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Optimization of the compressive strength of five-component-concrete mix using Scheffe's theory –a case study of mound soil concrete

[1]O. U. Orie and [2]N. N. Osadebe
[1]Civil Engineering Department, University of Benin, Benin City, Nigeria.
[2]Civil Engineering Department, University of Nigeria, Nsukka, Nigeria.

Abstract

The paper presents the report of an investigation carried out to optimize some mechanical properties of a five-component-concrete mix. Mound soil (MS), randomly selected from some habitats of a common tropical specie of termites from Iyeke-Ogba, Nigeria was investigated as a fifth component in concrete. The work applied Scheffe's optimization technique and obtained a mathematical model of the form $f(x_1,x_2,.x_3.x_4, x_5)$ where x, j = 1, 2, 3, 4, 5 are proportions of the concrete components namely; cement, fine aggregate, mound soil, coarse aggregates and water/cement ratio. Scheffe's experimental design was followed to mould various cube samples measuring 150mm x 150mm x 150mm, with different ingredient components which were tested for 7, 14 and 28 days strength. Software for the design of mound soil concrete (MSC) was proposed. The results show that the optimum mix was 1.00:1.59:0.46:3.34:0.53 with a compressive strength of 43.72N/mm^2. The paper concludes that concrete can be designed as a five component mix in structural engineering rather than using admixtures in undersigned percentages.

Keywords
Concrete, Admixture, Strength, Workability and Fifth-component.

1.0 Introduction

Every activity that must be successful in human endeavour requires planning. The soul of planning is the maximization of the desired outcome of the venture. In other to maximize gains or outputs it is often necessary to keep inputs or investments at the production level at the minimum. The process involved in this planning activity of maximization and minimization is referred to as optimization. In the science of optimization, the desired property or quantity to be optimized is referred to as the *objective function*. The raw materials or quantities whose amount of combinations will produce this objective function are referred to as *variables*. The variability of these variables produces different combinations and hence different outputs. Often the space of variation of the variability of the variables is not universal as some conditions limit them. These conditions are called *constraints*. For example, money is a factor of production and is known to be limited in supply. The constraint at any time is the amount of money available to the entrepreneur at the time of investment. Everybody can make concrete but not everybody can make structural concrete. Structural concretes are made with specified materials and specified strength. Concrete is heterogeneous, as it comprises sub-materials. Concrete is made up of; fine aggregates, coarse aggregates, cement, water, and sometimes admixtures. David and

[1]**Corresponding author**
[1]e-mail: ogheneale@yahoo.com, Telephone: 08023395190

Galliford [1] reports that modern research in concrete seeks to provide greater understanding of its constituent materials and possibilities of improving its desired qualities. For instance, Portland cement has been partially replaced with ground granulated blast furnace slag (GGBS), a by-product of the steel industry that has valuable cementitious properties Ecocem, [2].

2.0 Literature Review

Generally, concrete finds use in virtually all civil engineering works. In buildings, it finds application from the foundation to the roof. Concrete is good in compression but poor in tension. Hence in reinforced concrete design, it is assumed that the concrete in the tension zone of the member has failed, BS 8110, [3].

The task of concrete mix optimization implies selecting the most suitable concrete aggregates from the Data Base Genadij and Juris, [4]. Several methods have been applied. Examples are Mohan et al [5], Simon [6], Lech et al [7] and Czarnecki, et al [8]. Nordstrom and Munoz [9] proposed an approach which adopts the equilibrium mineral assemblage concept of geochemical thermodynamics as a basis for establishing mix proportions. Bloom and Bentur [10] reports that optimization of mix designs requires detailed knowledge of concrete properties. Low water-cement ratios lead to increased strength but negatively will lead to an accelerated and higher shrinkage, apart from the larger deformations, the acceleration of hydration and strength will cause cracking at early ages.

Genadij and Juris [4] stated that the task of concrete mix optimization implies selecting the most suitable concrete aggregates from a data base. According to the discussion, aggregate takes up 60 – 90% of the total volume of concrete. Proper selection of aggregate type and particle size distribution affect the main properties of concrete – workability of concrete mix as well as mechanical strength, permeability, durability and the total cost of hardened concrete, therefore aggregate mix design is an essential part of concrete mix design and optimization.

Osuji [11] used the principle of Bulk Density to determine the optimum combination of binary aggregates found in Edo state, Nigeria. He reported that the mix combination with gravel gave the weakest compressive strength. Simplex lattice approach has been used to optimize the deflection and shear characteristics of laterized concrete. The results demonstrated that laterized concrete can be used in constructing cylindrical storage structures Ukamaka, [12].

Scheffe and Osadebe's mathematical models have been used to optimize some mechanical properties of concrete made from Rice Husk Ash (RHA) -a pozzolanic waste material Obam, [13]. It was observed that RHA generally produced concrete with a low compressive strength of $3.2N/mm^2$ with an optimum water cement ratio of 0.86.

Felix et al [14] showed that inclusion of mound soil, in mortar matrix resulted in a compressive strength value of up to 40.08 N/mm^2, and addition of 5% of mound soil to a concrete mix of 1:2:4:0.56 (cement: sand: coarse aggregate: water) resulted in an increase of up to 20.35% in compressive strength

3.0 Background theory

Let the objective function be y –the parameter to be optimized, for example compressive strength or yield, and y depends on other factors say $x_1, x_2, x_3 ..., x_n$ – the variables Obam, [13]. These variables are also subject to some auxiliary conditions such as limits or boundaries, termed constraints. In concrete, a major objective is the compressive strength and it depends primarily on the proportions of the constituent materials such as; fine aggregate, coarse aggregate, cement, water and sometimes additives or modifiers which we can represent mathematically as x_1, x_2, x_3, x_4 and x_5 respectively. Assuming concrete as a unit mixture we can write that

$$x_1 + x_2 + x_3 + x_4 + x_5 = 1 \qquad (3.1)$$

Hence, optimizing any function y depending on the proportion of n variables, we say that

$$x_1 + x_2 + x_3 +,.., x_n = 1 \qquad (3.2)$$

3.1 Simplex Lattice Method

Simplex is defined as the structural representation of the line or planes joining the assumed positions of the constituents (atoms) of the material Jackson, [15].

If a mixture has a total of q components and x_i be the proportions of the ith component in the mixture such that, $x_i \geq 0(i = 1,2,...q)$. Since the mixture is a complete whole, i.e., unity,

$$x_1 + x_2 + x_3 + ... + x_q = 1 \text{ or} \sum x_i - 1 = 0 \qquad (3.3)$$

where, $i = 1,2...q$. Thus the factor space is a regular $(q-1)$ dimensional simplex. In a $(q-1)$-dimensional simplex, if $q = 2$, we have 2 points of connectivity. This gives a straight line simplex lattice. If $q = 3$, we have a triangular simplex lattice and for $q = 4$ it is a tetrahedron simplex lattice, etc. Taking a whole factor space in the design, we have a (q, m) simplex lattice whose properties are defined as follows:

(i) the factor space has uniformly distributed points

(ii) simplex lattice designs are saturated Akhnarova and Afarov, [16]

For each component, there exist $(m+1)$ similar levels $x_i = 0, 1/m, 2/m...1$ and all possible combinations are derived from such values of components combinations. For instance, if we have $(q,2)$ lattice, that is a second –degree polynomial, $(m = 2)$, the following levels of every factor must be used: $0, 1/2$ and 1. For $(q,3)$ lattice, that is a third-degree polynomial, $(m = 3)$ the levels of every factor are: $0, 1/3, 2/3$ and 1. It has also been shown that the number of points in (q, m) lattice is given by [99],

$$C^m{}_{q+m-1} = q(q+1)...(q+m-1)/m! \qquad [3.4]$$

Hence, in a $(3,2)$ lattice, the number of points or coefficients in the Polynomial is given by $(3(3+1)/2!$ or 6 and in a (5, 2) which is considered in the present work we have $\frac{5(5+1)}{2!}$ or15

3.2 The (5, 2) Lattice Model

The properties studied in the assumed polynomial are real-valued functions on the simplex and are termed *responses*. Mixture properties were described using polynomials assuming that a polynomial function of degree n in the q variables $x_1, x_2,...x_q$, subject to equation 3.3 and will be called a (q, n) polynomial having a general form

$$y = b_0 + \sum b_i x_i + \sum b_{ij} x_i x_j + \sum b_{ijk} x_i x_j x_k + \sum b_{i1},_{i2}...i_n x_{i1} x_{i2} x_{in} \qquad (3.5)$$

where, $(1 \leq i \leq q, 1 \leq i \leq j \leq q, 1 \leq i \leq j \leq k \leq q)$ respectively and b is a constant coefficient. The usable form of equation 3.4 is

$$\hat{Y} = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5 + b_{12}x_1x_2 + b_{13}x_1x_3 + b_{14}x_1x_4 + b_{15}x_1x_5 + b_{23}x_2x_3$$
$$+ b_{24}x_2x_4 + b_{25}x_2x_5 + b_{34}x_3x_4 + b_{35}x_3x_5 + b_{45}x_4x_5 + b_{11}x^2{}_1 + b_{22}x^2{}_2 + b_{33}x^2{}_3 + b_{44}x^2{}_4 + b_{55}x^2{}_5 \qquad (3.6)$$

Equation 3.5 is subject to equation 3.1. After performing the necessary evaluation, we derive the $(5,2)$ polynomial equation given by,

$$\hat{Y} = \alpha_1 x_1 + \alpha_2 x_2 + \alpha_3 x_3 + \alpha_4 x_4 + \alpha_5 x_5 + \alpha_{12} x_1 x_2 + \alpha_{13} x_1 x_3 + \alpha_{14} x_1 x_4 + \alpha_{15} x_1 x_5 + \\ + \alpha_{23} x_2 x_3 + \alpha_{24} x_2 x_4 + \alpha_{25} x_2 x_5 + \alpha_{34} x_3 x_4 + \alpha_{35} x_3 x_5 + \alpha_{45} x_4 x_5 \quad (3.7)$$

Equation 3.6 can be written in compact form as

$$\hat{Y} = \sum \alpha_i x_i + \sum \alpha_{ij} x_i x_j \quad (3.8)$$

where, $1 \le i \le q, 1 \le i \le j \le q, 1 \le i \le j \le q$ respectively and α_i are the coefficients of the regression equation.

Let the response function to the pure components (x_i) be denoted by (y_i) and the response to a 1:1 binary mixture of components i and j be y_{ij}, from equation 6 it can be written that

$$\sum \alpha_i x_i = \sum y_i x_i \quad (3.9)$$

where, $i = 1$ to 5. The general equations for evaluating a_i and a_{ij} are found to be of the form

$$y_i = \alpha_i \quad (3.10)$$

$$\alpha_{ij} = 4_{ij} - 2y_i - 2y_j \quad (3.11)$$

The number of α_{ij} values given by (Scheffe, 1958) [17].

$$q(q-1)/2! = 5(5+1)/2! = 15$$

The design matrix as shown in Table 4.1 or $x_1^{(1)}, x_2^{(1)}, x_3^{(1)}, x_4^{(4)}$ and $x_5^{(1)}$ for the ith experimental points are referred to as Pseudo-Components. For any actual component *Z*, the pseudo-component (*x*) is given by

$$X = AZ \quad (3.12)$$

where *A* is the inverse of *Z* matrix and

$$Z = BX^T \quad (3.13)$$

where *B* is the inverse of *Z* matrix and X^T is the transpose of matrix X .

4.0 Experimental program

4.1 Materials

Crushed granite from Ifon was used, the maximum diameter of which was 14mm. The grading and properties of the coarse aggregate conformed to BS882. Okhuahe River Sand (OKRS) was used. It consisted of quartzite with the grading and properties conforming to BS882.

Mound soil from Iyeke-Ogba area in Edo State of Nigeria was used. It formed the main material on which the investigation was directed. According to the specification of BS3148:1980, potable water was used.

4.2 Preparation of samples

The materials for the experiment were sourced and transferred to the laboratory where they were allowed to dry. The mound soil was pulverized using wooden Mortar and Pestle. Sampling was carried out using the quartering method.

4.3 Results

Table 4.1: Design Matrix for Scheffe's (5, 2) Lattice (Pseudo and Real components)

Pseudo-Components						Response Comp.	Actual Variables				
No.	X_1	X_2	X_3	X_4	X_5		Z_1	Z_2	Z_3	Z_4	Z_5
1	1	0	0	0	0	Y_1	1	1	0.5	2	0.5
2	0	1	0	0	0	Y_2	1	2	1.5	5	0.55
3	0	0	1	0	0	Y_3	1	1.5	0.25	3	0.325
4	0	0	0	1	0	Y_4	1	3	1	6	0.6
5	0	0	0	0	1	Y_5	1	2.5	2	1.5	0.5
6	$\frac{1}{2}$	$\frac{1}{2}$	0	0	0	Y_{12}	1	1.5	1	3.5	0.525
7	$\frac{1}{2}$	0	$\frac{1}{2}$	0	0	Y_{13}	1	1.25	0.375	2.5	0.5
8	$\frac{1}{2}$	0	0	$\frac{1}{2}$	0	Y_{14}	1	1.25	0.75	4	0.55
9	$\frac{1}{2}$	0	0	0	$\frac{1}{2}$	Y_{15}	1	2.25	1.25	1.75	0.5
10	0	$\frac{1}{2}$	$\frac{1}{2}$	0	0	Y_{23}	1	1.75	0.875	4	0.538
11	0	$\frac{1}{2}$	0	$\frac{1}{2}$	0	Y_{24}	1	2.5	1.25	5.5	0.575
12	0	$\frac{1}{2}$	0	0	$\frac{1}{2}$	Y_{25}	1	2.25	1.75	3.25	0.525
13	0	0	$\frac{1}{2}$	$\frac{1}{2}$	0	Y_{34}	1	2.25	0.625	4.5	0.563
14	0	0	$\frac{1}{2}$	0	$\frac{1}{2}$	Y_{35}	1	2	1.125	2.25	0.513
15	0	0	0	$\frac{1}{2}$	$\frac{1}{2}$	Y_{35}	1	2.75	1.5	3.75	0.55
Control											
1	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{4}$	0	0	C_1	1	1.375	0.688	3	0.514
2	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	0	C_2	1	1.625	0.813	4	0.544
3	0	$\frac{1}{4}$	0	0	$\frac{3}{4}$	C_3	1	2.375	1.875	2.375	0.503
4	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	C_4	1	2.125	1.063	3.5	0.538
5	$\frac{1}{8}$	0	$\frac{1}{2}$	$\frac{1}{8}$	$\frac{1}{4}$	C_5	1	1.875	0.813	2.875	0.525
6	$\frac{1}{4}$	0	$\frac{3}{4}$	0	0	C_6	1	1.375	0.312	2.75	0.644
7	$\frac{1}{4}$	0	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	C_7	1	2	0.938	2.125	0.531
8	$\frac{1}{5}$	$\frac{1}{5}$	$\frac{1}{5}$	$\frac{1}{5}$	$\frac{1}{5}$	C_8	1	2	1.05	2.3	0.535

Legend:

X_1 = Fraction of Ordinary Portland cement (OPC) X_2 = Fraction fine aggregate (Okhuahe river Sand, OKRS)

X_3 = Fraction of Mound Soil, X_4 = Fraction of coarse aggregate, X_5 = Water cement ratio

Y_i and Y_{ij} are the response functions and C_i are extra points acting as controls

Table 4.2: Compressive Strength Test Results and Replication Variance

Expt. No.	Replication	Response Y_r (N/mm^2)	Response Symbol	$\sum Y_r$	$\hat{Y}$	$(\sum Y_r)^2$	S_i^2
1	1A 1B 1C	37.333 34.667 40.000	Y_1	111.997	37.332	14.220	4.740
2	2A 2B 2C	6.667 13.778 8.222	Y_2	28.667	9.5565	27.951	9.317
3	3A 3B 3C	42.000 44.000 40.889	Y_3	126.886	42.300	4.971	1.657
4	4A 4B 4C	25.778 28.889 20.000	Y_4	74.667	24.889	40.692	13.564
5	5A 5B 5C	3.111 3.556 3.778	Y_5	10.445	3.482	0.231	0.077
6	6A 6B 6C	37.333 36.889 36.889	Y_{12}	111.111	37.037	0.132	0.044
7	7A 7B 7C	36.222 40.000 36.444	Y_{13}	112.666	37.555	8.989	2.996
8	8A 8B 8C	37.778 42.444 40.888	Y_{14}	121.111	40.370	11.287	3.762
9	9A 9B 9C	16.222 19.111 20.000	Y_{15}	55.333	18.444	7.703	2.568
10	10A 10B 10C	33.778 38.889 42.222	Y_{23}	114.889	38.300	36.620	12.207
11	11A 11B 11C	1.556 1.333 0.889	Y_{24}	3.778	1.259	0.230	0.077
12	12A 12B 12C	12.444 12.000 11.778	Y_{25}	36.222	12.074	0.230	0.077

Table 4.3: Compressive Strength Test Results and Replication Variance Continued

Expt. No.	Replication	Response Y_r (N/mm^2)	Response Symbol	$\sum Y_r$	$\hat{Y}$	$(\sum Y_r)^2$	S_i^2
13	13A 13B 14C	30.222 33.333 32.889	Y_{34}	96.444	32.148	5.662	]1.887
14	14A 14B 14C	34.000 25.333 35.556	Y_{35}	94.889	31.630	60.682	20.227
15	15A 15B 15C	10.000 8.667 11.778	Y_{45}	30.445	10.148	4.872	1.624

Table 4.3: Compressive Strength Test Results and Replication Variance Continued

Expt. No.	Replication	Response Y_r (N/mm^2)	Response Symbol	$\sum Y_r$	$\hat{Y}$	$(\sum Y_r)^2$	S_i^2
Control							
1	16A 16B 16C	32.444 35.556 32.444	C_1	100.444	33.485	6.457	2.152
2	17A 17B 17C	35.556 25.556 26.667	C_2	87.779	29.260	60.084	20.028
3	18A 18B 18C	3.556 10.444 9.333	C_3	23.333	7.778	27.351	9.117
4	19A 19B 19C	32.889 24.444 22.222	C_4	79.555	26.518	28.837	9.612
5	20A 20B 20C	39.111 33.333 40.889	C_5	113.333	37.778	31.213	10.404
6	21A 21B 21C	28.444 32.444 28.444	C_6	89.332	29.777	6.221	2.074
7	22A 22B 22C	27.111 27.333 37.667	C_7	92.111	30.704	73.117	24.372
8	23A 23B 24C	34.222 39.111 36.222	C_8	109.555	36.518	12.084	4.028
						$\sum$	156.611

Hence, to obtain the replication variance, $S_y^2 = \frac{156.611}{22} = 7.119$ and $S_y = \sqrt{7.119} = 2.668$

4.4 The Regression equation

Based on equations 3.10 and 3.11;

$\alpha_1 = 37.33$, $\alpha_2 = 9.56$, $\alpha_3 = 42.3$, $\alpha_4 = 24.89$, $\alpha_5 = 3.48$

$\alpha_{12} = 4 \times 37.04 - 2 \times 37.33 - 2 \times 9.56 = 54.38$

$\alpha_{13} = 4 \times 37.56 - 2 \times 37.33 - 2 \times 42.3 = -8.98$

Similarly,

$\alpha_{14} = 37.04$, $\alpha_{15} = -7.86$, $\alpha_{23} = 49.48$, $\alpha_{24} = -63.86$, $\alpha_{25} = 22.2$, $\alpha_{34} = -5.78$,

$\alpha_{35} = 34.96$ and $\alpha_{45} = -16.14$

Substituting into equation 3.2. and 4.1, we have

$$\hat{Y} = 37.33x_1 + 9.56x_2 + 42.3x_3 + 24.89x_4 + 3.48x_5 + 54.38x_1x_2 - 8.98x_1x_3 + 37.04x_1x_4$$
$$- 7.86x_1x_5 + +49.48x_2x_3 - 63.86x_2x_4 + 22.2x_2x_5 - 5.78x_3x_4 + 34.96x_3x_5 - 16.14x_4x_5 \quad (4.1)$$

Equation 4.1 is therefore the mathematical model for the optimization of the compressive strength of a 5-component concrete mix using mound soil as the fifth component.

4.5 Testing the Fitness of the Regression Polynomial

Table 4.4: t-Test Statistics

S/N	Response Symbol	*t*
1	C_1	3.21
2	C_2	1.62
3	C_3	0.63
4	C_4	0.57
5	C_5	0.02
6	C_6	2.82
7	C_7	0.67
8	C_8	1.72

4.5.1 *t*-value from the table

Significant level, $\alpha = 0.05$ and $t_{\alpha/i}(V_c) = t_{0.05/8}(7) = 3.5$. This is higher than all the calculated values in Table 4.4, hence the model is adequate.

Table 4.5: *F*- Statistics Results

S/N	Response Symbol	$\left(Y_K - \hat{Y}_K\right)^2$	$\left(Y_E - \hat{Y}_E\right)^2$
1	C_1	20.322	146.797
2	C_2	0.080	2.338
3	C_3	449.398	478.078
4	C_4	6.047	11.580
5	C_5	77.458	4.186
6	C_6	0.642	27.269
7	C_7	471.194	3.806
8	C_8	56.867	37.715

Y_K = Experimental values (responses)

Y_E = Expected or theoretically calculated values (responses)

$$S_K^2 = (Y_K - \hat{Y}_K)^2 / 8 = 135.251$$

$$S_E^2 = (Y_E - \hat{Y}_E)^2 / 8 = 88.971$$

Hence, F = higher of the two values divided by the lower

$$F = 135.251/88.971 = 1.52$$

From fisher table (Akhnarova and Afarov, 1982) [1], $F_{0.95}(7,7) = 3.9$. This is higher than all the calculated values in Table 4.5, hence the model is adequate.

4.6 Optimization program in Q-basic (oriecom)

```
10 REM A QBasic program that optimizes the proportion of concrete mixes
15 REM Scheffe's Model for compressive strength
20 REM Variable used:
30 REM Z1,Z2,Z3,Z4,Z5,X1,X2,X3,X4,X5,Ymax,Yout,Yin
40 REM begin mahn program
41 OPEN "ORIEOU.OOU" FOR APPEND AS #1

50 LET Count = 0
60 CLS
70 GOSUB 100
CLOSE #1
80 END
90 REM End of main program
100 REM Procedure Begin
110 LET Ymax = 0
120 PRINT #1,
130 PRINT #1,
    140 PRINT #1, "MATHEMATICAL MODELS FOR THE OPTIMIZATION OF THE
    MECHANICAL PROPERTIES"
    160 PRINT #1, "OF THE CONCRETE MADE FROM RIVER SAND AND MOUND
    SOIL"
    170 PRINT #1,
    180 INPUT " ENTER DESIRED STRENGTH"; Yin
    185 PRINT #1, "ENTER DESIRED STRENGTH"; Yin
    186 PRINT #1,
    187 PRINT #1,
    190 GOSUB 400
    200 FOR X1 = 0 TO 1 STEP .01
    210 FOR X2 = 0 TO 1 – X1 STEP .01
    220 FOR X3 = 0 TO 1 – X1 – X2 STEP .01
    230 FOR X4 = 0 TO 1 – X1 – X2 – X3 STEP .01
    235 LET  X5 = 1 – X1 – X2 – X3 – X4
    240 LET Yout = 37.33 * X1 + 9.56 * X2 + 42.3 * X3 + 24.89 * X4 + 3.48 * X5 + 54.38
    * X1 * X2 – 8.98 * X1 * X3 + 37.04 * X1 * X4 – 7.86 * X1 * X5 + 49.48 * X2 * X3 –
    63.86 * X2 * X4 + 22.2 * X2 * X5 – 5.78 * X3 * X4 + 34.96 * X3 * X5 – 16.14 * X4 *
    X5
    250 GOSUB 500

    260 IF (ABS (Yin – Yout) <= .001) THEN 270 ELSE 290
    270 LET Count = Count + 1
    280 GOSUB 600
    285 NEXT X4
    290 NEXT X3
    291 NEXT X2
    292 NEXT X1

    295 PRINT #1
    300 IF (count > 0) THEN GOTO 310 ELSE GOTO 340
    310 PRINT #1, "THE Maximum Value of Strength Predictable By This Model
```

```
Is"; Ymax; "N / sq.mm."; ""
320 SLEEP (2)
330 GOTO 360
340 PRINT #1, "Sorry! Desired Strength Out Of Range Of Model."
350 LEEP 2
360 RETURN
400 REM Procedure PrintHeading
410 PRINT #1
420 PRINT #1, TAB (1); "Count"; TAB (7); "X1"; TAB (15); "X2"; TAB (23); "X3"; TAB
(31); "X4"; TAB (39); "X5"; TAB (47); "Y"; TAB (55); "Z1"; TAB (63); "Z2"; TAB (71);
"Z3" TAB (79); "Z4"; TAB(87) ; "Z5"
430 PRINT #1,
440 RETURN
500 REM Procedure CheckMax
510 IF Ymax < Yout THEN Ymax = Yout ELSE Ymax = Ymax
520 RETURN
600 REM Procedure OutResults
610 LET Z1 = XI + X2 + X3 + X4 + X5
620 LET Z2 = X1 + 2 * X2 + 1.5 * X3 + 3 * X4 + 2.5 * X5
630 LET Z3 = .5 * X1 + 1.5 * X2 + .25 * X3 + 6 * X4 + 1.5 * X5
640 LET Z4 = 2 * x1 + 5 * X2 + 3 * X3 + 6 * X4 + 1.5 * X5
645 LET Z5 = .5 * X1 + .55 * X2 + .525 * X3 + .6 * X4 + .5 * X5
650 PRINT #1, TAB (1); Count; USING "####.###"; X1; X2; X3; X4; X5; Yout; Z1; Z2;
Z3; Z4; Z5
660 RETURN
```

5.0 Some examples of executed programs

5.1 Mathematical models for optimization of the mechanical properties of the concrete made from river sand and mound soil

Enter desired strength 30

Count	X1	X2	X3	X4	X5	Y	Z1	Z2	Z3	Z4	Z5
1	0.000	0.640	0.300	0.000	0.060	29.999	1.000	1.880	1.155	4.190	0.539
2	0.060	0.580	0.250	0.000	0.110	30.001	1.000	1.870	1.183	3.935	0.535
3	0.070	0.440	0.260	0.000	0.230	30.001	1.000	1.915	1.220	3.465	0.529
4	0.070	0.610	0.240	0.000	0.080	30.001	1.000	1.850	1.170	4.030	0.536
5	0.080	0.690	0.230	0.000	0.000	30.001	1.000	1.805	1.133	4.300	0.540
6	0.090	0.230	0.310	0.000	0.370	30.000	1.000	1.940	1.208	2.815	0.519
7	0.090	0.420	0.250	0.000	0.240	30.000	1.000	1.905	1.217	3.390	0.527
8	0.150	0.050	0.380	0.000	0.420	30.000	1.000	1.870	1.085	2.320	0.512
9	0.210	0.230	0.240	0.000	0.320	30.000	1.000	1.830	1.150	2.770	0.517
10	0.220	0.200	0.250	0.000	0.330	30.000	1.000	1.820	1.132	2.685	0.516

The Maximum Value Of Strength Predictable By This Model Is 43.71582 N/sq.mm.

Enter desired strength 60

Count	X1	X2	X3	X4	X5	Y	Z1	Z2	Z3	Z4	Z5

Sorry! Desired strength out of range of model.

Enter desired strength 43.71582

Count	X1	X2	X3	X4	X5	Y	Z1	Z2	Z3	Z4	Z5
1	0.000	0.170	0.830	0.000	0.000	43.716	1.000	1.585	0.463	3.340	0.529

The Maximum Value Of Strength Predictable By This Model Is 43.71582 N/sq.mm.

6.0 Discussion of results

The results of the transformation from Pseudo-Components to Actual or Real Components are shown in Table 4.1. These have been placed side by side to allow for clarity. These were obtained from manual calculation after a preliminary experimental work had been carried out. Table 4.2 presents experimental and replication variance results. The replication variance was necessary for the regression model testing. The results for the model testing are presented in Tables 4.4 and 4.5. In respective case, the *t*-Test and the *F*-Statistics value from statistical tables was higher than any of the calculated values. Hence, the model is adequate. The user of the ORIECOM only need specify the desired compressive strength which must be within the optimum, and the program will give the mix proportions.

7.0 Conclusion

The paper provided an optimized design perspective of the use of admixtures instead of the use of un-designed percentage addition which is currently prevalent in the concrete industry of the world.

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