ANALYSIS OF RESULTS FROM

TELLTALE-INSTRUMENTED STATIC PILE LOADING TESTS

Quee Soon Lee

B.A.Sc.

A thesis

submitted in partial fulfillment of the

requirements for the degree of

Master of Engineering

Under the supervision of

Dr. Bengt H. Fellenius

Department of Civil Engineering

University of Ottawa

Ottawa, Canada

April 27, 1988

UNIVERSITY OF OTTAWA
FACULTY OF SCIENCE AND ENGINEERING
DEPARTMENT OF CIVIL ENGINEERING

CERTIFICATE OF APPROVAL

The thesis by

QUEE SOON LEE

entitled

Analysis of results from
telltale-instrumented static pile loading tests

is accepted in partial fulfillment
of the requirements for the degree of
Master of Engineering

April 27, 1988

Dr. Erman Evgin, P. Eng. Associate Professor	Dr. Bengt H. Fellenius, P.Eng. Professor, Supervisor

SUMMARY

Numerical procedures for analysis of results from a telltale-instrumented static loading test have been developed for the IBM-PC and compatible machines. The theory of the methods of analysis, program, user's manual, and examples of analysis are presented in this report.

The objectives of the study were to develop interactive numerical procedures to determinate load distribution in a test pile.

The numerical procedures for load distribution analysis were based on limit equilibrium method as proposed by Leonards and Lovell (1979). In this study, the Leonards-Lovell method was generalized for multiple telltales by discretizing the pile at telltale locations. Leonards-Lovell method was expanded to include residual (locked-in) stress and strain, and an iterative procedure to account for variation of elastic modulus in a non-linear elastic pile. Results were also included for graphical determination of the applied load at full shaft resistance mobilization based on Leonards-Lovell proposal.

A numerical method for determining quantitatively the potential amount of residual strain along the length of the pile was developed using the redundant equilibrium, stress-strain relationship, and stress compatibility equations in segments between telltales.

To illustrate the above objectives, two examples were performed using field results from two static tests on telltale instrumented piles.

The load distribution analysis of the examples with consideration of residual compression and variation of elastic modulus in the test loaded pile was found to be significantly different from results obtained using the conventional elastic column approach.

ACKNOWLEDGEMENTS

The Author expresses his appreciation for the stimulating discussions and criticism given by his colleagues Dr. Amintore Fusco and Mr. Nizamudeen Khan throughout this project. The help of Mr. Richard Moore in maintaining the micro-computer is gratefully acknowledged. Sincere thanks are due to my wife Ku Ing for her support.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

NOTATIONS AND SYMBOLS

A	Cross-sectional area of pile
b	Diameter of pile
C	Ratio of compression of a pile due to applied head load, R_s, supported entirely by shaft resistance over the corresponding column compression.
C'	Ratio of measured pile compression over the theoretical column compression.
D	Depth of pile embedment
E	Elastic modulus of pile
L	Length of pile
n	Constant; when plot of Q vs δ is linear
N	Normalised contribution of shaft resistance
Q	Applied load on pile head
Q(z)	Load function along the pile
r_s	Unit shaft resistance
$r_s(z)$	Shaft resistance function along the pile
R_u	Ultimate pile resistance
R_s	Total shaft resistance
R_t	Total toe resistance
z	Depth below the ground surface
Δ	Pile head movement
δ	Axial pile compression
δ_e	Elastic pile compression assuming toe bearing only
δ_s	Elastic compression of soil at pile toe
δ_{sp}	Limiting plastic compression of soil at pile toe
δ_{Rt}	Compression due to load, R_t
δ_{Rs}	Compression due to load, R_s
δ_{col}	Column compression due to point load
σ	Stress in pile
ϵ	Strain in pile
α	Ratio of toe resistance to applied load on pile head

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Piles are structural foundation members which have small diameter to length ratio. They are used primarily to transmit foundation loads through less competent soil to bearing in more competent soil located at greater depth. In the design of pile foundations, it is necessary to be able to determine pile capacity. This is done by means of theoretical analysis as well as in-situ testing. The axial compression loading test is the most common in-situ test used to investigate pile capacity. A loading test consists of applying load to the pile head by jacking against a reaction system. The magnitude and duration of each load increment depend on the chosen test procedure.

In a conventional pile test programme, measurements are limited to recording applied load and head movement. This restricts the test results to determination of total capacity. To make possible a separation of the capacity on shaft and toe resistance requires measurements of pile stress and/or pile compression along various points in the pile using telltales or other types of strain gauges.

Leonards and Lovell (1979) presented a method for separation of shaft and toe resistances in the analysis of results from a telltale-instrumented loading test. The method builds on the pile-head load-movement data and the shortening of the pile as measured with a telltale to the pile toe. In this Thesis, the analysis according to Leonards-Lovell method has been generalized to include more than one telltale and expanded to include the effect of residual stress, and non-linear elastic pile behaviour. The analysis methods have been developed for use in a computer program.

Telltales are displacement reference rods which ends are grouted or anchored in the pile at selected locations. The deformation between the pile head and the telltale end is obtained by mounting a dial gauge at the upper end of the telltale rod and referencing the gauge to a reference plate at the pile head. The telltale rods are normally enclosed in oil-filled guide pipes or polyethylene tubes to enable friction-free measurements. The measurements over known lengths enable a detailed analysis of strain along the pile, load distribution, and deformation behaviour of the tested pile.

For a representative load distribution analysis of a pile, it is necessary to place several telltales in the pile. The analysis is complicated by the influence of residual (locked-in) stress, variation of pile elastic modulus, and variation of shaft resistance distribution.

1.2 STATEMENT OF THE PROBLEM

In conventional analysis of telltale instrumented loading tests, the effect of residual strain (locked-in strain) is not accounted for. However, the residual strain has a considerable influence on the load distribution evaluated from the telltale data.

In this report, a numerical procedure is developed to determine the residual load in a pile by combining data from two or more telltales. The principle of the analysis is based on forcing an agreement between the load distribution determined from one telltale to that determined from another (usually the toe telltale). The agreement is obtained by means of adding residual compression to the compression measured by the first telltale.

1.3 OBJECTIVE

The objective of this study is to develop an interactive numerical procedures for analysis of results from a telltale-instrumented static loading test using a computer.

1.4 SCOPE

The scope of this study is confined to development of numerical procedures to obtain load distribution along the test loaded pile. The numerical procedures for determination of load distribution is based on an expanded Leonards-Lovell method. To account for elastic modulus variation along the pile, an updating procedure for elastic modulus is adopted. The expanded Leonards-Lovell method includes consideration of residual strain (locked-in strain). To determine the residual compression in each segment, a matching procedure is used for a test pile with more than one telltale.

1.5 OUTLINE OF REPORT

Chapter 2 presents a literature review of limit load and load distribution analyses.

The limit load reviews the methods proposed by Chin (1970), Brinch Hansen (1963), Butler and Hoy (1977), and Davisson (1972).

The load distribution analysis reviews the method proposed by Leonards and Lovell (1979). Chapter 2 also presents the Leonards-Lovell method including the analysis of results from tests using more than one telltale, procedure for considering variation of elastic modulus, and locked-in (residual) stress or strain. Finally, a method is presented for determining quantitatively the potential amount of residual strain.

Chapter 3 details the computer programs and numerical procedures adopted to implement the load distribution analyses.

Chapter 4 contains the User's Manual showing the program flow from screen to screen. Two examples are used to illustrate the use of the program.

Chapter 5 contains general conclusions on the use and limitations of the computer programs.

CHAPTER 2

LITERATURE REVIEW AND THEORETICAL BACKGROUND

2.1 INTRODUCTION

The capacity or ultimate resistance of a statically test loaded pile is reached when the loading causes rapid progressive deformation. The applied load at this occurrence is called limit load or failure load. The limit load is reached when the applied load on the pile has exhausted both the ultimate shaft and toe resistance that the soil could provide. The typical load-movement curve is approximately parabolic or hyperbolic when the applied load approaches the limit load.

In practice, however, the limit load is usually not well defined. This has led to development of numerous semi-empirical criteria for determining the ultimate resistance. Most criteria in use define the ultimate resistance from the shape of the load-movement curve. In this study, the numerical procedures for determining ultimate resistance are restricted to methods for limit load proposed by Chin (1970), Brinch Hansen (1963), Butler and Hoy (1977), and Davisson (1972). These methods and others are presented by Fellenius (1975; 1980).

Theoretical methods available for load distribution and load-movement analysis of pile subjected to a loading test can be divided into transfer function methods, elasticity based solutions, and finite element methods.

Transfer function methods are formulated based on satisfying force equilibrium, moment equilibrium, and measured (or empirical) relationships between pile resistance and pile movement at various points along the pile.

Elasticity based solution and finite element methods are based on continuum mechanics theory.

The methods provide reasonable values of load-movement and load distribution for a pile provided that the constituitive equations of the medium and the pile-soil interaction can be modelled appropriately (Vesic, 1970; Poulos and Davis, 1980).

However, there are some shortcomings of the theoretical methods in calculating the load-movement and load distribution which can be overcome by means of telltales or other means for measurements of strain. The measurements provide data for analysis of load distribution based on force equilibrium, stress-strain relationship, and stress compatibility equations in the pile.

The methods commonly used for analysis of load distribution are:

1) Elastic column method
2) Leonards-Lovell method

In the elastic column method, the average segment load in the pile is obtained from the measured deformations using Hooke's law. Consideration of shaft resistance distribution is not included until after the calculations of the telltale data are completed.

Leonards and Lovell (1979) proposed a method for load distribution analysis of the pile based on elastic theory where the effect of shaft resistance distribution along the pile is considered directly in the calculations.

Residual stress or strain is the locked-in pile compression that occurs prior to the loading test. Rebound of the pile during the pile driving and reconsolidation of the soil after installation are the two main causes of residual stress or strain. Several researchers (e.g., Fellenius and Samson, 1967; Hunter and Davisson, 1969; O'Neill et al., 1982;, and Briaud and Tucker, 1984) have discussed this phenomenon.

Usually engineering materials are assumed to exhibit an approximate linear stress-strain relationship under loading below the yield point. However, the modulus of prestressed concrete piles has been found to vary with stress level as reported by Fellenius (1978), Yu (1984), and Taki (1987).

2.2 LIMIT LOAD ANALYSIS

2.2.1 Chin Method

Based on general work by Kondner (1963), Chin (1970) proposed a method for approximating the load-movement curve approaching failure with a hyperbolic equation in the form of Eq. 2.1a or Eq. 2.1b.

A plot of the test data with the ordinate Δ/Q and the abscissa Δ (Chin's stability plot) usually produces a straight line plot when approaching failure as shown in Fig. 2.1. C_1 is the slope of the straight line and C_2 is the y-intercept of the linear plot.

$$Q = \frac{\Delta}{C_1 \quad + C_2} \tag{2.1a}$$

$$\frac{\Delta}{Q} = C_1\Delta + C_2 \tag{2.1b}$$

where Q = Applied load on pile head
Δ = Pile head movement
C_1 = Constant; slope
C_2 = Constant; y-intercept

The ultimate resistance, R_u, is the asymptote of the hyperbolic curve generated from the test data. The ultimate resistance is the inverse of slope C_1 as given by Eq. 2.2.

$$R_u = \frac{1}{C_1} \tag{2.2}$$

2.2.2 Brinch Hansen 80% Criterion

Brinch Hansen (1963) proposed the 80% criterion for determining the ultimate resistance. The ultimate resistance is defined as the load that gives four times the pile head movement as opposed to the movement obtained at 80% of the load. This method postulates that the load-movement curve is parabolic and in the form of Eq. 2.3a or Eq. 2.3b.

A plot of the test data with the ordinate $\sqrt{\Delta}/Q$ and the abscissa Δ usually produces a straight-line plot when approaching failure as shown in Fig. 2.2. C_1 is the slope of the straight line and C_2 is the y-intercept of the linear plot.

$$Q = \frac{\sqrt{\Delta}}{C_1 \Delta + C_2} \tag{2.3a}$$

$$\frac{\sqrt{\Delta}}{Q} = C_1 \Delta + C_2 \tag{2.3b}$$

where

Q = Applied load on pile head
Δ = Pile head movement
C_1 = Constant; slope
C_2 = Constant; y-intercept

In this criterion, the ultimate resistance, R_u, and the pile head movement at failure, Δ_u, are determined from the following relationships.

$$R_u = \frac{1}{2\sqrt{C_1 \; C_2}} \quad (2.4)$$

$$\Delta_u = \frac{C_2}{C_1} \quad (2.5)$$

2.2.3 Modified Butler and Hoy Method

Butler and Hoy (1977) detailed a method for defining the ultimate resistance as proposed by Nordlund (Chellis, 1961). According to this method, the ultimate resistance is equal to the load at the intersection of the tangent sloping 0.14 mm/KN (0.05 inch/ton) and the tangent to the initial straight portion of the curve.

Fellenius (1980) proposed a modified version of Butler and Hoy method. Ultimate resistance in this criterion is defined as the load at the intersection of tangent sloping 14 mm/KN with the tangent parallel to the elastic line. The limit load construction using this method is shown in Fig. 2.3.

2.2.4 Davisson Offset Limit

Davisson (1972) proposed a method to determine the limit load based on the work using the quick test loading procedure and wave equation analysis. Davisson assumed that the limit load is reached at a head movement defined by Eq.2.6.

$$\Delta = \delta_{[illegible]} + \delta_{[illegible]} + \delta_{[illegible]p} \quad (2.6)$$

where

Δ = Pile head movement

$\delta_{[illegible]}$ = Elastic pile compression assuming toe bearing only

$\delta_{[illegible]}$ = Elastic compression of soil at toe (quake)

$\delta_{[illegible]p}$ = Plastic compression of the soil at toe

Davisson proposed a diameter dependent value of δ_m and δ_{mp} equal to 4 mm (0.15 inch) plus 8% of the pile diameter.

The limit load construction using Davisson offset method is shown in Fig. 2.4. The limit load is defined graphically as the load at the intersection of the offset line and the load-movement curve. The offset line is governed by Eq. 2.7.

$$Q = \frac{AE}{L} \left(\Delta + (4 + 8b)x10^{-3} \right) \qquad (2.7)$$

where

Q = Applied load on pile head
Δ = Pile head movement
b = Diameter of pile
A = Cross-sectional area of pile
E = Elastic modulus of pile
L = Length of pile

2.3 LOAD DISTRIBUTION ANALYSIS BY THE ELASTIC COLUMN METHOD

The load distribution analysis using the elastic column method is adapted from Hooke's Law.

$$\sigma = E\,\epsilon \qquad (2.8)$$

where

σ = Stress
ϵ = Strain
E = Elastic modulus

The average segment load in an axially loaded elastic column using telltale measurements is given by Eq. 2.9.

$$Q_{ave\ i,i+1} = \frac{A_{i,i+1}\ E_{i,i+1}}{L_{i+1} - L_i}(\delta_{i+1} - \delta_i) \qquad (2.9)$$

where

$Q_{ave\ i,i+1}$ = Average load in pile Segment i,i+1
$A_{i,i+1}$ = Pile cross-sectional area in segment i,i+1
$E_{i,i+1}$ = Elastic modulus in Segment i,i+1
L_i = Length from ground surface to Telltale i
L_{i+1} = Length from ground surface to Telltale i+1
δ_i = Axial compression over the length to Telltale i
δ_{i+1} = Axial compression over the length to Telltale i+1

Usually, the average load is assumed to be equal to the load in the pile at the mid-point between ends of Telltales i and i+1. However, this assumption is only valid if the shaft resistance is constant along the pile between the telltale ends, which is rarely the case. Therefore, this method will not give a representative load distribution in the pile using the average load when the gauge length between the telltale is long. The elastic column load method inherently neglects the variation of the load along each segment due to shaft resistance.

2.4 LEONARDS-LOVELL METHOD

2.4.1 Basic definitions

A load distribution analysis was proposed by Leonards and Lovell (1979) as based on satisfying the vertical force equilibrium and elastic stress-strain relationship of the pile. The proposed method gives a continuous load distribution along the pile as based on an assumed shaft resistance distribution.

In an axial compression static test, the vertical forces acting on the pile are shown in Fig. 2.5. The applied load, Q, is the sum of the mobilized shaft and toe resistance components, as follows:

$$Q = R_s + R_t \tag{2.10}$$

Q = Load applied on pile head
R_s = Total shaft resistance
R_t = Total toe resistance

The pile axial compression, δ, under applied head load, Q, can be expressed in terms of compression due to shaft resistance and the portion of the load reaching the pile toe as indicated in Eq. 2.11 and Fig. 2.5.

$$\delta_{measured} = \delta_{Rt} + \delta_{Rs} \tag{2.11}$$

where

δ_{Rt} = Column compression due to toe resistance
δ_{Rs} = Compression due to shaft resistance

From axial elastic compression consideration, the compressions due to toe and shaft resistance, R_t and R_s, are given by Eqs. 2.12 and 2.13, respectively.

$$\delta_{Rt} = \frac{R_t L}{AE} \tag{2.12}$$

$$\delta_{Rs} = \int_0^L \frac{z r_s(z)}{AE} dz \tag{2.13}$$

$r_s(z)$ is the shaft resistance distribution along a unit length of the pile.

2.4.2 Ratios C' and C

Leonards and Lovell (1979) defined a ratio, C', as the ratio of measured pile compression over the theoretical compression of the pile assumed as a freestanding column subjected to the same load, Q. The ratio C' is mathematically expressed by Eq. 2.14.

$$C' \ \delta_{col} = \delta_{measured} \tag{2.14}$$

where

δ_{col} = Theoretical pile column compression

The theoretical column compression under applied head load, Q, is given by Eq. 2.15.

$$\delta_{col} = \frac{QL}{AE} \tag{2.15}$$

Leonards and Lovell (1979) also defined a ratio, C, as the ratio of compression due only to the shaft resistance, R_s, over the corresponding theoretical compression of the pile as a free standing column subjected to the same load, R_s. The ratio C is mathematically expressed by Eq. 2.16.

$$C \ \delta_{Rs,col} = \delta_{Rs} \tag{2.16}$$

where

δ_{Rs} = Compression due to shaft resistance

$\delta_{Rs,col}$ = Column compression due to applied load, R_s

Combining Eqs. 2.11, 2.14, and 2.16 gives Eq. 2.17.

$$C \ \delta_{Rs,col} = C' \ \delta_{col} - \delta_{Rt} \tag{2.17}$$

Substituting values of δ_{col}, $\delta_{Rs\ col}$ and R_t into Eq. 2.17 as given by Eqs. 2.15, 2.16, and 2.10 will give Eqs. 2.18a and 2.18b.

$$C'\frac{QL}{AE} = C\frac{R_s L}{AE} + \frac{R_t L}{AE} \tag{2.18a}$$

$$C'Q = CR_s + R_t \tag{2.18b}$$

2.4.3 Ratio α

It is useful to express a ratio, α, of the toe resistance over the applied load :

$$\alpha = \frac{R_t}{Q} \tag{2.19}$$

Substituting Eqs. 2.10 and 2.18b into 2.19 gives the relationship according to Eq. 2.20.

$$\alpha = \frac{C' - C}{1 - C} \tag{2.20}$$

In Leonards and Lovell method, the separation of the applied load into toe and shaft resistance is obtained by solving for α. The two parameters in Eq. 2.20 governing α are C and C'. C is calculated from the assumed shaft resistance distribution. C' is measured.

Substitution of the values of δ_{Rs} and $\delta_{Rs,col}$ as given by Eqs. 2.13 and 2.21 into Eq. 2.16 will give Eq. 2.22, which is the mathematical definition for the centroid of the areas under the shaft resistance distribution $r_s(z)$.

$$\delta_{Rs,.001} = \int_{o}^{L_i} \frac{r_s(z)}{AE} \, dz \qquad (2.21)$$

$$C = \frac{\int_{o}^{L_i} z \, r_s(z) \, dZ}{\int_{o}^{L_i} r_s(z) \, dZ} \qquad (2.22)$$

2.4.4 Point of full mobilization of shaft resistance

Leonards and Lovell (1979) also proposed a method for determining the applied load at point of full mobilization of shaft resistance.

At the point of full mobilization of shaft resistance, the shaft resistance is assumed to remain at the peak value (i.e plastic failure assumption). At the point of full mobilization of shaft resistance, the rate of change of load transfer in a pile is given by Eq. 2.23.

$$\frac{dR_s}{dQ} = 0 \quad ; \quad \frac{dR_t}{dQ} = 1 \qquad (2.23)$$

Differentiating Eq. 2.18 with respect to Q, gives a coefficient, n, according to Eq. 2.24.

$$n = \frac{AE}{L}\frac{d\delta}{dQ} = C' + Q\frac{dC'}{dQ} \qquad (2.24)$$

The coefficient, n is constant when a plot of applied load, Q, versus measured compression, δ, is linear.

A graphical method to obtain the applied load at point of full mobilization of shaft resistance, based on Eq. 2.24, is shown in Fig. 2.6.

Solving the differential equation Eq. 2.24 gives Eq. 2.25.

$$C' = n - \frac{k}{Q} \tag{2.25}$$

Eq. 2.25 implies that, when full shaft resistance is developed, a plot of C' versus 1/Q is a straight line with slope, k, and y-intercept, n. When n is less than unity, the shaft resistance is not fully mobilized. Full shaft resistance is mobilized when n is equal to unity. When n is greater than unity, yielding or buckling of the pile is implied.

2.4.5 Use of more than one telltale in a pile

As developed in this report, Leonards-Lovell method can be generalized to include analysis of more than one telltale. In the method proposed, the pile is conveniently discretized at the telltale locations. Discretization at the telltales, gives rise to two segment types as shown in Fig. 2.7.

A segment having the pile head as the upper boundary and an end of a telltale as the lower boundary is a Type 1 segment. A segment between two telltales, i.e., having both upper and lower boundaries defined by an end of telltale, is a Type 2 segment. The applied load on a Type 1 segment is the applied test load. The load at the upper boundary of a Type 2 segment has to be calculated from knowledge of shaft resistance distribution.

The vertical force equilibrium equations governing the generalized Type 1 segment (i) and Type 2 segment (i, i+1) are given by Eqs. 2.26a and 2.26b, respectively.

$$Q = R_{si} + R_{ti} \tag{2.26a}$$

$$Q_{i,i+1} = R_{si,i+1} + R_{ti,i+1}$$

$$= (R_{si+1} - R_{si}) + R_{ti+1} \tag{2.26b}$$

where

Q = Load applied to pile head
$Q_{i,i+1}$ = Load applied to top of Segment i,i+1
R_{si} = Shaft resistance along length of Telltale i
R_{si+1} = Shaft resistance along length of Telltale i+1
$R_{si,i+1}$ = Shaft resistance along length of Segment i,i+1
R_{ti} = Load in pile at end of Telltale i
R_{ti+1} = Load in pile at end of Telltale i+1
$R_{ti,i+1}$ = Load in Segment i, i+1 at end of Telltale i+1

The segment compression due to the applied load, Q, for the Type 1 segment (i) and Type 2 segment (i+1) is given by Eqs. 2.27a and 2.27b, respectively.

$$\delta_i = \int_0^{L_i} \epsilon_i(z)\, dz$$

$$\delta_i = \int_0^{L_i} \frac{Q_i(z)}{A_i E_i}\, dz \tag{2.27a}$$

$$\delta_{i,i+1} = \int_{L_i}^{L_{i+1}} \frac{Q_{i,i+1}(z)}{A_{i,i+1} E_{i,i+1}}\, dz \tag{2.27b}$$

where

δ_i = Compression of segment i

$\epsilon_i(z)$ = Strain function along the pile

$Q(z)$ = Load function along the pile

L_i = Length from ground surface to Telltale i

A_i = Cross-sectional area of segment i

E_i = elastic modulus of segment i

The equivalent segment compression defined by Eqs. 2.27a and 2.27b can be calculated by considering the separate contributions from the shaft and toe resistances.

The toe resistance compression component is calculated considering column compression of the segment under applied toe load.

The shaft resistance compression component is calculated using shaft resistance acting at the shear centroid as shown in Fig. 2.8.

Hence, the combined segment compression under applied pile head load, Q, for the generalized Type 1 segment (i) and Type 2 segment (i+1) are given by Eqs. 2.28a and 2.28b, respectively.

$$\delta_i = \frac{L_i}{A_i E_i} (R_{ti} + C_i R_{si}) \tag{2.28a}$$

$$\delta_{i,i+1} = \frac{L_{i,i+1}}{A_{i,i+1} E_{i,i+1}} (R_{ti,i+1} + C_{i,i+1} R_{si,i+1}) \tag{2.28b}$$

where

$L_{i,i+1}$ = $L_{i+1} - L_i$

$R_{ti,i+1}$ = R_{ti+1}; Load in pile at the end of Telltale i+1

$R_{si,i+1}$ = $R_{si+1} - R_{si}$; Shaft resistance along Segment i,i+1

$C_{i,i+1}$ = Centroid of shaft resistance distribution for Segment i,i+1

Similarly, the location of the centroid under the shear resistance distribution for generalized Type 1 segment (i) and Type 2 segment (i,i+1) is given by Eqs.2.29a and 2.29b, respectively.

$$C_i = \frac{\int_0^{L_i} z r_m(z)\, dZ}{\int_0^{L_i} r_m(z)\, dZ} \qquad (2.29a)$$

$$C_{i,i+1} = \frac{\int_{L_i}^{L_{i+1}} z r_m(z)\, dZ}{\int_{L_i}^{L_{i+1}} r_m(z)\, dZ} \qquad (2.29b)$$

The toe resistance for the generalized Type 1 segment (i) and Type 2 segment (i,i+1) in Eqs. 2.30a and 2.30b, are obtained by substituting Eqs. 2.26a and 2.26b into Eqs. 2.28a and 2.28b, respectively.

$$R_{ti} = \frac{Es_i \delta_i - Q_i C_i}{1 - C_i} \qquad (2.30a)$$

$$R_{ti,i+1} = \frac{Es_{i,i+1} \delta_{i,i+1} - Q_{i,i+1} C_{i,i+1}}{1 - C_{i,i+1}} \qquad (2.30b)$$

where

$$Es_i = \frac{A_i E_i}{L_i}$$

The two unknowns are the location of the centroids under the shaft resistance distribution and the residual compression of the respective segments. The centroids of the shaft resistance distribution is calculated from an assumed shaft resistance distribution.

2.4.6 Residual Compression

Residual stress and strain are stress and strain locked in the pile as a result of the driving and reconsolidation after driving.

The effect of residual stresses on load transfer behavior in piles is shown in Fig. 2.9. (Holloway et al., 1978). When an applied load, q, mobilizes a linearly increasing unit shaft resistance distribution Curve 1 in an initially unstressed pile, a corresponding load distribution Curve 1, results. If the pile is subjected to residual compression corresponding to unit shaft resistance according to Curve 2, the resulting residual load distribution is Curve 2. The resulting load distribution for the pile taking residual compression into account will give rise to shaft resistance distribution and load distribution corresponding to Curve 3.

In a telltale-instrumented test, locked-in stress and strain are not measured because telltale dials are not installed and zero readings taken until well after the pile installation. To account for the true pile segment compression, the segment residual compression must be added to the compression measured during the static loading as shown in Fig. 2.9.

Replacing the measured compression in Eqs. 2.30a and 2.30b with the actual compression from Eqs. 2.31a and 2.31b, the load in pile at the telltale end of the generalized Type 1 segment (i) and Type 2 segment (i,i+1) are given by Eqs. 2.31a and 2.31b, respectively.

$$R_{ti} = \frac{Es_i(\delta_i+\delta_{oi}) - Q_iC_i}{1 - C_i} \tag{2.31a}$$

$$R_{ti,i+1} = \frac{Es_{i,i+1}(\delta_{i,i+1}+\delta_{oi,i+1}) - Q_{i,i+1}C_{i,i+1}}{1 - C_{i,i+1}} \tag{2.31b}$$

where

δ_{oi} = Residual compression in segment i

$\delta_{oi,i+1}$ = Residual compression in Segment i,i+1

2.4.7 Residual Compression Match

The residual compression match procedure is based on matching the load distribution along the pile as shown in Fig. 2.10. The determined load distribution at the lowest telltale is used as the reference for forcing an agreement of the load distribution from the other telltales. The agreement is obtained by means of adding the residual compression to the compression measured by the other telltales.

In the program, the matching procedure begins with determination of the shaft and toe resistance at the lowest telltale from the test data, selected shaft resistance, and assumed cumulative residual compression at the lowest telltale.

The load in the pile at the end of Telltale i+1 is given by Eq. 2.32. It has the same derivation as Eqs. 2.31a and 2.31b.

$$R_{ti+1} = \frac{Es_{i+1}(\delta_{i+1}+\delta_{oi+1}) - Q_{i+1}C_{i+1}}{1 - C_{i+1}} \tag{2.32}$$

$$Es_{i+1} = \frac{A_{i+1}E_{i+1}}{L_{i+1}}$$; Slope of elastic line <Segment i+1>

Q_{i+1} = Load in pile at end of Telltale i+1

δ_{i+1} = Measured compression along length of Telltale i+1

δ_{oi+1} = Residual compression along length of Telltale i+1

C_{i+1} = Centroids of the shaft resistance distribution

The shaft resistance along length of Telltale i+1 is given by Eq. 2.32.

$$R_{si+1} = Q - R_{ti+1} \tag{2.32}$$

From the shaft resistance distribution input, the relative shaft resistance at telltale locations are calculated. The relative shaft resistance is normalized with respect to the lowest telltale as shown in Fig. 2. 11. The normalized ratio of the shaft resistance is obtained from integration of the assumed shaft resistance distribution given by Eq. 2.33a or Eq. 2.33b for the Segments i and i,i+1, respectively.

$$N_i = \frac{\int_o^{L_i} r_s(z)\, dZ}{\int_o^{L} r_s(z)\, dZ} \tag{2.33a}$$

$$N_{i,i+1} = \frac{\int_{L_i}^{L_{i+1}} r_s(z)\, dZ}{\int_{o}^{L} r_s(z)\, dZ} \qquad (2.33b)$$

Using the normalized shaft resistance for Telltale i and the shaft resistance along length of Telltale i+1 in Eq. 2.32, the shaft resistance along length of Telltale i is obtained using Eq. 2.34.

$$R_{si} = N_i R_{si+1} \qquad (2.34)$$

where

N_i = Normalized shaft resistance along length of Telltale i

From vertical force equilibrium in Segment i, load in the pile at the end of Telltale i is given by Eq. 2.35.

$$R_{ti} = Q - R_{si} \qquad (2.35)$$

For compatibility of stress, load in the pile at the end of Telltale i, R_{ti}, calculated from shaft resistance distribution consideration is equal to the value using expanded Leonards-Lovell for Telltale i. Expressing Leonards-Lovell formulation for Telltale i in terms of residual compression gives Eq.2.36.

$$\delta_{oi} = \frac{R_{ti}(1-C_i) + QC_i}{Es_i} - \delta_i \qquad (2.36)$$

The relationship between the residual compression values at the two telltales is given by Eq. 2.37. This relationship is obtained from substituting the value of R_{ti} obtained from shaft resistance distribution into Eq. 2.36 for the residual compression at Telltale i.

$$\delta_{oi} = \frac{(Q-N_iR_{mi+1})(1-C_i) + QC_i}{Es_i} - \delta_i \qquad (2.37)$$

The load in the pile at the end of Telltale i+1 is calculated using Segment (i,i+1) with the respective segment properties and the difference in compression values measured from the two telltales. The load in the pile at the end of Telltale i+1 is given by Eq. 2.38. The parameters used in Eq. 2.38 are defined in Eqs. 2.29b, 2.39, 2.40 and slope of elastic line input.

$$R_{ti,i+1} = \frac{Es_{i,i+1}(\delta_{i,i+1}+\delta_{oi,i+1}) - Q_{i,i+1}C_{i,i+1}}{1 - C_{i,i+1}} \qquad (2.38)$$

From compatibility of strain, the residual compression along the length L_{i+1} is equal to the components of residual compression obtained from individual segments forming the length of L_{i+1}. This gives rise to Eq. 2.40 when considering Segments i, i+1 and i,i+1.

$$(\delta_{i+1} + \delta_{oi+1}) = (\delta_i + \delta_{oi}) + (\delta_{i,i+1} + \delta_{oi,i+1}) \qquad (2.40)$$

From compatibility of stress at Telltale i, the applied load on head of Segment i,i+1 is given by Eq. 2.41.

$$Q_{i,i+1} = R_{ti} \qquad (2.41)$$

For compatibility of stress, the load in the pile at the end of telltale i+1 calculated by Eqs. 2.32 and 2.39 is the same as shown by Eq. 2.42.

$$R_{ti,i+1} = R_{ti+1} \tag{2.42}$$

When Eq. 2.42 is satisfied for an assumed shaft resistance distribution and residual compression, it implies that the assumed values have satisfied the vertical force equilibrium, shaft resistance distribution assumption, and elastic stress-strain relationship.

For a pile with more than two telltales, the same numerical formulation has been used to develop the equations for residual compression match by considering the vertical force equilibrium, stress compatibility, and stress-strain relationship of the pile at the telltale locations.

2.4.8 Variation of Elastic Modulus

In a pile subjected to axial loading test, the upper portion of the pile is under higher stress.

For pile material that exhibits varying elastic modulus under different stress level, the pile is expected to experience variation of elastic modulus along the pile. For example, Yu (1984) reported that the modulus of prestressed concrete pile varied from 4.4 GPa to 2.1 GPa for a stress range of 0.7 MPa to 41.4 MPa.

In the program developed, the elastic modulus is iterated using one of the empirically determined modulus-stress variation relationship as shown below.

1) Linear modulus-stress variation
2) Non-linear modulus-stress variation
3) Janbu's tangent modulus-stress variation
4) Hyperbolic modulus-stress variation

Iteration is stopped when the new average load calculated for the segments are within acceptable limit of the previous average load.

In the numerical procedure adopted, the elastic modulus variation is used to update the slope of elastic line in the expanded Leonards and Lovell formula.

CHAPTER 3

COMPUTER PROGRAM

3.1 INTRODUCTION

A computer program has been developed for load distribution analysis of results from telltale-instrumented static loading tests. The program can be divided into three sections, as follows:

1) Data and data file management programs, which are programs with subroutines for creating and editing data files.

2) Residual compression matching programs including subroutines for searching the set of residual compression at telltale locations that satisfies the force equilibrium, stress compatibility, and stress-strain relationship of the pile.

3) Leonards-Lovell calculation program, which program consists of subroutines for load distribution analysis including the effects of residual compression and elastic modulus variation. Also included are the results for graphical determination of the applied load at full shaft mobilization.

Flowchart 1, Appendix B, presents how all these programs are linked.

3.2 RESIDUAL COMPRESSION MATCHING PROGRAM

Flowchart 2, Appendix B, presents the overall structure of the residual compression match program. This program is divided into initialization, solution, and post solution stages.

In the initialization stage, the geometry and material parameters are entered.

The shaft resistance distribution input consists of numerical procedures for calculating the relative shaft resistance and centroid of the area under the shaft resistance distribution. The relative shaft resistance of a segment is the area bounded by the shaft resistance distribution along the length of the segment.

The relative shaft resistance contribution and centroid of shaft resistance distribution are calculated from the assumed shaft resistance distribution.

The area under the shaft resistance distribution for the segment is obtained using integration by part of the assumed linear "piece-wise" shaft resistance distribution. The normalized shaft resistance contribution is the ratio of the cumulative area under the shaft resistance distribution curve to the respective telltale over the cumulative area to the lowest telltale.

The Leonards-Lovell C-ratio is the centroid of the area bounded by the shaft resistance distribution. It is determined by taking moment of the shaft resistance using the pile head as the pivot.

The residual compression at the lowest telltale is input as a specific value or range depending on the search option chosen.

The load in the pile at a telltale location is calculated using an assumed shaft resistance distribution and residual compression over the length of the lowest telltale. The load in pile at the telltale end is calculated using Type 1 and Type 2 segments. The criterion for obtaining the residual compression match is based on convergence of the load in pile at the telltale end using the redundant set of equilibrium, stress-strain relationship, and stress compatibilities governing Type 2 segments.

In Type 1 segments, the load in pile at the lowest telltale (usually at pile toe) is calculated using telltale compression measured from the pile head to the telltale end. The load in pile at the lowest telltale end using Type 1 segment is given by Eq. 2.36. The load in the pile at other telltale locations is obtained by proportioning the ratio of the cumulative shaft resistance contribution. This is followed by a numerical subroutine for backcalculating the cumulative residual compression at the other telltale locations using Eq. 2.40.

In the following computation, the load in the pile at the upper telltale of Type 2 segment assumes the load value already computed for this location from the respective Type 1 segment. The load in the pile at the lower telltale locations is then calculated by solving Eq. 2.43. The equation is derived based on stress compatibility and stress-strain relationships for each segment between telltales. The data used in this subroutine are the compression for segments between telltales,assumed shaft resistance distribution, and residual compressions conforming to the values obtained by Type 1 segment calculation.

The program developed has two different search options for obtaining the residual compression match.

In the first search algorithm, residual compression match is performed for a specific input of an assumed residual compression at the lowest telltale. In this method, the convergence of the results using the redundant conditions are not necessarily satisfied. A check is necessary to confirm the load in the pile at the telltale end of the asummed residual compression match agrees with the load distribution determined from the lowest telltale.

In the second search algorithm, the load and the load distribution in a pile at the telltale locations are calculated using an assumed residual compression at the lowest telltale as given within a specified range. The specified range of residual compression is divided into twenty values having equal increments. The residual compression at the lowest telltale that gives the best load distribution match is then obtained from visual inspection of the output.

For a pile experiencing elastic modulus variation with stress, an additional iterative subroutine is needed. It consists of an average stress calculation subroutine and an elastic modulus updating procedure. The average stress calculation subroutine consists of solving the force parameters in Eqs. 2.35a and 2.35b. Then, an updated elastic modulus value is calculated corresponding to the average load in the segment under consideration.

The modulus-stress variation relationship is modeled using an empirically determined relationship. The subroutine developed uses one of the following modulus-stress variation models :

1) Linear modulus-stress variation
2) Non-linear modulus-stress variation
3) Janbu's tangent modulus-stress variation
4) Hyperbolic modulus-stress variation

The iteration for the elastic modulus is stopped when the average load used for updating the elastic modulus converges within the set limit of the previous average load used.

The other post-solution options are an output table for the residual compression match analysis, shaft resistance distribution, and load distribution.

3.3 LEONARDS-LOVELL CALCULATION PROGRAM

The structure of Leonards-Lovell calculation program is shown in Flowchart 3, Appendix B. This program is divided into initialization, solution, and post-solution stages.

In the initialization stage, the geometry and material data are entered. Test loading results are obtained from a sequential text file created by the data entry program. The data entry also includes the option for manual input of C-ratio or calculate the C-ratio from assumed shaft resistance distribution. The C-ratio calculation subroutine is the same subroutine found in the residual compression match program. Lastly, the residual compression for each segment is input.

The solution stage involves a calculation algorithm using the Leonards-Lovell formula to obtain the shaft resistance and toe resistance at the telltale locations at different load levels.

The post-solution option consists of subroutines for the output of Leonards-Lovell analysis results, C' determination and plot, and recalculation options with different points of reentry.

The C' determination subroutine consists of a numerical algorithm solving Eq. 2.18b for the telltales at the different load levels. The graphical results needed for producing the plots of C' versus 1/Q and C' versus Q is included. These plots provide the visual inspection for determination of the applied load at full shaft resistance mobilization.

CHAPTER 4

USER'S MANUAL

4.1 Introduction

This User's Manual provides an outline of the various program functions, a definition of input quantities, a description of the output, and some sample problems.

The programs use extensive interactive prompting and the program flow is based on menu driven format. Furthermore, it offers features that allow recalculation using different material and soil properties without redoing the entire input.

4.2 System requirements

Tellpile, Version 1.1, is written on IBM PC using the BASICA language. Running the program on IBM PC compatible machines may require the inclusion of the appropriate DOS and BASIC, as explained below:

1) In formatting the blank program master disk, the DOS system provided for the compatible machine should be installed. After transferring all program files from the distribution disk to the new master program disk, the COMMAND.COM file should be replaced with the COMMAND.COM file from the DOS disk supplied for the compatible machine.

2) In IBM compatible machine that does not run IBM version of BASICA, the appropriate BASIC module should be copied on to the new master program disk (e.g. GWBASIC.EXE). Then, a new autoexec.bat file should be created that invokes the appropriate version of BASIC and then runs the HELLO program.

4.3 Installing Tellpile, Version 1.1

Tellpile, Version 1.1, is distributed on a single disk containing programs and sample data.

4.3.1 Dual floppy system

To create a backup copy of program and Data disk, two formatted blank disks are needed.

Label the formatted blank disks, as follows:

Tellpile, Version 1.1, Master disk
Tellpile, Version 1.1, Data disk

Boot your DOS system. Remove the DOS disk and replace it with the Tellpile disk and place this just formatted Master disk in Drive B.

Then, type COPY *.* B: <RETURN> to create the Master disk.

Thereafter, create the Data disk by placing the just formatted Data disk in Drive B and type COPY *.FIL B: <RETURN>, which causes all files with ending attachment .FIL on the distributed disk to be now copied to the Data disk.

Then, type COPY *.DAT B: <RETURN>, which causes all files with ending attachment .DAT on the distributed disk to be copied to the Data disk.

4.3.2 Hard disk system

At the DOS command level, create a new sub-directory by typing: MD/TELLPILE <RETURN>

Place the distributed Tellpile disk in Drive A. Then, type COPY A:*.*C: <RETURN> which copy TELLPILE program and data files in the hard disk, subdirectory TELLPILE. Then, type

RENAME AUTOEXEC.BAT TELLPILE.BAT, this rename the AUTOEXEC.BAT file to TELLPILE.BAT in the hard disk.

If data are to be stored in a separate Data disk, it is created by placing a blank formatted Data disk in Drive A and type COPY C:TELLPILE *.FIL A: <RETURN>. This causes all files with ending attachment .FIl on the TELLPILE sub-directory to be copied to the Data disk. Then, type COPY C:TELLPILE *.DAT A: <RETURN>. This completes the Data disk installation.

4.3.3 Configure the program default drives

The default drives for the Master Program and Data disk are Drives A and B, respectively. The default setting can be reconfigured, as follows:

Invoke BASICA by typing the word BASICA at the DOS command level prompt, A>. Then, type: LOAD"MENU.BAS", with the system responding with ok, then type: RUN. Reconfiguring the default program disk drive by means of the self explainatory Option 10 in the MAIN MENU selection.

4.4 STARTING THE ANALYSIS

4.4.1 Using Drives A and B

Insert the Master disk in Drive A and the Data disk in Drive B. Close the drive doors and turn the computer on.

The AUTOEXEC.BAT file is automatically loaded. It will invoke the disk version of BASICA and run the greeting program HELLO.

The HELLO program first verifies that the correct Data disk is in Drive B by checking for the data file list. When the correct Data disk is detected, then a greeting message is displayed and the user is directed to the Main Menu.

4.4.2 Using Drives A and C

Boot the system using the hard disk in Drive C. Then, place the Data disk in Drive A. Then, type cd TELLPILE, which change the directory to the TELLPILE subdirectory. Then, type TELLPILE to load and run the TELLPILE batch file. TELLPILE batch file follows the AUTOEXEC batch file start-up procedure as described above. The program default setting for the Program disk drive and Data disk drive are A and B, respectively. Hence, the Program drive and Data drive should be reconfigured using Option 10 in the MAIN MENU selection.

4.4.3 Using Drive C only

Boot the system. Then type cd TELLPILE, which change the directory to the TELLPILE subdirectory. Then, type TELLPILE which load and run the TELLPILE batch file. TELLPILE batch file follows the AUTOEXEC batch file start-up procedure as describe above. The program default setting for the Program disk drive and Data disk drive are A and B, respectively. Hence, the Program drive and Data drive should be reconfigured using Option 10 in the MAIN MENU selection.

4.5 Main Menu

After the startup procedure, the main menu program is displayed:

```
        * MAIN MENU *

   1>  ENTER A NEW DATA FILE
   2>  LIST FILES IN DATA DISK
   3>  PRINT A DATA FILE
   4>  RENAME A DATA FILE
   5>  DELETE A DATA FILE
   6>  TRIM THE NUMBER OF TELLTALES IN AN 'ORIGINAL FILE'
   7>  EDIT DATA IN AN 'ANALYSIS FILE'

   8>  RESIDUAL COMPRESSION MATCH
   9>  LEONARDS-LOVELL 'ANALYSIS FILE' CALCULATION

   10> CONFIGURE DISK DRIVES
   11> QUIT

       WHICH OPTION DO YOU WISH TO USE ?
```

To demonstrate the various functions of the options in the MAIN MENU, a sample run using Example 1 is carried out below. The data are also available on the Master disk and can be copied over to the Data disk.

4.5.1 ENTER A NEW DATA FILE (OPTION 1)

This option is used to enter new test loading data for analysis.

The program loads the ENTERFIL subprogram and displays:

* ENTER A NEW DATA FILE *

This program is used to enter and store data from a static loading test which includes data from a maximum of TEN telltales.

The uppermost telltale is Telltale ONE.

ENTER <RETURN> TO CONTINUE

Hit the **<RETURN>** key to obtain the next screen:

Enter <RETURN> to exit to MAIN MENU

Enter <PILE NAME> to continue.
{maximum 30 characters}

? **EXAMPLE 1 <RETURN>**

The <RETURN> key will invoke the MAIN MENU display. For this example, enter **EXAMPLE 1**

The program now prompts with:

* OPTIONS OF UNITS *

1. DATA IN SI UNITS
2. DATA IN IMPERIAL UNITS

WHICH OPTION DO YOU WISH TO USE?

2 **<RETURN>**

Option 2, was selected because the data are in Imperial Units.

The program now prompts with:

```
* NUMBER OF TELLTALE(S) IN TEST LOADED PILE *
      {MAXIMUM 10 TELLTALES}

ENTER <NUMBER OF TELLTALE> IN THE TEST PILE
```

? 3 <RETURN>

Enter 3 followed by <RETURN> because tree telltales were included in this test. Then, the program prompts for the name of each telltale as shown below:

```
* NAME OF TELLTALES *

UPPERMOST TELLTALE IS TELLTALE 1

ENTER NAME OF TELLTALE 1
  <MAXIMUM 6 CHARACTERS>
```

?3C <RETURN>

```
ENTER NAME OF TELLTALE 2
  <MAXIMUM 6 CHARACTERS>
```

?8H <RETURN>

```
ENTER NAME OF TELLTALE 3
  <MAXIMUM 6 CHARACTERS>
```

?1A <RETURN>

After naming the telltales, the program prompts for the geometric input data, as shown below:

```
* LENGTH FROM GROUND SURFACE *
      UNIT IN FEET

LF  = LENGTH OF PILE STICKUP
LC  = LENGTH OF CASING
LT1 = LENGTH FROM GROUND SURFACE TO TELLTALE END 3C
LT2 = LENGTH FROM GROUND SURFACE TO TELLTALE END 8H
LT3 = LENGTH FROM GROUND SURFACE TO TELLTALE END 1A

ENTER LENGTH OF PILE STICKUP
```

? 0 **<RETURN>**

```
ENTER LENGTH OF CASING
```

? 0 **<RETURN>**

```
ENTER LENGTH FROM GROUND SURFACE TO TELLTALE END 3C
```

?56.7 **<RETURN>**

```
ENTER LENGTH FROM GROUND SURFACE TO TELLTALE END 8H
```

?86.2 **<RETURN>**

```
ENTER LENGTH FROM GROUND SURFACE TO TELLTALE END 1A
```

?104.9 **<RETURN>**

Thereafter, the program prompts for how many sets of load level data to enter :

```
    * NUMBER OF SETS OF TEST DATA *
          {MAXIMUM 150 SETS}

NUMBER OF DATA SET TO INPUT = ? 7
```

Thereafter, the program requests the test data:

```
          * DATA ENTRY *

NUMBER OF DATA SET TO INPUT = 7

EACH SET OF DATA SHOULD CONTAIN :
Q, Mh, C1, C2, C3

Q    = LOAD APPLIED ON THE PILE HEAD (TON)
Mh   = MOVEMENT OF THE PILE HEAD (INCHES)
C1   = COMPRESSION TO TELLTALE END 3C (INCHES)
C2   = COMPRESSION TO TELLTALE END 8H (INCHES)
C3   = COMPRESSION TO TELLTALE END 1A (INCHES)

   * ENTER 7 SETS OF DATA *
```

The data are entered, as follows:

```
? 34,.056,.046,.052,.052 <RETURN>
? 90,.139,.093,.119,.120 <RETURN>
? 135,.275,.166,.184,.186 <RETURN>
? 168,.496,.213,.235,.237 <RETURN>
? 180,.496,.227,.249,.252 <RETURN>
? 191,.776,.242,.264,.267 <RETURN>
? 224,1.857,.288,.314,.317 <RETURN>
```

When all the load, movement, and deformation data are entered, the program displays edit options in the following submenu:

```
* EDIT OPTIONS *

1. REVIEW FILE
2. CORRECT FILE
3. STORE FILE
4. RETURN TO MAIN MENU

WHICH OPTION DO YOU WISH TO USE ?
```

4.5.1.1 REVIEW FILE (SUB-OPTION 1)

Sub-Option 1 displays the data entered earlier, as shown below:

* DATA *

	Q	Mh	C1	C2	C3
1>	34.0	0.056	0.046	0.052	0.052
2>	90.0	0.139	0.093	0.119	0.120
3>	135.0	0.275	0.166	0.184	0.186
4>	168.0	0.496	0.213	0.235	0.237
5>	180.0	0.496	0.227	0.249	0.252
6>	191.0	0.776	0.242	0.264	0.267
7>	224.0	1.857	0.288	0.314	0.317

ENTER <RETURN> TO CONTINUE

<RETURN>, returns the program to the EDIT OPTIONS menu.

4.5.1.2 CORRECT FILE (SUB-OPTION 2)

Sub-Option 2 allows changes to be made in the data entered earlier. The program prompts with message as shown below:

```
    * EDIT DATA *

ENTER <1> EXIT TO EDIT OPTIONS SUBMENU
ENTER <2> TO CHANGE DATA
```

Selecting Option 1, by responding with 1 <RETURN>, will cause the program to branch back to the EDIT OPTIONS menu.

To proceed with changing the data, select Option 2 by responding with 2 <RETURN>. The program now prompts for the number rows of data to be changed. The permissible range of number to respond with lies between 1 and the maximum number of rows of data in the file. For this example, enter 2 rows:

```
HOW MANY ROWS OF DATA DO YOU WISH TO CHANGE ?
```

2 <RETURN>

Then, the program prompts for the ID number of each row of data to be changed. Each data row to be changed has to be entered followed by the return key. For this example, enter Rows 4 and 6:

```
ENTER THE ROW-NUMBER(S) TO BE CHANGED ?
```

4 <RETURN>
6 <RETURN>

The program now displays the rows to be changed:

```
* DATA ROW(S) TO BE CHANGED *

     Q         Mh        C1        C2        C3

1>  168.0     0.496     0.213     0.235     0.237
2>  191.0     0.776     0.242     0.264     0.267

        ENTER <RETURN> TO CONTINUE
```

Notice, the row numbers on the screen are not the number of the original row numbers, but simply the sequential numbers of the identified rows.

Upon complete viewing of the data rows to be changed, the program will continue when the return key is entered and prompt with the following options:

```
ENTER <1> TO CHANGE DATA
ENTER <2> TO TRY AGAIN
ENTER <3> RETURN TO EDIT OPTIONS SUBMENU
```

Option 2, TO TRY AGAIN, will return the program to the beginning of the TO CHANGE DATA option.

Option 3, RETURN TO EDIT OPTIONS SUBMENU, is self-explanatory.

After selecting Option 1, by responding with 1 <RETURN>, the program proceeds with prompting for change as shown below:

```
* DATA ROW (S) TO BE CHANGED *

      Q        Mh        C1        C2        C3

1>  168.0    0.496     0.213     0.235     0.237
2>  191.0    0.776     0.242     0.264     0.267

ENTER  Q,Mh,C1,C2,C3 FOR DATA ROW 1 ?
```

165,.496,.213,.235,.237 <RETURN>

```
ENTER  Q,Mh,C1,C2,C3 FOR DATA ROW 2 ?
```

190,.776,.242,.264,.267 <RETURN>

When all the data are entered for each row where change is requested, the program prompts with :

```
ENTER <1> TO TRY AGAIN
ENTER <2> TO ACCEPT CHANGES
```

Option 1, TO TRY AGAIN, branches the program to the beginning of TO CHANGE DATA option.

Option 2, makes the changes above permanent and displays the changed data:

```
* DATA ROW(S) ARE CHANGED TO *

      Q        Mh        C1        C2        C3

1>  165.0    0.496     0.213     0.235     0.237
2>  190.0    0.776     0.242     0.264     0.267

        ENTER <RETURN> TO CONTINUE
```

Responding with <RETURN>, the program returns to the EDIT OPTION menu.

4.5.1.3 STORE FILE (SUB-OPTION 3)

Sub-Option 3 is used to store the file which can be retrieved for further analysis.

Data files are stored under two different file types. Use of two file types, is due to that Leonards-Lovell analysis program output table can only accommodate data from two telltales at a time.

Data files with more than two telltales are automatically saved as type "Original File". Data files with less than two telltales are automatically saved as type "Analysis File".

An Original File with more than two telltales can be trimmed to an Analysis File by reducing the number of telltales in the original file and store the file under a different file name. This option is provided in the MAIN MENU, Option 6, TRIM THE NUMBER OF TELLTALES IN AN ORIGINAL FILE.

The STORE FILE Sub-Option is selected by entering 3 <RETURN> in response to the prompt in the EDIT OPTIONS submenu. The program displays the message:

```
                    * STORE FILE OPTION *

THIS PROGRAM STORES THE DATA FILE AS 'ORIGINAL' FILE WHEN THE
TEST LOADED PILE HAS MORE THEN TWO TELLTALES. TEST DATA WITH
ONE OR TWO TELLTALES ARE STORED AS 'ANALYSIS' FILE BY DEFAULT.

                 ENTER <RETURN> TO CONTINUE
```

On entering <RETURN> the program displays the message:

> The uppermost telltale is Telltale ONE.
>
> It should be noted that subsequent program for analysis are designed for 'Analysis File' with ONE or TWO Telltales.
>
> Hence, for a data file having more than two Telltales, 'Analysis File(s)' consisting of one or two telltales should be created using the option of <TRIM TELLTALE IN 'ORIGINAL' FILE> in the MAIN MENU, after storing the 'ORIGINAL' file.
>
> This should be done prior to any analysis being attempted.
>
> ENTER <RETURN> TO CONTINUE

<RETURN> causes the program to proceed with storing the data file. Upon completion, the computer returns the program to MAIN MENU.

4.5.1.4 RETURN TO MAIN MENU (SUB-OPTION 4)

Sub-Option 4 in the EDIT OPTIONS submenu returns the program to the MAIN MENU without storing the data.

4.5.2 LIST FILES IN DATA DISK (OPTION 2)

Option 2 is used to list the data files in the data disk and is selected by entering 2 <RETURN> in response to the prompt in MAIN MENU. The computer now prompts with the following sub-menu:

```
* LIST FILES IN DATA DISK *

  1. LIST 'ORIGINAL FILES' IN DATA DISK
  2. LIST 'ANALYSIS FILES' IN DATA DISK
  3. RETURN TO MAIN MENU

  WHICH OPTION DO YOU WISH TO USE ?
```

4.5.2.1 LIST 'ORIGINAL FILES' IN DATA DISK (SUB-OPTION 1)

Sub-Option 1 displays the names of 'original files' in the data disk.

```
* LIST OF 'ORIGINAL FILES' IN DATA DISK *

  1> EXAMPLE 1
  2> EXAMPLE 2

  ENTER <RETURN> TO CONTINUE
```

<RETURN> causes the program to prompt with :

```
    * OPTIONS *

1. PRINT THE LIST OF FILES IN DATA DISK
2. RETURN TO LIST FILES IN DATA DISK SUBMENU

WHICH OPTION DO YOU WISH TO USE ?
```

Option 1 prints the lists of 'Original' and 'Analysis' files in the data disk in the printer. Upon completion of printing, the program returns to the LIST FILES IN DATA DISK sub-menu.

Option 2 returns the program to the LIST FILES IN DATA DISK sub-menu.

4.5.2.2 LIST 'ANALYSIS FILES' IN DATA DISK (SUB-OPTION 2)

Sub-Option 2 displays the names of 'analysis files' in the data disk.

```
   * LIST OF 'ANALYSIS FILES' IN DATA DISK *

    1> EXAMPLE 1 * Ttales 3C&1A
    2> EXAMPLE 2 * Ttales 6&11

    ENTER <RETURN> TO CONTINUE
```

<RETURN> causes the program to prompt with :

```
     * OPTIONS *

1. PRINT THE LIST OF FILES IN DATA DISK
2. RETURN TO LIST FILES IN DATA DISK SUBMENU

WHICH OPTION DO YOU WISH TO USE ?
```

Option 1 prints the lists of 'original' and 'analysis' files in the data disk in the printer. Upon completion of printers, the program returns to the LIST FILES IN DATA DISK sub-menu.

Option 2 returns the program to the LIST FILES IN DATA DISK sub-menu.

4.5.2.3 RETURN TO MAIN MENU (SUB-OPTION 3)

Sub-Option 3 in the LIST FILE sub-menu returns the program to the MAIN MENU.

4.5.3 PRINT A DATA FILE (OPTION 3)

Option 3 is used to obtained a hard copy of a specific data file and is selected by entering 3 <RETURN> in response to the prompt in the MAIN MENU. The program now prompts with the following sub-menu:

```
* PRINT A DATA FILE *

  1. PRINT AN 'ORIGINAL FILE'
  2. PRINT AN 'ANALYSIS FILE'
  3. RETURN TO MAIN MENU

  WHICH OPTION DO YOU WISH TO USE ?
```

4.5.3.1 PRINT AN 'ORIGINAL FILE' (SUB-OPTION 1)

Sub-Option 1 displays the list of 'original files' in the data disk and prompts:

```
      * LIST OF 'ORIGINAL FILES' IN DATA DISK *

        1> EXAMPLE 1
        2> EXAMPLE 2

       ENTER <RETURN> EXIT TO PRINT A DATA FILE MENU

       ENTER <FILE NUMBER> TO BE PRINTED
```

<RETURN> causes the program to return to the PRINT A DATA FILE sub-Menu.

Responding with a number corresponding to the appropriate file number as listed by the program will cause that file to be printed. For example, responding with 1 <RETURN> will cause the printer to print the EXAMPLE 1 test data as shown in Table 4.1.

After printing, the program returns to the PRINT A DATA FILE sub-menu.

4.5.3.2 PRINT AN 'ANALYSIS FILE' (SUB-OPTION 2)

Sub-Option 2 is similar to Sub-Option 1, the same prompts are used. In Sub-Option 2, the data file listing will consist of only 'analysis file'. Selecting the number corresponding to the file number in the 'analysis file' list causes a hard copy of that file to be printed. After printing, the program returns to the PRINT A DATA FILE sub-menu.

4.5.3.3 RETURN TO MAIN MENU (SUB-OPTION 3)

Sub-Option 3 returns the program to the MAIN MENU.

4.5.4 RENAME A DATA FILE (OPTION 4)

Option 4 is used to rename a data file in the data disk and is selected by entering 4 <RETURN> in response to the prompt in the MAIN MENU. The program now prompts with the following sub-menu:

```
              * RENAME A DATA FILE *

        1. RENAME AN 'ORIGINAL FILE'
        2. RENAME AN 'ANALYSIS FILE'
        3. RETURN TO MAIN MENU

         WHICH OPTION DO YOU WISH TO USE ?
```

4.5.4.1 RENAME AN 'ORIGINAL FILE' (SUB-OPTION 1)

Sub-Option 1 displays the list of 'original files' in the data disk with the prompt as shown below:

```
   * LIST OF 'ORIGINAL FILES' IN DATA DISK *

     1> EXAMPLE 1
     2> EXAMPLE 2

ENTER <RETURN> EXIT TO RENAME A DATA FILE MENU

ENTER <FILE NUMBER> TO BE RENAMED
```

<RETURN> causes the program to return to RENAME A DATA FILE sub-menu.

Responding with a number corresponding to the appropriate file number as listed on the screen will cause the program to prompt for the new name of the data file selected. For example, responding with 1 <RETURN> will cause the program to list EXAMPLE 1 and prompt for the new name as shown below:

```
DATA FILE TO BE RENAMED: EXAMPLE 1

ENTER <NEW FILE NAME> {MAXIMUM 30 CHARACTERS} ?
TEST EXAMPLE 1
```

The program then returns to RENAME A DATA FILE sub-menu.

4.5.4.2 RENAME AN 'ANALYSIS FILE' (SUB-OPTION 2)

Sub-Option 2 is similar to Sub-Option 1, the same prompts are used. In Sub-Option 2, the data file listing consists of 'analysis file' only. Selecting the number corresponding to the file number in the 'analysis file' list causes the program to prompt for the new name for that file. When the renaming is completed, the program returns to RENAME A DATA FILE sub-menu.

4.5.4.3 RETURN TO MAIN MENU (SUB-OPTION 3)

Sub-Option 3 returns the program to the MAIN MENU.

4.5.5 DELETE A DATA FILE (OPTION 5)

Option 5 is used to delete a data file from the data disk and is selected by entering 5 <RETURN> in respond to the prompt in MAIN MENU. The program now prompts with the following sub-menu:

```
 * DELETE A DATA FILE *

   1. DELETE AN 'ORIGINAL FILE'
   2. DELETE AN 'ANALYSIS FILE'
   3. RETURN TO MAIN MENU

   WHICH OPTIONS DO YOU WISH TO USE ?
```

4.5.5.1 DELETE AN 'ORIGINAL FILE' (SUB-OPTION 1)

Sub-Option 1 displays the list of 'original files' in the data disk with the prompt as shown:

```
   * LIST OF 'ORIGINAL FILES' IN DATA DISK *

     1> EXAMPLE 1
     2> EXAMPLE 2


ENTER <RETURN> EXIT TO RENAME A DATA FILE MENU

ENTER <FILE NUMBER> TO BE RENAMED
```

<RETURN> causes the program to return to DELETE A DATA FILE sub-menu.

Responding with a number corresponding to the appropriate file number as listed by the program results in that data file being deleted from the disk. For example, responding with 1 <RETURN> will cause the program to delete the data file EXAMPLE 1 from the data disk. The program then returns to DELETE A DATA FILE sub-menu.

4.5.5.2 DELETE AN 'ANALYSIS FILE' (SUB-OPTION 2)

Sub-Option 2 is similar to Sub-Option 1 and the same prompts are used. In Sub-Option 2, the data file listing consists of 'Analysis File', only. Selecting the number corresponding to the file number in the 'analysis file' list causes the program to delete the 'analysis file' from the Data disk. The program then returns to DELETE A DATA FILE sub-menu.

4.5.5.3 RETURN TO MAIN MENU (SUB-OPTION 3)

Sub-Option 3 returns the program to the MAIN MENU.

4.5.6 TRIM THE NUMBER OF TELLTALES IN AN ORIGINAL FILE (OPTION 6)

Option 6 is used to trim the number of telltales in the original files which has more than two telltales in order to utilize the Leonards-Lovell analysis option. It is selected by entering 6 <RETURN> in respond to the prompt in MAIN MENU. The program now prompts with the following:

```
                    TRIM TELLTALE PROGRAM

THIS PROGRAM IS USED TO TRIM THE NUMBER OF TELLTALES IN AN
'ORIGINAL' FILE AND CREATE 'ANALYSIS' FILE(S) WITH VARIOUS
COMBINATIONS OF TELLTALES. (MAXIMUM 2 TELLTALES)

THE NAME OF THE 'ANALYSIS' FILE WILL BE THE NAME OF THE
'ORIGINAL' FILE WITH ADDITION OF AN <*> AND THE RESPECTIVE
TELLTALE NAMES ATTACHED.

                ENTER <RETURN> TO CONTINUE
```

<RETURN> causes the program to prompt with:

```
            * TRIM TELLTALE MENU *

    1. TRIM THE NUMBER OF TELLTALES IN AN 'ORIGINAL FILE'
    2. RETURN TO MAIN MENU

       WHICH OPTIONS DO YOU WISH TO USE ?
```

4.5.6.1 TRIM THE NUMBER OF TELLTALES IN AN 'ORIGINAL FILE' (SUB-OPTION 1)

Sub-Option 1 displays the list of 'original files' in the data disk with the prompt as shown:

```
      * LIST OF 'ORIGINAL FILES' IN DATA DISK *

      1> EXAMPLE 1
      2> EXAMPLE 2

 ENTER <RETURN> EXIT TO TRIM TELLTALE MENU

 ENTER <FILE NUMBER> TO HAVE NUMBER OF TELLTALES TRIMMED ?
```

<RETURN> causes the program to return to TRIM TELLTALE sub-menu.

Responding with a number corresponding to the appropriate file number as listed by the program causes in the telltale of that data file to be displayed and prompting for the number of telltales to be retained. For example, responding with 1 <RETURN> causes the program to list the telltales in EXAMPLE 1 file with prompt as shown:

```
     * LIST OF TELLTALES IN 'ORIGINAL' FILE *

NAME OF TELLTALE 1 IS 3C
NAME OF TELLTALE 2 IS 8H
NAME OF TELLTALE 3 IS 1A

     * NUMBER OF TELLTALE IN 'ANALYSIS' FILE *

ENTER <NUMBER OF TELLTALE> IN NEW TRIMMED 'ANALYSIS' FILE
       {MINIMUM 1, MAXIMUM 2}
? 2 <RETURN>
```

The user has to input the number of telltales that are in this new file. For this example, two telltales will be retained. Thereafter, input 2 <RETURN> in response and the program will prompt with :

```
ENTER FIRST <TELLTALE NUMBER> TO BE RETAINED ?
```

1 <RETURN>

```
ENTER SECOND <TELLTALE NUMBER> TO BE RETAINED ?
```

3 <RETURN>

The responses create and store a new 'analysis' file called EXAMPLE 1 *3C&1A, which contains test data with results from Telltales 3C and 1A. The program returns to TRIM THE NUMBER OF TELLTALES IN AN 'ORIGINAL FILE' sub-menu.

4.5.6.2 RETURN TO MAIN MENU (SUB-OPTION 2)

Sub-Option 2 returns the program to the MAIN MENU.

4.5.7 EDIT DATA IN AN 'ANALYSIS FILE' (OPTION 7)

Option 7 is used to edit the 'Analysis File' and is selected by entering 7 **<RETURN>** in response to the prompt in MAIN MENU. The program will first check to see if any 'Analysis File' is in memory. if so, it will proceed to "EDIT ANALYSIS FILE MENU'. If not, then the program will display a message indicating no "Analysis File" is in memory and display the list of 'Analysis File' in the Data disk. The program then prompts for the data file to be selected and returns to "EDIT ANALYSIS FILE MENU".

```
* EDIT ANALYSIS FILE MENU *

1. CALL ANALYSIS FILE
2. REVIEW FILE
3. PRINT FILE
4. MAKE CHANGES IN DATA FILE
5. TRIM NUMBER OF DATA ROW(S)
6. STORE FILE UNDER 'TRIM FILE'
7. STORE FILE
8. RETURN TO MAIN MENU

WHICH OPTION DO YOU WISH TO USE ?
```

4.5.7.1 CALL ANALYSIS FILE (SUB-OPTION 1)

Sub-Option 1 displays the list of 'analysis files' in the data disk with the prompt as shown:

```
* LIST OF 'ANALYSIS FILES' IN DATA DISK *

  1> EXAMPLE 1 * Ttales 3C&1A
  2> EXAMPLE 2 * Ttales 6&11

 ENTER <RETURN> EXIT TO EDIT ANALYSIS FILE MENU

 ENTER <FILE NUMBER> TO BE CALLED
```

<RETURN> causes the program to return to EDIT ANALYSIS FILE sub-menu.

Responding with a number corresponding to the appropriate file number as listed by the program results in the program reading the selected data file from the data disk and returning to the EDIT ANALYSIS FILE sub-menu.

4.5.7.2 REVIEW FILE (SUB-OPTION 2)

Sub-Option 2 displays the data in the analysis file called as shown in Table 4.1.

<RETURN> causes the program to return to EDIT ANALYSIS FILE sub-menu.

4.5.7.3 PRINT FILE (SUB-OPTION 3)

Sub-Option 3 lists the 'Analysis File' in the data disk and prompts for the appropriate data file to be printed:

```
   * LIST OF 'ANALYSIS FILES' IN DATA DISK *

     1> EXAMPLE 1 * Ttales 3C&1A
     2> EXAMPLE 2 * Ttales 6&11

ENTER <RETURN> EXIT TO PRINT A DATA FILE MENU

ENTER <FILE NUMBER> TO BE PRINTED
```

<RETURN> causes the program to return to EDIT ANALYSIS FILE sub-menu.

Responding with a number corresponding to the appropriate file number as listed by the program results in the printing of that file. For example, responding with 1 <RETURN> causes the printer to print EXAMPLE 1 as shown in Table 4.1. The program then returns to EDIT ANALYSIS FILE sub-menu.

If the printer is not there, the program will prompt with a message and returns to the EDIT ANALYSIS file menu.

4.5.7.4. MAKE CHANGES IN DATA FILE (SUB-OPTION 4)

Sub-Option 4 allows changes to be made in a stored file or data in active memory. On selecting this option, the program prompts with:

```
  * MAKE CORRECTION IN ANALYSIS FILE DATA *

  1. PROCEED TO MAKE CORRECTION
  2. RETURN TO EDIT ANALYSIS FILE MENU

WHICH OPTION DO YOU WISH TO USE ?
```

The procedure to make changes in 'Analysis File' in Sub-Option is similiar to Sub-Option 2, Correct File, in Section 4.5.1.2.

The changes made on the data are registered only in the active memory of the computer. To make the changes permanent, store the changed data in the Data disk using Option 7 in EDIT ANALYSIS FILE MENU.

4.5.7.5 TRIM NUMBER OF DATA ROW(S) (SUB-OPTION 5)

Sub-Option 5 reduces the number of rows of data in an 'analysis file' and is selected by responding with 5 <RETURN>. The program now prompts with:

```
                  * TRIM NUMBER OF DATA ROWS *

THIS PROGRAM WILL TRIM THE NUMBER OF DATA ROWS IN THE ANALYSIS
FILE CALLED UP

ENTER <1> PROCEED WITH TRIMMING FILE
ENTER <2> RETURN TO EDIT ANALYSIS FILE MENU
```

Responding with 1 <RETURN>, the program displays the data file with the respective row number and prompts for the number of rows to be retained in the trim file:

* DATA FILE TO BE TRIMMED *

Pile : EXAMPLE 1

	Q	Mh	C1	C2
1>	34.0	0.056	0.046	0.052
2>	90.0	0.139	0.093	0.119
3>	135.0	0.275	0.166	0.186
3>	168.0	0.496	0.213	0.235
4>	180.0	0.496	0.227	0.249
5>	191.0	0.776	0.242	0.264
6>	224.0	1.857	0.288	0.314

ENTER <RETURN> TO CONTINUE

<RETURN> causes the program to prompt for how many of rows of data to be retained in the trimmed file. For this example, the number of rows to be retained in the trimmed file is 3.

* NUMBER OF DATA ROWS TO BE RETAINED *

ENTER <NUMBER OF ROWS> IN THE TRIMMED DATA FILE?

3 <RETURN>

The program now prompts for the row ID number for the rows to be retained.

```
* ROWS TO BE RETAINED *
```

? 1 <RETURN>
? 4 <RETURN>
? 6 <RETURN>

The program now display the rows selected to be retained:

```
              * TRIMMED DATA FILE *
1>     34.0      0.056      0.046      0.052
2>    168.0      0.496      0.213      0.235
3>    191.0      0.776      0.242      0.264

            ENTER <RETURN> TO CONTINUE
```

<RETURN> causes the program to prompt with:

```
ENTER <1> EXECUTE TRIM
ENTER <2> TRY AGAIN
ENTER <3> RETURN TO EDIT ANALYSIS FILE MENU
```

Responding with 1 <RETURN> causes the trimmed data row replacing the recalled data in the active memory. The program then returns to the EDIT ANALYSIS FILE MENU.

At this stage, the changes made are stored in the active memory of the computer and not stored in the data disk. To store the trimmed data in the Data disk use Option 6 in EDIT ANALYSIS FILE MENU.

Responding with 2 <RETURN> causes the program to branch to the beginning of this option and prompts for how many rows to be retained in the trimmed file.

Responding with 3 <RETURN> returns, the program to EDIT ANALYSIS FILE MENU.

4.5.7.6 STORE FILE UNDER 'TRIM FILE' (SUB-OPTION 6)

Sub-Option 6 stores the data contained in the computer active memory as a trimmed file. On selecting this option, the program prompts with:

```
                    STORE FILE UNDER 'TRIM FILE'

THIS PROGRAM IS USED TO STORE THE TRIMMED FILE. THE TRIMMED
FILE WILL BE THE NAME OF THE CALLED 'ANALYSIS FILE' WITH THE
ADDITION OF THE WORD <TRIM> ATTACHED AT THE END OF THE
ANALYSIS FILE NAME.

ENTER <1> SAVE FILE IN MEMORY AS 'TRIMMED FILE'
ENTER <2> RETURN TO EDIT ANALYSIS FILE MENU
```

Responding with 1 <RETURN>, the program proceed with saving the data file in memory into the data disk as a new trimmed file and return to EDIT ANALYSIS FILE MENU.

Responding with 2 <RETURN>, the program returns to the EDIT ANALYSIS FILE MENU.

4.5.7.7 STORE FILE (SUB-OPTION 7)

Sub-Option 7 stores the data in the computer active memory. On selecting this option, the program prompts with:

```
            * STORE FILE IN MEMORY *

THIS OPTION CAN BE USED TO STORE FILE FROM ANOTHER DISKETTE BY
FIRST USING THE CALL FILE OPTION THEN REPLACING THE DISK IN
DRIVE #2 WITH THE DESIRED STORAGE DISK.

ENTER <1> TO PROCEED
ENTER <2> RETURN TO EDIT ANALYSIS FILE MENU
```

Responding with 1 <RETURN>, the program stores the data file in memory at the designated data disk and return to EDIT ANALYSIS FILE MENU.

Responding with 2 <RETURN>, the program returns to EDIT ANALYSIS FILE MENU.

4.5.7.8 RETURN TO MAIN MENU (SUB-OPTION 8)

Sub-Option 8 returns the program to the MAIN MENU.

4.5.8 RESIDUAL COMPRESSION MATCH PROGRAM (OPTION 8)

Option 8 is used for residual compression match analysis of telltale instrumented data. This option is selected by entering 8 <RETURN> in response to the prompt in the MAIN MENU.

The program now prompts with the following options:

```
1 > A SPECIFIC MATCH - FOR AN ASSUMED RESIDUAL COMPRESSION
    AT LOWER TELLTALE
2>  MATCHES- FOR AN ASSUMED RESIDUAL COMPRESSION RANGE AT
    LOWER TELLTALE
3>  RETURN TO MAIN MENU

WHICH OPTION DO YOU WISH TO USE ?
```

4.5.8.1 A specific match - for an assumed residual compression at lower telltale. (Sub-Option 1)

Sub-Option begin by prompting for the data for residual compression match analysis:

```
                  * RESIDUAL COMPRESSION MATCH *

                   * PILE NAME FOR MATCHING *
                    (MAXIMUM 30 CHARACTERS)

ENTER <PILE NAME>
? EXAMPLE 1 <RETURN>
```

For this example, enter EXAMPLE 1 followed by <RETURN>. The program now prompts for the system of units to be used:

```
                      * OPTIONS OF UNITS *

                    1. DATA IN SI UNIT
                    2. DATA IN IMPERIAL UNITS

            WHICH OPTION DO YOU WISH TO USE
? 2 <RETURN>
```

EXAMPLE 1 contains data in imperial units, therefore, enter 2 <RETURN> in response to this prompt. Thereafter, the program prompts for the number of telltales used for this residual compression match.

```
 * NUMBER OF TELLTALES USED FOR RESIDUAL COMPRESSION MATCH *
            (MINIMUM 2 AND MAXIMUM 3 TELLTALES)

ENTER <NUMBER OF TELLTALES> TO BE USED FOR MATCHING
? 3 <RETURN>
```

In this example, two telltales were used, hence, enter 3 <RETURN> in respond to this prompt. Thereafter, the program prompts for the name of the telltales.

```
ENTER THE NAME OF TELLTALE 1 <MAXIMUM 4 CHARACTERS>
? 3C <RETURN>
```

```
ENTER THE NAME OF TELLTALE 2 <MAXIMUM 4 CHARACTERS>
? 8H <RETURN>
```

```
ENTER THE NAME OF TELLTALE 3 <MAXIMUM 4 CHARACTERS>
? 1A <RETURN>
```

Then, the program prompts for the length of the pile stickup, casing, and lengths to the telltales as shown below with the appropriate response.

```
              * LENGTH FROM GROUND SURFACE *
                      UNIT IN FEET

              LF  = LENGTH OF PILE STICKUP
              LC  = LENGTH OF CASING
              LT1 = LENGTH TO TELLTALE 3C
              LT2 = LENGTH TO TELLTALE 8H
              LT3 = LENGTH TO TELLTALE 1A

ENTER LENGTH OF PILE STICKUP
? 0 <RETURN>

ENTER LENGTH OF CASING
? 0 <RETURN>

ENTER LENGTH TO TELLTALE 3C, LT1
? 56.7 <RETURN>

ENTER LENGTH TO TELLTALE 8H, LT2
? 86.2 <RETURN>

ENTER LENGTH TO TELLTALE 1A, LT3
? 104.9 <RETURN>
```

The program now prompts for the load and compression data to be entered.

Sub-Option 2 allows for changes to the above data entered before proceeding further.

Sub-Option 1 prompts for the slope of elastic line for the different pile segments.

```
            * SLOPE OF ELASTIC LINE, AE/L *

                    * OPTIONS *

1. ENTER EACH SEGMENTS AE/L, SEPARATELY
2. ENTER AE/L TO TELLTALE 2 AND PROPORTION THE REST
? 2 <RETURN>
```

Sub-Option 1 prompts for the slope of elastic line for each segment.

```
* SLOPE OF ELASTIC LINE, AE/L *
UNIT IN TON/IN

ES1  = SLOPE OF ELASTIC LINE FROM HEAD TO TELLTALE 3C
ES2  = SLOPE OF ELASTIC LINE FROM HEAD TO TELLTALE 8H
ES3  = SLOPE OF ELASTIC LINE FROM HEAD TO TELLTALE 1A
ES12 = SLOPE OF ELASTIC LINE BETWEEN TELLTALES 3C&8H
ES13 = SLOPE OF ELASTIC LINE BETWEEN TELLTALES 3C&1A
ES23 = SLOPE OF ELASTIC LINE BETWEEN TELLTALES 8H&1A

ENTER ES1
? 612.0 <RETURN>
```

```
ENTER ES2
? 397.7 <RETURN>
```

```
ENTER ES3
? 323.6 <RETURN>
```

```
ENTER ES12
? 1335.9 <RETURN>
```

```
ENTER ES13
? 686.7 <RETURN>
```

```
ENTER ES23
? 1736.5 <RETURN>
```

Sub-Option 2 prompts for the slope of elastic line for the segment between the pile head and lowest telltale used for the analysis. The slope of elastic line for the rest of the segments are calculated based on the inverse proportion of their lengths as shown in this example.

```
                * SLOPE OF ELASTIC LINE, AE/L *

                        UNIT IN TON/IN

ENTER ES 3 = AE/L TO TELLTALE 1A

ENTER ES 3
? 323.6 <RETURN>
```

For each segment (telltale length), the program calculates the Leonard-Lovell C-ratio from the shaft resistance distribution input.

```
             * LEONARDS-LOVELL C-RATIO FROM ASSUMED *
                  SHAFT RESISTANCE DISTRIBUTION

          * SHAPE OF SHAFT RESISTANCE DISTRIBUTION *

1. TRIANGULAR
2. RECTANGULAR
3. MULTI-LAYERED TRAPEZOIDS < MAX. 10>

WHICH OPTION DO YOU WISH TO USE ?
3 <RETURN>
```

Sub-Option 1 selects a triangular shaft resistance distribution and computes the C-ratio for each telltale length.

Sub-Option 2 selects a rectangular shaft resistance distribution and computes the C-ratio for each telltale length.

Sub-Option 3 allows for selection of a shaft resistance distribution defined by up to ten trapezoids. In this sub-option, the program first prompts for the number of layers defining the shaft resistance distribution:

```
                 * NUMBER OF SOIL LAYERS *
              (MINIMUM 2 AND MAXIMUM 10 LAYERS)

ENTER <NUMBER OF SOIL LAYERS> TO LOWEST TELLTALE
? 7 <RETURN>
```

Thereafter, the program prompts for the depth to these layers from the soil surface.

```
* DEPTH TO SOIL LAYERS FROM GROUND SURFACE *
UNIT IN FEET

ENTER DEPTH TO LOWER BOUNDARY OF LAYER 1
? 3.7 <RETURN>

ENTER DEPTH TO LOWER BOUNDARY OF LAYER 2
? 12.7 <RETURN>

ENTER DEPTH TO LOWER BOUNDARY OF LAYER 3
? 52.7 <RETURN>

ENTER DEPTH TO LOWER BOUNDARY OF LAYER 4
? 74.5 <RETURN>

ENTER DEPTH TO LOWER BOUNDARY OF LAYER 5
? 80.8 <RETURN>

ENTER DEPTH TO LOWER BOUNDARY OF LAYER 6
? 95.3 <RETURN>
```

The shaft resistance distribution is defined by the relative unit shaft resistance at the top and bottom interfaces of each layer:

```
* RELATIVE SHAFT RESISTANCE PER UNIT LENGTH *
FOR SOIL LAYER 1

T1 = SHAFT RESISTANCE AT THE TOP OF SOIL LAYER
T2 = SHAFT RESISTANCE AT THE BOTTOM OF THE LAYER

ENTER T1 , T2
? 0,.104 <RETURN>
```

```
         * RELATIVE SHAFT RESISTANCE PER UNIT LENGTH *
                      FOR SOIL LAYER 2

T 3 = SHAFT RESISTANCE AT THE TOP OF SOIL LAYER
T 4 = SHAFT RESISTANCE AT THE BOTTOM OF THE LAYER

ENTER T3 , T4
? .104,.114 <RETURN>
```

```
         * RELATIVE SHAFT RESISTANCE PER UNIT LENGTH *
                      FOR SOIL LAYER 3

T 5 = SHAFT RESISTANCE AT THE TOP OF SOIL LAYER
T 6 = SHAFT RESISTANCE AT THE BOTTOM OF THE LAYER

ENTER T5 , T6
? .114,.217 <RETURN>
```

```
         * RELATIVE SHAFT RESISTANCE PER UNIT LENGTH *
                      FOR SOIL LAYER 4

T 7 = SHAFT RESISTANCE AT THE TOP OF SOIL LAYER
T 8 = SHAFT RESISTANCE AT THE BOTTOM OF THE LAYER

ENTER T7 , T8
? .217,.758 <RETURN>
```

```
         * RELATIVE SHAFT RESISTANCE PER UNIT LENGTH *
                      FOR SOIL LAYER 5

T 9 = SHAFT RESISTANCE AT THE TOP OF SOIL LAYER
T10 = SHAFT RESISTANCE AT THE BOTTOM OF THE LAYER

ENTER T9 , T10
? .758,1.594 <RETURN>
```

```
* RELATIVE SHAFT RESISTANCE PER UNIT LENGTH *
FOR SOIL LAYER 6

T11 = SHAFT RESISTANCE AT THE TOP OF SOIL LAYER
T12 = SHAFT RESISTANCE AT THE BOTTOM OF THE LAYER

ENTER T11 , T12
? 1.594,.348 <RETURN>
```

```
* RELATIVE SHAFT RESISTANCE PER UNIT LENGTH *
FOR SOIL LAYER 7

T13 = SHAFT RESISTANCE AT THE TOP OF SOIL LAYER
T14 = SHAFT RESISTANCE AT THE BOTTOM OF THE LAYER

ENTER T13 , T14
? .384,.384 <RETURN>
```

The program then computes the respective C-ratio and prompts for the residual compression input for the length of the pile.

```
* RESIDUAL COMPRESSION *

UNIT IN INCHES

RC 3 = RESIDUAL COMPRESSION TO TELLTALE 1A

ENTER ASSUMED <RESIDUAL COMPRESSION> TO TELLTALE 1A
? 0.175 <RETURN>
```

The program now prompts for the residual compression in the lower segment of the test pile. The program then calculate the load at the different telltale locations based on the data input. The program will display the residual compression match results on the screen as shown in Appendix A, page A5.

The program now prompts with the sub-options below:

```
                    * SUB-OPTIONS *

1. REVIEW RESIDUAL COMPRESSION MATCH RESULTS
2. PRINT RESIDUAL COMPRESSION MATCH RESULTS
3. PRINT SHAFT AND LOAD DISTRIBUTION
4. RECALCULATE WITH DIFFERENT SHAFT RESISTANCE DISTRIBUTION
5. RECALCULATE WITH DIFFERENT RESIDUAL COMPRESSION
6. RECALCULATE WITH DIFFERENT LOAD DATA
7. COMPLETE RECALCULATION
8. ITERATION PROCEDURE FOR NON-LINEAR ELASTIC PILE
9. RETURN TO MAIN MENU

WHICH OPTION DO YOU WISH TO USE ?
```

4.5.8.1.1 REVIEW RESIDUAL COMPRESSION MATCH RESULTS

Sub-Option 1 displays on the screen the residual compression match results as shown in Appendix A, page A5.

4.5.8.1.2 PRINT RESIDUAL COMPRESSION MATCH RESULTS

Sub-Option 2 prints a hard copy of the residual compression match results as shown in Appendix A, page A5.

4.5.8.1.3 PRINT SHAFT AND LOAD DISTRIBUTION

Sub-Option 3 prints a hard copy of the shaft and load distribution along the pile corresponding to the match results as shown in Appendix A, page A6.

4.5.8.1.4 RECALCULATE WITH DIFFERENT SHAFT RESISTANCE DISTRIBUTION

Sub-Option 4 recalculates the residual compression match analysis with a different shaft resistance distribution.

4.5.8.1.5 RECALCULATE WITH DIFFERENT RESIDUAL COMPRESSION

Sub-Option 5 recalculates the residual compression match analysis with different residual compression values.

4.5.8.1.6 RECALCULATE WITH DIFFERENT LOAD DATA

Sub-Option 6 recalculates the residual compression match analysis with different load and compression data.

4.5.8.1.7 COMPLETE RECALCULATION

Sub-Option 7 erases the memory and return to the beginning of the residual compression match program.

4.5.8.1.8 ITERATION PROCEDURE FOR NON-LINEAR ELASTIC PILE

Sub-option 8 is used to iterate residual compression match for non-linear elastic pile. Example 2 is used for illustrating this option. A solution to the residual compression match analysis is obtained when a convergence of the average load in the pile segments and slope of elastic line satisfy the non-linear modulus-stress relationship, deformation, and equilibrium conditions.

This option first prompts for the cross-sectional area of the equivalent uniform pile as shown below:

```
* ITERATION FOR NON-LINEAR ELASTIC PILE *

* CROSS-SECTIONAL AREA OF PILE *

ENTER <CROSS-SECTIONAL AREA> OF UNIFORM PILE
<UNIT IN IN^2>
? 200 <RETURN>
```

The program then display the load in the telltale ends and shear centroids.

```
ITERATION 0

SEGMENT          OLD Qave               NEW Qave
                             <TON>
  1               450.0                  449.6
  2               450.0                  435.6
  3               450.0                  416.8
  12              450.0                  613.7
  13              450.0                  562.0
  23              450.0                  509.9

ENTER <RETURN> TO CONTINUE
```

The program then prompts with the options of selecting the non-linear modulus-stress relationship.

```
* ELASTIC MODULUS AS A FUNCTION OF STRESS *

* OPTIONS OF EXPRESSING MODULUS-STRESS RELATIONSHIP *

1. LINEAR MODULUS-STRESS VARIATION
2. NON-LINEAR MODULUS-STRESS VARIATION
3. JANBU'S TANGENT MODULUS-STRESS VARIATION
4. HYPERBOLIC MODULUS-STRESS VARIATION

WHICH OPTION DO YOU WISH TO USE
? 2 <RETURN>
```

In this example, Sub-Option 2 is selected as the modulus-stress relationship to be used for the residual compression match analysis. The non-linear modulus-stress relation in Sub-Option 2 is defined:

MODULUS = [10^(K1/k2)]*[k2^(1/k2)]*[STRESS^(1-1/k2)]

where k1 = constant
      k2 = constant

From the regression of the test results of EXAMPLE 2, the regression constants for non-linear modulus-stress formulation are shown in Fig. 4.12. The program then prompts for input of constants k1 and k2.

Thereafter, the program recalculates the forces in the pile and the corresponding slope of elastic line are computed using the selected modulus-stress relationship and pile geometry. The old and new values of the slope of elastic line at the shear centroids and telltale ends are shown on the screen for visual comparison.

ITERATION 0

SEGMENT	OLD AE/L	NEW AE/L
	<TON/IN>	
1	310.2	252.8
2	195.2	160.0
3	156.0	128.9
12	526.8	405.7
13	313.8	245.6
23	776.0	618.2

ENTER <RETURN> TO CONTINUE

Responding with <RETURN>, the program returns to the previous sub-menu. Visual inspection of the results of the first iteration indicates the slope of elastic line, AE/L value for the segments have not converged into a constant value. To proceed with the next iteration select Sub-Option 8 again. The results of the new average load and slope of elastic line will be displayed in the format shown above.

A solution is obtained when the average load and slope of elastic line of the segments from subsequent calculations converge to a constant value as shown by the results of the fifth iteration in this example.

ITERATION 5

SEGMENT	OLD Qave	NEW Qave
	<TON>	
1	448.7	448.7
2	408.5	408.5
3	354.6	354.6
12	469.8	469.6
13	263.3	143.5
23	143.9	143.5

ENTER <RETURN> TO CONTINUE

ITERATION 5

SEGMENT	OLD AE/L	NEW AE/L
	<TON/IN>	
1	252.8	252.8
2	161.9	161.9
3	132.7	132.7
12	425.9	425.9
13	281.8	281.8
23	777.6	778.1

ENTER <RETURN> TO CONTINUE

In Sub-Option 1 of the modulus-stress formulation menu, the linear modulus-stress relation is defined by:

MODULUS = K1 * STRESS + k2

where k1 = slope of linear relation; constant
k2 = Y-intercept; constant

The program then prompts for input of constants k1 and k2. Thereafter, the program recalculates the forces in the pile and the procedure for obtaining a match is similiar to the procedure used in the example of Sub-Option 2.

In Sub-Option 3 of the modulus-stress formulation menu, the Janbu's tangent modulus-stress relation is defined by:

MODULUS = m*STRESSr*{(STRESS/STRESSr}^(1-j)}

where m = modulus number
j = stress exponent
STRESSr = reference stress (100 KPa or 14.5 psi)

The program then prompts for input of m and j. Thereafter, the program recalculates the forces in the pile and the procedure for obtaining a match is similiar to the procedure used in the example of Sub-Option 2.

In Sub-Option 4 of the modulus-stress formulation menu, the Hyperbolic modulus-stress relation is defined by:

MODULUS = {[1-2*k2*STRESS]+[1-4*k2*STRESS]^(0.5)}/(2*k1)

where STRESS = STRAIN/(k1 + k2*STRAIN)
k1 = constant
k2 = constant

The program prompt for input of k1 and k2. Thereafter, the program recalculates the forces in the pile and the procedure for obtaining a match is similiar to the procedure used in the example of Sub-Option 2.

4.5.8.1.9 RETURN TO MAIN MENU

Sub-Option 9 returns the program to the main menu.

4.5.8.2 Matches - for an assumed residual compression range at lower telltale (Sub-Option 2)

Sub-Option 2 is similiar to Sub-Option 1 in Sec. 4.5.8.1, in the data and pile geometry input. This Sub-Option is illustrated using the same EXAMPLE 1 data.

After the program computes for the C-ratio with the test data and pile geometry input, it prompts for a range of the residual compression values for the lowest telltale as shown below:

```
                    * RESIDUAL COMPRESSION *

                        UNIT IN INCHES

     < RANGE OF RESIDUAL COMPRESSION AT TELLTALE 2 >

R1 = MINIMUM VALUE OF ASSUMED RESIDUAL COMPRESSION
R2 = MAXIMUM VALUE OF ASSUMED RESIDUAL COMPRESSION

ENTER R1, R2
? 0,0.5 <RETURN>
```

The program then calculates the load at the telltale ends and shear centroids. The program then displays the residual compression match results on the screen as shown in Appendix A, page A4.

Thereafter, the program prompts with the sub-options below:

```
                      * SUB-OPTIONS *

1. REVIEW RESIDUAL COMPRESSION MATCH RESULTS
2. PRINT RESIDUAL COMPRESSION MATCH RESULTS
3. RECALCULATE WITH DIFFERENT SHAFT RESISTANCE DISTRIBUTION
4. RECALCULATE WITH DIFFERENT RESIDUAL COMPRESSION
5  RECALCULATE WITH DIFFERENT SLOPE OF ELASTIC LINE
6. RECALCULATE WITH DIFFERENT LOAD DATA
7. COMPLETE RECALCULATION
8. RETURN TO MAIN MENU

WHICH OPTION DO YOU WISH TO USE ?
```

4.5.8.2.1 REVIEW RESIDUAL COMPRESSION MATCH RESULTS

Sub-Option 1 displays the match results on the screen.

4.5.8.2.2 PRINT RESIDUAL COMPRESSION MATCH RESULTS

Sub-Option 2 prints a hard copy of the match results.

4.5.8.2.3 RECALCULATE WITH DIFFERENT SHAFT RESISTANCE DISTRIBUTION

Sub-Option 3 recalculates the residual compression match analysis with a different shaft resistance distribution.

4.5.8.2.4 RECALCULATE WITH DIFFERENT RESIDUAL COMPRESSION

Sub-Option 4 recalculates the residual compression match analysis with different residual compression values.

4.5.8.2.5 RECALCULATE WITH DIFFERENT SLOPE OF ELASTIC LINE

Sub-Option 5 recalculates the residual compression match analysis with different slope of elastic line values.

4.5.8.2.6 RECALCULATE WITH DIFFERENT LOAD DATA

Sub-Option 6 recalculates the residual compression match analysis with different load and compression data.

4.5.8.2.7 COMPLETE RECALCULATION

Sub-Option 7 erases the memory and return to the beginning of the residual compression match program.

4.5.8.2.8 RETURN TO MAIN MENU

Sub-Option 8 returns the program to the main menu.

4.5.9 LEONARDS-LOVELL CALCULATION PROGRAM (OPTION 9)

Option 9 is load distribution analysis using the expanded Leonards-Lovell method. On selecting this option, the program prompts with the selection of the "Analysis File" to be used as shown:

```
                    * LIST OF 'ANALYSIS FILE' *

        1) EXAMPLE 1 * Ttales 3H & 1A
        2) EXAMPLE 2 * Ttales 6 & 11

ENTER <RETURN> RETURN TO MAIN MENU

ENTER <FILE NUMBER> TO BE CALLED
? 1 <RETURN>
```

Responding with <RETURN> causes the program to return to the main menu.

Responding with a number corresponding to any of the file listed in the screen causes the program to read the load that analysis file.

The program then prompts for the slope of elastic line input with options as shown:

```
                 * SLOPE OF ELASTIC LINE, AE/L *

                          * OPTIONS *

1. ENTER EACH SEGMENTS AE/L, SEPARATELY
2. ENTER AE/L TO TELLTALE 2 AND PROPORTION THE REST
? 1 <RETURN>
```

Sub-Option 1 prompts for the slope of elastic line for each segments.

```
                  * SLOPE OF ELASTIC LINE, AE/L *

                         UNIT IN TON/IN

 ES 1  = AE/L TO TELLTALE 3H
 ES 2  = AE/L TO TELLTALE 1A
 ES 12 = AE/L BETWEEN TELLTALES 3H & 1A

 ENTER ES 1
? 612.0 <RETURN>
```

```
 ENTER ES 2
? 323.6 <RETURN>
```

```
 ENTER ES 12
? 397.7 <RETURN>
```

Sub-Option 2 prompts for the slope of elastic line of the segment between the pile head and lowest telltale.

```
                  * SLOPE OF ELASTIC LINE, AE/L *

                         UNIT IN TON/IN

ENTER ES 2 = AE/L TO TELLTALE 1A

ENTER ES 2
? 323.6 <RETURN>
```

The slope of elastic line for the rest of the segments are calculated based on the inverse proportion of their lengths as shown in this example.

Thereafter, for analysis file with two telltales, the program prompts with options as shown:

```
DO YOU WISH TO CALCULATE FOR BOTH TELLTALES

ENTER <1> TO CALCULATE ONE TELLTALE ONLY

ENTER <2> TO CALCULATE FOR BOTH TELLTALES
? 2 <RETURN>
```

Responding with 1 <RETURN>, the program then prompts for the telltales to use for calculation.

In this example, respond with 2 <RETURN> for calculation with both telltales.

The program then prompts with option for Leonard-Lovell C-ratio input.

```
                    * LEONARDS-LOVELL C-RATIO *

1. INPUT C-RATIO
2. COMPUTE C-RATIO FROM SHAFT RESISTANCE DISTRIBUTION

WHICH OPTION DO YOU WISH TO USE
? 2 <RETURN>
```

Sub-Option 1 prompts for Leonards-Lovell C-ratio for each segments.

Sub-Option 2 prompts for shaft resistance distribution input that is to be used for the Leonards-Lovell C-ratio calculation as shown below:

```
          * LEONARDS-LOVELL C-RATIO FROM ASSUMED *
              SHAFT RESISTANCE DISTRIBUTION

        * SHAPE OF SHAFT RESISTANCE DISTRIBUTION *

1. TRIANGULAR
2. RECTANGULAR
3. MULTI-LAYERED TRAPEZOIDS < MAX. 10>

WHICH OPTION DO YOU WISH TO USE ?
```

3 <RETURN>

Sub-Option 1 selects a triangular shaft resistance distribution and compute for the respective C-ratio.

Sub-Option 2 selects a rectangular shaft resistance distribution and compute the respective C-ratio.

Sub-Option 3 selects a shaft resistance distribution containing up to ten trapezoids. This Sub-Option first prompts for the number of layers defining the shaft resistance distribution as shown below:

```
                 * NUMBER OF SOIL LAYERS *
             (MINIMUM 2 AND MAXIMUM 10 LAYERS)

ENTER <NUMBER OF SOIL LAYERS> TO LOWEST TELLTALE
```

? 7 <RETURN>

Thereafter, the program prompts for the depth to these layers from the soil surface.

```
       * DEPTH TO SOIL LAYERS FROM GROUND SURFACE *
                      UNIT IN FEET

ENTER DEPTH TO LOWER BOUNDARY OF LAYER 1
```

? 3.7 <RETURN>

```
ENTER DEPTH TO LOWER BOUNDARY OF LAYER 2
? 12.7 <RETURN>

ENTER DEPTH TO LOWER BOUNDARY OF LAYER 3
? 52.7 <RETURN>

ENTER DEPTH TO LOWER BOUNDARY OF LAYER 4
? 74.5 <RETURN>

ENTER DEPTH TO LOWER BOUNDARY OF LAYER 5
? 80.8 <RETURN>

ENTER DEPTH TO LOWER BOUNDARY OF LAYER 6
? 95.3 <RETURN>
```

The shaft resistance distribution is defined when the shaft resistance at the top and bottom interfaces of each layer are input as shown below:

```
          * RELATIVE SHAFT RESISTANCE PER UNIT LENGTH *
                       FOR SOIL LAYER 1

T1 = SHAFT RESISTANCE AT THE TOP OF SOIL LAYER
T2 = SHAFT RESISTANCE AT THE BOTTOM OF THE LAYER

ENTER T1 , T2
? 0,.104 <RETURN>

          * RELATIVE SHAFT RESISTANCE PER UNIT LENGTH *
                       FOR SOIL LAYER 2

T 3 = SHAFT RESISTANCE AT THE TOP OF SOIL LAYER
T 4 = SHAFT RESISTANCE AT THE BOTTOM OF THE LAYER

ENTER T3 , T4
? .104,.114 <RETURN>
```

```
* RELATIVE SHAFT RESISTANCE PER UNIT LENGTH *
              FOR SOIL LAYER 3

T 5 = SHAFT RESISTANCE AT THE TOP OF SOIL LAYER
T 6 = SHAFT RESISTANCE AT THE BOTTOM OF THE LAYER

ENTER T5 , T6
? .114,.217 <RETURN>
```

```
* RELATIVE SHAFT RESISTANCE PER UNIT LENGTH *
              FOR SOIL LAYER 4

T 7 = SHAFT RESISTANCE AT THE TOP OF SOIL LAYER
T 8 = SHAFT RESISTANCE AT THE BOTTOM OF THE LAYER

ENTER T7 , T8
? .217,.758 <RETURN>
```

```
* RELATIVE SHAFT RESISTANCE PER UNIT LENGTH *
              FOR SOIL LAYER 5

T 9 = SHAFT RESISTANCE AT THE TOP OF SOIL LAYER
T10 = SHAFT RESISTANCE AT THE BOTTOM OF THE LAYER

ENTER T9 , T10
? .758,1.594 <RETURN>
```

```
* RELATIVE SHAFT RESISTANCE PER UNIT LENGTH *
              FOR SOIL LAYER 6

T11 = SHAFT RESISTANCE AT THE TOP OF SOIL LAYER
T12 = SHAFT RESISTANCE AT THE BOTTOM OF THE LAYER

ENTER T11 , T12
? 1.594,.348 <RETURN>
```

```
              * RELATIVE SHAFT RESISTANCE PER UNIT LENGTH *
                            FOR SOIL LAYER 7

T13 = SHAFT RESISTANCE AT THE TOP OF SOIL LAYER
T14 = SHAFT RESISTANCE AT THE BOTTOM OF THE LAYER

ENTER T13 , T14
? .384,.384 <RETURN>
```

The program then computes the respective C-ratio and prompts for the residual compression input as shown below:

```
                        * RESIDUAL COMPRESSION *

                            UNIT IN INCHES

RC 1 = RESIDUAL COMPRESSION TO TELLTALE 1
RC 2 = RESIDUAL COMPRESSION TO TELLTALE 2

ENTER  RC1 , RC2
? 0.051, 0.175 <RETURN>
```

The program then performs the Leonards-Lovell load distribution calculations and prompts with the option of inserting blank line in the printout.

```
* OPTIONS TO INSERT BLANK LINE IN THE PRINTOUT *

1. RANDOMLY PLACED BLANK LINE(S)
2. EVENLY SPACED BLANK LINES
3. NO BLANK LINE
4. RETURN TO PREVIOUS MENU

WHICH OPTION DO YOU WISH TO USE
? 3 <RETURN>
```

Sub-Option 1 allows any number of blank lines to placed at any locations in the printout. This option prompts for the number of blank lines to be inserted and the locations of the blank line with respect to the identity line number.

Sub-Option 2 prints a blank line at the specified line spacing. This option prompts for the line interval between the blank lines.

Sub-Option 3 prints the Leonards-Lovell calculation table without inserting any blank line between the results.

Sub-Option 4 returns the program to the Leonards-Lovell C-ratio input menu.

A hard copy of the Leonards-Lovell calculation as shown in Appendix A, page A1 is then printed out.

The program then prompts with the following Sub-Options:

```
            * SUB-OPTIONS *

1. PRINT C' VS Q AND 1/Q ANALYSIS
2. COMPLETE RECALCULATION
3. RECALCULATE WITH DIFFERENT RESIDUAL COMPRESSION
4. RECALCULATE WITH DIFFERENT AE/L, C-RATIO, RESIDUAL
   COMPRESSION
5. PRINT THE SAME RESULTS AGAIN
6. RETURN TO MAIN MENU

WHICH OPTION DO YOU WISH TO USE
?
```

4.5.9.1 Print C' vs Q and 1/Q analysis

Sub-option 1 prints the results for analysis of the applied load at full shaft resistance mobilization as shown in Appendix A, page A12.

4.5.9.2 Complete Recalculation

Sub-Option 2 performs a complete recalculation of the Leonards-Lovell analysis.

4.5.9.3 RECALCULATE WITH DIFFERENT RESIDUAL COMPRESSION

Sub-Option 3 recalculates the Leonards-Lovell analysis with different residual compression values.

4.5.9.4 RECALCULATE WITH DIFFERENT AE/L, C-RATIO, RESIDUAL COMPRESSION

Sub-Option 4 recalculates the Leonards-Lovell analysis with different slope of elastic line, C-ratio, and residual compression values.

4.5.9.5 PRINT THE SAME RESULTS AGAIN

Sub-Option 5 prints an additional copy of the Leonards-Lovell results.

4.5.9.6 RETURN TO MAIN MENU

Sub-Option 6 returns the program to the main menu.

4.5.10 CONFIGURE DISK DRIVES (OPTION 10)

Option 10 is used to reconfigure the default disk drive setting of the program and data disks. On selecting this option, the program prompts with :

```
                    * CONFIGURE DISK DRIVES *

This program is used to change the default as given below:

                   Program disk drive  : A
                   Data disk drive     : B

             * SUB-OPTIONS *

1. Change program default disk setting
2. Change data default setting
3. Save default settings as shown above
4. Return to main menu

WHICH OPTION DO YOU WISH TO USE ?
```

4.5.10.1 Change program default setting

Sub-Option 1 prompts for the disk setting for the program disk as shown below:

```
       CURRENT DEFAULT DISK DRIVE FOR PROGRAM DISK : A

       * SET NEW DEFAULT DISK DRIVE FOR PROGRAM DISK *

              A> DISK DRIVE A
              B> DISK DRIVE B
              C> DISK DRIVE C
              D> DISK DRIVE D

         WHICH OPTION DO YOU WISH TO USE ?
```

Responding with the appropriate alphabet will assign that alphabet as the new default program disk drive.

It should be noted that the default setting altered using this sub-option has to be stored using Sub-Option 3 in order for it to be effective.

4.5.10.2 Change data default setting

Sub-Option 2 prompts for the disk setting for the data disk as shown below:

```
CURRENT DEFAULT DISK DRIVE FOR DATA DISK : B

* SET NEW DEFAULT DISK DRIVE FOR DATA DISK *

     A> DISK DRIVE A
     B> DISK DRIVE B
     C> DISK DRIVE C
     D> DISK DRIVE D

WHICH OPTION DO YOU WISH TO USE ?
```

Responding with the appropriate alphabet will assign that alphabet as the new default data disk drive.

It should be noted that the default setting altered using this sub-option has to be stored using Sub-Option 3 in order for it to be effective.

4.5.10.3 Save default settings as shown above

Sub-Option 3 save the default settings of both the program and data disk drives as shown in the prompt.

4.5.10.4 Return to main menu

Sub-Option 4 returns the program to the MAIN MENU.

4.5.11 QUIT (OPTION 11)

Option 11 is used to end the Tellpile analysis and return the computer to the DOS command level at the default program drive setting. This Option 11 in the MAIN MENU.

4.6 EXAMPLES OF TRIAL RUNS

4.6.1 Example 1 - Elastic pile

This example is selected to illustrate the procedure for using the program to perform the load distribution analysis on a linear elastic pile.

The location of instrumentations in Example 1 pile is shown in Fig.4.1. Example 1 is a H-pile with size HP 305 mm by 132 kg/m (12 HP 74). The modulus of elasticity (E) is 200 GPa (29 X 10^6 psi). The results of the static pile test data used in this example is shown in Table 4.1.

The procedure for entering the results of Example 1 into the program database is shown in Sec. 4.5.1.

The limit load analysis for Example 1, using the graphical solutions as outlined in Sec. 2.2, is tabulated in Table 4.2. These results give an indication of the range of where the ultimate resistance load occurred for the test pile. The test results from this load level will also be used for the residual compression match and full shaft resistance mobilization analysis. In Example 1, the set of data with load on pile head of 180.0 to 224.0 tons is selected for the residual compression match analysis.

In load distribution analysis of Example 1, the two unknown parameters in using the Leonards-Lovell and residual compression match analysis are the shaft resistance distribution and the magnitude of the residual compression in the pile.

To determine the probably shaft resistance distribution to be used for these analysis, trials run using Leonards-Lovell analysis with different shaft resistance distribution and zero residual compression at the toe telltale are carried out. The procedure for Leonards-Lovell analysis is shown in Sec 4.5.9. The results for shaft resistance distribution with triangular, rectangular and seven trapezoidal layers are shown in pages A1 to A3, Appendix A. The shaft resistance distribution with seven trapezoidal layers is obtained by differentiating the regressional polynomials describing the load distribution curve and dividing the results by the shaft perimeter area of the pile as shown in Khan (1987).

The results from residual compression match analysis using the rectangular shaft resistance distribution assumption indicated consistent amount of toe load for small increment in the applied load. The results in the other shaft resistance distribution assumptions showed random fluctuation in the computed toe load even for data with small difference in the applied load. Hence, the rectangular shaft resistance is selected for the residual compression match analysis.

The residual compression match is performed by selecting Option 8 of the Main Menu.

Sub-Option 2, Matches - For an assumed residual compression range at the lower telltale, is first carried out to narrow the range of residual compression that will give a match. This procedure is shown in Sec. 4.5.8.2. The results of this analysis is shown in page A4, Appendix A.

The range of permissible residual compression satisfying the match criterion can be narrow by omitting match with negative toe resistance. This range is further reduced by estimating the pausible range of residual load for pile in this type of soil to be around 60 tons . These have been the basis of selecting the residual compression match of 0.175 inches over the length of Telltale 1A for further specific residual compression analysis. The specific residual compression match procedure is shown in Sec. 4.5.8.1. The results of the specific match and corresponding load distribution are shown in pages A5 and A6, Appendix A.

To check for the validity of the assumed parameters, the residual compression match analysis is repeated for test results with pile head load of 202.0 tons. The results of the analysis are shown in pages A7 to A8, Appendix A. The result of the residual compression match and shaft resistance distribution for the two set of test data are noted to be consistent with each other. Fig. 4.2 is a comparison of the load distribution in pile for the two different load level using the same shaft resistance distribution and residual compression assumptions.

Fig. 4.3 shows the effect of residual compression on the load distribution analysis. Results of residual compression match and load distribution with assumption of zero residual compression in pile toe is shown pages A9 and A10, Appendix A. Comparison to load distribution obtained by the elastic column method is also shown in the figure. Results of the elastic column analysis is shown in Table 4.3.

With the matched residual compression determined for all the segments, Leonards-Lovell calculation for different load level is computed using Option 9 of the Main Menu. Leonards-Lovell analysis for a maximum of two telltales at a time is performed using procedure outlined in Sec. 4.5.9. The results of Leonards-Lovell analysis for telltales 3C and 1A is shown in page A11, Appendix A.

The C', Q and 1/Q table in page A12, Appendix A is generated using sub-option 1, as shown in Sec. 4.5.9.1. The load on pile head when full shaft resistance mobilization analysis is determined from the plot of C' vs Q and 1/Q as shown in Fig. 4.4.

The results of the Leonards-Lovell analysis with triangular and seven trapezoidal layers shaft resistance distribution assumptions are shown in pages A13 and A14, Appendix A. Fig. 4.5 shows the load-movement diagram for shaft resistance mobilized using the various shaft resistance distribution assumptions.

4.6.2 Example 2 - Non-linear elastic pile

This example is selected to illustrate the procedure for using the program to perform the load distribution analysis on non-linear elastic pile.

The location of the instrumentations in Example 2 pile is shown in Fig. 4.6. Example 2 is a 420 mm (16.5) octagonal precast prestressed concrete pile. The pile has a net cross-sectional area of 0.13 m^2 (200 in^2), a circumference of 1.4 m (4.6 ft), and was installed through a steel casing of 92.7 feet. The variation of the modulus of elasticity (E) of this pile is derived from analysis of results from the cased portion of the pile as reported by Yu (1984). The regression of the constants in the non-linear formulation of the modulus of elasticity is shown in Fig. 4.7. The results of the static pile test data used in this example is shown in Table 4.4.

The procedure for entering the results of Example 2 into the program database following the procedure described in Sec. 4.5.1.

The limit load analysis results for Example 2 is tabulated in Table 4.5. This pile was noted to fail structurally when the load on pile head was increased from 510 to 540 tons. Hence, the pile load of 450 tons was selected for the residual compression analysis.

The residual compression match is performed by selecting Option 8 of the Main Menu.

To determine the probably shaft resistance distribution to be used for these analysis, trials run using Leonards-Lovell analysis with different shaft resistance distribution and zero residual compression at the toe telltale are carried out. The procedure for Leonards-Lovell analysis is shown in Sec 4.5.9. The results for shaft resistance distribution with triangular, rectangular and ten trapezoidal layers are shown in pages A15 to A17, Appendix A. The shaft resistance distribution with ten trapezoidal layers is obtained by differentiating the regressional polynomials describing the load distribution curve and dividing the results by the shaft perimeter area of the pile as shown in Taki (1987).

The results from residual compression match analysis using the ten trapezoidal layers shaft resistance distribution assumption indicated consistent amount of toe load for small increment in the applied load.

Then, Sub-Option 2, Matches - For an assumed residual compression range at the lower telltale, is carried out with shaft resistance distribution and cumulative residual compression at the pile toe with range of 0 to 1.0 inches. The procedure is shown in Sec. 4.5.8.2. The results of these analysis are shown in page A18, Appendix A.

The range of permissible residual compression satisfying the match criterion can be narrow by omitting results indicating negative toe resistance. This range is further reduced by estimating the pausible range of residual load for pile in this type of soil to be around 60 tons . These have been the basis of selecting the residual compression match of 0.500 inches over the length of Telltale 11 for further specific residual compression analysis.

The specific residual compression match for Example 2 assuming the pile is linear elastic pile is shown in Sec. 4.5.8.1. The result of this analysis is shown in pages A19 and A20, Appendix A.

However, to include the effect of modulus variation with stress, the iteration procedure as shown in Sec. 4.5.8.1.8 have to be carried out. This iteration procedure is sub-option 8 of the specific residual compression match procedure.

Convergence to a solution after the fifth iteration is apparent from the results of the iterations as shown in pages A21 to A26, Appendix A. Then, the residual compression match results and load distribution for the non-linear elastic pile are printout using sub-option 2 and 3. The results of this residual compression match and load distribution are shown in pages A27 and A28, Appendix A.

The load distribution diagram showing the effect of modulus variation with stress in shown in Fig. 4.8. This figure also incorporates the load distribution obtained by the elastic column approach. Results of the elastic column approach analysis for this pile is shown in Table 4.6. The results of residual compression match for non-linear elastic pile analysis assuming zero residual compression at the pile toe is shown in pages A29 and A30, Appendix A.

With the matched residual compression determined for all the segments, Leonards-Lovell calculation for different load level is computed using Option 9 of the Main Menu. Leonards-Lovell analysis for a maximum of two telltales at a time is performed as indicated in Sec. 4.5.9. The results of Leonards-Lovell analysis for telltales 6 and 11 is shown in page 31, Appendix A. The results of Leonards-Lovell analysis for non-linear elastic pile is valid only for the load level which the slope of elastic line match the value used in this analysis.

CHAPTER 5

CONCLUSIONS

Load distribution obtained from calculation with and without considering the effect of residual compression shows considerable difference. This is illustrated by the results of the two examples in the report.

The load distribution analysis was found to be affected by elastic modulus variation along the pile as shown by the results obtained from the analysis of the prestressed concrete pile, Example 2. However, it should be noted that load distribution analysis of a non-linear elastic pile is very much a function of the distance between the telltales and the accuracy of the telltale data.

The basic shortcomings of the expanded Leonards-Lovell method are the sensitivity of the method to error in the elastic modulus and error in load and deformation data.

For very short segments, small error in the measured compression will give rise to significant difference in residual compression match results.

The computerization of the expanded Leonards-Lovell method has enable a more comprehensive study of load distribution to be undertaken based on results from telltale-instrumented loading tests.

REFERENCES

ASTM, 1981. Standard method of testing pile under axial compressive load. American Society for Testing and Materials, Annual book of ASTM Standards, Part 4, Designation D1143-81, 15 p.

BRINCH-HANSEN, J., 1963. Hyperbolic stress-strain response. Cohesive soil. American Society of Civil Engineers, ASCE Journal for Soil Mechanics and Foundation Engineering, Vol. 89, SM4, pp. 241-242.

BRIAUD, J. L. and TUCKER, L., 1984. Piles in Sand. A method including residual stresses. American Society of CIvil Engineers, ASCE Journal of Geotechnical Engineering, Vol. 110, No. 11, pp. 1666-1679.

BUTLER, H. D. and HOY, H. E., 1977. User manual for Texas quick-load method for foundation load test. Federal Highway Administration, Office of Development, Washington, 59 p.

CHIN, F. K., 1970. Estimate of the ultimate load of piles not carried to failure. Proceedings of the 2nd Southeast Asian Conference on Soil Engineering, Singapore, pp. 81-90.

COYLE, H. M., and REESE, L. C., 1966. Load transfer for axially loaded piles in clay. American Society of Civil Engineers, ASCE Journal for Soil Mechanics and Foundation Engineering, Vol. 92, SM2, pp. 1-26.

DAVISSON, M. T., 1972. High capacity piles. Proceedings, Lecture series, Innovations in Foundation Construction, American Society of Civil Engineering, ASCE Illinois Section, Chicago, 52 p.

FELLENIUS, B. H., 1975. Test loading of piles. Methods, interpretation and proof testing. American Society of Civil Engineers, ASCE Journal of the Geotechnical Engineering Division, Vol. 101, GT9, pp. 855-869.

FELLENIUS, B. H. and SAMSON, L., 1976. Testing of drivability of concrete piles and disturbance to sensitive clay. Canadian Geotechnical Journal, Vol. 13, No. 2, pp. 139-160.

FELLENIUS, B. H., 1980. The analysis of results from routine pile load tests. Ground Engineering, Foundation Publishing Ltd., London, Vol.13, No.6, pp. 19-31.

FELLENIUS, B. H., O'BRIEN, A. J., RIKER, R. E., and TRACY, G. R., 1983. Dynamic monitoring and conventional pile testing procedures. Proceedings of ASCE Conference on Dynamic Measurements of Piles and Piers, ASCE Spring Convention, Philadelphia, 19 p.

HOLLOWAY, D. M., CLOUGH, G. W., and VESIC, A. S., 1978. A rational procedure for evaluating the behaviour of impact-driven piles. American Society for Testing and Material, ASTM Symposium on Behaviour of Deep Foundations, R. Lundgren, Editor, Special Technical Publication, STP 670, 1978, pp. 355-357.

HUNTER, A. H., and DAVISSON, M. T., 1969. Measurements of pile load transfer. Performance of Deep Foundations, American Society for Testing and Materials, ASTM STP 444, pp. 106-107.

KONDNER, R. L., 1963. Hyperbolic stress-strain response. Cohesive soil. American Society of Civil Engineers, ASCE Journal of the Soil Mechanics and Foundations Division, Vol. 95, SM 1, pp. 115-143.

KHAN, N., 1987. Load distribution in test loaded instrumented steel piles. Thesis for the degree of Master of Applied Science in Civil Engineering, University of Ottawa, Canada. 176p.

LEONARDS, G. A., and LOVELL, D., 1979. Interpretation of load tests on high-capacity driven piles. American Society of Testing and Materials, ASTM STP 670, R. Lundgren Editor, pp. 388-415.

POULOS, H. G., and DAVIS, E. H., 1980. Pile foundation analysis and design. Series in Geotechnical Engineering, Chapter 5, Settlement analysis of single piles. John Wiley and Sons, pp. 71-108.

TAKI, I., 1987. Load distribution in test loaded prestressed concrete piles. Thesis for the degree of Master of Engineering in Civil Engineering, University of Ottawa, Canada. 155p.

VESIC, A. S., 1970. Load transfer in pile-soil systems. Design and installation of pile foundations and cellular structures. Envo Publishing Company, H. Y. Fang Editor, pp. 47-73.

YU, A. M., 1984. Evaluation of deformation modulus of prestressed concrete piles. Thesis for the degree of Master of Engineering in Civil Engineering, University of Ottawa, Canada. 126 p.

- TABLES -

TABLE 4.1

* DATA FROM PILE TEST LOADING *

PILE : EXAMPLE 1

* LENGTH FROM GROUND SURFACE *

Length of pile stickup	+0.0 FEET
Length to casing toe	+0.0 FEET
Length to end of Telltale 3C	+56.7 FEET
Length to end of Telltale 8H	+86.2 FEET
Length to end of Telltale 1A	+104.9 FEET

Q	Mh	C1	C2	C3
+34.0	+0.056	+0.046	+0.052	+0.052
+90.0	+0.139	+0.108	+0.119	+0.120
+135.0	+0.275	+0.166	+0.184	+0.186
+168.0	+0.496	+0.213	+0.235	+0.237
+180.0	+0.614	+0.227	+0.249	+0.252
+202.0	+1.014	+0.249	+0.281	+0.283
+224.0	+1.857	+0.288	+0.314	+0.317

Q = LOAD APPLIED ON THE PILE HEAD (TONS)
Mh = MOVEMENT OF PILE HEAD (INCHES)
C1 = COMPRESSION FROM PILE HEAD TO TELLTALE 3C (INCHES)
C2 = COMPRESSION FROM PILE HEAD TO TELLTALE 8H (INCHES)
C3 = COMPRESSION FROM PILE HEAD TO TELLTALE 1A (INCHES)

TABLE 4.2 LIMIT LOAD FOR EXAMPLE 1

DAVISSON METHOD	184.0 TONS
BUTLER AND HOY METHOD	*
BRINCH HANSEN 80% CRITERION	234.0 TONS
CHIN METHOD	251.0 TONS
MAXIMUM APPLIED LOAD	224.0 TONS

TABLE 4.3 LOAD DISTRIBUTION USING ELASTIC COLUMN APPROACH; EXAMPLE 1

DEPTH LENGTH	42.0 9.8	51.8 9.8	66.6 19.7	81.3 9.8	95.6 18.7
LOAD Q	Qave 2B-6F	Qave 6F-3C	Qave 3C-4D	Qave 4D-8H	Qave 8H-1A
34.0	14.2	8.0	4.3	13.2	0.0
90.0	39.5	28.8	12.6	14.3	2.1
135.0	64.0	50.4	20.9	18.7	3.3
168.0	90.0	68.8	27.7	18.0	4.5
180.0	90.7	73.0	28.9	17.3	5.2
202.0	109.9	49.4	44.6	20.4	4.7
224.0	118.1	95.6	34.9	18.7	6.4

TABLE 4.4

" DATA FROM PILE TEST LOADING "

PILE : EXAMPLE 2

" LENGTH FROM GROUND SURFACE "

Length of pile stickup	+0.0 FEET
Length to casing toe	+92.7 FEET
Length to end of Telltale 6	+103.6 FEET
Length to end of Telltale 9	+164.6 FEET
Length to end of Telltale 11	+206.0 FEET

Q	Mh	C1	C2	C3
+90.0	+0.256	+0.190	+0.255	+0.270
+210.0	+0.801	+0.521	+0.728	+0.737
+300.0	+1.277	+0.802	+1.164	+1.189
+390.0	+1.863	+1.131	+1.664	+1.716
+450.0	+2.364	+1.395	+2.062	+2.172
+510.0	+2.972	+1.705	+2.528	+2.710

Q = LOAD APPLIED ON THE PILE HEAD (TONS)
Mh = MOVEMENT OF PILE HEAD (INCHES)
C1 = COMPRESSION FROM PILE HEAD TO TELLTALE 6 (INCHES)
C2 = COMPRESSION FROM PILE HEAD TO TELLTALE 9 (INCHES)
C3 = COMPRESSION FROM PILE HEAD TO TELLTALE 11 (INCHES)

TABLE 4.5 LIMIT LOAD FOR EXAMPLE 2

DAVISSON METHOD (Extrapolated)	*
BUTLER AND HOY METHOD	*
BRINCH HANSEN 80% CRITERION	*
CHIN METHOD	1059.2 TONS
MAXIMUM APPLIED LOAD	510.0 TONS

* N.B. The limit load criterion was not reached.

TABLE 4.6 LOAD DISTRIBUTION USING ELASTIC COLUMN APPROACH; EXAMPLE 2

DEPTH	68.6	92.1	115.1	131.6	150.6	179.6	200.3
LOAD Q	Qave 4,5	Qave 5,6	Qave 6,7	Qave 7,8	Qave 8,9	Qave 9,10	Qave10,11
90.0	70.7	28.0	44.5	11.6	40.7	-13.8	82.7
210.0	188.9	75.8	117.4	74.0	99.3	-14.8	61.7
300.0	285.5	119.1	170.1	127.9	178.6	-11.8	93.9
390.0	374.1	189.6	219.7	203.2	258.5	22.9	64.1
450.0	438.2	253.8	263.8	268.7	311.0	73.1	59.3
510.0	504.2	331.8	317.2	350.7	366.6	146.4	21.8

— FIGURES —

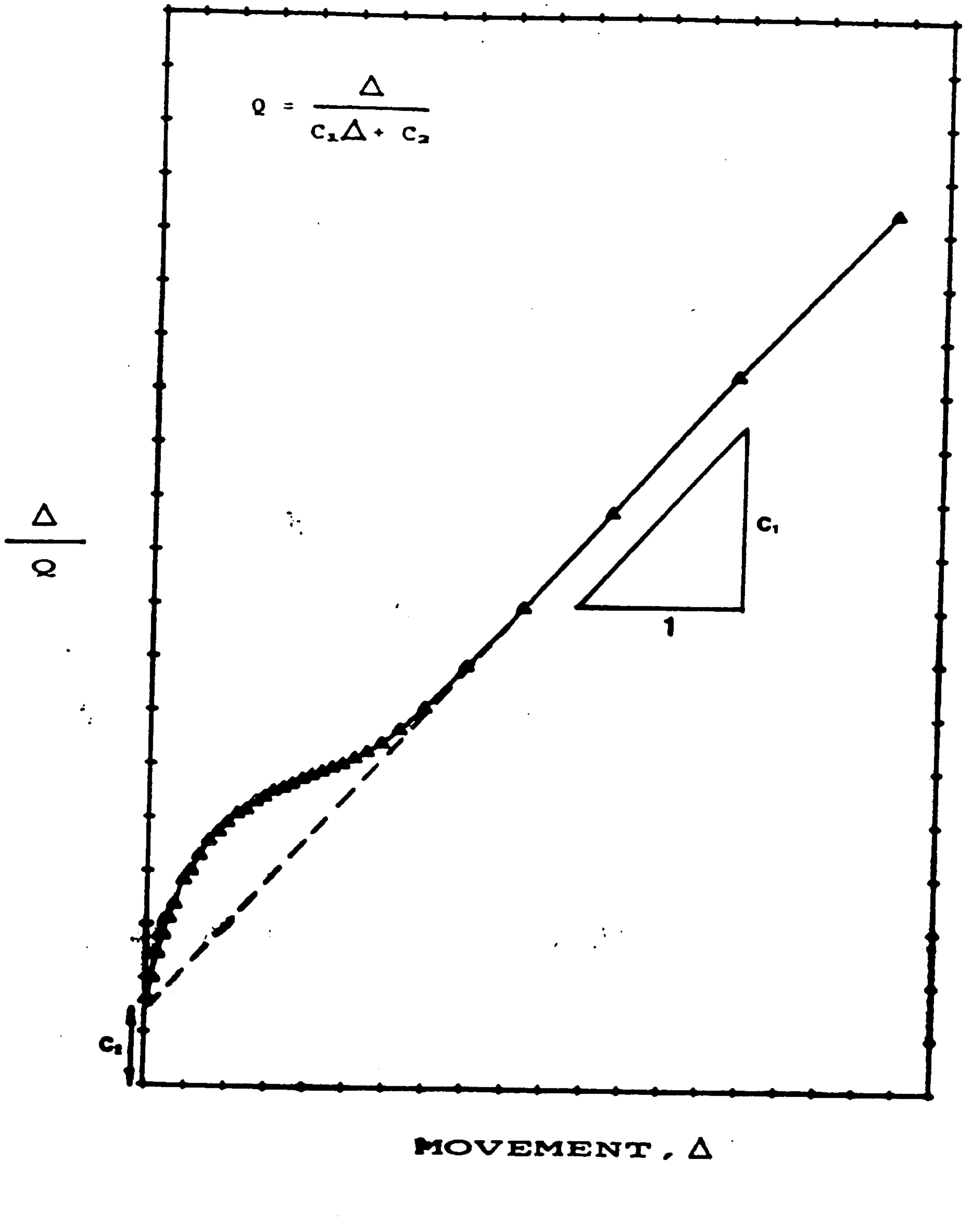


FIGURE 2.1 CHIN STABILITY PLOT

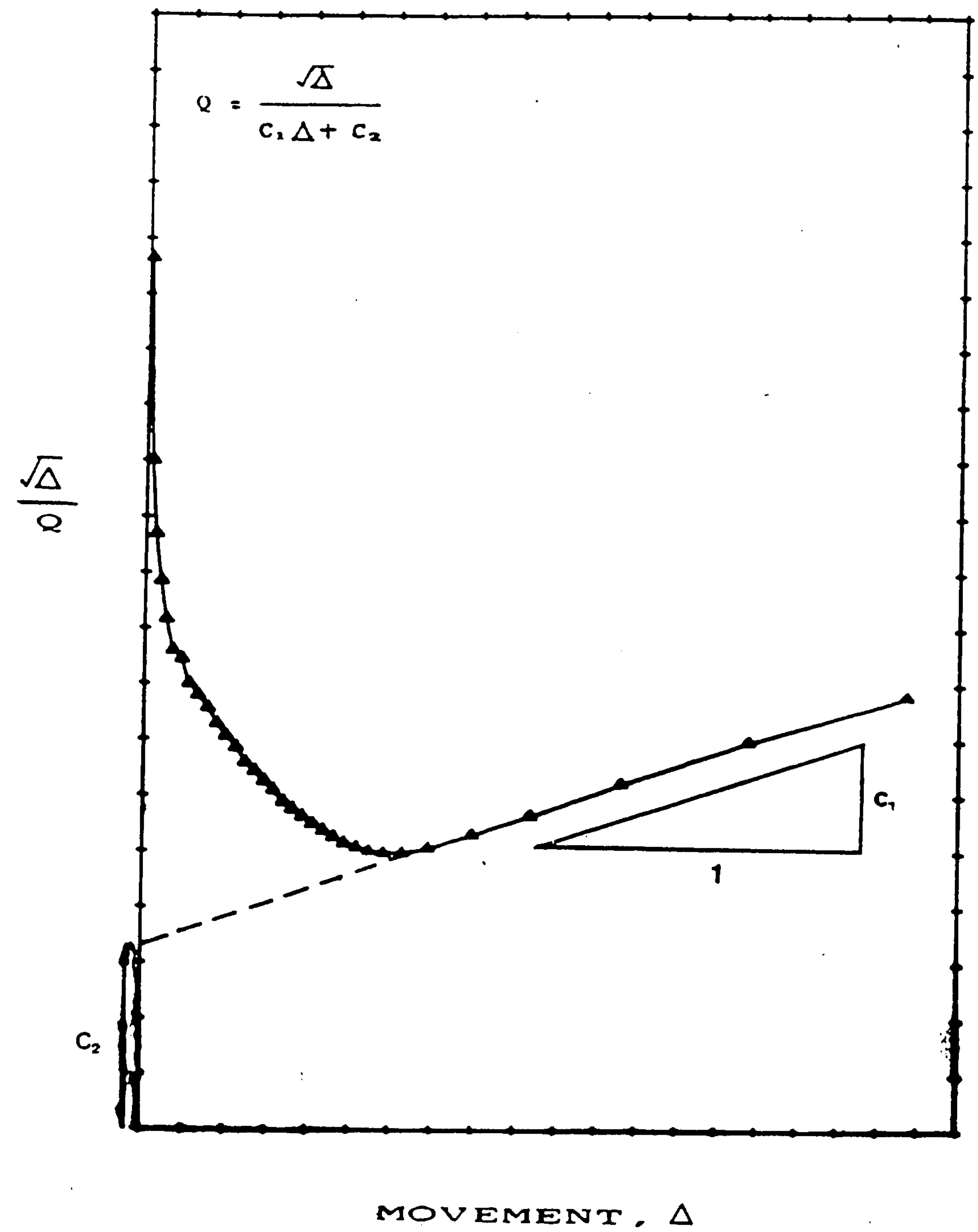


FIGURE 2.2 BRINCH HANSEN 80% CRITERION

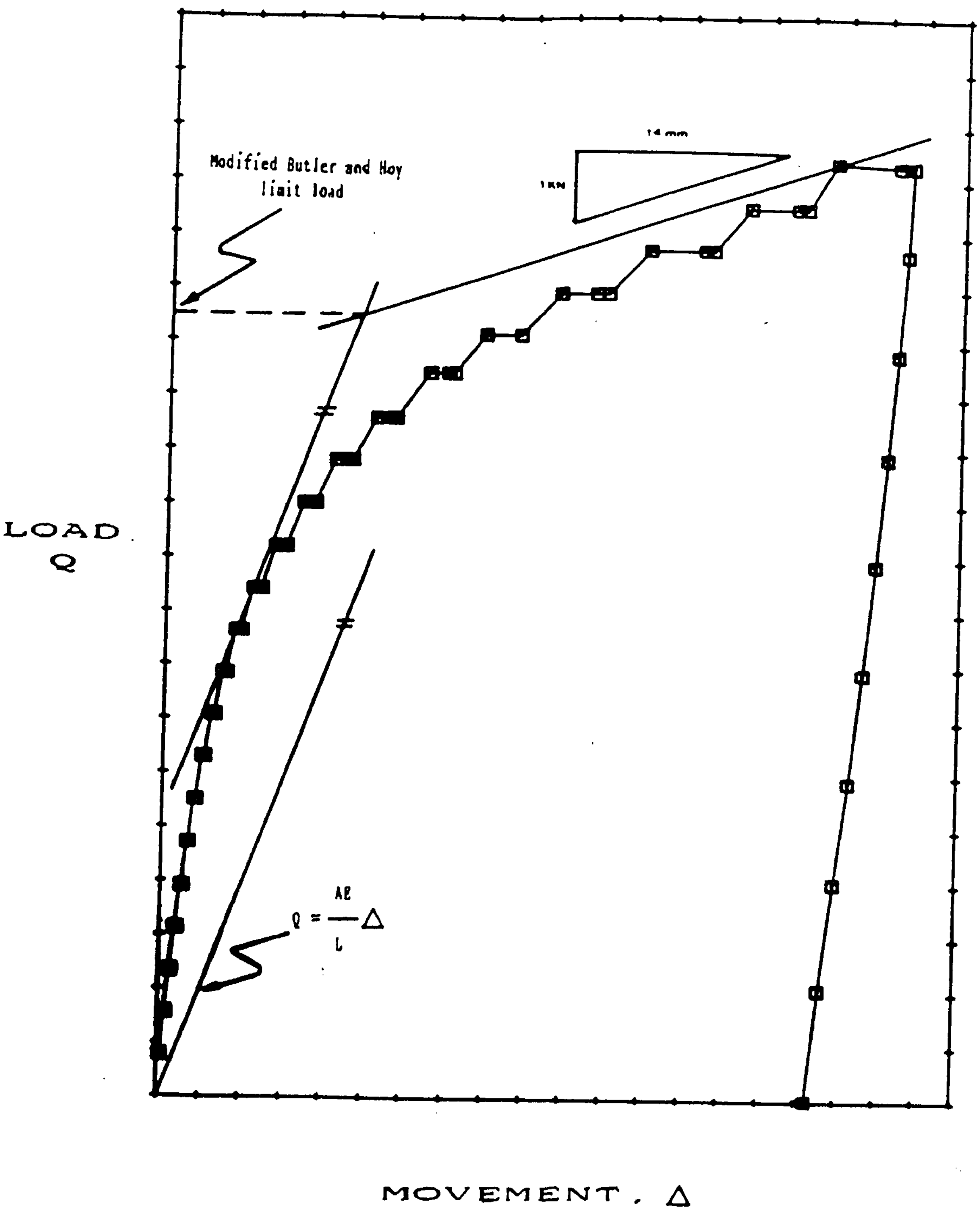


FIGURE 2.3 MODIFIED BUTLER HOY METHOD

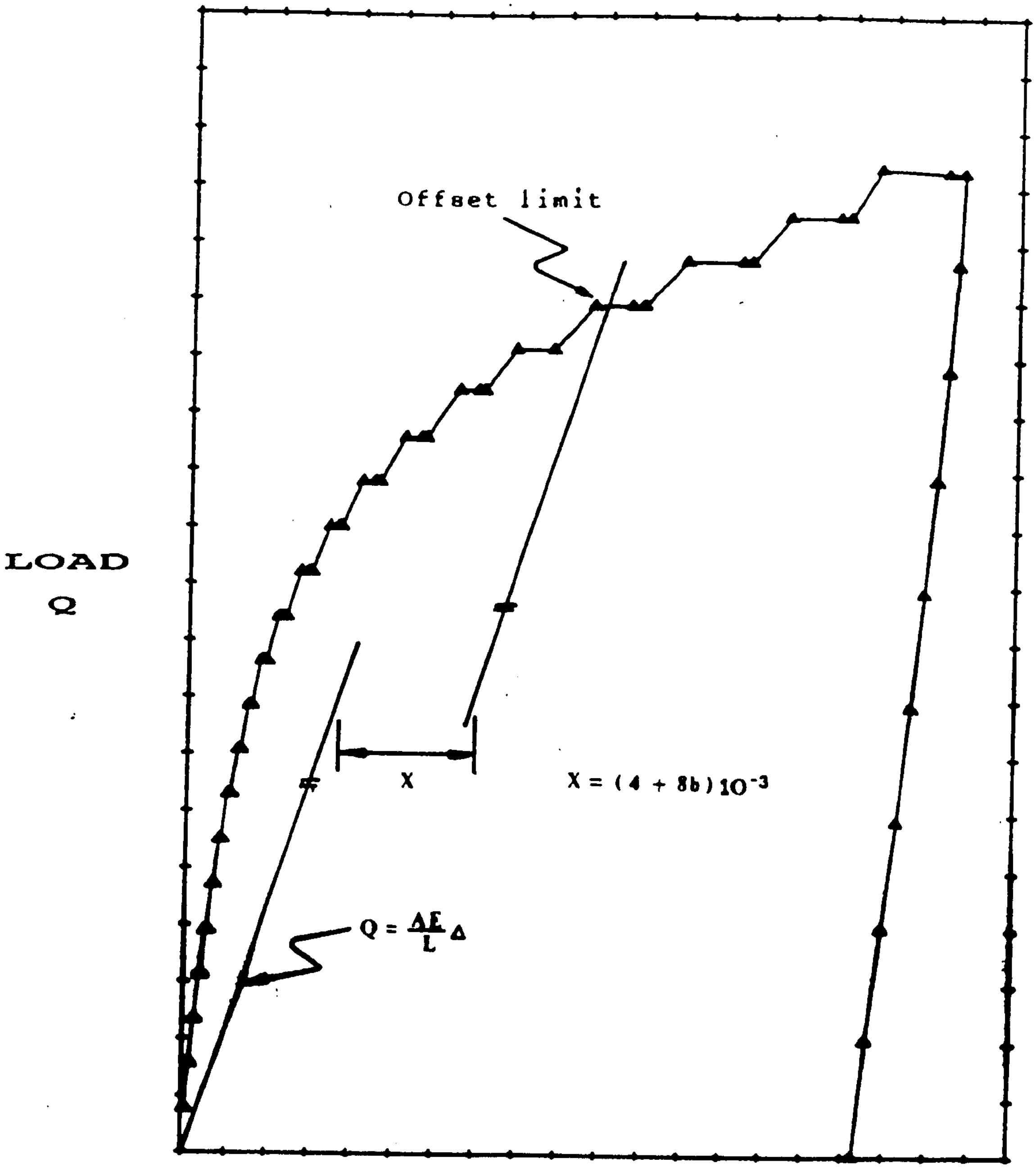


FIGURE 2.4 DAVISSON OFFSET METHOD

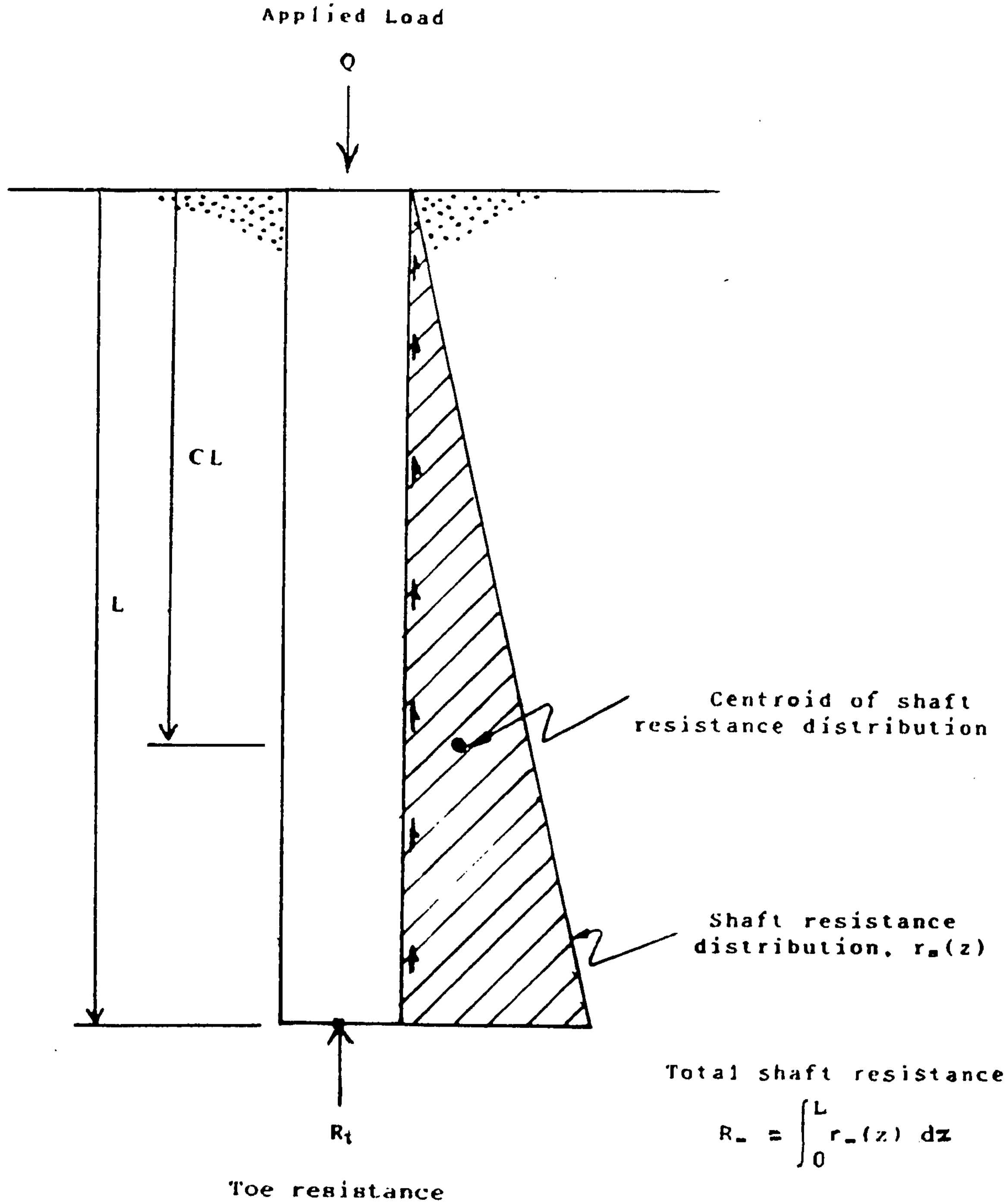


FIGURE 2.5 LEONARDS-LOVELL METHOD

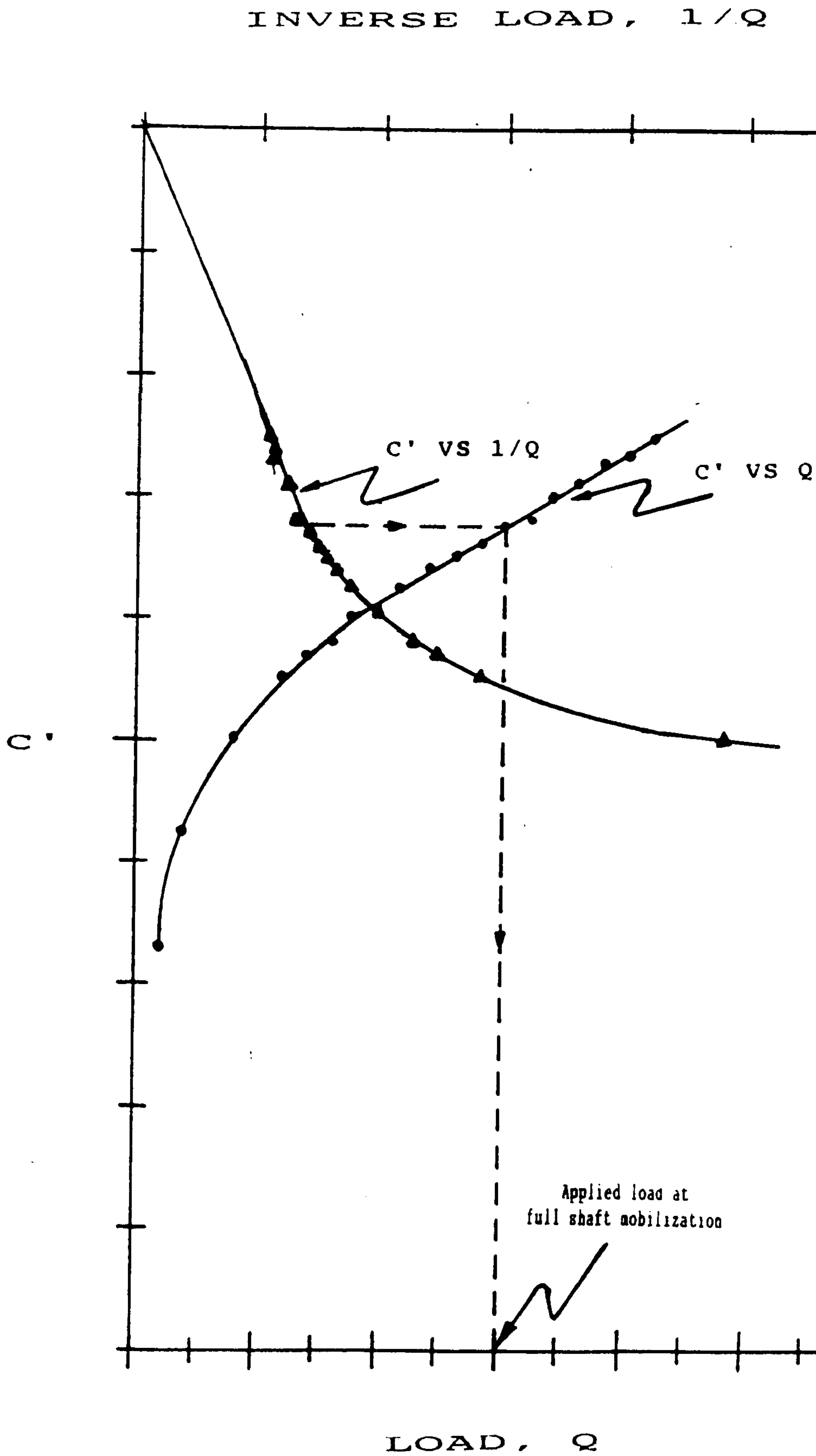


FIGURE 2.6 FULL SHAFT MOBILIZATION ANALYSIS
(C' VS Q and C' VS 1/Q PLOTS)

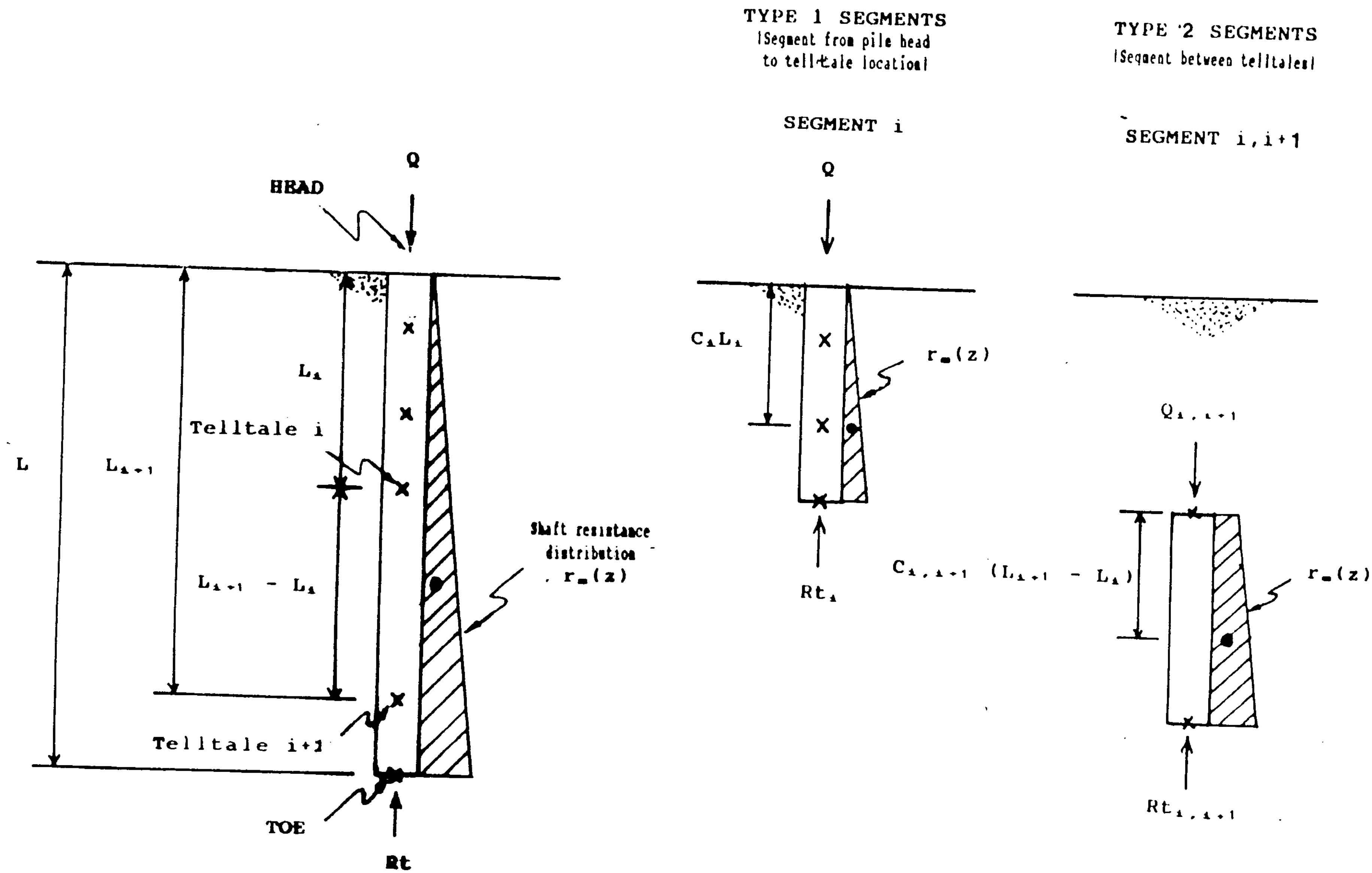


FIGURE 2.7 LEONARDS-LOVELL METHOD (MULTIPLE TELLTALES)

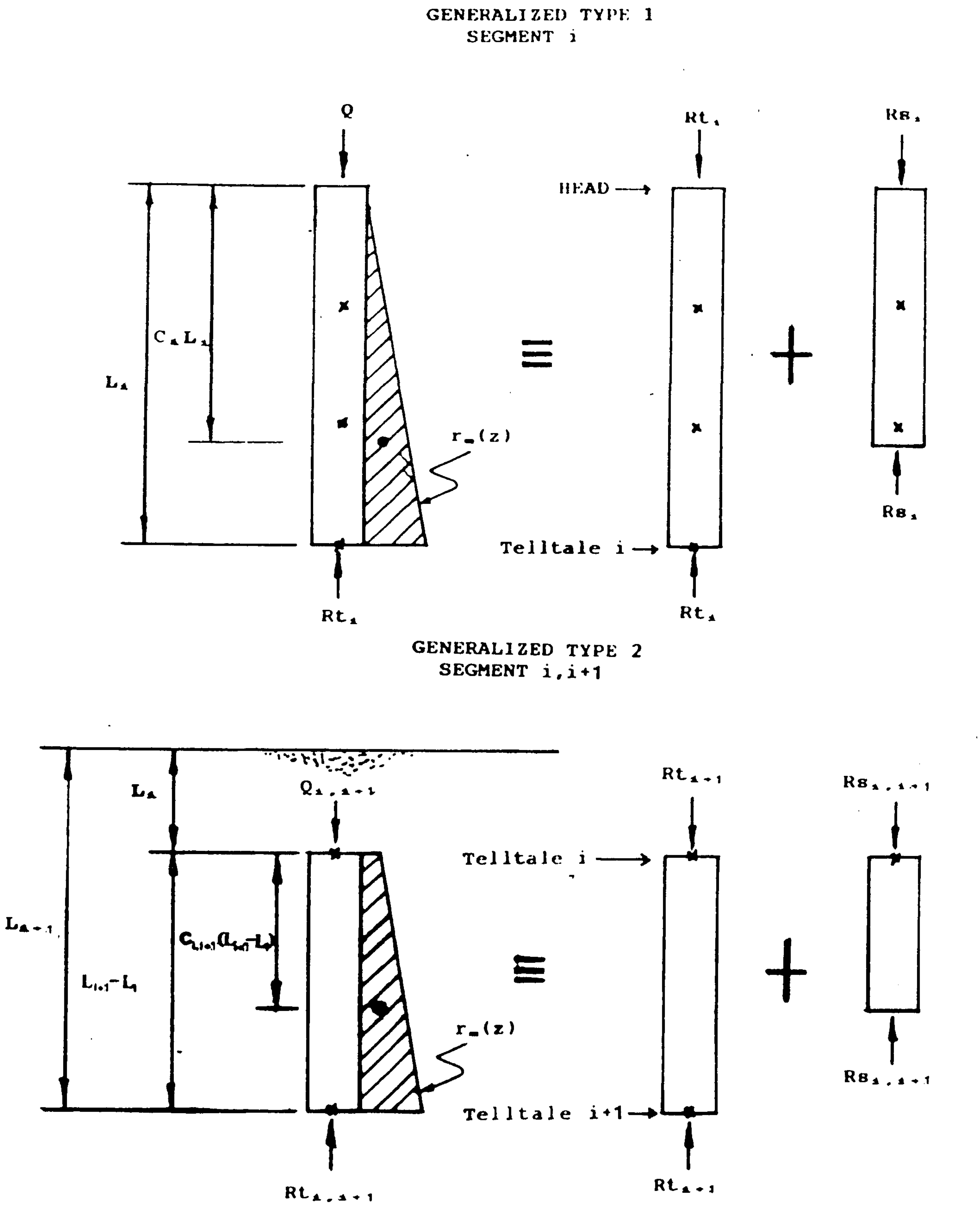
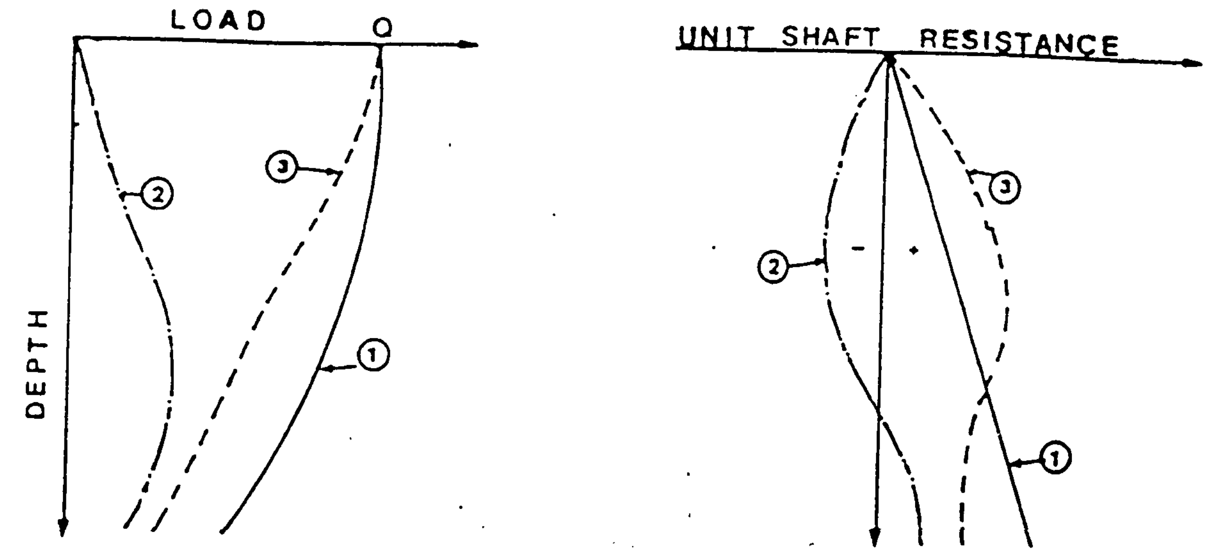
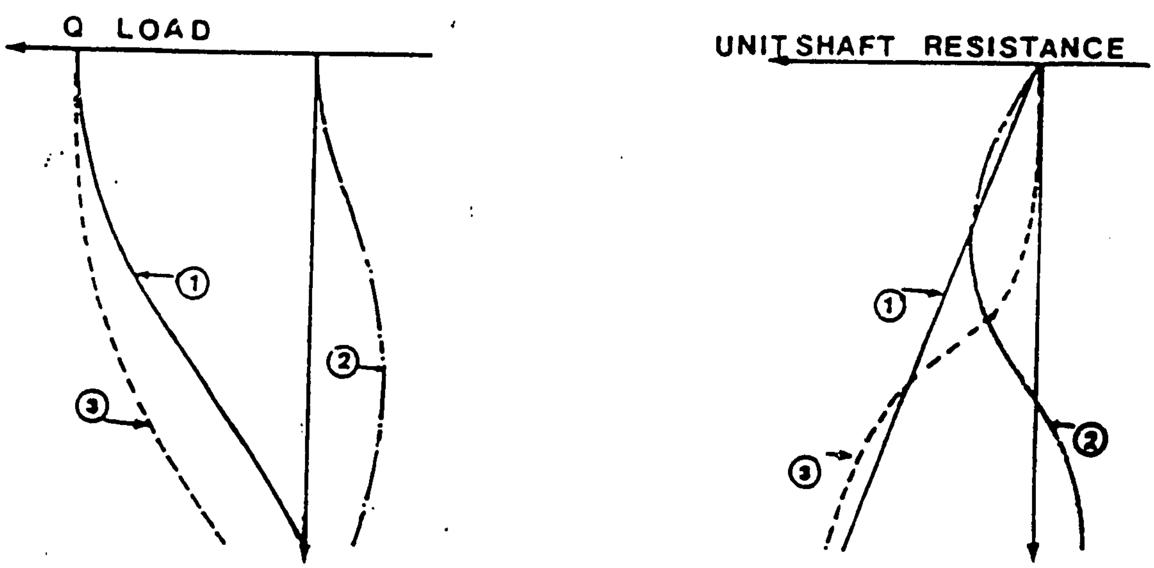


FIGURE 2.8 EQUIVALENT SEGMENT LOAD



(a)
COMPRESSION TEST



(b)
TENSION TEST

Fig. 2.9 Load transfer behaviour for piles in compression and tension considering residual stresses (after Holloway et al. 1978)

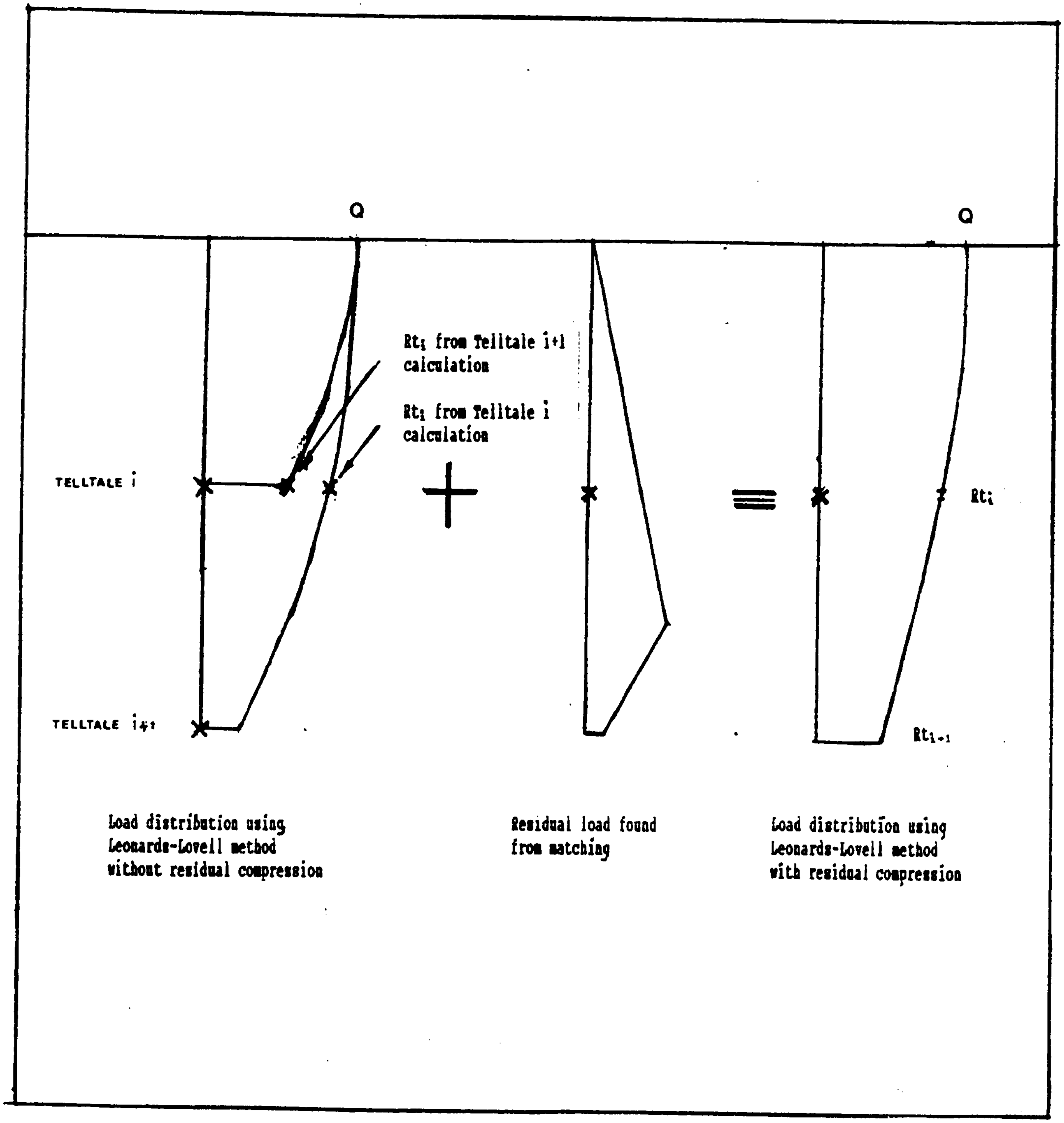
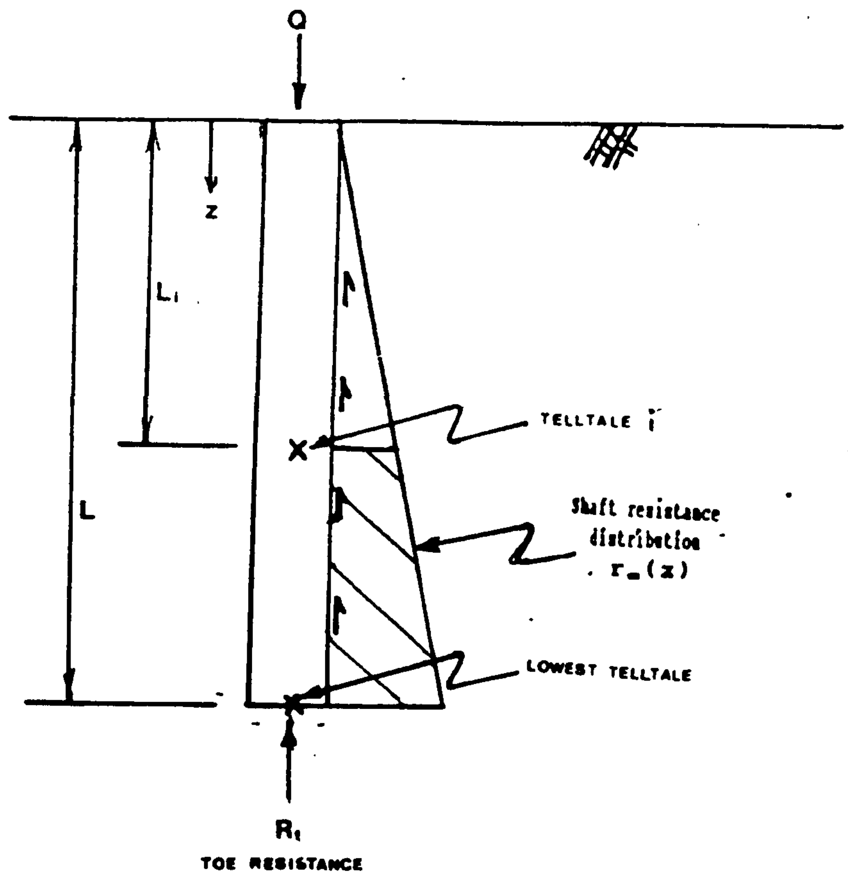


FIGURE 2.10 LOAD DISTRIBUTION USING LEONARDS-LOVELL WITH AND WITHOUT RESIDUAL COMPRESSION



$$\text{Normalized ratio, } N_i = \frac{\text{Total shaft resistance over length } L_i}{\text{Total shaft resistance over length } L}$$

$$= \frac{\text{Area (triangle)}}{\text{Area (hatched triangle)}}$$

$$= \frac{\int_{L_i}^{0} rs(z)dz}{\int_{L}^{0} rs(z)dz}$$

FIGURE 2.11 NORMALIZATION OF SHAFT RESISTANCE

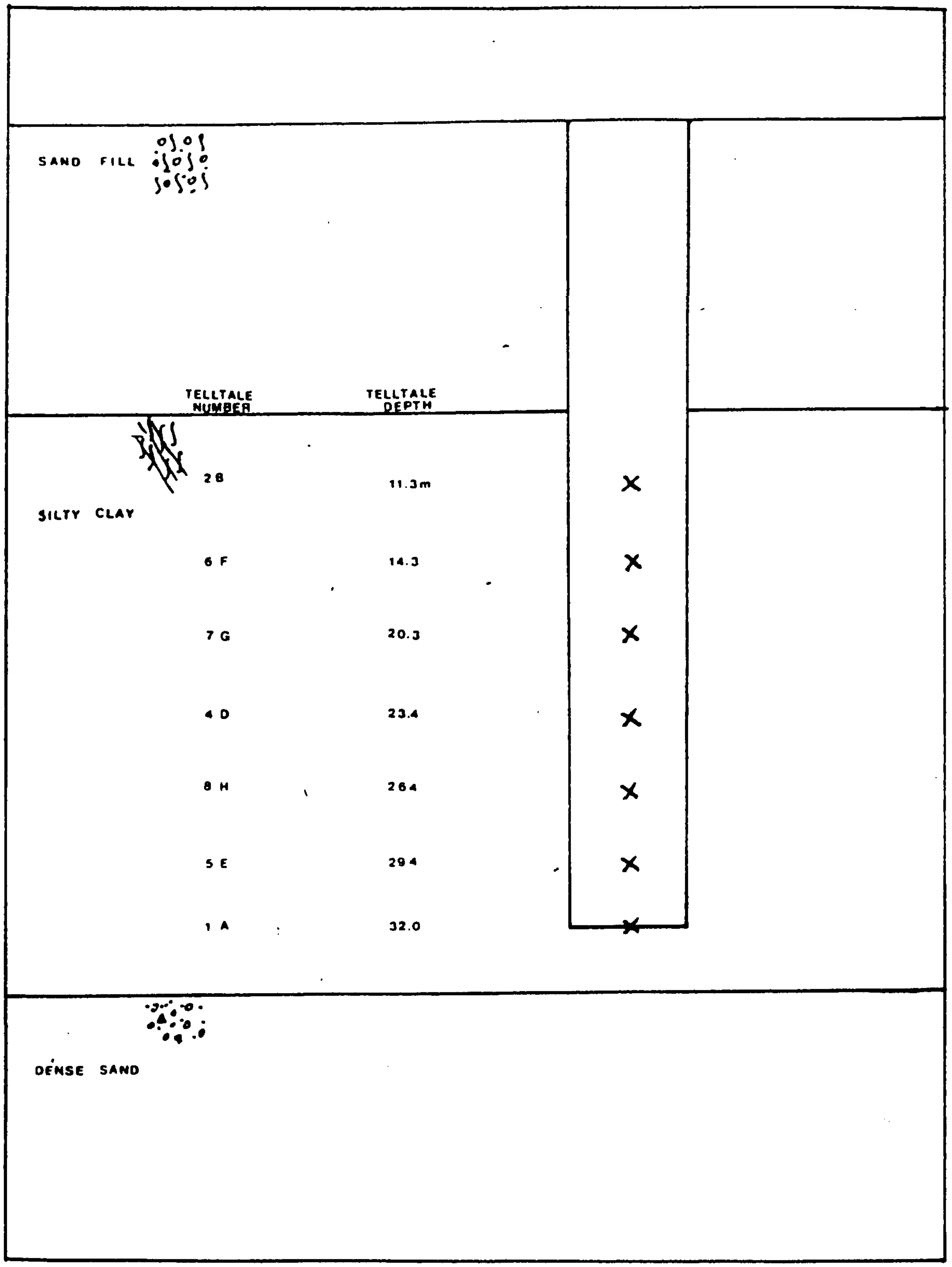


FIGURE 4.1 LOCATION OF INSTRUMENTATION IN EXAMPLE 1

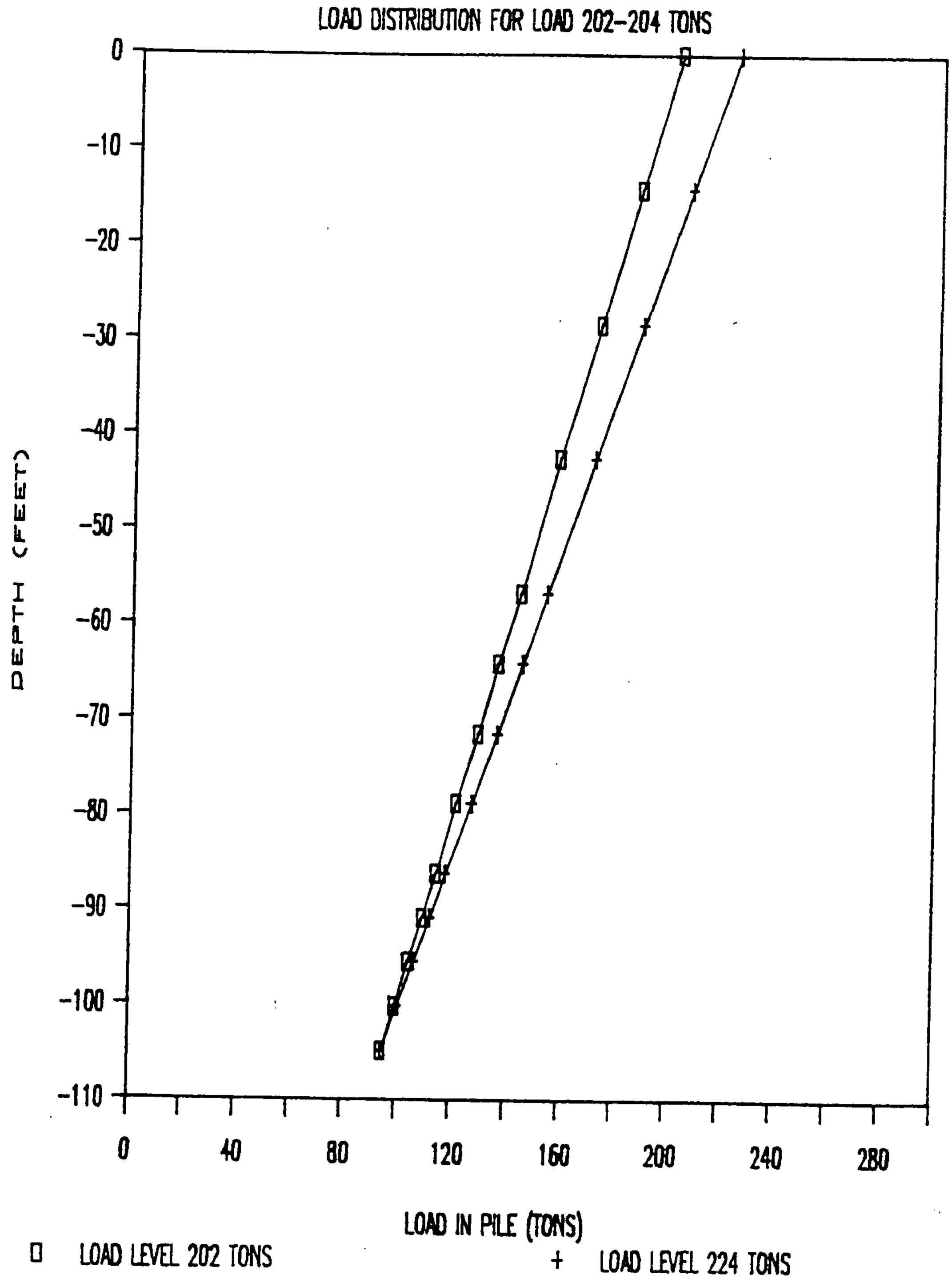


FIGURE 4.2 LOAD DISTRIBUTION FOR EXAMPLE 1 FOR LOAD LEVEL 202 AND 224 TONS

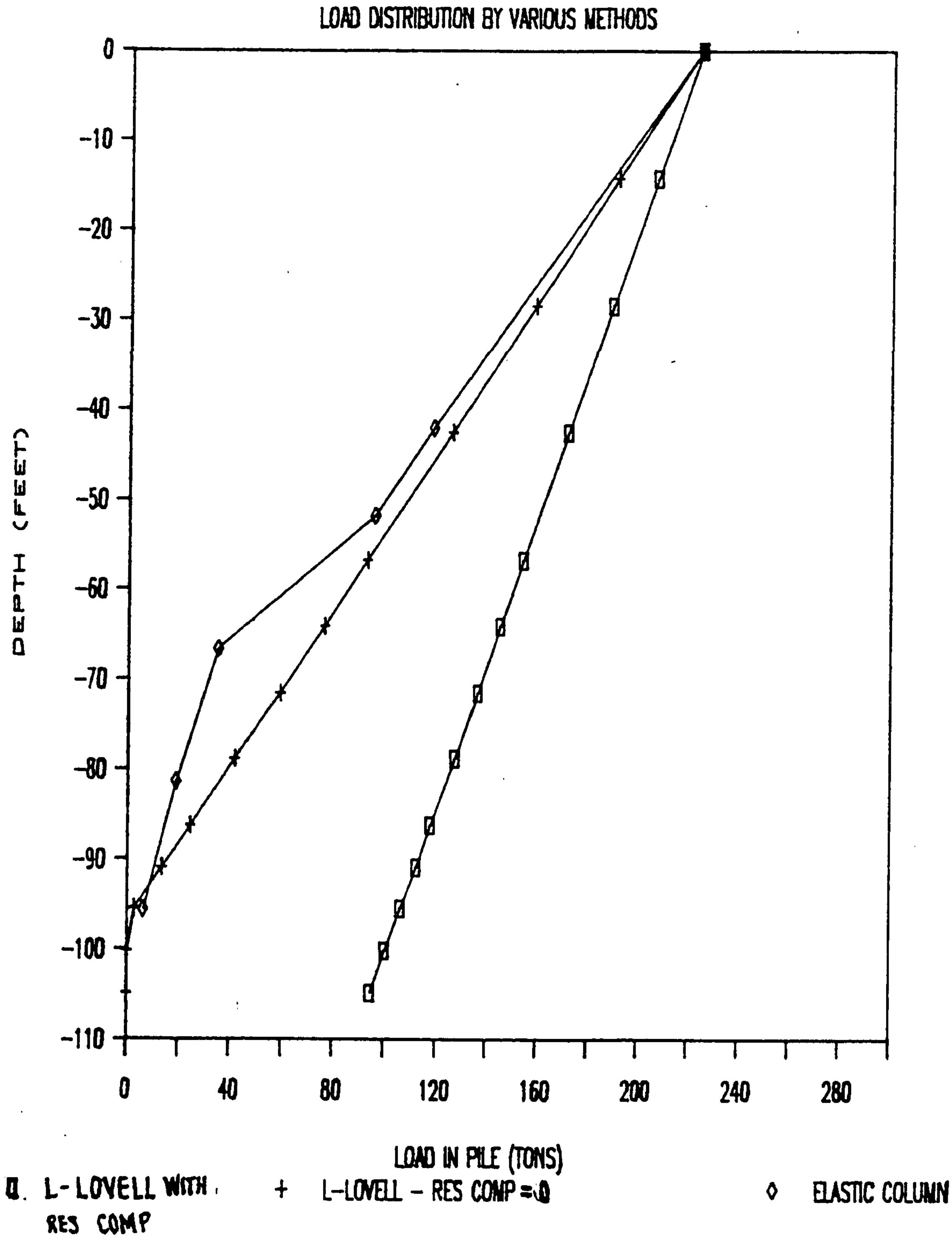


FIGURE 4.3 LOAD DISTRIBUTION CONSIDERING RESIDUAL COMPRESSION

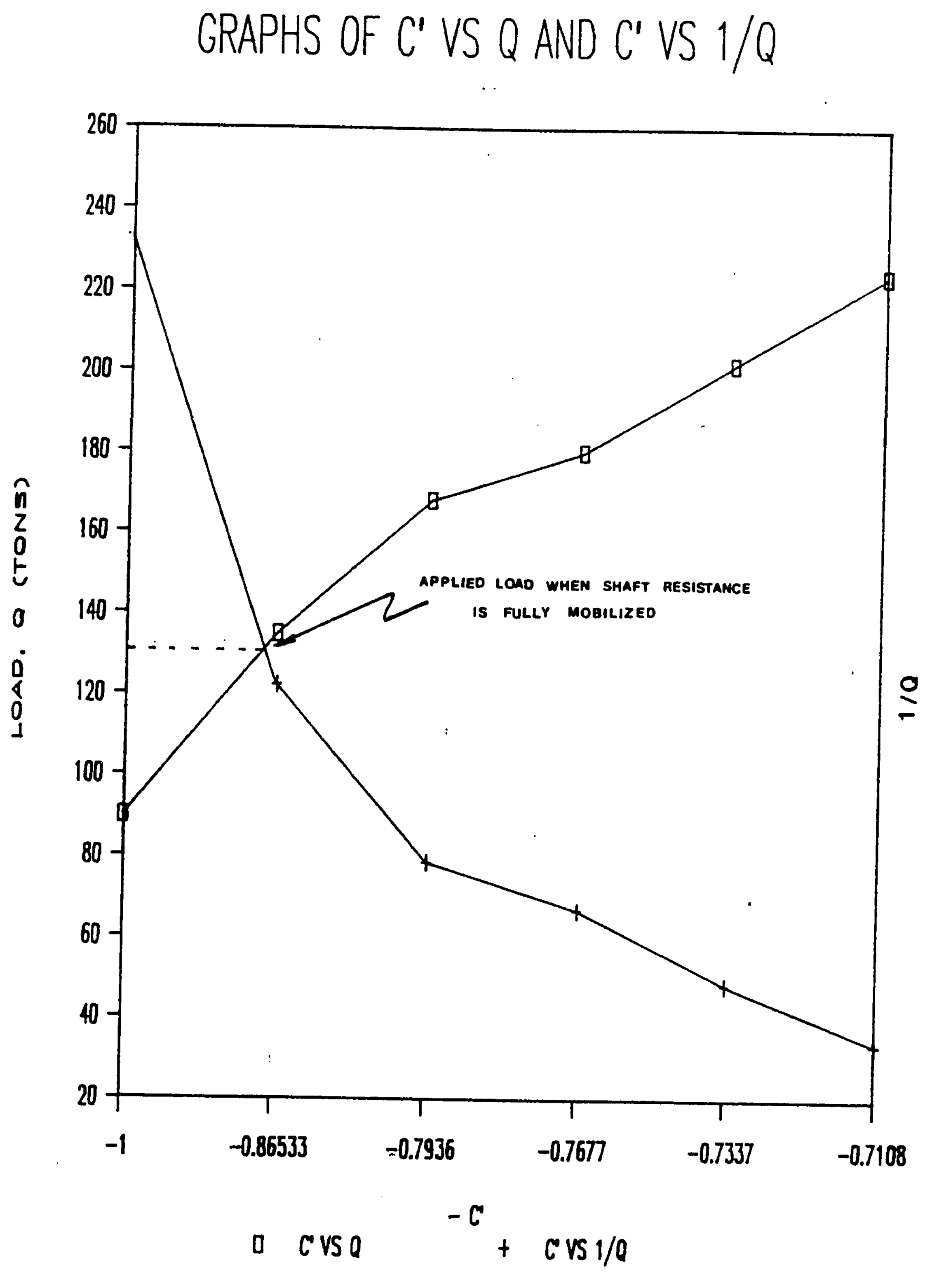


FIGURE 4.4 FULL SHAFT MOBILIZATION ANALYSIS FOR EXAMPLE 1

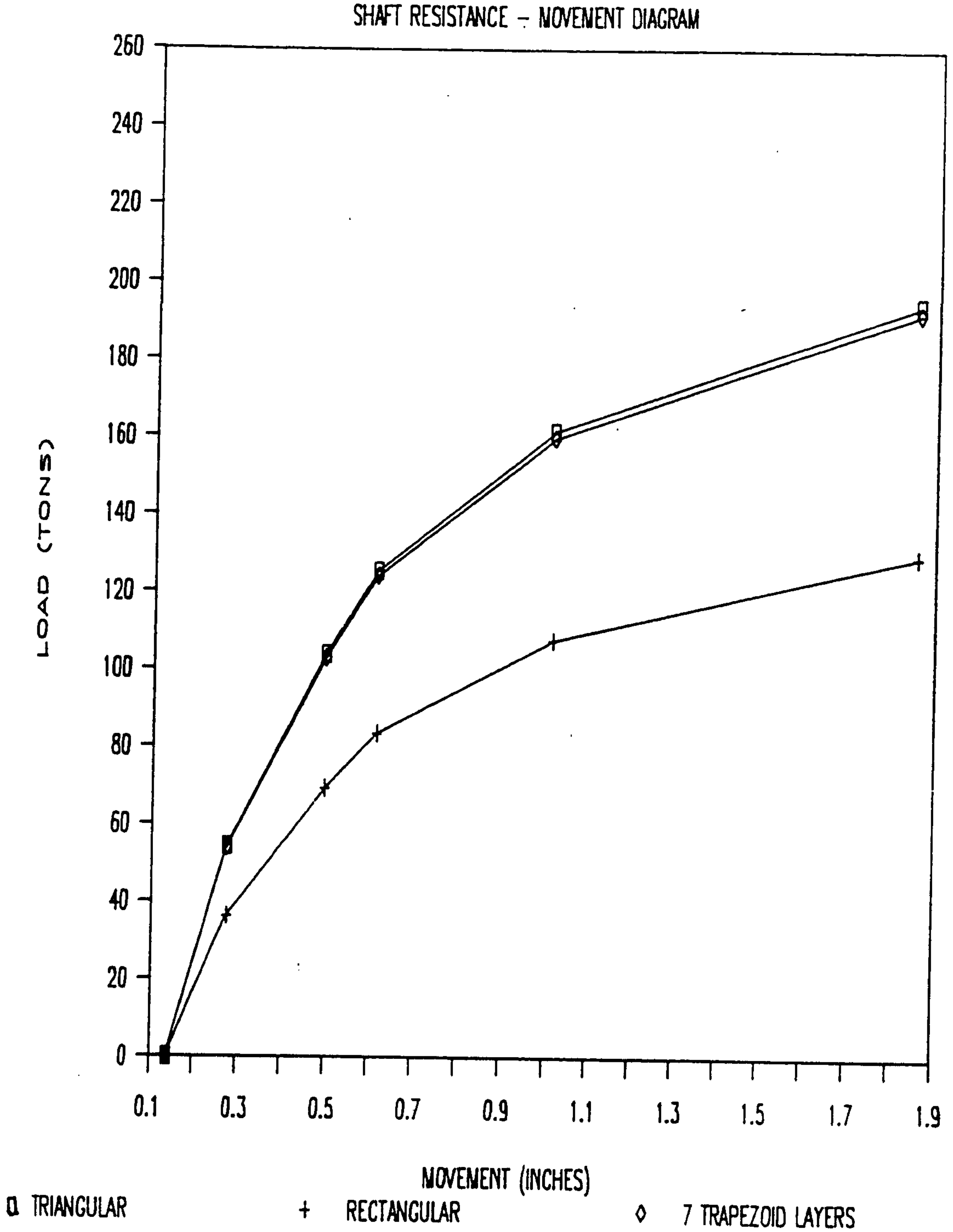


FIGURE 4.5 LOAD MOVEMENT DIAGRAM FOR DIFFERENT SHAFT RESISTANCE DISTRIBUTION; EXAMPLE 1

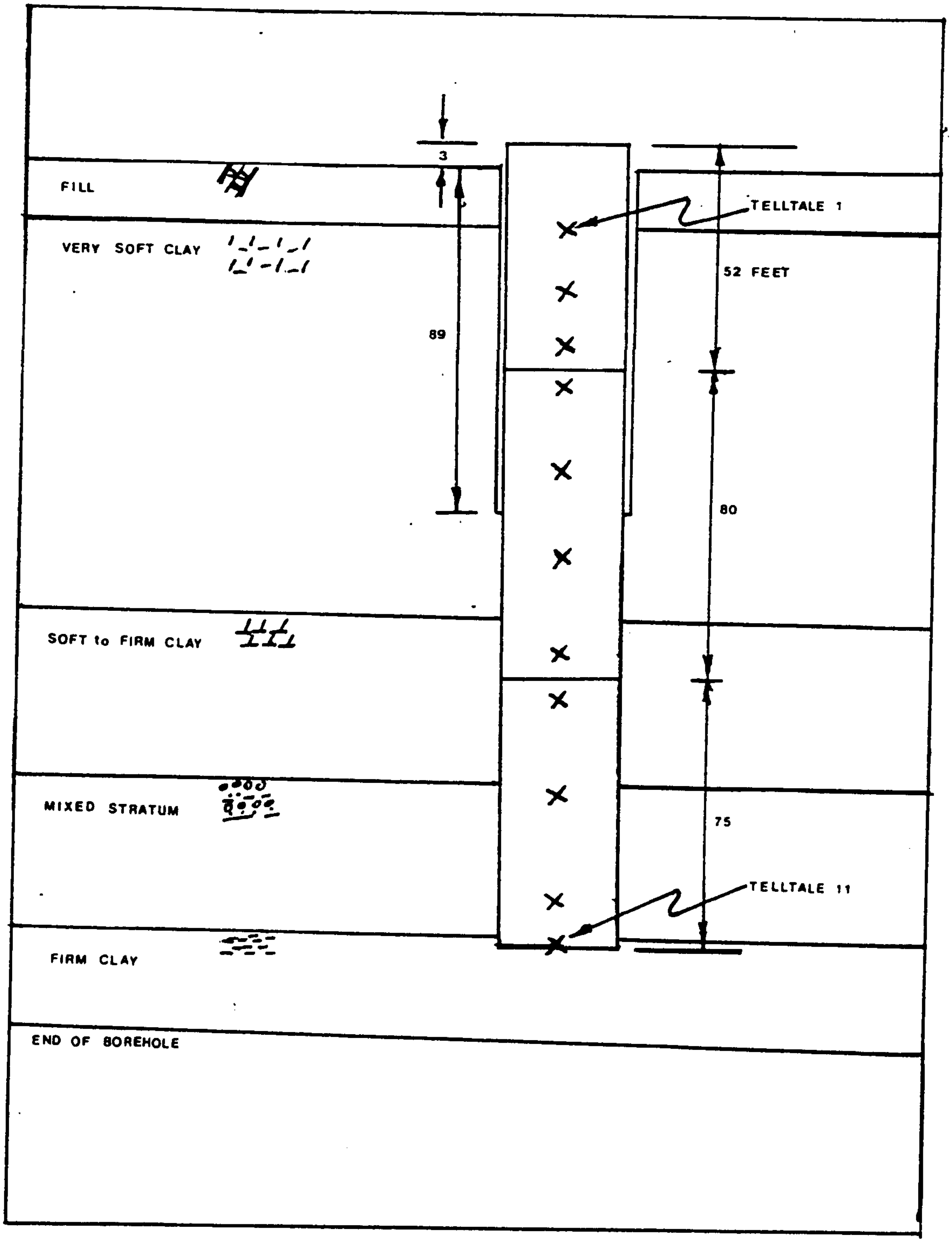


FIGURE 4.6 LOCATION OF INSTRUMENTATION IN EXAMPLE 2

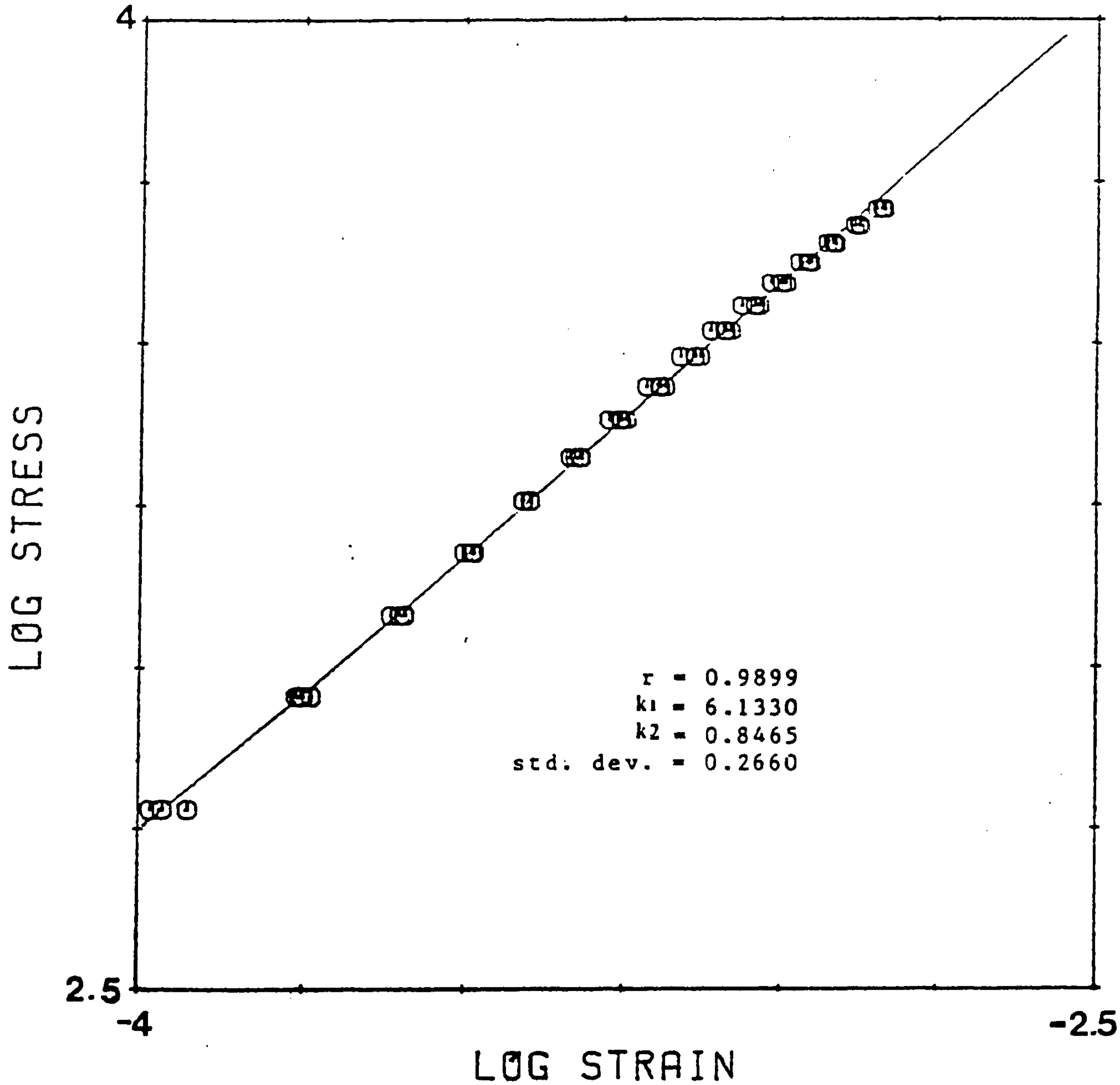


FIGURE 4.7 MODULUS FORMULATION - NON-LINEAR APPROACH

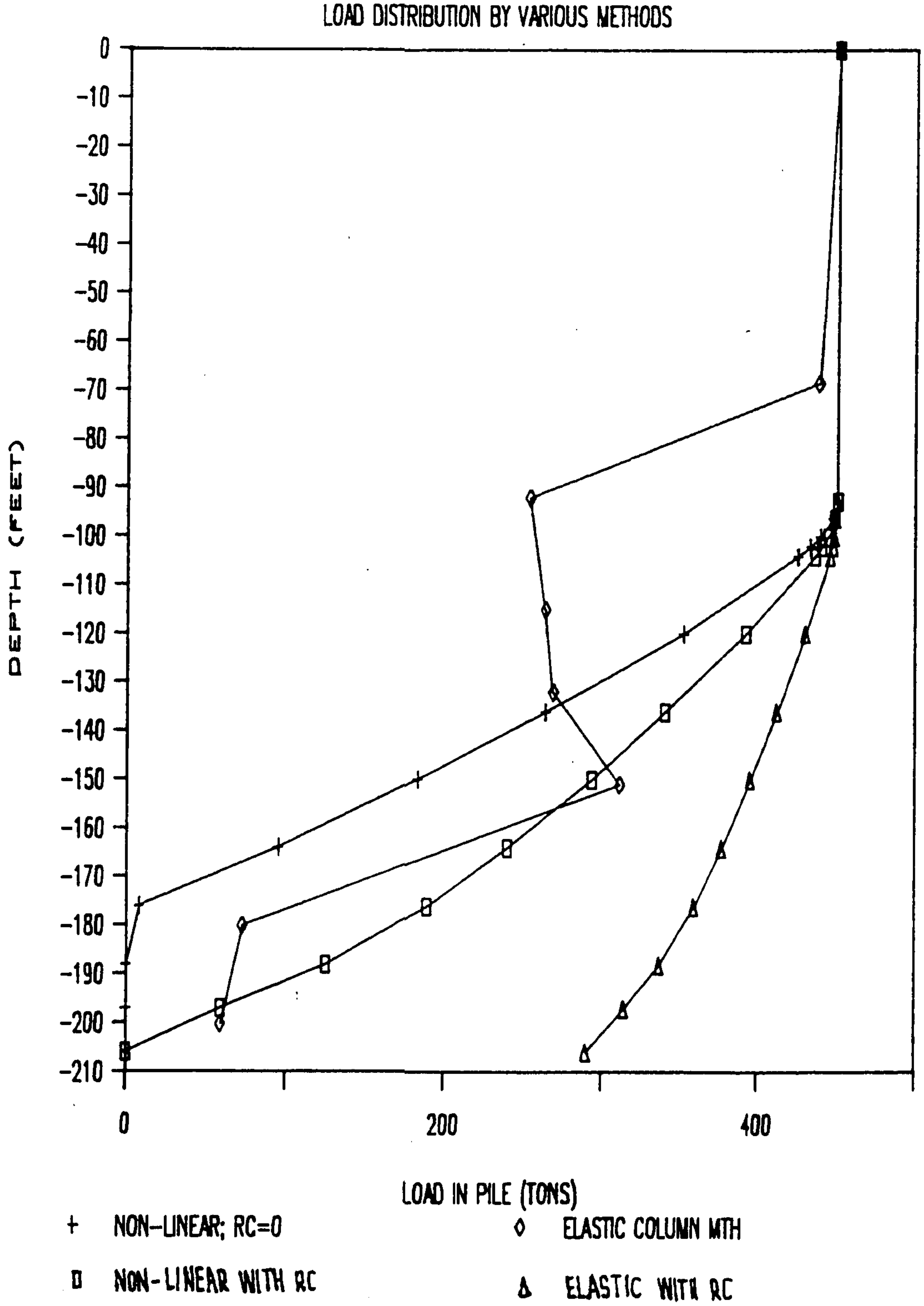


FIGURE 4.8 LOAD DISTRIBUTION FOR EXAMPLE 2 CONSIDERING VARIATION OF ELASTIC MODULUS

– APPENDIX A –
ANALYSIS OUTPUT

ANALYSIS OF STATIC PILE TEST LOADING BY EXPANDED LEONARDS-LOVELL METHOD

Pile : EXAMPLE 1 * Ttales 3C & 1A

Length of pile stickup	+0.0	FT
Length to casing toe	+0.0	FT
Length to end of Telltale 3C	+56.7	FT
Length to end of Telltale 1A	+104.9	FT

* RELATIVE SHAFT RESISTANCE DISTRIBUTION *
TRIANGULAR

ES2= +323.6 CR2= +0.667 RC2= +0.000

Q	Mh	C2	Mt2	EL2	SL2
+34.0	+0.056	+0.052	+0.004	-17.5	+51.5
+90.0	+0.139	+0.120	+0.019	-63.5	+153.5
+135.0	+0.275	+0.186	+0.089	-89.4	+224.4
+168.0	+0.496	+0.237	+0.259	-105.9	+273.9
+180.0	+0.614	+0.252	+0.362	-115.4	+295.4
+202.0	+1.014	+0.283	+0.731	-129.3	+331.3
+224.0	+1.857	+0.317	+1.540	-140.3	+364.3

Q = APPLIED LOAD ON PILE HEAD, <TON>
Mh = MOVEMENT OF PILE HEAD, <IN>
C2 = COMPRESSION OVER LENGTH OF TELLTALE 1A, <IN>
Mt2 = MOVEMENT OF PILE AT END OF TELLTALE 1A, <IN>
EL2 = LOAD IN PILE AT END OF TELLTALE 1A, <TON>
SL2 = SHAFT RESISTANCE OVER LENGTH OF TELLTALE 1A, <TON>

ES2 = SLOPE OF ELASTIC LINE TO TELLTALE 1A, <TON/IN>
CR2 = LEONARDS-LOVELL C-RATIO TO TELLTALE 1A
RC2 = RESIDUAL COMPRESSION OVER LENGTH OF TELLTALE 1A, <IN>

ANALYSIS OF STATIC PILE TEST LOADING
BY EXPANDED LEONARDS-LOVELL METHOD

Pile : EXAMPLE 1 * Ttales 3C & 1A

Length of pile stickup	+0.0	FT
Length to casing toe	+0.0	FT
Length to end of Telltale 3C	+56.7	FT
Length to end of Telltale 1A	+104.9	FT

* RELATIVE SHAFT RESISTANCE DISTRIBUTION *
RECTANGULAR

ES2= +323.6 CR2= +0.500 RC2= +0.000

Q	Mh	C2	Mt2	EL2	SL2
+34.0	+0.056	+0.052	+0.004	-0.3	+34.3
+90.0	+0.139	+0.120	+0.019	-12.3	+102.3
+135.0	+0.275	+0.186	+0.089	-14.6	+149.6
+168.0	+0.496	+0.237	+0.259	-14.6	+182.6
+180.0	+0.614	+0.252	+0.362	-16.9	+196.9
+202.0	+1.014	+0.283	+0.731	-18.8	+220.8
+224.0	+1.857	+0.317	+1.540	-18.8	+242.8

Q = APPLIED LOAD ON PILE HEAD, <TON>
Mh = MOVEMENT OF PILE HEAD, <IN>
C2 = COMPRESSION OVER LENGTH OF TELLTALE 1A, <IN>
Mt2 = MOVEMENT OF PILE AT END OF TELLTALE 1A, <IN>
EL2 = LOAD IN PILE AT END OF TELLTALE 1A, <TON>
SL2 = SHAFT RESISTANCE OVER LENGTH OF TELLTALE 1A, <TON>

ES2 = SLOPE OF ELASTIC LINE TO TELLTALE 1A, <TON/IN>
CR2 = LEONARDS-LOVELL C-RATIO TO TELLTALE 1A
RC2 = RESIDUAL COMPRESSION OVER LENGTH OF TELLTALE 1A, <IN>

ANALYSIS OF STATIC PILE TEST LOADING
BY EXPANDED LEONARDS-LOVELL METHOD

Pile : EXAMPLE 1 * Ttales 3C & 1A

Length of pile stickup	+0.0	FT
Length to casing toe	+0.0	FT
Length to end of Telltale 3C	+56.7	FT
Length to end of Telltale 1A	+104.9	FT

* RELATIVE SHAFT RESISTANCE DISTRIBUTION *
7 TRAPEZOIDAL LAYERS

ES1= +612.0 ES2= +323.6 CR1= +0.592 CR2= +0.676

RC1= +0.021 RC2= +0.175

Q	Mh	C1	C2	C12	Mt2	EL1	SL1	EL2	SL2
+34.0	+0.056	+0.046	+0.052	+0.006	+0.004	+51.2	-17.2	+155.7	-121.7
+90.0	+0.139	+0.108	+0.120	+0.012	+0.019	+62.9	+27.1	+106.9	-16.9
+135.0	+0.275	+0.166	+0.186	+0.020	+0.089	+84.6	+50.4	+78.9	+56.1
+168.0	+0.496	+0.213	+0.237	+0.024	+0.259	+107.3	+60.7	+61.0	+107.0
+180.0	+0.614	+0.227	+0.252	+0.025	+0.362	+110.9	+69.1	+51.0	+129.0
+202.0	+1.014	+0.249	+0.283	+0.034	+0.731	+112.0	+90.0	+36.0	+166.0
+224.0	+1.857	+0.288	+0.317	+0.029	+1.540	+138.5	+85.5	+24.1	+199.9

Q = APPLIED LOAD ON PILE HEAD, <TON>
Mh = MOVEMENT OF PILE HEAD, <IN>
C2 = COMPRESSION OVER LENGTH OF TELLTALE 1A, <IN>
Mt2 = MOVEMENT OF PILE AT END OF TELLTALE 1A, <IN>
EL2 = LOAD IN PILE AT END OF TELLTALE 1A, <TON>
SL2 = SHAFT RESISTANCE OVER LENGTH OF TELLTALE 1A, <TON>

ES2 = SLOPE OF ELASTIC LINE TO TELLTALE 1A, <TON/IN>
CR2 = LEONARDS-LOVELL C-RATIO TO TELLTALE 1A
RC2 = RESIDUAL COMPRESSION OVER LENGTH OF TELLTALE 1A, <IN>

* RESIDUAL COMPRESSION MATCH *

Pile : EXAMPLE 1

* LOAD AND COMPRESSION DATA *

Applied load on pile head	+224.0	TON
Movement of pile head	+1.857	IN
Compression over length of Telltale 3C	+0.288	IN
Compression over length of Telltale 8H	+0.314	IN
Compression over length of Telltale 1A	+0.317	IN
Compression between Telltales 3C & 8H	+0.026	IN
Compression between Telltales 3C & 1A	+0.029	IN
Compression between Telltales 8H & 1A	+0.003	IN

* LENGTH FROM GROUND SURFACE *

Length of pile stickup	+0.0	FT
Length to casing toe	+0.0	FT
Length to Telltale end 3C	+56.7	FT
Length to Telltale end 8H	+86.2	FT
Length to Telltale end 1A	+104.9	FT

* SLOPE OF ELASTIC LINE, AE/L *

AE/L to Telltale 3C	+612.0	TON/IN
AE/L to Telltale 8H	+397.7	TON/IN
AE/L to Telltale 1A	+323.6	TON/IN
AE/L for segment between Telltales 3C & 8H	+1135.9	TON/IN
AE/L for segment between Telltales 3C & 1A	+686.7	TON/IN
AE/L for segment between Telltales 8H & 1A	+1736.5	TON/IN

* RELATIVE SHAFT RESISTANCE DISTRIBUTION *
RECTANGULAR

RESIDUAL COMPRESSION (IN)			DIFFERENCE IN RC (IN)			TOE RESISTANCE (TON)
RC1	RC2	RC3	RC2 - RC1	RC3 - RC1	RC3 - RC2	EL3
-0.0292	-0.0016	+0.0000	+0.0276	+0.0292	+0.0016	-18.8
-0.0221	+0.0151	+0.0250	+0.0372	+0.0471	+0.0099	-2.7
-0.0149	+0.0318	+0.0500	+0.0467	+0.0649	+0.0182	+13.5
-0.0078	+0.0485	+0.0750	+0.0563	+0.0828	+0.0265	+29.7
-0.0006	+0.0652	+0.1000	+0.0659	+0.1006	+0.0348	+45.9
+0.0065	+0.0819	+0.1250	+0.0754	+0.1185	+0.0431	+62.1
+0.0136	+0.0987	+0.1500	+0.0850	+0.1364	+0.0513	+78.2
+0.0208	+0.1154	+0.1750	+0.0946	+0.1542	+0.0596	+94.4
+0.0279	+0.1321	+0.2000	+0.1041	+0.1721	+0.0679	+110.6
+0.0351	+0.1488	+0.2250	+0.1137	+0.1899	+0.0762	+126.8
+0.0422	+0.1655	+0.2500	+0.1233	+0.2078	+0.0845	+143.0
+0.0494	+0.1822	+0.2750	+0.1329	+0.2256	+0.0928	+159.1
+0.0565	+0.1989	+0.3000	+0.1424	+0.2435	+0.1011	+175.3
+0.0637	+0.2157	+0.3250	+0.1520	+0.2613	+0.1093	+191.5
+0.0708	+0.2324	+0.3500	+0.1616	+0.2792	+0.1176	+207.7
+0.0780	+0.2491	+0.3750	+0.1711	+0.2970	+0.1259	+223.9
+0.0851	+0.2658	+0.4000	+0.1807	+0.3149	+0.1342	+240.0
+0.0922	+0.2825	+0.4250	+0.1903	+0.3328	+0.1425	+256.2
+0.0994	+0.2992	+0.4500	+0.1999	+0.3506	+0.1508	+272.4
+0.1065	+0.3160	+0.4750	+0.2094	+0.3685	+0.1590	+288.6
+0.1137	+0.3327	+0.5000	+0.2190	+0.3863	+0.1673	+304.8

* RESIDUAL COMPRESSION MATCH *

Pile : EXAMPLE 1

* LOAD AND COMPRESSION DATA *

Applied load on pile head	+224.0	TON
Movement of pile head	+1.876	IN
Compression over length of Telltale 3C	+0.288	IN
Compression over length of Telltale 8H	+0.314	IN
Compression over length of Telltale 1A	+0.317	IN
Compression between Telltales 3C & 8H	+0.026	IN
Compression between Telltales 3C & 1A	+0.029	IN
Compression between Telltales 8H & 1A	+0.003	IN

* LENGTH FROM GROUND SURFACE *

Length of pile stickup	+0.0	FT
Length to casing toe	+0.0	FT
Length to Telltale end 3C	+56.7	FT
Length to Telltale end 8H	+86.2	FT
Length to Telltale end 1A	+104.9	FT

* SLOPE OF ELASTIC LINE, AE/L *

AE/L to Telltale 3C	+612.0	TON/IN
AE/L to Telltale 8H	+397.7	TON/IN
AE/L to Telltale 1A	+323.6	TON/IN
AE/L for segment between Telltales 3C & 8H	+1135.9	TON/IN
AE/L for segment between Telltales 3C & 1A	+686.7	TON/IN
AE/L for segment between Telltales 8H & 1A	+1736.5	TON/IN

* RELATIVE SHAFT RESISTANCE DISTRIBUTION *

RECTANGULAR

* LEONARDS-LOVELL C-RATIO *

C-Ratio to Telltale 3C	+0.500
C-Ratio to Telltale 8H	+0.500
C-Ratio to Telltale 1A	+0.500
C-Ratio between Telltales 3C & 8H	+0.500
C-Ratio between Telltales 3C & 1A	+0.500
C-Ratio between Telltales 8H & 1A	+0.500

* MATCHED RESIDUAL COMPRESSION USING SEGMENTS FROM PILE HEAD*

Residual compression over length of Telltale 3C	+0.021	IN
Residual compression over length of Telltale 8H	+0.115	IN
Residual compression over length of Telltale 1A	+0.175	IN
Residual compression between Telltales 3C & 8H	+0.095	IN
Residual compression between Telltales 3C & 1A	+0.154	IN
Residual compression between Telltales 8H & 1A	+0.060	IN

* MATCHED RESIDUAL COMPRESSION USING SEGMENTS BETWEEN TELLTALES *

Residual compression between Telltales 3C & 8H	+0.094	IN
Residual compression between Telltales 3C & 1A	+0.152	IN
Residual compression between Telltales 8H & 1A	+0.058	IN

* RESULT FROM TELLTALE 3C *

Load in pile at end of Telltale 3C	+154.0	TON
Shaft resistance over length of Telltale 3C	+70.0	TON

* RESULT FROM TELLTALE 8H *

Load in pile at end of Telltale 8H	+117.5	TON
Shaft resistance over length of Telltale 8H	+106.5	TON

* RESULT FROM TELLTALE 1A *

Load in pile at end of Telltale 1A	+94.4	TON
Shaft resistance over length of Telltale 1A	+129.6	TON

* RESULTS FROM SEGMENTS BETWEEN TELLTALES *

RC 1 & 2 - Load in pile at end of Telltale 8H	+120.0	TON
RC 1 & 3 - Load in pile at end of Telltale 1A	+97.7	TON
RC 2 & 3 - Load in pile at end of Telltale 1A	+100.0	TON

* SHAFT AND LOAD DISTRIBUTION ALONG THE PILE *

Pile :EXAMPLE 1

Load on pile : 224 TON

* SHAFT RESISTANCE DISTRIBUTION *
RECTANGULAR

* LOAD DISTRIBUTION *

Location	Depth (FT)	Load distribution Shaft (TON)	Toe
Pile stickup	+0.0	+0.0	+224.0
Ground surface	+0.0	+0.0	+224.0
Casing toe	+0.0	+0.0	+224.0
	-14.2	+17.5	+206.5
Shear centroid <3C>	-28.4	+35.0	+189.0
	-42.5	+52.5	+171.5
Telltale end 3C	-56.7	+70.0	+154.0
	-64.1	+79.1	+144.9
Shear centroid <3C&8H>	-71.5	+88.3	+135.7
	-78.8	+97.4	+126.6
Telltale end 8H	-86.2	+106.5	+117.5
	-90.9	+112.3	+111.7
Shear centroid <8H&1A>	-95.5	+118.0	+106.0
	-100.2	+123.8	+100.2
Telltale end 1A	-104.9	+129.6	+94.4

* RESIDUAL COMPRESSION MATCH *

Pile : EXAMPLE 1

* LOAD AND COMPRESSION DATA *

Applied load on pile head	+202.0	TON
Movement of pile head	+1.014	IN
Compression over length of Telltale 3C	+0.249	IN
Compression over length of Telltale 8H	+0.281	IN
Compression over length of Telltale 1A	+0.283	IN
Compression between Telltales 3C & 8H	+0.032	IN
Compression between Telltales 3C & 1A	+0.034	IN
Compression between Telltales 8H & 1A	+0.002	IN

* LENGTH FROM GROUND SURFACE *

Length of pile stickup	+0.0	FT
Length to casing toe	+0.0	FT
Length to Telltale end 3C	+56.7	FT
Length to Telltale end 8H	+86.2	FT
Length to Telltale end 1A	+104.9	FT

* SLOPE OF ELASTIC LINE, AE/L *

AE/L to Telltale 3C	+612.0	TON/IN
AE/L to Telltale 8H	+397.7	TON/IN
AE/L to Telltale 1A	+323.6	TON/IN
AE/L for segment between Telltales 3C & 8H	+1135.9	TON/IN
AE/L for segment between Telltales 3C & 1A	+686.7	TON/IN
AE/L for segment between Telltales 8H & 1A	+1736.5	TON/IN

* RELATIVE SHAFT RESISTANCE DISTRIBUTION *
RECTANGULAR

* LEONARDS-LOVELL C-RATIO *

C-Ratio to Telltale 3C	+0.500
C-Ratio to Telltale 8H	+0.500
C-Ratio to Telltale 1A	+0.500
C-Ratio between Telltales 3C & 8H	+0.500
C-Ratio between Telltales 3C & 1A	+0.500
C-Ratio between Telltales 8H & 1A	+0.500

* MATCHED RESIDUAL COMPRESSION USING SEGMENTS FROM PILE HEAD*

Residual compression over length of Telltale 3C	+0.034	IN
Residual compression over length of Telltale 8H	+0.116	IN
Residual compression over length of Telltale 1A	+0.175	IN
Residual compression between Telltales 3C & 8H	+0.082	IN
Residual compression between Telltales 3C & 1A	+0.141	IN
Residual compression between Telltales 8H & 1A	+0.059	IN

* MATCHED RESIDUAL COMPRESSION USING SEGMENTS BETWEEN TELLTALES *

Residual compression between Telltales 3C & 8H	+0.081	IN
Residual compression between Telltales 3C & 1A	+0.139	IN
Residual compression between Telltales 8H & 1A	+0.058	IN

* RESULT FROM TELLTALE 3C *

Load in pile at end of Telltale 3C	+143.9	TON
Shaft resistance over length of Telltale 3C	+58.1	TON

* RESULT FROM TELLTALE 8H *

Load in pile at end of Telltale 8H	+113.6	TON
Shaft resistance over length of Telltale 8H	+88.4	TON

* RESULT FROM TELLTALE 1A *

Load in pile at end of Telltale 1A	+94.4	TON
Shaft resistance over length of Telltale 1A	+107.6	TON

* RESULTS FROM SEGMENTS BETWEEN TELLTALES *

RC 1 & 2 - Load in pile at end of Telltale 8H	+115.6	TON
RC 1 & 3 - Load in pile at end of Telltale 1A	+97.1	TON
RC 2 & 3 - Load in pile at end of Telltale 1A	+99.0	TON

* SHAFT AND LOAD DISTRIBUTION ALONG THE PILE *

Pile :EXAMPLE 1

Load on pile : 202 TON

* SHAFT RESISTANCE DISTRIBUTION *
RECTANGULAR

* LOAD DISTRIBUTION *

Location	Depth (FT)	Load distribution Shaft (TON)	Toe
Pile stickup	+0.0	+0.0	+202.0
Ground surface	+0.0	+0.0	+202.0
Casing toe	+0.0	+0.0	+202.0
	-14.2	+14.5	+187.5
Shear centroid <3C>	-28.4	+29.1	+172.9
	-42.5	+43.6	+158.4
Telltale end 3C	-56.7	+58.1	+143.9
	-64.1	+65.7	+136.3
Shear centroid <3C&8H>	-71.5	+73.3	+128.7
	-78.8	+80.8	+121.2
Telltale end 8H	-86.2	+88.4	+113.6
	-90.9	+93.2	+108.8
Shear centroid <8H&1A>	-95.5	+98.0	+104.0
	-100.2	+102.8	+99.2
Telltale end 1A	-104.9	+107.6	+94.4

* RESIDUAL COMPRESSION MATCH *

Pile : EXAMPLE 1

* LOAD AND COMPRESSION DATA *		
Applied load on pile head	+224.0	TON
Movement of pile head	+1.876	IN
Compression over length of Telltale 3C	+0.288	IN
Compression over length of Telltale 8H	+0.314	IN
Compression over length of Telltale 1A	+0.317	IN
Compression between Telltales 3C & 8H	+0.026	IN
Compression between Telltales 3C & 1A	+0.029	IN
Compression between Telltales 8H & 1A	+0.003	IN
* LENGTH FROM GROUND SURFACE *		
Length of pile stickup	+0.0	FT
Length to casing toe	+0.0	FT
Length to Telltale end 3C	+56.7	FT
Length to Telltale end 8H	+86.2	FT
Length to Telltale end 1A	+104.9	FT
* SLOPE OF ELASTIC LINE, AE/L *		
AE/L to Telltale 3C	+612.0	TON/IN
AE/L to Telltale 8H	+397.7	TON/IN
AE/L to Telltale 1A	+323.6	TON/IN
AE/L for segment between Telltales 3C & 8H	+1135.9	TON/IN
AE/L for segment between Telltales 3C & 1A	+686.7	TON/IN
AE/L for segment between Telltales 8H & 1A	+1736.5	TON/IN

* RELATIVE SHAFT RESISTANCE DISTRIBUTION *
RECTANGULAR

* LEONARDS-LOVELL C-RATIO *	
C-Ratio to Telltale 3C	+0.500
C-Ratio to Telltale 8H	+0.500
C-Ratio to Telltale 1A	+0.500
C-Ratio between Telltales 3C & 8H	+0.500
C-Ratio between Telltales 3C & 1A	+0.500
C-Ratio between Telltales 8H & 1A	+0.500

* MATCHED RESIDUAL COMPRESSION USING SEGMENTS FROM PILE HEAD*		
Residual compression over length of Telltale 3C	-0.029	IN
Residual compression over length of Telltale 8H	-0.002	IN
Residual compression over length of Telltale 1A	+0.000	IN
Residual compression between Telltales 3C & 8H	+0.028	IN
Residual compression between Telltales 3C & 1A	+0.029	IN
Residual compression between Telltales 8H & 1A	+0.002	IN
* MATCHED RESIDUAL COMPRESSION USING SEGMENTS BETWEEN TELLTALES *		
Residual compression between Telltales 3C & 8H	+0.026	IN
Residual compression between Telltales 3C & 1A	+0.025	IN
Residual compression between Telltales 8H & 1A	-0.001	IN

* RESULT FROM TELLTALE 3C *		
Load in pile at end of Telltale 3C	+92.7	TON
Shaft resistance over length of Telltale 3C	+131.3	TON
* RESULT FROM TELLTALE 8H *		
Load in pile at end of Telltale 8H	+24.5	TON
Shaft resistance over length of Telltale 8H	+199.5	TON
* RESULT FROM TELLTALE 1A *		
Load in pile at end of Telltale 1A	-18.8	TON
Shaft resistance over length of Telltale 1A	+242.8	TON
* RESULTS FROM SEGMENTS BETWEEN TELLTALES *		
RC 1 & 2 - Load in pile at end of Telltale 8H	+29.0	TON
RC 1 & 3 - Load in pile at end of Telltale 1A	-12.8	TON
RC 2 & 3 - Load in pile at end of Telltale 1A	-8.3	TON

* SHAFT AND LOAD DISTRIBUTION ALONG THE PILE *

Pile :EXAMPLE 1

Load on pile : 224 TON

* SHAFT RESISTANCE DISTRIBUTION *
RECTANGULAR

* LOAD DISTRIBUTION *

Location	Depth (FT)	Load distribution Shaft (TON)	Toe
Pile stickup	+0.0	+0.0	+224.0
Ground surface	+0.0	+0.0	+224.0
Casing toe	+0.0	+0.0	+224.0
	-14.2	+32.8	+191.2
Shear centroid <3C>	-28.4	+65.6	+158.4
	-42.5	+98.4	+125.6
Telltale end 3C	-56.7	+131.3	+92.7
	-64.1	+148.3	+75.7
Shear centroid <3C&8H>	-71.5	+165.4	+58.6
	-78.8	+182.5	+41.5
Telltale end 8H	-86.2	+199.5	+24.5
	-90.9	+210.4	+13.6
Shear centroid <8H&1A>	-95.5	+221.2	+2.8
	-100.2	+232.0	-8.0
Telltale end 1A	-104.9	+242.8	-18.8

ANALYSIS OF STATIC PILE TEST LOADING BY EXPANDED LEONARDS-LOVELL METHOD

Pile : EXAMPLE 1 * Ttales 3C & 1A

Length of pile stickup	+0.0	FT
Length to casing toe	+0.0	FT
Length to end of Telltale 3C	+56.7	FT
Length to end of Telltale 1A	+104.9	FT

* RELATIVE SHAFT RESISTANCE DISTRIBUTION *
RECTANGULAR

ES1= +612.0 ES2= +323.6 CR1= +0.500 CR2= +0.500

RC1= +0.021 RC2= +0.175

Q	Mh	C1	C2	C12	Mt2	EL1	SL1	EL2	SL2
+34.0	+0.056	+0.046	+0.052	+0.006	+0.004	+48.0	-14.0	+112.9	-78.9
+90.0	+0.139	+0.108	+0.120	+0.012	+0.019	+67.9	+22.1	+100.9	-10.9
+135.0	+0.275	+0.166	+0.186	+0.020	+0.089	+93.9	+41.1	+98.6	+36.4
+168.0	+0.496	+0.213	+0.237	+0.024	+0.259	+118.4	+49.6	+98.6	+69.4
+180.0	+0.614	+0.227	+0.252	+0.025	+0.362	+123.6	+56.4	+96.4	+83.6
+202.0	+1.014	+0.249	+0.283	+0.034	+0.731	+128.5	+73.5	+94.4	+107.6
+224.0	+1.857	+0.288	+0.317	+0.029	+1.540	+154.2	+69.8	+94.4	+129.6

Q = APPLIED LOAD ON PILE HEAD, <TON>
Mh = MOVEMENT OF PILE HEAD, <IN>
C1 = COMPRESSION OVER LENGTH OF TELLTALE 3C, <IN>
C2 = COMPRESSION OVER LENGTH OF TELLTALE 1A, <IN>
C12 = COMPRESSION BETWEEN TELLTALES 3C and 1A, <IN>
Mt2 = MOVEMENT OF PILE AT END OF TELLTALE 1A, <IN>
EL1 = LOAD IN PILE AT END OF TELLTALE 3C, <TON>
SL1 = SHAFT RESISTANCE OVER LENGTH OF TELLTALE 3C, <TON>
EL2 = LOAD IN PILE AT END OF TELLTALE 1A, <TON>
SL2 = SHAFT RESISTANCE OVER LENGTH OF TELLTALE 1A, <TON>

ES1 = SLOPE OF ELASTIC LINE TO TELLTALE 3C, <TON/IN>
ES2 = SLOPE OF ELASTIC LINE TO TELLTALE 1A, <TON/IN>
CR1 = LEONARDS-LOVELL C-RATIO TO TELLTALE 3C
CR2 = LEONARDS-LOVELL C-RATIO TO TELLTALE 1A
RC1 = RESIDUAL COMPRESSION OVER LENGTH OF TELLTALE 3C, <IN>
RC2 = RESIDUAL COMPRESSION OVER LENGTH OF TELLTALE 1A, <IN>

* APPLIED LOAD AT FULL SHAFT RESISTANCE MOBILIZATION ANALYSIS *

Pile : EXAMPLE 1 * Ttales 3C & 1A

Q	1/Q	Telltale 3C C'	Telltale 1A C'
+34.0	+0.02941	+1.20600	+2.16051
+90.0	+0.01111	+0.87720	+1.06069
+135.0	+0.00741	+0.84773	+0.86533
+168.0	+0.00595	+0.85243	+0.79359
+180.0	+0.00556	+0.84320	+0.76765
+202.0	+0.00495	+0.81802	+0.73371
+224.0	+0.00446	+0.84423	+0.71076

ANALYSIS OF STATIC PILE TEST LOADING
BY EXPANDED LEONARDS-LOVELL METHOD

Pile : EXAMPLE 1 * Ttales 3C & 1A

Length of pile stickup	+0.0	FT
Length to casing toe	+0.0	FT
Length to end of Telltale 3C	+56.7	FT
Length to end of Telltale 1A	+104.9	FT

* RELATIVE SHAFT RESISTANCE DISTRIBUTION *
TRIANGULAR

ES1= +612.0 ES2= +323.6 CR1= +0.667 CR2= +0.667

RC1= +0.021 RC2= +0.175

Q	Mh	C1	C2	C12	Mt2	EL1	SL1	EL2	SL2
+34.0	+0.056	+0.046	+0.052	+0.006	+0.004	+55.0	-21.0	+152.4	-118.4
+90.0	+0.139	+0.108	+0.120	+0.012	+0.019	+56.8	+33.2	+106.4	-16.4
+135.0	+0.275	+0.166	+0.186	+0.020	+0.089	+73.3	+61.7	+80.5	+54.5
+168.0	+0.496	+0.213	+0.237	+0.024	+0.259	+93.6	+74.4	+64.0	+104.0
+180.0	+0.614	+0.227	+0.252	+0.025	+0.362	+95.3	+84.7	+54.5	+125.5
+202.0	+1.014	+0.249	+0.283	+0.034	+0.731	+91.7	+110.3	+40.6	+161.4
+224.0	+1.857	+0.288	+0.317	+0.029	+1.540	+119.3	+104.7	+29.6	+194.4

Q = APPLIED LOAD ON PILE HEAD, <TON>
Mh = MOVEMENT OF PILE HEAD, <IN>
C1 = COMPRESSION OVER LENGTH OF TELLTALE 3C, <IN>
C2 = COMPRESSION OVER LENGTH OF TELLTALE 1A, <IN>
C12 = COMPRESSION BETWEEN TELLTALES 3C and 1A, <IN>
Mt2 = MOVEMENT OF PILE AT END OF TELLTALE 1A, <IN>
EL1 = LOAD IN PILE AT END OF TELLTALE 3C, <TON>
SL1 = SHAFT RESISTANCE OVER LENGTH OF TELLTALE 3C, <TON>
EL2 = LOAD IN PILE AT END OF TELLTALE 1A, <TON>
SL2 = SHAFT RESISTANCE OVER LENGTH OF TELLTALE 1A, <TON>

ES1 = SLOPE OF ELASTIC LINE TO TELLTALE 3C, <TON/IN>
ES2 = SLOPE OF ELASTIC LINE TO TELLTALE 1A, <TON/IN>
CR1 = LEONARDS-LOVELL C-RATIO TO TELLTALE 3C
CR2 = LEONARDS-LOVELL C-RATIO TO TELLTALE 1A
RC1 = RESIDUAL COMPRESSION OVER LENGTH OF TELLTALE 3C, <IN>
RC2 = RESIDUAL COMPRESSION OVER LENGTH OF TELLTALE 1A, <IN>

ANALYSIS OF STATIC PILE TEST LOADING
BY EXPANDED LEONARDS-LOVELL METHOD

Pile : EXAMPLE 1 * Ttales 3C & 1A

Length of pile stickup	+0.0	FT
Length to casing toe	+0.0	FT
Length to end of Telltale 3C	+56.7	FT
Length to end of Telltale 1A	+104.9	FT

* RELATIVE SHAFT RESISTANCE DISTRIBUTION *
7 TRAPEZOIDAL LAYERS

ES2= +323.6 CR2= +0.676 RC2= +0.000

Q	Mh	C2	Mt2	EL2	SL2
+34.0	+0.056	+0.052	+0.004	-19.0	+53.0
+90.0	+0.139	+0.120	+0.019	-67.9	+157.9
+135.0	+0.275	+0.186	+0.089	-95.8	+230.8
+168.0	+0.496	+0.237	+0.259	-113.7	+281.7
+180.0	+0.614	+0.252	+0.362	-123.8	+303.8
+202.0	+1.014	+0.283	+0.731	-138.7	+340.7
+224.0	+1.857	+0.317	+1.540	-150.6	+374.6

Q = APPLIED LOAD ON PILE HEAD, <TON>
Mh = MOVEMENT OF PILE HEAD, <IN>
C2 = COMPRESSION OVER LENGTH OF TELLTALE 1A, <IN>
Mt2 = MOVEMENT OF PILE AT END OF TELLTALE 1A, <IN>
EL2 = LOAD IN PILE AT END OF TELLTALE 1A, <TON>
SL2 = SHAFT RESISTANCE OVER LENGTH OF TELLTALE 1A, <TON>

ES2 = SLOPE OF ELASTIC LINE TO TELLTALE 1A, <TON/IN>
CR2 = LEONARDS-LOVELL C-RATIO TO TELLTALE 1A
RC2 = RESIDUAL COMPRESSION OVER LENGTH OF TELLTALE 1A, <IN>

ANALYSIS OF STATIC PILE TEST LOADING
BY EXPANDED LEONARDS-LOVELL METHOD

Pile : EXAMPLE 2 * Ttales 6 & 11

Length of pile stickup	+0.0	FT
Length to casing toe	+92.7	FT
Length to end of Telltale 6	+103.6	FT
Length to end of Telltale 11	+206.0	FT

* RELATIVE SHAFT RESISTANCE DISTRIBUTION *
TRIANGULAR

ES2= +132.7   CR2= +0.817   RC2= +0.000

Q	Mh	C2	Mt2	EL2	SL2
+90.0	+0.256	+0.270	-0.014	-205.5	+295.5
+210.0	+0.801	+0.737	+0.064	-402.0	+612.0
+300.0	+1.277	+1.189	+0.088	-475.8	+775.8
+390.0	+1.863	+1.716	+0.147	-495.2	+885.2
+450.0	+2.364	+2.172	+0.192	-432.4	+882.4
+510.0	+2.972	+2.710	+0.262	-310.3	+820.3

Q = APPLIED LOAD ON PILE HEAD, <TON>
Mh = MOVEMENT OF PILE HEAD, <IN>
C2 = COMPRESSION OVER LENGTH OF TELLTALE 11, <IN>
Mt2 = MOVEMENT OF PILE AT END OF TELLTALE 11, <IN>
EL2 = LOAD IN PILE AT END OF TELLTALE 11, <TON>
SL2 = SHAFT RESISTANCE OVER LENGTH OF TELLTALE 11, <TON>

ES2 = SLOPE OF ELASTIC LINE TO TELLTALE 11, <TON/IN>
CR2 = LEONARDS-LOVELL C-RATIO TO TELLTALE 11
RC2 = RESIDUAL COMPRESSION OVER LENGTH OF TELLTALE 11, <IN>

ANALYSIS OF STATIC PILE TEST LOADING
BY EXPANDED LEONARDS-LOVELL METHOD

Pile : EXAMPLE 2 * Ttales 6 & 11

Length of pile stickup	+0.0	FT
Length to casing toe	+92.7	FT
Length to end of Telltale 6	+103.6	FT
Length to end of Telltale 11	+206.0	FT

* RELATIVE SHAFT RESISTANCE DISTRIBUTION *
RECTANGULAR

ES2= +132.7 CR2= +0.725 RC2= +0.000

Q	Mh	C2	Mt2	EL2	SL2
+90.0	+0.256	+0.270	-0.014	-107.0	+197.0
+210.0	+0.801	+0.737	+0.064	-198.0	+408.0
+300.0	+1.277	+1.189	+0.088	-217.2	+517.2
+390.0	+1.863	+1.716	+0.147	-200.1	+590.1
+450.0	+2.364	+2.172	+0.192	-138.3	+588.3
+510.0	+2.972	+2.710	+0.262	-36.8	+546.8

Q = APPLIED LOAD ON PILE HEAD, <TON>
Mh = MOVEMENT OF PILE HEAD, <IN>
C2 = COMPRESSION OVER LENGTH OF TELLTALE 11, <IN>
Mt2 = MOVEMENT OF PILE AT END OF TELLTALE 11, <IN>
EL2 = LOAD IN PILE AT END OF TELLTALE 11, <TON>
SL2 = SHAFT RESISTANCE OVER LENGTH OF TELLTALE 11, <TON>

ES2 = SLOPE OF ELASTIC LINE TO TELLTALE 11, <TON/IN>
CR2 = LEONARDS-LOVELL C-RATIO TO TELLTALE 11
RC2 = RESIDUAL COMPRESSION OVER LENGTH OF TELLTALE 11, <IN>

ANALYSIS OF STATIC PILE TEST LOADING
BY EXPANDED LEONARDS-LOVELL METHOD

Pile : EXAMPLE 2 * Ttales 6 & 11

Length of pile stickup	+0.0	FT
Length to casing toe	+92.7	FT
Length to end of Telltale 6	+103.6	FT
Length to end of Telltale 11	+206.0	FT

* RELATIVE SHAFT RESISTANCE DISTRIBUTION *
10 TRAPEZOIDAL LAYERS

ES2= +132.7 CR2= +0.793 RC2= +0.000

Q	Mh	C2	Mt2	EL2	SL2
+90.0	+0.256	+0.270	-0.014	-171.7	+261.7
+210.0	+0.801	+0.737	+0.064	-332.0	+542.0
+300.0	+1.277	+1.189	+0.088	-387.0	+687.0
+390.0	+1.863	+1.716	+0.147	-393.9	+783.9
+450.0	+2.364	+2.172	+0.192	-331.5	+781.5
+510.0	+2.972	+2.710	+0.262	-216.4	+726.4

Q = APPLIED LOAD ON PILE HEAD, <TON>
Mh = MOVEMENT OF PILE HEAD, <IN>
C2 = COMPRESSION OVER LENGTH OF TELLTALE 11, <IN>
Mt2 = MOVEMENT OF PILE AT END OF TELLTALE 11, <IN>
EL2 = LOAD IN PILE AT END OF TELLTALE 11, <TON>
SL2 = SHAFT RESISTANCE OVER LENGTH OF TELLTALE 11, <TON>

ES2 = SLOPE OF ELASTIC LINE TO TELLTALE 11, <TON/IN>
CR2 = LEONARDS-LOVELL C-RATIO TO TELLTALE 11
RC2 = RESIDUAL COMPRESSION OVER LENGTH OF TELLTALE 11, <IN>

* RESIDUAL COMPRESSION MATCH *

Pile : EXAMPLE 2

* LOAD AND COMPRESSION DATA *

Applied load on pile head	+450.0	TON
Movement of pile head	+2.364	IN
Compression over length of Telltale 6	+1.395	IN
Compression over length of Telltale 9	+2.062	IN
Compression over length of Telltale 11	+2.172	IN
Compression between Telltales 6 & 9	+0.667	IN
Compression between Telltales 6 & 11	+0.777	IN
Compression between Telltales 9 & 11	+0.110	IN

* LENGTH FROM GROUND SURFACE *

Length of pile stickup	+0.0	FT
Length to casing toe	+92.7	FT
Length to Telltale end 6	+103.6	FT
Length to Telltale end 9	+164.6	FT
Length to Telltale end 11	+206.0	FT

* SLOPE OF ELASTIC LINE, AE/L *

AE/L to Telltale 6	+310.2	TON/IN
AE/L to Telltale 9	+195.2	TON/IN
AE/L to Telltale 11	+156.0	TON/IN
AE/L for segment between Telltales 6 & 9	+526.8	TON/IN
AE/L for segment between Telltales 6 & 11	+313.8	TON/IN
AE/L for segment between Telltales 9 & 11	+776.2	TON/IN

* RELATIVE SHAFT RESISTANCE DISTRIBUTION *
10 TRAPEZOIDAL LAYERS

RESIDUAL COMPRESSION (IN)			DIFFERENCE IN RC (IN)			TOE RESISTANCE (TON)
RC1	RC2	RC3	RC2 - RC1	RC3 - RC1	RC3 - RC2	EL3
+0.0538	+0.0081	+0.0000	-0.0457	-0.0538	-0.0081	-87.0
+0.0539	+0.0246	+0.0500	-0.0294	-0.0039	+0.0254	-49.3
+0.0541	+0.0411	+0.1000	-0.0130	+0.0459	+0.0589	-11.7
+0.0542	+0.0575	+0.1500	+0.0033	+0.0958	+0.0925	+26.0
+0.0543	+0.0740	+0.2000	+0.0197	+0.1457	+0.1260	+63.7
+0.0545	+0.0905	+0.2500	+0.0360	+0.1955	+0.1595	+101.4
+0.0546	+0.1069	+0.3000	+0.0523	+0.2454	+0.1931	+139.1
+0.0547	+0.1234	+0.3500	+0.0687	+0.2953	+0.2266	+176.7
+0.0549	+0.1399	+0.4000	+0.0850	+0.3451	+0.2601	+214.4
+0.0550	+0.1564	+0.4500	+0.1014	+0.3950	+0.2936	+252.1
+0.0551	+0.1728	+0.5000	+0.1177	+0.4449	+0.3272	+289.8
+0.0553	+0.1893	+0.5500	+0.1340	+0.4947	+0.3607	+327.5
+0.0554	+0.2058	+0.6000	+0.1504	+0.5446	+0.3942	+365.1
+0.0555	+0.2223	+0.6500	+0.1667	+0.5945	+0.4277	+402.8
+0.0557	+0.2387	+0.7000	+0.1831	+0.6443	+0.4613	+440.5
+0.0558	+0.2552	+0.7500	+0.1994	+0.6942	+0.4948	+478.2
+0.0559	+0.2717	+0.8000	+0.2157	+0.7441	+0.5283	+515.9
+0.0561	+0.2882	+0.8500	+0.2321	+0.7939	+0.5618	+553.5
+0.0562	+0.3046	+0.9000	+0.2484	+0.8438	+0.5954	+591.2
+0.0563	+0.3211	+0.9500	+0.2648	+0.8937	+0.6289	+628.9
+0.0565	+0.3376	+1.0000	+0.2811	+0.9435	+0.6624	+666.6

* RESIDUAL COMPRESSION MATCH *

Pile : EXAMPLE 2

* LOAD AND COMPRESSION DATA *

Applied load on pile head	+450.0	TON
Movement of pile head	+2.364	IN
Compression over length of Telltale 6	+1.395	IN
Compression over length of Telltale 9	+2.062	IN
Compression over length of Telltale 11	+2.172	IN
Compression between Telltales 6 & 9	+0.667	IN
Compression between Telltales 6 & 11	+0.777	IN
Compression between Telltales 9 & 11	+0.110	IN

* LENGTH FROM GROUND SURFACE *

Length of pile stickup	+0.0	FT
Length to casing toe	+92.7	FT
Length to Telltale end 6	+103.6	FT
Length to Telltale end 9	+164.6	FT
Length to Telltale end 11	+206.0	FT

* SLOPE OF ELASTIC LINE, AE/L *

AE/L to Telltale 6	+310.2	TON/IN
AE/L to Telltale 9	+195.2	TON/IN
AE/L to Telltale 11	+156.0	TON/IN
AE/L for segment between Telltales 6 & 9	+526.8	TON/IN
AE/L for segment between Telltales 6 & 11	+313.8	TON/IN
AE/L for segment between Telltales 9 & 11	+776.2	TON/IN

* RELATIVE SHAFT RESISTANCE DISTRIBUTION *

10 TRAPEZOIDAL LAYERS

* LEONARDS-LOVELL C-RATIO *

C-Ratio to Telltale 6	+0.965
C-Ratio to Telltale 9	+0.812
C-Ratio to Telltale 11	+0.793
C-Ratio between Telltales 6 & 9	+0.534
C-Ratio between Telltales 6 & 11	+0.603
C-Ratio between Telltales 9 & 11	+0.567

* MATCHED RESIDUAL COMPRESSION USING SEGMENTS FROM PILE HEAD*

Residual compression over length of Telltale 6	+0.055	IN
Residual compression over length of Telltale 9	+0.173	IN
Residual compression over length of Telltale 11	+0.500	IN
Residual compression between Telltales 6 & 9	+0.118	IN
Residual compression between Telltales 6 & 11	+0.445	IN
Residual compression between Telltales 9 & 11	+0.327	IN

* MATCHED RESIDUAL COMPRESSION USING SEGMENTS BETWEEN TELLTALES *

Residual compression between Telltales 6 & 9	+0.118	IN
Residual compression between Telltales 6 & 11	+0.445	IN
Residual compression between Telltales 9 & 11	+0.327	IN

* RESULT FROM TELLTALE 6 *

Load in pile at end of Telltale 6	+445.0	TON
Shaft resistance over length of Telltale 6	+5.0	TON

* RESULT FROM TELLTALE 9 *

Load in pile at end of Telltale 9	+377.1	TON
Shaft resistance over length of Telltale 9	+72.9	TON

* RESULT FROM TELLTALE 11 *

Load in pile at end of Telltale 11	+289.8	TON
Shaft resistance over length of Telltale 11	+160.2	TON

* RESULTS FROM SEGMENTS BETWEEN TELLTALES *

RC 1 & 2 - Load in pile at end of Telltale 9	+377.1	TON
RC 1 & 3 - Load in pile at end of Telltale 11	+289.8	TON
RC 2 & 3 - Load in pile at end of Telltale 11	+289.8	TON

* SHAFT AND LOAD DISTRIBUTION ALONG THE PILE *

Pile :EXAMPLE 2

Load on pile : 450 TON

* SHAFT RESISTANCE DISTRIBUTION *
10 TRAPEZOIDAL LAYERS

Soil layer number	Depth (FT)	Shaft resistance developed Top (TSF)	Bottom
1	-92.7	+0.000	+0.000
2	-103.0	+0.000	+0.467
3	-117.0	+0.467	+0.507
4	-122.0	+0.507	+0.581
5	-155.0	+0.581	+0.662
6	-159.0	+0.662	+0.694
7	-167.0	+0.694	+0.761
8	-182.0	+0.761	+0.975
9	-194.0	+0.975	+1.460
10	-206.0	+1.460	+1.460

* LOAD DISTRIBUTION *

Location	Depth (FT)	Load distribution Shaft (TON)	Toe
Pile stickup	+0.0	+0.0	+450.0
Ground surface	+0.0	+0.0	+450.0
Casing toe	-92.7	+0.0	+450.0
	-96.3	+0.6	+449.4
Shear centroid <6>	-100.0	+2.2	+447.8
	-101.8	+3.5	+446.5
Telltale end 6	-103.6	+5.0	+445.0
	-119.9	+20.0	+430.0
Shear centroid <6&9>	-136.2	+38.0	+412.0
	-150.4	+54.7	+395.3
Telltale end 9	-164.6	+72.9	+377.1
	-176.3	+90.6	+359.4
Shear centroid <9&11>	-188.1	+112.9	+337.1
	-197.0	+135.9	+314.1
Telltale end 11	-206.0	+160.2	+289.8

ITERATION 0

SEGMENT	OLD QAVE		NEW QAVE
		<TON>	
1	+450.0		+449.8
2	+450.0		+436.3
3	+450.0		+416.8
12	+450.0		+614.9
13	+450.0		+558.3
23	+450.0		+503.8

ENTER <RETURN> TO CONTINUE

ITERATION 0

SEGMENT	OLD AE/L		NEW AE/L
		<TON/IN>	
1	+310.2		+252.7
2	+195.2		+160.0
3	+156.0		+128.9
12	+526.8		+405.6
13	+313.8		+245.9
23	+776.2		+619.6

ENTER <RETURN> TO CONTINUE

ITERATION 1

SEGMENT	OLD QAVE		NEW QAVE
		<TON>	
1	+449.8		+449.4
2	+436.3		+406.4
3	+416.8		+344.3
12	+614.9		+449.8
13	+558.3		+201.6
23	+503.8		+63.2

ENTER <RETURN> TO CONTINUE

ITERATION 1

SEGMENT	OLD AE/L		NEW AE/L
		<TON/IN>	
1	+252.7		+252.8
2	+160.0		+162.0
3	+128.9		+133.4
12	+405.6		+429.2
13	+245.9		+295.8
23	+619.6		+902.7

ENTER <RETURN> TO CONTINUE

ITERATION 2

SEGMENT	OLD QAVE	<TON>	NEW QAVE
1	+449.4		+449.5
2	+406.4		+411.4
3	+344.3		+356.5
12	+449.8		+477.5
13	+201.6		+261.3
23	+63.2		+137.0

ENTER <RETURN> TO CONTINUE

ITERATION 2

SEGMENT	OLD AE/L	<TON/IN>	NEW AE/L
1	+252.8		+252.8
2	+162.0		+161.7
3	+133.4		+132.6
12	+429.2		+424.6
13	+295.8		+282.2
23	+902.7		+784.6

ENTER <RETURN> TO CONTINUE

ITERATION 3

SEGMENT	OLD QAVE		NEW QAVE
		<TON>	
1	+449.5		+449.5
2	+411.4		+410.5
3	+356.5		+354.2
12	+477.5		+472.4
13	+261.3		+250.3
23	+137.0		+123.4

ENTER <RETURN> TO CONTINUE

ITERATION 3

SEGMENT	OLD AE/L		NEW AE/L
		<TON/IN>	
1	+252.8		+252.8
2	+161.7		+161.7
3	+132.6		+132.7
12	+424.6		+425.4
13	+282.2		+284.4
23	+784.6		+799.6

ENTER <RETURN> TO CONTINUE

ITERATION 4

SEGMENT	OLD QAVE		NEW QAVE
		<TON>	
1	+449.5		+449.5
2	+410.5		+410.7
3	+354.2		+354.7
12	+472.4		+473.3
13	+250.3		+252.3
23	+123.4		+125.9

ENTER <RETURN> TO CONTINUE

ITERATION 4

SEGMENT	OLD AE/L		NEW AE/L
		<TON/IN>	
1	+252.8		+252.8
2	+161.7		+161.7
3	+132.7		+132.7
12	+425.4		+425.3
13	+284.4		+284.0
23	+799.6		+796.8

ENTER <RETURN> TO CONTINUE

ITERATION 5

SEGMENT	OLD QAVE	NEW QAVE
	<TON>	
1	+449.5	+449.5
2	+410.7	+410.7
3	+354.7	+354.6
12	+473.3	+473.1
13	+252.3	+252.0
23	+125.9	+125.4

ENTER <RETURN> TO CONTINUE

ITERATION 5

SEGMENT	OLD AE/L	NEW AE/L
	<TON/IN>	
1	+252.8	+252.8
2	+161.7	+161.7
3	+132.7	+132.7
12	+425.3	+425.3
13	+284.0	+284.0
23	+796.8	+797.3

ENTER <RETURN> TO CONTINUE

* RESIDUAL COMPRESSION MATCH *

Pile : EXAMPLE 2

* LOAD AND COMPRESSION DATA *		
Applied load on pile head	+450.0	TON
Movement of pile head	+2.364	IN
Compression over length of Telltale 6	+1.395	IN
Compression over length of Telltale 9	+2.062	IN
Compression over length of Telltale 11	+2.172	IN
Compression between Telltales 6 & 9	+0.667	IN
Compression between Telltales 6 & 11	+0.777	IN
Compression between Telltales 9 & 11	+0.110	IN
* LENGTH FROM GROUND SURFACE *		
Length of pile stickup	+0.0	FT
Length to casing toe	+92.7	FT
Length to Telltale end 6	+103.6	FT
Length to Telltale end 9	+164.6	FT
Length to Telltale end 11	+206.0	FT
* SLOPE OF ELASTIC LINE, AE/L *		
AE/L to Telltale 6	+252.8	TON/IN
AE/L to Telltale 9	+161.7	TON/IN
AE/L to Telltale 11	+132.7	TON/IN
AE/L for segment between Telltales 6 & 9	+425.3	TON/IN
AE/L for segment between Telltales 6 & 11	+284.0	TON/IN
AE/L for segment between Telltales 9 & 11	+797.3	TON/IN
* RELATIVE SHAFT RESISTANCE DISTRIBUTION *		
10 TRAPEZOIDAL LAYERS		
* LEONARDS-LOVELL C-RATIO *		
C-Ratio to Telltale 6	+0.965	
C-Ratio to Telltale 9	+0.812	
C-Ratio to Telltale 11	+0.793	
C-Ratio between Telltales 6 & 9	+0.534	
C-Ratio between Telltales 6 & 11	+0.603	
C-Ratio between Telltales 9 & 11	+0.567	
* MATCHED RESIDUAL COMPRESSION USING SEGMENTS FROM PILE HEAD*		
Residual compression over length of Telltale 6	+0.383	IN
Residual compression over length of Telltale 9	+0.477	IN
Residual compression over length of Telltale 11	+0.500	IN
Residual compression between Telltales 6 & 9	+0.094	IN
Residual compression between Telltales 6 & 11	+0.117	IN
Residual compression between Telltales 9 & 11	+0.023	IN
* MATCHED RESIDUAL COMPRESSION USING SEGMENTS BETWEEN TELLTALES *		
Residual compression between Telltales 6 & 9	+0.143	IN
Residual compression between Telltales 6 & 11	+0.133	IN
Residual compression between Telltales 9 & 11	+0.055	IN
* RESULT FROM TELLTALE 6 *		
Load in pile at end of Telltale 6	+435.6	TON
Shaft resistance over length of Telltale 6	+14.4	TON
* RESULT FROM TELLTALE 9 *		
Load in pile at end of Telltale 9	+240.4	TON
Shaft resistance over length of Telltale 9	+209.6	TON
* RESULT FROM TELLTALE 11 *		
Load in pile at end of Telltale 11	-10.9	TON
Shaft resistance over length of Telltale 11	+460.9	TON
* RESULTS FROM SEGMENTS BETWEEN TELLTALES *		
RC 1 & 2 - Load in pile at end of Telltale 9	+195.2	TON
RC 1 & 3 - Load in pile at end of Telltale 11	-22.8	TON
RC 2 & 3 - Load in pile at end of Telltale 11	-70.7	TON

* SHAFT AND LOAD DISTRIBUTION ALONG THE PILE *

Pile :EXAMPLE 2

Load on pile : 450 TON

* SHAFT RESISTANCE DISTRIBUTION *
10 TRAPEZOIDAL LAYERS

Soil layer number	Depth (FT)	Shaft resistance developed Top (TSF)	Bottom
1	-92.7	+0.000	+0.000
2	-103.0	+0.000	+0.467
3	-117.0	+0.467	+0.507
4	-122.0	+0.507	+0.581
5	-155.0	+0.581	+0.662
6	-159.0	+0.662	+0.694
7	-167.0	+0.694	+0.761
8	-182.0	+0.761	+0.975
9	-194.0	+0.975	+1.460
10	-206.0	+1.460	+1.460

* LOAD DISTRIBUTION *

Location	Depth (FT)	Load distribution Shaft (TON)	Toe
Pile stickup	+0.0	+0.0	+450.0
Ground surface	+0.0	+0.0	+450.0
Casing toe	-92.7	+0.0	+450.0
	-96.3	+1.6	+448.4
Shear centroid <6>	-100.0	+6.4	+443.6
	-101.8	+10.0	+440.0
Telltale end 6	-103.6	+14.4	+435.6
	-119.9	+57.5	+392.5
Shear centroid <6&9>	-136.2	+109.4	+340.6
	-150.4	+157.5	+292.5
Telltale end 9	-164.6	+209.6	+240.4
	-176.3	+260.7	+189.3
Shear centroid <9&11>	-188.1	+324.7	+125.3
	-197.0	+390.9	+59.1
Telltale end 11	-206.0	+460.9	-10.9

* RESIDUAL COMPRESSION MATCH *

Pile : EXAMPLE 2

* LOAD AND COMPRESSION DATA *		
Applied load on pile head	+450.0	TON
Movement of pile head	+2.364	IN
Compression over length of Telltale 6	+1.395	IN
Compression over length of Telltale 9	+2.062	IN
Compression over length of Telltale 11	+2.172	IN
Compression between Telltales 6 & 9	+0.667	IN
Compression between Telltales 6 & 11	+0.777	IN
Compression between Telltales 9 & 11	+0.110	IN
* LENGTH FROM GROUND SURFACE *		
Length of pile stickup	+0.0	FT
Length to casing toe	+92.7	FT
Length to Telltale end 6	+103.6	FT
Length to Telltale end 9	+164.6	FT
Length to Telltale end 11	+206.0	FT
* SLOPE OF ELASTIC LINE, AE/L *		
AE/L to Telltale 6	+263.9	TON/IN
AE/L to Telltale 9	+166.1	TON/IN
AE/L to Telltale 11	+132.7	TON/IN
AE/L for segment between Telltales 6 & 9	+448.1	TON/IN
AE/L for segment between Telltales 6 & 11	+267.0	TON/IN
AE/L for segment between Telltales 9 & 11	+660.3	TON/IN
* RELATIVE SHAFT RESISTANCE DISTRIBUTION *		
10 TRAPEZOIDAL LAYERS		
* LEONARDS-LOVELL C-RATIO *		
C-Ratio to Telltale 6	+0.965	
C-Ratio to Telltale 9	+0.812	
C-Ratio to Telltale 11	+0.793	
C-Ratio between Telltales 6 & 9	+0.534	
C-Ratio between Telltales 6 & 11	+0.603	
C-Ratio between Telltales 9 & 11	+0.567	
* MATCHED RESIDUAL COMPRESSION USING SEGMENTS FROM PILE HEAD*		
Residual compression over length of Telltale 6	+0.307	IN
Residual compression over length of Telltale 9	+0.246	IN
Residual compression over length of Telltale 11	+0.000	IN
Residual compression between Telltales 6 & 9	-0.061	IN
Residual compression between Telltales 6 & 11	-0.307	IN
Residual compression between Telltales 9 & 11	-0.246	IN
* MATCHED RESIDUAL COMPRESSION USING SEGMENTS BETWEEN TELLTALES *		
Residual compression between Telltales 6 & 9	-0.061	IN
Residual compression between Telltales 6 & 11	-0.307	IN
Residual compression between Telltales 9 & 11	-0.246	IN
* RESULT FROM TELLTALE 6 *		
Load in pile at end of Telltale 6	+425.6	TON
Shaft resistance over length of Telltale 6	+24.4	TON
* RESULT FROM TELLTALE 9 *		
Load in pile at end of Telltale 9	+94.5	TON
Shaft resistance over length of Telltale 9	+355.5	TON
* RESULT FROM TELLTALE 11 *		
Load in pile at end of Telltale 11	-331.5	TON
Shaft resistance over length of Telltale 11	+781.5	TON
* RESULTS FROM SEGMENTS BETWEEN TELLTALES *		
RC 1 & 2 - Load in pile at end of Telltale 9	+94.5	TON
RC 1 & 3 - Load in pile at end of Telltale 11	-331.5	TON
RC 2 & 3 - Load in pile at end of Telltale 11	-331.5	TON

* SHAFT AND LOAD DISTRIBUTION ALONG THE PILE *

Pile :EXAMPLE 2

Load on pile : 450 TON

* SHAFT RESISTANCE DISTRIBUTION *
10 TRAPEZOIDAL LAYERS

Soil layer number	Depth (FT)	Shaft resistance developed Top (TSF)	Bottom
1	-92.7	+0.000	+0.000
2	-103.0	+0.000	+0.467
3	-117.0	+0.467	+0.507
4	-122.0	+0.507	+0.581
5	-155.0	+0.581	+0.662
6	-159.0	+0.662	+0.694
7	-167.0	+0.694	+0.761
8	-182.0	+0.761	+0.975
9	-194.0	+0.975	+1.460
10	-206.0	+1.460	+1.460

* LOAD DISTRIBUTION *

Location	Depth (FT)	Load distribution Shaft (TON)	Toe
Pile stickup	+0.0	+0.0	+450.0
Ground surface	+0.0	+0.0	+450.0
Casing toe	-92.7	+0.0	+450.0
	-96.3	+2.7	+447.3
Shear centroid <6>	-100.0	+10.8	+439.2
	-101.8	+17.0	+433.0
Telltale end 6	-103.6	+24.4	+425.6
	-119.9	+97.6	+352.4
Shear centroid <6&9>	-136.2	+185.4	+264.6
	-150.4	+267.0	+183.0
Telltale end 9	-164.6	+355.5	+94.5
	-176.3	+442.0	+8.0
Shear centroid <9&11>	-188.1	+550.7	-100.7
	-197.0	+662.9	-212.9
Telltale end 11	-206.0	+781.5	-331.5

ANALYSIS OF STATIC PILE TEST LOADING
BY EXPANDED LEONARDS-LOVELL METHOD

Pile : EXAMPLE 2 * Ttales 6 & 11

Length of pile stickup	+0.0	FT
Length to casing toe	+92.7	FT
Length to end of Telltale 6	+103.6	FT
Length to end of Telltale 11	+206.0	FT

* RELATIVE SHAFT RESISTANCE DISTRIBUTION *
10 TRAPEZOIDAL LAYERS

ES1= +252.8   ES2= +132.7   CR1= +0.965   CR2= +0.793

RC1= +0.383   RC2= +0.500

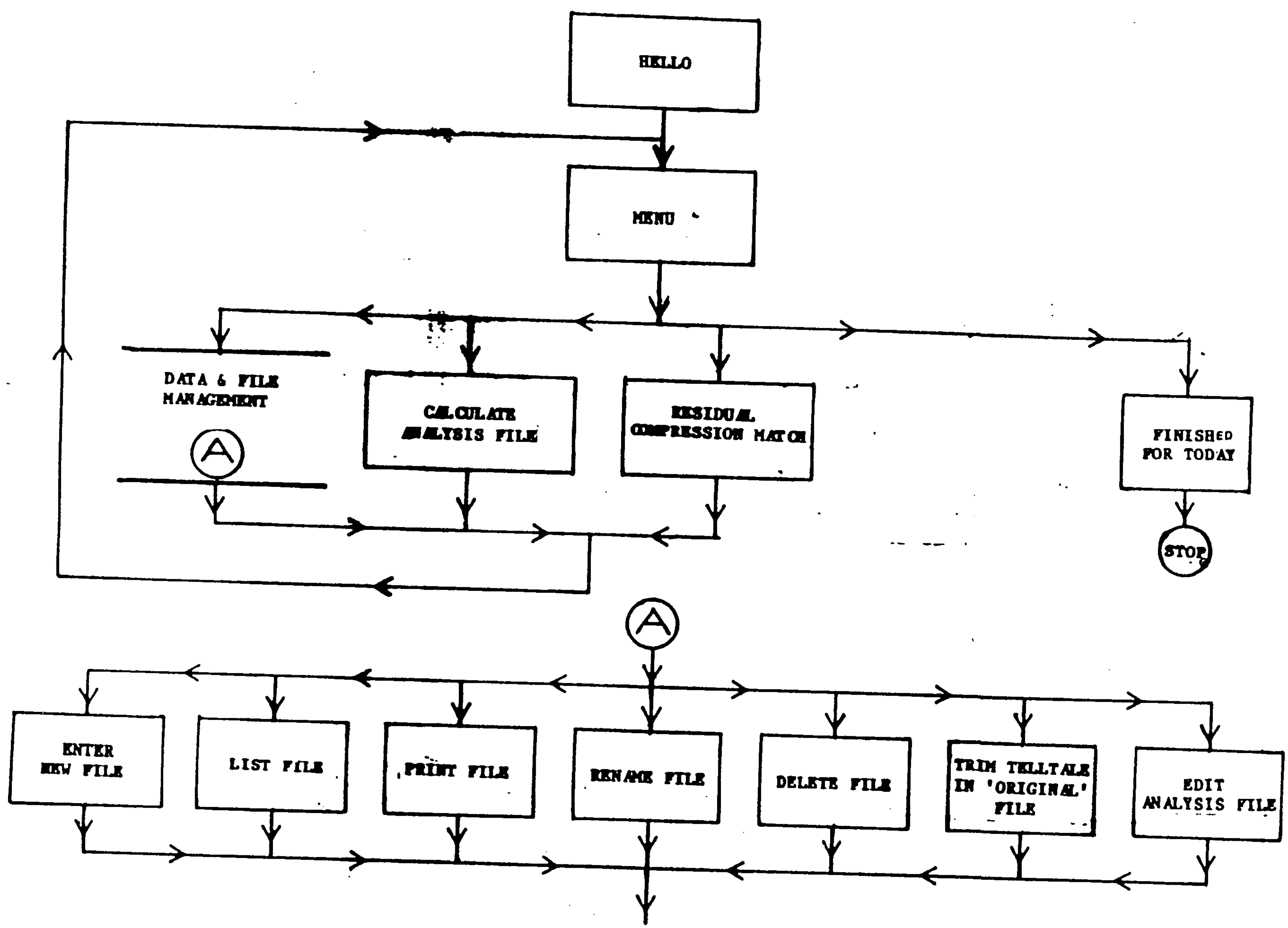
Q	Mh	C1	C2	C12	Mt2	EL1	SL1	EL2	SL2
+90.0	+0.256	+0.190	+0.270	+0.080	-0.014	+1649.9	-1559.9	+148.8	-58.8
+210.0	+0.801	+0.521	+0.737	+0.216	+0.064	+737.0	-527.0	-11.5	+221.5
+300.0	+1.277	+0.802	+1.189	+0.387	+0.088	+287.7	+12.3	-66.5	+366.5
+390.0	+1.863	+1.131	+1.716	+0.585	+0.147	+183.5	+206.5	-73.4	+463.4
+450.0	+2.364	+1.395	+2.172	+0.777	+0.192	+435.2	+14.8	-11.0	+461.0
+510.0	+2.972	+1.705	+2.710	+1.005	+0.262	+1017.5	-507.5	+104.1	+405.9

Q = APPLIED LOAD ON PILE HEAD, <TON>
Mh = MOVEMENT OF PILE HEAD, <IN>
C1 = COMPRESSION OVER LENGTH OF TELLTALE 6, <IN>
C2 = COMPRESSION OVER LENGTH OF TELLTALE 11, <IN>
C12 = COMPRESSION BETWEEN TELLTALES 6 and 11, <IN>
Mt2 = MOVEMENT OF PILE AT END OF TELLTALE 11, <IN>
EL1 = LOAD IN PILE AT END OF TELLTALE 6, <TON>
SL1 = SHAFT RESISTANCE OVER LENGTH OF TELLTALE 6, <TON>
EL2 = LOAD IN PILE AT END OF TELLTALE 11, <TON>
SL2 = SHAFT RESISTANCE OVER LENGTH OF TELLTALE 11, <TON>

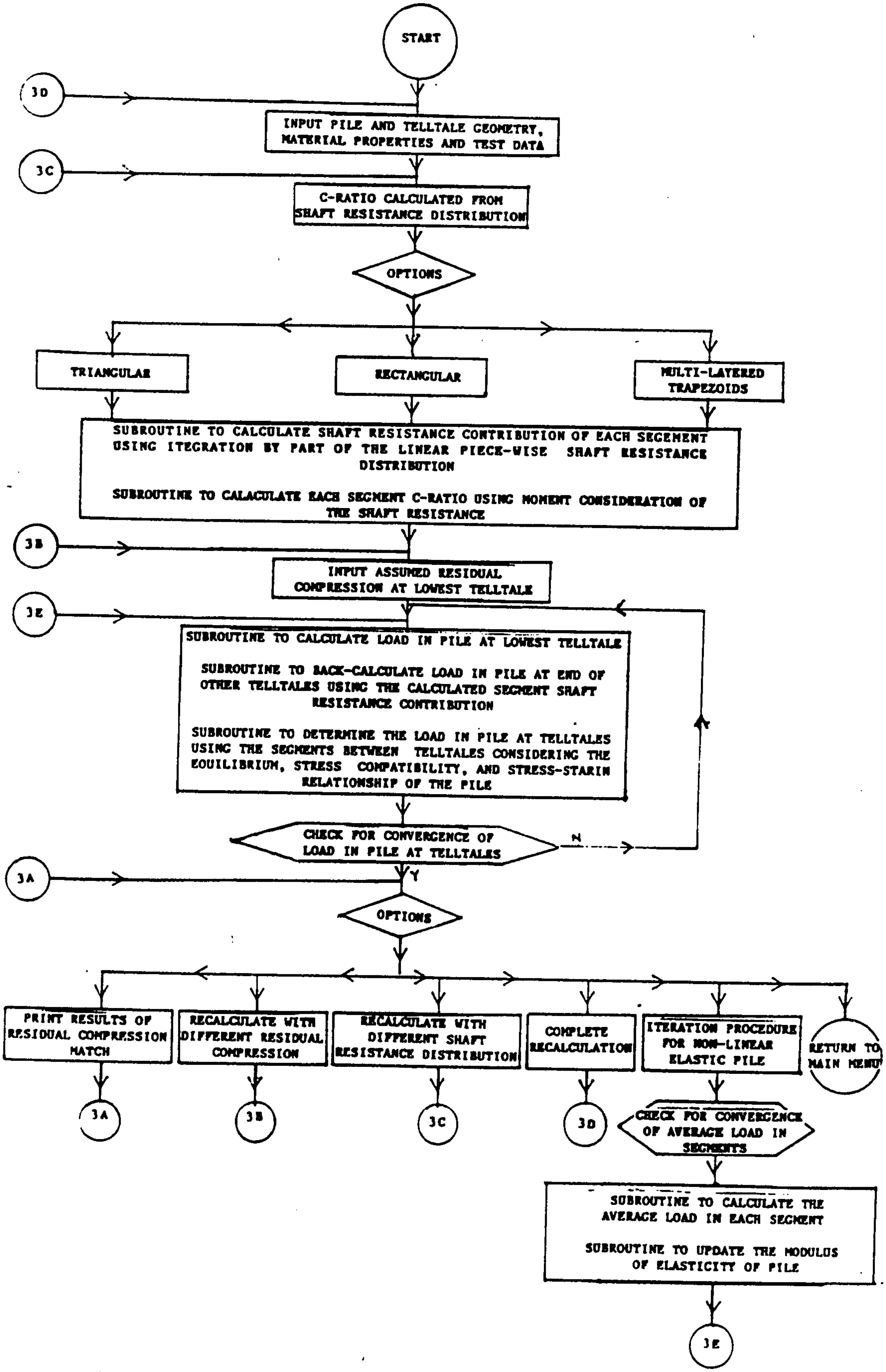
ES1 = SLOPE OF ELASTIC LINE TO TELLTALE 6, <TON/IN>
ES2 = SLOPE OF ELASTIC LINE TO TELLTALE 11, <TON/IN>
CR1 = LEONARDS-LOVELL C-RATIO TO TELLTALE 6
CR2 = LEONARDS-LOVELL C-RATIO TO TELLTALE 11
RC1 = RESIDUAL COMPRESSION OVER LENGTH OF TELLTALE 6, <IN>
RC2 = RESIDUAL COMPRESSION OVER LENGTH OF TELLTALE 11, <IN>

– APPENDIX B –

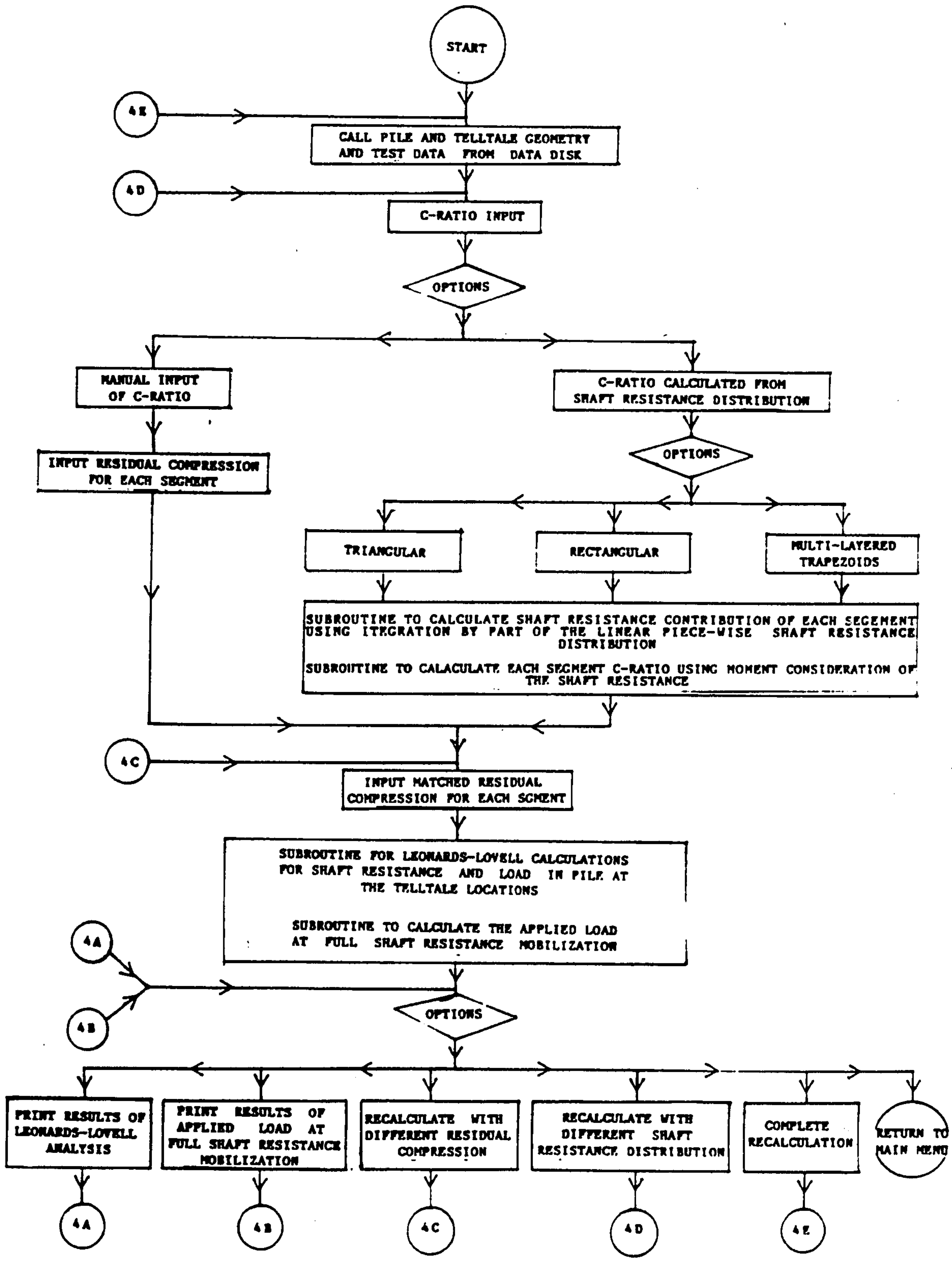
FLOWCHARTS



FLOWCHART 1 : OVERALL PROGRAMS FLOW



FLOWCHART 2 : RESIDUAL COMPRESSION MATCH



FLOWCHART 3: EXPANDED LEONARDS-LOVELL