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Interactive Softwares for Costing of Concrete Based on its Elasticity Modulus

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Abstract- Softwares have been developed for estimating the modulus of elasticity, E, of concrete. These softwares can predict several possible combinations of mix proportions of concrete components that can yield concrete of desired elasticity modulus, E. The determination of optimum cost of concrete based on a specified modulus of elasticity, entails several time wasting manual calculations of the total cost of all the mix proportions predicted for the specified modulus of elasticity by the software. Here, the focus is on developing interactive softwares for cost analysis of normal concrete based on its elastic modulus. The interactive softwares were developed using Scheffe's and Osadebe's statistical theories. The softwares developed, can predict all possible combinations of mix proportions as well as the total cost of concrete of desired modulus of elasticity. Conversely, it can predict the modulus of elasticity, E, obtainable from concrete of a given mix proportion and cost. In addition it can predict the cheapest mix proportion that can yield a desired modulus of elasticity of concrete. The costs obtained from the softwares based on Scheffe's and Osadebe's theories, compare favourable with market costs, as well as with each other.

Index Terms- softwares, cost of analysis, concrete, elastic modulus, Scheffe's theory. Osadebe's theory.

I. INTRODUCTION

A knowledge of the modulus of elasticity, E, of concrete, is necessary in the analysis and design of concrete members. More than anything else, the proportions of the constituent elements of concrete mix determines its modulus of elasticity (Myers, 1999). Thus, the cost of concrete based on its elastic modulus, depends on the cost of individual components. Presently the predictions of concrete cost based on its elastic modulus are carried out using conventional methods of concrete mix design. These methods require trial mixes (Simon, 2003 and Osadebe's theory, Usually, concrete is optimized to meet any desired performance criteria at minimum cost. Effectively and efficiently optimized concrete mixes usually have better properties, satisfy intended use and minimizes cost.

In this work, softwares based on Scheffe's (2003), are developed for easy, instantaneous, accurate and economical prediction of optimum concrete cost whole at same time satisfying the performance criterion of elastic modulus.

II. THEORITICAL BACKGROUND

The softwares are based on models derived from Scheffe's and Osadebe's theories of optimization.

2.1 Scheffe's theory

Scheffe's theory (1958) and some experimental data were used to derive one of the models on which the software is based. In his own work, Scheffe's considered experiments with mixtures in which the desired property of a product depends on the proportions of the constituents present as the atoms of a mixture. According to the theory, the sum of the proportions of the constituents, X_i, must be equal to one, i.e.

$$\sum X_i = 1 \qquad \text{.......................... (1)}$$

and the proportion of each constituent must be equal or greater than zero, i.e.

$$X_i \geq 0 \qquad \text{.......................... (2)}$$

Normal concrete has four components and so it is analyzed using a three-dimensional factor space (i.e a tetrahedron) Scheffe represented the property (response) of the mixture with the following polynomial expression.

$$Y = b_0 + \sum_{i=1} b_i x_i + \sum b_{ij} x_i x_j \qquad \text{........ (3)}$$

The application of Scheffe's expression to normal concrete (a four – component mixture represented by a 3-dimensional space), yielded the following equation

$$Y_i = b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_{12}X_1X_2 + b_{13}X_1X_3 + b_{14}X_1X_4 + b_{23}X_2X_3 + b_{24}X_2X_4 + b_{34}X_3X_4 \qquad \text{........(4)}$$

And the final Scheffe's model derived for the costing of a four- component concrete mix based on its elastic modulus, is as follows (Egbulonu, 2011):

$$Y = 41.31X_1 + 50.04X_2 + 25.21X_3 + 19.24X_4 - 95.58X_1X_2 - 28.64X_1X_3 + 22.10X_1X_4 - 55.76X_2X_3 - 25.96X_2X_4 + 14.26X_3X_4 \qquad \text{........ (5)}$$

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In order to satisfy the condition given by Eqn(1), actual concrete mixes such as 1:2:4 and 1:3:6 must be transformed using Eqn(6).

$$[Z] = [A][X] \qquad \text{………..……..…(6)}$$

where,……..

[Z] = matrix of actual component proportion..
[A] = matrix of arbitrary mix proportions.
[X] = matrix of pseudo component proportions

2.2 OSADEBE'S THEORY

Osadebe's theory is the second theory used in deriving the second model on which the second software is based. On his own, Osadebe(2003) represented the response (property of interest(with a continuous function, F(z), which is differentiated with respect to its predictors, Z_i. Taylor series was used to develop the model (mathematical equation). The response function, Y(z), which depends on the proportion of the constituents of the mixture components and not on the quantities, is continuous and differentiable with respect to its predictors, Z_i.

$$F_{(z)} = \sum F^{m}(Z^{(0)})* \ (Z_i - Z^{(0)})/m!$$

…………..……………………………….……………... (7)

where

Z_i is the ratio of the actual proportions of components to the total quantity of concrete, S.

m is the degree of the response function

$$0 \le m \le \infty$$

Using Taylors series, the response function, $F_{(z)}$ was expanded up to the second order in the neighbourhood of a chosen point $Z^{(0)} = Z_1^{(0)}, Z_2^{(0)}, Z_3^{(0)}$ and $Z_4^{(0)}$ to obtain Eqn(8)

$$F(z) = F_0(Z^{(0)})*(Z_1 - Z^{(0)})/0! + \sum F'(Z_i - Z^{(0)})'/1! + \sum F'(Z^{(0)})*(Z_i - Z^{(0)})^2/2! + \sum F''(Z^{(0)})*(Z_i - Z^{(0)})*(Z_1 - Z^{(0)})^2/2!$$

……………………….…………. (8)

where

$$1 \le i \le 4$$

The function, $F(z)$ was used in deriving the following model for the determination of the modulus of elasticity, E, of concrete which is a four- component mixture.

where

$$\mathbf{Y} = 5351667.6400\,\mathbf{Z_1} + 888151.9143\,\mathbf{Z_2} + 1835.219102\mathbf{Z_3} + 2392.479301\mathbf{Z_4} - 10609392.05\mathbf{Z_1Z_2} - 5791804.077\,\mathbf{Z_1Z_3} - 5620199.635\mathbf{Z_1Z_4} - 699734.4294\,\mathbf{Z_2Z_3} - 786415.528\,\mathbf{Z_2Z_4} + 12085.08274\,\mathbf{Z_3Z_4} \quad \text{……………………………..… } \mathbf{(9)}$$

Its derivation is contained elsewhere (Egbulonu, 2011).

2.3 Cost Analysis

The functional portion, Z_i, determined from the model for elastic modulus i.e. Eqn(9), are used in estimating the total costs of concrete mixes.

For 1m³ concrete, the following condition must be satisfied

$$Z_1 + Z_2 + Z_3 + Z_4 = 1 \quad \text{……………………………………………………………………….…..…(10)}$$

In a compact form, Eqn(10) becomes

$$\sum_{i=1}^{4} Z_i = 1 \quad \text{………………………………………………………………………………….... (11)}$$

But, 1m³ of concrete weighs 2400kg.

Therefore,

$$\sum_{i=1}^{4} Z_i = 2400\text{Kg} \quad \text{………………………………………………………………….… (12)}$$

And so, the quantity of constituents are calculated as follows:

$$\text{Quantity of water} = \frac{Z_1}{\sum Z_i} * 2400 \quad \text{…………………………………………………..….(13)}$$

Quantity of cement = $\frac{Z_2}{\sum Z_i} * 2400$ * …………………………………………………….....…'.(14)

Quantity of sand = $\frac{Z_3}{\sum Z_i} * 2400$ * …………………………………………………………...(15)

Quantity of crushed rock = $\frac{Z_4}{\sum Z_i} * 2400$ * ……………………………………………………..…(16)

where Z_1, Z_2, Z_3 and Z_4 are the proportions of water, cement, sand and crushed rock respectively. Assuming w, c, k, and p are the unit costs (i.e.cost per Kilogram), then the cost of each concrete constituent is as follows:

Cost of water = $\frac{Z_1}{\sum Z_i} * 2400 * w$ …………………………………………..………..…(17)

Cost of cement = $\frac{Z_2}{\sum Z_2} * 2400 * c$ ………………………………………………………...(18)

Cost of sand = $\frac{Z_3}{\sum Z_3} * 2400 * c$ …………………………………………….................(19)

Cost of crushed rock = $\frac{Z_1}{\sum Z_i} * 2400 * p$ ……………………………………………..…(20)

In oder to obtain the cost of each concrete mix, the costs of all concrete components are summed.
The total cost of concrete = (Cost of water + Cost of cement + Cost of sand + Cost of crushed rock)

$$= \frac{2400}{\sum_{i=1}^{4} Z}(Z_1 + Z_2 + Z_3 + Z_4) \qquad \text{…………………………………………… (21)}$$

III. COMPUTER SOFTWARES

Two softwares are developed, one from each of the Scheffe's and Osadebe's models for elastic modulus and cost function. The first software (given in Appendix A) was developed from Scheffe's model (i.e Eqn(5)) and the cost function (i.e Eqn(21)) while the second software was based on Osadebe's model (i.e Eqn(9)) and the cost function (i.e Eqn(21)). Each software has two parts, the first part which can predict the modulus of elasticity, E, when the mix properties are specified, and the second part which can predict the mix proportions, given the modulus of elasticity of concrete.

The softwares are writhen in **Q-Basic** language. The mix proportions obtained from the software based on Scheffe's and Osadebe's models based on specified modulus of elasticity, E, of $30Nmm^2$, are given in Tables 1 and 2.

IV. RESULTS AND ANALYSIS

4.1 Sscheffe- based estimate for modulus of elasticity

The computer results for optimization and estimation of cost using Scheffe's theory when modulus of elasticity of $30N/mm^2$ is fed into the computer, are presented in Table 1

Table 1:Output of Scheffe-based cost and mix ratios corresponding to an input of elastic modulus of 30N/mm^2

S/N	Cost (N)	X_1	X_2	X_3	X_4	Y	Z_1	Z_2	Z_3	Z_4
1	19819.18	0.80	0.06	0.04	0.28	30.00	0.58	1.00	2.20	3.48
2	19488.64	0.30	0.01	0.15	0.54	30.00	0.60	1.00	2.24	3.78
3	19846.22	0.32	0.00	0.26	0.42	30.00	0.59	1.00	2.10	3.62
4	20150.31	0.37	0.03	0.21	0.39	30.00	0.58	1.00	2.02	3.44
5	20710.05	0.44	0.05	0.21	0.31	30.00	0.57	1.00	1.87	3.16
6	21042.8	0.50	0.14	0.03	0.33	30.00	0.56	1.00	1.83	2.94
7	21802.87	0.57	0.10	0.12	0.21	30.00	0.55	1.00	1.64	2.69
8	22728.99	0.64	0.03	0.26	0.07	30.00	0.54	1.00	1.43	2.44
9	22699.82	0.66	0.14	0.05	0.15	30.00	0.53	1.00	1.49	2.36

$Cost_{min}$= 19488.64 COUNT= 2… Z1:Z2:Z3:Z4= 0.60: 1.00: 2.24:32.78

where Z_1, Z_2, Z_3 and Z_4 are the real proportions of water, cement, sand and crushed rock respectively.

And X_1, X_2, X_3 and X_4 are the pseudo proportions of water, cement, sand and crushed rock respectively.

From the Table 1, the real mix ratio, 0.54:1.00:1.43:2.44 yielded a concrete with a maximum cost of ₦22,728.99 while the real mix ratio, 0.60:1.00:2.24:3.78 gave a concrete with minimum cost of ₦19,488.64. Thus, the use of real mix ratio of 0.60:1.00:2.24:3.78, will result into a saving cost of ₦3,240.35 (16.62%) over the use of the mix ratio, 0.54:1.00:1.43:2.44.

4.2 Osadebe- based Cost Estimates for modulus of elasticity.

The computer results for optimization and cost estimates using Osadebe's theory when a modulus of elasticity of 30N/sq m is fed into the computer are presented thus.

Table 2: Output of Osadebe-based cost estimates and mix ratios corresponding to input of elastic modulus of 30N/Sq.mm

S/N	Cost (N)	Z_1	Z_2	Z_3	Z_4	Y	S_1	S_2	S_3	S_4
1	18665.29	0.10	0.12	0.21	0.53	30.00	0.63	1.00	2.47	4.53
2	22421.78	0.10	0.18	0.31	0.41	30.00	0.53	1.00	1.67	2.24
3	23722.58	0.10	0.20	0.28	0.42	30.00	0.51	1.00	1.36	2.05

where S_1, S_2, S_3 and S_4 are real proportions of water, cement, sand and crushed rock respectively.

and Z_1, Z_2, Z_3 and Z_4 are the fractional proportions of water, cement, sand and crushed rock respectively.

From the Table 2, the real mix ratio, 0.51:1.0:1.36:2.05 gave a concrete with a maximum cost of ₦23,772.58 while the real mix ratio 0.63:1.0:2.47:4.53 gave a concrete which has the least cost of ₦18,665.29. Thus, the use of real mix ratio, will result into a saving of ₦5,057.29 (i.e 27.09%) over the use of the mix ratio, 0.51: 1.0:1.36:2.05.

Comparison of Cost estimates

A comparison of cost estimates given in Tables 1 and 2 shows that for the elastic modulus of 30N/mm^2**,** the maximum percentage difference between the least cost predicted by the software based on Scheffe's model and least cost predicted by the software based on Osadebe model, is 4.44% percent. Since the percentage difference is insignificant, any of the two softwares can be used in obtaining accurately the cost estimates of concrete based on its elastic modulus.

V. Conclusion

These softwares developed can predict several mix ratios that can yield concrete of desired elastic modulus, as well as the total cost of each concrete mix ratio. And the use of the softwares in the design and costing of concrete based on its elastic modulus, is simple and inexpensive, All that is required is the inputation of the desired elastic modulus and the unit prices of water , cement, sand and coarse aggregate.

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APPENDIX A : MODULUS COST ESTIMATES BY SCHEFFE'S

```
CLS
 REM ****APPENDIX E****13/12/09
 REM COST ANALYSIS AND MODULUS OF ELASTICITY:31/08/08
 REM THIS WAS WRITTEN BY BEN EGBULONU
 REM CIVIL ENGINEERING DEPARTMENT, FUTO
 REM THIS IS FOR ANALYSIS OF COST OF MATRIALS AND ALL POSSIBLE MIXES WHEN
 REM MODULUS OF ELASTICITY IS GIVEN AND MINIMUM COST/MIX and ALL COSTS RQD**
 REM A Q-BASIC PROGRAMM THAT OPTIMISES CONCRETE MIX PROPORTIONS
 REM VARIABLES USED ARE
 REM X1,X2,X3,X4,Z1,Z2,Z3,Z4,Ymax,Yout,Yin
 REM COST OF MATRIALS PER kg***C(cement)=32;K(sand)=3.2;P(agg)=6,w(water=1.2)
     PRINT "ENTER C=;K=;P=;w="; C; K; P; w;
     INPUT C, K, P, w
     REM TO DEFINE WHAT IS GIVEN AND WHAT REQUIRED TO DETERMINE.
     REM WHEN MIX IS GIVEN G=1 0R G=2 IF E IS GIVEN
     PRINT "DEFINE WHAT IS GIVEN AS G="; G;
     INPUT G
     IF G = 1 THEN  ELSE GOTO 5
     REM MIX GIVEN AS Z1,Z2,Z3,Z4.
     PRINT "ENTER VALUE OF W/C=Z1"; Z1
     INPUT Z1
     PRINT "ENTER VALUE OF CEMENT=Z1"; Z2
     INPUT Z2
     PRINT "ENTER VALUE OF SAND=Z3"; Z3
     INPUT Z3
     PRINT "ENTER VALUE OF CRUSH ROCK =Z4"; Z4
     INPUT Z4
     LET X1 = 40 * Z1 - 16 * Z2 + 0 * Z3 - 2 * Z4
     LET X2 = -60 * Z1 + 26 * Z2 + 1 * Z3 + 2 * Z4
     LET X3 = -20 * Z1 + 9 * Z2 - 2 * Z3 + 2 * Z4
     LET X4 = 40 * Z1 = -18 * Z2 + 1 * Z3 - 2 * Z4
     LET MOE = 41.31 * X1 + 50.04 * X2 + 25.21 * X3 + 19.24 * X4 - 95.58 *
     X1 * X2 - 28.64 * X1 * X3 + 22.1 * X1 * X4 - 55.76 * X2 * X3 - 25.96
     * X2 * X4 + 14.26 * X3 * X4
     REM PRINT VALUE MOR
     PRINT "VALUE OF MOE="; MOE; "X1"; X1, "X2"; X2; "X3"; X3; "X4"; X4;
  GOTO 7
5 LET COUNT = 0
 CLS
 GOSUB 10
 PRINT "Tmin=";Tmin;"COUNT=";COUNT;"Z1:Z2:Z3:Z4"; USING "###.##"; Z1;Z2;Z3;Z4
7 END
 REM END OF MAIN PROGRAMM
10 REM PROCEDURE BEGINS
 LET Ymax = 0
 LET Tmin = 100000
 PRINT
 PRINT
 REM A COMPUTER MODEL FOR COMPUTING CONCRETE MIX PROPORTIONS
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```
 PRINT "CORRESPONDING TO A REQUIRED MOE"
 PRINT
 INPUT "ENTER DESIRED MOE"; Yin
 GOSUB 70
 FOR X1 = O TO 1 STEP .01
 FOR X2 = O TO 1 - X1 STEP .01
 FOR X3 = O TO 1 - X1 - X2 STEP .01
 LET X4 = 1 - X1 - X2 - X3
 LET Yout = 41.31 * X1 + 50.04 * X2 + 25.21 * X3 + 19.24 * X4 - 95.58 * X1
 * X2 - 28.64 * X1 * X3 + 22.1 * X1 * X4 - 55.76 * X2 * X3 - 25.96 * X2 *
  X4 + 14.26 * X3 * X4
 GOSUB 80
 IF (ABS(Yin - Yout) <= .001) THEN 20 ELSE 30
20 LET COUNT = COUNT + 1
 GOSUB 90
30 NEXT X3
 NEXT X2
 NEXT X1
 PRINT
 IF (COUNT > 0) THEN GOTO 40 ELSE GOTO 50
40 PRINT "THE MAXIMUM MOR PREDICTABLE"
 PRINT "BY THIS MODEL IS"; Ymax; "N/sq.mm"
 SLEEP (2)
 GOTO 60
50 PRINT "SORRY! DESIRED MOE OUT OF RANGE OF MODEL"
 SLEEP 2
60 RETURN
70 REM PROCEDURE PRINT HEADING
 REM
 PRINT "COUNT X1 X2 X3 X4 Y Z1 Z2 Z3 Z4"
 REM
 RETURN
80 REM PROCEDURE CHECK MAX
 IF Ymax < Yout THEN Ymax = Yout ELSE Ymax = Ymax
 RETURN
90 REM PROCEDURE OUT RESULTS
 LET Z1 = .5 * X1 + .55 * X2 + .6 * X3 + .65 * X4
 LET Z2 = X1 + X2 + X3 + X4
 LET Z3 = 1 * X1 + 2 * X2 + 2 * X3 + 3 * X4
 LET Z4 = 1.5 * X1 + 3 * X2 + 4 * X3 + 5 * X4
    LET ZSUM = Z1 + Z2 + Z3 + Z4
      LET Tcost = (2600 / ZSUM) * (W * Z1 +C * Z2 + K * Z3 + P * Z4)
   IF Tmin > Tcost THEN Tmin = Tcost ELSE Tmin = Tmin
 PRINT TAB(1); COUNT; Tcost; USING "###.##"; X1; X2; X3; X4; Yout; Z1; Z2;
 Z3; Z4
 RETURN
```

APPENDIX B: MODULUS COST ESTIMATES BY OSADEBE'S

```
CLS
 REM FOR APPENDIX G** 13/12/09
 REM ** MAXIMUM** RUN TIME =60sec TO 5mins ***
 REM A Q-BASIC PROGRAMM THAT OPTIMISES CONCRETE MIX PROPORTIONS
 REM THIS WAS WRITTEN BY BEN EGBULONU
 REM CIVIL ENGINEERING DEPARTMENT, FUTO
 REM VARIABLES USED ARE : Z1,Z2,Z3,Z4,S1,S2,S3,S4,Ssum,Ymax,Yout,Yin
 REM MODEL USED ELASTIC MODULUS
 REM PROGRAM PRINTING SPLIT IN 1ST-17, THEN 20s TO ENTER PRINTING WINDOW.
 REM MAIN PROGRAMM BEGINS
```

```
 REM COST OF MATRIALS PER kg**C(cement)=32;K(sand)=3.2;P(agg)=6,w(water=1.2)
    PRINT "ENTER C=;K=;P=;w="; C; K; P; w;
    INPUT C, K, P, w
    REM WHEN MIX IS GIVEN G=1 0R G=2 IF E IS GIVEN
    PRINT "DEFINE WHAT IS GIVEN AS G="; G;
    INPUT G
    IF G = 1 THEN  ELSE GOTO 5
    REM MIX GIVEN AS ACTUAL MIX RATIOS, S1.S2.S3.S4.
    PRINT "ENTER VALUE OF W/C=S1"; S1
    INPUT S1
    PRINT "ENTER VALUE OF CEMENT=S2"; S2
    INPUT S2
    PRINT "ENTER VALUE OF SAND=S3"; S3
    INPUT S3
    PRINT "ENTER VALUE OF AGG=S4"; S4
    INPUT S4
    LET Ssum = S1 + S2 + S3 + S4
    REM CALCULATING FRACTIONAL PARTS
    LET Z1 = S1 / Ssum: Z2 = S2 / Ssum: Z3 = S3 / Ssum: Z4 = S4 / Ssum
  REM   ****** CEFFICIENTS OS REGRESSION *******
    A1 = 5351667.64#: A2 = 888151.9142999999#: A3 = 1835.219102#
    A4 = 2392.479301#: A5 = -10609392.05#: A6 = -5791804.077#
    A7 = -5620199.635#: A8 = -699734.4294#: A9 = -786415.528#
    A10 = 12085.08274#
  REM CALCULATING ACTUAL MODULUS OF ELASTICITY
    LET MOE = A1 * Z1 + A2 * Z2 + A3 * Z3 + A4 * Z4 + A5 * Z1 * Z2 + A6 *
    Z1 * Z3 + A7 * Z1 * Z4 + A8 * Z2 * Z3 + A9 * Z2 * Z4 + A10 * Z3 * Z4
    REM PRINT VALUE OF MOE
    PRINT "VALUE OF MOE="; MOE; "S1"; S1; "S2"; S2; "S3"; S3; "S4"; S4;
    "Z1"; Z1; "Z2"; Z2; "Z3"; Z3; "Z4"; Z4
    GOTO 7
5 LET COUNT = 0
 CLS
 GOSUB 10
7 END
 REM END OF MAIN PROGRAMM
10 REM PROCEDURE BEGINS
 LET Ymax = 0
 PRINT
 PRINT
 REM A COMPUTER MODEL FOR COMPUTING CONCRETE MIX PROPORTIONS
 PRINT "CORRESPONDING TO A REQUIRED MODULUS OF ELASTICITY"
PRINT
 INPUT "ENTER DESIRED MODULUS OF ELASTICITY"; Yin
 GOSUB 70
 FOR Z1 = O.035 TO .25 STEP .001
 FOR Z2 = .07 TO .28 STEP .001
 FOR Z3 = .22 TO .35 STEP .001
 LET Z4 = 1 - Z1 - Z2 - Z3
REM        ****** CEFFICIENTS OS REGRESSION *******
    A1 = 5351667.64#: A2 = 888151.9142999999#: A3 = 1835.219102#
    A4 = 2392.479301#: A5 = -10609392.05#: A6 = -5791804.077#
    A7 = -5620199.635#: A8 = -699734.4294#: A9 = -786415.528#
    A10 = 12085.08274#
LET Yout = A1 * Z1 + A2 * Z2 + A3 * Z3 + A4 * Z4 + A5 * Z1 * Z2 + A6 * Z1 * Z3 + A7 * Z1 * Z4 + A8 * Z2 * Z3 + A9 * Z2 *
Z4 + A10 * Z3 * Z4
 IF ABS(Yin - Yout) <= .001 THEN 20 ELSE GOTO 30
20 LET COUNT = COUNT + 1
 GOSUB 90
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```
30 NEXT Z3
 NEXT Z2
 NEXT Z1
 PRINT
 IF (COUNT > 0) THEN GOTO 60 ELSE GOTO 50
50 PRINT "SORRY! DESIRED MOE OUT OF RANGE OF MODEL"
  SLEEP 1
60 RETURN
70 REM PROCEDURE PRINT HEADING
 REM
 PRINT "COUNT Z1 Z2 Z3 Z4 Y S1 S2 S3 S4"
 REM
 RETURN
90 REM PROCEDURE OUT RESULTS
 LET S1 = Z1 / Z2: S2 = Z2 / Z2: S3 = Z3 / Z2: S4 = Z4 / Z2
LET SSUM = S1 + S2 + S3 + S4
     LET Tcost = (2600 / SSUM) * (W *S1 + C * S2 + K * S3 + P * S4)
 PRINT TAB(1); COUNT; Tcost; USING "###.##"; Z1; Z2; Z3; Z4; Yout; S1; S2;
 S3; S4
 RETURN
 REM ************** 1ST PRINTING 0-18,NEXT 17-37,ETC.**********
 PRINT TAB(1); COUNT; USING "###.##"; Z1; Z2; Z3; Z4; Yout; S1; S2; S3; S4
100 RETURN
```