MEMO TO: G. F. Kemper  
State Highway Engineer  
Chairman, Research Committee

SUBJECT: Research Report No. 547, Computerized Analysis of Moisture-Density Data; HPR-PL-1(15), Part III-B

Attached is the above-cited, research report which describes a computerized approach to the analysis of raw data obtained in moisture-density tests. The computer program has already been implemented here and in Materials as an aid in analyzing maximum density and optimum moisture content in field control and for specification comparisons.

Respectfully submitted,

[Signature]
Jas. H. Havens  
Director of Research

RCD/mm/gh  
Attachment  
cc: Research Committee
### Computerized Analysis of Moisture-Density Data

A mathematical algorithm is described and presented for estimating optimum moisture content and maximum dry density from moisture-density data obtained from ASTM Standard Test Methods D 698 and D 1557, which are often, even though incorrectly, referred to as the Standard Proctor Test and Modified Proctor Test, respectively. However, the algorithm can be used to analyze moisture-density data obtained by non-standard procedures. The algorithm is written in Fortran IV for use with the IBM 370/165 computer and Calcomp 663 drum plotter. Documentation of this computer program includes detailed input instructions, coding sheets, flow chart, variable descriptions, example problem, example output, and example job control cards.
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**Introduction**

The computer program, MOSDEN-0, estimates the optimum moisture content and maximum dry density from a fitted-curve representation of moisture-density data obtained using ASTM Standard Test Methods D 698 and D 1557 or other procedures. Values of dry density are calculated from the input values of moisture content and wet weight plus tare (mold). The computer program uses the IBM 370/165 computer and Calcomp 663 drum plotter and is written in Fortran IV. This program is very useful in analyzing a large number of data sets and provides a systematic procedure for drawing an appropriate curve through a given set of moisture-density data points.

**Input/Output Instructions and Examples**

A typical data sheet for recording moisture-density data is illustrated in Figure 1. Input instructions and coding sheets, Figure 2, necessary for organizing input data for the computer program are given in APPENDIX A. Also, the relationship between the number of data sets to be analyzed in a given computer run and the amount of central processing unit (CPU) time required is given by Figure 3 in the same appendix. Use of the computer program to analyze a typical set of laboratory data is illustrated in APPENDIX B. First, an actual set of laboratory data is given in Figure 4. Next, the use of the coding sheets is demonstrated in Figure 5, using the laboratory data given in

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**Figure 1. Laboratory Data Sheet for Recording Data from Moisture-Density Test.**
Figure 4. Figures 6, 7, and 8 of APPENDIX B show the different types of output, both printed and plotted, produced by the computer program. Additional examples of plotted output are given in APPENDIX C.

Source Program

APPENDIX D gives a brief description of the computer system and the storage resources required by the computer program. In addition, a flow chart of MOSDEN-0 is provided in APPENDIX E. Finally, a complete source listing of the computer program is given in APPENDIX F.

Method of Solution

Analytical curve-fitting procedures are used in the computer program to represent the moisture-content-versus-dry-density data. A least-squares polynomial of a preselected degree is fitted to the moisture-content-dry-density data using the method proposed by Forsythe (1) and programmed by Thrailkill, et al. (2). The polynomial has the form

\[ p(x) = c_1 + c_2 x + c_3 x^2 + \ldots + c_n x^{(k-1)}, \]  

in which \( p(x) \) is the polynomial with terms having constant coefficients \( c_n \) for the abscissa terms \( x \) with integer powers \( (k - 1) \) and \( k \) is the number of constant coefficients. Derivatives are obtained on the polynomial \( p(x) \) as follows:

\[ \frac{d(p(x))}{dx} = \sum (k - 1) c_{(k-1)} x^{(k-2)}. \]  

The peak of the fitted polynomial is taken as the location of the optimum moisture content and maximum dry density. The computer program determines the peak of the fitted polynomial by finding the point where the slope given by Equation 2 becomes zero in the vicinity of the largest value of dry density.

Although the procedure for selecting the degree of polynomial to fit data does not follow rigorous guidelines, this does not pose any great problems. The computer program allows the use of polynomials as large as six degrees, provided there are seven or more data points. Past experience (3) indicates that a satisfactory fit can usually be obtained using a degree of polynomial equal to the number of data points minus two. Slightly different results will be obtained if a degree of polynomial equal to the number of data points minus one is used. The choice of the degree of polynomial usually affects the calculated value of maximum dry density more than the optimum moisture content. However, the difference will usually be quite small. Generally, the calculated value of the maximum dry density tends to be greater when a degree of polynomial equal to the number of data points minus one is used.

In APPENDIX C, Examples 1, 3, 4, and 5 compare cases where a degree of polynomial equal to \( n - 1 \) yields larger estimates of the maximum dry density than a degree of polynomial equal to \( n - 2 \) (\( n \) is the number of data points). Therefore, if lower estimates of the maximum dry density are desired, a degree of polynomial equal to the number of data points minus two is recommended.

Inasmuch as the true values for the optimum moisture content and maximum dry density are rarely if ever known, the choice between using a degree of polynomial equal to \( n - 2 \) or \( n - 1 \) basically remains a matter of individual judgment. APPENDIX C shows examples of plotted output which compare different polynomial fits on the same sets of data. APPENDIX C also shows performance of the computer program on sets of data obtained from soils having different values for the liquid limit.

Program Capabilities

A maximum of 18 data points may be specified for one set of moisture-density data. Each set of moisture-density data must have at least three data values before the computer program can be
used. The computer program ignores any data point lying on the “dry side” of the moisture-density curve which has a decreased value of density from the previous point; otherwise this would cause a decrease in dry density before the data point having the largest value of dry density is reached. Similarly, the computer program ignores any data point lying on the “wet side” of the moisture-density curve having an increased value of density relative to the preceding point. These procedures are effective in removing spurious data, and Example 1 in APPENDIX C illustrates a case where this procedure was used.

If any of the plotting software for the Calcomp plotter or line-print plotter is unavailable or incompatible with the version found in the computer program, the program may be adapted for use by either removing the necessary statements or by making the appropriate changes in individual source statements to obtain compatibility. Also, the computer program may be run on Librarian (4) using the job control cards given in APPENDIX A. Finally, the program can analyze any number of data sets for each submission and is restricted only by the central processing unit (CPU) time specified by the job control cards and (or) the computer system.

References


3. McNulty, E. G.; Computerized Analysis of Stress-Strain Consolidation Data, Division of Research, Kentucky Department of Transportation, March 1977.

Appendix A.

INPUT INSTRUCTIONS FOR MOSDEN-0
MOSDEN-0

INPUT INSTRUCTIONS
FOR
ANALYSIS OF MOISTURE-DENSITY DATA

<table>
<thead>
<tr>
<th>COLUMNS</th>
<th>NAME</th>
<th>FORMAT</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>TEST DESIGNATION CARD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-80</td>
<td>BCD</td>
<td>20A4</td>
<td>Alphanumeric information entered on this card serves as the plot title and description of the test.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2.</th>
<th>SOIL DESCRIPTION AND DATE OF TEST CARD</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1-20</td>
<td>COLOR</td>
<td>5A4</td>
<td>The color and type of soil used in the moisture-density test are entered.</td>
</tr>
<tr>
<td>21-30</td>
<td>WL</td>
<td>2A4,A2</td>
<td>Liquid limit of the soil is entered, as a percent, as alphanumeric information.</td>
</tr>
<tr>
<td>31-40</td>
<td>WP</td>
<td>2A4,A2</td>
<td>Plastic limit of the soil is entered, as a percent, as alphanumeric information.</td>
</tr>
<tr>
<td>41-52</td>
<td>DATE</td>
<td>3A4</td>
<td>The month, day, and year on which the moisture-density test was performed are entered as alphanumeric information.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3.</th>
<th>ANALYSIS AND TEST INFORMATION CARD</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>NDEG</td>
<td>I2</td>
<td>The degree of polynomial to be used in fitting the moisture-density data is entered as a right-justified integer in these two columns. The maximum degree of polynomial which can be used in the computer program is six. For seven or fewer data points, the maximum degree of polynomial which can be used is equal to the number of data points minus one. In addition, experience indicates that an acceptable fit can usually be obtained with a degree of polynomial equal to the number of data points minus two. However, a polynomial having a degree of two generally does not provide an acceptable fit. If Columns 1-2 are left blank, NDEG will be set equal to the number of data points minus two or six, whichever is smaller.</td>
</tr>
</tbody>
</table>
MOSDEN-G
Moisture-Density Test
Data Analysis
Computer Program Coding Sheet

TEST DESIGNATION TO BE USED AS PLOT TITLE (BCD)

1. 

LIQUID LIMIT PLASTIC LIMIT
COLOR (WL) (WP) DATE

2. 

NDEG NLAYER N BLOWS WTHAM DIA HEIGHT WEIGHT

3. 

NDEG — Degree of polynomial used in curve fitting.
NLAYER — Number of layers or lifts compacted (if left blank, default value is 3).
N BLOWS — Number of blows per compacted lift (if left blank, default value is 25).
WTHAM — Weight of hammer in pounds (if left blank, default value is 6.5 pounds).

DIA — Inner diameter of cylindrical compaction mold in feet (if left blank, default value is 0.333 feet).
HEIGHT — Interior height of compaction mold in feet (if left blank, default value is 0.383 feet).
WEIGHT — Weight of compaction mold (if left blank, default value is 9.36 pounds).

NOTE: Wet weight plus tare must have the same units as weight of compaction mold, WEIGHT, found in Card No. 3.

A separate Card No. 4 is needed for each compacted moisture-density specimen.

Repeat Cards 1 through 4 for each set of Moisture-Density data.

Figure 2. Computer Program Coding Sheet.
<table>
<thead>
<tr>
<th>Column Range</th>
<th>Field Name</th>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>11-12</td>
<td>NLAYER</td>
<td>I2</td>
<td>The number of layers or lifts of soil placed in the compaction mold is entered as a right-justified integer. If these columns are left blank, a default value of 3 is used.</td>
</tr>
<tr>
<td>21-22</td>
<td>NBLOWS</td>
<td>I2</td>
<td>The number of blows applied to each layer of material is entered as a right-justified integer. If these columns are left blank, a default value of 25 is used.</td>
</tr>
<tr>
<td>31-40</td>
<td>WTHAM</td>
<td>F10.0</td>
<td>The weight in pounds of the hammer used in compacting each layer of material may be entered if the number is expressed with a decimal. If these columns are left blank, a default value of 5.5 pounds is used.</td>
</tr>
<tr>
<td>41-50</td>
<td>DIA</td>
<td>F10.0</td>
<td>The inner diameter in feet of the cylindrical compaction mold can be entered if the number is expressed with a decimal. If these columns are left blank, a default value of 0.33333 feet is used.</td>
</tr>
<tr>
<td>51-60</td>
<td>HEIGHT</td>
<td>F10.0</td>
<td>The interior height, in feet, of the cylindrical compaction mold can be entered if the number is expressed with a decimal. If these columns are left blank, a default value of 0.383 foot is used.</td>
</tr>
<tr>
<td>61-70</td>
<td>WEIGHT</td>
<td>F10.0</td>
<td>The weight, in pounds or grams, of the cylindrical compaction mold can be entered if the number is expressed with a decimal. If these columns are left blank, a default value of 9.36 pounds is used.</td>
</tr>
</tbody>
</table>

4. MOISTURE CONTENT AND WET WEIGHT PLUS TARE DATA CARDS

<table>
<thead>
<tr>
<th>Column Range</th>
<th>Field Name</th>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-10</td>
<td>WC()</td>
<td>F10.0</td>
<td>The water content is entered in the first ten columns, as a percent, and expressed with a decimal.</td>
</tr>
<tr>
<td>11-20</td>
<td>DRYD()</td>
<td>F10.0</td>
<td>The wet material weight plus the weight of mold (tare) is entered and expressed with a decimal. This parameter can be expressed in either pounds or grams, but must have the same units as the weight of the compaction mold, WEIGHT, given in Columns 61-70 of Data Card No. 3. If Columns 61-70 of Card No. 3 have been left blank, then the values of DRYD() must have units of pounds.</td>
</tr>
<tr>
<td>21-22</td>
<td>L</td>
<td>I2</td>
<td>When this parameter has a non-zero integer value, the computer program stops reading data for the current moisture-density curve.</td>
</tr>
</tbody>
</table>

(An additional Card No. 4 is needed for each compacted moisture-density specimen up to a maximum of 18).

Note: Repeat Cards Nos. 1 through 4 for each additional moisture-density curve.
Figure 3. Approximate Central Processing Unit (CPU) Time versus Number of Individual Data Sets for Source Version of Computer Program, MOSDEN-0.
JOB CONTROL CARDS

The following set of job control cards applies when the IBM 370 in McVey Hall at the University of Kentucky is used. These cards describe the JCL necessary for a source deck run on the hands-on reader with a P (Pickup) card in front of the deck. The standard JOB card immediately below includes the waste paper option.

//N13EGM JOB(1009-51001,1,,,,W),MCNULTY,MSGLEVEL=REGION=268K
/*PASSWORD
/*MESSAGE --> PLOT JOB
/*MESSAGE --> PLEASE CHARGE PLOT TO 1009-51001
/*SETUP TAPE=(SCRATCH,RINGIN)
/*JOBPARM K=0
//S EXEC LIBRARIAN,SYSTEM=,UKU.@EXT03, SUBSYS=LIBR2
-OPT INDEX
-SEL MOSDENO,XKTX,EXEC,LIST,SEQ=/73,8,10,10/, TEMP
-END
/*
//T EXEC FORTGCLP,PARM,FORT='ID,SOURCE'
//FORT.SYSIN DD DSN=&&TEMP(MOSDENO,DISP=(OLD,PASS)
//TO.SYSIN DD*

DATA CARDS
/

The next set of job control cards applies when the IBM 370/168 computer in Frankfort is used via the remote job entry terminal No. 7 located at the Division of Research in Lexington.

//DTRN13GM JOB(43179019),MCNULTY,TIME=(0,59),CLASS=D
/*JOBPARM P=TT,K=0
//STEP EXEC ADR
//GO.SYSIN DD *
-SEL R02006S,BHLB,EXEC,LIST,SEQ=/73,8,10,10/,NORESEQ, TEMP
-REP 10
$JOB
C
-DEL 3500,3520
-DEL 6070
-DEL 6120,6130
-DEL 6310,6450
-DEL 6500
-DEL 6590
-DEL 6650,6690
-DEL 6760
-DEL 6900,7040
-DEL 7270,7310
-INS 8500
$ENTRY
-DATA

DATA CARDS

-END
/*
//STEPA EXEC WAT567,REGION=320K
//GO.SYSIN DD DSN=&&LIBR,DISP=(OLD,PASS)
/*
Appendix B.

EXAMPLE PROBLEM
Highway Materials Research Laboratory  
Kentucky Department of Highways  
Lexington, Kentucky

**III-13-2** PROCTOR COMPACTION

<table>
<thead>
<tr>
<th>Wet Weight plus Tare (lbs.)</th>
<th>Wet Weight (lbs.)</th>
<th>Wet Density (lbs./cu. ft.)</th>
<th>Moisture Determination</th>
<th>Dry Density (lbs./cu. ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>13.02</td>
<td>186</td>
<td>87.09</td>
<td>81.5</td>
<td>5.59</td>
</tr>
<tr>
<td>13.33</td>
<td>L-60</td>
<td>100.92</td>
<td>91.82</td>
<td>9.10</td>
</tr>
<tr>
<td>13.55</td>
<td>L-78</td>
<td>129.03</td>
<td>114.72</td>
<td>14.31</td>
</tr>
<tr>
<td>13.45</td>
<td>L-36</td>
<td>77.94</td>
<td>68.49</td>
<td>9.45</td>
</tr>
</tbody>
</table>

![Columns 11-20 on Data Card Number 4](image)

Columns 1-10 on Data Card Number 4

Form S-2  
6-1-57

Figure 4. Example Set of Laboratory Data Recorded for Moisture-Density Test III-13-2.
### MOSDEN-0
Moisture-Density Test
Data Analysis
Computer Program Coding Sheet

**TEST DESIGNATION TO BE USED AS PLOT TITLE (BCD)**

<table>
<thead>
<tr>
<th>NDEG</th>
<th>NLAYER</th>
<th>NBLOWS</th>
<th>WTHAM</th>
<th>DIA</th>
<th>HEIGHT</th>
<th>WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| NDEG  | - Degree of polynomial used in curve fitting. |
| NLAYER | - Number of layers or lifts compacted (if left blank, default value is 3). |
| NBLOWS | - Number of blows per compacted lift (if left blank, default value is 25). |
| WTHAM | - Weight of hammer in pounds (if left blank, default value is 5.5 pounds). |

<table>
<thead>
<tr>
<th>WATER CONTENT (%)</th>
<th>WET WEIGHT PLUS TARE</th>
<th>DRYD (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NOTE: Wet weight plus tare must have the same units as weight of compaction mold, WEIGHT, found in Card No. 3.

A separate Card No. 4 is needed for each compacted moisture-density specimen.

Repeat Cards 1 through 4 for each set of moisture-density data.

---

Figure 5. Example Use of MOSDEN-0 Coding Sheet for Data from Moisture-Density Test 111-13-2.
DESCRIPTION OF SOIL: LIQUID LIMIT = 34.00 PLASTIC LIMIT = 21.00

DATE OF TESTING = 06-23-78

NUMBER OF LAYERS: 3
WEIGHT OF HAMMER = 5.50 LBS
MOLD: WT = 9.4 GR, LBS VOL = 0.0334 CU FT

WATER CONTENT, WT% | WT OF SOIL IN MOLD | WET UNIT WEIGHTS, PCF | DRY DENSITY, PCF
--- | --- | --- | ---
11.0 | 2.66 | 109.51 | 11.0
13.0 | 3.97 | 118.78 | 3.66
17.0 | 4.19 | 125.36 | 109.51
21.0 | 4.09 | 122.37 | 21.0

OPTIMUM MOISTURE CONTENT = 15.6% MAXIMUM DRY DENSITY = 107.7 PCF DEGREE POLYNOMIAL = 3

Figure 6. Computer Printout of Results.

Figure 7. Example of Plot Output Produced by Line Printer.
Figure 8. Example of Plot Output Produced by Calcomp Drum Plotter.
Appendix C.

ADDITIONAL EXAMPLES OF ANALYZED

MOISTURE-DENSITY DATA
EXAMPLE 1

221-18-1

LIQUID LIMIT = 29

<table>
<thead>
<tr>
<th>Degree</th>
<th>Optimum Moisture Content (%)</th>
<th>Maximum Dry Density (pcf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>15.9</td>
<td>104.2</td>
</tr>
<tr>
<td>4</td>
<td>15.9</td>
<td>105.1</td>
</tr>
</tbody>
</table>

Figure 9. Example 1, Test 221-18-1, Liquid Limit = 29, Degree of Polynomial = 3.

Figure 10. Example 1, Test 221-18-1, Liquid Limit = 29, Degree of Polynomial = 4.
**EXAMPLE 2**

24-2-2

LIQUID LIMIT = 34

<table>
<thead>
<tr>
<th>Degree of Polynomial</th>
<th>Optimum Moisture Content (%)</th>
<th>Maximum Dry Density (pcf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>18.4</td>
<td>106.3</td>
</tr>
<tr>
<td>4</td>
<td>18.3</td>
<td>106.1</td>
</tr>
</tbody>
</table>

Figure 11. Example 2, Test 24-2-2, Liquid Limit = 34, Degree of Polynomial = 3.

Figure 12. Example 2, Test 24-2-2, Liquid Limit = 34, Degree of Polynomial = 4.
Figure 13. Example 3, Test 24-2-3, Liquid Limit = 34, Degree of Polynomial = 3.

Figure 14. Example 3, Test 24-2-3, Liquid Limit = 34, Degree of Polynomial = 4.
Example 4

24-1-1 STD

LIQUID LIMIT = 44

<table>
<thead>
<tr>
<th>Degree of Polynomial</th>
<th>Optimum Moisture Content (%)</th>
<th>Maximum Dry Density (pcf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>23.7</td>
<td>99.7</td>
</tr>
<tr>
<td>4</td>
<td>24.2</td>
<td>101.6</td>
</tr>
</tbody>
</table>

Figure 15. Example 4, Test 24-1-1, Liquid Limit = 44, Degree of Polynomial = 3.

Figure 16. Example 4, Test 24-1-1, Liquid Limit = 44, Degree of Polynomial = 4.
Figure 17. Example 5, Test 111-12-6, Liquid Limit = 59, Degree of Polynomial = 4.

Figure 18. Example 5, Test 111-12-6, Liquid Limit = 59, Degree of Polynomial = 5.
Appendix D.

COMPUTER SYSTEM DESCRIPTION
### COMPUTER SYSTEM DESCRIPTION

#### Computer
- **Manufacturer**: IBM
- **Model number**: System/370 Model 165 II
- **Work length**:
  - Single Precision - 4 bytes, 32 bits
  - Double Precision - 8 bytes, 64 bits
- **Core access speed**: 700 nano seconds
- **Virtual storage**: 16 mega bytes (maximum)

#### Peripheral Equipment
- **Line printers**: IBM/3211 Chain Printers
- **Card readers**: IBM/2821-5 I/O Control Unit
- **Card punch**: IBM/3505 Card Reader
- **Magnetic tape drives**: IBM/029 Card Key Punch
- **IBM Tape Unit 2401 processes tape at 75 inches/second**
- **Uses 800 bytes per inch density magnetic tape**
- **Processes 60,000 bytes/second**
- **Uses either 9 or 7 track tapes**
- **Calcomp 663 Digital Incremental Drum plotter**

#### Plotters

#### Storage Requirements of Source Program
- **Total storage requirements of computer program is around 110K**

<table>
<thead>
<tr>
<th>File</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAIN</td>
<td>11156</td>
</tr>
<tr>
<td>CURVE</td>
<td>4012</td>
</tr>
<tr>
<td>FLSQFY</td>
<td>954</td>
</tr>
<tr>
<td>FCODA</td>
<td>908</td>
</tr>
<tr>
<td>FGFEFTY</td>
<td>1816</td>
</tr>
<tr>
<td>Plot buffer requires up to</td>
<td>80K</td>
</tr>
</tbody>
</table>
Appendix E.

FLOW CHART FOR MOSDEN-0
FLOW CHART FOR
MOSDEN-0

START

Call CALCOMF plot buffer

Do next problem

Read in test designation for use as plot title

Read in soil description and data of testing

Read in degree of polynomial and test information

Read in value of moisture content (g) in increasing order along with values of wet weight plus tare

Calculate wet weight of material in mold

Output present test information

Calculate dry density

Location data point having maximum dry density

Are there increases in values of dry density before the maximum value of dry density is reached?

NO

YES

Ignore data points causing localized dips in moisture-density curve by setting weighting factor to $W() = 0.0001$

Count number of data points ignored in this step

Are there increases in values of dry density after the maximum value of dry density has been passed?

NO

YES

Ignore data points causing localized dips in moisture-density curve by setting weighting factor to $W() = 0.0001$

Count number of data points ignored in this step

Check degree of polynomial if some data points have been ignored and adjust degree of polynomial accordingly

CALL FLQSRY to fit least-squares orthogonal polynomial to moisture-density data

Find peak of polynomial representation of moisture-density data as an estimate of the optimum moisture content and maximum dry density

PRINT all newly determined results

Call SUBROUTINE CURVE to plot all results

Has a control end been encountered?

NO

YES

STOP
Appendix F.

MOSDEN-0 COMPUTER PROGRAM
COMPUTERIZED ANALYSIS
OF
MOISTURE-DENSITY DATA
(PROCTOR)
TO DETERMINE
THE
OPTIMUM MOISTURE CONTENT
AND THE
MAXIMUM DRY DENSITY
BY
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THIS COMPUTER PROGRAM USES A
LEAST-SQUARES ORTHOGONAL POLYNOMIAL TO
FIT THE MOISTURE-DENSITY DATA. THE CURVE
FITTINGS SUBROUTINE, FLSQFY, IS BASED ON
THE METHOD PROPOSED BY FORSYTHE (1957).
THE OPTIMUM MOISTURE CONTENT AND MAXIMUM
DRY DENSITY IS DETERMINED FROM THE FITTED
POLYNOMIAL REPRESENTATION OF THE DATA.

THIS COMPUTER PROGRAM IS WRITTEN IN FORTRAN IV AND PRODUCES
PLOTTED OUTPUT USING THE IBM 370/165 II COMPUTER AND CALCOMP 663
DRUM PLOTTER. THE COMPUTER PROGRAM WAS DEVELOPED UNDER THE
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VARIABLE DEFINITIONS

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ALPHA1 ) SCRATCH ARRAY FOR SUBROUTINE FLSQFY.

BCD( ) 2044
PLOT TITLE AND COMPUTER PRINTOUT HEADING.

BETA1 ) SCRATCH ARRAY FOR SUBROUTINE FLSQFY.

BIG
ORDINATE VALUE OF DATA POINT HAVING GREATEST DRY DENSITY.

BOUND1 STARTING ABCISSA VALUE USED IN SEARCH FOR LOCATION OF MAXIMUM
DRY DENSITY ON POLYNOMIAL REPRESENTATION OF MOISTURE-DENSITY
DATA. VALUES OF % MOISTURE CONTENT ARE ABCISSAS.

BOUND2 ENDING ABCISSA VALUE USED IN SEARCH FOR LOCATION OF MAXIMUM
DRY DENSITY ON POLYNOMIAL REPRESENTATION OF MOISTURE-DENSITY
DATA.

C( ) COEFFICIENTS USED IN SETTING UP ALL POLYNOMIAL EQUATIONS.

COLOR 5A4 DESCRIPTION OF SOIL APPEARANCE.

DATA1 ) PRINCIPLE SCRATCH ARRAY FOR PLOTTING LIBRARY BUFFER.

DATE 3A4 DATE ON WHICH MOISTURE-DENSITY COMPACTION TEST WAS RUN.

DELTA INCREMENT TO BE USED IN GENERATION OF EVENLY SPACED VALUES OF A
GIVEN PARAMETER.

DIA DIAMETER OF COMPACTION MOLD IN FEET.

DMAX MAXIMUM ORDINATE VALUE USED FOR SCALING MOISTURE-DENSITY DATA FOR
PLOTTING BY LINE PRINTER.

DMIN MINIMUM ORDINATE VALUE USED FOR SCALING MOISTURE-DENSITY DATA FOR
PLOTTING BY LINE PRINTER.

DRY() ) ARRAY IN WHICH DRY DENSITIES OF DATA POINTS ARE STORED.

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00000590 00000600 00000610 00000620 00000630 00000640 00000650 00000660 00000670 00000680 00000690 00000700 00000710 00000720 00000730 00000740 00000750 00000760 00000770 00000780 00000790 00000800 00000810 00000820 00000830 00000840 00000850 00000860 00000870 00000880 00000890 00000900 00000910 00000920 00000930 00000940 00000950 00000960 00000970 00000980 00000990 00001000 00001010 00001020 00001030 00001040 00001050 00001060 00001070 00001080 00001090 00001100 00001110 00001120 00001130 00001140 00001150 00001160 00001170 00001180 00001190 00001200 00001210 00001220 00001230 00001240 00001250 00001260 00001270 00001280 00001290 00001300 00001310 00001320 00001330

38
C DRYMAX
C MAXIMUM VALUE OF DRY DENSITY AS FOUND ON POLYNOMIAL REPRESENTATION.
C OF MOISTURE-DENSITY DATA.
C FACTOR
C THE VARIABLE IS USED IN MAIN PROGRAM TO ALLOW CALCULATION OF
C VALUES OF DRY DENSITY IN CORRECT UNITS OF WEIGHT.
C FPN
C FLOATING POINT NUMBER USED IN PLOTTING NUMERICAL VALUES ON
C CALCCMP PLOTTER.
C HEIGHT
C HEIGHT OF COMPACTION MOLD IN FEET.
C I
C DO LCOP PARAMETER.
C IBIG
C ARRAY LOCATION FOR THE DATA POINT HAVING THE LARGEST DRY DENSITY.
C IDEG
C INTEGER PARAMETER USED TO TEST WHETHER POLYNOMIAL DEGREE
C CAN BE REDUCED TO ACCOUNT FOR DATA POINTS WHICH HAD BEEN THROWN
C OUT BECAUSE OF LOCALIZED DIPS IN MOISTURE-DENSITY CURVE.
C IFIRST
C THIS VARIABLE IS SET EQUAL TO ONE WHEN THE FIRST PORTION OF
C THE POLYNOMIAL FIT THAT HAS A POSITIVE SLOPE IS FOUND. THEN
C TESTS ARE MADE FROM THIS POINT ON TO DETECT WHERE POLYNOMIAL
C PEAKS, THAT IS, WHERE SLOPE BECOMES NEGATIVE AGAIN.
C IN
C COMPUTER INPUT UTILITY DEVICE NUMBER FOR READ STATEMENTS.
C IDOUT
C COMPUTER OUTPUT UTILITY DEVICE NUMBER FOR WRITE STATEMENTS.
C ISTART
C INTERGER DO-LOOP PARAMETER USED TO LOCATE WHERE POLYNOMIAL CURVE
C PEAKS. THIS VARIABLE IS USED TO GET A MORE PRECISE ESTIMATE
C OF OPTIMUM MOISTURE CONTENT.
C ISUM
C INTEGER COUNTER THAT KEEPS TRACK OF HOW MANY DATA POINTS WILL NOT
C BE FITTED BECAUSE OF LOCALIZED DIPS IN MOISTURE-DENSITY CURVE.
C THIS VARIABLE IS THEN USED TO TRY AND REDUCE THE SPECIFIED DEGREE
C OF POLYNOMIAL IF POSSIBLE.
C ITEST
C THIS PARAMETER IS USED IN TWO WAYS: ONE, IT SERVES AS A
C TEST TO CHECK THAT THE SPECIFIED DEGREE OF POLYNOMIAL IS NOT LARGER
C THAN POSSIBLE AFTER SOME DATA POINTS HAVE BEEN REJECTED;
C ALSO, THIS PARAMETER IS USED TO INCLUDE THE PEAK OF THE FITTING
C POLYNOMIAL IN THE SCALING OF VERTICAL VALUES.
C J
C DO-LOOP PARAMETER.
C L
C TRIP ARGUMENT THAT INDICATES END OF CURRENT DATA SET DURING INPUT
C WHEN IT BECOMES EQUAL TO ONE.
C MDC
C WATFIV PARAMETER FOR SUBROUTINE FLSQFY THAT REPRESENTS THE NUMBER
C OF DATA POINTS, PLUS THE DEGREE OF POLYNOMIAL, AND PLUS ONE.
C NBLOWS
C NUMBER OF BLOWS APPLIED TO EACH LAYER PLACED INTO COMPACTION MOLD.
C NDATA
C NUMBER OF DATA POINTS ON MOISTURE-DENSITY CURVE.
C NDG
C WATFIV PARAMETER FOR SUBROUTINE FLSQFY THAT IS SET EQUAL TO THE
C DEGREE OF POLYNOMIAL PLUS ONE. IN OTHER WORDS, NDG REPRESENTS

39
THE NUMBER OF COEFFICIENTS NEEDED TO DESCRIBE A POLYNOMIAL OF A GIVEN DEGREE.

DOEG

DEGREE OF POLYNOMIAL USED IN CURVE FITTING.

NLAYER

NUMBER OF LAYERS PLACED INTO COMPACTION MOLD.

OPTMOS

OPTIMUM MOISTURE CONTENT EXPRESSED AS A PERCENT.

PI

PLASTICITY INDEX.

PI

PLOT SUBROUTINE WHICH SETS UP LIBRARY BUFFER FOR IBM 370/165 II COMPUTER.

POL

SCRATCH ARRAY FOR SUBROUTINE FLSQFY.

PRI

SCRATCH ARRAY FOR SUBROUTINE FLSQFY.

SI

SCRATCH ARRAY FOR SUBROUTINE FLSQFY.

SGMSQI

SCRATCH ARRAY FOR SUBROUTINE FLSQFY.

VOL

VOLUME OF COMPACTION MOLD IN CUBIC FEET.

WI

WEIGHTING ARRAY FOR DATA POINTS FROM MOISTURE DENSITY CURVE. DATA POINTS CAUSING LOCALIZED DIPS IN CURVE ARE ELIMINATED FROM FITTING CONSIDERATIONS BY ASSIGNING WI TO BE 0.0001 INSTEAD OF THE USUAL 1.0.

WCI

WATER CONTENT EXPRESSED AS A PERCENT.

WEIGHT

WEIGHT OF COMPACTION MOLD IN GRAMS OR POUNDS.

WL

LIQUID LIMIT EXPRESSED AS A PERCENT.

WMAX

MAXIMUM ABSCISSA VALUE FOR SCALING MOISTURE-DENSITY DATA FOR PLOTTING BY LINE PRINTER.

WMIN

MINIMUM ABSCISSA VALUE FOR SCALING MOISTURE-DENSITY DATA FOR PLOTTING BY LINE PRINTER.

WP

PLASTIC LIMIT EXPRESSED AS A PERCENT.

WTHAM

WEIGHT OF COMPACTION HAMMER IN POUNDS OR GRAMS.

XI

ARRAY PARAMETER FOR STORAGE OF GENERATED SEARCH ABSCISSAS FOR USE WITH FITTED POLYNOMIAL.

XBIG

MOISTURE CONTENT (%) AT DATA POINT HAVING MAXIMUM DRY DENSITY.

X1

X2

X3

X4

X5

X1 = X
X2 = X**X
X3 = X**X*X
X4 = X**X*X*X
X5 = X**X*X*X*X
These variables set up polynomial terms for a particular abscissa value, \( x \). These terms will be paired with their respective coefficients to calculate ordinate values and slopes at different portions of polynomial fit.

These variables set up polynomial terms for a particular abscissa value, \( x \). These terms will be paired with their respective coefficients to calculate ordinate values and slopes at different portions of polynomial fit.

Array for storage of various ordinate values.

*******************************************************************

The program uses the following subroutines and computer supplied buffers:

1. MAIN PROGRAM

2. SUBROUTINE CURVE - plotting of reduced data and the polynomial representation of this data. calcomp and line-printer plotting procedures are found in this subroutine.

3. SUBROUTINE FLSQFY - least-squares curve fitting algorithm that uses orthogonal polynomials. this subroutine calls subroutines fcoda and fgefyt.

4. SUBROUTINE PLOTS - set up plot library buffer for IBM 370/165 II computer.

5. PLOT LIBRARY SUBROUTINES: axis, dashln, grid, factor, line, logaxis, number, plot, plots, scale, symbol

6. LINE-PRINTER PLOTTING SUBROUTINES: box, graph, plotem, scaler, square

*******************************************************************

COMMON /BLDK1/ CDLORI51, WU3L, WPI3I, OATE(3) 0002850

COMMON /BLOK2/ XWORKI150, YWORKI150 0002860

COMMON /BLDK3/ !BIG DIMENSION W120, CW120, ALPH4(34), BETAl34, $34, SGMSQ134, PR134, IPOI34 0002870

DIMENSION WCI20, ORD120, DATA11024, BCD120 0002880

DIMENSION X(103), Y(103) 0002890

CALL PLOTS(DATA, 4096) 0002900
CALL PLOT(0.0, -12.0, -3) 0002910
CALL PLOT(0.0, 1.0, -3) 0002920

INPUT AND OUTPUT UTILITY DEVICE NUMBERS FOR COMPUTER.
IN=5 0002930
IGUT=6 0002940

PI=355./113. 0002950

WRITE(IGUT, 1000) 0002960

0002970 0002980 0002990
0003000 0003010
0003020 0003030
0003040 0003050
0003060 0003070
0003080 0003090
0003100 0003110
0003120 0003130
0003140 0003150
0003160 0003170
0003180 0003190
0003200 0003210
0003220 0003230
0003240 0003250
0003260 0003270
0003280 0003290
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0003380 0003390
0003400 0003410
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0003460 0003470
0003480 0003490
0003500 0003510
0003520 0003530
0003540 0003550
0003560 0003570
0003580 0003590
0003600 0003610
1000 FORMAT('I1')
C 10 CONTINUE
C WRITE(IOUT,1140)
C READ IN DESIGNATION FOR USE AS OUTPUT LABEL AND PLOT TITLE.
C READ(IN,1010,END=160) BCD
1010 FORMAT(20A4)
C READ IN DESCRIPTION OF SOIL (COLOR, TYPE), ATTIPERG LIMITS,
C AND DATE OF TESTING.
C READ(IN,1020) COLOR, WL, WP, DATE
1020 FORMAT(5A4,9A4,A2,2A4,A2,3A4)
C READ IN DEGREE OF POLYNOMIAL USED IN FITTING MOISTURE-DENSITY
C DATA. EXPERIENCE HAS SHOWN THAT FOR 8 OR FEWER DATA POINTS
C THE BEST DEGREE IS USUALLY EQUAL TO THE NUMBER OF DATA POINTS
C MINUS TWO, HOWEVER THE MAXIMUM DEGREE WHICH CAN BE USED IS SIX.
C IF NDEG=0 OR CARD COLUMNS 1-10 ARE LEFT BLANK, NDEG WILL BE SET
C EQUAL TO THE NUMBER OF DATA POINTS MINUS TWO OR SIX, WHICH EVER
C IS SMALLER.
C ALSO, READ IN SAME CARD THE NUMBER OF LAYERS (OR LIFTS),
C NUMBER OF BLOWS PER LAYER, AND WEIGHT OF THE HAMMER (EITHER IN
C POUNDS OR GRAMS). IF COLUMNS 11-30 ARE LEFT BLANK, THEN DEFAULT
C VALUES FOR THESE QUANTITIES WILL BE 25, 3, AND 5.50 RESPECTIVELY.
C ALSO, READ IN MOLD DIMENSIONS (INNER DIAMETER AND HEIGHT) IN FEET
C AND WEIGHT OF MOLD IN POUNDS OR GRAMS. IF COLUMNS 31-70 ARE
C LEFT BLANK, DEFAULT VALUES FOR THESE QUANTITIES WILL BE
C 0.33333, 0.383, AND 9.36 RESPECTIVELY.
C READ(IN,1030) NDEG, NLAYER, NBLOWS, WTHAM, DIA, HEIGHT, WEIGHT
1030 FORMAT(31F1,8X,4F10.0)
C IF(NLAYER.LT.0.0001) NLAYER=3
C IF(NBLOWS.LT.0.0001) NBLOWS=25
C IF(WTHAM.LT.0.0001) WTHAM=5.50
C IF(DIA.LT.0.0001) DIA=0.333333
C IF(HEIGHT.LT.0.0001) HEIGHT=0.383
C IF(WEIGHT.LT.0.0001) WEIGHT=9.36
C VOL = PI*(DIA**2/4)*HEIGHT
42 DO 40 I =1,20
C FACTOR=1.0
C IF (WEIGHT.LT.20) FACTOR=453.6
C READ IN UP TO TWENTY DATA POINTS, WATER CONTENT (%), WEIGHT OF
C MOLD PLUS SOIL (IN GRAMS OR LBS.). A PLUS ONE IN COLUMNS 21-22
C ENDS A GIVEN SET OF MOISTURE-DENSITY DATA. THE COMPUTER PROGRAM
C WILL STOP LOCKING FOR MORE DATA WHEN A CONTROL CARD (/*) IS
C ENCOUNTERED AT END OF DATA.
C DO 20 I =1,20
C READ (IN,1050) WC(I), DRYD(I)
1050 FORMAT(2F10.2,12)
C NDATA = I
C IF (L.NE.0) GO TO 30
C 20 CONTINUE
C 30 CONTINUE
C IF(NDEG.EQ.0.AND.NDATA.EQ.3) NDEG=2
C IF(NDEG.EQ.0.AND.NDATA.EQ.4) NDEG=3
C IF(NDEG.EQ.0.AND.NDATA.LE.6) NDEG=NDATA-2
C IF(NDEG.EQ.0.AND.NDATA.GT.8) NDEG=6
C CALCULATION OF WET WEIGHT OF MATERIAL IN MOLD.
C DO 40 I =1,NDATA
C DRYD(I)=DRYD(I)-WEIGHT
C 40 CONTINUE
OUTPUT PRESENT TEST INFORMATION

WRITE (IOUT, 1060) BCD
1060 FORMAT (143, 10x, 20A4)

WRITE (IOUT, 1070) COLOR, WL, WP, DATE

WRITE (IOUT, 1080) NLAYER, NBLOWS, WTHAM, WEIGHT, VOL
1080 FORMAT (143, 5x, *NUMBER OF LAYERS:*, 12, 4X, *NO. OF BLOWS/LAYER:*, I3, 4X, 00004480

WRITE (IOUT, 1100) WC(J), J=1, NDATA
1100 FORMAT (33, 10x, *WATER CONTENT, W%, 15X, 10F4.2, 3X)

WRITE (IOUT, 1110) DRYD(J), J=1, NDATA
1110 FORMAT (33, 10x, *DRY DENSITY, PCF, 15X, 10F9.2, 1X)

WRITE (IOUT, 1120) (ORYD(J), J=1, NDATA)
1120 FORMAT (24, 10x, *WET UNIT WEIGHS, PCF, 15X, 10F7.2, 3X)

WRITE (IOUT, 1130) (DRYD(J), J=1, NDATA)
1130 FORMAT (33, 10x, *DRY DENSITY, PCF, 15X, 10F9.2, 1X)

INITIALIZING ALL POLYNOMIAL COEFFICIENTS AND WEIGHTING FACTORS.

DG 70 =1,20
C(II)=0.0
W(I)=1.0
70 CONTINUE

NEGLECT DATA POINTS PRODUCING LOCALIZED DIPS IN THE MOISTURE-DENSITY CURVE.

ISUM=0
DG 80 I = 1, IBIG
IF (I.EQ.1) GO TO 80
IF (DRYD(I).LT.DRYD(I-1)) W(I)=0.0001
IF (DRYD(I).LT.DRYD(I-1)) ISUM=1+ISUM
80 CONTINUE

MUST REDUCE DEGREE OF POLYNOMIAL IF THERE ARE DATA POINTS WHICH HAVE BEEN GIVEN LOW WEIGHTING FACTORS.

I=DEG=NDEG
ITEST=NDATA-ISUM-1
IF(INDEG.LE.ITEST) GOTO 95
IDEG=NDEG-ISUM
IF(IDEG.GE.3) NDEG=NDEG-ISUM
95 CONTINUE
C EXPERIENCE HAS SHOWN ANYTHING LESS THAN A POLYNOMIAL DEGREE OF
THREE IS NOT VERY EFFECTIVE IN FITTING THE DATA IN A REASONABLE
C FASHION.
C IF(INDEG.LE.2) NDEG=2
C PREPARING DATA TO BE FITTED BY LEAST-SQUARES ORDINARY POLYNOMIAL.
C NDC=NDEG+1
MDC=NDEG+NDATA+1
DO 100 I=1,NDATA
Y(I)=DRYDI(I)
XWORK(I)=WC(I)
YWORK(I)=DRYCI(I)
100 CONTINUE
C CALL FLSQFYINDEG,NDATA,WC,V,W,C,ALPHA,BETA,S,SGMSQ,PR,PO,NDC,MDC
C SEARCHING FOR OPTIMUM MOISTURE CONTENT ON FITTED POLYNOMIAL
C REPRESENTATION OF MOISTURE-DENSITY CURVE.
C INITIALLY SETTING SEARCH INTERVAL TO FIND LOCATION OF PEAK IN
MOISTURE-DENSITY CURVE AT DATA POINTS BEFORE AND AFTER ONE
HAVING MAXIMUM DRY-DENSITY.
C IF(IBIG.GT.1) BOUND1=WC(IBIG-1)
IF(IBIG.EQ.1) BOUND1=WC(1)
IF(IBIG.LT.NDATA) BOUND2=WC(IBIG+1)
IF(IBIG.EQ.NDATA) BOUND2=WC(NDATA)
ISTART=D
C DO 150 J=1,3
X(I)=BOUND1
DELTAS=(BOUND2-BOUND1)/100.
C DO 110 I=2,101
X(I)=X(I-1)+DELTAS
110 CONTINUE
C DO 130 I=1,101
X1=X(I)
X2=X(I)*X(I)
X3=X(I)*X(I)*X(I)
X4=X(I)+X1+X2+X3
X5=X(I)*X(I)+X(I)*X(I)*X(I)
X6=X(I)*X(I)*X(I)+X(I)*X(I)*X(I)
Y(I)=C(2)+2*C(3)*X1+3*C(4)*X2+4*C(5)*X3+5*C(6)*X4+6*C(7)*X5
IF(J.EQ.1.AND.I.EQ.1.AND.Y(I).LE.0) IFIRST=999
IF(J.EQ.1.AND.Y(I).GT.0) IFIRST=1
IF(J.EQ.1.AND.IFIRST.EQ.1) GO TO 120
IF(J.EQ.1.AND.IFIRST.GT.1) GO TO 130
120 CONTINUE
IF(Y(I).LT.0) ISTART=1
IF(Y(I).LT.0) GO TO 140
130 CONTINUE
C IF(ISTART.EQ.0) ISTART=50
140 CONTINUE
C BOUND1=X(ISTART-1)
BOUND2=X(ISTART+1)
190 CONTINUE
C OPTMOS=X(ISTART-1)+X(ISTART+1)/2.0
X1=OPTMOS
X2=OPTMOS*OPTMOS
X3 = OPTMOS * OPTMOS * OPTMOS
X4 = OPTMOS * OPTMOS * OPTMOS * OPTMOS
X5 = OPTMOS * OPTMOS * OPTMOS * OPTMOS * OPTMOS
DRYMAX = C(1) * C(2) * X1 * C(3) * X2 * C(4) * X3 + C(5) * X4 + C(6) * X5 + C(7) * X6

1140 FORMAT( *130(*'-1'))

WRITE(*1150) OPTMOS, DRYMAX, NDEG
1150 FORMAT(*101, 'OPTIMUM MOISTURE CONTENT = ', F5.1, '*X', F5.1, 'PCF', 3X, 'DEGREE POLYNOMIAL = ', F5.1)

CALL CURVE(NDEG, NDATA, WC, DRYD, C, BCD, OPTMOS, DRYMAX)
160 CONTINUE
CALL PLOT(15.0, 0.0, -3)
CALL PLOT(15.0, 0.0, 999)
STOP
END

C 1140 FORMAT(*130(*'-1'))
C WRITE(*1150) OPTMOS, DRYMAX, NDEG
1150 FORMAT(*101, 'OPTIMUM MOISTURE CONTENT = ', F5.1, '*X', F5.1, 'PCF', 3X, 'DEGREE POLYNOMIAL = ', F5.1)

C CALL PLOTTING SUBROUTINE THAT PLOTS DATA USING CALCOMP DRUM
C PLOTTER AND LINE PRINTER.
C CALL CURVE(NDEG, NDATA, WC, DRYD, C, BCD, OPTMOS, DRYMAX)
C CALL PLOT(15.0, 0.0, -3)
C CALL PLOT(15.0, 0.0, 999)
C STOP
C END

G LEVEL 20.1 MAIN DATE = 78229 09/00/55
C C PLOTTING SUBROUTINE
C SUBROUTINE CURVE(NDEG, NDATA, WC, DRYD, C, BCD, OPTMOS, DRYMAX)
C COMMON /BLOCK1/ COLOR, W1, W1, DATE
C COMMON /BLOCK2/ XWORK(150), YWORK(150)
C COMMON /BLOCK3/ IBIG
C DIMENSION WC(20), DRYD(20), C(20), X(103), Y(103), BCD(20)
C ITEST = NDATA
IF(DRYMAX.GT.DRYD(IBIG)) DRYD(NDATA+1)=DRYMAX
IF(DRYMAX.GT.DRYD(IBIG)) ITEST=NDATA+1
CALL SCALE(DRYD, 8.0, ITEST-1)
IF(DRYMAX.GT.DRYD(IBIG)) DRYD(NDATA+1)=DRYD(NDATA+1)
IF(DRYMAX.GT.DRYD(IBIG)) DRYD(NDATA+2)=DRYD(NDATA+2)
CALL SCALE(WC, 8.0, NDATA)
CALL FACTOR(0.83)
CALL SYMBOL(0.5, 9.5, 0.14, BCD, 0.0, 80)
CALL AX(0.0, 0.0, 3, 'DRY DENSITY, PCF', 16, 8.0, 9.0, DRYD(NDATA+1),
1 DRYD(NDATA+2)
CALL AX(0.0, 0.0, 3, 'MOISTURE CONTENT, %', 20, 8.0, 0.0, WC(NDATA+1),
1 WC(NDATA+2))
CALL LINE(WC, DRYD, NDATA, 1-1, 1)
C DELTA=OPTMOS-WC(11))/10.0
C DELETE FOLLOWING DEFINITION OF DELTA WHEN WATFIV IS BEING USED
C TO RUN COMPUTER PROGRAM.
C DELTA=(WC(NDATA+1)-OPTMOS)/10.0
C YWORK(I+NDATA)=DRYMAX
C XWORK(I+NDATA)=OPTMOS
X(I)=OPTMOS
Y(I)=DRYMAX

00005870
00005880
00005890
00005900
00005910
00005920
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00006460
00006470
00006480
00006490
00006500
00006510
00006520
00006530
00006540
00006550
DO 10 I = 2, 10
X(I) = X(I-1) - DELTA
Y(I) = DRYMAX
XWORK(I+NDATA) = X(I-1) - DELTA
YWORK(I+NDATA) = DRYMAX
10 CONTINUE

DELTA = (DRYMAX - DRY(I))/10.0
C
DELETE FOLLOWING DEFINITION FOR DELTA WHEN WATFIV IS BEING USED
C
TO RUN COMPUTER PROGRAM.

G LEVEL 20.1 CURVE DATE = 78229 09/00/55

G

CALL DASHLN(X, Y, 10, 1)
CALL SYMBOL(1, 0.5, 0.5, 0.1, 0, 0.25, 0.0, 0.3, 'COLOR', 0.0, 0.3)
CALL SYMBOL(10.5, 8.5, 0.1, 0.0, 0.16, 0.0, 0.3, 'DEG', 0.0, 0.0, 0.3)
FPN = NDEG
CALL NUMBER(13.5, 8.5, 0.0, 0.1, 0.0, 0.3)
CALL SYMBOL(4.5, 0.5, 0.0, 0.1, 0.0, 0.3, 'OPTIMUM MOISTURE CONTENT (%) =', 0.0, 0.3)
CALL NUMBER(16.7, 8.5, 0.0, 0.1, 0.0, 0.3, 'DPTMJUM DRY DENSITY = PFC*0.0, 0.31')
CALL GRID(10.0, 0.0, 0.0, 0.5, 0.0, 0.1, 0.0, 0.1)
CALL GRID(-1.0, -1.0, 1.0, 10.0, 0.1, 0.0, 0.1)
C
DELTA = WC(NDATA)/WC(1)/100.
X(1) = WC(1)
30 CONTINUE

C

CALL DASHLN(X, Y, 10, 1)
CALL SYMBOL(1, 0.5, 0.5, 0.1, 0, 0.25, 0.0, 0.3, 'COLOR', 0.0, 0.3)
CALL SYMBOL(10.5, 8.5, 0.1, 0.0, 0.16, 0.0, 0.3, 'DEG', 0.0, 0.0, 0.3)
FPN = NDEG
CALL NUMBER(13.5, 8.5, 0.0, 0.1, 0.0, 0.3)
CALL SYMBOL(4.5, 0.5, 0.0, 0.1, 0.0, 0.3, 'OPTIMUM MOISTURE CONTENT (%) =', 0.0, 0.3)
CALL NUMBER(16.7, 8.5, 0.0, 0.1, 0.0, 0.3, 'DPTMJUM DRY DENSITY = PFC*0.0, 0.31')
CALL GRID(10.0, 0.0, 0.0, 0.5, 0.0, 0.1, 0.0, 0.1)
CALL GRID(-1.0, -1.0, 1.0, 10.0, 0.1, 0.0, 0.1)
C
DELTA = WC(NDATA)/WC(1)/100.
X(1) = WC(1)
30 CONTINUE

C

CALL DASHLN(X, Y, 10, 1)
CALL SYMBOL(1, 0.5, 0.5, 0.1, 0, 0.25, 0.0, 0.3, 'COLOR', 0.0, 0.3)
CALL SYMBOL(10.5, 8.5, 0.1, 0.0, 0.16, 0.0, 0.3, 'DEG', 0.0, 0.0, 0.3)
FPN = NDEG
CALL NUMBER(13.5, 8.5, 0.0, 0.1, 0.0, 0.3)
CALL SYMBOL(4.5, 0.5, 0.0, 0.1, 0.0, 0.3, 'OPTIMUM MOISTURE CONTENT (%) =', 0.0, 0.3)
CALL NUMBER(16.7, 8.5, 0.0, 0.1, 0.0, 0.3, 'DPTMJUM DRY DENSITY = PFC*0.0, 0.31')
CALL GRID(10.0, 0.0, 0.0, 0.5, 0.0, 0.1, 0.0, 0.1)
CALL GRID(-1.0, -1.0, 1.0, 10.0, 0.1, 0.0, 0.1)
C
DELTA = WC(NDATA)/WC(1)/100.
X(1) = WC(1)
30 CONTINUE

C

CALL DASHLN(X, Y, 10, 1)
CALL SYMBOL(1, 0.5, 0.5, 0.1, 0, 0.25, 0.0, 0.3, 'COLOR', 0.0, 0.3)
CALL SYMBOL(10.5, 8.5, 0.1, 0.0, 0.16, 0.0, 0.3, 'DEG', 0.0, 0.0, 0.3)
FPN = NDEG
CALL NUMBER(13.5, 8.5, 0.0, 0.1, 0.0, 0.3)
CALL SYMBOL(4.5, 0.5, 0.0, 0.1, 0.0, 0.3, 'OPTIMUM MOISTURE CONTENT (%) =', 0.0, 0.3)
CALL NUMBER(16.7, 8.5, 0.0, 0.1, 0.0, 0.3, 'DPTMJUM DRY DENSITY = PFC*0.0, 0.31')
CALL GRID(10.0, 0.0, 0.0, 0.5, 0.0, 0.1, 0.0, 0.1)
CALL GRID(-1.0, -1.0, 1.0, 10.0, 0.1, 0.0, 0.1)
C
DELTA = WC(NDATA)/WC(1)/100.
X(1) = WC(1)
30 CONTINUE

C

CALL DASHLN(X, Y, 10, 1)
CALL SYMBOL(1, 0.5, 0.5, 0.1, 0, 0.25, 0.0, 0.3, 'COLOR', 0.0, 0.3)
CALL SYMBOL(10.5, 8.5, 0.1, 0.0, 0.16, 0.0, 0.3, 'DEG', 0.0, 0.0, 0.3)
FPN = NDEG
CALL NUMBER(13.5, 8.5, 0.0, 0.1, 0.0, 0.3)
CALL SYMBOL(4.5, 0.5, 0.0, 0.1, 0.0, 0.3, 'OPTIMUM MOISTURE CONTENT (%) =', 0.0, 0.3)
CALL NUMBER(16.7, 8.5, 0.0, 0.1, 0.0, 0.3, 'DPTMJUM DRY DENSITY = PFC*0.0, 0.31')
CALL GRID(10.0, 0.0, 0.0, 0.5, 0.0, 0.1, 0.0, 0.1)
CALL GRID(-1.0, -1.0, 1.0, 10.0, 0.1, 0.0, 0.1)
C
DELTA = WC(NDATA)/WC(1)/100.
X(1) = WC(1)
30 CONTINUE

C

CALL DASHLN(X, Y, 10, 1)
CALL SYMBOL(1, 0.5, 0.5, 0.1, 0, 0.25, 0.0, 0.3, 'COLOR', 0.0, 0.3)
CALL SYMBOL(10.5, 8.5, 0.1, 0.0, 0.16, 0.0, 0.3, 'DEG', 0.0, 0.0, 0.3)
FPN = NDEG
CALL NUMBER(13.5, 8.5, 0.0, 0.1, 0.0, 0.3)
CALL SYMBOL(4.5, 0.5, 0.0, 0.1, 0.0, 0.3, 'OPTIMUM MOISTURE CONTENT (%) =', 0.0, 0.3)
CALL NUMBER(16.7, 8.5, 0.0, 0.1, 0.0, 0.3, 'DPTMJUM DRY DENSITY = PFC*0.0, 0.31')
CALL GRID(10.0, 0.0, 0.0, 0.5, 0.0, 0.1, 0.0, 0.1)
CALL GRID(-1.0, -1.0, 1.0, 10.0, 0.1, 0.0, 0.1)
C
DELTA = WC(NDATA)/WC(1)/100.
X(1) = WC(1)
30 CONTINUE

C

CALL DASHLN(X, Y, 10, 1)
CALL SYMBOL(1, 0.5, 0.5, 0.1, 0, 0.25, 0.0, 0.3, 'COLOR', 0.0, 0.3)
CALL SYMBOL(10.5, 8.5, 0.1, 0.0, 0.16, 0.0, 0.3, 'DEG', 0.0, 0.0, 0.3)
FPN = NDEG
CALL NUMBER(13.5, 8.5, 0.0, 0.1, 0.0, 0.3)
CALL SYMBOL(4.5, 0.5, 0.0, 0.1, 0.0, 0.3, 'OPTIMUM MOISTURE CONTENT (%) =', 0.0, 0.3)
CALL NUMBER(16.7, 8.5, 0.0, 0.1, 0.0, 0.3, 'DPTMJUM DRY DENSITY = PFC*0.0, 0.31')
CALL GRID(10.0, 0.0, 0.0, 0.5, 0.0, 0.1, 0.0, 0.1)
CALL GRID(-1.0, -1.0, 1.0, 10.0, 0.1, 0.0, 0.1)
C 40 CONTINUE

C X(102)=WC(NDATA+1)
X(103)=WC(NDATA+2)
Y(1102)=ORYO(NDATA+1)
Y(1103)=ORYO(NDATA+2)
CALL LINE (X,Y,101,1,0,0)

C DMAX=1.05*DRYMAX
DMIN=DRYDI11
WMAX=WCI
WMIN=WCI
NPTS=20+101+NDATA
CALL SCALER(WMAX,WMIN,DMAX,DMIN)
CALL SQUARE
CALL BOX
CALL PLOTEM(***,XWORK,YWORK,NPTS)
CALL GRAPH(*MOISTURE CONTENT, W%,20,*DRY DENSITY, PCF*,16)
RETURN
END

SUBROUTINE FLSQFY(N,M,X,Y,W,ETA,S,SGMSQ,ALPHA,PR,PO,MN1)
DIMENSION C(NL),ALPHA(MN1),BETA(MN1),S(MN1),SGMSQ(MN1),PR(MN1),PO(MN1)
S(N1),W(N),X(M),Y(M)
GAMDA=1.
NO=0.
CALL FGEFY(T(N,NO,X,Y,W,ETA,S,SGMSQ,ALPHA,PR,PO,M,N1))
CALL FCODEA(N,C,PO,PR,ALPHA,BETA,GAMDA,S,N+1)
RETURN
END

SUBROUTINE FCODEA(N,C,PO,PR,ALPHA,BETA,GAMDA,S,N)
DIMENSION C(N),ALPHA(N),BETA(N),PM(N),PR(N),S(N)
N=N+1
DO 10 IB=1,N1
C(IB)=0.
PM(IB)=0.
10 PR(IB)=0.
PR(1)=1.
C(1)=S(1)
DO 20 I=1,N
T2=0.

G LEVEL 20.1  MAIN  DATE = 78229  09/00/55

NUMAL1B
UNIVERSITY OF KENTUCKY
COMPUTER CENTER
MCVEY HALL
LEXINGTON,KENTUCKY
BASIC REFERENCE: FORSYTHE, G.E. 1957 "GENERATION AND USE OF
ORTHOGONAL POLYNOMIALS FOR DATA FITTING ON A
DIGITAL COMPUTER." J. SOC. INDUST. APPL.
MATH VOL. 5, PP 74-88.

G LEVEL 20.1  FCODEA  DATE = 78229  09/00/55

47
N1=I+1
DO 20 IB=1,N1
T1=(T2-ALPHA(I)*PRI(IB)-BETA(I)*PM(IB))/GAMDA
T2=PRI(IB)
PM(IB)=PRI(IB)
PRI(IB)=T1
20 C(IB)=C(IB)+T1*S(I+1)
RETURN
END

G LEVEL 20.1  FGEFYT  DATE = 78229  09/00/55

SUBROUTINE FGEFYT(N0,X,Y,WS,BETA,S,SMGSQ,ALPHA,PR,PQ,M,N1)
DIMENSION X(M),Y(M),BETA(N1),ALPHA(N1),S(N1),SMGSQ(N1),PR(M),
$PO(M),PM(M)
1000 FORMAT(32H THERE IS AN ERROR IN YOUR DATA)
  IF IN =NO =M 10,30,20
10 IF(N-NC-M+1)=50,40,40
20 PRINT 1000
  GOTO 210
30 BETA(NO+1)=0.
  DSQ=0.
  WPP=0.
  LXACT=0.
  IF(N-NC-M+1)=50,40,40
40 LXACT=1
50 DO 80 J=1,M
  PRI(J)=1.
  PO(J)=0.
60 WPP=WPP+W(J)
  IF(LXACT)=80,70,80
70 DSQ=DSQ+W(J)*Y(J)*Y(J)
80 CONTINUE
  NON=NO+1
  NN=NN+1
  DO 200 I=NON,NN
  LREEDO=M-I+NO
  WYP=0.
  WXPP=0.
  DO 120 J=1,M
  TEMP=I*X(J)-ALPHA(J)*PRI(J)-BETA(J)*PO(J)
  WPP=WPP+TEMP**2
  PO(J)=PRI(J)
  PRI(J)=TEMP
  BETA(J)=BETA(J)**2
120 CONTINUE
  IF(LREEDO)=140,130,130
130 S(I)=WYP/WPP
140 IF(LXACT)=110,150,160
150 DSQ=DSQ-S(I)*S(I)*WPP
  BR=LREEDO
  SMGSQ(I)=DSQ/BR
  GOTO 170
160 SMGSQ(I)=0.
170 IF(I-NN)=180,200,200
180 ALPHA(I)=WPP/WPP
  WPOP=WPP
  WPP=0.
  DO 190 J=1,M
  TEMP=(I*X(J)-ALPHA(J))*PRI(J)-BETA(J)*PO(J)
  WPP=WPP+W(J)*TEMP**2
  PO(J)=PRI(J)
190 PRI(J)=TEMP
  BETA(J)=BETA(J)**2
200 CONTINUE
210 RETURN
END