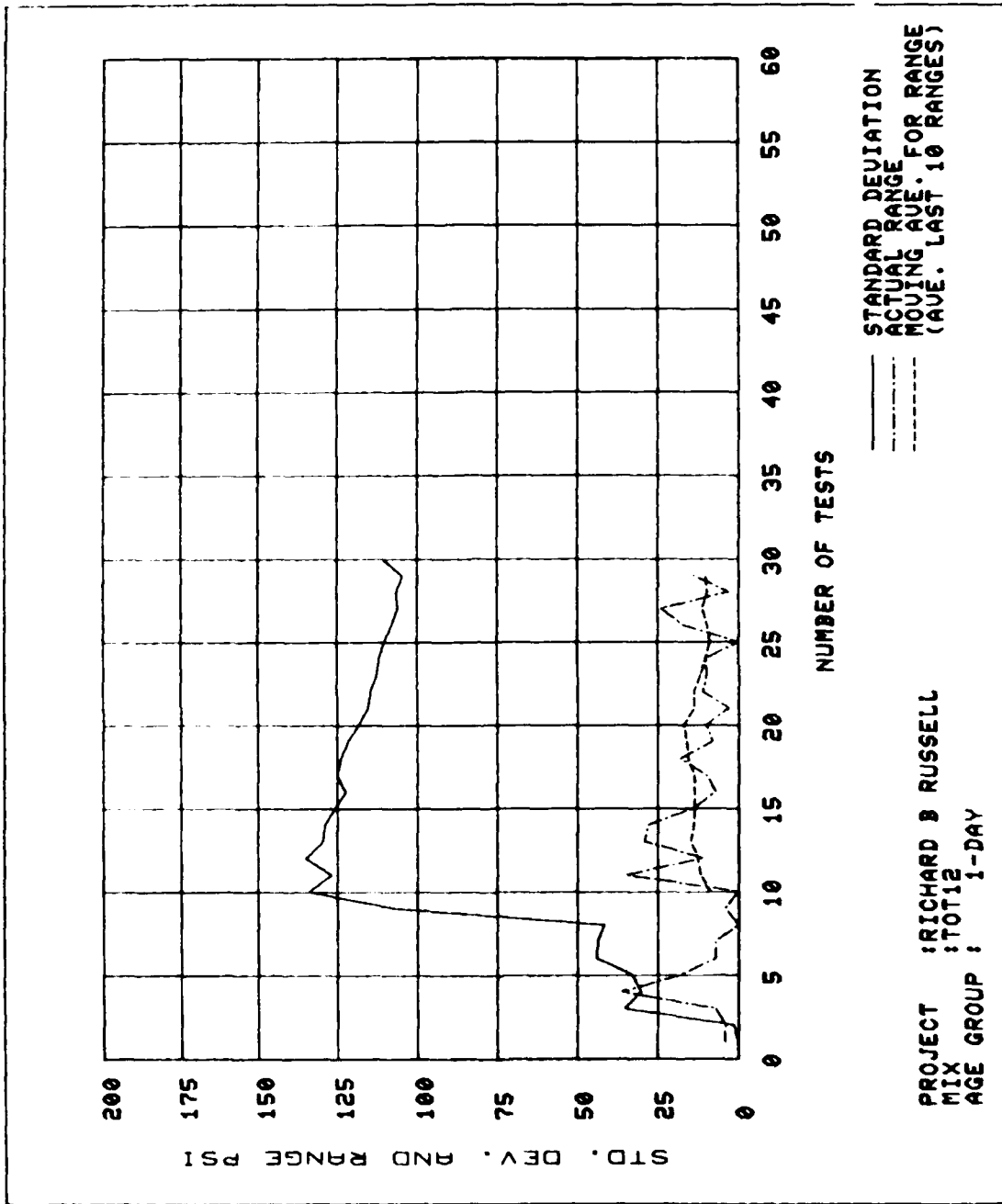


Figure 9. (Sheet 19 of 27)

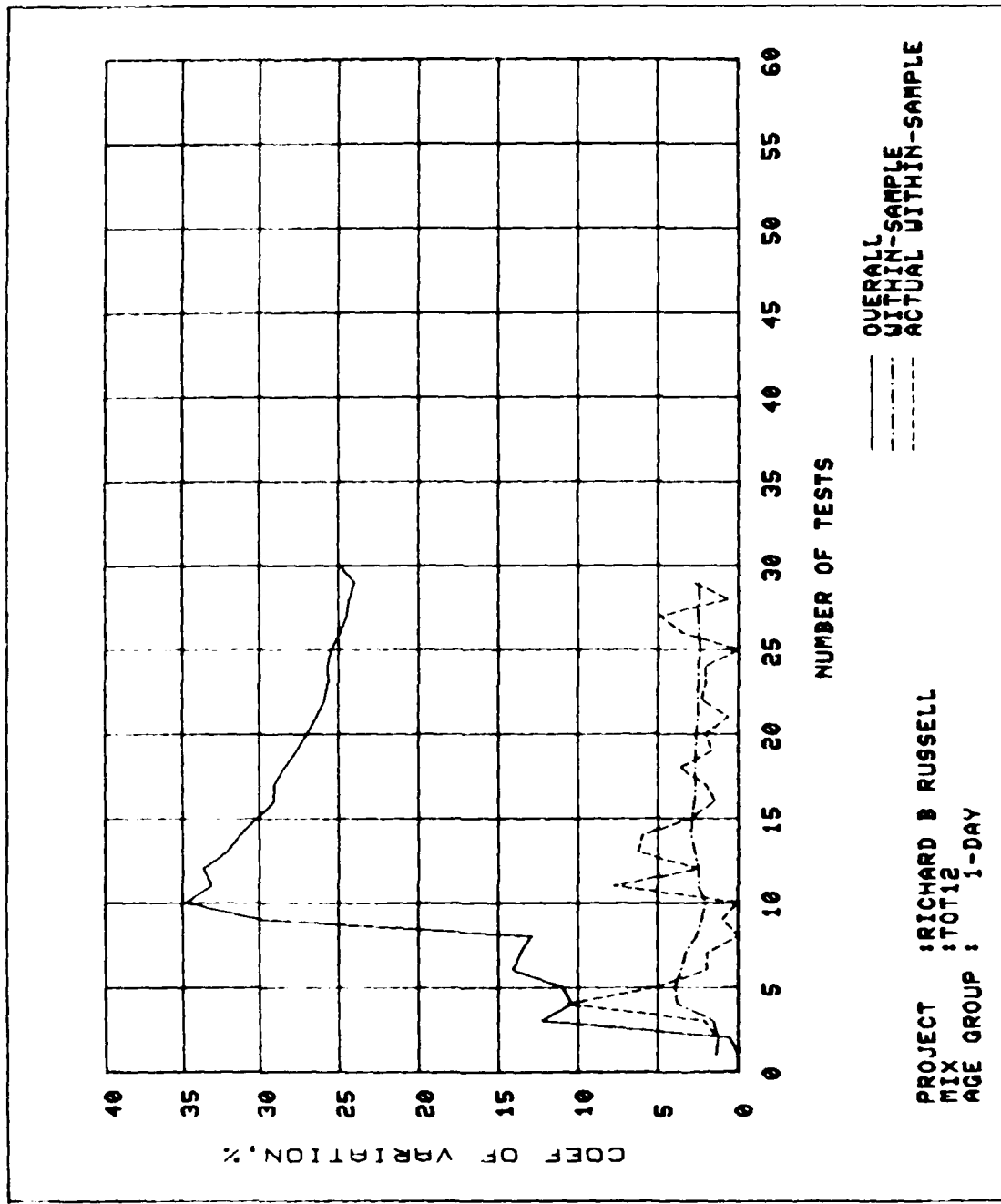


Figure 9. (Sheet 20 of 27)

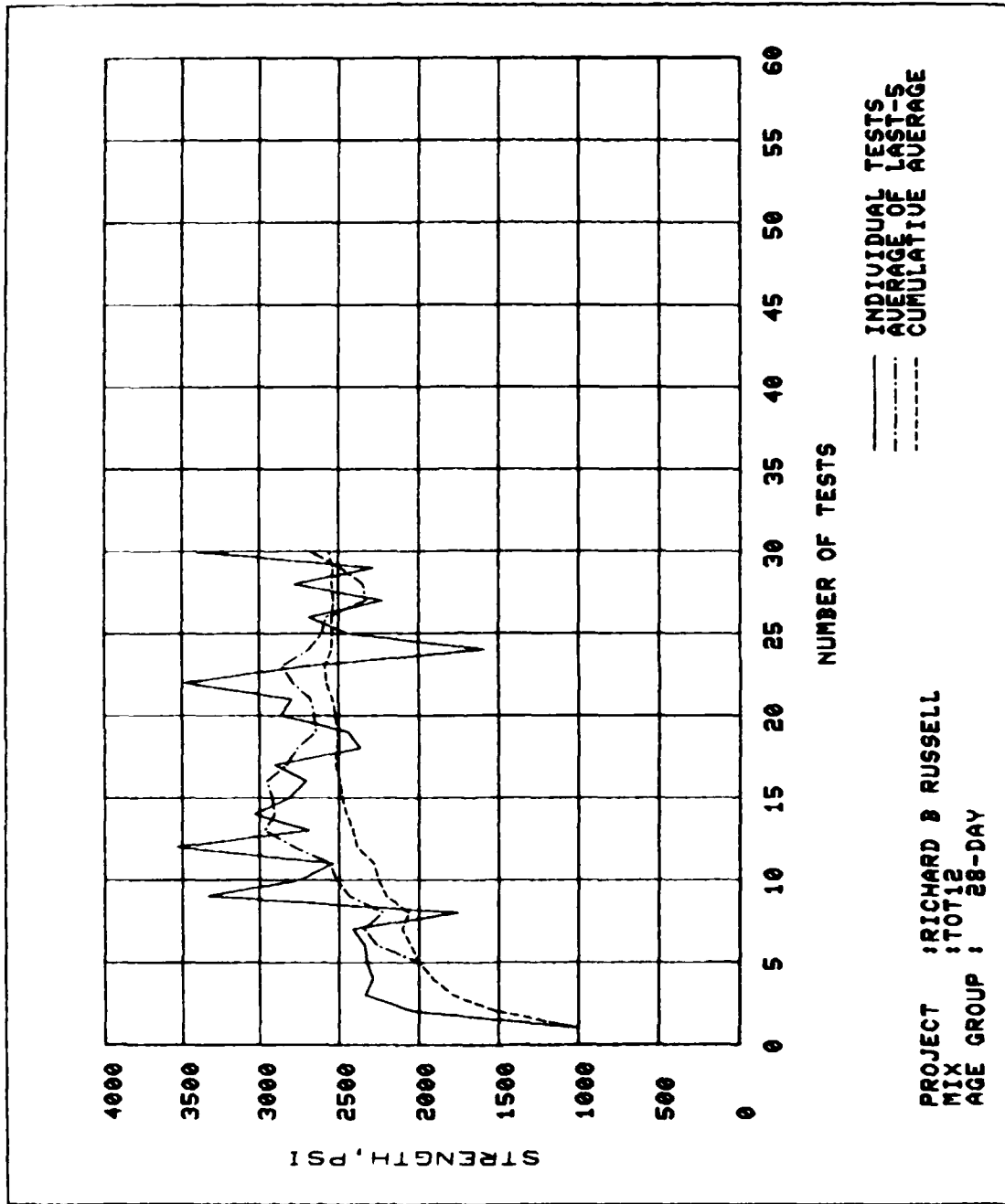


Figure 9. (Sheet 21 of 27)

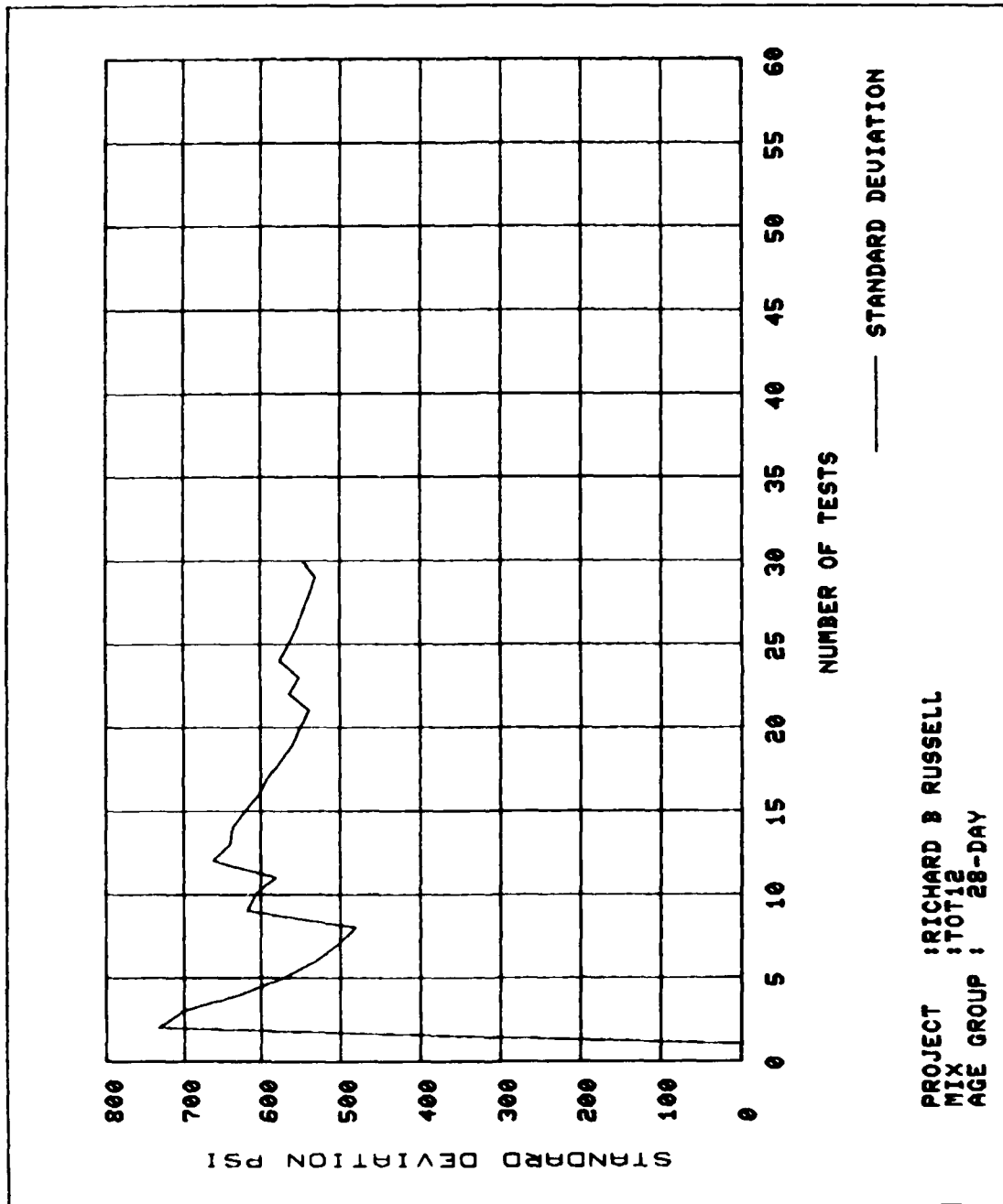


Figure 9. (Sheet 22 of 27)

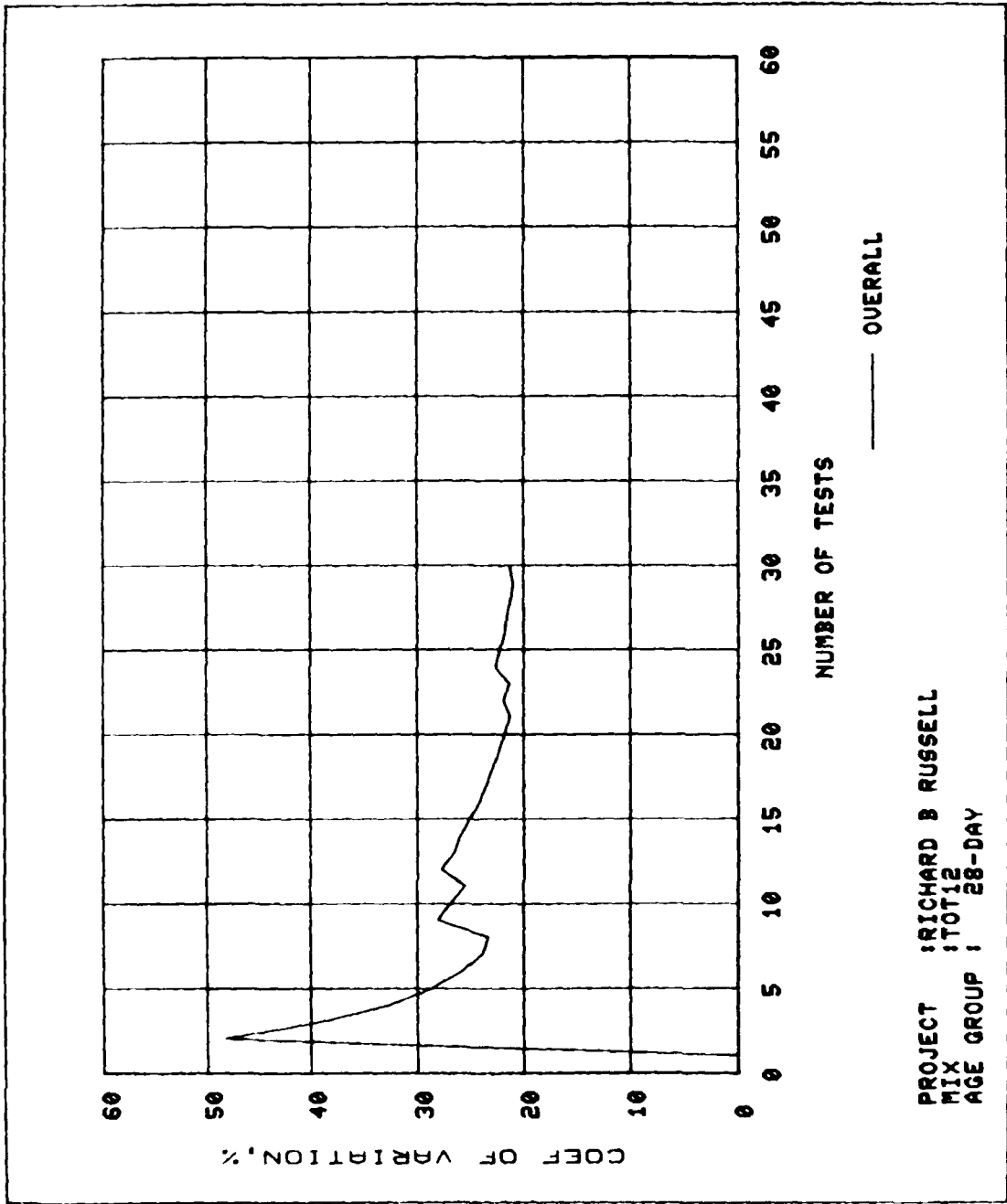


Figure 9. (Sheet 23 of 27)

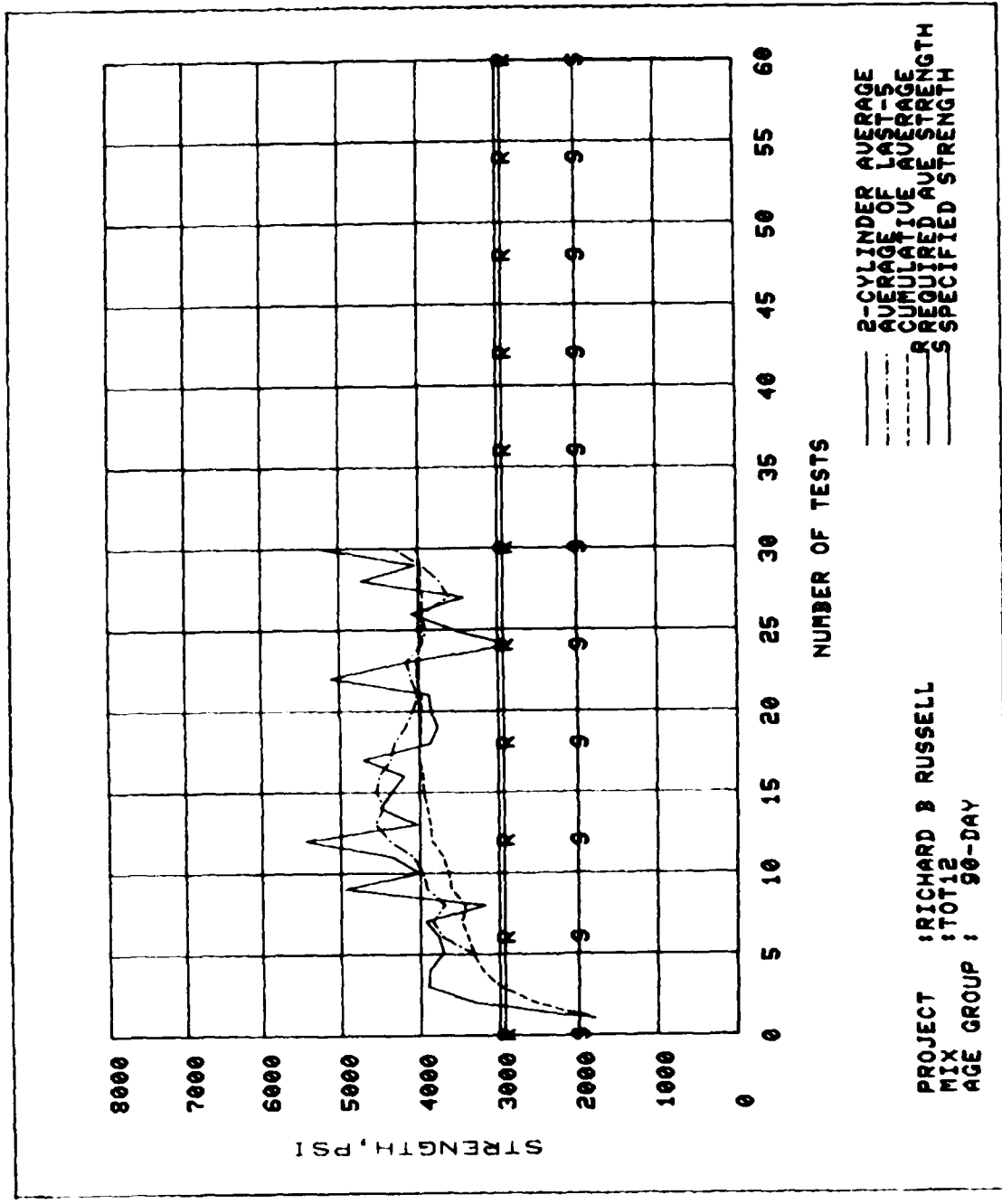


Figure 9. (Sheet 24 of 27)

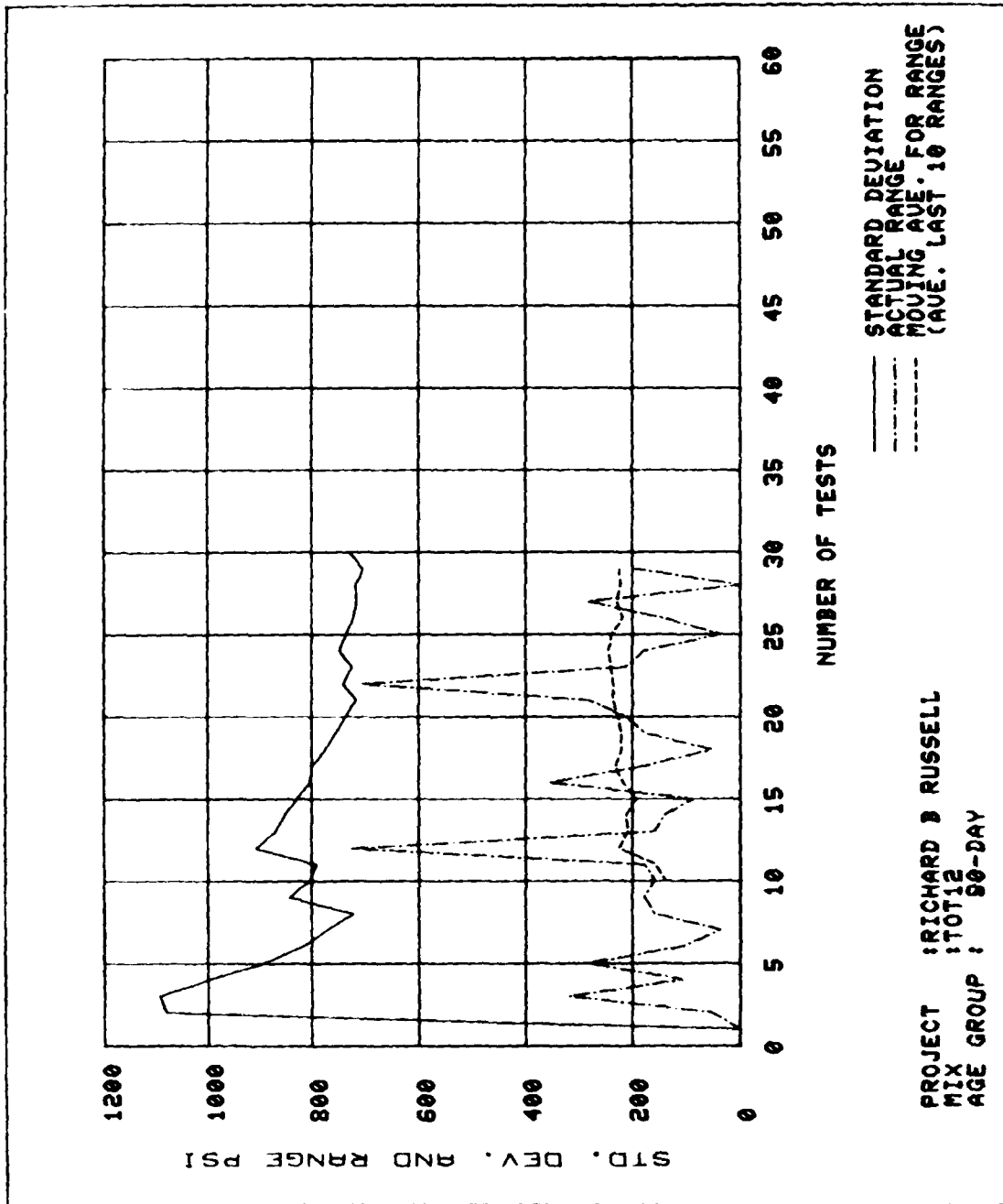


Figure 9. (Sheet 25 of 27)

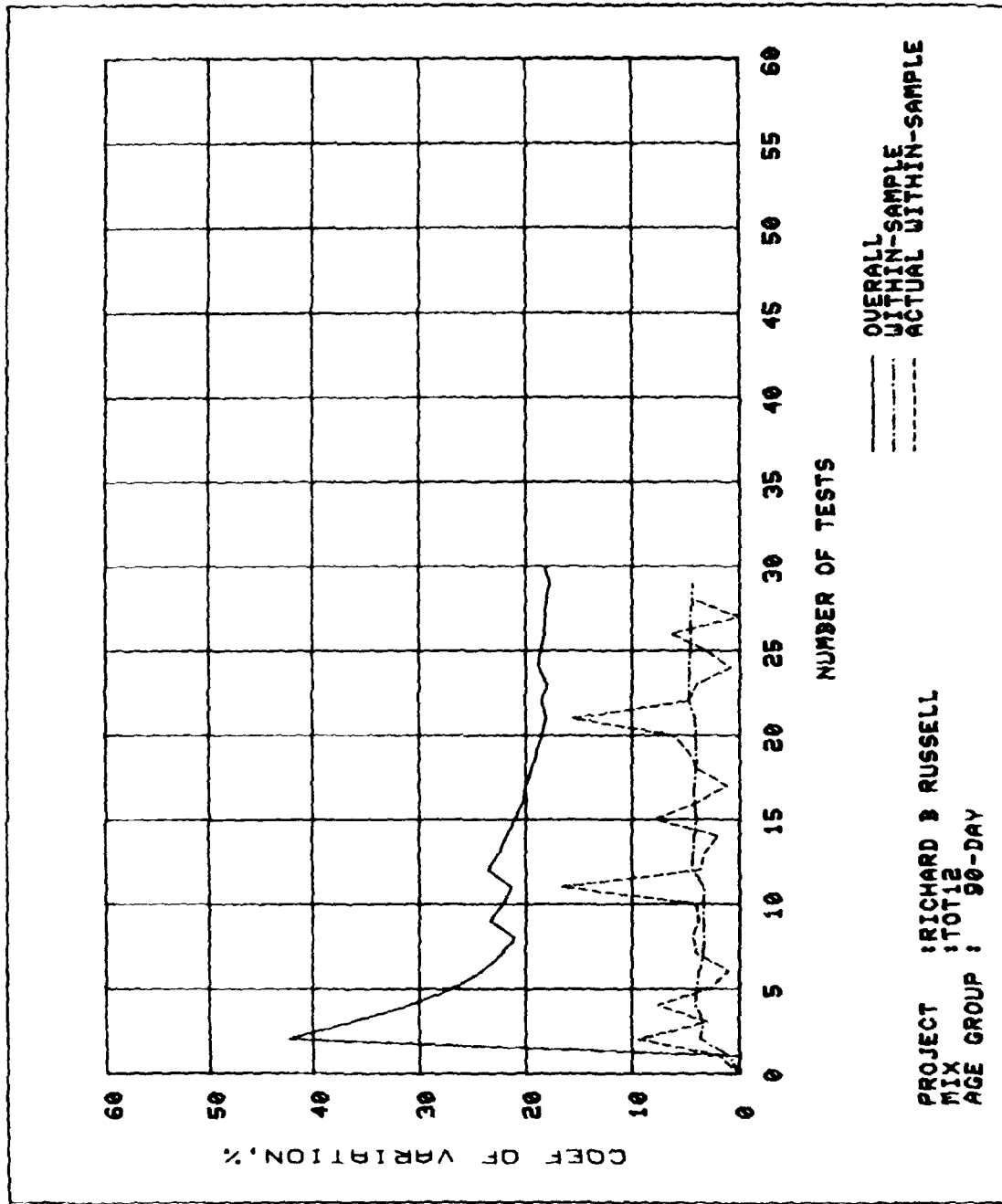


Figure 9. (Sheet 26 of 27)

DO YOU WISH TO RETURN TO TABLE OPTION(Y OR N) - N
DO YOU WISH TO RETURN TO PLOT OPTION(Y OR N) - N
IS RESTART FILE TO BE GENERATED(Y OR N) - Y
ENTER NAME OF OUTPUT FILE - F2
DO YOU WISH TO MAKE ANOTHER RUN(Y OR N) - N

*

For WES or MACON systems:

*RUN WESLIB/CORPS/X0064,R

For BOEING system:

C>OLD,CORPS/UN=CECELB
C>CALL,CORPS,X0064

ENTER DEVICE SPEED(30 OR 120) - 120

DO YOU WISH TO ENTER DATA FROM TERMINAL(Y OR N) - N

ENTER NAME OF INPUT FILE - F2

IS INPUT DATA FROM A RESTART FILE(Y OR N) - Y

DO YOU WISH TO ANALYZE FIELD DATA(Y OR N) - Y

IS STRUCTURAL CONCRETE TO BE ANALYZED(Y OR N) - N

ENTER SLOPE, Y-INTERCEPT, AND NO. POINTS
FOR LABORATORY REGRESSION CURVE - 4.953 1022 30

ENTER UNITS FOR SLUMP(A2), STRENGTH(A3) AND TEMPERATURE(A1) - IN PSI F

ENTER NUMBER OF COPIES OF OUTPUT TO BE MADE - 3

DO YOU WISH TO LIST TABLES(Y OR N) - Y

DO YOU WISH TO LIST SUMMARY TABLE(Y OR N) - Y

Figure 10. Example showing a step-by-step execution of program using a restart file that contains field test results (Sheet 1 of 18)

U.S. ARMY CORPS OF ENGINEERS
EVALUATION OF CONCRETE STRENGTH DATA

PAGE: 1
DATE: 02/24/83
TIME: 16156

PROJECT: RICHARD B RUSSELL
CONTRACT: DACU78-21-C0084
P.C.: 2000. T: 1.282 MAX SIZE AGGR: 6.00 U/C: 0.67
MIX: TOTL2
DESIGN AGE: 90-DAY

SUMMARY TABLE

AVERAGE WATER/CEMENT RATIO 0.
AVERAGE SLUMP, IN 2.52
AVERAGE AIR CONTENT, % 5.6
REQUIRED 1-DAY ACCELERATED STRENGTH, PSI 38.
REQUIRED AVERAGE 1-DAY ACCELERATED STRENGTH, PSI 189.
SPECIFIED STRENGTH FOR 90-DAY STRENGTHS, PSI 2000.
REQUIRED AVERAGE 90-DAY STRENGTH, PSI 3240.

COEF. VARIATION

AGE TEST	NO. TEST	SUM OF TEST PSI	SUM OF SQUARED PSI ²	TEST AVERAGE	RANGE	WITHIN GROUP			STD DEV
						PSI	N	PSI	
1	59	26998.	13020709.	458.	12.	2.6	23.4	107.	
7	59	81653.	8759739.	1385.	XXXXX	XXXXX	55.2	868.	
28	59	173103.	530296484.	2934.	XXXXX	XXXXX	24.7	724.	
90	59	248606.	1091416720.	4214.	286.	6.0	20.6	870.	
385	0	0.	0.	0.	XXXXX	XXXXX	0.	0.	

LINEAR REGRESSION OF 1-DAY AND DESIGN AGE(90-DAY) LAB DATA

EQUATION FOR LAB DATA IS : Y(90-DAY) = 1822. * 4.9538X(1-DAY)
NO. OF POINTS ON CURVE IS : 30

Figure 10. (Sheet 2 of 18)

DO YOU WISH TO LIST PREDICTED STRENGTHS(Y OR N) - Y

U.S. ARMY CORPS OF ENGINEERS
 EVALUATION OF CONCRETE STRENGTH DATA

PAGE: 2
 DATE: 02/24/83
 TIME: 16156

PROJECT: RICHARD B RUSSELL
 CONTRACT: DACU78-21-C-0084
 FCI: 2000. T: 1.282 MAX SIZE AGGR: 8.00 U/C: 0.67

MIX: T012
 DESIGN AGE: 90-DAY
 U/C: 0.67

PREDICTED STRENGTHS

N	PREDICTED STRENGTHS		STRENGTH		DIFFERENCE	
	ACCELERATED 1-DAY (PSI)	PREDICTED 90-DAY (PSI)	ACTUAL 90-DAY (PSI)	DIFFERENCE 90-DAY (PSI)	DIFFERENCE 90-DAY (%)	DIFFERENCE 90-DAY (%)
1	267.	3144.	1786.	-1358.5	-76.1	
2	265.	3135.	3316.	181.5	5.5	
3	327.	3448.	3008.	466.4	11.9	
4	305.	3333.	3891.	558.3	14.3	
5	336.	3486.	2278.	227.8	6.1	
6	380.	3704.	3767.	62.9	1.7	
7	358.	3595.	3928.	339.8	8.4	
8	351.	3661.	3183.	-377.5	-11.0	
9	622.	4993.	4943.	49.2	0.8	
10	635.	4987.	4815.	-952.8	-23.7	
11	375.	3679.	4348.	668.6	15.3	
12	591.	4749.	5447.	697.8	12.8	
13	430.	3958.	4041.	89.2	2.2	
14	531.	4452.	4561.	48.0	1.1	
15	489.	4839.	4361.	-478.0	-2.0	
16	478.	4150.	4809.	661.1	1.8	
17	588.	4734.	4704.	-30.4	-0.6	
18	536.	4477.	3873.	-603.8	-15.6	
19	511.	4353.	3776.	-577.0	-15.3	
20	420.	3992.	3958.	-46.3	-1.2	
21	422.	3918.	3873.	-39.2	-1.0	
22	533.	4462.	5111.	649.1	12.7	
23	377.	3689.	4156.	466.7	11.2	
24	345.	3631.	2855.	-665.8	-23.2	
25	373.	3669.	3555.	-114.5	-3.2	
26	460.	4100.	4085.	-15.4	-0.4	
27	416.	3882.	3431.	-451.4	-13.2	
28	560.	4546.	4782.	176.8	3.7	
29	402.	3813.	4060.	236.9	6.8	
30	658.	5081.	5236.	144.9	2.8	

Figure 10. (Sheet 4 of 18)

U.S. ARMY CORPS OF ENGINEERS
EVALUATION OF CONCRETE STRENGTH DATA

PAGE: 3
DATE: 02/24/83
TIME: 16:56

PROJECT: RICHARD B RUSSELL
CONTRACT: DACJ78-21-C0084
F-CI: 2000, T1 1.282 MAX SIZE AGGR: 6.00 U/C: 0.67

MIX: TOT12
DESIGN AGE: 90-DAY
U/C: 0.67

N	PREDICTED STRENGTHS				
	ACCELERATED 1-DAY (PSI)	PREDICTED 90-DAY (PSI)	STRENGTH ACTUAL 90-DAY (PSI)	DIFFERENCE 90-DAY (PSI)	DIFFERENCE 90-DAY (%)
31	367.	3640.	1786.	-1853.8	-103.8
32	365.	3630.	3371.	-258.8	-7.7
33	337.	3491.	4413.	921.8	26.9
34	306.	3330.	3896.	585.8	14.6
35	337.	3489.	3714.	225.3	6.1
36	380.	3784.	3767.	63.9	1.7
37	368.	3595.	3886.	330.8	8.4
38	356.	3686.	3233.	-352.3	-10.9
39	633.	4957.	5448.	490.8	9.0
40	635.	4987.	4620.	-447.7	-9.0
41	375.	3679.	5447.	1767.6	32.6
42	591.	4747.	5447.	699.8	12.0
43	536.	4476.	4521.	118.6	2.6
44	636.	4474.	5566.	1081.2	19.5
45	539.	4492.	5486.	963.8	17.7
46	576.	4645.	5256.	610.3	11.6
47	588.	4734.	5709.	974.6	17.1
48	541.	4502.	3873.	-628.6	-16.2
49	517.	4380.	3781.	-599.2	-15.8
50	586.	4426.	3861.	-563.8	-14.0
51	527.	4432.	3873.	-559.2	-14.4
52	533.	4462.	5061.	1196.1	21.2
53	377.	3685.	4656.	966.7	20.8
54	350.	3556.	3852.	309.4	8.0
55	373.	3688.	3610.	-68.0	-1.7
56	560.	4596.	5086.	489.3	9.6
57	521.	4403.	3431.	-972.0	-28.3
58	561.	4549.	5722.	1172.9	20.5
59	502.	4306.	5050.	744.1	14.7
AVERAGE	458.	4089.	4214.	665.2	21.2
STD ERROR OF EST.					

Figure 10. (Sheet 5 of 18)

DO YOU WISH TO LIST INPUT DATA (Y OR N) - Y

Figure 10. (Sheet 6 of 18)

U.S. ARMY CORPS OF ENGINEERS
EVALUATION OF CONCRETE STRENGTH DATA

PROJECT: RICHARD B RUSSELL
CONTRACT: DACU78-2-C0084
F.C.I. 2000. T1 1.282

MIXTURE: 2000. T1 1.282
MAX SIZE AGGR: 6.00 U/C1 0.67

DATE: 02/24/83
PAGE: 4
TIME: 16156

MIXI TCT:2
DESIGN AGE: 90-DAY
U/C1 0.67

BATCH INPUT

MIX DATE	SAMPLE NUMBER	SLUMP (IN)	AIR (%)	AIR CONC (%)	TEMP (F)	REMARKS
79 4 19	1	3.00	6.5	53	67	G-03-33A
79 5 10	55	3.75	7.0	53	53	G-05-33C
79 5 17	68	3.50	6.8	55	55	G-03-33A
79 5 18	76	3.35	5.8	55	55	G-03-33A
79 5 19	99	3.35	5.8	55	55	G-06-35
79 5 19	107	1.00	5.0	50	50	G-06-35
79 5 30	115	1.50	5.0	55	55	G-06-35
79 5 30	156	3.00	7.0	50	50	F-05-33
79 5 1	155	3.50	5.1	52	52	F-05-33
79 5 3	178	3.35	5.5	50	50	F-03-33
79 5 5	303	3.00	5.6	55	55	F-06-33
79 5 15	337	3.00	5.5	55	55	F-03-33
79 5 16	353	3.00	5.9	56	56	F-05-31
79 5 18	375	3.35	7.0	59	59	F-05-31
79 5 18	383	1.75	6.8	55	55	F-03-31
79 5 19	398	1.35	6.3	50	50	F-03-33
79 5 33	333	3.00	7.3	53	53	G-06-33
79 5 33	350	3.00	5.5	50	50	G-06-31
79 5 35	365	1.50	5.5	53	53	G-05-35
79 5 30	373	3.75	5.0	58	58	G-05-30
79 6 6	588	1.50	5.5	50	50	G-05-30
79 6 6	566	1.75	5.3	50	50	G-03-33
79 6 8	598	3.00	7.0	53	53	G-03-33
79 6 11	533	3.50	5.0	56	56	G-05-19
79 6 13	555	3.75	5.3	50	50	G-01-30
79 6 15	570	3.00	5.3	50	50	G-06-31
79 6 15	600	3.75	6.6	53	53	G-03-19

Figure 10. (Sheet 7 of 18)

U.S. ARMY CORPS OF ENGINEERS
EVALUATION OF CONCRETE STRENGTH DATA

PAGE: 5
DATE: 02/24/83
TIME: 16:56

PROJECT: RICHARD B RUSSELL
CONTRACT: DACW78-21-C-0084
F.C.I. 2000. T1 1.282 MAX SIZE AGGR: 6.00 W/C: 0.67

MIX: TOT12
DESIGN AGE: 90-DAY

TEST RESULTS

MIX DATE	SAMPLE	CYLINDER STRENGTH (PSI)						
		1-D	1-D	7-D	28-D	90-D	90-D	365-D
78 4 18 1	RESTART	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
78 5 10 55	365	365	369	595	999	1786	1786	1786
78 5 17 68	339	335	776	3336	3363	5067	3389	3389
78 5 18 76	301	308	893	3390	3037	3955	3759	3955
78 5 19 98	355	318	858	3335	3573	3855	3855	3855
78 5 19 107	371	389	831	3351	3767	XXXX	XXXX	XXXX
78 5 20 115	381	355	833	2515	3079	3873	3873	3873
78 5 30 156	357	355	878	1780	3185	3301	3301	3301
78 5 1 155	633	633	1573	3336	6033	5863	5863	5863
78 5 3 178	637	633	1331	3751	6103	3936	3936	3936
78 5 5 303	376	376	1008	3538	5343	5631	5631	5631
78 5 15 337	573	608	1309	3537	5636	5358	5358	5358
78 5 16 353	535	525	1051	3480	3478	5583	5583	5583
78 5 18 350	516	585	1036	3033	5500	5531	5531	5531
78 5 18 376	575	607	1186	3813	6380	5631	5631	5631
78 5 19 303	577	547	1061	3706	6365	5166	5166	5166
78 5 19 308	585	551	1115	3900	5881	5637	5637	5637
78 5 23 333	531	551	1036	3370	3941	3785	3785	3785
78 5 23 350	530	503	983	3550	3759	3883	3883	3883
78 5 25 355	575	516	1619	3885	3955	3757	3757	3757
78 5 30 373	517	537	1008	3795	3787	3979	3979	3979
78 5 30 389	531	526	1588	3585	5383	5969	5969	5969
78 6 6 558	371	303	1038	3706	3803	6509	6509	6509
78 6 6 566	350	350	716	1593	3759	3971	3971	3971
78 6 8 508	368	378	973	3550	3653	3556	3556	3556
78 6 11 523	580	580	1008	3888	5103	5067	5067	5067
78 6 13 555	507	535	986	3338	3340	3501	3501	3501
78 6 15 570	538	503	1365	3776	5689	5863	5863	5863
78 6 15 600	503	500	903	3381	5050	5050	5050	5050

Figure 10. (Sheet 8 of 18)

ENTER NUMBER OF AGE GROUPS FOR WHICH
STATISTICAL TABLES ARE TO BE LISTED - 3

ENTER TEST AGES OF GROUPS TO BE VIEWED - 1 28 90

U.S. ARMY CORPS OF ENGINEERS
EVALUATION OF CONCRETE STRENGTH DATA

PAGE: 6
DATE: 02/24/83
TIME: 16:56

PROJECT: RICHARD B RUSSELL
CONTRACT: DACU78-2-C0084
F.C.I. 2000. T1 1.282 MAX SIZE AGGR: 6.00 U/C1 0.67

MIX: TOT: 2
DESIGN AGE: 90-DAY
U/C1 0.67

BATCH STATISTICS

MIX DATA		SAMPLE NUMBER	SEQUENCE NUMBER	CUMULATIVE AVERAGES		
VR	NO DA			U/C	SUMP	AIR
88	88	RESTART	1	0.	2.18	5.4
79	4 19	1	2	0.	2.21	5.5
78	5 18	55	3	0.	2.26	5.5
78	5 17	68	4	0.	2.30	5.5
79	5 18	76	5	0.	2.33	5.5
79	5 19	96	6	0.	2.36	5.5
79	5 19	107	7	0.	2.32	5.5
79	5 30	115	8	0.	2.30	5.5
79	5 30	156	9	0.	2.31	5.5
79	5 1	155	10	0.	2.24	5.5
79	5 3	178	11	0.	2.37	5.5
79	5 5	303	12	0.	2.39	5.5
79	5 15	337	13	0.	2.40	5.5
79	5 16	353	14	0.	2.41	5.5
79	5 16	350	15	0.	2.43	5.5
79	5 18	375	16	0.	2.45	5.6
79	5 18	383	17	0.	2.43	5.6
79	5 18	398	18	0.	2.41	5.6
79	5 33	333	19	0.	2.42	5.6
79	5 33	350	20	0.	2.43	5.6
79	5 35	365	21	0.	2.44	5.6
79	5 39	373	22	0.	2.44	5.6
79	5 39	380	23	0.	2.42	5.6
79	6 6	558	24	0.	2.41	5.6
79	6 6	586	25	0.	2.42	5.6
79	6 8	598	26	0.	2.45	5.6
79	6 11	533	27	0.	2.46	5.6
79	6 13	555	28	0.	2.49	5.6
79	6 15	570	29	0.	2.50	5.6
79	6 15	600	30	0.	2.52	5.6

Figure 10. (Sheet 10 of 18)

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 DATE: 02/24/83
 TIME: 16156

J.S. ARMY CORPS OF ENGINEERS
 EVALUATION OF CONCRETE STRENGTH DATA

PROJECT: RICHARD B RUSSELL
 CONTRACT: DACW78-21-C0084
 F.C.: 2000. T: 1.282 MAX SIZE AGGR: 6.00 U/C: 0.67

TOTL
 DESIGN AGE: 90-DAY
 U/C: 0.67

REPORT FOR 1 DAY STRENGTHS

SAMPLE NUMBER	CYCL AVE	CUM AVE	L-5 AVE	RANGE		L-10		COEF OF VAR				STD DEV
				ACT	PSI	ACT	PSI	ACT	UU	VAR	PSI	
RESTART	XXXX	444	487	XXXX	12	10	XXXX	2.4	24.9	111		
1	367	441	479	4	12	28	XXXX	0.8	24.8	110		
55	355	439	468	XXXX	12	28	XXXX	XXXX	24.7	109		
68	337	436	466	4	12	28	XXXX	0.8	24.9	108		
76	305	432	466	7	11	27	XXXX	1.4	25.2	109		
99	337	429	342	37	12	30	XXXX	7.6	25.3	109		
107	380	428	345	18	12	31	XXXX	3.7	25.1	107		
115	358	426	343	6	12	32	XXXX	1.2	25.0	107		
156	355	424	347	2	12	30	XXXX	0.4	25.2	106		
155	633	430	413	0	12	28	XXXX	0.4	25.6	110		
178	635	435	472	4	11	28	XXXX	0.8	25.6	113		
303	375	433	471	0	11	8	XXXX	0.8	25.8	112		
337	591	437	518	35	12	11	XXXX	7.1	25.9	113		
353	636	439	564	0	11	11	XXXX	0.8	25.7	113		
350	636	441	534	39	13	14	XXXX	7.8	25.5	112		
375	539	444	515	72	13	18	XXXX	14.4	27.2	112		
383	570	446	554	14	13	17	XXXX	2.8	26.8	112		
388	588	449	554	6	13	17	XXXX	1.2	26.8	113		
333	541	451	556	20	13	19	XXXX	3.9	24.9	113		
350	517	453	551	27	14	22	XXXX	5.3	24.7	112		
365	526	454	548	19	14	23	XXXX	3.7	24.7	111		
373	587	456	548	20	14	25	XXXX	3.9	24.3	110		
380	533	457	520	4	14	22	XXXX	0.8	24.1	110		
558	377	456	486	12	14	23	XXXX	2.3	24.0	109		
566	350	454	463	0	13	19	XXXX	0.8	24.1	109		
598	373	452	432	10	13	13	XXXX	2.0	24.1	109		
533	560	454	438	0	13	12	XXXX	0.8	24.0	109		
555	521	455	435	28	13	14	XXXX	5.5	23.8	108		
570	551	457	471	25	14	15	XXXX	4.9	23.6	108		
600	602	458	501	3	13	12	XXXX	0.6	23.4	107		

REQUIRED AVERAGE STRENGTH FOR ABOVE DATA = 189. PSI

Figure 10. (Sheet 11 of 18)

PAGE: 8
DATE: 02/24/83
TIME: 16156

U.S. ARMY CORPS OF ENGINEERS
EVALUATION OF CONCRETE STRENGTH DATA

PROJECT: RICHARD B RUSSELL
CONTRACT: DACW78-81-C0084
F.C.I. 2000. T1 1.282 MAX SIZE AGGR: 5.00 U/C: 0.67

MIXI
DESIGN AGE: 90-DAY
TOT12
AGE: U/C: 0.67

REPORT FOR 28 DAY STRENGTHS

SAMPLE NUMBER	CUP AVE --- PSI	L-S AVE --- PSI	COEF VAR --- %	STD DEV --- PSI
RESTART				
1	2563	2601	21.3	546
55	2512	2343	24.1	606
68	2520	2505	23.9	604
76	2553	2616	23.9	618
99	2578	2838	24.8	622
107	2599	2810	23.9	622
116	2629	2889	23.9	626
156	2644	3085	24.8	634
165	2621	3070	24.6	642
178	2639	3069	24.4	644
303	2667	3142	24.7	659
317	2689	3190	24.7	665
323	2709	3184	24.7	670
323	2721	3270	24.8	678
359	2738	3609	24.5	672
375	2762	3622	24.7	683
383	2783	3655	24.8	690
398	2807	3488	26.0	702
313	2818	3524	24.8	699
369	2823	3480	24.7	689
385	2834	3678	24.8	707
373	2872	3888	24.8	713
386	2886	3633	24.7	715
656	2901	3700	24.6	730
688	2877	3369	26.4	729
633	2889	3246	26.2	729
656	2904	3254	26.1	730
670	2911	3176	24.9	726
680	2926	3189	24.9	728
680	2934	3647	24.7	724

Figure 10. (Sheet 12 of 18)

DO YOU WISH TO PLOT DATA(Y OR N) - Y

DO YOU WANT REPLOT CAPILITIES(Y OR N) - Y

ARE HIR CONTENTS AND SLUMPS TO BE PLOTTED(Y OR N) - N

DO YOU WISH TO PLOT PREDICTED STRENGTHS(Y OR N) - Y

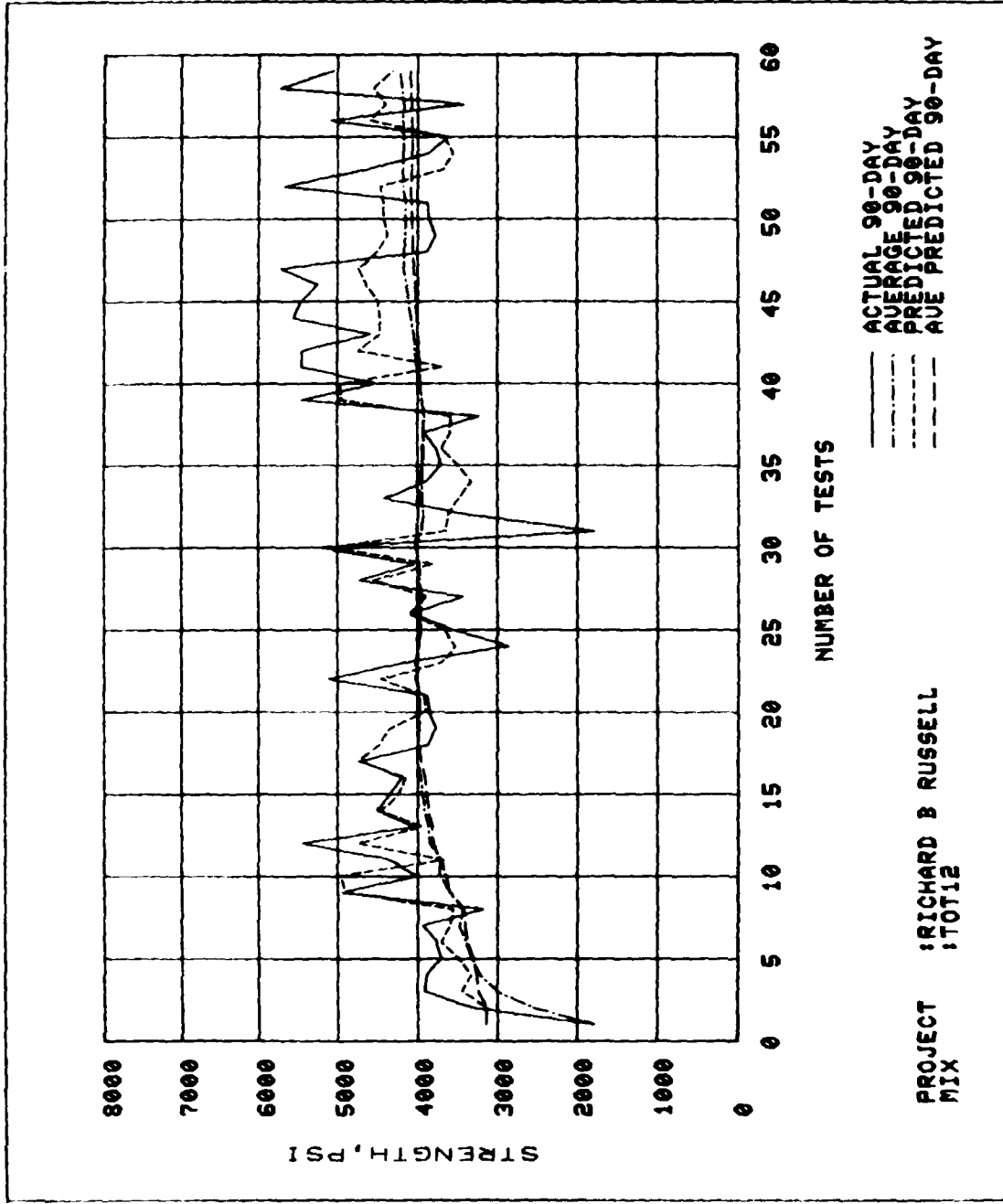


Figure 10. (Sheet 15 of 18)

DO YOU WANT TO REPLOT USING YOUR OWN SCALE(Y OR N) - Y
ENTER XMIN,XMAX,YMIN,YMAX - 30 60 3000 6000

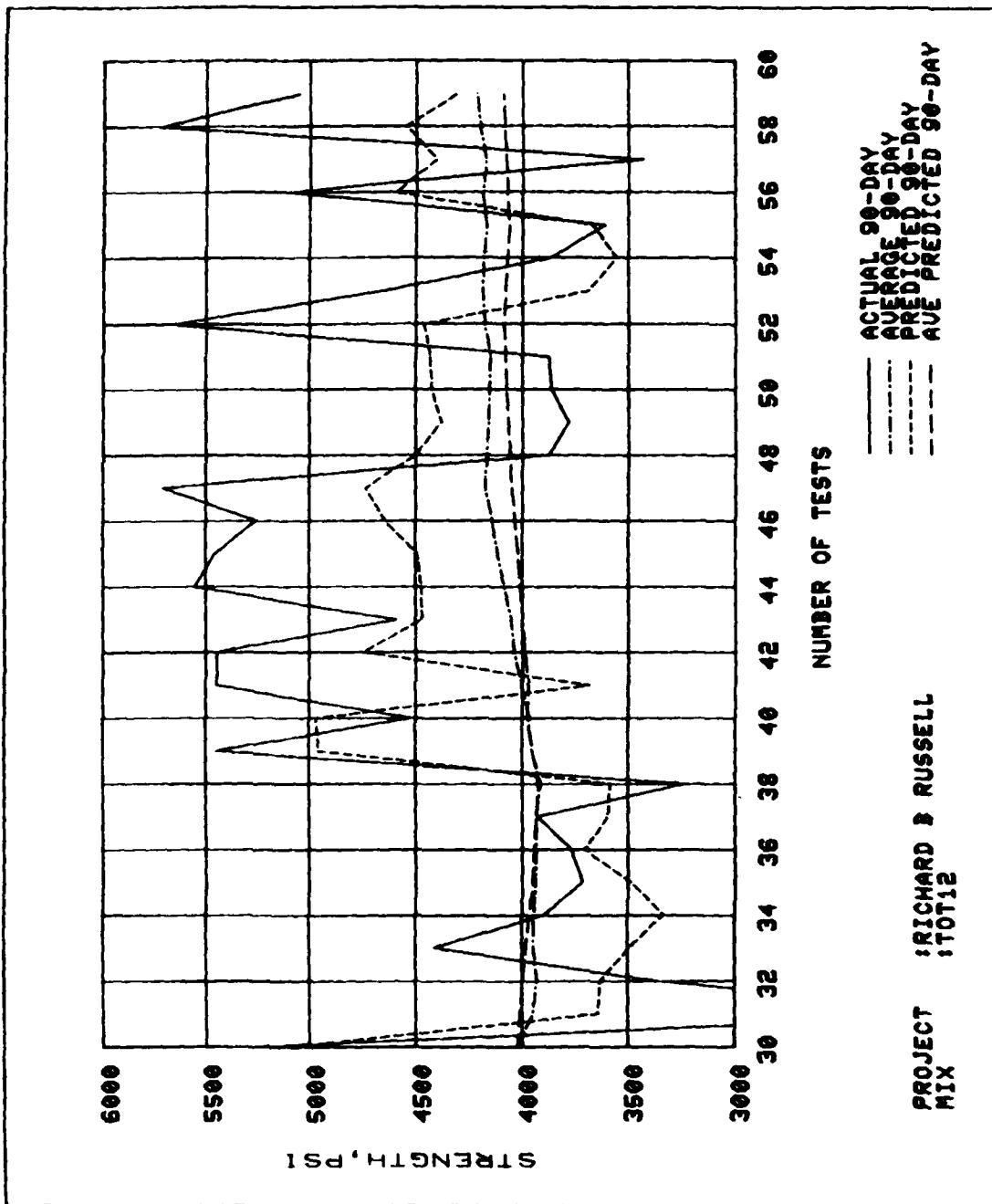


Figure 10. (Sheet 17 of 18)

DO YOU WANT TO REPLOT USING YOUR OWN SCALE(Y OR N) - N

ENTER NUMBER OF AGE GROUPS FOR WHICH
STATISTICAL TABLES ARE TO BE PLOTTED - 0

DO YOU WISH TO RETURN TO TABLE OPTION(Y OR N) - N

DO YOU WISH TO RETURN TO PLOT OPTION(Y OR N) - N

IS RESTART FILE TO BE GENERATED(Y OR N) - N

DO YOU WISH TO MAKE ANOTHER RUN(Y OR N) - N

*

PART VII: CONCLUDING STATEMENT

19. The program described in this report is the third-generation program for performing this general sort of analysis of Corps of Engineers concrete strength data. The previous programs were prepared by Lamond (1974) and Bradstreet and Hughes (1979).

20. Strength data used in the examples of this report were taken from test results of concrete used in Richard B. Russell Dam. A study of these results has been made by Ragan (1983). A discussion of this sort of work has been published by Lamond (1979).

REFERENCES

- American Concrete Institute. 1982. "Recommended Practice for Evaluation of Strength Test Results of Concrete, ACI 214-77," ACI Manual of Concrete Practice, 1982, Part 1, Detroit, Mich.
- American Concrete Institute. 1982. "Use of Accelerated Strength Testing, ACI 214.1R-81," ACI Manual of Concrete Practice, 1982, Part 1, Detroit, Mich.
- American Concrete Insitute. 1982. "Building Code Requirements for Reinforced Concrete, ACI 318-77," ACI Manual of Concrete Practice, 1982, Part 4, Detroit, Mich.
- American Society for Testing and Materials. 1982. "Making and Curing Concrete Test Specimens in the Field," Designation: C 31-69 (Reapproved 1980), 1982 Book of ASTM Standards, Part 14, Philadelphia, Pa.
- American Society for Testing and Materials. 1982. "Compressive Strength of Cylindrical Concrete Specimens," Designation: C 39-81, 1982 Book of ASTM Standards, Part 14, Philadelphia, Pa.
- American Society for Testing and Materials. 1982. "Making and Curing Concrete Test Specimens in the Laboratory," Designation: C 192-81, 1982 Book of ASTM Standards, Part 14, Philadelphia, PA.
- American Society for Testing and Materials. 1982. "Making Accelerated Curing and Testing of Concrete Compression Test Specimens," Designation: C 684-81, 1982 Book of ASTM Standards, Part 14, Philadelphia, Pa.
- Bradstreet, D. J. and Hughes, K. L. 1979. "Statistical Evaluation of Concrete Test," Computer Program No. 742-E1-G3060, U. S. Army Corps of Engineers Seattle District, Seattle, Wash.
- Lamond, J. F. 1974. "Summary and Evaluation of Concrete Test Specimens," Computer Program No. 742-F3-ROCl0, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.
- Lamond, J. F. 1979. "Accelerated Strength Testing by Warm Water Method," ACI Journal, Proceedings, Vol 76, No. 4, pp 499-512.
- Ragan, S. A. 1983. "Concrete Quality Assurance Using Accelerated Strength Testing," Miscellaneous Paper C-83- , U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.
- U. S. Army Corps of Engineers. 1982. "Standard Practice for Concrete," EM 1110-2-2000, U. S. Government Printing Office, Washington, D. C.

APPENDIX A
DERIVATION OF 95 PERCENT CONFIDENCE INTERVAL FOR THE MEAN RESPONSE
OF THE DESIGN-AGE STRENGTH FOR A GIVEN ACCELERATED STRENGTH

Assumptions

- (1) Confidence interval:

$$Ci = t S_{y \cdot x}$$

where Ci = 95 percent confidence interval

$S_{y \cdot x}$ = Standard error of estimate

t = t-distribution factor for 95 percent confidence interval, for n = 1 to 29, t-distribution factor is 12.706, 4.303, 3.182, 2.776, 2.571, 2.447, 2.365, 2.306, 2.262, 2.228, 2.201, 2.179, 2.160, 2.145, 2.131, 2.120, 2.110, 2.101, 2.093, 2.086, 2.080, 2.074, 2.069, 2.064, 2.060, 2.056, 2.052, 2.048, and 2.045, respectively; for n \geq 30, t-distribution factor is 1.960.

n = Number of points on regression curve

- (2) Standard error of estimate:

$$S_{y \cdot x} = \sqrt{\frac{n-1}{n-2} (\sigma_y^2 - b^2 \sigma_x^2)} \quad (\text{See Appendix B for derivation})$$

where $S_{y \cdot x}$ = Standard error of estimate

b = Slope of regression curve

n = Number of points on regression curve

σ_x = Standard deviation of accelerated strengths

σ_y = Standard deviation of design-age strengths

- (3) Standard deviation of accelerated strengths:

$$\sigma_x = \sqrt{\frac{\sum X_i^2 - \frac{(\sum X_i)^2}{n}}{n-1}}$$

where n = Number of points on regression curve

σ_x = Standard deviation of accelerated strengths

X_i = An individual accelerated strength

(4) Standard deviation of design-age strengths:

$$\sigma_y = \sqrt{\frac{\sum Y_i^2 - \frac{(\sum Y_i)^2}{n}}{n-1}}$$

where n = Number of points on regression curve

σ_y = Standard deviation of design-age strengths

Y_i = An individual design-age strength

Derivation

Description of Operation

Resulting Equation

Entering confidence interval from (1) above

$$C_i = t S_{y \cdot x}$$

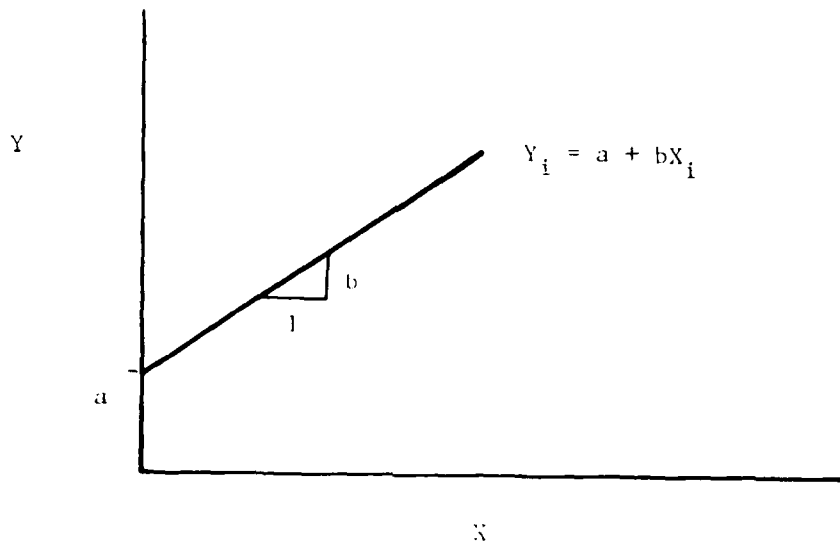
Substituting for ' $S_{y \cdot x}$ ' from (2) above

$$C_i = t \sqrt{\frac{n-1}{n-2} (\sigma_y^2 - b^2 \sigma_x^2)}$$

Substituting for ' σ_x ' from (3) above and for ' σ_y ' from (4) above

$$C_i = t \sqrt{\frac{1}{n-2} \left(\sum Y_i^2 - \frac{(\sum Y_i)^2}{n} - b^2 \left(\sum X_i^2 - \frac{(\sum X_i)^2}{n} \right) \right)}$$

APPENDIX B
DERIVATION OF STANDARD ERROR OF ESTIMATE



Regression Curve

Assumptions

- (1) Sum of squares of error:

$$SSE = \sum (Y_i - a - X_i)^2$$

where a = Y-intercept for regression curve
 SSE = Sum of squares of errors
 X_i = An individual accelerated strength
 Y_i = An individual design-age strength

(2) Regression equation:

$$Y_i = a + bX_i ; a = \bar{Y} - b\bar{X}$$

where a = Y-intercept for regression curve

b = Slope of regression curve

X_i = An individual accelerated strength

\bar{X} = Average accelerated strength

Y_i = An individual design-age strength

\bar{Y} = Average design-age strength

(3) Slope of regression curve:

$$b = \frac{Y_i - \bar{Y}}{X_i - \bar{X}} ; (Y_i - \bar{Y}) = b(X_i - \bar{X})$$

where b = Slope of regression curve

X_i = An individual accelerated strength

\bar{X} = Average accelerated strength

Y_i = An individual design-age strength

\bar{Y} = Average design age strength

(4) Standard deviation of accelerated strengths:

$$\sigma_X = \sqrt{\frac{\Sigma(X_i - \bar{X})^2}{n - 1}} ; \Sigma(X_i - \bar{X})^2 = (n - 1)\sigma_X^2$$

where n = Number of points on regression curve

σ_X = Standard deviation of accelerated strengths

X_i = An individual accelerated strength

\bar{X} = Average accelerated strength

(5) Standard deviation of design-age strengths:

$$\sigma_Y = \sqrt{\frac{\Sigma(Y_i - \bar{Y})^2}{n - 1}} ; \Sigma(Y_i - \bar{Y})^2 = (n - 1)\sigma_Y^2$$

where n = Number of points on regression curve

σ_Y = Standard deviation of design-age strength

Y_i = An individual design-age strength

\bar{Y} = Average design-age strength

- (6) Unbiased estimation $S_{y \cdot x}^2$ of σ^2 with $n - 2$ degrees of freedom (σ = standard deviation):

$$S_{y \cdot x}^2 = \frac{SSE}{n - 2}$$

where n = Number of points on regression curve

$S_{y \cdot x}$ = Unbiased estimator of standard deviation

SSE = Sum of squares of errors

Derivation

Description of Operation

Resulting Equation

Entering equation for $S_{y \cdot x}^2$ from (6) above

$$S_{y \cdot x}^2 = \frac{SSE}{n - 2}$$

Substituting for 'SSE' from (1) above

$$S_{y \cdot x}^2 = \frac{\sum (Y_i - a - X_i)^2}{n - 2}$$

Substituting for 'a' from (2) above

$$S_{y \cdot x}^2 = \frac{\sum ((Y_i - \bar{Y}) - b(X_i - \bar{X}))^2}{n - 2}$$

Collecting terms

$$S_{y \cdot x}^2 = \frac{\sum ((Y_i - \bar{Y})^2 - 2b(X_i - \bar{X})(Y_i - \bar{Y}) + b^2(X_i - \bar{X})^2)}{n - 2}$$

Substituting for ' $(Y_i - \bar{Y})$ ' from (3) above

$$S_{y \cdot x}^2 = \frac{\sum ((Y_i - \bar{Y})^2 - b^2(X_i - \bar{X})^2)}{n - 2}$$

Substituting for ' $(X_i - \bar{X})^2$ ' from (4) above and for ' $(Y_i - \bar{Y})^2$ ' from (5) above

$$S_{y \cdot x}^2 = \frac{(n - 1)(\sigma_y^2 - b^2(n - 1)\sigma_x^2)}{n - 2}$$

Taking square root

$$S_{y \cdot x} = \sqrt{\frac{(n - 1)}{(n - 2)}(\sigma_y^2 - b^2\sigma_x^2)}$$