ALGORITHM FOR CONCRETE MIX DESIGN BASED ON BRITISH METHOD

Ezeh, J. C. and Ibearugbulem, Owus M.
Civil Enginerring Department
Federal Universityof Technology, Owerri, Nig.

ABSTRACT

Most of the methods of concrete mix design developed over the years were geared towards manual approach. Apart from being characterized by rigorous complication in computation, manual concrete mix design is prone to errors and mistakes inherent in the calculation during interpolations and reading of charts. Useful time is also wasted in the processes involved in the manual method. This paper presents the result of a study aimed at solving the above problems through the development of a mathematical algorithm based on the British Method of concrete mix design. The tables used in this algorithm are the same as those used in the British Method, however, Charts or figures in the British method were converted into polynomial equations. QBASIC program was written to ease the use of the algorithm, and was also used in solving two examples. The results obtained from the algorithm were compared with those obtained based on the British method and the differences between them were found to be less than 10% in each example. Hence, the algorithm developed in this paper is working with minimum error. It is recommended for use in obtaining good results for normal weight concrete mix design.

Key words: Concrete mix design; British method; Manual Approach; Algorithm.

INTRODUCTION

Numerous methods of concrete mix design have been developed over the years. Most of these methods are based on manual concrete mix design. The manual method of concrete mix design is associated with problems that include: rigorous complications in computation and reading of charts; need for skilled and experienced designers; wastage of useful time in the processes; prone to errors and mistakes , especially during interpolations and reading of charts. These problems have become a major constraint, and interest is being generated on the need for an alternative approach to concrete mix design.

High – performance concrete (HPC) has been referred to as "engineered concrete", implying that an HPC mixture is not specified in a generic recipe, but rather designed to meet project – specific needs (Simon [1]). The readily availability of digital computers has revolutionized the entire system of concrete mix design especially for HPC. The objective of this paper is to contribute to the availability of engineered concrete mixes. According to Shetty [2], concrete mix design is defined as the process of selecting suitable ingredients of concrete and determining the relative quantities with the objective of producing an economical HPC. This definition of mix design emphasizes two main requirements thus: that the concrete should have certain minimum specified properties; and it has to be as economical as possible (Neville [3]). Also, Jackson[4] in his own definition noted that concrete mix design is a procedure that ensures that for any given set of conditions, the proportion of the constituent materials are chosen so as to produce an HPC at a minimum cost .

With the above definitions in focus, the authors of this paper developed an algorithm based on the British Method of concrete mix design. To achieve our objective, the charts in the British Method were converted into polynomial equations and the tables in that method were also adopted .The algorithm was tested with examples and the results obtained were compared with those obtained by Teychenne et. al. [5] and the comparison showed that the differences between them were all less the 10%. Considering the present readily availability of PCs, we strongly recommend this algorithm for use in concrete mix design.

ALGORITHM AND TRANSFORMATION OF FIGURES INTO EQUATIONS:

The procedure involved in this method is described as follows:

STEP 1: The figure for relationship between the standard deviation and characteristic strength was used to calculate target mean strength.

$$F_m = F_c + K * S. \qquad ...(1)$$

F_m, F_c and S are target mean strength, characteristic strength and standard deviation. *K* is the probability factor for 5% defection. According to Teychenne et al [5], *K* is taken as 1.645 and the standard deviation can be predicted using table 1.

STEP 2: Free water/cement ratio was calculated using table 2 and the figure for "relationship between compressive strength and water-cement ratio." (Teychenne et al [5]).

We transformed the figure for "relationship between compressive strength and free water-cement ratio ($F_{w/c}$) into two parabolic equations for uncrushed and crushed stones as follows:

$$F_{w/c} = 0.000295\, F_m^2 - 0.0312\, F_m + 1.291 \qquad ...(2)$$

$$F_{w/c} = 0.00008519157\, F_m^2 - 0.01571\, F_m + 1.0097 \qquad ...(3)$$

$$F_{w/c} = 0.000295\, F_m^2 - 0.0312\, F_m + 1.351 \qquad ...(4)$$

$$F_{w/c} = 0.00008519157\, F_m^2 - 0.01571\, F_m + 1.0697 \qquad ...(5)$$

Equations (2) and (3) are for uncrushed stone with compressive strength of (10 – 42)Mpa and (42 – 80)Mpa respectively. Equations (4) and (5) are for crushed stone with compressive strength of (10 – 42)Mpa and (42 – 80)Mpa respectively.

STEP 3: Free water content (Fwc) for the required workability was determined from table 3 (Teychenne et al [5]).

STEP 4: The cement content was calculated by substituting the values obtained in steps 2 and 3 into equation (6).

$$C = Fwc / F_{w/c} \qquad ...(6)$$

STEP 5: Here the figure for "wet density of fully compacted concrete (Wdcc)" was used to calculate the wet density of the fully compacted concrete. The figure was transformed into six linear equations as:

$$Wdcc = -1.71875\, Fwc + 2896.875 \qquad ...(7)$$

$$Wdcc = -1.59375\, Fwc + 2804.375 \qquad ...(8)$$

$$Wdcc = -1.4375\, Fwc + 2703.75 \qquad ...(9)$$

$$Wdcc = -1.25\, Fwc + 2605 \qquad ...(10)$$

Wdcc = -1.03125 Fwc + 2493.125 ...(11)

Wdcc = -0.925 Fwc + 2402 ...(12)

Equations (7), (8), (9), (10), (11) and (12) were equations obtained for saturated surface dry densities (SSDD) of 2.9, 2.8, 2.7, 2.6, 2.5 and 2.4 respectively.

STEP 6: The aggregate content (Ac) was calculated by substituting the values obtained in steps 3, 4 and 5 into equation (13).

Ac = Wdcc – C – Fwc ...(13)

STEP 7: The figure for "proportion of fine aggregate for BS 882 grading zones 1, 2, 3 and 4. (Teychenne et al [5]) was used to determine the proportion of fine aggregate (Pfa) required. This figure was transformed into 60 linear equations. The 60 linear equations consist of 20 equations each for the three maximum sizes of aggregates: 10mm, 20mm and 40mm respectively.

Maximum aggregate size of 10mm:

i). Slump of 0 – 10mm

For 100% passing

$Pfa = 12.5\ F_{w/c} + 20$ ...(14)

For 80% passing

$Pfa = 15\ F_{w/c} + 23$ ...(15)

For 60% passing

$Pfa = 17.5\ F_{w/c} + 28$ ...(16)

For 40% passing

$Pfa = 22.5\ F_{w/c} + 35$ ...(17)

For 15% passing

$Pfa = 22.5\ F_{w/c} + 47$ ...(18)

ii). Slump of 10 – 30mm

For 100% passing

$Pfa = 15\ F_{w/c} + 20$ ...(19)

For 80% passing

$Pfa = 12.5\ F_{w/c} + 27$ ...(20)

For 60% passing

$Pfa = 15\ F_{w/c} + 31$ ...(21)

For 40% passing

$Pfa = 22.5\ F_{w/c} + 37$ ...(22)

For 15% passing

$Pfa = 27.5\ F_{w/c} + 45$ ...(23)

iii). Slump of 30 – 60mm

For 100% passing

$Pfa = 12.5\ F_{w/c} + 22$ ...(24)

For 80% passing

$Pfa = 15\ F_{w/c} + 27$ ...(25)

For 60% passing

$Pfa = 15\ F_{w/c} + 34$ ...(26)

For 40% passing

$Pfa = 20\ F_{w/c} + 41$ ...(27)

For 15% passing

$Pfa = 30\ F_{w/c} + 48$ ...(28)

iv). Slump of 60 – 180mm

For 100% passing

$Pfa = 12.5\ F_{w/c} + 27$ ...(29)

For 80% passing

$Pfa = 15\ F_{w/c} + 31$ ...(30)

For 60% passing

$Pfa = 17.5\ F_{w/c} + 37$ ...(31)

For 40% passing

$Pfa = 25\ F_{w/c} + 45$ ...(32)

For 15% passing

$Pfa = 27.5\ F_{w/c} + 56$ ...(33)

Maximum aggregate size of 20mm:

i). Slump of 0 – 10mm

For 100% passing

$Pfa = 12.5\ F_{w/c} + 14.25$ ...(34)

For 80% passing

$Pfa = 13.33\ F_{w/c} + 17$ ...(35)

For 60% passing

$Pfa = 16.67\ F_{w/c} + 19.99$ ...(36)

For 40% passing

$Pfa = 20.83\ F_{w/c} + 24.751$ ...(37)

For 15% passing
$$Pfa = 26.67\ F_{w/c} + 29.499 \quad ...(38)$$

ii). Slump of 10 – 30mm
For 100% passing
$$Pfa = 10.83\ F_{w/c} + 16.251 \quad ...(39)$$
For 80% passing
$$Pfa = 15\ F_{w/c} + 18 \quad ...(40)$$
For 60% passing
$$Pfa = 18.33\ F_{w/c} + 21 \quad ...(41)$$
For 40% passing
$$Pfa = 22.5\ F_{w/c} + 26.25 \quad ...(42)$$
For 15% passing
$$Pfa = 27.5\ F_{w/c} + 31.75 \quad ...(43)$$

iii). Slump of 30 – 60mm
For 100% passing
$$Pfa = 11.67\ F_{w/c} + 17.99 \quad ...(44)$$
For 80% passing
$$Pfa = 15\ F_{w/c} + 19.5 \quad ...(45)$$
For 60% passing
$$Pfa = 16.67\ F_{w/c} + 24.499 \quad ...(46)$$
For 40% passing
$$Pfa = 22.5\ F_{w/c} + 29.75 \quad ...(47)$$
For 15% passing
$$Pfa = 27.5\ F_{w/c} + 35.75 \quad ...(48)$$

iv). Slump of 60 – 180mm
For 100% passing
$$Pfa = 13.33\ F_{w/c} + 20 \quad ...(49)$$
For 80% passing
$$Pfa = 15\ F_{w/c} + 23.5 \quad ...(50)$$
For 60% passing
$$Pfa = 19.17\ F_{w/c} + 27.25 \quad ...(51)$$
For 40% passing
$$Pfa = 22.5\ F_{w/c} + 35.25 \quad ...(52)$$
For 15% passing
$$Pfa = 26.67\ F_{w/c} + 43.5 \quad ...(53)$$

Maximum aggregate size of 40mm:
i). Slump of 0 – 10mm
For 100% passing
$$Pfa = 14.17\ F_{w/c} + 9.25 \quad ...(54)$$
For 80% passing
$$Pfa = 15\ F_{w/c} + 12 \quad ...(55)$$
For 60% passing
$$Pfa = 18.33\ F_{w/c} + 14 \quad ...(56)$$
For 40% passing
$$Pfa = 22.5\ F_{w/c} + 17.75 \quad ...(57)$$
For 15% passing
$$Pfa = 26.67\ F_{w/c} + 23 \quad ...(58)$$

ii). Slump of 10 – 30mm
For 100% passing
$$Pfa = 11.67\ F_{w/c} + 14.5 \quad ...(59)$$
For 80% passing
$$Pfa = 15\ F_{w/c} + 13.5 \quad ...(60)$$
For 60% passing
$$Pfa = 17.5\ F_{w/c} + 16.25 \quad ...(61)$$
For 40% passing
$$Pfa = 22.5\ F_{w/c} + 20.25 \quad ...(62)$$
For 15% passing
$$Pfa = 28.33\ F_{w/c} + 24.5 \quad ...(63)$$

iii). Slump of 30 – 60mm
For 100% passing
$$Pfa = 13.33\ F_{w/c} + 13.5 \quad ...(64)$$
For 80% passing
$$Pfa = 14.17\ F_{w/c} + 16.25 \quad ...(65)$$
For 60% passing
$$Pfa = 17.5\ F_{w/c} + 19.25 \quad ...(66)$$
For 40% passing
$$Pfa = 21.67\ F_{w/c} + 24.5 \quad ...(67)$$
For 15% passing
$$Pfa = 27.5\ F_{w/c} + 28.75 \quad ...(68)$$

iv). Slump of 60 – 180mm
For 100% passing
$$Pfa = 14.17\ F_{w/c} + 16.25 \quad ...(69)$$
For 80% passing
$$Pfa = 15\ F_{w/c} + 19.5 \quad ...(70)$$
For 60% passing

$$Pfa = 19.17\ F_{w/c} + 27.25 \quad ...(71)$$

For 40% passing

$$Pfa = 21.67\ F_{w/c} + 30 \quad ...(72)$$

For 15% passing

$$Pfa = 27.5\ F_{w/c} + 35.75 \quad ...(73)$$

Fine aggregate content, Fac is given as

$$Fac = Pfa * Ac \quad ...(74)$$

Coarse aggregate content, Cac is given as

$$Cac = Ac - Fac \quad (75)$$

QBASIC PROGRAM FOR USE

For ease in the application of this Algorithm, a QBASIC program was developed using the equations therein (that is equations 1, 2, 3 …75). The program is as shown in the appendix.

TEST OF ALGORITHM

Two examples were used to test the working of the algorithm.

EXAMPLE 1: Determine the mix design using the following data.

Fc = 30 Mpa at 28 days; Cement type is OPC; Slump is 10 – 30 mm; Maximum size of aggregate is 20 mm; Maximum Free water-cement ratio is 0.55; Minimum Cement content is 290 kg/m³; Degree of control is poor site; Type of aggregate is uncrushed; Relative density of aggregate is 2.6; and fine aggregate grading zone is zone 3 (80% passing).

COMPUTER BASED SOLUTION

When problem was used in the QBASIC program, the outcome is as follows:

WATER CONTENT = 160 KG

CEMENT CONTENT = 326.2975 KG

FINE AGGREGATE CONTENT = 486.4918 KG

COARSE AGGREGATE CONTENT=1432.211KG

EXAMPLE 2: Determine the mix design using the following data.

Fc = 15 Mpa at 28 days; Cement type is OPC; Slump is 30 – 60 mm; Maximum size of aggregate is 40 mm; Maximum Free water-cement ratio is 0.50; Minimum Cement content is 290 kg/m³Standard deviation is 6 Mpa; Type of aggregate is uncrushed; Relative density of aggregate is 2.5; and fine aggregate grading zone is zone 4 (100% passing).

COMPUTER BASED SOLUTION

When problem was used in the QBASIC program, the outcome is as follows:

WATER CONTENT = 160 KG

CEMENT CONTENT = 320 KG

FINE AGGREGATE CONTENT= 372.6744 KG

COARSE AGGREGATE CONTENT=1475.451 KG

RESULT AND CONCLUSION

The results gotten by this algorithm to the nearest 5kg for examples 1 and 2 are shown in tables 4 and 5.

For examples 1 and 2, the results gotten by Teychenne et al [5] are shown in tables 6 and 7. The differences between their results and the results from this algorithm are shown in tables 8 and 9.

A critical look at the results shows that the absolute percentage differences between the results from Teychenne et al [5] and the Algorithm are all less than 10% for all the components in the ratio of ***water : cement : fine aggregate : coarse aggregate***. However, if the components are based on the ratio of ***water : cement : aggregate*** then it will be noticed that the absolute percentage differences are all less than 5%. This implies closeness of the two sets of result. In statistics, difference of up to 10% is acceptable (Nwaogazie, 1999 [6]). The difference that arose here could be attributed to some round off approximations. It could also be attributed to error introduced by Teychenne et al while interpolating and reading off values from the curves. All the same, the difference is negligible and tolerable. Knowing the fact that the results by Teychenne et al [5] are approximate results and the difference between their results and the results from Algorithm is less than 10%, one can safely say that the results from the Algorithm are good approximate results. Based on these results, conclusion can be drawn that the algorithm presented in this paper is working well, and the authors strongly recommend its use in obtaining good approximate results for normal weight concrete (NWC) and high performance concrete (HPC) mix design.

Table 1: Standard deviation for various degrees of control (Teychenne et. al.[5])

Degree of control	**Standard Deviation**
Laboratory	2.0 - 3.5
Excellent site	3.5 - 4.5
Average site	5.0 - 6.0
Poor site	7.0 - 8.0

Table 2: Approximate compressive strength of concrete mixes made with s free water-cement ratio of 0.5 (Teychenne et. al.[5])

Type of cement	Type of coarse Aggregate	Compressive strength at the age of (days)			
		3	7	28	91
OPC CEMENT	Uncrushed	22	30	42	49
	Crushed	27	36	49	56
SRC CEMENT	Uncrushed	29	37	48	54
	Crushed	34	43	55	51
OPC – ordinary Portland cement SRC – sulphur Resistant cement					

Table 3: Approximate free water contents (kg/m³) required to give various levels of workability (Teychenne et. al.[5])

Slump (mm)		0-10	10-30	30-60	60-180
V-B(s)		> 12	6-12	3-6	0 - 3
Maximum size of aggregate (mm)	Type of aggregate				
10	Uncrushed	150	180	205	225
	crushed	180	205	230	250
20	Uncrushed	135	160	180	195
	crushed	170	190	210	225
40	Uncrushed	115	140	160	175
	crushed	155	175	190	205

Table 4: Result of Algorithm for Example 1

Cement (kg) Nearest 5kg	Water (kg) Nearest 5kg	Fine agg. (kg) Nearest 5kg	Coarse agg. (kg) Nearest 5kg
330	160	490	1430

Table 5: Result of Algorithm for Example 2

Cement (kg) Nearest 5kg	Water (kg) Nearest 5kg	Fine agg. (kg) Nearest 5kg	Coarse agg. (kg) Nearest 5kg
320	160	370	1480

Table 6: Result of Teychenne et. al. [5] for Example1

Cement (kg)	Water (kg)	Fine agg. (kg)	Coarse agg. (kg)
340	160	515	1385

Table 7: Result of Teychenne et. al. [5] for Example 2

Cement (kg)	Water (kg)	Fine agg. (kg)	Coarse agg. (kg)
320	160	405	1440

Table 8: Difference between the two results for Example 1

	Cement	Water	Fine agg.	Coarse agg.
Teychenne	340	160	515	1385
Algorithm	330	160	490	1430
Difference	10	0	25	-45
Percentage	3%	0%	4.85%	-3.25%

Table 9: Difference between the two results for Example 2

	Cement	Water	Fine agg.	Coarse agg.
Teychenne	320	160	405	1440
Algorithm	320	160	370	1480
Difference	0	0	35	-40
Percentage	0%	0%	8.64%	-2.78%

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APPENDIX

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PRINT "WHAT IS RELATIVE COMBINED DENSITY OF THE AGGREGATE": INPUT RDA
PRINT "WHAT IS THE CHARACTERISTIC STRENGTH OF THE CONCRETE": INPUT FC
PRINT "WHAT IS THE CEMENT TYPE - 1 FOR ORDINARY PORTLAND CEMENT"
PRINT " 2 FOR SULPHATE RESISTANT CEMENT": INPUT CT
PRINT "WHAT IS THE EXPECTED SLUMP VALUE - 1 FOR 0-10, 2 FOR 10-30, 3 FOR 30-60,"
PRINT " 4 FOR 60 -180": INPUT SLUMP
PRINT "WHAT IS THE MAXIMUM AGGREGATE SIZE - 10, 20 OR 40": INPUT AZ
PRINT "WHAT IS THE TYPE OF AGGREGATE - 1 FOR CRUSHED, 2 FOR UNCRUSHED": INPUT TA
PRINT "WHAT IS THE MAXIMUM FREE WATER CEMENT RATIO": INPUT MFWCR
PRINT "WHAT IS THE MINIMUM CEMENT CONTENT": INPUT MCC
PRINT "WHAT IS THE DEGREE OF CONTOL - 1 FOR LABORATORY, 2 FOR EXCELLENT SITE,"
PRINT " 3 FOR AVERAGE SITE, 4 FOR POOR SITE": INPUT DOC
PRINT "WHAT IS THE  GRADING ZONE OF FINE AGGREGATE": INPUT ZONE
IF DOC = 1 THEN SS = 3.5
IF DOC = 2 THEN SS = 4.5
IF DOC = 3 THEN SS = 6
IF DOC = 4 THEN SS = 8
FM = FC + 1.645 * SS
IF TA = 1 AND FM < 41.9 THEN FWCR = .000295 * FM ^ 2 - .0312 * FM + 1.351
IF TA = 1 AND FM > 41.9 THEN FWCR = .00008519157# * FM ^ 2 - .01571 * FM + 1.0697
IF TA = 2 AND FM < 41.9 THEN FWCR = .000295 * FM ^ 2 - .0312 * FM + 1.291
IF TA = 2 AND FM > 41.9 THEN FWCR = .00008519157# * FM ^ 2 - .01571 * FM + 1.0097
IF FWCR > MFWCR THEN FWCR = MFWCR
IF AZ = 40 THEN GOTO 40
IF AZ = 20 THEN GOTO 20
IF TA = 1 THEN GOTO 10
IF SLUMP = 1 THEN FWC = 150
IF SLUMP = 2 THEN FWC = 180
IF SLUMP = 3 THEN FWC = 205
IF SLUMP = 4 THEN FWC = 225
GOTO 60

10      IF SLUMP = 1 THEN FWC = 180
IF SLUMP = 2 THEN FWC = 205
IF SLUMP = 3 THEN FWC = 230
IF SLUMP = 4 THEN FWC = 250
GOTO 60
20      IF TA = 1 THEN GOTO 30
IF SLUMP = 1 THEN FWC = 135
IF SLUMP = 2 THEN FWC = 160
IF SLUMP = 3 THEN FWC = 180
IF SLUMP = 4 THEN FWC = 195
GOTO 60
30      IF SLUMP = 1 THEN FWC = 170
IF SLUMP = 2 THEN FWC = 190
IF SLUMP = 3 THEN FWC = 210
IF SLUMP = 4 THEN FWC = 225
GOTO 60
40      IF TA = 1 THEN GOTO 50
IF SLUMP = 1 THEN FWC = 115
IF SLUMP = 2 THEN FWC = 140
IF SLUMP = 3 THEN FWC = 160
IF SLUMP = 4 THEN FWC = 175
GOTO 60
50      IF SLUMP = 1 THEN FWC = 155
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IF SLUMP = 2 THEN FWC = 175
IF SLUMP = 3 THEN FWC = 190
IF SLUMP = 4 THEN FWC = 205
60 CC = FWC / FWCR
IF CC < MCC THEN CC = MCC: FWC = CC * FWCR
IF RDA = 2.9 OR RDA > 2.9 THEN WDCC = -1.71875 * FWC + 2896.875
IF RDA < 2.9 AND RDA > 2.79 THEN WDCC = -1.59375 * FWC + 2804.375
IF RDA < 2.8 AND RDA > 2.69 THEN WDCC = -1.4375 * FWC + 2703.75
IF RDA < 2.7 AND RDA > 2.59 THEN WDCC = -1.25 * FWC + 2605
IF RDA < 2.6 AND RDA > 2.49 THEN WDCC = -1.03125 * FWC + 2493.125
IF RDA < 2.5 AND RDA > 2.39 THEN WDCC = -.925 * FWC + 2402
IF RDA < 2.39 THEN CLS : PRINT "THE CHOICE OF AGGREGATE IS NOT AEQUATE";
IF RDA < 2.39 THEN PRINT "FOR BRITISH CONCRETE MIX DESIGN": GOTO 200
AC = WDCC - CC - FWC
IF AZ = 40 THEN GOTO 140
IF AZ = 20 THEN GOTO 100
IF SLUMP = 4 THEN GOTO 90
IF SLUMP = 3 THEN GOTO 80
IF SLUMP = 2 THEN GOTO 70
IF ZONE = 4 THEN PFA = 12.5 * FWCR + 20
IF ZONE = 3 THEN PFA = 15 * FWCR + 23
IF ZONE = 2 THEN PFA = 17.5 * FWCR + 28
IF ZONE = 1 THEN PFA = 22.5 * FWCR + 35
GOTO 180
70      IF ZONE = 4 THEN PFA = 15 * FWCR + 20
IF ZONE = 3 THEN PFA = 12.5 * FWCR + 27
IF ZONE = 2 THEN PFA = 15 * FWCR + 34
IF ZONE = 1 THEN PFA = 22.5 * FWCR + 37
GOTO 180
80      IF ZONE = 4 THEN PFA = 12.5 * FWCR + 22
IF ZONE = 3 THEN PFA = 15 * FWCR + 27
IF ZONE = 2 THEN PFA = 15 * FWCR + 34
IF ZONE = 1 THEN PFA = 20 * FWCR + 41
GOTO 180
90      IF ZONE = 4 THEN PFA = 12.5 * FWCR + 27
IF ZONE = 3 THEN PFA = 15 * FWCR + 31
IF ZONE = 2 THEN PFA = 17.5 * FWCR + 37
IF ZONE = 1 THEN PFA = 25 * FWCR + 45
GOTO 180
100     IF SLUMP = 4 THEN GOTO 130
IF SLUMP = 3 THEN GOTO 120
IF SLUMP = 2 THEN GOTO 110
IF ZONE = 4 THEN PFA = 12.5 * FWCR + 14.25
IF ZONE = 3 THEN PFA = 13.33 * FWCR + 17
IF ZONE = 2 THEN PFA = 16.67 * FWCR + 19.99
IF ZONE = 1 THEN PFA = 20.83 * FWCR + 24.751
GOTO 180
110     IF ZONE = 4 THEN PFA = 10.83 * FWCR + 16.251
IF ZONE = 3 THEN PFA = 15 * FWCR + 18
IF ZONE = 2 THEN PFA = 18.33 * FWCR + 21
IF ZONE = 1 THEN PFA = 22.5 * FWCR + 26.25
GOTO 180
120     IF ZONE = 4 THEN PFA = 11.67 * FWCR + 17.99
IF ZONE = 3 THEN PFA = 15 * FWCR + 19.5
IF ZONE = 2 THEN PFA = 16.67 * FWCR + 24.499
IF ZONE = 1 THEN PFA = 22.5 * FWCR + 29.75
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GOTO 180
130     IF ZONE = 4 THEN PFA = 13.33 * FWCR + 20
IF ZONE = 3 THEN PFA = 15 * FWCR + 23.5
IF ZONE = 2 THEN PFA = 19.17 * FWCR + 27.25
IF ZONE = 1 THEN PFA = 22.5 * FWCR + 35.25
GOTO 180
140     IF SLUMP = 4 THEN GOTO 170
IF SLUMP = 3 THEN GOTO 160
IF SLUMP = 2 THEN GOTO 150
IF ZONE = 4 THEN PFA = 14.17 * FWCR + 9.25
IF ZONE = 3 THEN PFA = 15 * FWCR + 12
IF ZONE = 2 THEN PFA = 18.33 * FWCR + 14
IF ZONE = 1 THEN PFA = 22.5 * FWCR + 17.75
GOTO 180
150     IF ZONE = 4 THEN PFA = 11.67 * FWCR + 14.5
IF ZONE = 3 THEN PFA = 15 * FWCR + 13.5
IF ZONE = 2 THEN PFA = 17.5 * FWCR + 16.25
IF ZONE = 1 THEN PFA = 22.5 * FWCR + 20.25
GOTO 180
160     IF ZONE = 4 THEN PFA = 13.33 * FWCR + 13.5
IF ZONE = 3 THEN PFA = 14.17 * FWCR + 16.25
IF ZONE = 2 THEN PFA = 17.5 * FWCR + 19.25
IF ZONE = 1 THEN PFA = 21.67 * FWCR + 24.5
GOTO 180
170     IF ZONE = 4 THEN PFA = 14.17 * FWCR + 16.25
IF ZONE = 3 THEN PFA = 15 * FWCR + 19.5
IF ZONE = 2 THEN PFA = 19.17 * FWCR + 27.25
IF ZONE = 1 THEN PFA = 21.67 * FWCR + 30
180     FAC = PFA / 100 * AC
CAC = AC - FAC
WC = FWC / CC
FA = FAC / CC
CA = CAC / CC
C = CC / CC

REM  RESULT
PRINT "WATER CONTENT =", FWC; "KG"
PRINT "CEMENT CONTENT =", CC; "KG"
PRINT "FINE AGGREGATE CONTENT =", FAC; "KG"
PRINT "COARSE AGGREGATE CONTENT =", CAC; "KG"
200
```