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1. Report No.	2. Government Accession No.	3.
FHWA/TX-79/33+177-16		

4. Title and Subtitle	5. Report Date
NOMOGRAPHS FOR THE DESIGN OF CRCP STEEL REINFORCEMENT	August 1979
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
C. S. Noble, B. F. McCullough, and J. C. M. Ma	Research Report No. 177-16
9. Performing Organization Name and Address	10. Work Unit No.
Center for Highway Research The University of Texas at Austin Austin, Texas 78712	11. Contract or Grant No. Research Study 3-8-75-177
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Texas State Department of Highways and Public Transportation, Transportation Planning Division P.O. Box 5051 Austin, Texas 78763	Interim
	14. Sponsoring Agency Code

15. Supplementary Notes

Study conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration. Research Study Title: "Development and Implementation of the Design, Construction, and Rehabilitation of Rigid Pavements."

16. Abstract

The purpose of this study was to develop graphical procedures (nomographs) for the design of continuously reinforced concrete pavement (CRCP) for implementation by the Texas State Department of Highways and Public Transportation for a range of specified local conditions. Use of this set of nomographs as a design tool supplementary to the CRCP-2 computer program model will facilitate the design of CRCP, substantially reducing both the time and cost involved in the design process, and at the same time accounting for the effect of regional and local environment.

Regression equations were developed for the prediction of three design parameters and then principles of nomography were applied to these mathematical relationships to prepare three corresponding nomographs. The choice of equations was made following multiple linear and nonlinear least squares fits to a fractional factorial of simulated observations which were output from the CRCP-2 computer program. Theoretical models developed at the Center for Highway Research and the variations of the three design parameters with each of the relevant input variables over the range of the simulated data were considered in deciding on the form of the regression equations.

"Standard error of residuals" and "R^2" (proportion of variance explained by the regression equation) statistics were considered in the final choice of coefficients for the regression equations. Confidence prediction limits were determined using multiple linear regression techniques for application to nomograph predictions. A recommended procedure for the use of the nomographs with appropriate limiting criteria has been outlined along with an example.

17. Key Words	18. Distribution Statement
nomographs, continuously reinforced concrete pavement, CRCP-2, least squares, environment, fractional factorial, variance, regression analysis, confidence prediction limits, limiting criteria	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	121	

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by

C. S. Noble, B. F. McCullough, and J. C. M. Ma

Research Report Number 177-16

Development and Implementation of the Design, Construction and Rehabilitation of Rigid Pavements

Research Project 3-8-75-177

conducted for

Texas
State Department of Highways and Public Transportation

in cooperation with the
U. S. Department of Transportation
Federal Highway Administration

by the

CENTER FOR HIGHWAY RESEARCH

THE UNIVERSITY OF TEXAS AT AUSTIN

August 1979

The contents of this report reflect the view of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

PREFACE

This is the sixteenth in the series of reports describing the work done in the project entitled "Development and Implementation of the Design, Construction, and Rehabilitation of Rigid Pavements." The project is conducted at the Center for Highway Research, The University of Texas at Austin, as part of the Cooperative Highway Research Program sponsored by the State Department of Highways and Public Transportation and the Federal Highway Administration.

This report presents the results of an analytical study undertaken to develop regression equations and nomographs for use as a supplementary tool in the design of steel reinforcement in continuously reinforced concrete pavement by the Texas State Department of Highways and Public Transportation.

The writers are particularly grateful to Gerald Peck, Larry Buttler, and James L. Brown of the Texas State Department of Highways and Public Transportation for their assistance in the selection of the simulated data throughout the course of the study; to Ion Raconel for initiating preliminary investigations associated with the study, to Virgil Anderson, from Purdue University, for his guidance in selection of the design factorial; to David McKenzie, from The University of Texas at Austin, whose expertise in the fields of statistics and computer programming proved invaluable; to James I. Daniel, and Gary Elkins, for their assistance with the regression analysis; to Patrick McIntyre and Arthur Taute, of The University of Texas at Austin, who prepared the nomographs; to Julie Muckelroy, who drafted the charts and graphs; to Mona Roberts and Marie Fisher, who typed this report; and finally to Arthur Frakes for his efforts in editing the report and coordinating the publication.

Christopher S. Noble
B. Frank McCullough
James C. M. Ma

August 1979

LIST OF REPORTS

Report No. 177-1, "Drying Shrinkage and Temperature Drop Stresses in Jointed Reinforced Concrete Pavement," by Felipe R. Vallejo, B. Frank McCullough, and W. Ronald Hudson, describes the development of a computerized system capable of analysis and design of a concrete pavement slab for drying shrinkage and temperature drop, August 1975.

Report No. 177-2, "A Sensitivity Analysis of Continuously Reinforced Corcrete Pavement Model CRCP-1 for Highways," by Chypin Chiang, B. Frank McCullough, and W. Ronald Hudson, describes the overall importance of this model, the relative importance of the input variables of the model and recommendcations for efficient use of the computer program, August 1975.

Report No. 177-3, "A Study of the Performance of the Mays Ride Meter," by Yi Chin Hu, Hugh J. Williamson, B. Frank McCullough, and W. Ronald Hudson, discusses the accuracy of measurements made by the Mays Ride Meter and their relationship to roughness measurements made with the Surface Dynamics Profilometer, January 1977.

Report No. 177-4, "Laboratory Study of the Effect of Non-Uniform Foundation Support on CRC Pavements," by Enrique Jiminez, W. Ronald Hudson, and B. Frank McCullough, describes the laboratory tests of CRC slab models with voids beneath them. Deflection, crack width, load transfer, spalling, and cracking are considered. Also used is the SLAB 49 computer program that models the CRC laboratory slab as a theoretical approach. The physical laboratory results and the theoretical solutions are compared and analyzed, and the accuracy is determined, August 1977.

Report No. 177-6, "Sixteenth Year Progress Report on Experimental Continuously Reinforced Concrete Pavement in Walker County," by Thomas P. Chesney, and B. Frank McCullough, presents a summary of data collection and analysis over a 16 year period. During that period, numerous findings resulted in changes in specifications and design standards. These data will be valuable for shaping guidelines for future construction, April 1976.

Report No. 177-7, "Continuously Reinforced Concrete Pavement: Structural Performance and Design/Construction Variables," by Pieter J. Strauss, B. Frank McCullough, and W. Ronald Hudson, describes a detailed analysis of design, construction, and environmental variables that may have an effect on the structural performance of a CRCP, May 1977.

Report No. 177-9, "CRCP-2, An Improved Computer Program for the Analysis of Continuously Reinforced Concrete Pavements," by James Ma and B. Frank McCullough, describes the modification of a computerized system capable of analysis of a continuously reinforced concrete pavement based on drying shrinkage and temperature drop, August 1977.

Report No. 177-10, "Development of Photographic Techniques for Performance Condition Surveys," by Pieter Strauss, James Long, and B. Frank McCullough, discusses the development of a technique for surveying heavily trafficked highways without interrupting the flow of traffic, May 1977.

Report No. 177-11, "A Sensitivity Analysis of Rigid Pavement-Overlay Design Procedure," by B. C. Nayak, W. Ronald Hudson, B. Frank McCullough, gives a sensitivity analysis of input variables of Federal Highway Administration computer-based overlay design procedure RPOD1, June 1977.

Report No. 177-12, "A Study of CRCP Performance: New Construction versus Overlay," by James I. Daniel, W. Ronald Hudson, and B. Frank McCullough, documents the performance of several continuously reinforced concrete pavements (CRCP) in Texas, September 1977.

Report No. 177-13, "A Rigid Pavement Overlay Design Procedure for Texas SDHPT," by Otto Schnitter, W. R. Hudson and B. F. McCullough, describes a procedure recommended for use by the Texas SDHPT for designing both rigid and flexible overlays on existing rigid pavements. The procedure incorporates the results of condition surveys to predict the existing pavement remaining life, field and lab testing to determine material properties, and elastic layer theory to predict the critical stresses in the pavement structure, May 1978.

Report No. 177-14, "A Methodology to Determine an Optimum Time to Overlay," by James I. Daniel, B. F. McCullough, and W. R. Hudson, describes the development of a mathematical model for predicting the optimum time to overlay an existing rigid pavement (being prepared for submission).

Report No. 177-15, "Precast Repair of Continuously reinforced Concrete Pavement," by Gary Eugene Elkins, B. F. McCullough and W. R. Hudson, describes an investigation into the applicability of using precast slabs to repair CRCP, presents alternate repair strategies, and makes new recommendations on installation and field testing procedures (being prepared for submission).

Report No. 177-16, "Nomographs for the Design of CRCP Steel Reinforcement," by C. S. Noble, B. F. McCullough, and J. C. M. Ma, presents the results of an analytical study undertaken to develop regression equations and nomographs for use as a supplementary tool in the design of steel reinforcement in continuously reinforced concrete pavement by the Texas State Department of Highways and Public Transportation, August 1979.

ABSTRACT

The purpose of this study was to develop graphical procedures (nomographs) for the design of continuously reinforced concrete pavement (CRCP) for implementation by the Texas State Department of Highways and Public Transportation for a range of specified local conditions. Use of this set of nomographs as a supplementary design tool with the CRCP-2 computer program model will facilitate the design of CRCP, substantially reducing both the time and cost involved in the design process, and at the same time accounting for the effect of regional and local environment.

First, regression equations were developed for the prediction of three design parameters, and then principles of nomography were applied to these mathematical relations to prepare three corresponding nomographs. The choice of equations was made following multiple linear and nonlinear least squares fits to a fractional factorial of simulated observations which were output from the CRCP-2 computer program. Theoretical models developed at the Center for Highway Research and the variations of the three design parameters with each of the relevant input variables over the range of the simulated data were considered in deciding on the form of the regression equations.

"Standard error of residuals" and "R^2" (proportion of variance explained by the regression equation) statistics were considered in the final choice of coefficients for the regression equations. Confidence prediction limits were determined using multiple linear regression techniques for application to nomograph predictions. A recommended procedure for the use of the nomographs has been outlined along with an example. Limiting criteria were established in a separate report (Ref 18) for each design parameter (inference space) following an accuracy analysis of the nomographs and inspection of residual plots. These criteria should be used with the nomographs for the particular set of environmental conditions applicable to the locality of the planned pavement.

KEY WORDS: nomographs, continuously reinforced concrete pavement, CRCP-2 computer program, environment, regression analysis, least squares, fractional factorial, variance, confidence prediction limits, limiting criteria, inference space.

SUMMARY

The CRCP-2 computer program, developed in Research Report Number 177-9, "CRCP-2, An Improved Computer Program for the Analysis of Continuously Reinforced Concrete Pavements" (Ref 8), provides a comprehensive procedure for the detailed design of continuously reinforced concrete pavement, accounting for the effect of variation in environment. Using this program, simulated data were prepared for a selected range of values of input variables. Following an analysis of variance and studies of earlier models, the regression equations were fitted to the data using linear and nonlinear least squares techniques. Nomographs were then prepared from these equations for use as supplementary design tools for the CRCP-2 program in conjunction with limiting criteria on important design parameters established in a separate study. Accuracy analyses were performed and inference spaces established along with confidence prediction limits. A step-by-step procedure for the design of steel reinforcement in continuously reinforced concrete pavement has been recommended and a design example outlined.

IMPLEMENTATION STATEMENT

The nomographs, regression equations, and confidence prediction limits developed in this study can be used in conjunction with the limiting criteria established in a separate report, being prepared contemporaneously, for the design of steel reinforcement in continuously reinforced concrete pavements. The procedure outlined in this study enables the designer to recommend a detailed design for the particular environmental conditions appropriate to the locality of the planned road. The procedure is comprehensive, is easy to use, and allows the designer to specify a range of values for design parameters corresponding to the uncertainty in the design.

This design procedure should be incorporated into the Texas State Department of Highways and Public Transportation manual for the design of continuously reinforced concrete pavement as soon as possible.

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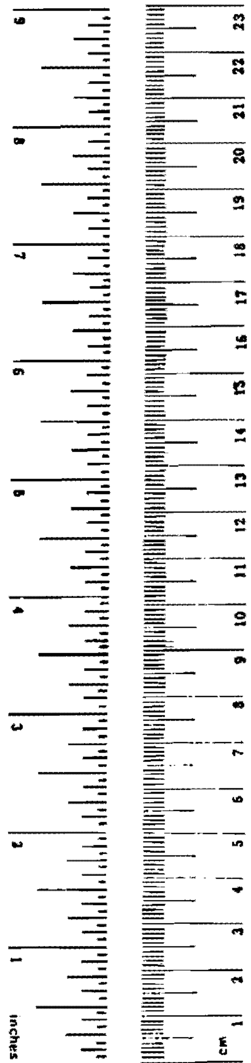
METRIC CONVERSION FACTORS

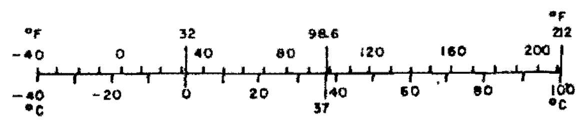
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



CHAPTER 1. INTRODUCTION

Background

Continuously reinforced concrete pavement is considered a relatively new pavement type by many engineers, although it has been in use since 1921 when it was first introduced by the Bureau of Public Roads, on the Columbia Pike near Arlington, Virginia. The next reported use of continuously reinforced concrete pavement was in the fall of 1938, when the State of Indiana, in cooperation with the Bureau of Public Roads, constructed an experimental pavement involving several test sections.

The highway departments of the States of Indiana, Illinois, Texas, California, Mississippi, New Jersey, Michigan, Maryland, and Pennsylvania have laid other pavements of this type that have provided good service for a number of years. The oldest of these are approximately 30 years of age.

After there were several successful experiences with CRCP on experimental projects, the use of CRCP increased substantially, especially during the sixties. Several research studies in rigid pavement design led to the development of the design procedures currently used for CRCP (Refs 1, 2, 3, 4, and 5).

In 1972, and NCHRP study was conducted at The university of Texas at Austin. It consisted of a review of design and construction variables, theoretical studies, field surveys, and laboratory investigations. The fundamental philosophy of this review was that, through a combination of field observations and laboratory studies, reliable procedures could be achieved to develop mathematical models that simulate field performance of CRCP. Based on these mathematical models, the CRCP-1 computer program was developed to calculate the stresses in concrete and steel, the crack width, and the crack spacing resulting from concrete volume changes due to temperature and shrinkage (Ref 6).

Generally, the engineer is encouraged to design each pavement for the soil conditions, traffic, materials, etc. present at the site and to be wary of inappropriate boundary values and practices. However, in order to cover such a wide variety of input variables, he needs a large-scale experiment to anticipate the effects of the individual variations of the variables and the variations in groups. Thus, a sensitivity analysis of the behavior of CRCP using the CRCP-1 model was conducted for the Texas SDHPT as reported in CFHR Report No. 177-2 (Ref 7). From the results of this study, the relative importance of about 15 input variables was determined in order to investigate the effect of changes in values of these variables on the CRCP behavior. The list of the input variables includes the steel properties, the concrete properties, the friction-movement relationships, and temperature variations, In addition to establishing relative importance, the study revealed several inconsistencies of the initial model at extreme boundary conditions that resulted in modification of the computer program.

The next step in the development was to include the effect of wheel load stresses on crack spacing history. The NCHRP 1-15 Study, "Design of Continuously Reinforced Concrete Pavements for Highways," found that heavy volumes of 18-kip single axle loads resulted in reduced crack spacings (Ref 6). The study of the effect of wheel load stress on pavement behavior and its interaction with the other input variables is discussed in CFHR Report 177-9 (Ref 8), which describes the development of the CRCP-2 model. This development process is outlined in flowchart form in the upper part of Fig 1.1.

Summary Capabilities of CRCP-2

The CRCP-2 program (model) has the capability to predict the time history of crack spacing, crack width, concrete stress, and steel stress for a range of material properties, environmental conditions, and pavement structure geometry. The concrete properties of shrinkage, strength, and stiffness, as well as the temperature, are allowed to vary with time. The remaining concrete properties, steel properties, and geometry are time invariant, with the exception that the time to the first wheel load application may be selected.

Figure 1.2 shows plots of the daily temperature changes from the concrete placement temperature, average crack spacing, steel stress, and crack width history for a given set of conditions. The first day on which there is a 280-psi stress resulting from a wheel load placed on the pavement is also shown. These histories would vary drastically, depending upon the input variables.

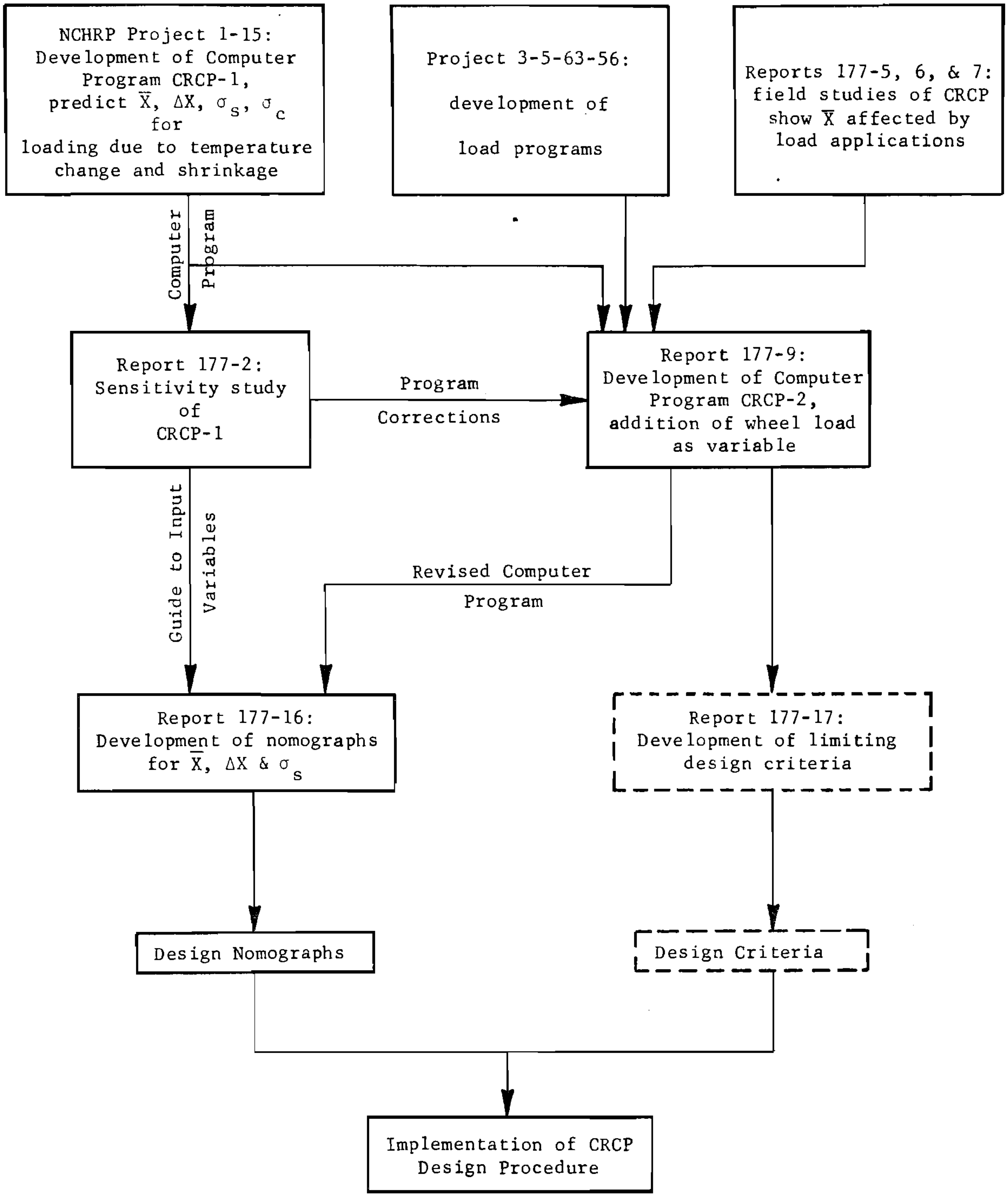
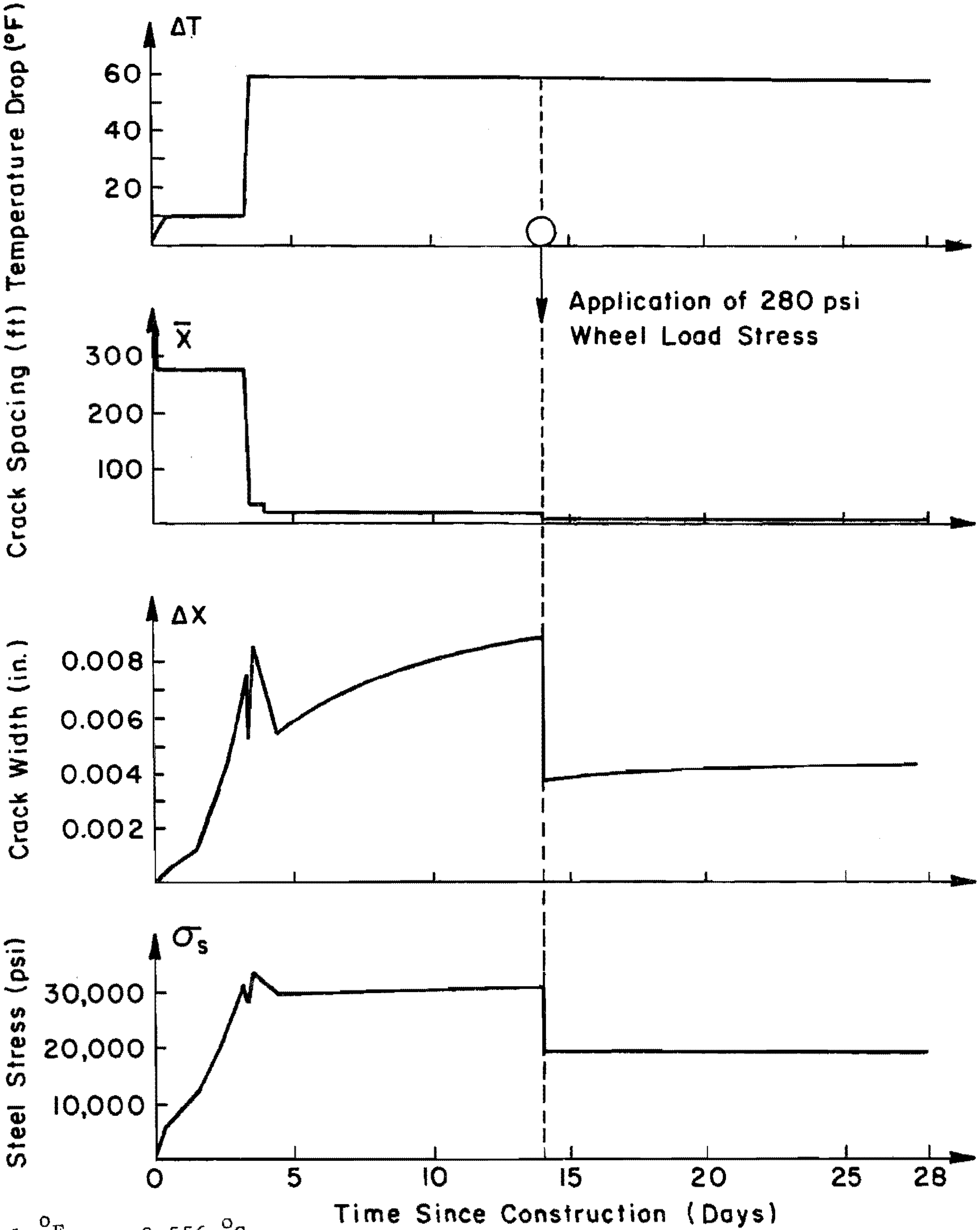


Fig 1.1. Development of CRCP design procedure - flowchart.



1 ^{o}F = 0.556 ^{o}C
1 foot = 304.8 mm
1 inch = 25.4 mm
1 psi = 6.89 kPa

Fig 1.2. Time history of temperature change, crack spacing, crack width, and steel stress for a typical set of conditions (Appendix B).

Thus, with established limits (i.e., design criteria) for each of the factors, a pavement thickness and a steel reinforcement may be established for the other inputs, using the computer program.

Design Needs

In a design for estimation purposes, the need often arises for an approximate solution. Thus, the application of a detailed computer program is not necessary from the point of view of a feasibility investigation.

An alternative to this is the development of design nomographs that permit solutions for crack spacing, crack width, and steel stress considering only the most sensitive variables and fixing the others. The designer may then obtain an approximate solution that recognizes predetermined confidence limits. At the time of final design, a more exact solution may be obtained by use of the CRCP-2 computer program.

The lower portion of Fig 1.1 outlines the steps used in developing the design nomographs. First, a factorial computational experiment was established to obtain all relevant interactions and, hence, the basis for a statistically reliable model. Solutions of CRCP-2 were made for all the desired combinations of input variables. Regression equations were then developed that permitted solution of crack spacing, crack width, and steel stress for the most sensitive input variables. Using the regression equations, nomographs were then plotted.

Objective

The objective of this study is to develop graphical (nomograph) methods for the design of CRCP:

(1) to provide sufficient steel to insure that transverse cracks in the concrete are small enough to prevent passage of surface water downward into the underlying material, and to provide adequate aggregate interlock for load transfer across the crack;

(2) to keep the steel stresses below the predetermined allowable values; and

(3) to develop an acceptable average spacing of the transverse cracks.

Use of the nomographs will facilitate the CRCP design process by substantially reducing the time and cost involved, particularly where computer facilities are difficult to access or estimating phases of the planning process do not permit a detailed analysis.

Scope

This report describes the development of a set of nomographs to be used as a supplementary tool to the CRCP-2 computer program. The interaction, range, form, and limiting criteria for all appropriate CRCP-2 input variables are established. The significant input variables are related in mathematical and graphical models to crack spacing, crack width, and steel stress. Specifically then, the scope of this study was to quantify these relationships and present them in graphical form (nomographs), along with boundary conditions for the appropriate inference spaces and confidence prediction intervals.

CHAPTER 2. PROBLEM AND APPROACH

Description of the Problem

In traditional CRCP design procedures, four subsystems are considered, each as an independent process. These four are closely related and almost the same set of variables is used for each of the procedures. The four subsystems are

(1) pavement thickness design,
(2) reinforcing steel design,
(3) subbase design, and
(4) terminal treatment design.

Previously, these procedures were independently applied and then combined to form the resulting pavement structure (Ref 4).

The CRCP design procedures must take into account not only the stresses developed by external forces (wheel loads) but also the stresses developed by internal forces. The external forces affect pavement thickness and subbase design, and the internal forces affect the design of the reinforcing steel and the terminal treatment. These two aspects of the design problem must be treated together because it is the resultant interaction of these internal and external forces which affects the overall pavement behavior.

Approach

The CRCP-2 program (Ref 8) models the interactions mentioned above and outputs predicted final values of crack spacing, crack width, and steel stress. Hence, the appropriate input variables for the graphical models (nomographs) were selected from the variables used as inputs to CRCP-2.

Further, in order to build the nomographs, it was necessary to quantify the relationships between the significant input variables and the design parameters crack spacing, crack width, and steel stress. To do this, multiple regression analysis and analysis of variance were performed using simulated data (observations) generated as output from CRCP-2 from an appropriate set of values of the input variables.

The mathematical formulation of these relationships having been established by the regression techniques (Chapter 3), principles of nomography were then applied to these equations to develop a nomograph for the prediction of each of the three design parameters (Chapter 4).

Regression techniques were also used to determine confidence prediction intervals for each nomograph. An analysis of the accuracy of each nomograph as a predictor of CRCP-2 output was also performed to ensure that predictions are within design tolerances.

Use of CRCP-2 Output

Referring to Fig 1.2 (page 4), it is apparent that the three dependent variables decrease in discrete steps with time since construction, while crack width and steel stress increase gradually between steps. This figure has been plotted for the first 28 days to illustrate this trend in each case, for the typical set of data listed in Appendix B.

However, the values of these dependent variables which were used in the regression analysis were those eventually attained when the pavement had reached equilibrium. These values are shown under the heading "At the end of the analysis period," for the typical set of data listed in Appendix B. In this manner, the values of the dependent variables used in the regression analysis were obtained from the CRCP-2 outputs for the different sets of conditions described in Chapter 3. These values are summarized along with the corresponding values of the independent variables in Appendix C.

CHAPTER 3. DEVELOPMENT OF REGRESSION MODELS

Regression equations were developed to model relationships between relevent input variables and the design parameters crack spacing, crack width, and steel stress. The choice of equations was made following linear and non-linear least squares fit to a simulated set of observations generated as output from the CRCP-2 computer program. This development occurred in several stages.

Choice of Input Variables and Design of Experiment

In order to generate the necessary observations of the three design parameters, it was decided to vary 10 of the 21 CRCP-2 input variables (factors) at three levels each while holding the other 11 constant. This decision was based on the findings from the sensitivity study (Ref 7) and subsequent studies. Values were selected to cover the appropriate inference space after consultation with the Texas SDHPT. The variables used and the values chosen are listed in Table 3.1. A more detailed explanation of these variables is included in Ref 9.

In order to obtain a manageably small yet truly representative set of observations of variables for prediction, a $1/3^5$ replicate of a 3^{10} factorial experiment (Refs 10 and 11) using a completely randomized design was carried out. This design was chosen with all two-factor interactions measurable, so that all main effects and two-factor interactions could be accurately estimated from only 3^5, or 243, observations. The design factorial is incorporated in this report as Appendix A, and a typical CRCP-2 computer printout, as Appendix B. A summary of the complete set of "observations" resulting from the experiment, showing values of the three design parameters for each combination of values of the ten input variables which were varied, is given in Appendix C.

It should be noted that all important combinations of the input variable values likely to be encountered in practical CRCP design were covered in the

TABLE 3.1. VALUES OF VARIABLES USED IN ANALYSIS OF CRCP-2

(a) Input Variables

Variables	Symbol	Values for Levels 1	2	3
Wheel load stress (psi)	σ_w	60	170	280
Daily temperature change (°F)	ΔT_i	8	34	60
Final temperature change (°F)	ΔT_F	35	55	75
Friction movement ratio	F/y	-10	-80	-150
Concrete slab thickness (in.)	D	7	10	12
Concrete shrinkage strain	Z	2×10^{-4}	5×10^{-4}	8×10^{-4}
Concrete tensile strength (psi)	f_t	500	650	800
Thermal coefficient ratio	α_s/α_c	0.75	1.00	1.50
Bar diameter (in.)	Φ	1/2	5/8	3/4
Percent reinforcement	p	0.40	0.65	0.90

(b) Variables Held at Constant Level

Type of reinforcement	Deformed bar
Yield stress of steel (psi)	60,000
Elastic modulus of steel (psi)	29,000,000
Thermal coefficient of steel (in./in./°F)	6×10^{-6}
Unit weight of concrete (pcf)	150
Flexural-tensile factor	0.86
Curing temperature (°F)	75
Number of days to full-strength concrete	28
Number of days to minimum temperature	28
Number of days to wheel load application	14
Slab movement (in.)	-0.1

1 psi = 6.894 kPa

1 °F = 0.556 °C

1 in. = 25.4 mm

1 pcf = 16.02 kg/m^3

factorial, extending over the extremes of the ranges of each variable. Hence, this experiment can also serve as the basis for a sensitivity analysis of the CRCP-2 model.

Theoretical Background to Form of Regression Models

Theoretical relationships developed at CFHR (Ref 9) between the design parameters and the relevant input variables (Table 3.1) were considered in the initial investigation of the form of the regression models. From these relationships, it is apparent that

crack spacing is proportional to $$\frac{f_t^{a_1} \times \phi^{a_2} \times \alpha_s^{a_3}}{p^{a_4} \times \sigma_w^{a_5}}$$

and crack width is proportional to $$\frac{f_t^{b_1} \times \phi^{b_2}}{p^{b_3} \times \sigma_w^{b_4}}$$

where

a_1, a_2, a_3, a_4, a_5, b_1, b_2, b_3, and b_4 are positive constants and the other variables are as defined in Table 3.1.

These theoretical trends were confirmed by an inspection of the variation of each of the design parameters with the input variables over the appropriate range using the simulated data set generated by the factorial experiment. This was done using a series of plots of each of the design parameters against each of the input variables with the other input variables held constant, using the complete 243 observations. From these it was clear that

crack spacing increases with increasing D, f_t, α_s/α_c, and Φ, but decreases with increasing σ_w, ΔT_i, ΔT_f, F/y, Z, and p;

crack width increases with increasing Z, f_t, α_s/α_c, and Φ, but decreases with increasing σ_w, ΔT_i, ΔT_f, F/y, D, and p;

steel stress increases with increasing ΔT_f, D, f_t, α_s/α_c, and Φ,

but decreases with increasing σ_w, ΔT_i, F/y, Z, and p.

Form of Independent Variables in Regression Models

In order to ensure reasonable prediction of design parameters from the nomographs for all values of the input variables (independent variables) likely to be encountered in practice, each independent variable was transformed into a format based on its extreme (boundary) values, for the purposes of the regression analysis. The format used for each variable is shown in Table 3.2. For example, for the variable "wheel load stress" (σ_w), the transformation ($1 + \sigma_w/1000$) was used so that the value used in the regression equation would lie between one and two for all values of σ_w likely to be encountered in practice (even for the zero wheel load case).

Description and Results of Regression Analysis

The final choice of regression equations was then made following multiple linear and nonlinear least squares fits of the transformed input variables (independent variables) to the simulated set of 243 observations of the design parameters (dependent variables) previously described. Stepwise linear regression computer programs, SPSS Multiple Regression (Ref 12) and STEP-01 (Ref 13) were used in the linear analyses, with logarithmic transformations of both independent and dependent variables to reflect the exponential nature of the relationships discussed earlier. Better fits resulted using these transformations than any other tried (e.g.,orthogonal polynomials), with more variance being explained by fewer independent variables (and less prediction error) for all three dependent variables. Also, these regression analyses confirmed the trends established by the theoretical developments and plots discussed previously. Copies of the results of these analyses (computer printouts) are included in this report as Appendix D.1. Computer program BMD07R-Nonlinear Least Squares (Ref 14)- was used for the nonlinear analysis. This second approach was adopted since, owing to the exponential nature of the relationship (and the bias introduced by the transform), some improvement in fit might be obtained by nonlinear analysis, particularly if the error was additive rather than multiplicative. Results of this analysis are included in Appendix D.S.

TABLE 3.2. TRANSFORMATIONS OF CRCP INPUT VARIABLES FOR USE IN THE REGRESSION ANALYSIS

Independent Variable	Transformation Used
σ_w	$1 + \frac{\sigma_w}{1000}$
ΔT_i	$1 + \frac{\Delta T_F}{100}$
ΔT_F	$1 + \frac{\Delta T_F}{100}$
F/y	$1 + \frac{1}{200} \frac{F}{y}$
D	$1 + \frac{D}{20}$
Z	$1 + 1000Z$
f_t	$1 + \frac{f_t}{1000}$
α_s/α_c	$1 + \frac{1}{2} \frac{\alpha_s}{\alpha_c}$
ϕ	$1 + \phi$
p	$1 + p$

Residual plots, standard error of estimate and R^2 (proportion of variance explained by the regression equation) statistics were considered in the final choice of coefficients in each regression equation. These final equations are summarized in Table 3.3, and the nonlinear equations, in Table 3.4.

Nonlinear Regression Models

In general, if linear regression is performed using logarithmic transforms of the dependent variable (Y) and the independent variables (X_1, ... X_n) the model becomes

$$\log Y = C_o + C_1 \log X_1 + \ldots + C_n \log X_n + \text{error term (E)}$$

or

$$Y = C_o X_1^{C_1} \ldots X_n^{C_n} E$$

where

C_o, ..., C_n are constants.

Hence the error term is multiplicative in this model.

However, the nonlinear model would be

$$Y = K_o X_1^{K_1} \ldots X_n^{K_n} + \text{error term } (E')$$

where

K_o, ... , K_1 are constants.

Hence the error term is additive in this model.

A comparison was then made of the goodness of fit of both the linear and nonlinear regression models, since the form of the error term was unknown in this case. The results of this comparison are summarized in Table 3.5. It is apparent from these that the improvement in fit owing to the use of nonlinear

TABLE 3.3. LINEAR REGRESSION EQUATIONS FOR DESIGN PARAMETERS

$$\overline{X} = \frac{1.32\left(1 + \frac{f_t}{1000}\right)^{6.70} \left(1 + \frac{\alpha_s}{2\alpha_c}\right)^{1.15} \left(1 + \phi\right)^{2.19}}{\left(1 + \frac{\sigma_w}{1000}\right)^{5.20} \left(1 + p\right)^{4.60} \left(1 + 1000Z\right)^{1.79}}$$

$R^2 = 90.2\%$

Standard error = 2.12 feet

$$\Delta X = \frac{0.00932\left(1 + \frac{f_t}{1000}\right)^{6.53} \left(1 + \phi\right)^{2.20}}{\left(1 + \frac{\sigma_w}{1000}\right)^{4.91} \left(1 + p\right)^{4.55}}$$

$R^2 = 92.7\%$

Standard error = 0.013 in.

$$\sigma_s = \frac{47{,}300\left(1 + \frac{\Delta T_F}{100}\right)^{0.425} \left(1 + \frac{f_t}{1000}\right)^{4.09}}{\left(1 + \frac{\sigma_w}{1000}\right)^{3.14} \left(1 + 1000\,Z\right)^{0.494} \left(1 + p\right)^{2.74}}$$

$R^2 = 92.2\%$

Standard error = 9830 psi

where

$\overline{X}$	=	Crack spacing (feet),	1 foot	=	304.8 mm
ΔX	=	Crack width (in.),	1 in.	=	25.4 mm
σ_s	=	Steel stress (psi).	1 psi	=	6.89 kPa

All other variables are as defined in Table 3.1.

Note: Analysis of variance indicated, for each equation, that the inclusion of further terms (independent variables) did not significantly improve either the R^2 or standard error of residuals statistics.

TABLE 3.4. NON-LINEAR ALTERNATE SET OF REGRESSION EQUATIONS

$$\bar{X} = \frac{1.72\left(1 + \frac{f_t}{1000}\right)^{6.33}\left(1 + \frac{\alpha_s}{2\alpha}\right)^{1.70}\left(1 + \phi\right)^{2.67}}{\left(1 + \frac{\sigma_w}{1000}\right)^{4.03}\left(1 + 1000\dot{z}\right)^{1.87}\left(1 + p\right)^{6.23}}$$

R^2 = 90.4%

Standard error = 2.11 feet

$$\Delta X = \frac{0.0139\left(1 + \frac{f_t}{1000}\right)^{5.89}\left(1 + \phi\right)^{2.32}}{\left(1 + \frac{\sigma_w}{1000}\right)^{4.10}\left(1 + p\right)^{5.03}}$$

R^2 = 94.0%

Standard error = 0.012 in.

$$\sigma_s = \frac{47{,}300\left(1 + \frac{\Delta T_F}{100}\right)^{0.402}\left(1 + \frac{f_t}{1000}\right)^{4.03}}{\left(1 + \frac{\sigma_w}{1000}\right)^{3.07}\left(1 + 1000Z\right)^{0.468}\left(1 + p\right)^{2.75}}$$

R^2 = 92.6%

Standard error = 9570 psi

where

$\bar{X}$	=	Crack spacing (feet),	1 foot	=	304.8 mm
ΔX	=	Crack width (in.),	1 in.	=	25.4 mm
σ_s	=	Steel stress (psi).	1 psi	=	6.894 kPa

All other variables are as defined in Table 3.1.

Note: Analysis of variance indicated, for each equation, that the inclusion of further terms (independent variables) did not significantly improve either the R^2 or standard error of residuals statistics.

TABLE 3.5. COMPARISON OF GOODNESS OF FIT OF LINEAR AND NON-LINEAR REGRESSION MODELS

SUMMARY STATISTICS

	Dependent Variable		
	Crack Spacing	Crack Width	Steel Stress
Mean	6.314 feet	0.0503 in.	66,031 psi
Standard deviation	6.705 feet	0.0465 in.	61,830 psi
Degrees of freedom	236	238	237
Linear Model			
Standard error of residuals	2.124 feet	0.0127 in.	9,826 psi
R^2	90.21%	92.67%	92.24%
Mean square error (MSE)	4.513 $feet^2$	0.000161 $in.^2$	96,545,000 $feet^2$
Nonlinear Model			
Standard error of residuals	2.108 feet	0.0115 in.	9,572 psi
R^2	90.36%	93.95%	92.63%
Mean square error (MSE)	4.444 $feet^2$	0.000133 $in.^2$	91,615,000 $feet^2$
F-Test			
$F = \frac{\text{MSE linear model}}{\text{MSE nonlinear model}}$	1.016	1.213	1.054
Level of significance	> 25%	∿ 6%	> 25%
Improvement of nonlinear fit over linear fit	Not significant at 25% level	Not significant at 5% level	Not significant at 25% level

1 foot = 304.8 mm, 1 in. = 25.4 mm, 1 psi = 6.894 kPa

coefficients was not significant at the 5 percent level for crack width and at the 25 percent level for both crack spacing and steel stress. It was thus decided to use the expressions derived from the linear fit because strict confidence intervals were to be determined using linear regression procedures (Chapter 4). However, the alternative set of regression equations with coefficients based on the nonlinear regression are listed for completeness in Table 3.4. It should be noted that if these equations were to be used, the confidence intervals shown in Chapter 4 would be conservative.

Outliers

For all three design parameters, regression analysis which were performed with major outliers removed from the data set showed no significant improvement in prediction accuracy.

Summary

In the light of the foregoing, it was decided to use the regression equations summarized in Table 3.3 as the basis for the construction of the nomographs. These equations gave satisfactory R^2 and standard error values and agreed with the format indicated by the previous theoretical development and summary plots from the sample data. Some slight improvement in goodness of fit to the sample data was seen for the equations developed using the nonlinear analysis (Table 3.5). However, this was not considered sufficiently significant to offset the uncertainty which would have been introduced if these equations were to be used with the confidence limits described in Chapter 4. This uncertainty would have occurred because the confidence intervals were derived using a linear analysis (with logarithmic transforms) and as such, are conservative on the equations in Table 3.3, but not necessarily on those in Table 3.4.

CHAPTER 4. CRCP DESIGN NOMOGRAPHS AND CONFIDENCE LIMITS

Design Charts - Nomographs

Using the principles of nomography (Refs 15 and 16) and the regression equations summarized in Table 3.3, separate design charts (nomographs) were prepared for the prediction of crack spacing, crack width, and steel stress in the design of CRCP. These are shown in Figs 4.1, 4.2, and 4.3, respectively.

Confidence Prediction Limits

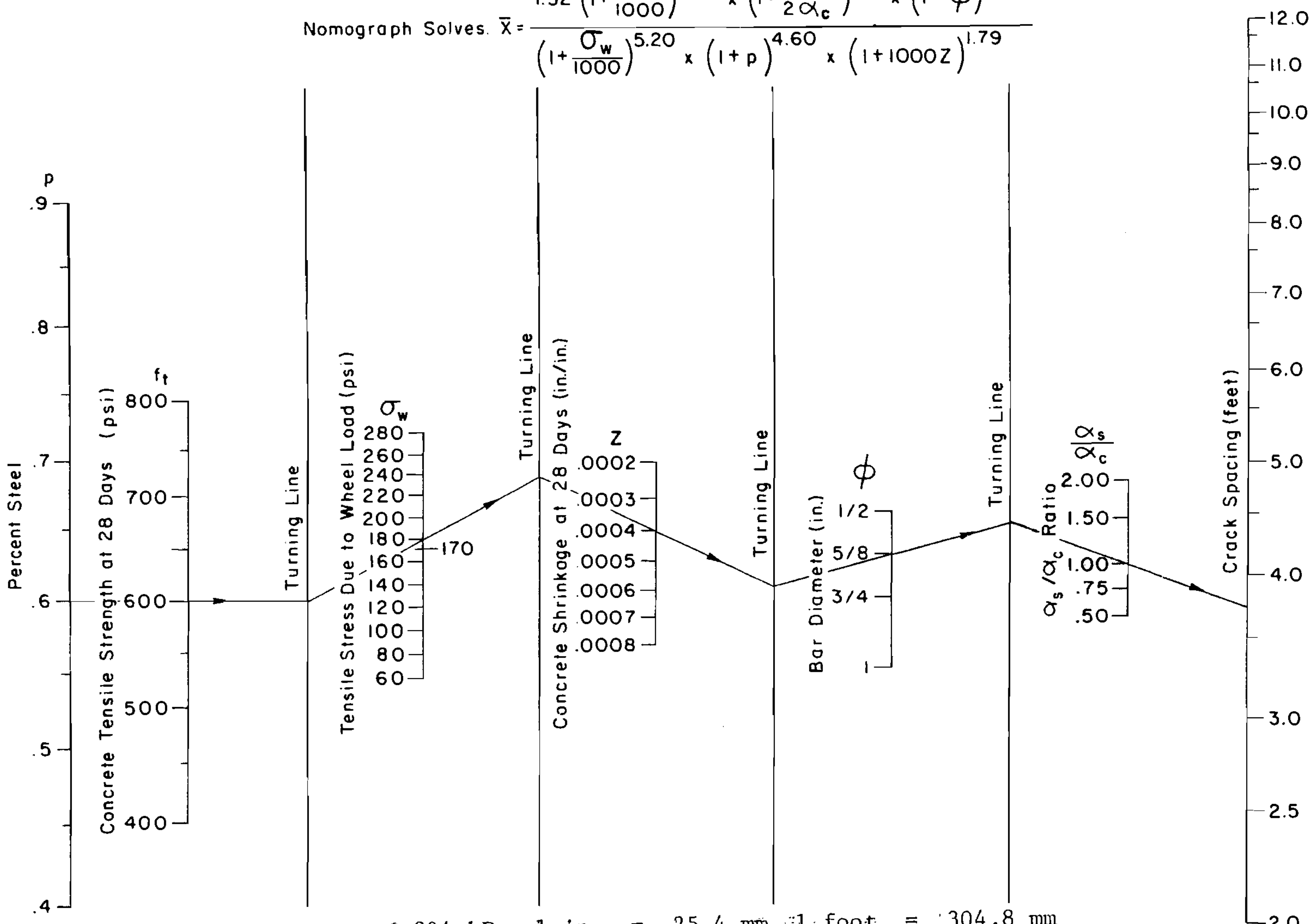
Using the CPIY linear regression program (Ref 17) and logarithmic transformations of the appropriate dependent and independent variables, the 90 percent and 97 1/2 percent confidence limits on each of the three design parameters, crack spacing, crack width, and steel stress, were calculated for the regression models summarized in Table 3.3. A copy of the output from the analysis is included as Appendix D.3. These confidence limits can then be used with the nomographs in the design procedure. To this end, graphs of the variation of these confidence limits with the value of each design parameter for the appropriate inference range are included as Figs 4.4, 4.5 and 4.6.

It should be noted that since the regression equations are of an exponential form, strict confidence intervals cannot be determined using existing computer software (e.g., from the nonlinear regression models). Hence, it is necessary to use logarithmic transformations and the linear regression techniques in the program CPIY to determine these confidence limits. Transformations of these confidence limits are then conservative for the exponential models.

In practice, use of Figs 4.4, 4.5, and 4.6 in conjunction with the corresponding nomographs enables the designer to estimate the uncertainty associated with the values of the design parameter (crack spacing, crack width, and steel stress) indicated by the nomographs. These values are for the chosen value of percentage of steel and the values of the other input variables determined by the properties of materials used and the appropriate environmental conditions.

Nomograph Solves

$$\bar{X} = \frac{1.32\left(1+\frac{f_t}{1000}\right)^{6.70} \times \left(1+\frac{\alpha_s}{2\alpha_c}\right)^{1.15} \times \left(1+\phi\right)^{2.19}}{\left(1+\frac{\sigma_w}{1000}\right)^{5.20} \times \left(1+p\right)^{4.60} \times \left(1+1000Z\right)^{1.79}}$$



1 psi = 6.894 kPa, 1 in. = 25.4 mm, 1 foot = 304.8 mm

Fig 4.1. Nomograph for prediction of crack spacing.

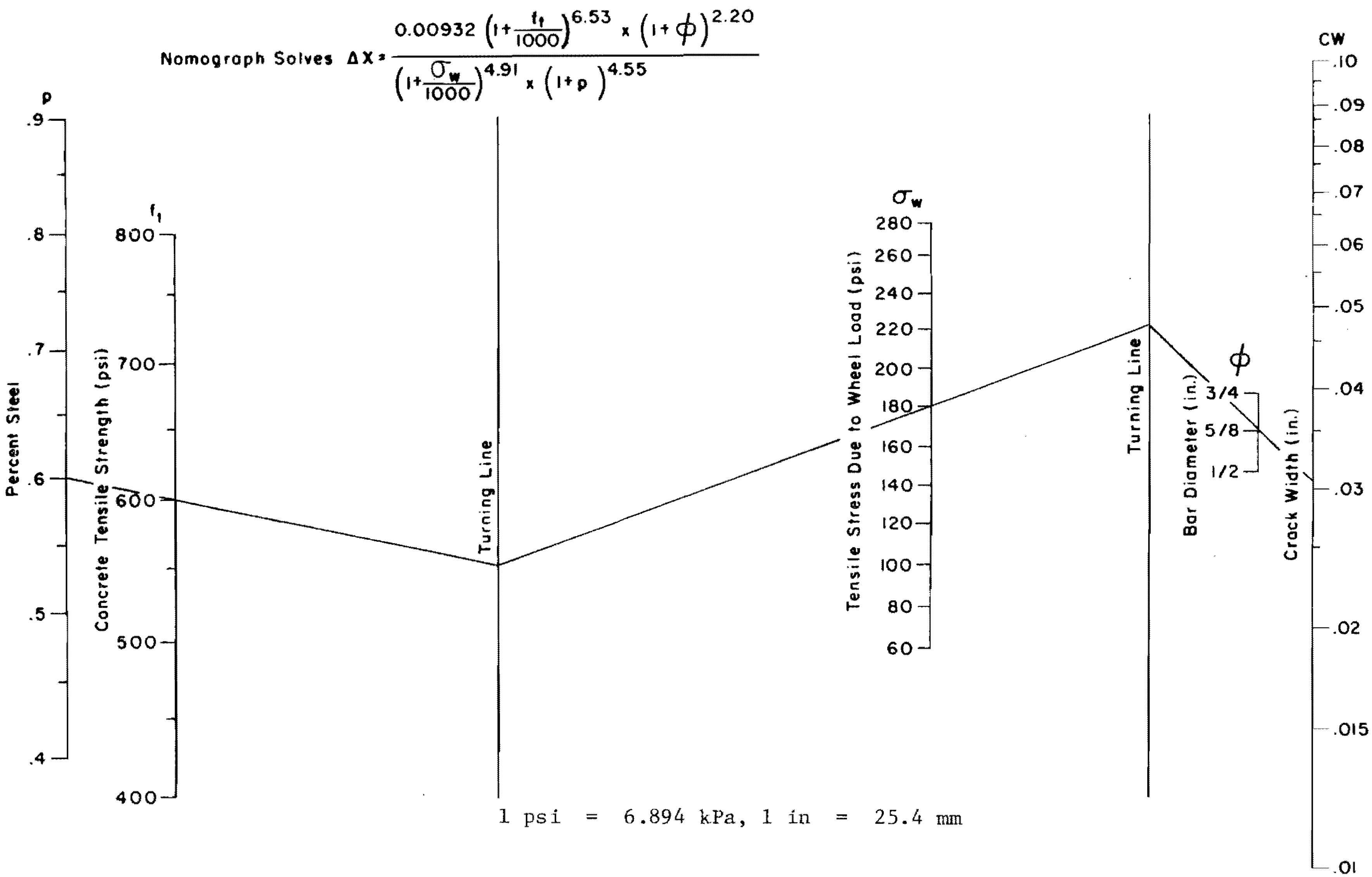
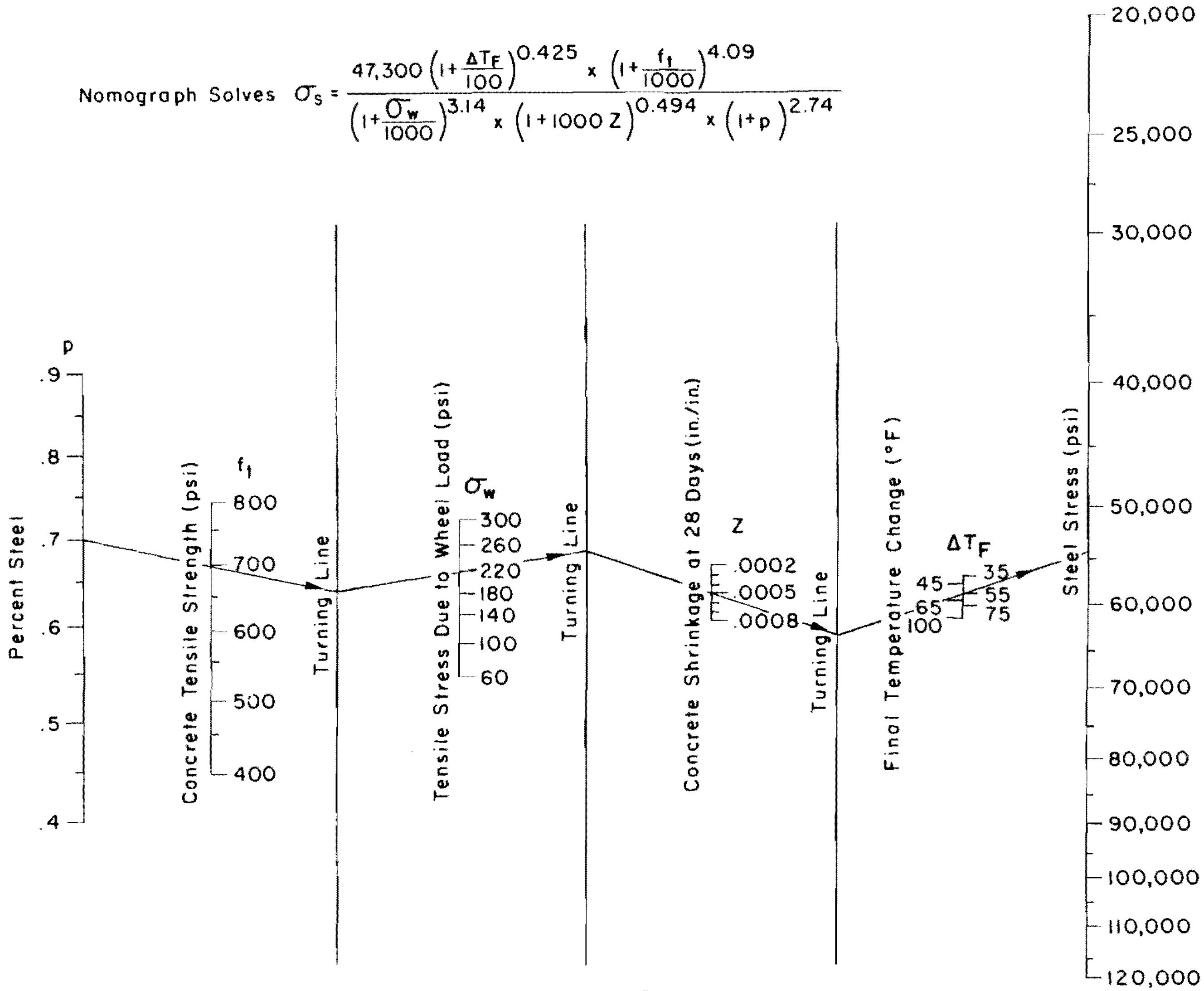


Fig 4.2. Nomograph for prediction of crack width.

Nomograph Solves $$\sigma_s = \frac{47{,}300\left(1+\frac{\Delta T_F}{100}\right)^{0.425} \times \left(1+\frac{f_t}{1000}\right)^{4.09}}{\left(1+\frac{\sigma_w}{1000}\right)^{3.14} \times \left(1+1000\,Z\right)^{0.494} \times \left(1+p\right)^{2.74}}$$



1 psi = 6.894 kPa, 1 F° = 0.556 C°

Fig 4.3. Nomograph for prediction of steel stress.

That is, a range of values in crack spacing can be determined from Fig 4.4 such that this parameter will be within this range with either 80 percent or 95 percent probability. Similarly, two upper limits on each of crack width and steel stress can be determined from Figs 4.5 and 4.6, respectively, such that the appropriate parameters will be below these limits with either 90 percent or 97 1/2 percent probability.

Accuracy Analysis

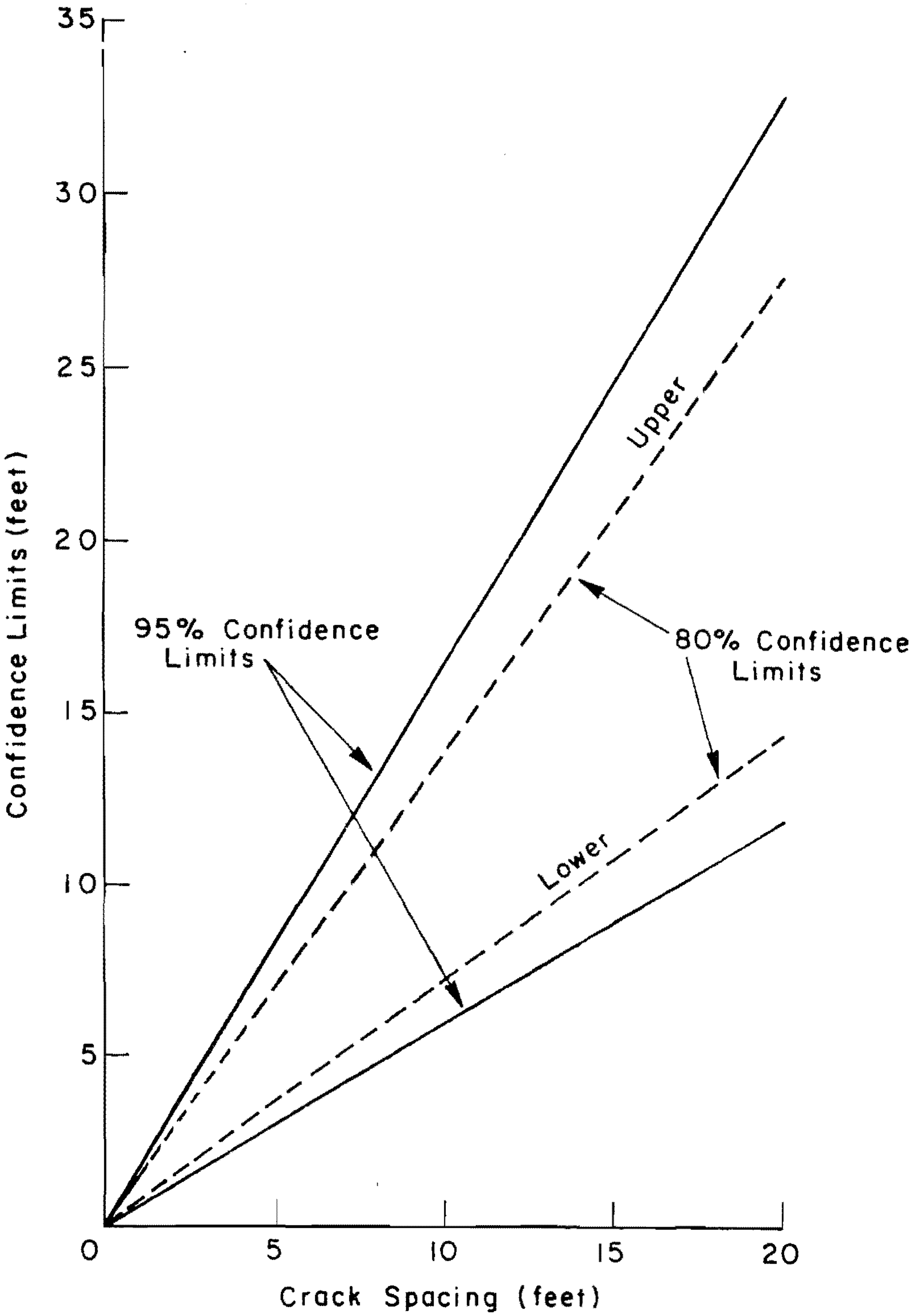
A set of test data consisting of 35 different combinations of the CRCP-2 input variables which had not been used in the initial regression analysis was prepared. Values for the different design parameters (crack spacing, crack width, and steel stress) corresponding to each of the 35 combinations were then computed with the CRCP-2 program.

Initially, design parameter values for some of the combinations, as obtained from the nomographs, were compared with values from the regression equations. Subsequently, the parameter values obtained from the nomographs were compared to the computed values. A further check on the amount of variation accounted for by the regression equation was accomplished by fixing values of the regression variables and varying the values of the variables not included in the regression equations.

Nomographs Compared to the Regression Equations. The nomographs compare well with the regression equations (Table 4.1), particularly when the values of the design parameters fall within expected maximum boundary vlaues. Using the root mean square residual as an estimate of variance for the samples, coefficients of variation of roughly five percent were obtained from the comparison within the boundary values.

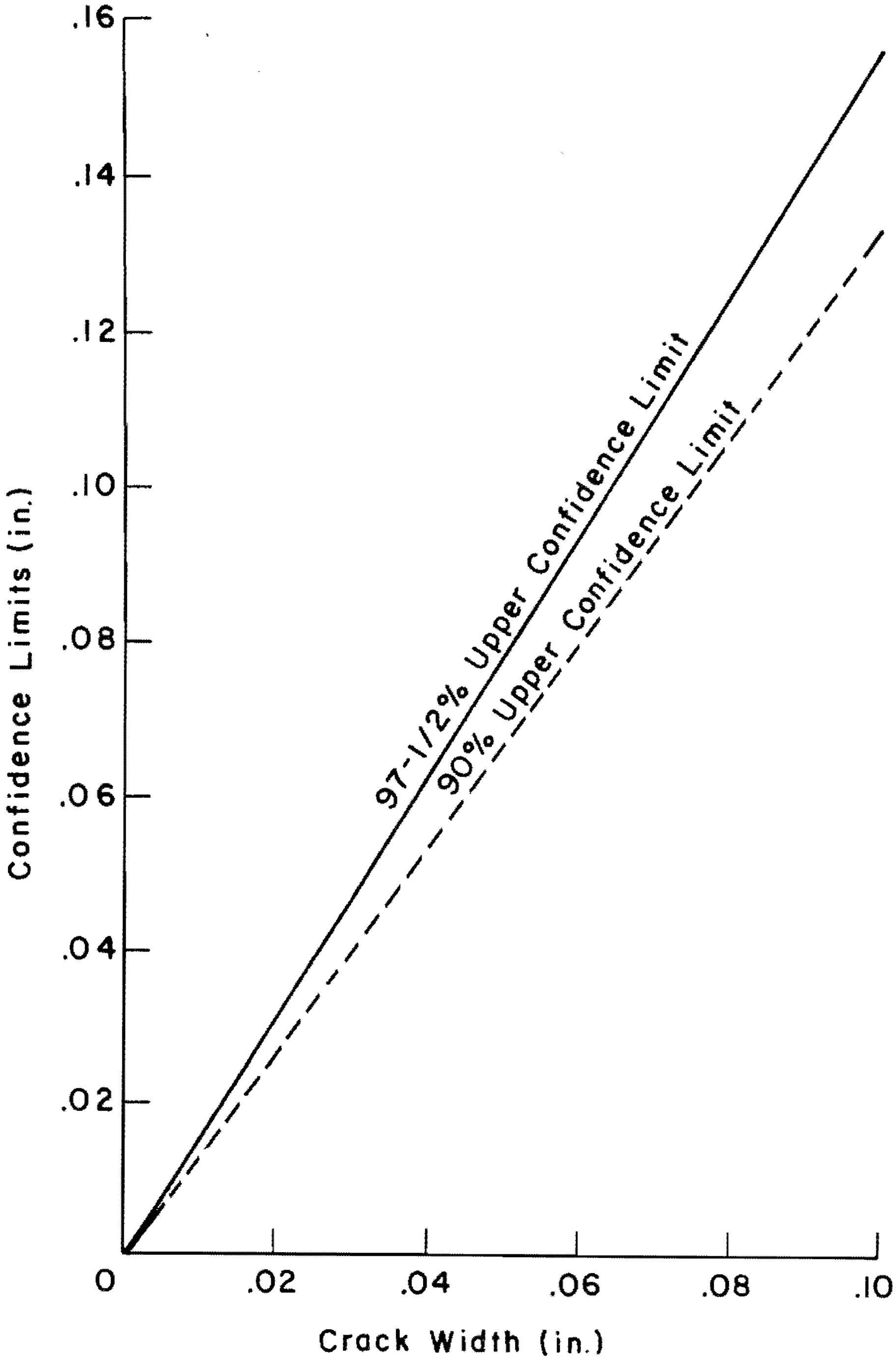
Nomographs Compared to the Computed Values. When unbounded values of the design parameters are used in the comparison in Table 4.2, coefficients of variation defined and calculated as above are greater than in the case where the data set results in parameter values which fall within the proposed boundaries. In the latter case, coefficients of variation of 11 to 20 percent were obtained.

Variables not Included in the Regression Equations. As confirmed by the regression analysis, the variations of the design parameter values produced purely by changing these variables are small, as may be seen in Table 4.3.



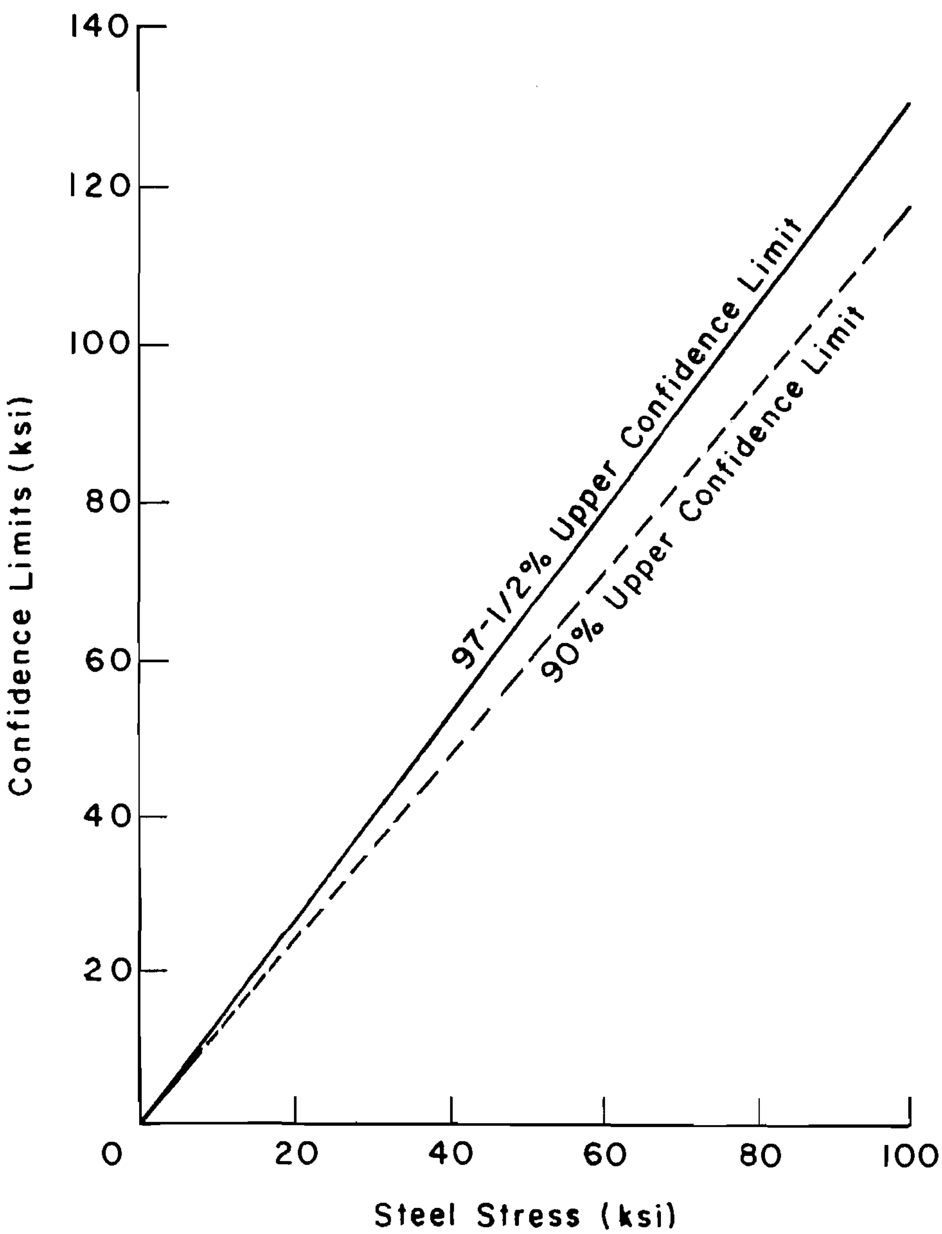
1 foot = 304.8 mm

Fig 4.4. Confidence limits for crack spacing (to be used with Fig 4.1.).



1 in. = 25.4 mm

Fig 4.5. Confidence limits for crack width (to be used with Fig 4.2.).



1 ksi = 6.894 MPa

Fig 4.6. Confidence limits for steel stress (to be used with Fig 4.3.).

TABLE 4.1. COMPARISON OF RESULTS OF DESIGN PARAMETER VALUES AS OBTAINED FROM NOMOGRAPHS AND REGRESSION EQUATIONS

	Dependent Variable		
	Crack Spacing	Crack Width	Steel Stress
Statistic:			
Degrees of freedom	24	12	21
Root mean square residual	5.5 feet	0.0163 in.	21.5 ksi
Coefficient of variation (percent)	33	23	21
Statistics obtained when design parameters fall within these boundaries:			
	<20 feet	<0.1 in.	<100 ksi
Degrees of freedom	14	10	11
Root mean square residual	1.177 feet	0.0089 in.	6.5 ksi
Coefficient of variation (percent)	20	19	11

TABLE 4.2 COMPARISON OF RESULTS OF DESIGN PARAMETER VALUES AS OBTAINED FROM NOMOGRAPHS AND COMPUTER VALUES

	Dependent Variable		
	Crack Spacing	Crack Width	Steel Stress
Statistic:			
Degrees of freedom	18	9	20
Root mean square residual	3.09 feet	0.0042 in.	14.1 ksi
Coefficient of variation (percent)	17	6	14
Statistics obtained when design parameters fall within these boundaries:			
	<20 feet	<0.1 in.	<100 ksi
Degrees of freedom	10	6	11
Root mean square residual	0.44 feet	0.0005 in.	1.8 ksi
Coefficient of variation (percent)	5.4	1.2	3

TABLE 4.3 SENSITIVITY OF DESIGN PARAMETER VALUES (DEPENDENT VARIABLES) TO CHANGES IN INDEPENDENT VARIABLES NOT INCLUDED IN REGRESSION EQUATION

Independent Variable	Range	Crack Spacing (feet)	Crack Width (in.)	Steel Stress (psi)
		Range of Values of Design Parameters — Dependent Variables		
Daily temperature change ΔT_i (°F)	8 to 60	4.17 to 3.34	0.039 to 0.031	62,460 to 54,710
Number days to first wheel load application, and final temperature change ΔT_p (°F)	{14 and 55} to {∞ and 35}	3.33 to 2.96	0.031 to 0.024	- -
Final temperature change ΔT_p (°F)	75 to 35	2.96 to 2.96	0.033 to 0.024	- -
Friction movement ratio F/Y	-80 to -150	2.96 to 2.96	0.024 to 0.028	45,860 to 50,960
Thickness of concrete D (in.)	7 to 12	3.89 to 3.89	0.036 to 0.036	59,980 to 59,980
	Coefficient of variation	15 percent	18 percent	13 percent

1 °F = 0.556 °C

1 in. = 25.4 mm

1 foot = 304.8 mm

1 psi = 6.894 kPa

The small sample of values tested shows coefficients of variation calculated as above ranging from 13 to 18 percent for the different design parameters.

Summary

(1) Values of the design parameters as obtained from the nomographs are generally within 25 percent of the computer program values, provided that the initial and resulting parameter values fall within a practical range.

(2) Loss of accuracy due to the use of nomographs instead of the regression equation can mostly be attributed to the lack of accuracy of the "end result scale" of the nomograph. When considering the variation and uncertainty of the input used, it can be said that this small loss of accuracy is insignificant.

(3) When extreme values of input parameters are used, the "turning lines" of the nomographs have to be very long and may have to be extended. Use of values normally encountered in the field, however, does not create such problems.

CHAPTER 5. DESIGN PROCEDURE

Design Procedure

In order to use Figs 4.1, 4.2, 4.3, 4.4, 4.5, and 4.6 to design the percentage of steel reinforcement in CRCP, the designer should first determine the values of concrete-tensile strength, coefficients of thermal expansion of concrete and steel, wheel load stress, steel bar diameter, shrinkage strain, and maximum temperature variation for the materials and environmental conditions appropriate to the design situation. A method for the selection of these values is detailed in Ref 18. The procedure then becomes one of estimating the percentage of steel to be used in order to satisfy the limiting criteria for these conditions on crack width, crack spacing, and steel stress as established in Ref 18. This is achieved by following the steps outlined below. It should be noted here that the contemporary design slab thicknesses of CRCP range from 7 inches to 12 inches. A procedure for the selection of thickness is also detailed in Ref 18.

(1) Mark the values of the appropriate input variables (as listed above) on their respective scales on each of the three nomographs.

(2) Choose a likely value of the percentage of steel to be used (p) and mark this value on the scale for p on each nomograph.

(3) Working from left to right, draw a line joining the marked values on scales 1 and 2 for the crack spacing nomograph; then proceed until the line intersects the first turning line.

(4) Draw a new line from this point, joining it to the marked value on scale 3, and proceed until it intersects the second turning line.

(5) Repeat this process for the remaining two turning lines and scales 4, 5, and 6 until the value of crack spacing can be read from the scale on the far right.

(6) If this value is not inside the recommended range for the appropriate environmental conditions and material properties specified in Ref 18, repeat steps 2 through 5 for larger percentages of steel until the limiting criteria are satisfied.

(7) Repeat steps 2 through 6 for the crack width and steel stress nomographs and relevant limiting criteria.

(8) If the values obtained in steps 6 and 7 for all three nomographs are inside the respective limiting criteria, then repeat the entire process using successively smaller values of p until one of the three nomographs indicates a final value (of crack spacing, crack width, or steel stress) which is "just inside" the limits. This value of p is then the design value to be recommended.

(9) The designer should then enter Figs 4.4, 4.5, and 4.6 on the abscissa scale with values of crack spacing, crack width, and steel stress (respectively) obtained from the corresponding nomographs for the final value of p recommended in step 8. The upper and lower confidence limits for crack spacing and the upper confidence limits for crack width and steel stress should then be read from the respective ordinate scales of each figure.

(10) Thus, the designer should finally recommend a steel percentage, along with both the corresponding 80 and 95 percent confidence limits on crack spacing and both the 90 percent and 97 1/2 percent upper confidence limits on crack width and steel stress, which use of this p will predict. That is, the designer recommends a percent steel, along with a range of values of crack spacing that will include the actual value 80 percent of the time (or with 80 percent certainty), as predicted by the model, as well as a slightly wider range that will include the actual value 95 percent of the time. Also, the designer recommends the corresponding upper limits on crack width and steel stress such that, for the chosen value of p, these parameters will fall below these limits 90 percent (or 97 1/2 percent) of the time, or with 90 percent (or 97 1/2 perdent) certainty.

NOTE: These ranges could be used in conjunction with limiting criteria established in Ref 18 if a more conservative design is required.

(11) The equations should be used as a check on the nomograph design.

Example:

Predetermined values of design inputs:

f_t = 800 psi: concrete tensile strength,

σ_w = 280 psi: wheel stress,

z = 0.0005 in./in.: shrinkage strain,

ϕ = 0.5 in.: steel bar diameter,

α_s = 6×10^{-6} in./in./°F: thermal coefficient of steel,

α_c = 4×10^{-6} in./in./°F: thermal coefficient of concrete, and

ΔT_F = 75°F: maximum predicted temperature drop after construction.

Recommended limiting design criteria (Ref 18) for the previous environmental conditions and material properties:

Limiting range on crack spacing: 3.5 feet $\leq \bar{X} \leq$ 8.0 feet.

Upper limit on crack width: $\Delta X \leq$ 0.048 in.

Upper limit on steel stress: $\sigma_s \leq$ 67.5 ksi.

Initial (assumed) value of steel percentage: p = 0.65 percent.

First iteration:

From Fig 4.1, corresponding values of crack spacing $\bar{X}$ = 4.5 feet.

From Fig 4.2, corresponding values of crack width ΔX = 0.034 in.

From Fig 4.3, corresponding values of steel stress σ_s = 65 ksi.

Other iterations:

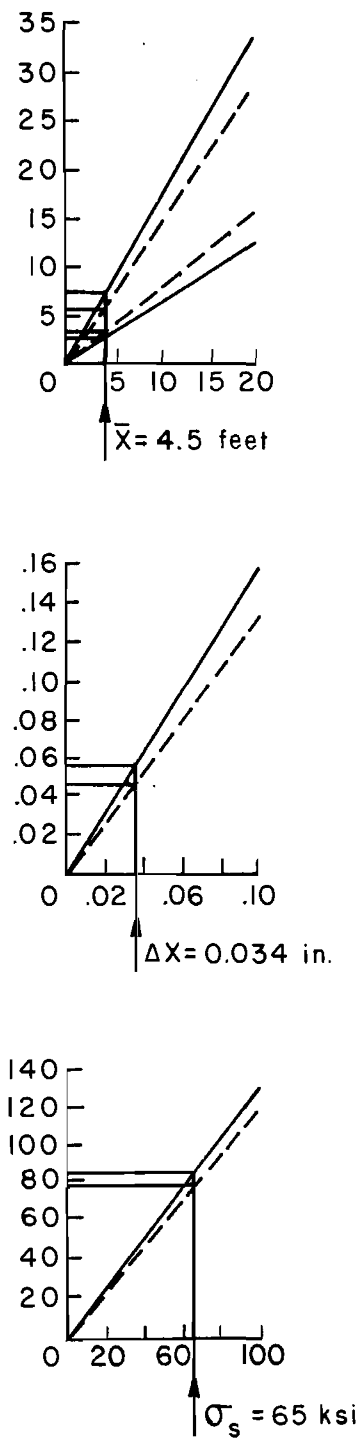
All limiting criteria are satisfied here. However, other designs using less steel or reduced slab thickness would be considered in this example until the most economical design was obtained.

Confidence intervals (use Figs 4.4, 4.5, and 4.6):

Referring to Fig 5.1 on the following page, the 80 percent confidence interval for crack spacing is from 3.4 to 6.4 feet, and the 95 percent confidence interval for crack spacing is from 2.8 to 7.6 feet.

The 90 percent upper confidence limit for crack width is 0.046 inch, and the 97 1/2 percent upper confidence limit for crack width is 0.054 inch.

The 90 percent upper confidence limit for steel stress is 78 ksi, and the 97 1/2 percent upper confidence limit for steel stress is 87 ksi.



Crack Spacing

For $\bar{X} = 4.5$ ft, Fig 4.4 Implies
95% Upper Confidence Limit = 7.6 feet
80% Upper Confidence Limit = 6.4 feet
80% Lower Confidence Limit = 3.4 feet
95% Lower Confidence Limit = 2.8 feet

Crack Width

For $\Delta X = 0.034$ in., Fig 4.5 Implies
97-1/2% Confidence Limit = 0.054 in.
90% Confidence Limit = 0.046 in.

Steel Stress

For $\sigma_s = 65$ ksi, Fig 4.6 Implies
97-1/2% Confidence Limit = 87 ksi
90% Confidence Limit = 78 ksi

1 foot = 304.8 mm
1 in. = 25.4 mm
1 ksi = 6.894 MPa

Fig 5.1. Use of confidence prediction charts in design example.

CHAPTER 6. CONCLUSIONS

Conclusions

Based on this study, the following recommendations were made.

(1) A set of nomographs based on regression analysis of the results computed by the CRCP-2 computer program has been prepared. The uniaxial force equilibrium model used in the computer program CRCP-2 is the only rational model available which considers the internal forces caused by the difference in thermal coefficients between the concrete and the steel materials and, therefore, is the most suitable tool available for the analysis of CRCP.

(2) Spacing of transverse cracks that occur in continuously reinforced concrete pavements is the most important variable affecting the behavior of the pavement. Relatively large distances between cracks result in a highter accumulation of drag forces from the subgrade due to frictional resistance, thus producing high steel stress at the crack and large crack widths. Closer crack spacing reduces the frictional restraint and, thus, the steel stress and the crack width.

(3) Nomographs produced in this study can predict steel stress at the crack (where the stress is maximum), average crack spacing, average crack width at minimum temperature.

(4) The limiting design criteria for the above dependent variables are discussed in Research Report No. 177-17, "Limiting Criteria for the Design of CRCP," (to be published)

(5) The nomographs (Chapter 4) should be used in conjunction with the limiting design criteria (Ref 18) for the design of steel percentage in CRCP for the materials chosen and local environmental conditions, as outlined in Chapter 5 of this report. Explicit guidelines for the selection of values of the input variables to be used with the nomographs and a detailed procedure for the, and design of slab thickness are given in Ref 18.

(6) Charts giving confidence prediction limits should be used in conjunction with the nomographs in order that the designer can specify a range of each of the variables (crack spacing, crack width, and steel stress) corresponding to the uncertainty inherent in the procedure. These limits may also be used in conjunction with Ref 18 in place of the mean values (recommended by the nomographs) if a conservative design is warranted.

(7) The major recommendation is that this entire CRCP design procedure should be incorporated into the Texas State Department of

Highways and Public Transportation Operations and Procedures Manual as soon as possible as the only rational guideline available at this time.

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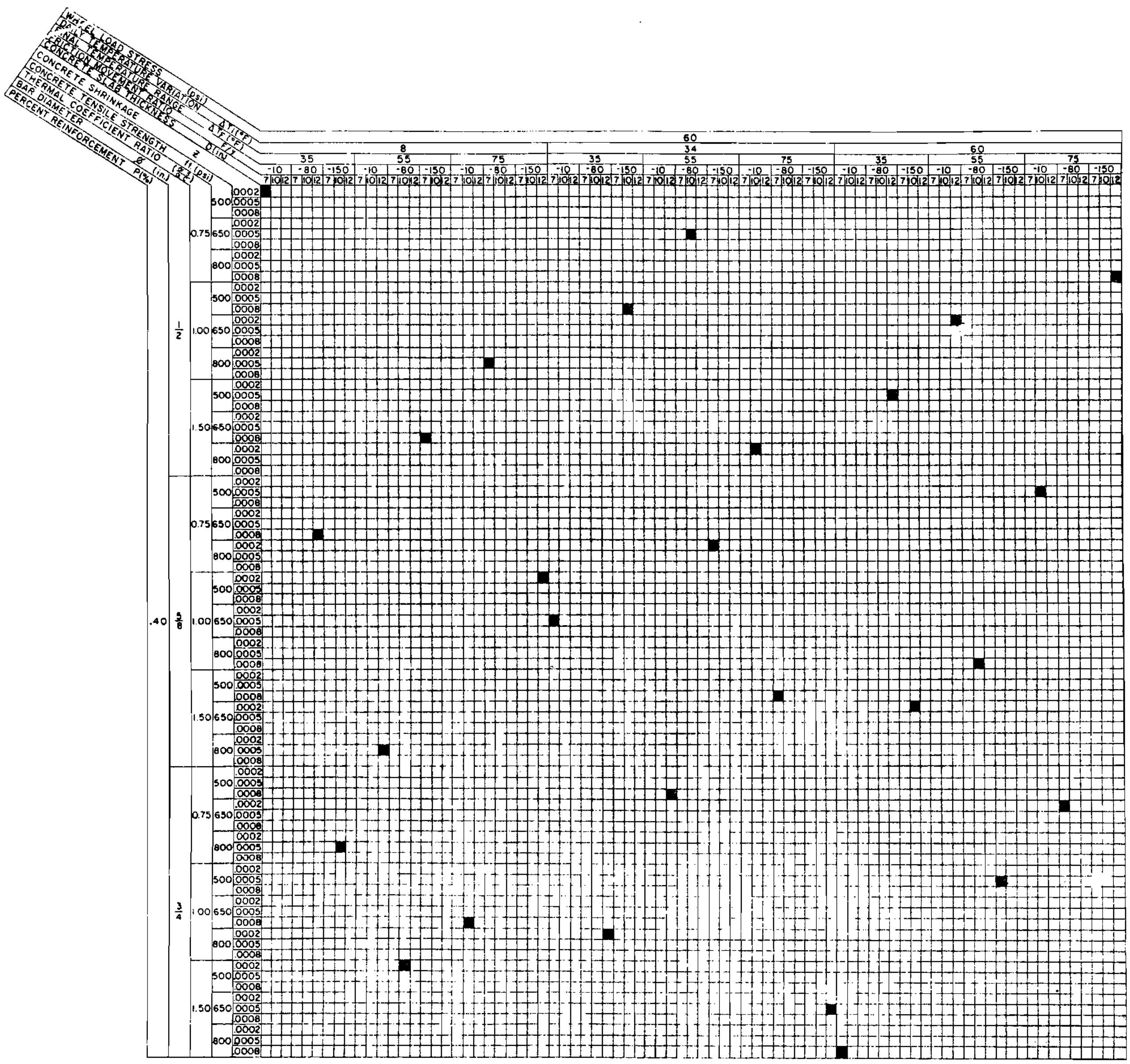
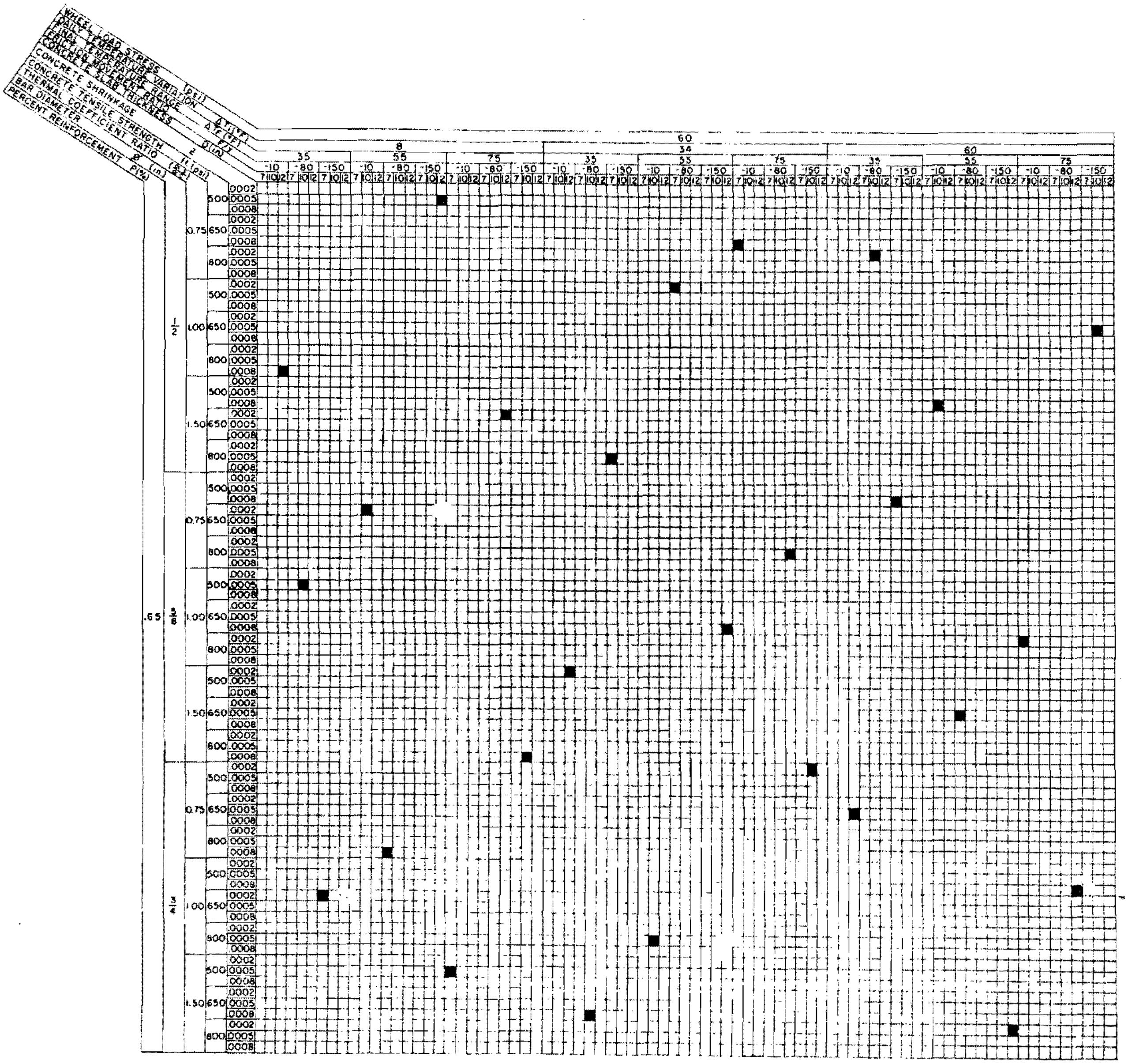
APPENDIX A

DESIGN FACTORIAL FOR SIMULATED DATA

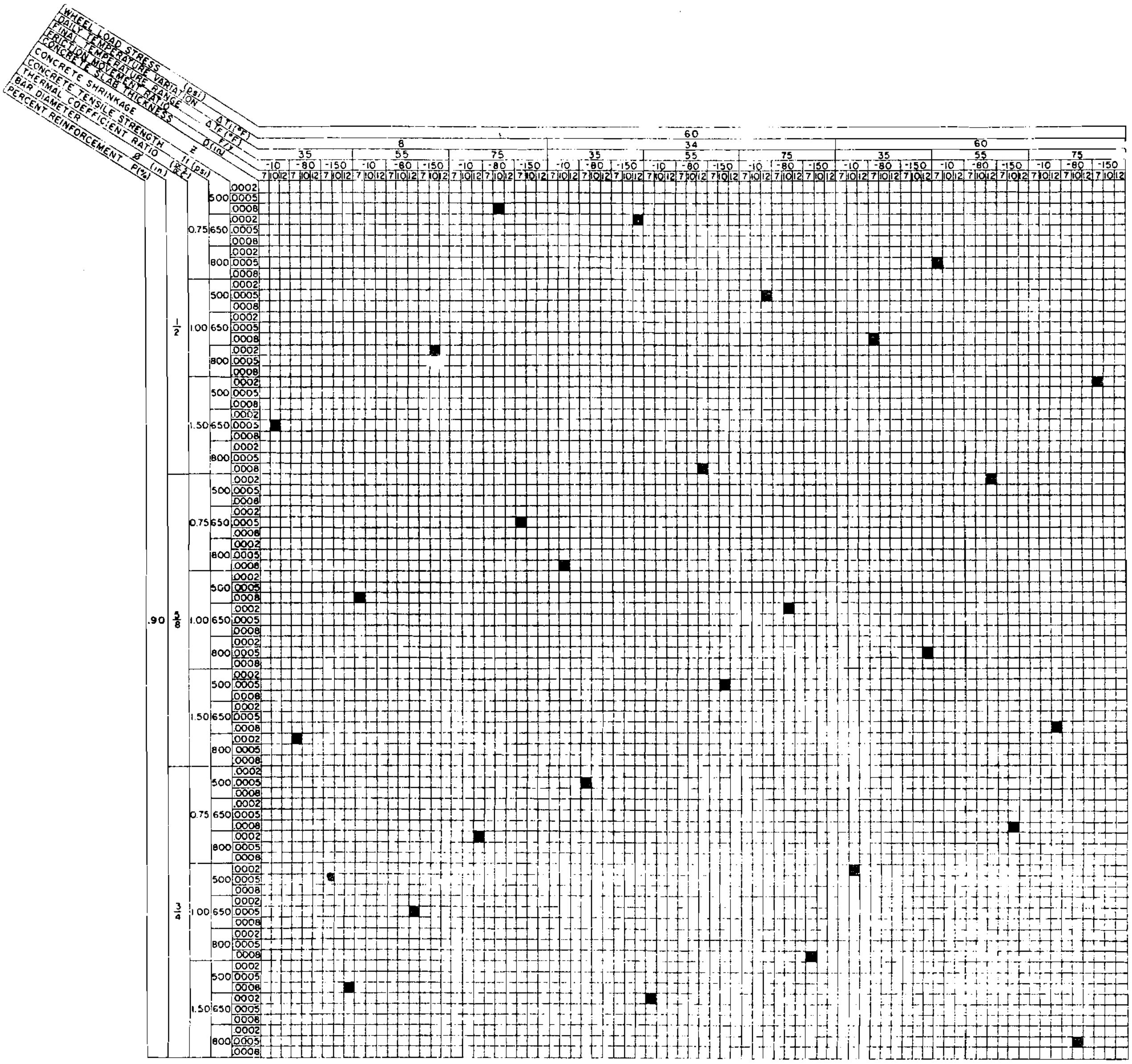


The squares marked in black indicate treatment combinations (observations) selected for use in the data set (See Page 9 of text). Twenty-seven observation are indicated here.

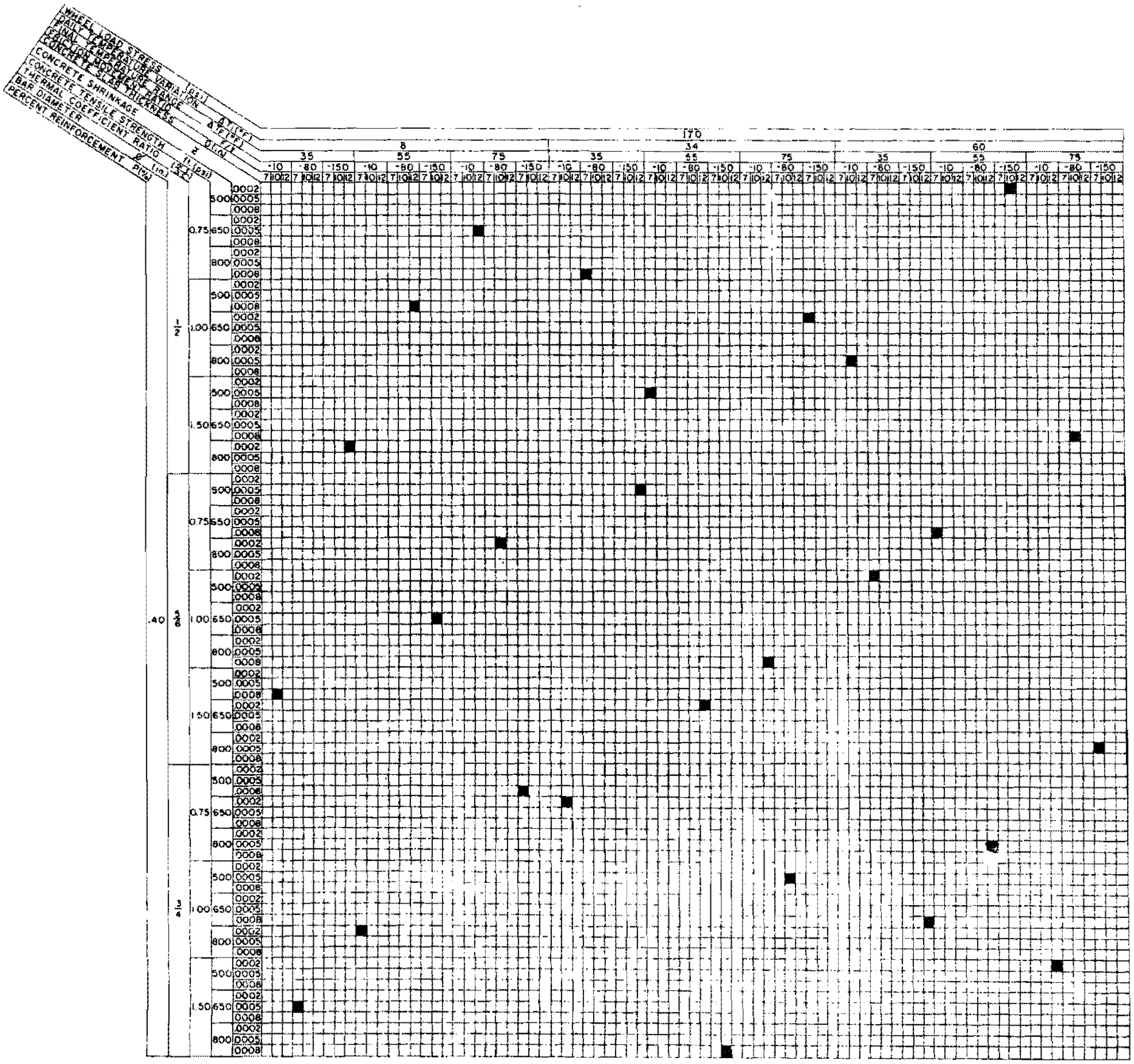
Observations used in design factorial (Continued).



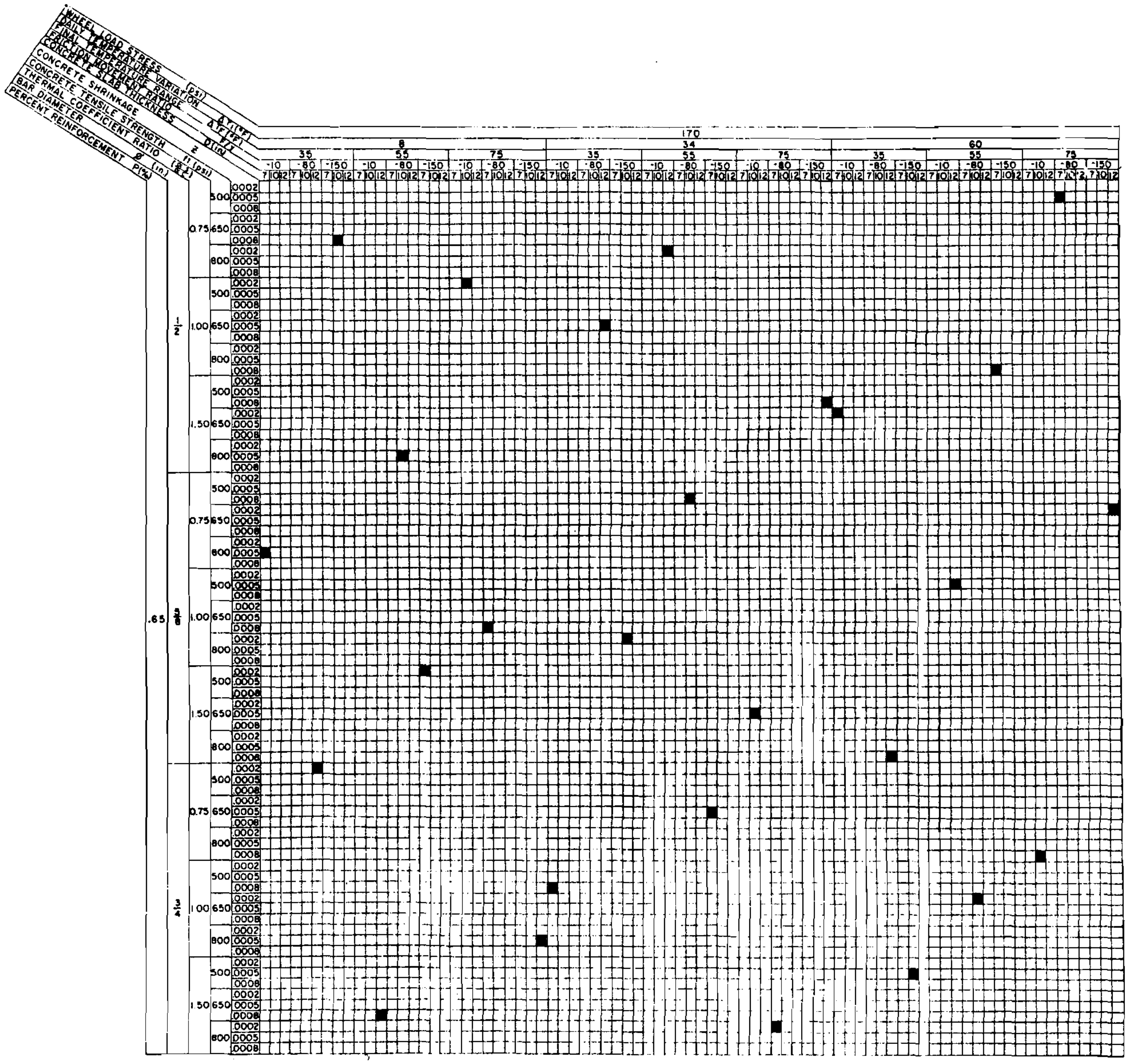
The squares marked in black indicate treatment combinations (observations) selected for use in the data set (See Page 9 of text). Twenty-seven observations are indicated here.



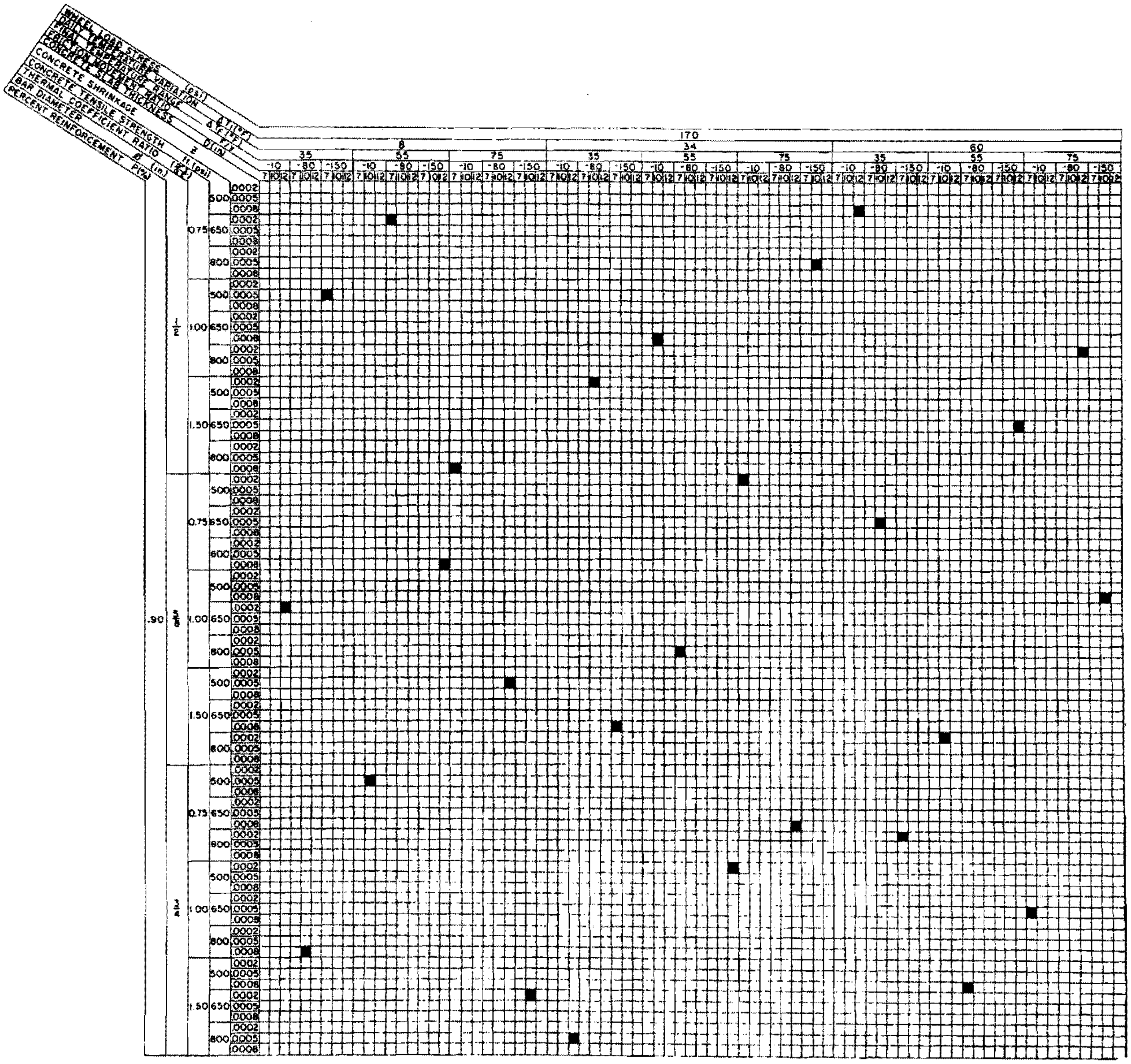
The squares marked in black indicate treatment combinations (observations) selected for use in the data set (See Page 9 of text). Twenty-seven observations are indicated here.



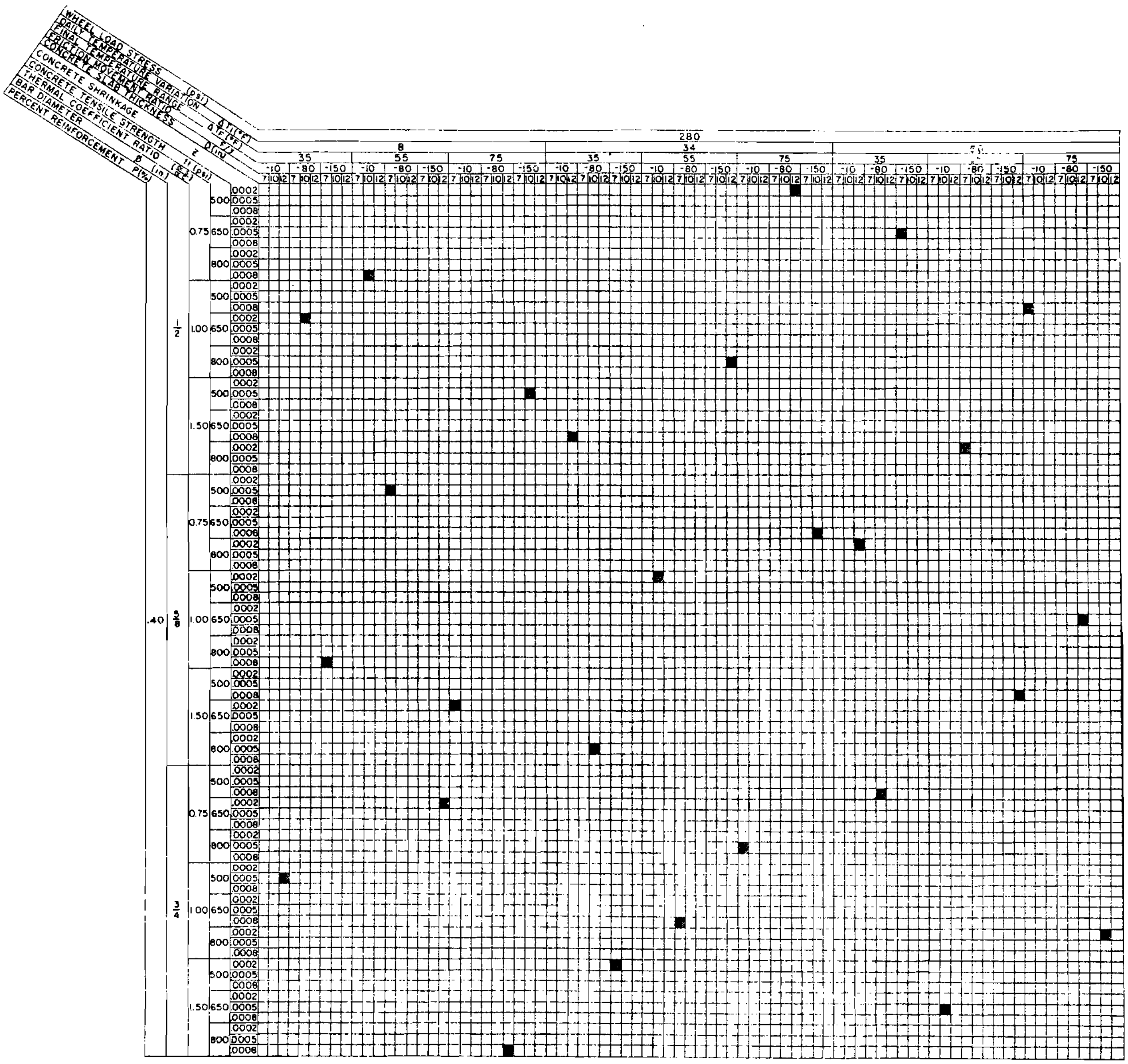
The squares marked in black indicate treatment combinations (observations) selected for use in the data set (See Page 9 of text). Twenty-seven observations are indicated here.



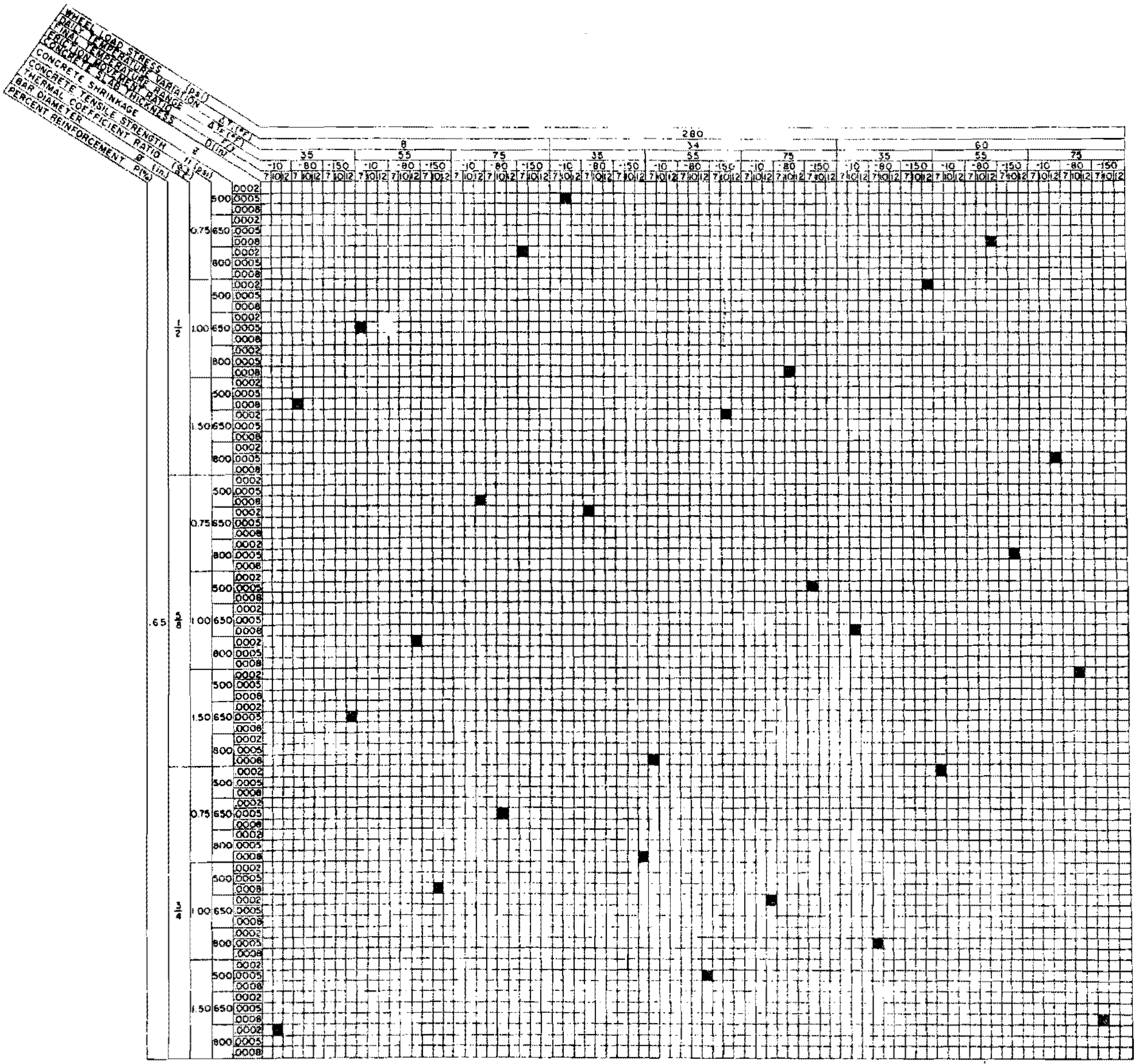
The squares marked in black indicate treatment combinations (observations) selected for use in the data set (See Page 9 of text). Twenty-seven observations are indicated here.



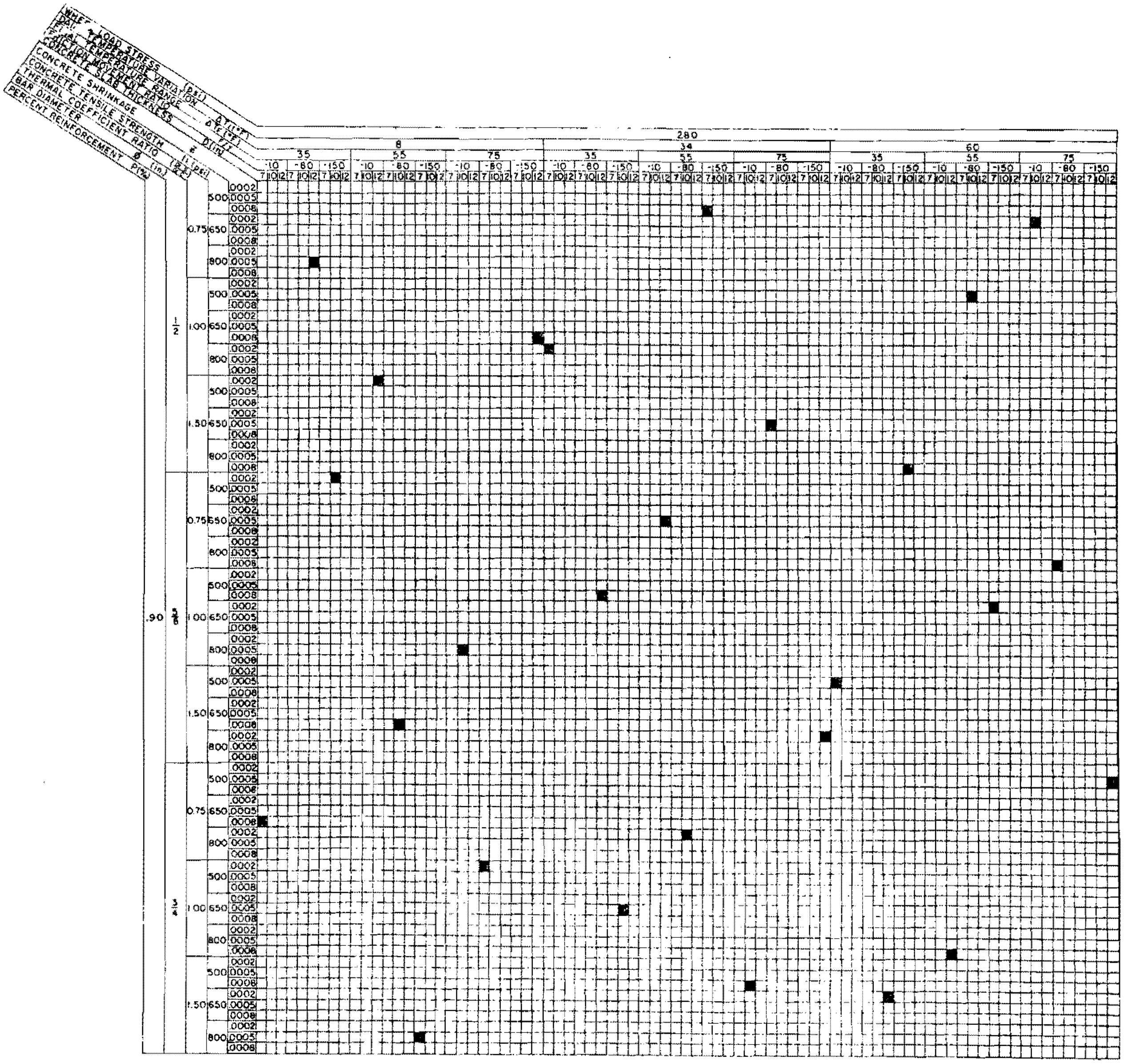
The squares marked in black indicate treatment combinations (observations) selected for use in the data set (See Page 9 of text). Twenty-seven observations are indicated here.



The squares marked in black indicate treatment combinations (observations) selected for use in the data set (See Page 9 of text). Twenty-seven observations are indicated here.



The squares marked in black indicate treatment combinations (observations) selected for use in the data set (See Page 9 of text). Twenty-seven observations are indicated here.



The squares marked in black indicate treatment combinations (observations) selected for use in the data set (See Page 9 of text). Twenty-seven observations are indicated here.

APPENDIX B

CRCP-2 COMPUTER PROGRAM - EXAMPLE PRINTOUT

```
CRCPNOM TEST RUNS
25

PROB
    2      OBSERVATION CODE: 2220212201

        ***************************************************
        *                                                 *
        *                STEEL PROPERTIES                 *
        *                                                 *
        ***************************************************

              TYPE OF LONGITUDINAL REINFORCEMENT IS
                          DEFORMED BARS

              PERCENT REINFORCEMENT = 6.500E-01
              BAR DIAMETER          = 5.000E-01
              YIELD STRESS          = 6.000E+04
              ELASTIC MODULUS       = 2.900E+07
              THERMAL COEFFICIENT   = 6.000E-06

        ***************************************************
        *                                                 *
        *               CONCRETE PROPERTIES               *
        *                                                 *
        ***************************************************

              SLAB THICKNESS      = 1.200E+01
              THERMAL COEFFICIENT = 4.000E-06
              TOTAL SHRINKAGE     = 5.000E-04
              UNIT WEIGHT CONCRETE= 1.500E+02

             TENSILE STRENGTH DATA
             **********************

              NO TENSILE STRENGTH DATA IS INPUT BY USER
              THE FOLLOWING AGE-TENSILE STRENGTH RELATIONSHIP
              IS USED WHICH IS BASED ON THE RECOMMENDATION
              GIVEN BY U.S. BUREAU OF RECLAMATION

              AGE,  TENSILE
             (DAYS) STRENGTH

               0.0    0.0
               1.0  309.8
               3.0  493.1
               5.0  582.3
               7.0  634.9
              14.0  724.3
              21.0  775.5
              28.0  799.9
```

```
***********************************************
*                                             *
*     SLAB-BASE FRICTION CHARACTERISTICS      *
*              F-Y RELATIONSHIP               *
*                                             *
***********************************************
```

TYPE OF FRICTION CURVE IS A PARABOLA

MAXIMUM FRICTION FORCE= 1.0000
MOVEMENT AT SLIDING = -.1000

```
******************************
*                            *
*     TEMPERATURE DATA       *
*                            *
******************************
```

CURING TEMPERATURE= 75.0

DAY	MINIMUM TEMPERATURE	DROP IN TEMPERATURE
1	65.0	10.0
2	65.0	10.0
3	65.0	10.0
4	15.0	60.0
5	15.0	60.0
6	15.0	60.0
7	15.0	60.0
8	15.0	60.0
9	15.0	60.0
10	15.0	60.0
11	15.0	60.0
12	15.0	60.0
13	15.0	60.0
14	15.0	60.0
15	15.0	60.0
16	15.0	60.0
17	15.0	60.0
18	15.0	60.0
19	15.0	60.0
20	15.0	60.0
21	15.0	60.0
22	15.0	60.0
23	15.0	60.0
24	15.0	60.0
25	15.0	60.0
26	15.0	60.0
27	15.0	60.0
28	15.0	60.0

MINIMUM TEMPERATURE EXPECTED AFTER
CONCRETE GAINS FULL STRENGTH = 0.0 DEGREES FAHRENHEIT
DAYS BEFORE REACHING MIN. TEMP. = 28.0 DAYS

```
*************************************************
*                                               *
*                EXTERNAL LOAD                  *
*                                               *
*************************************************

      WHEEL LOAD STRESS (PSI)= 2.800E+02
      LOAD APPLIED AT        =  14. TH DAY


*************************************************
*                                               *
*       ITERATION AND TOLERANCE CONTROL         *
*                                               *
*************************************************

 MAXIMUM ALLOWABLE NUMBER OF ITERATIONS=   60

 RELATIVE CLOSURE TOLERANCE=  5.0 PERCENT
```

CRCPNOM TEST RUNS

PROB
2 OBSERVATION CODE: 22202122

TIME (DAYS)	TEMP DROP	DRYING SHRINKAGE	TENSILE STRGTH	CRACK SPACING	CRACK WIDTH	MAXIMUM CONCRETE STRESS	MAXIMUM STRESS IN THE STEEL
.50	10.0	3.072E-09	219.1	244.1	9.650E-04	7.509E+01	1.312E+04
1.50	10.0	9.158E-06	364.4	244.1	2.461E-03	1.359E+02	2.226E+04
2.50	10.0	4.536E-05	454.3	244.1	7.523E-03	2.389E+02	3.745E+04
3.28	10.0	8.012E-05	506.4	244.1	1.345E-02	3.201E+02	4.920E+04
3.30	20.0	8.134E-05	507.7	244.1	2.015E-02	3.919E+02	6.114E+04
3.33	30.0	8.265E-05	509.1	244.1	2.728E-02	4.561E+02	7.189E+04
3.37	40.0	8.411E-05	510.6	122.1	2.054E-02	3.947E+02	6.283E+04
3.41	50.0	8.592E-05	512.5	122.1	2.484E-02	4.341E+02	6.963E+04
3.50	60.0	9.005E-05	516.9	122.1	2.951E-02	4.732E+02	7.630E+04
4.50	60.0	1.318E-04	561.4	122.1	3.470E-02	5.139E+02	8.133E+04
5.50	60.0	1.680E-04	595.9	122.1	3.917E-02	5.466E+02	8.530E+04
6.50	60.0	1.986E-04	622.2	122.1	4.294E-02	5.727E+02	8.842E+04
7.50	60.0	2.247E-04	641.7	122.1	4.611E-02	5.937E+02	9.091E+04
8.50	60.0	2.468E-04	655.1	122.1	4.877E-02	6.108E+02	9.291E+04
9.50	60.0	2.659E-04	668.2	122.1	5.109E-02	6.253E+02	9.460E+04
10.50	60.0	2.824E-04	681.1	122.1	5.313E-02	6.378E+02	9.604E+04
11.50	60.0	2.967E-04	693.7	122.1	5.493E-02	6.487E+02	9.729E+04
12.50	60.0	3.094E-04	706.1	122.1	5.652E-02	6.582E+02	9.838E+04
13.50	60.0	3.206E-04	718.3	122.1	5.796E-02	6.667E+02	9.934E+04
14.50	60.0	3.306E-04	728.1	45.1	2.355E-02	7.043E+02	6.091E+04
15.50	60.0	3.395E-04	735.6	45.1	2.396E-02	7.081E+02	6.122E+04
16.50	60.0	3.476E-04	743.0	45.1	2.433E-02	7.114E+02	6.150E+04
17.50	60.0	3.549E-04	750.4	45.1	2.467E-02	7.145E+02	6.175E+04
18.50	60.0	3.615E-04	757.7	45.1	2.498E-02	7.173E+02	6.198E+04
19.50	60.0	3.676E-04	764.9	45.1	2.526E-02	7.198E+02	6.219E+04
20.50	60.0	3.731E-04	772.0	45.1	2.553E-02	7.221E+02	6.238E+04
21.50	60.0	3.782E-04	777.3	45.1	2.576E-02	7.242E+02	6.255E+04
22.50	60.0	3.830E-04	780.8	45.1	2.598E-02	7.261E+02	6.270E+04
23.50	60.0	3.873E-04	784.3	45.1	2.618E-02	7.279E+02	6.284E+04
24.50	60.0	3.914E-04	787.8	45.1	2.637E-02	7.295E+02	6.297E+04
25.50	60.0	3.952E-04	791.3	45.1	2.654E-02	7.310E+02	6.309E+04
26.50	60.0	3.987E-04	794.7	45.1	2.671E-02	7.324E+02	6.320E+04
27.50	60.0	4.020E-04	798.2	45.1	2.686E-02	7.337E+02	6.331E+04

AT THE END OF THE ANALYSIS PERIOD

CRACK SPACING = 3.755E+00 FEET
CRACK WIDTH = 3.382E-02 INCHES
MAX CONCRETE STRESS= 7.892E+02 PSI
MAX STEEL STRESS = 7.007E+04 PSI,
CONC.TENS.STRENGTH = 7.999E+02 PSI

STA-TION	DIS-TANCE	CONCRETE MOVEMENT	FRICTION FORCE	CONCRETE STRESS	STEEL STRESS
1	0.0	0.000E+00	0.000E+00	5.092E+02	-8.186E+03
2	.2	-1.650E-04	4.062E-02	5.092E+02	-8.186E+03
3	.5	-3.299E-04	5.744E-02	5.092E+02	-8.186E+03
4	.7	-4.949E-04	7.035E-02	5.092E+02	-8.186E+03
5	.9	-6.599E-04	8.123E-02	5.091E+02	-8.186E+03
6	1.1	-8.248E-04	9.082E-02	5.091E+02	-8.186E+03
7	1.4	-9.898E-04	9.949E-02	5.091E+02	-8.186E+03
8	1.6	-1.155E-03	1.075E-01	5.091E+02	-8.186E+03
9	1.8	-1.320E-03	1.149E-01	5.091E+02	-8.186E+03
10	2.0	-1.485E-03	1.218E-01	5.091E+02	-8.186E+03
11	2.3	-1.650E-03	1.284E-01	5.091E+02	-8.186E+03
12	2.5	-1.815E-03	1.347E-01	5.091E+02	-8.186E+03
13	2.7	-1.980E-03	1.407E-01	5.091E+02	-8.186E+03
14	2.9	-2.145E-03	1.464E-01	5.091E+02	-8.186E+03
15	3.2	-2.310E-03	1.520E-01	5.091E+02	-8.186E+03
16	3.4	-2.474E-03	1.573E-01	5.091E+02	-8.186E+03
17	3.6	-2.639E-03	1.625E-01	5.091E+02	-8.186E+03
18	3.8	-2.804E-03	1.675E-01	5.091E+02	-8.186E+03
19	4.1	-2.969E-03	1.723E-01	5.091E+02	-8.186E+03
20	4.3	-3.134E-03	1.770E-01	5.091E+02	-8.186E+03
21	4.5	-3.299E-03	1.816E-01	5.091E+02	-8.186E+03
22	4.7	-3.464E-03	1.861E-01	5.091E+02	-8.186E+03
23	5.0	-3.629E-03	1.905E-01	5.091E+02	-8.186E+03
24	5.2	-3.794E-03	1.948E-01	5.091E+02	-8.186E+03
25	5.4	-3.959E-03	1.990E-01	5.091E+02	-8.186E+03
26	5.6	-4.124E-03	2.031E-01	5.091E+02	-8.186E+03
27	5.9	-4.289E-03	2.071E-01	5.091E+02	-8.186E+03
28	6.1	-4.454E-03	2.110E-01	5.091E+02	-8.186E+03
29	6.3	-4.619E-03	2.149E-01	5.091E+02	-8.186E+03
30	6.5	-4.784E-03	2.187E-01	5.091E+02	-8.186E+03
31	6.8	-4.949E-03	2.225E-01	5.091E+02	-8.186E+03
32	7.0	-5.114E-03	2.261E-01	5.091E+02	-8.186E+03
33	7.2	-5.279E-03	2.298E-01	5.091E+02	-8.186E+03
34	7.4	-5.444E-03	2.333E-01	5.091E+02	-8.186E+03
35	7.7	-5.609E-03	2.368E-01	5.091E+02	-8.186E+03
36	7.9	-5.774E-03	2.403E-01	5.090E+02	-8.187E+03
37	8.1	-5.939E-03	2.437E-01	5.090E+02	-8.187E+03
38	8.3	-6.104E-03	2.471E-01	5.090E+02	-8.187E+03
39	8.6	-6.269E-03	2.504E-01	5.090E+02	-8.187E+03
40	8.8	-6.434E-03	2.536E-01	5.090E+02	-8.187E+03
41	9.0	-6.599E-03	2.569E-01	5.090E+02	-8.187E+03
42	9.2	-6.764E-03	2.601E-01	5.090E+02	-8.187E+03
43	9.5	-6.929E-03	2.632E-01	5.090E+02	-8.187E+03
44	9.7	-7.094E-03	2.663E-01	5.090E+02	-8.187E+03
45	9.9	-7.259E-03	2.694E-01	5.090E+02	-8.187E+03
46	10.1	-7.423E-03	2.725E-01	5.090E+02	-8.187E+03
47	10.4	-7.588E-03	2.755E-01	5.064E+02	-7.788E+03
48	10.6	-7.754E-03	2.785E-01	4.970E+02	-6.347E+03
49	10.8	-7.919E-03	2.814E-01	4.876E+02	-4.905E+03
50	11.0	-8.085E-03	2.843E-01	4.783E+02	-3.463E+03

(Continued)

51	11,3	-8,251E-03	2,872E-01	4,689E+02	-2,021E+03
52	11,5	-8,417E-03	2,901E-01	4,595E+02	-5,795E+02
53	11,7	-8,584E-03	2,930E-01	4,501E+02	8,622E+02
54	11,9	-8,751E-03	2,958E-01	4,408E+02	2,304E+03
55	12,2	-8,918E-03	2,986E-01	4,314E+02	3,746E+03
56	12,4	-9,085E-03	3,014E-01	4,220E+02	5,188E+03
57	12,6	-9,253E-03	3,042E-01	4,126E+02	6,629E+03
58	12,8	-9,421E-03	3,069E-01	4,033E+02	8,071E+03
59	13,1	-9,589E-03	3,097E-01	3,939E+02	9,513E+03
60	13,3	-9,758E-03	3,124E-01	3,845E+02	1,095E+04
61	13,5	-9,927E-03	3,151E-01	3,751E+02	1,240E+04
62	13,7	-1,010E-02	3,177E-01	3,657E+02	1,384E+04
63	14,0	-1,027E-02	3,204E-01	3,564E+02	1,528E+04
64	14,2	-1,043E-02	3,230E-01	3,470E+02	1,672E+04
65	14,4	-1,060E-02	3,257E-01	3,376E+02	1,816E+04
66	14,6	-1,078E-02	3,283E-01	3,282E+02	1,961E+04
67	14,9	-1,095E-02	3,308E-01	3,189E+02	2,105E+04
68	15,1	-1,112E-02	3,334E-01	3,095E+02	2,249E+04
69	15,3	-1,129E-02	3,360E-01	3,001E+02	2,393E+04
70	15,5	-1,146E-02	3,385E-01	2,907E+02	2,537E+04
71	15,8	-1,163E-02	3,410E-01	2,813E+02	2,681E+04
72	16,0	-1,180E-02	3,435E-01	2,720E+02	2,826E+04
73	16,2	-1,197E-02	3,460E-01	2,626E+02	2,970E+04
74	16,4	-1,215E-02	3,485E-01	2,532E+02	3,114E+04
75	16,7	-1,232E-02	3,510E-01	2,438E+02	3,258E+04
76	16,9	-1,249E-02	3,535E-01	2,345E+02	3,402E+04
77	17,1	-1,267E-02	3,559E-01	2,251E+02	3,546E+04
78	17,3	-1,284E-02	3,583E-01	2,157E+02	3,691E+04
79	17,6	-1,301E-02	3,607E-01	2,063E+02	3,835E+04
80	17,8	-1,319E-02	3,632E-01	1,969E+02	3,979E+04
81	18,0	-1,336E-02	3,656E-01	1,876E+02	4,123E+04
82	18,2	-1,354E-02	3,679E-01	1,782E+02	4,267E+04
83	18,5	-1,371E-02	3,703E-01	1,688E+02	4,412E+04
84	18,7	-1,389E-02	3,727E-01	1,594E+02	4,556E+04
85	18,9	-1,406E-02	3,750E-01	1,501E+02	4,700E+04
86	19,1	-1,424E-02	3,773E-01	1,407E+02	4,844E+04
87	19,4	-1,442E-02	3,797E-01	1,313E+02	4,988E+04
88	19,6	-1,459E-02	3,820E-01	1,219E+02	5,132E+04
89	19,8	-1,477E-02	3,843E-01	1,125E+02	5,277E+04
90	20,0	-1,495E-02	3,866E-01	1,032E+02	5,421E+04
91	20,3	-1,512E-02	3,889E-01	9,378E+01	5,565E+04
92	20,5	-1,530E-02	3,912E-01	8,440E+01	5,709E+04
93	20,7	-1,548E-02	3,934E-01	7,502E+01	5,853E+04
94	21,0	-1,566E-02	3,957E-01	6,565E+01	5,997E+04
95	21,2	-1,583E-02	3,979E-01	5,627E+01	6,142E+04
96	21,4	-1,601E-02	4,002E-01	4,689E+01	6,286E+04
97	21,6	-1,619E-02	4,024E-01	3,751E+01	6,430E+04
98	21,9	-1,637E-02	4,046E-01	2,813E+01	6,574E+04
99	22,1	-1,655E-02	4,068E-01	1,875E+01	6,718E+04
100	22,3	-1,673E-02	4,090E-01	9,371E+00	6,863E+04
101	22,5	-1,691E-02	4,112E-01	-7,750E-03	7,007E+04

APPENDIX C

SUMMARY OF SIMULATED OBSERVATIONS

σ_w (psi)	ΔT_i (^oF)	ΔT_F (^oF)	F/y	D (in.)	Z	f_t (psi)	α_s/α_c	ϕ (in.)	p (%)	$\bar{x}$ (ft)	Δx (in.)	σ_s (psi)
60	8	35	-10	7	.0002	500	.750	.500	.400	12.240	.05894	98050
280	34	75	-10	7	.0005	800	.750	.750	.400	9.899	.12470	106300
170	60	55	-10	7	.0008	650	.750	.625	.400	5.874	.08385	86250
60	34	55	-150	10	.0005	500	1.500	.625	.900	2.158	.01710	40470
280	60	35	-150	10	.0008	800	1.500	.500	.900	1.359	.01482	32190
170	8	75	-150	10	.0002	650	1.500	.750	.900	4.133	.02193	51750
60	60	75	-80	12	.0008	500	1.000	.750	.650	2.599	.03754	46320
280	8	55	-80	12	.0002	800	1.000	.625	.650	7.487	.04250	74640
170	34	35	-80	12	.0005	650	1.000	.500	.650	3.333	.02625	56370
60	8	35	-150	10	.0005	800	.750	.750	.400	23.086	.19950	141900
280	34	75	-150	10	.0008	650	.750	.625	.400	2.974	.04887	58470
170	60	55	-150	10	.0002	500	.750	.500	.400	3.571	.02552	60690
60	34	55	-80	12	.0008	800	1.500	.500	.900	3.222	.03690	64180
280	60	35	-80	12	.0002	650	1.500	.750	.900	2.034	.00753	27400
170	8	75	-80	12	.0005	500	1.500	.625	.900	1.214	.01113	31690
60	60	75	-10	7	.0002	800	1.000	.625	.650	11.650	.07976	104400
280	8	55	-10	7	.0005	650	1.000	.500	.650	1.607	.01539	39760
170	34	35	-10	7	.0008	500	1.000	.750	.650	1.687	.01980	27860
60	8	35	-80	12	.0008	650	.750	.625	.400	12.160	.14600	123400
280	34	75	-80	12	.0002	500	.750	.500	.400	1.530	.01424	41890
170	60	55	-80	12	.0005	800	.750	.750	.400	15.400	.16180	124900
60	34	55	-10	7	.0002	650	1.500	.750	.900	8.266	.03377	63400
280	60	35	-10	7	.0005	500	1.500	.625	.900	.588	.00439	15120
170	8	75	-10	7	.0008	800	1.500	.500	.900	2.302	.02897	55740
60	60	75	-150	10	.0005	650	1.000	.500	.650	3.810	.04044	73490
280	8	55	-150	10	.0008	500	1.000	.750	.650	.981	.01309	22120
170	34	35	-150	10	.0002	800	1.000	.625	.650	13.310	.05408	84940
60	34	35	-80	7	.0005	500	.750	.750	.900	2.198	.01918	33530
280	60	75	-80	7	.0008	800	.750	.625	.900	1.877	.03474	41870
170	8	55	-80	7	.0002	650	.750	.500	.900	2.297	.01612	46870
60	60	55	-10	10	.0008	500	1.500	.500	.650	2.239	.02577	50530
280	8	35	-10	10	.0002	800	1.500	.750	.650	17.050	.05629	80730
170	34	75	-10	10	.0005	650	1.500	.625	.650	3.967	.03552	63590
60	8	75	-150	12	.0002	500	1.000	.625	.400	9.536	.06605	94480
280	34	55	-150	12	.0005	800	1.000	.500	.400	9.150	.08490	112000
170	60	35	-150	12	.0008	650	1.000	.750	.400	10.120	.11500	97270
60	34	35	-10	10	.0008	800	.750	.625	.900	4.289	.05201	64160
280	60	75	-10	10	.0002	650	.750	.500	.900	.905	.00841	30420
170	8	55	-10	10	.0005	500	.750	.750	.900	1.449	.01573	28120
60	60	55	-150	12	.0002	800	1.500	.750	.650	19.890	.08069	98560
280	8	35	-150	12	.0005	650	1.500	.625	.650	3.347	.02389	48020
170	34	75	-150	12	.0008	500	1.500	.500	.650	1.254	.01605	37130
60	8	75	-80	7	.0005	800	1.000	.500	.400	15.250	.15880	158500
280	34	55	-80	7	.0008	650	1.000	.750	.400	4.271	.05614	60960
170	60	35	-80	7	.0002	500	1.000	.625	.400	6.258	.02733	58690
60	34	35	-150	12	.0002	650	.750	.500	.900	4.824	.02321	59200
280	60	75	-150	12	.0005	500	.750	.750	.900	.681	.00885	21760
170	8	55	-150	12	.0008	800	.750	.625	.900	2.644	.03780	49840
60	60	55	-80	7	.0005	650	1.500	.625	.650	6.943	.05367	79340
280	8	35	-80	7	.0008	500	1.500	.500	.650	.680	.00753	19150
170	34	75	-80	7	.0002	800	1.500	.750	.650	14.210	.07269	94590
60	8	75	-10	10	.0008	650	1.000	.750	.400	13.500	.18980	131500
280	34	55	-10	10	.0002	500	1.000	.625	.400	3.394	.02020	49630
170	60	35	-10	10	.0005	800	1.000	.500	.400	18.300	.13930	147500
60	60	35	-150	7	.0008	500	.750	.625	.650	1.945	.02423	35970
280	8	75	-150	7	.0002	800	.750	.500	.650	3.793	.03411	70430
170	34	55	-150	7	.0005	650	.750	.750	.650	4.473	.04747	60170
60	8	55	-80	10	.0002	500	1.500	.750	.400	18.320	.07534	95150
280	34	35	-80	10	.0005	800	1.500	.625	.400	13.390	.09390	106500
170	60	75	-80	10	.0008	650	1.500	.500	.400	6.160	.07693	101800
60	34	75	-10	12	.0005	500	1.000	.500	.900	1.381	.01490	39540

σ_w (psi)	ΔT_i (^oF)	ΔT_F (^oF)	F/y	D (in.)	Z	f_t (psi)	α_s/α_c	ϕ (in.)	p (%)	$\bar{x}$ (ft)	Δx (in.)	σ_s (psi)
280	60	55	-10	12	.0008	800	1.000	.750	.900	2.315	.03040	39200
170	8	35	-10	12	.0002	650	1.000	.625	.900	4.304	.01806	47070
60	60	35	-80	10	.0002	800	.750	.500	.650	7.586	.03802	77230
280	8	75	-80	10	.0005	650	.750	.750	.650	2.341	.03000	43010
170	34	55	-80	10	.0008	500	.750	.625	.650	1.709	.02468	35820
60	8	55	-10	12	.0005	800	1.500	.625	.400	31.750	.23960	178800
280	34	35	-10	12	.0008	650	1.500	.500	.400	4.042	.04358	69610
170	60	75	-10	12	.0002	500	1.500	.750	.400	9.162	.04894	77320
60	34	75	-150	7	.0008	800	1.000	.750	.900	3.858	.05515	60870
280	60	55	-150	7	.0002	650	1.000	.625	.900	1.614	.00960	32760
170	8	35	-150	7	.0005	500	1.000	.500	.900	.971	.00786	24740
60	60	35	-10	12	.0005	650	.750	.750	.650	5.552	.04801	61730
280	8	75	-10	12	.0008	500	.750	.625	.650	.796	.01320	25270
170	34	55	-10	12	.0002	800	.750	.500	.650	7.586	.05189	90370
60	8	55	-150	7	.0008	650	1.500	.500	.400	8.213	.09340	113009
280	34	35	-150	7	.0002	500	1.500	.750	.400	4.348	.01610	41430
170	60	75	-150	7	.0005	800	1.500	.625	.400	12.700	.11230	120000
60	34	75	-80	10	.0002	650	1.000	.625	.900	4.304	.02981	62140
280	60	55	-80	10	.0005	500	1.000	.500	.900	.492	.00479	19010
170	8	35	-80	10	.0008	800	1.000	.750	.900	3.086	.03569	44410
60	34	35	-150	10	.0008	500	1.000	.500	.400	5.380	.06076	84340
280	60	75	-150	10	.0002	800	1.000	.750	.400	13.180	.09452	103200
170	8	55	-150	10	.0005	650	1.000	.625	.400	9.479	.08723	100400
60	60	55	-80	12	.0002	500	.750	.625	.900	2.152	.01504	39560
280	8	35	-80	12	.0005	800	.750	.500	.900	2.324	.02041	46080
170	34	75	-80	12	.0008	650	.750	.750	.900	2.163	.03528	40740
60	8	75	-10	7	.0005	500	1.500	.750	.650	4.281	.03779	59590
280	34	55	-10	7	.0008	800	1.500	.625	.650	3.342	.03925	57280
170	60	35	-10	7	.0002	650	1.500	.500	.650	7.636	.02532	65830
60	34	35	-80	12	.0002	800	1.000	.750	.400	46.850	.18340	146000
280	60	75	-80	12	.0005	650	1.000	.625	.400	4.443	.04859	71250
170	8	55	-80	12	.0008	500	1.000	.500	.400	2.882	.03754	61310
60	60	55	-10	7	.0005	800	.750	.500	.900	3.213	.03378	62850
280	8	35	-10	7	.0008	650	.750	.750	.900	1.343	.01700	23280
170	34	75	-10	7	.0002	500	.750	.625	.900	1.210	.01110	31640
60	8	75	-150	10	.0008	800	1.500	.625	.650	6.932	.08542	95210
280	34	55	-150	10	.0002	650	1.500	.500	.650	3.221	.01455	50150
170	60	35	-150	10	.0005	500	1.500	.750	.650	2.258	.01631	33350
60	34	35	-10	7	.0005	650	1.000	.625	.400	18.960	.14250	132300
280	60	75	-10	7	.0008	500	1.000	.500	.400	1.060	.01568	33400
170	8	55	-10	7	.0002	800	1.000	.750	.400	33.470	.18310	145900
60	60	55	-150	10	.0008	650	.750	.750	.900	2.579	.03686	42580
280	8	35	-150	10	.0002	500	.750	.625	.900	.766	.00420	17850
170	34	75	-150	10	.0005	800	.750	.500	.900	2.295	.02888	55630
60	8	75	-80	12	.0002	650	1.500	.500	.650	8.909	.04449	90820
280	34	55	-80	12	.0005	500	1.500	.750	.650	1.016	.00856	22570
170	60	35	-80	12	.0008	800	1.500	.625	.650	5.199	.05514	70450
60	60	35	-10	10	.0002	500	1.000	.750	.900	3.000	.01276	35030
280	8	75	-10	10	.0005	800	1.000	.625	.900	2.418	.02631	49080
170	34	55	-10	10	.0008	650	1.000	.500	.900	1.337	.01752	35240
60	8	55	-150	12	.0005	500	.750	.500	.650	2.512	.02647	53810
280	34	35	-150	12	.0008	800	.750	.750	.650	3.570	.04462	50020
170	60	75	-150	12	.0002	650	.750	.625	.650	3.694	.03316	61110
60	34	75	-80	7	.0008	500	1.500	.625	.400	6.402	.07923	90980
280	60	55	-80	7	.0002	800	1.500	.500	.400	14.330	.06289	106300
170	8	35	-80	7	.0005	650	1.500	.750	.400	13.660	.09453	96740
60	60	35	-150	12	.0005	800	1.000	.625	.900	6.448	.04873	72050
280	8	75	-150	12	.0008	650	1.000	.500	.900	.873	.01284	29820
170	34	55	-150	12	.0002	500	1.000	.750	.900	1.742	.01023	30750
60	8	55	-80	7	.0008	800	.750	.750	.650	7.538	.10570	89470
280	34	35	-80	7	.0002	650	.750	.625	.650	3.116	.01649	42420
170	60	75	-80	7	.0005	500	.750	.500	.650	1.088	.01398	33940

σ_w (psi)	ΔT_i (°F)	ΔT_F (°F)	F/y	D (in.)	Z	f_t (psi)	α_s/α_c	ϕ (in.)	p (%)	$\bar{x}$ (ft)	Δx (in.)	σ_s (psi)
60	34	75	-10	10	.0002	800	1.500	.500	.400	32.760	.16260	173600.
280	60	55	-10	10	.0005	650	1.500	.750	.400	6.725	.05481	71820.
170	8	35	-10	10	.0008	500	1.500	.625	.400	4.051	.04345	60140.
60	60	35	-80	7	.0008	650	1.000	.500	.900	2.370	.02368	44500.
280	8	75	-80	7	.0002	500	1.000	.750	.900	.965	.00725	25400.
170	34	55	-80	7	.0005	800	1.000	.625	.900	3.224	.03006	53470.
60	8	55	-10	10	.0002	650	.750	.625	.650	7.880	.05328	81320.
280	34	35	-10	10	.0005	500	.750	.500	.650	.678	.00620	19110.
170	60	75	-10	10	.0008	800	.750	.750	.650	4.211	.06845	65630.
60	34	75	-150	12	.0005	650	1.500	.750	.400	15.940	.13820	121900.
280	60	55	-150	12	.0008	500	1.500	.625	.400	1.329	.01599	29990.
170	8	35	-150	12	.0002	800	1.500	.500	.400	32.760	.10300	135500.
60	8	35	-80	10	.0005	500	1.000	.625	.650	4.458	.03410	58080.
280	34	75	-80	10	.0008	800	1.000	.500	.650	2.407	.03497	58370.
170	60	55	-80	10	.0002	650	1.000	.750	.650	6.376	.03620	62160.
60	34	55	-10	12	.0008	500	.750	.750	.400	6.742	.09522	83490.
280	60	35	-10	12	.0002	800	.750	.625	.400	11.660	.06102	88090.
170	8	75	-10	12	.0005	650	.750	.500	.400	6.090	.07616	101200.
60	60	75	-150	7	.0002	500	1.500	.500	.900	2.765	.01414	51190.
280	8	55	-150	7	.0005	800	1.500	.750	.900	3.096	.02513	45430.
170	34	35	-150	7	.0008	650	1.500	.625	.900	1.617	.01752	30930.
60	8	35	-10	12	.0008	800	1.000	.500	.650	5.706	.06433	87430.
280	34	75	-10	12	.0002	650	1.000	.750	.650	4.250	.03077	56850.
170	60	55	-10	12	.0005	500	1.000	.625	.650	1.567	.01499	33610.
60	34	55	-150	7	.0002	800	.750	.625	.400	21.760	.14580	139400.
280	60	35	-150	7	.0005	650	.750	.500	.400	3.177	.02844	56830.
170	8	75	-150	7	.0008	500	.750	.750	.400	2.712	.04452	47760.
60	60	75	-80	10	.0005	800	1.500	.750	.900	6.192	.05405	73050.
280	8	55	-80	10	.0008	650	1.500	.625	.900	1.137	.01357	27040.
170	34	35	-80	10	.0002	500	1.500	.500	.900	1.814	.00634	31480.
60	8	35	-150	7	.0002	650	1.000	.750	.650	12.750	.05075	74690.
280	34	75	-150	7	.0005	500	1.000	.625	.650	.823	.00921	25690.
170	60	55	-150	7	.0008	800	1.000	.500	.650	3.566	.04605	70440.
60	34	55	-80	10	.0005	650	.750	.500	.400	10.150	.10510	123300.
280	60	35	-80	10	.0008	500	.750	.750	.400	1.659	.02113	27320.
170	8	75	-80	10	.0002	800	.750	.625	.400	18.650	.16220	146300.
60	60	75	-10	12	.0008	650	1.500	.625	.900	2.156	.02720	46050.
280	8	55	-10	12	.0002	500	1.500	.500	.900	.738	.00348	23510.
170	34	35	-10	12	.0005	800	1.500	.750	.900	5.418	.03765	56960.
60	60	35	-80	12	.0005	500	1.500	.500	.400	7.977	.05436	89920.
280	8	75	-80	12	.0008	800	1.500	.750	.400	9.058	.11430	101000.
170	34	55	-80	12	.0002	650	1.500	.625	.400	19.120	.08087	108000.
60	8	55	-10	7	.0008	500	1.000	.625	.900	1.616	.02099	34390.
280	34	35	-10	7	.0002	800	1.000	.500	.900	4.137	.01760	52340.
170	60	75	-10	7	.0005	650	1.000	.750	.900	2.319	.02522	42550.
60	34	75	-150	10	.0002	500	.750	.750	.650	4.249	.03746	59310.
280	60	55	-150	10	.0005	800	.750	.625	.650	3.437	.03703	57400.
170	8	35	-150	10	.0008	650	.750	.500	.650	2.376	.02945	49850.
60	60	35	-10	7	.0008	800	1.500	.750	.400	27.170	.27840	165900.
280	8	75	-10	7	.0002	650	1.500	.625	.400	12.750	.06774	99790.
170	34	55	-10	7	.0005	500	1.500	.500	.400	4.111	.03311	68040.
60	8	55	-150	10	.0002	800	1.000	.500	.900	6.895	.03692	78410.
280	34	35	-150	10	.0005	650	1.000	.750	.900	1.522	.01244	25570.
170	60	75	-150	10	.0008	500	1.000	.625	.900	1.010	.01479	28570.
60	34	75	-80	12	.0005	800	.750	.625	.650	6.873	.08482	94790.
280	60	55	-80	12	.0008	650	.750	.500	.650	1.203	.01754	32660.
170	8	35	-80	12	.0002	500	.750	.750	.650	4.780	.02418	47960.
60	60	35	-150	10	.0002	650	1.500	.625	.400	22.310	.07233	100900.
280	8	75	-150	10	.0005	500	1.500	.500	.400	1.954	.01804	48440.
170	34	55	-150	10	.0008	800	1.500	.750	.400	13.590	.15580	120000.
60	8	55	-80	12	.0005	650	1.000	.750	.900	3.865	.03549	53180.
280	34	35	-80	12	.0008	500	1.000	.625	.900	.587	.02699	15110.

σ_w (psi)	ΔT_i (^oF)	ΔT_F (^oF)	F/y	D (in.)	Z	f_t (psi)	α_s/α_c	ϕ (in.)	p (%)	$\bar{x}$ (ft)	Δx (in.)	σ_s (psi)
170	60	75	-80	12	.0002	800	1.000	.500	.900	4.137	.02894	68760.
60	34	75	-10	7	.0008	650	.750	.500	.650	2.534	.04102	61040.
280	60	55	-10	7	.0002	500	.750	.750	.650	1.008	.00753	22480.
170	8	35	-10	7	.0005	800	.750	.625	.650	7.364	.06315	81510.
60	8	35	-150	12	.0008	500	1.500	.750	.900	2.069	.02207	32540.
280	34	75	-150	12	.0002	800	1.500	.625	.900	4.308	.02304	58050.
170	60	55	-150	12	.0005	650	1.500	.500	.900	1.727	.01397	40690.
60	34	55	-80	7	.0002	500	1.000	.500	.650	4.292	.02355	61630.
280	60	35	-80	7	.0005	800	1.000	.750	.650	4.170	.03357	50760.
170	8	75	-80	7	.0008	650	1.000	.625	.650	2.224	.03238	47210.
60	60	75	-10	10	.0005	500	.750	.625	.400	6.315	.07836	90340.
280	8	55	-10	10	.0008	800	.750	.500	.400	6.059	.08659	101400.
170	34	35	-10	10	.0002	650	.750	.750	.400	20.010	.09967	104300.
60	8	35	-80	7	.0002	800	1.500	.625	.900	14.360	.04337	77870.
280	34	75	-80	7	.0005	650	1.500	.500	.900	1.166	.01073	35420.
170	60	55	-80	7	.0008	500	1.500	.750	.900	1.146	.01364	24240.
60	34	55	-10	10	.0005	800	1.000	.750	.650	12.710	.11390	105700.
280	60	35	-10	10	.0008	650	1.000	.625	.650	1.564	.01847	30110.
170	8	75	-10	10	.0002	500	1.000	.500	.650	2.146	.01546	48840.
60	60	75	-150	12	.0008	800	.750	.500	.400	10.600	.16830	150600.
280	8	55	-150	12	.0002	650	.750	.750	.400	10.000	.07053	85340.
170	34	35	-150	12	.0005	500	.750	.625	.400	4.550	.03994	61450.
60	8	35	-10	10	.0005	650	1.500	.500	.900	3.685	.02498	57050.
280	34	75	-10	10	.0008	500	1.500	.750	.900	.737	.00956	22480.
170	60	55	-10	10	.0002	800	1.500	.625	.900	6.463	.02765	62560.
60	34	55	-150	12	.0008	650	1.000	.625	.650	4.448	.05681	70080.
280	60	35	-150	12	.0002	500	1.000	.500	.650	7.042	.03306	19610.
170	8	75	-150	12	.0005	800	1.000	.750	.650	6.354	.06802	78410.
60	60	75	-80	7	.0002	650	.750	.750	.400	15.560	.13520	120500.
280	8	55	-80	7	.0005	500	.750	.625	.400	1.695	.01866	35610.
170	34	35	-80	7	.0008	800	.750	.500	.400	9.088	.11090	119400.
60	34	35	-10	12	.0002	500	1.500	.625	.650	10.430	.03206	66590.
280	60	75	-10	12	.0005	800	1.500	.500	.650	3.755	.03382	70070.
170	8	55	-10	12	.0008	650	1.500	.750	.650	4.272	.04956	59500.
60	60	55	-150	7	.0005	500	1.000	.750	.400	8.128	.07437	82690.
280	8	35	-150	7	.0008	800	1.000	.625	.400	7.951	.09154	94350.
170	34	75	-150	7	.0002	650	1.000	.500	.400	9.186	.06458	104700.
60	8	75	-80	10	.0008	500	.750	.500	.900	1.153	.01878	35190.
280	34	55	-80	10	.0002	800	.750	.750	.900	3.461	.02469	47240.
170	60	35	-80	10	.0005	650	.750	.625	.900	1.410	.01265	27740.
60	34	35	-150	7	.0005	800	1.500	.500	.650	8.900	.05986	94280.
280	60	75	-150	7	.0008	650	1.500	.750	.650	1.802	.02325	36120.
170	8	55	-150	7	.0002	500	1.500	.625	.650	4.470	.01930	52000.
60	60	55	-80	10	.0008	800	1.000	.625	.400	16.490	.20760	153800.
280	8	35	-80	10	.0002	650	1.000	.500	.400	10.330	.04420	85640.
170	34	75	-80	10	.0005	500	1.000	.750	.400	4.785	.05188	66620.
60	8	75	-10	12	.0002	800	.750	.750	.900	6.152	.05377	72830.
280	34	55	-10	12	.0005	650	.750	.625	.900	1.133	.01243	26970.
170	60	35	-10	12	.0008	500	.750	.500	.900	.941	.01180	24150.
60	34	35	-80	10	.0008	650	1.500	.750	.650	5.696	.05981	66200.
280	60	75	-80	10	.0002	500	1.500	.625	.650	1.100	.00630	29730.
170	8	55	-80	10	.0005	800	1.500	.500	.650	6.357	.04982	86060.
60	60	55	-10	12	.0002	650	1.000	.500	.400	18.370	.09920	131200.
280	8	35	-10	12	.0005	500	1.000	.750	.400	2.423	.01991	35740.
170	34	75	-10	12	.0008	800	1.000	.625	.400	10.600	.15120	127800.
60	8	75	-150	7	.0005	650	.750	.625	.900	2.477	.03103	50490.
280	34	55	-150	7	.0008	500	.750	.500	.900	.477	.00700	18730.
170	60	35	-150	7	.0002	800	.750	.750	.900	4.038	.02101	44050.

APPENDIX D

RESULTS OF REGRESSION ANALYSIS
TYPICAL COMPUTER PRINTOUT

APPENDIX D.1

LINEAR REGRESSION ANALYSIS (LOGARITHMIC TRANSFORMATIONS)

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****************************************
*           COMPUTATION CENTER         *
*     UNIVERSITY OF TEXAS AT AUSTIN    *
* SOCIAL SCIENCES COMPUTING LABORATORY *
****************************************

S P S S - - STATISTICAL PACKAGE FOR THE SOCIAL SCIENCES

CDC 6000/CYBER 70 VERSION 6.5  -  INSTALLED 11 APR 1977

<<<NOTE>>> IN THIS VERSION:
                GET ARCHIVE AND MERGE FILES NOT AVAILABLE
                SORT CASES NOT AVAILABLE
                NONLINEAR NOT AVAILABLE



RUN NAME        MULTIPLE REGRESSION FOR CRCP2 NOMOGRAPHS-3DVS AND 10IVS
FILE NAME       SPSTHEO  REGRESSION ON RAW DATA-THEORETICAL A ANOVA BASIS
VARIABLE LIST   A,B,C,D,E,F,G,H,I,J,CS,CW,SS
N OF CASES      243
INPUT MEDIUM    DISK
INPUT FORMAT    FIXED(5F5.0,F5.4,F5.0,3F5.3,F10.3,F10.5,F10.0)

ACCORDING TO YOUR INPUT FORMAT, VARIABLES ARE TO BE READ AS FOLLOWS

VARIABLE  FORMAT  RECORD   COLUMNS

A         F 5. 0     1       1-  5
B         F 5. 0     1       6- 10
C         F 5. 0     1      11- 15
D         F 5. 0     1      16- 20
E         F 5. 0     1      21- 25
F         F 5. 4     1      26- 30
G         F 5. 0     1      31- 35
H         F 5. 3     1      36- 40
I         F 5. 3     1      41- 45
J         F 5. 3     1      46- 50
CS        F10. 3     1      51- 60
CW        F10. 5     1      61- 70
SS        F10. 0     1      71- 80


 THE INPUT FORMAT PROVIDES FOR  13 VARIABLES.   13 WILL BE READ
 IT PROVIDES FOR  1 RECORDS (*CARDS*) PER CASE.  A MAXIMUM OF
 80 *COLUMNS* ARE USED ON A RECORD.
```

```
VAR LABELS      CS CRACK SPACING FT./
                CW CRACK WIDTH IN./
                SS STEEL STRESS PSI./
                A  WHEEL LOAD STRESS PSI./
                B  DAILY TEMPERATURE VARIATION DEG.F/
                C  FINAL TEMPERATURE RANGE DEG.F/
                D  FRICTION MOVEMENT RATIO/
                E  CONCRETE SLAB THICKNESS IN./
                F  CONCRETE SHRINKAGE STRAIN/
                G  CONCRETE TENSILE STRENGTH PSI./
                H  THERMAL COEFFICIENT RATIO/
                I  STEEL BAR DIAMETER IN./
                J  STEEL PERCENT REINFORCEMENT PCT/
COMPUTE         LNCS=LN(CS)
COMPUTE         LNCW=LN(CW)
COMPUTE         LNSS=LN(SS)
COMPUTE         LGA1=LG10(1+A/1000)
COMPUTE         LGB1=LG10(1+B/100)
COMPUTE         LGC1=LG10(1+C/100)
COMPUTE         LGD1=LG10(1-D/200)
COMPUTE         LGE1=LG10(1+E/20)
COMPUTE         LGF1=LG10(1+1000*F)
COMPUTE         LGG1=LG10(1+G/1000)
COMPUTE         LGH1=LG10(1+H/2)
COMPUTE         LGI1=LG10(1+I)
COMPUTE         LGJ1=LG10(1+J)
REGRESSION      VARIABLES=LGCS,LGCW,LGSS,LGA1 TO LGJ1/
                REGRESSION=LGCS WITH LGA1 TO LGJ1 (1)RESID=0/
                REGRESSION=LGCW WITH LGA1 TO LGJ1 (1)RESID=0/
                REGRESSION=LGSS WITH LGA1 TO LGJ1 (1)RESID=0
STATISTICS      1,2,3,4,5,6,9
READ INPUT DATA
FINISH

057200 CM NEEDED FOR REGRESSION
```

VARIABLE	MEAN	STANDARD DEV	CASES
LGCS	.6047	.4176	243
LGCW	-1.4591	.3821	243
LGSS	4.7586	.2363	243
LGA1	.0669	.0335	243
LGB1	.1215	.0699	243
LGC1	.1879	.0461	243
LGD1	.1368	.0910	243
LGF1	.1702	.0305	243
LGF1	.1702	.0722	243
LGG1	.2163	.0324	243
LGH1	.1858	.0434	243
LGI1	.2100	.0274	243
LGJ1	.2141	.0543	243

CORRELATION COEFFICIENTS.

A VALUE OF 99.00000 IS PRINTED
IF A COEFFICIENT CANNOT BE COMPUTED.

	LGCS	LGCW	LGSS	LGA1	LGB1	LGC1	LGD1	LGE1	LGF1	LGG1	LGH1	LGI1
LGCW	.90223											
LGSS	.93581	.93962										
LGA1	-.01746	-.43107	-.44607									
LGB1	-.05714	-.05775	-.06917	-.00000								
LGC1	-.09662	.05640	.08307	-.00000	-.00000							
LGD1	-.02327	-.02401	-.03082	-.00000	-.00000	-.00000						
LGE1	.02924	.03138	.02485	-.00000	-.00000	-.00000	-.00000					
LGF1	-.30972	.06708	-.15086	-.00000	-.00000	-.00000	-.00000	-.00000				
LGG1	.51953	.55378	.56151	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000			
LGH1	.11983	-.01941	.06340	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000		
LGI1	.14347	.15778	-.01713	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	
LGJ1	-.59829	-.64664	-.63028	-.00000	.00000	.00000	-.00000	-.00000	-.00000	.00000	.00000	.00000

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. LGC8

MEAN RESPONSE .60475 STD. DEV. .41758

VARIABLE(S) ENTERED ON STEP NUMBER 1.. LGJ1

MULTIPLE R	.59829	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.35795	REGRESSION	1.	15.10469	15.10469	134.36254	0
ADJUSTED R SQUARE	.35529	RESIDUAL	241.	27.09260	.11242		
STD DEVIATION	.33529	COEFF OF VARIABILITY	55.4 PCT				

-------------------- VARIABLES IN THE EQUATION --------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
LGJ1	-4.6002662	.39686597	134.36254 0	-.5982926 -1.62881
(CONSTANT)	1.5897631	.87657455E-01	328.91758 0	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE
LGA1	-.52099	1.00000	89.413371 0
LGB1	-.07131	1.00000	1.2265352 .269
LGC1	-.12058	1.00000	3.5409601 .061
LGD1	-.02904	1.00000	.20256037 .653
LGE1	.03650	1.00000	.32011206 .572
LGF1	-.38653	1.00000	42.155348 .000
LGG1	.64837	1.00000	174.06895 0
LGH1	.14955	1.00000	5.4900811 .020
LGI1	.17905	1.00000	7.9487456 .005

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. LGCS

VARIABLE(S) ENTERED ON STEP NUMBER 2.. LGG1

MULTIPLE R	.79238	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.62786	REGRESSION	2.	26.49406	13.24703	202.46052	.000
ADJUSTED R SQUARE	.62476	RESIDUAL	240.	15.70324	.06543		
STD DEVIATION	.25579	COEFF OF VARIABILITY	42.3 PCT				

------------------ VARIABLES IN THE EQUATION ------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
LGJ1	-4.6002662	.30277224	230.85209 0	-.5982926 -1.62881
LGG1	6.6949902	.50744537	174.06895 .000	.5195261 2.39441
(CONSTANT)	.14175337	.12852089	1.2165201 .271	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE
LGA1	-.68432	1.00000	210.50024 0
LGB1	-.09366	1.00000	2.1151485 .147
LGC1	-.15838	1.00000	6.1495238 .014
LGD1	-.03814	1.00000	.34823185 .556
LGE1	.04794	1.00000	.55051664 .459
LGF1	-.50771	1.00000	83.000925 0
LGH1	.19643	1.00000	9.5916372 .002
LGI1	.23518	1.00000	13.992856 .000

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. LGCS

VARIABLE(S) ENTERED ON STEP NUMBER 3.. LGA1

MULTIPLE R	.89562	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.80213	REGRESSION	3.	33.84786	11.28262	322.96133	0
ADJUSTED R SQUARE	.79965	RESIDUAL	239.	8.34944	.03493		
STD DEVIATION	.18691	COEFF OF VARIABILITY	30.9 PCT				

------------------- VARIABLES IN THE EQUATION -------------------

VARIABLE	B	STD ERROR B	F SIGNIFICANCE	BETA ELASTICITY
LGJ1	-4.6002662	.22123647	432.36696 0	-.5982926 -1.62881
LGG1	6.6949902	.37079166	326.01680 0	.5195261 2.39441
LGA1	-5.2007079	.35845626	210.50024 0	-.4174589 -.57533
(CONSTANT)	.48968367	.96924077E-01	25.525126 .000	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F SIGNIFICANCE
LGB1	-.12845	1.00000	3.9925502 .047
LGC1	-.21721	1.00000	11.784408 .001
LGD1	-.05231	1.00000	.65303619 .420
LGE1	.06574	1.00000	1.0331503 .310
LGF1	-.69627	1.00000	223.95175 .000
LGH1	.26938	1.00000	18.622269 .000
LGI1	.32253	1.00000	27.631872 .000

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. LGCS

VARIABLE(S) ENTERED ON STEP NUMBER 4.. LGF1

MULTIPLE R	.94766	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.89806	REGRESSION	4.	37.89562	9.47391	524.16540	.000
ADJUSTED R SQUARE	.89634	RESIDUAL	238.	4.30168	.01807		
STD DEVIATION	.13444	COEFF OF VARIABILITY	22.2 PCT				

---------------------- VARIABLES IN THE EQUATION ----------------------

VARIABLE	B	STD ERROR B	F SIGNIFICANCE	BETA ELASTICITY
LGJ1	-4.6002662	.15913194	835.70155 .000	-.5982926 -1.62881
LGG1	6.6909902	.26670466	630.14239 0	.5195261 2.39441
LGA1	-5.2007079	.25783200	406.86591 .000	-.4174589 -.57533
LGF1	-1.7922963	.11976574	223.95175 .000	-.3097172 -.50437
(CONSTANT)	.79469965	.72634294E-01	119.70784 0	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F SIGNIFICANCE
LGB1	-.17895	1.00000	7.8406406 .006
LGC1	-.30261	1.00000	23.890206 .000
LGD1	-.07288	1.00000	1.2654677 .262
LGE1	.09159	1.00000	2.0050821 .158
LGH1	.37530	1.00000	38.854152 0
LGI1	.44934	1.00000	59.957597 0

* MULTIPLE REGRESSION *

DEPENDENT VARIABLE.. LGCS

VARIABLE(S) ENTERED ON STEP NUMBER 5.. LGI1

MULTIPLE R	.95846	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.91864	REGRESSION	5.	38.76416	7.75283	535.20126	0
ADJUSTED R SQUARE	.91692	RESIDUAL	237.	3.43314	.01449		
STD DEVIATION	.12036	COEFF OF VARIABILITY	19.9 PCT				

------------------- VARIABLES IN THE EQUATION -------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
LGJ1	-4.6002662	.14246186	1042.7224 0	-.5982926 -1.62881
LGG1	6.6949902	.23876565	786.24189 0	.5195261 2.39441
LGA1	-5.2007079	.23082246	507.65514 0	-.4174589 -.57533
LGF1	-1.7922963	.10721952	279.42930 0	-.3097172 -.50437
LGI1	2.1869014	.28242757	59.957597 0	.1434668 .75939
(CONSTANT)	.33546299	.88009995E-01	14.528650 .000	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE
LGB1	-.20031	1.00000	9.8653255 .002
LGC1	-.33873	1.00000	30.587819 .000
LGD1	-.08158	1.00000	1.5810582 .210
LGE1	.10253	1.00000	2.5071045 .115
LGH1	.42010	1.00000	50.575987 .000

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. LGCS

VARIABLE(S) ENTERED ON STEP NUMBER 6.. LGH1

MULTIPLE R	.96592	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.93300	REGRESSION	6.	39.37005	6.56168	547.72533	.000
ADJUSTED R SQUARE	.93130	RESIDUAL	236.	2.82725	.01198		
STD DEVIATION	.10945	COEFF OF VARIABILITY	18.1 PCT				

------------------- VARIABLES IN THE EQUATION -------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
LGJ1	-4.6002662	.12955463	1260.8401 0	-.5982926 -1.62881
LGG1	6.6909902	.21713318	950.70879 0	.5195261 2.39441
LGA1	-5.2007079	.20990965	613.84697 0	-.4174589 -.57533
LGF1	-1.7922963	.97505290E-01	337.88061 .000	-.3097172 -.50437
LGI1	2.1869014	.25683927	72.499598 .000	.1434668 .75939
LGH1	1.1530235	.16213109	50.575907 .000	.1198272 .35427
(CONSTANT)	.12121893	.85518106E-01	2.0092073 .158	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE
LGB1	-.22073	1.00000	12.036579 .001
LGC1	-.37327	1.00000	38.042203 0
LGD1	-.08989	1.00000	1.9144999 .168
LGE1	.11298	1.00000	3.0384061 .083

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. LGCS

VARIABLE(S) ENTERED ON STEP NUMBER 7.. LGC1

MULTIPLE R	.97074	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.94233	REGRESSION	7.	39.76396	5.68057	548.60215	0
ADJUSTED R SQUARE	.94062	RESIDUAL	235.	2.43334	.01035		
STD DEVIATION	.10176	COEFF OF VARIABILITY	16.8 PCT				

------------------- VARIABLES IN THE EQUATION -------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
LGJ1	-4.6002662	.12044647	1458.7397 0	-.5982926 -1.62881
LGG1	6.6949902	.20186792	1099.9306 0	.5195261 2.39441
LGA1	-5.2007079	.19515223	710.19546 0	-.4174589 -.57533
LGF1	-1.7922963	.90650310E-01	390.91384 0	-.3097172 -.50437
LGI1	2.1869014	.23878252	83.879016 0	.1434668 .75939
LGH1	1.1530235	.15073268	58.514225 0	.1198272 .35427
LGC1	-.87443838	.14177393	38.042203 0	-.0966179 -.27170
(CONSTANT)	.28552693	.83850137E-01	11.595423 .001	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE
LGB1	-.23793	1.00000	14.041999 .000
LGD1	-.09690	1.00000	2.2178818 .138
LGE1	.12178	1.00000	3.5226191 .062

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. LGCS

VARIABLE(S) ENTERED ON STEP NUMBER 8.. LGB1

MULTIPLE R	.97242	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.94560	REGRESSION	8.	39.90172	4.98771	508.42260	.000
ADJUSTED R SQUARE	.94374	RESIDUAL	234.	2.29558	.00981		
STD DEVIATION	.09905	COEFF OF VARIABILITY	16.4 PCT				

------------------- VARIABLES IN THE EQUATION -------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
LGJ1	-4.6002662	.11723719	1539.6966 / 0	-.5982926 / -1.62881
LGG1	6.6949902	.19648917	1160.9744 / 0	.5195261 / 2.39441
LGA1	-5.2007079	.18995242	749.60980 / 0	-.4174589 / -.57533
LGF1	-1.7922963	.88234943E-01	412.60872 / 0	-.3097172 / -.50437
LGI1	2.1869014	.23242019	88.534123 / .000	.1434668 / .75939
LGH1	1.1530235	.14671643	61.761640 / .000	.1198272 / .35427
LGC1	-.87443838	.13799638	40.153464 / .000	-.0966179 / -.27170
LGB1	-.34112420	.91032831E-01	14.041999 / .000	-.0571361 / -.06856
(CONSTANT)	.32699041	.82362607E-01	15.761946 / .000	)

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE
LGD1	-.09976	1.00000	2.3422590 / .127
LGE1	.12538	1.00000	3.7214108 / .055

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. LGCS

VARIABLE(S) ENTERED ON STEP NUMBER 9.. LGE1

MULTIPLE R	.97286	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.94645	REGRESSION	9.	39.93781	4.43753	457.60063	0
ADJUSTED R SQUARE	.94439	RESIDUAL	233.	2.25949	.00970		
STD DEVIATION	.09848	COEFF OF VARIABILITY	16.3 PCT				

------------------ VARIABLES IN THE EQUATION ------------------

VARIABLE	B	STD ERROR B	F	SIGNIFICANCE	BETA	ELASTICITY
LGJ1	-4.6002662	.11656134	1557.6032	0	-.5982926	-1.62881
LGG1	6.6949902	.19535646	1174.4765	0	.5195261	2.39441
LGA1	-5.2007079	.18885739	758.32773	0	-.4174589	-.57533
LGF1	-1.7922963	.87726291E-01	417.40734	0	-.3097172	-.50437
LGI1	2.1869014	.23108035	89.563771	0	.1434668	.75939
LGH1	1.1530235	.14587064	62.479925	0	.1198272	.35427
LGC1	-.87443838	.13720087	40.620448	0	-.0966179	-.27170
LGB1	-.34112420	.90508050E-01	14.205307	.000	-.0571361	-.06856
LGE1	.40071871	.20772358	3.7214108	.055	.0292442	.11277
(CONSTANT)	.25879543	.89192423E-01	8.4169372	.004		

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F	SIGNIFICANCE
LGD1	-.10056	1.00000	2.3698362	.125

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE..   LGCS

VARIABLE(S) ENTERED ON STEP NUMBER 10..   LGD1

MULTIPLE R	.97314	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.94700	REGRESSION	10.	39,96065	3.99607	414,49881	.000
ADJUSTED R SQUARE	.94471	RESIDUAL	232.	2,23665	.00964		
STD DEVIATION	.09819	COEFF OF VARIABILITY	16.2 PCT				

---------------------- VARIABLES IN THE EQUATION ----------------------

VARIABLE	B	STD ERROR B	F SIGNIFICANCE	BETA ELASTICITY
LGJ1	-4.6002662	.11622021	1566.7606 0	-.5982926 -1.62881
LGG1	6.6949902	.19478472	1181.3814 0	.5195261 2.39441
LGA1	-5.2007079	.18830467	762.78603 .000	-.4174589 -.57533
LGF1	-1.7922963	.87469546E-01	419.86133 0	-.3097172 -.50437
LGI1	2.1869014	.23040405	90.090328 0	.1434668 .75939
LGH1	1.1530235	.14544373	62.847252 .000	.1198272 .35427
LGC1	-.87443838	.13679933	40.859260 .000	-.0966179 -.27170
LGB1	-.34112420	.90243164E-01	14.288822 .000	-.0571361 -.06856
LGE1	.40071871	.20711565	3.7432894 .054	.0292442 .11277
LGD1	-.10677682	.69361395E-01	2.3698362 .125	-.0232687 -.02415
(CONSTANT)	.27340091	.89436046E-01	9.3449015 .002	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F SIGNIFICANCE

ALL VARIABLES ARE IN THE EQUATION.

* M U L T I P L E   R E G R E S S I O N * * * * * * * * * * * * * *

DEPENDENT VARIABLE..   LGCS

COEFFICIENTS AND CONFIDENCE INTERVALS.

VARIABLE	B	STD ERROR B	T	95.0 PCT CONFIDENCE INTERVAL	
LGJ1	-4.6002662	.11622021	-39.582327	-4.8292481 ,	-4.3712843
LGG1	6.6949902	.19478472	34.371229	6.3112172 ,	7.0787632
LGA1	-5.2007079	.18830467	-27.618581	-5.5717137 ,	-4.8297021
LGF1	-1.7922963	.87469546E-01	-20.490518	-1.9646325 ,	-1.6199601
LGI1	2.1869014	.23040405	9.4915925	1.7329496 ,	2.6408531
LGH1	1.1530235	.14544373	7.9276259	.86646414 ,	1.4395828
LGC1	-.87443838	.13679933	-6.3921249	-1.1439662 ,	-.60491061
LGB1	-.34112420	.90243164E-01	-3.7800558	-.51892506 ,	-.16332333
LGE1	.40071871	.20711565	1.9347582	-.73492322E-02,	.80878664
LGD1	-.10677682	.69361395E-01	-1.5394272	-.24343555 ,	.29881910E-01
CONSTANT	.27340091	.89436046E-01	3.0569432	.97190259E-01,	.44961156

VARIANCE/COVARIANCE MATRIX OF THE UNNORMALIZED REGRESSION COEFFICIENTS.

	LGA1	LGB1	LGC1	LGD1	LGE1	LGF1	LGG1	LGH1	LGI1	LGJ1
LGA1	.03546									
LGB1	.00000	.00814								
LGC1	.00000	.00000	.01871							
LGD1	.00000	.00000	.00000	.00481						
LGE1	.00000	.00000	.00000	.00000	.04290					
LGF1	.00000	.00000	.00000	.00000	.00000	.00765				
LGG1	.00000	.00000	.00000	.00000	.00000	.00000	.03794			
LGH1	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.02115		
LGI1	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.05309	
LGJ1	.00000	-.00000	-.00000	.00000	.00000	.00000	-.00000	-.00000	-.00000	.01351
	LGA1	LGB1	LGC1	LGD1	LGE1	LGF1	LGG1	LGH1	LGI1	LGJ1

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE..   LGCS

S U M M A R Y   T A B L E

STEP	VARIABLE ENTERED	VARIABLE REMOVED	F TO ENTER OR REMOVE	SIGNIFICANCE	MULTIPLE R	R SQUARE	R SQUARE CHANGE	SIMPLE R	OVERALL F	SIGNIFICANCE
1	LGJ1		134,36254	0	,59829	,35795	,35795	-,59829	134,36254	0
2	LGG1		174,06895	0	,79238	,62786	,26991	,51953	202,46052	,000
3	LGA1		210,50024	0	,89562	,80213	,17427	-,41746	322,96133	0
4	LGF1		223,95175	,000	,94766	,89806	,09592	-,30972	524,16540	,000
5	LGI1		59,95760	0	,95846	,91864	,02058	,14347	535,20126	0
6	LGH1		50,57591	,000	,96592	,93300	,01436	,11983	547,72533	,000
7	LGC1		38,04220	0	,97074	,94235	,00934	-,09662	548,60215	0
8	LGB1		14,04200	,000	,97242	,94560	,00326	-,05714	508,42260	,000
9	LGE1		3,72141	,055	,97286	,94645	,00086	,02924	457,60063	0
10	LGD1		2,36984	,125	,97314	,94700	,00054	-,02327	414,49881	,000

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. LGCW

MEAN RESPONSE -1.45911 STD. DEV. .38210

VARIABLE(S) ENTERED ON STEP NUMBER 1.. LGJ1

MULTIPLE R	.64664	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.41815	REGRESSION	1.	14.77390	14.77390	173.19275	0
ADJUSTED R SQUARE	.41573	RESIDUAL	241.	20.55808	.08530		
STD DEVIATION	.29207	COEFF OF VARIABILITY	20.0 PCT				

------------------- VARIABLES IN THE EQUATION -------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
LGJ1	-4.5496148	.34570828	173.19275 0	-.6466415 .66765
(CONSTANT)	-.48493888	.76358040E-01	40.333366 0	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE
LGA1	-.56511	1.00000	112.68583 .000
LGB1	-.07571	1.00000	1.3835433 .241
LGC1	.07394	1.00000	1.3193761 .252
LGD1	-.03148	1.00000	.23810041 .626
LGE1	.04114	1.00000	.40689561 .524
LGF1	.08794	1.00000	1.8704514 .173
LGG1	.72599	1.00000	267.47265 .000
LGH1	-.02545	1.00000	.15554766 .694
LGI1	.20685	1.00000	10.727386 .001

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. LGCW

VARIABLE(S) ENTERED ON STEP NUMBER 2.. LGG1

MULTIPLE R	.85136	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.72482	REGRESSION	2.	25.60941	12.80471	316.08193	.000
ADJUSTED R SQUARE	.72253	RESIDUAL	240.	9.72257	.04051		
STD DEVIATION	.20127	COEFF OF VARIABILITY	13.8 PCT				

------------------- VARIABLES IN THE EQUATION -------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
LGJ1	-4.5496148	.23823852	364.69121	-.6466415
			0	.66765
LGG1	6.5301763	.39928705	267.47265	.5537843
			.000	-.96796
(CONSTANT)	-1.8973822	.10112759	351.99272	
			0	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE
LGA1	-.82174	1.00000	496.97962
			0
LGB1	-.11009	1.00000	2.9321082
			.088
LGC1	.10752	1.00000	2.7952821
			.096
LGD1	-.04578	1.00000	.50191322
			.479
LGE1	.05982	1.00000	.85840535
			.355
LGF1	.12787	1.00000	3.9730416
			.047
LGH1	-.03701	1.00000	.32776708
			.568
LGI1	.30078	1.00000	23.772415
			.000

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE..   LGCW

VARIABLE(S) ENTERED ON STEP NUMBER 3..   LGA1

MULTIPLE R	.95427	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.91064	REGRESSION	3.	32.17470	10.72490	811.85392	0
ADJUSTED R SQUARE	.90952	RESIDUAL	239.	3.15728	.01321		
STD DEVIATION	.11494	COEFF OF VARIABILITY	7.9 PCT				

------------------ VARIABLES IN THE EQUATION ------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
LGJ1	-4.5496148	.13604567	1118.3554 0	-.6466415 .66765
LGG1	6.5301763	.22801213	820.22673 0	.5537843 -.96796
LGA1	-4.9139808	.22042668	496.97962 0	-.4310652 .22531
(CONSTANT)	-1.5685541	.59601840E-01	692.59550 0	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE
LGB1	-.19319	1,00000	9.2267737 .003
LGC1	.18868	1,00000	8.7854763 .003
LGD1	-.08033	1,00000	1.5458817 .215
LGE1	.10498	1,00000	2.6521316 .105
LGF1	.22440	1,00000	12.619672 .000
LGH1	-.06494	1,00000	1.0079814 .316
LGI1	.52781	1,00000	91.908281 0

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. LGCW

VARIABLE(S) ENTERED ON STEP NUMBER 4.. LGI1

MULTIPLE R	.96723	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.93553	REGRESSION	4.	33.05428	8.26357	863.47079	.000
ADJUSTED R SQUARE	.93445	RESIDUAL	238.	2.27770	.00957		
STD DEVIATION	.09783	COEFF OF VARIABILITY	6.7 PCT				

------------------ VARIABLES IN THE EQUATION ------------------

VARIABLE	B	STD ERROR B	F SIGNIFICANCE	BETA ELASTICITY
LGJ1	-4.5496148	.11579427	1543.7436 .000	-.6466415 .66765
LGG1	6.5301763	.19407084	1132.2159 .000	.5537043 -.96796
LGA1	-4.9139808	.18761454	686.01545 0	-.4310652 .22531
LGI1	2.2007608	.22955963	91.908281 0	.1577805 -.31673
(CONSTANT)	-2.0307012	.69980973E-01	842.03876 0	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F SIGNIFICANCE
LGB1	-.22745	1.00000	12.929701 .000
LGC1	.22214	1.00000	12.302358 .001
LGD1	-.09458	1.00000	2.1392158 .145
LGE1	.12360	1.00000	3.6766783 .056
LGF1	.26419	1.00000	17.783642 .000
LGH1	-.07646	1.00000	1.3936415 .239

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. LGCW

VARIABLE(S) ENTERED ON STEP NUMBER 5.. LGF1

MULTIPLE R	.96955	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.94003	REGRESSION	5.	33.21326	6.64265	743.04658	0
ADJUSTED R SQUARE	.93877	RESIDUAL	237.	2.11872	.00894		
STD DEVIATION	.09455	COEFF OF VARIABILITY	6.5 PCT				

-------------------- VARIABLES IN THE EQUATION --------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
LGJ1	-4.5496148	.11191538	1652.6076 0	-.6466415 .66765
LGG1	6.5301763	.18756984	1212.0592 0	.5537843 -.96796
LGA1	-4.9139808	.18132981	734.39292 0	-.4310692 .22531
LGI1	2.2007608	.22186982	98.389607 0	.1577805 -.31673
LGF1	.35520195	.84229648E-01	17.783642 .000	.0670794 -.04143
(CONSTANT)	-2.0911500	.69139007E-01	914.79568 0	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE
LGB1	-.23583	1.00000	13.898146 .000
LGC1	.23033	1.00000	13.221177 .000
LGD1	-.09806	1.00000	2.2915836 .131
LGE1	.12815	1.00000	3.9404728 .048
LGH1	-.07928	1.00000	1.4925524 .223

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. LGCW

VARIABLE(S) ENTERED ON STEP NUMBER 6.. LGB1

MULTIPLE R	.97127	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.94337	REGRESSION	6.	33.33110	5.55518	655.22059	.000
ADJUSTED R SQUARE	.94193	RESIDUAL	236.	2.00089	.00848		
STD DEVIATION	.09208	COEFF OF VARIABILITY	6.3 PCT				

------------------ VARIABLES IN THE EQUATION ------------------

VARIABLE	B	STD ERROR B	F SIGNIFICANCE	BETA ELASTICITY
LGJ1	-4.5496148	.10898894	1742.5467 0	-.6466415 .66765
LGG1	6.5301763	.18266513	1278.0225 .000	.5537843 -.96796
LGA1	-4.9139808	.17658828	774.36046 0	-.4310652 .22531
LGI1	2.2007608	.21606821	103.74422 0	.1577805 -.31673
LGF1	.35520195	.82027154E-01	18.751473 .000	.0670794 -.04143
LGB1	-.31549575	.84628196E-01	13.898146 .000	-.0577497 .02628
(CONSTANT)	-2.0528017	.68112342E-01	908.32726 0	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F SIGNIFICANCE
LGC1	.23701	1.00000	13.986601 .000
LGD1	-.10091	1.00000	2.4176365 .121
LGE1	.13187	1.00000	4.1589382 .043
LGH1	-.08158	1.00000	1.5743390 .211

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE..   LGCW

VARIABLE(S) ENTERED ON STEP NUMBER 7..   LGC1

MULTIPLE R	.97291	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.94655	REGRESSION	7.	33.44349	4.77764	594.52041	0
ADJUSTED R SQUARE	.94496	RESIDUAL	235.	1.88849	.00804		
STD DEVIATION	.08964	COEFF OF VARIABILITY	6.1 PCT				

------------------ VARIABLES IN THE EQUATION ------------------

VARIABLE	B	STD ERROR B	F SIGNIFICANCE	BETA ELASTICITY
LGJ1	-4.5496148	.10610856	1838.4355 0	-.6466415 .66765
LGG1	6.5301763	.17783763	1348.3495 0	.5537843 -.96796
LGA1	-4.9139808	.17192138	816.97194 0	-.4310652 .22531
LGI1	2.2007608	.21035793	109.45305 0	.1577805 -.31673
LGF1	.35520195	.79859329E-01	19.783329 .000	.0670794 -.04143
LGB1	-.31549575	.82391630E-01	14.662932 .000	-.0577497 .02628
LGC1	.46709889	.12489721	13.986601 .000	.0564021 -.06015
(CONSTANT)	-2.1405701	.70342579E-01	926.02418 0	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F SIGNIFICANCE
LGD1	-.10387	1.00000	2.5521906 .111
LGE1	.13574	1.00000	4.3923432 .037
LGH1	-.08397	1.00000	1.6616041 .199

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. LGCH

VARIABLE(S) ENTERED ON STEP NUMBER 8.. LGE1

MULTIPLE R	.97341	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.94753	REGRESSION	8.	33.47829	4.18479	528.26383	.000
ADJUSTED R SQUARE	.94574	RESIDUAL	234.	1.85369	.00792		
STD DEVIATION	.08900	COEFF OF VARIABILITY	6.1 PCT				

------------------- VARIABLES IN THE EQUATION -------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
LGJ1	-4.5496148	.10535089	1864.9743 0	-.6466415 .66765
LGG1	6.5301763	.17656778	1367.8136 0	.5537843 -.96796
LGA1	-4.9139808	.17069377	828.76534 .000	-.4310652 .22531
LGI1	2.2007608	.20885587	111.03306 .000	.1577805 -.31673
LGF1	.35520195	.79289091E-01	20.068911 .000	.0670794 -.04143
LGB1	-.31549575	.81803310E-01	14.874599 .000	-.0577497 .02628
LGC1	.46709889	.12400538	14.188504 .000	.0564021 -.06015
LGE1	.39347542	.18774547	4.3923432 .037	.0313816 -.04589
(CONSTANT)	-2.2075324	.76801842E-01	826.17281 0	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE
LGD1	-.10484	1.00000	2.5895157 .109
LGH1	-.08475	1.00000	1.6857841 .195

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. LGCW

VARIABLE(S) ENTERED ON STEP NUMBER 9.. LGD1

MULTIPLE R	.97371	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.94811	REGRESSION	9.	33.49867	3.72207	473.04525	0
ADJUSTED R SQUARE	.94611	RESIDUAL	233.	1.83332	.00787		
STD DEVIATION	.08870	COEFF OF VARIABILITY	6.1 PCT				

------------------- VARIABLES IN THE EQUATION -------------------

VARIABLE	B	STD ERROR B	F SIGNIFICANCE	BETA ELASTICITY
LGJ1	-4.5496148	.10499489	1877.6427 0	-.6466415 .66765
LGG1	6.5301763	.17597112	1377.1049 0	.5537843 -.96796
LGA1	-4.9139808	.17011696	834.39498 0	-.4310652 .22531
LGI1	2.2007608	.20815010	111.78729 0	.1577885 -.31673
LGF1	.35520195	.79021157E-01	20.205235 .000	.0670794 -.04143
LGB1	-.31509575	.81526881E-01	14.975639 .000	-.0577497 .02628
LGC1	.46709889	.12358634	14.284884 .000	.0564821 -.06015
LGE1	.39347542	.18711105	4.4221795 .037	.0313816 -.04589
LGD1	-.10083554	.62662012E-01	2.5895157 .109	-.0240141 .00945
(CONSTANT)	-2.1937396	.77020723E-01	811.25008 0	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F SIGNIFICANCE
LGH1	-.08522	1.00000	1.6973406 .194

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE..   LGCW

VARIABLE(S) ENTERED ON STEP NUMBER 10..   LGH1

MULTIPLE R	.97390	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.94849	REGRESSION	10.	33.51198	3.35120	427.18465	.000
ADJUSTED R SQUARE	.94627	RESIDUAL	232.	1.82000	.00784		
STD DEVIATION	.08857	COEFF OF VARIABILITY	6.1 PCT				

-------------------- VARIABLES IN THE EQUATION --------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
LGJ1	-4.5496148	.10483812	1883.2622	-.6466419
			.000	.66765
LGG1	6.5301763	.17570838	1381.2264	.5537843
			.000	-.96796
LGA1	-4.9139808	.16986296	836.89222	-.4310652
			0	.22531
LGI1	2.2007608	.20783931	112.12186	.1577805
			.000	-.31673
LGF1	.35520195	.78903172E-01	20.265707	.0670794
			.000	-.04143
LGB1	-.31549575	.81405154E-01	15.020460	-.0577497
			.000	.02628
LGC1	.46709880	.12340182	14.327637	.0564021
			.000	-.06015
LGE1	.39347542	.18683167	4.4354145	.0313816
			.036	-.04589
LGD1	-.10083554	.62568452E-01	2.5972658	-.0240141
			.108	.00945
LGH1	-.17092953	.13119963	1.6973406	-.0194130
			.194	.02177
(CONSTANT)	-2.1619791	.80677082E-01	718.12924	
			0	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE

ALL VARIABLES ARE IN THE EQUATION.

* M U L T I P L E   R E G R E S S I O N * * * * * * * * * * * * *

DEPENDENT VARIABLE..   LGCW

COEFFICIENTS AND CONFIDENCE INTERVALS.

VARIABLE	B	STD ERROR B	T	95.0 PCT CONFIDENCE INTERVAL	
LGJ1	-4.5496148	.10483812	-43.396569	-4.7561713	, -4.3430584
LGG1	6.5301763	.17570838	37.164854	6.1839883	, 6.8763643
LGA1	-4.9139808	.16986296	-28.929090	-5.2486519	, -4.5793096
LGI1	2.2007608	.20783931	10.588761	1.7912671	, 2.6102545
LGF1	.35520195	.78903172E-01	4.5017449	.19974361	, .51066029
LGB1	-.31549575	.81405154E-01	-3.8756238	-.47588360	, -.15510790
LGC1	.46709889	.12340182	3.7851865	.22396746	, .71023033
LGE1	.39347542	.18683167	2.1060424	.25371823E-01	, .76157902
LGD1	-.10083554	.62568452E-01	-1.6116035	-.22411052	, .22439454E-01
LGH1	-.17092953	.13119963	-1.3028202	-.42942053	, .87565480E-01
CONSTANT	-2.1619791	.80677082E-01	-26.797934	-2.3209324	, -2.0030257

VARIANCE/COVARIANCE MATRIX OF THE UNNORMALIZED REGRESSION COEFFICIENTS.

	LGA1	LGB1	LGC1	LGD1	LGE1	LGF1	LGG1	LGH1	LGI1	LGJ1
LGA1	.02885									
LGB1	.00000	.00663								
LGC1	.00000	.00000	.01523							
LGD1	.00000	.00000	.00000	.00391						
LGE1	.00000	.00000	.00000	.00000	.03491					
LGF1	.00000	.00000	.00000	.00000	.00000	.00623				
LGG1	.00000	.00000	.00000	.00000	.00000	.00000	.03087			
LGH1	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.01721		
LGI1	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.04320	
LGJ1	.00000	-.00000	-.00000	.00000	.00000	.00000	-.00000	-.00000	-.00000	.01099

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE..   LGCW

S U M M A R Y   T A B L E

STEP	VARIABLE ENTERED	VARIABLE REMOVED	F TO ENTER OR REMOVE	SIGNIFICANCE	MULTIPLE R	R SQUARE	R SQUARE CHANGE	SIMPLE R	OVERALL F	SIGNIFICANCE
1	LGJ1		173,19275	0	,64664	,41815	,41815	-,64664	173,19275	0
2	LGG1		267,47265	.000	,85136	,72482	,30668	,55378	316,08193	.000
3	LGA1		496,97962	0	,95427	,91064	,18582	-,43107	811,85392	0
4	LGI1		91,90828	0	,96723	,93553	,02489	,15778	863,47079	.000
5	LGF1		17,78364	,000	,96955	,94003	,00450	,06708	743,04658	0
6	LGB1		13,89815	,000	,97127	,94337	,00334	-,05775	655,22059	.000
7	LGC1		13,98660	,000	,97291	,94655	,00318	,05640	594,52041	0
8	LGE1		4,39234	,037	,97341	,94753	,00098	,03138	528,26383	.000
9	LGD1		2,58952	,109	,97371	,94811	,00058	-,02401	473,04525	0
10	LGH1		1.69734	.194	.97390	.94849	.00038	-.01941	427,18465	.000

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. LGSS

MEAN RESPONSE 4.75855 STD. DEV. .23626

VARIABLE(S) ENTERED ON STEP NUMBER 1.. LGJ1

MULTIPLE R	.63028	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.39725	REGRESSION	1.	5.36612	5.36612	158.83346	0
ADJUSTED R SQUARE	.39475	RESIDUAL	241.	8.14209	.03378		
STD DEVIATION	.18381	COEFF OF VARIABILITY	3.9 PCT				

-------------------- VARIABLES IN THE EQUATION --------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
LOJ1	-2.7419364	.21756367	158.83346 0	-.6302770 -.12338
(CONSTANT)	5.3056632	.48054203E-01	12374.864 0	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE
LGA1	-.57456	1.00000	118.27171 .000
LGB1	-.08910	1.00000	1.9203592 .167
LGC1	.10700	1.00000	2.7795892 .097
LGD1	-.03970	1.00000	.37876966 .539
LGE1	.03201	1.00000	.24614759 .620
LGF1	-.19432	1.00000	9.4177344 .002
LGG1	.72325	1.00000	263.23399 0
LGH1	.08166	1.00000	1.6111902 .206
LGI1	-.02207	1.00000	.11695203 .733

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE..   LGSS

VARIABLE(S) ENTERED ON STEP NUMBER 2.. LGG1

MULTIPLE R	.84412	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.71254	REGRESSION	2.	9.62513	4.81256	297.44769	.000
ADJUSTED R SQUARE	.71014	RESIDUAL	240.	3.88309	.01618		
STD DEVIATION	.12720	COEFF OF VARIABILITY	2.7 PCT				

------------------- VARIABLES IN THE EQUATION -------------------

VARIABLE	B	STD ERROR B	F	SIGNIFICANCE	BETA	ELASTICITY
LGJ1	-2.7419364	.15056011	331.66140	0	-.6302770	-.12338
LGG1	4.0940594	.25233829	263.23399	0	.5615067	.18608
(CONSTANT)	4.4601895	.63909821E-01	4870.4762	0		

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F	SIGNIFICANCE
LGA1	-.83198	1.00000	537.46007	0
LGB1	-.12901	1.00000	4.0453499	.045
LGC1	.15494	1.00000	5.8786567	.016
LGD1	-.05748	1.00000	.79226959	.374
LGE1	.04635	1.00000	.51455262	.474
LGF1	-.28138	1.00000	20.549334	.000
LGH1	.11825	1.00000	3.3892362	.067
LGI1	-.03196	1.00000	.24433563	.622

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. LGS8

VARIABLE(S) ENTERED ON STEP NUMBER 3.. LGA1

MULTIPLE R	.95473	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.91152	REGRESSION	3.	12.31297	4.10432	820.69851	0
ADJUSTED R SQUARE	.91041	RESIDUAL	239.	1.19524	.00500		
STD DEVIATION	.07072	COEFF OF VARIABILITY	1.5 PCT				

------------------- VARIABLES IN THE EQUATION -------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
LGJ1	-2.7419364	.83705882E-01	1073.0076 0	-.6302770 -.12338
LGG1	4.0940594	.14029081	851.62784 0	.5619067 .18608
LGA1	-3.1441882	.13562365	537.46067 0	-.4460701 -.04420
(CONSTANT)	4.6705375	.36671691E-01	16220.784 0	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE
LGB1	-.23254	1.00000	13.605355 .000
LGC1	.27927	1.00000	20.132167 .000
LGD1	-.10360	1.00000	2.5823962 .109
LGE1	.08354	1.00000	1.6727761 .197
LGF1	-.50717	1.00000	82.416440 .000
LGH1	.21314	1.00000	11.326020 .001
LGI1	-.05760	1.00000	.79229455 .374

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. LGSS

VARIABLE(S) ENTERED ON STEP NUMBER 4.. LGF1

MULTIPLE R	.96658	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.93428	REGRESSION	4.	12.62041	3.15510	845.80901	.000
ADJUSTED R SQUARE	.93317	RESIDUAL	238.	.88781	.00373		
STD DEVIATION	.06108	COEFF OF VARIABILITY	1.3 PCT				

------------------------ VARIABLES IN THE EQUATION ------------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
LGJ1	-2.7419364	.72293214E-01	1438.5326 0	-.6302770 -.12330
LGG1	4.0940594	.12116321	1141.7388 .000	.5615067 .18608
LGA1	-3.1441882	.11713238	720.54829 .000	-.4460701 -.04420
LGF1	-.49394624	.54409253E-01	82.416440 .000	-.1508615 -.01767
(CONSTANT)	4.7545981	.32997565E-01	20761.744 0	

----------- VARIABLES NOT IN THE EQUATION -----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE
LGB1	-.26981	1.00000	18.600119 .000
LGC1	.32404	1.00000	27.604249 0
LGD1	-.12021	1.00000	3.4750973 .064
LGE1	.09693	1.00000	2.2480468 .135
LGH1	.24730	1.00000	15.430426 .000
LGI1	-.06683	1.00000	1.0634004 .303

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE..   LGSS

VARIABLE(S) ENTERED ON STEP NUMBER 5.. LGC1

MULTIPLE R	.97014	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.94118	REGRESSION	5.	12.71363	2.54273	758.41403	0
ADJUSTED R SQUARE	.93994	RESIDUAL	237.	.79459	.00335		
STD DEVIATION	.05790	COEFF OF VARIABILITY	1.2 PCT				

------------------- VARIABLES IN THE EQUATION -------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
LGJ1	-2.7419364	.68536755E-01	1600.5443 0	-.6302770 -.12338
LGG1	4.0940590	.11486740	1270.3247 0	.5615067 .18608
LGA1	-3.1441882	.11104602	801.69852 0	-.0060701 -.04420
LGF1	-.49394624	.51582070E-01	91.698418 0	-.1508615 -.01767
LGC1	.42538428	.80672563E-01	27.804249 0	.0830717 .01680
(CONSTANT)	4.6746679	.34762092E-01	18083.801 0	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE
LGB1	-.28520	1.00000	20.895928 .000
LGD1	-.12707	1.00000	3.8730665 .050
LGE1	.10246	1.00000	2.5039702 .115
LGH1	.26140	1.00000	17.309120 .000
LGI1	-.07065	1.00000	1.1837657 .278

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. LGS8

VARIABLE(S) ENTERED ON STEP NUMBER 6.. LGB1

MULTIPLE R	.97261	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.94596	REGRESSION	6.	12.77826	2.12971	688.55113	.000
ADJUSTED R SQUARE	.94459	RESIDUAL	236.	.72996	.00309		
STD DEVIATION	.05562	COEFF OF VARIABILITY	1.2 PCT				

------------------------- VARIABLES IN THE EQUATION -------------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
LGJ1	-2.7419364	.65829279E-01	1734.9085 0	-.6302770 -.12338
LGG1	4.0940594	.11032967	1376.9672 0	.5615067 .18608
LGA1	-3.1441882	.10665926	869.00036 0	-.4460701 -.04420
LGF1	-.49394624	.49544372E-01	99.396414 0	-.1508615 -.01767
LGC1	.42538428	.77485674E-01	30.138390 .000	.0830717 .01680
LGB1	-.23365900	.51115400E-01	20.895928 .000	-.0691710 -.00597
(CONSTANT)	4.7030690	.33961999E-01	19176.804 0	

----------- VARIABLES NOT IN THE EQUATION -----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE
LGD1	-.13257	1.00000	4.2042406 .041
LGE1	.10690	1.00000	2.7166796 .101
LGH1	.27273	1.00000	18.884504 .000
LGI1	-.07371	1.00000	1.2836888 .258

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. LGSS

VARIABLE(S) ENTERED ON STEP NUMBER 7.. LGHI

MULTIPLE R	.97467	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.94998	REGRESSION	7.	12.83255	1.83322	637.60988	0
ADJUSTED R SQUARE	.94849	RESIDUAL	235.	.67566	.00288		
STD DEVIATION	.05362	COEFF OF VARIABILITY	1.1 PCT				

------------------ VARIABLES IN THE EQUATION ------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
LGJ1	-2.7419364	.63468320E-01	1866.3829 0	-.6302770 -.12338
LGG1	4.0940594	.10637271	1481.3163 0	.5615067 .18608
LGA1	-3.1441882	.10283394	934.85477 0	-.4460701 -.04420
LGF1	-.49394624	.47767469E-01	106.92885 0	-.1508615 -.01767
LGC1	.42538428	.74706660E-01	32.422331 0	.0830717 .01680
LGB1	-.23365900	.49282153E-01	22.479459 .000	-.0691710 -.00597
LGH1	.34516214	.79427403E-01	18.884504 .000	.0633992 .01348
(CONSTANT)	4.6389342	.35916274E-01	16682.221 0	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE
LGD1	-.13780	1.00000	4.5292792 .034
LGE1	.11112	1.00000	2.9252190 .089
LGI1	-.07661	1.00000	1.3815505 .241

* M U L T I P L F   R E G R E S S I O N *

DEPENDENT VARIABLE..   LGB8

VARIABLE(S) ENTERED ON STEP NUMBER 8.. LGD1

MULTIPLE R	.97516	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.95093	REGRESSION	8.	12.84538	1.60567	566.85358	.000
ADJUSTED R SQUARE	.94925	RESIDUAL	234.	.66283	.00283		
STD DEVIATION	.05322	COEFF OF VARIABILITY	1.1 PCT				

------------------------- VARIABLES IN THE EQUATION -------------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
LGJ1	-2.7419364	.62997032E-01	1894.4126 0	-.6302770 -.12330
LGG1	4.0940594	.10558284	1503.5630 0	.5615067 .18600
LGA1	-3.1441882	.10207034	948.89460 0	-.4460781 -.04420
LGF1	-.49394624	.47412769E-01	108.53473 0	-.1508615 -.01767
LGC1	.42538428	.74151921E-01	32.909256 .000	.0830717 .01600
LGB1	-.23365900	.48916205E-01	22.817099 .000	-.0691710 -.00597
LGH1	.34516214	.78837610E-01	19.168115 .000	.0633992 .01348
LGD1	-.80014855E-01	.37597266E-01	4.5292752 .034	-.0308183 -.00230
(CONSTANT)	4.6498790	.36018607E-01	16665.927 0	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE
LGE1	.11219	1.00000	2.9698149 .086
LGI1	-.07735	1.00000	1.4024336 .238

*** M U L T I P L E   R E G R E S S I O N ***

DEPENDENT VARIABLE.. LGS8

VARIABLE(S) ENTERED ON STEP NUMBER 9.. LGE1

MULTIPLE R	.97547	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.95155	REGRESSION	9.	12.85372	1.42819	508.44141	0
ADJUSTED R SQUARE	.94968	RESIDUAL	233.	.65449	.00281		
STD DEVIATION	.05300	COEFF OF VARIABILITY	1.1 PCT				

------------------ VARIABLES IN THE EQUATION ------------------

VARIABLE	B	STD ERROR B	F / SIGNIFICANCE	BETA / ELASTICITY
LGJ1	-2.7419364	.62733940E-01	1910.3598 0	-.6302770 -.12338
LGG1	4.0940594	.10514122	1516.2200 0	.5615067 .10608
LGA1	-3.1441882	.10164341	956.88241 0	-.4460701 -.04020
LGF1	-.49394624	.47214459E-01	109.44838 0	-.1508615 -.01767
LGC1	.42538428	.73841772E-01	33.186286 0	.0830717 .01680
LGB1	-.23365904	.48711607E-01	23.009134 .000	-.0691710 -.00597
LGH1	.34516214	.78507863E-01	19.329472 .000	.0633992 .01348
LGD1	-.80014855E-01	.37440011E-01	4.5674027 .034	-.0308183 -.00230
LGE1	.19266186	.11179723	2.9698149 .086	.0248507 .00689
(CONSTANT)	4.6170915	.40601636E-01	12931.530 0	

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F / SIGNIFICANCE
LGI1	-.07784	1.00000	1.4143217 .236

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE..   LGS8

VARIABLE(S) ENTERED ON STEP NUMBER 10..   LGI1

MULTIPLE R	.97562	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F	SIGNIFICANCE
R SQUARE	.95184	REGRESSION	10.	12.85769	1.28577	458.55241	.000
ADJUSTED R SQUARE	.94977	RESIDUAL	232.	.65052	.00280		
STD DEVIATION	.05295	COEFF OF VARIABILITY	1.1 PCT				

-------------------- VARIABLES IN THE EQUATION --------------------

VARIABLE	B	STD ERROR B	F	SIGNIFICANCE	BETA	ELASTICITY
LGJ1	-2.7419364	.62677838E-01	1913.7568	0	-.6302770	-.12338
LGG1	4.0940594	.10504787	1518.9161	0	.5615067	.18608
LGA1	-3.1441882	.10155316	958.58394	.000	-.4460701	-.04420
LGF1	-.49394624	.47172537E-01	109.64300	0	-.1508615	-.01767
LGC1	.42538428	.73776207E-01	33.245299	.000	.0830717	.01680
LGB1	-.23365904	.48668356E-01	23.050049	.000	-.0691710	-.00597
LGH1	.34516214	.78438154E-01	19.363844	.000	.0633992	.01348
LGD1	-.80014855E-01	.37406768E-01	4.5759244	.033	-.0308183	-.00230
LGE1	.19266186	.11169797	2.9750958	.086	.0248507	.00689
LGI1	-.14777351	.12425746	1.4143217	.236	-.0171341	-.00652
(CONSTANT)	4.6481231	.48233075E-01	9286.7840	0		

---------- VARIABLES NOT IN THE EQUATION ----------

VARIABLE	PARTIAL	TOLERANCE	F
			SIGNIFICANCE

ALL VARIABLES ARE IN THE EQUATION.

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. LGSS

COEFFICIENTS AND CONFIDENCE INTERVALS.

VARIABLE	B	STD ERROR B	T	95.0 PCT CONFIDENCE INTERVAL	
LGJ1	-2.7419364	.62677838E-01	-43.746507	-2.8654269 ,	-2.6184459
LGG1	4.0940594	.10504787	38.973275	3.8870897 ,	4.3010291
LGA1	-3.1441882	.10155316	-30.961007	-3.3442725 ,	-2.9441039
LGF1	-.49394624	.47172537E-01	-10.471055	-.58688755 ,	-.40100493
LGC1	.42538428	.73776207E-01	5.7658736	.28002731 ,	.57074126
LGB1	-.23365904	.48668356E-01	-4.8010466	-.32954748 ,	-.13777061
LGH1	.34516214	.78438154E-01	4.4004368	.19062008 ,	.49970428
LGD1	-.80014855E-01	.37406768E-01	-2.1390476	-.15371524 ,	-.63144719E-02
LGE1	.19266186	.11169797	1.7248466	-.27410162E-01,	.41273388
LGI1	-.14777351	.12425746	-1.1892526	-.39259077 ,	.97043755E-01
CONSTANT	4.6481231	.48233075E-01	96.367962	4.5530923 ,	4.7431539

VARIANCE/COVARIANCE MATRIX OF THE UNNORMALIZED REGRESSION COEFFICIENTS.

	LGA1	LGB1	LGC1	LGD1	LGE1	LGF1	LGG1	LGH1	LGI1	LGJ1
LGA1	.01031									
LGB1	.00000	.00237								
LGC1	.00000	.00000	.00544							
LGD1	.00000	.00000	.00000	.00140						
LGE1	.00000	.00000	.00000	.00000	.01248					
LGF1	.00000	.00000	.00000	.00000	.00000	.00223				
LGG1	.00000	.00000	.00000	.00000	.00000	.00000	.01104			
LGH1	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00615		
LGI1	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.01544	
LGJ1	.00000	-.00000	-.00000	.00000	.00000	.00000	-.00000	-.00000	-.00000	.00393

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE..   LGSS

S U M M A R Y   T A B L E

STEP	VARIABLE ENTERED	VARIABLE REMOVED	F TO ENTER OR REMOVE	SIGNIFICANCE	MULTIPLE R	R SQUARE	R SQUARE CHANGE	SIMPLE R	OVERALL F	SIGNIFICANCE
1	LGJ1		158,83346	0	,63028	,39725	,39725	-,63028	158,83346	0
2	LGG1		263,23399	0	,84412	,71254	,31529	,56151	297,44769	,000
3	LGA1		537,46007	0	,95473	,91152	,19898	-,44607	820,69851	0
4	LGF1		82,41644	,000	,96658	,93428	,02276	-,15086	845,80901	,000
5	LGC1		27,80425	0	,97014	,94118	,00690	,08307	758,41403	0
6	LGB1		20,89593	,000	,97261	,94596	,00478	-,06917	688,55113	,000
7	LGH1		18,88450	,000	,97467	,94998	,00402	,06340	637,60988	0
8	LGD1		4,52928	,034	,97516	,95093	,00095	-,03082	566,85358	,000
9	LGE1		2,96981	,086	,97547	,95155	,00062	,02485	508,44141	0
10	LGI1		1,41432	,236	,97562	,95184	,00029	-,01713	458,55241	,000

APPENDIX D.2

NON-LINEAR REGRESSION ANALYSIS

BMD07R - NON LINEAR LEAST SQUARES - REVISED NOVEMBER 19,1971

HEALTH SCIENCES COMPUTING FACILITY, UCLA

PROBLM CODE	CRKSP
NUMBER OF VARIABLES	7
INDEX OF THE DEPENDENT VARIABLE	7
INDEX OF THE WEIGHTING VARIABLE	-0
NUMBER OF CASES	243
NUMBER OF PARAMETERS	7
TOLERANCE	.000010
EPSILON	.000010
MAXIMUM NUMBER OF ITERATIONS	2
NUMBER OF VARIABLE FORMAT CARDS	1
ALTERNATE INPUT TAPE NUMBER	5
REWIND OPTION	NO
VARIABLE FORMAT	(F5.0,20X,F5.4,F5.0,3F5.3,F10.3,20X)

```
VERS 4.6 MNF,I=BMDSCR7,L=OUTPUT,E=4,Z,B=BMDSCR8.

                      SUBROUTINE FUN(F,D,P,X)
 000000B              DIMENSION X(1), D(1), P(1)
                C
                C      FUNCTION DEFINITION SUBROUTINE FOR BMD07R.
                C
 000000B              A=1000.
 000000B              B=1.
 000002B              C=2.
 000003B              F=(P(7))/((X(1)/A+B)**P(1))/((X(2)*A+B)**P(2))*((X(3)/A+B)**P(3))
                    41*((X(4)/C+B)**P(4))*((X(5)+B)**P(5))/((X(6)+B)**P(6))
 000052B              D(1)=(-ALOG(X(1)/A+B))*(P(7))/((X(1)/A+B)**P(1))/((X(2)*A+B)**P(2)
                    51)*((X(3)/A+B)**P(3))*((X(4)/C+B)**P(4))*((X(5)+B)**P(5))/((X(6)+B)
                    52**P(6))
 000125B              D(2)=(-ALOG(X(2)*A+B))*(P(7))/((X(1)/A+B)**P(1))/((X(2)*A+B)**P(2)
                    61)*((X(3)/A+B)**P(3))*((X(4)/C+B)**P(4))*((X(5)+B)**P(5))/((X(6)+B)
                    62**P(6))
 000200B              D(3)=(ALOG(X(3)/A+B))*(P(7))/((X(1)/A+B)**P(1))/((X(2)*A+B)**P(2))
                    71*((X(3)/A+B)**P(3))*((X(4)/C+B)**P(4))*((X(5)+B)**P(5))/((X(6)+B)*
                    72*P(6))
 000252B              D(4)=(ALOG(X(4)/C+B))*(P(7))/((X(1)/A+B)**P(1))/((X(2)*A+B)**P(2))
                    81*((X(3)/A+B)**P(3))*((X(4)/C+B)**P(4))*((X(5)+B)**P(5))/((X(6)+B)*
                    82*P(6))
 000324B              D(5)=(ALOG(X(5)+B))*(P(7))/((X(1)/A+B)**P(1))/((X(2)*A+B)**P(2))*(
                    91(X(3)/A+B)**P(3))*((X(4)/C+B)**P(4))*((X(5)+B)**P(5))/((X(6)+B)**P
                    92(6))
 000376B              D(6)=(-ALOG(X(6)+B))*(P(7))/((X(1)/A+B)**P(1))/((X(2)*A+B)**P(2))*
                   101((X(3)/A+B)**P(3))*((X(4)/C+B)**P(4))*((X(5)+B)**P(5))/((X(6)+B)**
                   102P(6))
 000451B              D(7)=1/((X(1)/A+B)**P(1))/((X(2)*A+B)**P(2))*((X(3)/A+B)**P(3))*((
                   111X(4)/C+B)**P(4))*((X(5)+B)**P(5))/((X(6)+B)*P(6))
 000516B              RETURN
 000520B              END
```

MINIMA		-10.0000E+19	-10.0000E+19	-10.0000E+19	-10.0000E+19	-10.0000E+19	-10.0000E+19	-10.0000E+19
MAXIMA		10.0000E+19	10.0000E+19	10.0000E+19	10.0000E+19	10.0000E+19	10.0000E+19	10.0000E+19

ITERATION	ERROR MEAN SQUARE	PARAMETERS						
0 0	45.1294E-01	52.0070E-01	17.9230E-01	66.9500E-01	11.5300E-01	21.8690E-01	46.0030E-01	13.2190E-01
1 0	44.4390E-01	40.3438E-01	18.7340E-01	63.3000E-01	16.9639E-01	26.7157E-01	62.4873E-01	17.2172E-01
2 11	44.4399E-01	40.3454E-01	18.7343E-01	63.3001E-01	16.9632E-01	26.7144E-01	62.4898E-01	17.2200E-01

THE PROCESS IS NOT CONVERGING

ASYMPTOTIC STANDARD DEVIATIONS OF THE PARAMETERS

21.7197E-02 99.0527E-03 23.5256E-02 14.6043E-02 22.5962E-02 67.9431E-02 12.5340E-02

ASYMPTOTIC CORRELATION MATRIX OF THE PARAMETERS

	1	2	3	4	5	6	7
1	1.00000	-.00244	.04108	.02171	.03375	-.07756	-.07106
2	-.00244	1.00000	.05841	.12519	.12331	-.00176	-.00957
3	.04108	.05841	1.00000	-.07678	-.17415	.60500	.54832
4	.02171	.12519	-.07678	1.00000	.08361	.35858	.31371
5	.03375	.12331	-.17415	.08361	1.00000	.53412	.47451
6	-.07756	-.00176	.60500	.35858	.53412	1.00000	.94816
7	-.07106	-.00957	.54832	.31371	.47451	.94816	1.00000

```
BMD07R - NON LINEAR LEAST SQUARES - REVISED NOVEMBER 19,1971

HEALTH SCIENCES COMPUTING FACILITY, UCLA

PROBLM CODE                         CRKWI

NUMBER OF VARIABLES                     5

INDEX OF THE DEPENDENT VARIABLE         5

INDEX OF THE WEIGHTING VARIABLE        -0

NUMBER OF CASES                       243

NUMBER OF PARAMETERS                    5

TOLERANCE                         .000010

EPSILON                           .000010

MAXIMUM NUMBER OF ITERATIONS            5

NUMBER OF VARIABLE FORMAT CARDS         1

ALTERNATE INPUT TAPE NUMBER             5

REWIND OPTION                        NO

VARIABLE FORMAT                 (F5.0,25X,F5.0,5X,2F5.3,10X,F10.5,10X)
```

```
VERS 4.6 MNF,I=BMDSCR7,L=OUTPUT,E=4,Z,B=BMDSCR8.                          UT2D 6400 17

                              SUBROUTINE FUN(F,D,P,X)
 0000008                      DIMENSION X(1), D(1), P(1)
                        C
                        C      FUNCTION DEFINITION SUBROUTINE FOR BMD07R.
                        C
 0000008                      A=1000.
 0000008                      B=1.
 0000028                      F=(P(5))/((X(1)/A+B)**P(1))*((X(2)/A+B)**P(2))*((X(3)+B)**P(3))/((
                            01X(4)+B)**P(4))
 0000338                      D(1)=(-ALOG(X(1)/A+B))*(P(5))/((X(1)/A+B)**P(1))*((X(2)/A+B)**P(2)
                            11)*((X(3)+B)**P(3))/((X(4)+B)**P(4))
 0000708                      D(2)=(ALOG(X(2)/A+B))*(P(5))/((X(1)/A+B)**P(1))*((X(2)/A+B)**P(2))
                            21*((X(3)+B)**P(3))/((X(4)+B)**P(4))
 0001258                      D(3)=(ALOG(X(3)+B))*(P(5))/((X(1)/A+B)**P(1))*((X(2)/A+B)**P(2))*(
                            31(X(3)+B)**P(3))/((X(4)+B)**P(4))
 0001628                      D(4)=(-ALOG(X(4)+B))*(P(5))/((X(1)/A+B)**P(1))*((X(2)/A+B)**P(2))*
                            41((X(3)+B)**P(3))/((X(4)+B)**P(4))
 0002178                      D(5)=1/((X(1)/A+B)**P(1))*((X(2)/A+B)**P(2))*((X(3)+B)**P(3))/((X(
                            514)+B)**P(4))
 0002518                      RETURN
 0002538                      END
```

MINIMA		-10.0000E+19	-10.0000E+19	-10.0000E+19	-10.0000E+19	-10.0000E+19
MAXIMA		10.0000E+19	10.0000E+19	10.0000E+19	10.0000E+19	10.0000E+19

ITERATION		ERROR MEAN SQUARE	PARAMETERS				
0	0	16.0995E-05	49.1400E-01	65.3020E-01	22.0080E-01	45.4960E-01	93.2000E-04
1	0	15.3704E-05	40.1575E-01	58.0864E-01	23.1980E-01	50.0834E-01	13.3376E-03
2	0	13.2767E-05	41.0601E-01	59.0439E-01	23.1785E-01	50.2882E-01	13.8339E-03
3	0	13.2747E-05	40.9444E-01	58.9154E-01	23.1737E-01	50.2876E-01	13.8927E-03
4	0	13.2746E-05	40.9520E-01	58.9242E-01	23.1744E-01	50.2867E-01	13.8863E-03
5	0	13.2746E-05	40.9515E-01	58.9236E-01	23.1743E-01	50.2867E-01	13.8867E-03

THE PROCESS IS NOT CONVERGING

ASYMPTOTIC STANDARD DEVIATIONS OF THE PARAMETERS

16.1272E-02	19.3564E-02	18.0811E-02	13.7909E-02	20.9336E-04

ASYMPTOTIC CORRELATION MATRIX OF THE PARAMETERS

	1	2	3	4	5
1	1.00000	.00000	.00000	-.00000	.11666
2	.00000	1.00000	.00000	-.00000	-.70907
3	.00000	.00000	1.00000	.00000	-.60139
4	-.00000	-.00000	.00000	1.00000	.34154
5	.11666	-.70907	-.60139	.34154	1.00000

BMD07R - NON LINEAR LEAST SQUARES - REVISED NOVEMBER 19,1971

HEALTH SCIENCES COMPUTING FACILITY, UCLA

PROBLM CODE	STSTR
NUMBER OF VARIABLES	6
INDEX OF THE DEPENDENT VARIABLE	6
INDEX OF THE WEIGHTING VARIABLE	-0
NUMBER OF CASES	243
NUMBER OF PARAMETERS	6
TOLERANCE	.000010
EPSILON	.000010
MAXIMUM NUMBER OF ITERATIONS	2
NUMBER OF VARIABLE FORMAT CARDS	1
ALTERNATE INPUT TAPE NUMBER	5
REWIND OPTION	NO
VARIABLE FORMAT	(F5.0,5X,F5.0,10X,F5.4,F5.0,10X,F5.3,20X,F10.0)

```
VERS 4.6 MNF,I=BMDSCR7,L=OUTPUT,E=4,Z,B=BMDSCR8.

                                SUBROUTINE FUN(F,D,P,X)
  000000B       2.              DIMENSION X(1), D(1), P(1)
                           C
                           C     FUNCTION DEFINITION SUBROUTINE FOR BMD07R.
                           C
  000000B       3.              A=1000.
  000000B       4.              B=1.
  000002B       5.              C=100.
  000003B       6.              F=(P(6))/((X(1)/A+B)**P(1))*((X(2)/C+B)**P(2))/((X(3)*A+B)**P(3))*
                              01((X(4)/A+B)**P(4))/((X(5)+1)**P(5))
  000044B       7.              D(1)=(-ALOG(X(1)/A+B))*(P(6))/((X(1)/A+B)**P(1))*((X(2)/C+B)**P(2)
                              11)/((X(3)*A+B)**P(3))*((X(4)/A+B)**P(4))/((X(5)+B)**P(5))
  000111B       8.              D(2)=(ALOG(X(2)/C+B))*(P(6))/((X(1)/A+B)**P(1))*((X(2)/C+B)**P(2))
                              21/((X(3)*A+B)**P(3))*((X(4)/A+B)**P(4))/((X(5)+B)**P(5))
  000156B       9.              D(3)=(-ALOG(X(3)*A+B))*(P(6))/((X(1)/A+B)**P(1))*((X(2)/C+B)**P(2)
                              31)/((X(3)*A+B)**P(3))*((X(4)/A+B)**P(4))/((X(5)+B)**P(5))
  000223B      10.              D(4)=(ALOG(X(4)/A+B))*(P(6))/((X(1)/A+B)**P(1))*((X(2)/C+B)**P(2))
                              41/((X(3)*A+B)**P(3))*((X(4)/A+B)**P(4))/((X(5)+B)**P(5))
  000270B      11.              D(5)=(-ALOG(X(5)+B))*(P(6))/((X(1)/A+B)**P(1))*((X(2)/C+B)**P(2))/
                              51((X(3)*A+B)**P(3))*((X(4)/A+B)**P(4))/((X(5)+B)**P(5))
  000335B      12.              D(6)=(1)*(P(6))/((X(1)/A+B)**P(1))*((X(2)/C+B)**P(2))/((X(3)*A+B)*
                              61*P(3))*((X(4)/A+B)**P(4))/((X(5)+B)**P(5))
  000400B      13.              RETURN
  000402B      14.              END
```

```
MINIMA                -10.0000E+19-10.0000E+19-10.0000E+19-10.0000E+19-10.0000E+19-10.0000E+19

MAXIMA                 10.0000E+19 10.0000E+19 10.0000E+19 10.0000E+19 10.0000E+19 10.0000E+19

ITERATION     ERROR       PARAMETERS
              MEAN
              SQUARE
   0  0    96.5450E+06 31.4420E-01 42.5380E-02 49.3950E-02 40.9410E-01 27.4190E-01 47.2790E+03
   1  3    91.6146E+06 30.6825E-01 40.2184E-02 46.8470E-02 40.3052E-01 27.5239E-01 47.2790E+03
   2 11    91.6202E+06 30.6772E-01 40.2020E-02 46.8291E-02 40.3008E-01 27.5246E-01 47.2790E+03

THE PROCESS IS NOT CONVERGING

ASYMPTOTIC STANDARD DEVIATIONS OF THE PARAMETERS

           11.7539E-02 80.2013E-03 50.9539E-03 13.0793E-02 77.9020E-03 88.7159E-03

ASYMPTOTIC CORRELATION MATRIX OF THE PARAMETERS

              1           2           3           4           5           6
   1       1.00000     -.00000     -.00000     -.00000      .00000      .15781
   2       -.00000     1.00000     -.00000      .00000     -.00000     -.39926
   3       -.00000     -.00000     1.00000     -.00000      .00000      .21022
   4       -.00000      .00000     -.00000     1.00000     -.00000     -.79389
   5        .00000     -.00000      .00000     -.00000     1.00000      .36354
   6        .15781     -.39926      .21022     -.79389      .36354     1.00000
```

THE AUTHORS

Christopher S. Noble is an Assistant Professor of Civil Engineering at The University of Texas at Austin. He gained experience in the design of composite, prestressed concrete and steel box girder bridges as well as other reinforced and prestressed concrete structures with the New South Wales Public Works Department in Australia. His research interests include applications of probabilistics, statistics, and decision analysis to civil engineering in general and pavement design in particular. He is presently concerned with research in the areas of pavement design and rehabilitation management systems, economic modelling and design, and distress prediction models for continuously reinforced concrete pavements.

B. Frank McCullough is a Professor of Civil Engineering at The University of Texas at Austin. He has interests in pavements and pavement design and has developed design methods for continuously reinforced concrete pavements currently used by the State Department of Highways and Public Transportation, U.S. Steel Corporation, and others. He has over 250 published technical papers and reports to his credit.

James Ma earned his B.S. and M.S. degrees in Civil Engineering at The University of Texas at Austin in 1974 and 1977. In 1977, he joined the Austin Research Engineers, Inc. doing analysis of jointed reinforced concrete pavement, jointed concrete pavement and pavement design for guideways. He is well versed in the latest analytical methods for rigid pavements including (1) finite elements, (2) discrete element methods, (3) JCP (FHWA method), and (4) CRCP methods developed in NCHRP project 1-15. While pursuing his Master's degree, Mr. Ma worked as an Assistant Research Engineer at The University of Texas at Austin, during which time he prepared a report for the Center for Highway Research on improved computer methods for analysis of continuously reinforced concrete pavement.