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An Engineering approach to Environmental and Housing Sustainability Using Osadebe's Second degree Polynomial Model

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Abstract: **The increasing human population has remained the primary factor for plastic waste generation. Expanded polystyrene (EPS) beads are cellular lightweight plastics material that consists of well-arranged spherically shaped particles that are composed of about 98% air and 2% polystyrene. Polystyrene foam is a non-biodegradable, material that commonly serve as a packaging material for fragile items. Several studies have examined the use of polystyrene beads as partial replacement for aggregate materials in the production of lightweight concrete. However, its general acceptance has been limited by the low strength properties of the resultant concrete. Usually, this is achieved through trial mixes on a trial-and-error basis. This method is generally difficult, especially when more concrete components are involved, hence, the need for a mathematical model that can accurately predict and optimize polystyrene concrete. Therefore, the aim of this study is to develop a mathematical model for the optimization of the mechanical properties of polystyrene lightweight concrete, using the Osadebe's second degree polynomial regression model. The materials used for this study were sand, water, coarse aggregate, ordinary limestone cement and expanded polystyrene beads. Except for polystyrene beads and coarse aggregates, which were mixed and batched together as a single material in volume, the materials were batched according to their weights. The partial replacement level considered was 12% replacement (88% coarse aggregate + 12% polystyrene) using an initial mix ratio of 1:3:6 (cement, sand and coarse aggregate) in accordance to BS EN 1992 for Structural Concrete for 20 N/mm^2. The materials were mixed manually in the laboratory and the test results of the corresponding concretes were used for developing the prediction and optimization models respectively. Curing for all specimens was done as per NIS 87 (2004). The 28th day laboratory test results for the compressive strength were also obtained. From the aggregate mix ratio of 1, 2.42, 0.462 and 4.68 for cement, sand, water and coarse aggregates respectively, the model predicted a compressive strength value of 35.59 N/mm^2 with an optimized strength of about 40.99 N/mm^2. The model's results demonstrated that polystyrene lightweight concrete can be used as partitions in high-rise buildings and achieve a concrete strength suitable for residential use.**

Keywords: **Polystyrene, Concrete, Lightweight, Sustainability, Environment, Housing, Waste, Mathematical Model, Optimization, Osadebe and Compressive Strength.**

1. INTRODUCTION

The consistent examination into the utilization of waste materials as options in contrast to usual materials in construction has been actuated by the increasing expense of conventional materials as well as the related impact of natural aggregates exhaustion from determined and ceaseless extraction. Recent studies have shown that waste materials can conveniently serve as construction materials that can fulfil the required or desired conditions effectively if adequately processed [1]. Although some natural aggregates may produce similar results, synthetic aggregates serve primarily as materials for the production of lightweight concrete. According [2], any concrete with a density lesser than or equalling 1800 kg/m^3 can be generally accepted as lightweight concrete. Lightweight mineral aggregates like perlite, vermiculite, pumice, expanded

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shale, slate, and clay, as well as plastic granules like expanded polystyrene foam (EPS), polyurethane, or other polymer materials, have been shown to be effective in the production of lightweight concrete in recent studies. Polystyrene lightweight concrete can be produced by aggregating expanded polystyrene (EPS) beads with other components in a concrete mix at varying degrees of densities of the various components. The primary reason why there has been a prolonged drought in gainful knowledge concerning the use of EPS in concrete production for modern structural designs has been the issue of low strength [1]. It is well known that the strength of the aggregate material determines the overall strength of the concrete and the strength of EPS beads in itself is near zero. However, new techniques that are capable of attaining total recycling of EPS beads in concrete that specifically aim at modifying them thermally cab be explored [1]. Expanded polystyrene (EPS) beads are a cellular, light-weight plastic made up of well-arranged, spherical particles that are made up of about 98% air and 2% polystyrene. They are lightweight plastic [3]. Its cell structure is closed; hence it is difficult for it to absorb water. It is excellently suited for thermal and sound insulation as well as impact resistance. Foam made of polystyrene is not biodegradable. In the packaging industry, they are typically used as materials for packaging delicate goods. They are frequently available because they are frequently utilized for the packaging of electronics and other household goods. Additionally, their availability has posed a disposal challenge due to their non-biodegradability. Thus, the use of polystyrene in concrete is also a valuable means of disposing of this industrial waste that is already posing a severe danger to the environment. When added to concrete, it produces lightweight concrete which helps to reduce self-weight of the building and also help in load reduction during construction. Such buildings are most likely to have increased thermal resistance. Usually, this is achieved through trial mixes on a trial-and-error basis. This method is generally difficult, especially when more concrete components are involved, hence, the need for polystyrene concrete mix optimization. Therefore, the aim of this study is to develop a mathematical model for the prediction and optimization of the mechanical properties of polystyrene lightweight concrete, using the Osadebe's second degree polynomial regression model. Therefore, this study was conducted with two main achievements in view. Firstly, from the environmentalist perspective of solving the challenges of waste disposal, and secondly from the perspective of the construction industry, to provide an alternative to natural aggregates in line with the UN SDG goal 11, which is aimed at developing sustainable cities and communities, by providing affordable housing.

2. DERIVATION OF OSADEBE'S MODEL

$$Z_1 + Z_2 + \cdots + Z_q = \sum_{i=1}^{q} Zi = 1 \qquad (1)$$

Where Z^i is the proportion of the mixture's components and q is the number of mixture components.

Z_1= Water/Cement Ratio

Z_2 = Binder (Cement)

Z_3 = Fine Aggregates (Sand)

Z_4 = Coarse Aggregates (88% Granite + 12% EPS)

Osadebe assumed that the response Y is continuous, differentiable in relation to its predictors, and that Taylor's series can be used to expand the region around a specific point, Z_0.

$$Z(0) = (Z_1^{(0)}, Z_2^{(0)}, \ldots, Z_q^{(0)})^r \qquad (2)$$

$$Y(z) = \sum_{m=0}^{q} F^m (Z)^{(0)} (Z_i - Z^{(0)}) \qquad (3)$$

Expanding to second order

$$Y(Z) = F(Z^{(0)}) + \sum_{i=1}^{q} \frac{\partial f(Z^{(0)})}{\partial Z_i}(Z_i - Z^{(0)}) + \frac{1}{2!}\sum_{i=1}^{q-1}\sum_{i=1}^{q} \frac{\partial^2 f(Z^0)}{\partial Z_i \partial Z_i}(Z_i - Z_i{}^{(0)})(Z_i - Z_i{}^{(0)})$$

$$+\sum_{i-1}^{q} \frac{\partial^2 f(Z^{(0)})}{\partial Z_i}(Z_i - (o)\ \ ) \qquad (4)$$

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The point Z^0 can be used as the origin for convenience without affecting the formulation's generality, and as a result;

$$Z_1^{(0)} = Z_1^{(0)} + Z_2^{(0)} + Z_3^{(0)} + \ldots, Z_q^{(0)} = 0 \quad (5)$$

Let:

$$b_0 = F(0), \qquad b_i = \frac{\partial F(0)}{\partial Z_i}, \qquad b_{ij} = \frac{\partial^2 F(0)}{2i\partial Z_i \partial j}, \qquad b_{ii} = \frac{\partial^2 F(0)}{2i\partial Z_i^2} \quad (6)$$

Substituting Equation (3.13) into Equation (3.8) gives:

$$Y(Z) = b_0 + \sum_{i-1}^{q} b_i Z_i + \sum_{i\le j\le q}^{q} b_{ij} Z_i Z_j + \sum_{i-1}^{q} b_{ii} Z_i^2 \quad (7)$$

Multiplying Equation (3.8) by b_0 gives the expression:

$$b_0 = b_0 Z_1 + b_0 Z_2 + \cdots \ldots + b_0 Z_q \quad (8)$$

Multiplying Equation (3.8) successively by $Z_1, Z_2 \ldots Z_q$ and rearranging, gives respectively:

$$Z_1^2 = Z_1 - Z_1 Z_2 - \cdots \ldots \ldots + Z_1 Z_q$$

$$Z_2^2 = Z_2 - Z_1 Z_2 - \cdots \ldots \ldots - Z_2 Z_q$$

$$Z_q^2 = Z_1 - Z_1 Z_q - \cdots \ldots \ldots - Z_{(q-1)} \quad (9)$$

Substituting Equations (3.13) and (3.15) into Eq. (3.16) and simplifying yields

$$Y(Z) = \sum_{i-1}^{q} \beta_i Z_i + \sum_{i\le j\le q}^{q} \beta_{ij} Z_i Z_j \quad (10)$$

Where

$$\beta_i = b_0 + b_i \ldots \ldots + b_{ii} \quad (11)$$

$$\beta_{ij} = b_{ij} - b_{ii} - b_{ij} \quad (12)$$

If the unknown constant coefficients β_i and β_{ij} are unique, then Osadebe's regression model equation is defined. The following is the regression equation if the degree of the polynomial, m, is 2 and the number of constituents, q, is 4;

$$Y = \beta_1 Z_1 + \beta_2 Z_2 + \beta_3 Z_3 + \beta_4 Z_4 + \beta_{12} Z_1 Z_2 + \beta_{13} Z_1 Z_3 + \beta_{14} Z_1 Z_4 + \beta_{23} Z_2 Z_3 + \beta_{24} Z_2 Z_4 + \beta_{34} Z_3 Z_4 \quad (13)$$

Therefore, Equation 3.21 is the mathematical model based on Osadebe's second-degree regression method.

3. DETERMINATION OF THE COEFFICIENTS OF THE OSADEBE'S REGRESSION EQUATION

In this model, N is the At point k, let $y^{(k)}$ be the response, and $Z^{(k)}$ is the vector that corresponds to the set of component proportions (predictors). That is:

$$Z^{(k)} = \{ Z_1^{(k)}, Z_2^{(k)}, \ldots\ldots., Z_q^{(k)} \} \quad (14)$$

Substituting the vector of Equation (13) into Equation (14) gives:

$$y^{(k)} = \sum_{i=1}^{q} \beta_i Z_i^{(k)} + \sum_{i\le j\le q}^{q} \beta_{ij} Z_i^{(k)} Z_j^{(k)} \qquad k = 1,2,\ldots,N \quad (15)$$

A set of N linear algebraic equations that can be written in matrix form as a result of successively substituting the predictor vectors at each of the N observation points into Equation (15). This is expresses thus:

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$$\boldsymbol{Z\beta} = \boldsymbol{y} \tag{16}$$

Where

$\boldsymbol{\beta}$ is a vector whose elements are the estimates of the regression coefficients.

$\boldsymbol{Z}$ is an $N \times N$ matrix whose elements are the mixture component proportions and functions of the component proportions.

$\boldsymbol{y}$ is a vector of the observations or responses at the various N observation points.

That is:

$$\boldsymbol{Z} = \begin{bmatrix} Z_1^{(1)} & Z_2^{(1)} & \cdots & Z_1^{(1)}Z_2^{(1)} & \cdots & Z_1^{(1)}Z_q^{(1)} & \cdots & Z_{q-1}^{(1)}Z_q^{(1)} \\ Z_1^{(2)} & Z_2^{(2)} & \cdots & Z_1^{(2)}Z_2^{(2)} & \cdots & Z_1^{(2)}Z_q^{(2)} & \cdots & Z_{q-1}^{(2)}Z_q^{(2)} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ Z_1^{(N-1)} & Z_2^{(N-1)} & \cdots & Z_1^{(N-1)}Z_2^{(N-1)} & \cdots & Z_1^{(N-)}Z_q^{(N-1)} & \cdots & Z_{q-1}^{(N-1)}Z_q^{(N-1)} \\ Z_1^{(N)} & Z_2^{(N)} & \cdots & Z_1^{(N)}Z_2^{(N)} & \cdots & Z_1^{(N)}Z_q^{(N)} & \cdots & Z_{q-1}^{(N)}Z_q^{(N)} \end{bmatrix}$$

$$\boldsymbol{\beta} = \begin{bmatrix} \beta_1 \\ \beta_2 \\ \vdots \\ \beta_q \\ \beta_{12} \\ \beta_{13} \\ \vdots \\ \beta_{1q} \\ \vdots \\ \beta_{q-1q} \end{bmatrix} \quad \text{and} \quad \boldsymbol{y} = \begin{bmatrix} y^1 \\ y^2 \\ \vdots \\ y^q \\ \vdots \\ y^N \end{bmatrix}$$

The solution to Equation (16) is given as:

$$\boldsymbol{\beta} = \boldsymbol{Z}^{-1}\boldsymbol{y} \tag{17}$$

Table 1: Osadebe's Regression Model(Si) and (Zi) components.

S/N	Mix ratios				Component's fraction			
	Water	Cement	Sand	Coarse /EPS	Water	Cement	Sand	Coarse /EPS
	S_1	S_2	S_3	S_4	Z_1	Z_2	Z_3	Z_4
1	0.35	1	1	2	0.08	0.229885	0.229885	0.45977
2	0.44	1	1.5	3	0.074	0.16835	0.252525	0.505051
3	0.45	1	2	3	0.07	0.155039	0.310078	0.465116
4	0.5	1	3	6	0.048	0.095238	0.285714	0.571429
5	0.43	1	2	4	0.058	0.13+459	0.269179	0.538358
6	0.48	1	2.5	5	0.053	0.111359	0.278396	0.556793
7	0.51	1	4	6	0.044	0.086881	0.347524	0.521286
8	0.33	1	3	5	0.035	0.107181	0.321543	0.535906

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9	0.55	1	2	5	0.064	0.116959	0.233918	0.584795
10	0.6	1	2.5	6	0.059	0.09901	0.247525	0.594059
Control Points								
11	0.55	1	1	2	0.121	0.21978	0.21978	0.43956
12	0.6	1	1.5	3	0.098	0.245902	0.245902	0.491803
13	0.44	1	2	4	0.059	0.134409	0.268817	0.537634
14	0.5	1	2.5	5	0.056	0.277778	0.277778	0.555556
15	0.4	1	3	6	0.038	0.096154	0.288462	0.576923
16	0.43	1	3.5	6.5	0.038	0.306212	0.306212	0.568679
17	0.35	1	4	7	0.028	0.080972	0.323887	0.566802
18	0.51	1	4.5	7.5	0.038	0.333087	0.333087	0.555144
19	0.48	1	4.8	7.6	0.035	0.072046	0.345821	0.54755
20	0.47	1	5	8	0.032	0.345543	0.345543	0.552868

Table 2: Coefficients of the component proportion to determine Osadebe's regression

Compressive Strength	Water Absorption	Cost Per M3
-21405	175.12	-1818500.00
5425.1	-3.3217	627840.00
19656	-197.67	554490.00
-8403.9	145.3	-456980.00
21054	-139.48	723250.00
25965	-407.4	200910.00
1.54E+05	-2079	10077000.00
-53865	587.59	-678520.00
-72119	921.07	-5049700.00
5775.9	-270.69	1116200.00

4. MATERIALS AND METHODS

The study adopted experimental and empirical modelling design methods. The materials used included water, sand, coarse aggregates, ordinary limestone cement expanded polystyrene beads. A Calabar cement dealer supplied the ordinary limestone cement of the Lafarge brand. Standard water as per [4] was used for specimen mixes and curing by [4] and [5]. Sand was obtained from the Calabar River beach. Granite chippings, also known as coarse aggregates, were obtained from S and V quarries limited in Akamkpa, which is located in Nigeria's Cross River State. The polystyrene beads used for this study were purchased from a Nigerian distributor in Owerri. Except for coarse aggregates and polystyrene beads, which were combined and batched together as a single material in volume, the rest of the materials were batched according to their respective weights. Therefore, the total number of components was 4. The Minitab, SPSS and MATLAB software were used in conducting the mathematical analysis and developing the models. The ***Predictor*** and ***Optimixer*** programs were developed in MATLAB to predict the model results as well as determine the optimal mixes based on equations 13, 16 and 17. In the laboratory, the various components were manually mixed, and the 28th day test served as the basis for conducting the model optimization. The partial replacement level considered was 12% replacement (88% coarse aggregate + 12% polystyrene) using a mix ratio of 1:3:6 (cement, sand and coarse aggregate) in accordance with [6] for Structural Concrete of 20 N/mm^2. Specimens curing was done as per [4] and [5]. The experiment was carried out in Workshop Five of the Strength of Material Lab at Cross River University of Technology in Calabar, Nigeria. The compressive strength of twenty different 150mm by 150mm cubes was determined by moulding and crushing them in their hardened state on day 28. The crushing force was calculated in accordance with [7] after the hardened concrete was subjected to an increasing compressive load up until the point of failure.

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5. RESULTS AND DISCUSSION OF FINDINGS

The regression analysis are presented in Table 3 and Table 4. The unstandardized coefficients in Table 3 will be fitted into equation 13 to produce the 28th day model equation for predicting the lightweight concrete compressive strength. The polynomial coefficients were determined and the model equation established and tested for goodness using the *F* statistic.

$\beta_1 = -21405,\ \beta_2 = 5425.1,\ \beta_3 = 19656,\ \beta_4 = -8403.9,\ \beta_{12} = 21054,\ \beta_{13} = 25965,\ \beta_{14} = 1540000,\ \beta_{23} = -53865,\ \beta_{24} = -72119,\ \beta_{34} = 5775.9$ -

As a result, the Osadebe's second degree model's resulting regression equation is:

$$Y = -21405Z_1 + 5425.1Z_2 + 19656Z_3 - 8403.9Z_4 + 21054Z_1Z_2 + 25965Z_1Z_3 + 1540000Z_1Z_4 - 53865Z_2Z_3 - 72119Z_2Z_4 + 5775.9\ Z_3Z_4 \quad (18)$$

5.1 Test for lack-of-fit

The lack of fit is insignificant, as shown in Table 4, with a p-value of 0.00, which is less than 0.05. Therefore, the conclusion is that Equation 18 is sufficient for predicting the Osadebe's model's 28th day strength of expanded polystyrene concrete.

5.2 Normal probability plot.

Figure 1 shows that the residuals are somewhat close to the reference line, indicating that the data does follow a normal distribution. Also, the estimated regression coefficient is presented in Table 3.

Table 3: Estimated Regression Coefficients for Compressive strength

Compressive Strength						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	Z_1	-21405	486.652	-.658	-.503	.625
	Z_2	5425.1	157.098	6.789	3.384	.006
	Z_3	19656	63.370	2.641	1.756	.107
	Z_4	-8403.9	851.852	-.018	-.041	.968
	$Z_1 * Z_2$	21054	1507.346	-.930	-.871	.403
	$Z_1 * Z_3$	25965	1118.944	1.223	.796	.443
	$Z_1 * Z_4$	1540000	344.379	.200	.232	.821
	$Z_2 * Z_3$	-53865	243.446	-.149	-.135	.895
	$Z_2 * Z_4$	-72119	263.024	-8.213	-4.522	.001
	$Z_3 * Z_4$	5775.9	486.652	-.658	-.503	.625

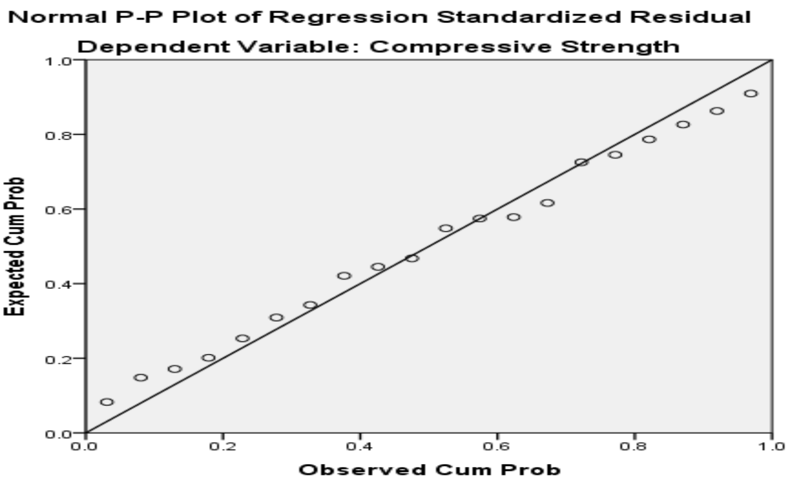

Figure 1. Normal probability plot for compressive strength residuals of Osadebe's model

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Table 4: Analysis of Variance for Compressive strength (Osadebe's component proportion model)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	10180.817	9	1131.202	139.428	.000[c]
	Residual	89.245	11	8.113		
	Total	10270.062[d]	20			

6. MODEL RESULTS

Data in Table 5 show the predicted results using equation (17). The model results to large extend agree with the experiments particularly for mix 1, mix4, mix 9 and mix 10. For mixes with compressive strength that were lesser than zer0 (0<), the results were assigned a strength value of zero (0) for ease of computation. This results were obtained from mix 11, mix 14, mix 16, mix 18 and mix 20. This is graphically illustrated in figure 2.

Table 5: Predicted Result of Osadebe's Regression Model

S/N	Z_1	Z_2	Z_3	Z_4	$Z_1 * Z_2$	$Z_1 * Z_3$	$Z_1 * Z_4$	$Z_2 * Z_3$	$Z_2 * Z_4$	Z3 * Z4	Predicted Compressive Strength	Experimental Compressive Strength
1	0.0909091	0.2020202	0.3030303	0.4040404	0.018	0.028	0.037	0.061	0.082	0.122	35.59	31.09
2	0.0666667	0.1333333	0.2666667	0.5333333	0.009	0.018	0.036	0.036	0.071	0.142	32.43	26.31
3	0.0513393	0.1116071	0.2790179	0.5580357	0.006	0.014	0.029	0.031	0.062	0.156	29.12	18.79
4	0.0421456	0.0957854	0.2873563	0.5747126	0.004	0.012	0.024	0.028	0.055	0.165	16.10	16.01
5	0.0763052	0.1606426	0.2811245	0.4819277	0.012	0.021	0.037	0.045	0.077	0.135	28.01	26.04
6	0.0654206	0.1437815	0.2875629	0.5032351	0.009	0.019	0.033	0.041	0.072	0.145	18.05	24.9
7	0.0578298	0.1299545	0.2923977	0.5198181	0.008	0.017	0.030	0.038	0.068	0.152	15.45	25.46
8	0.0583232	0.1215067	0.27339	0.5467801	0.007	0.016	0.032	0.033	0.066	0.149	16.92	25.14
9	0.0523969	0.1114827	0.2787068	0.5574136	0.006	0.015	0.029	0.031	0.062	0.155	25.11	25.53
10	0.0463918	0.1030928	0.2835052	0.5670103	0.005	0.013	0.026	0.029	0.058	0.161	16.42	16.54
11	0.0705615	0.1517451	0.284522	0.4931715	0.011	0.020	0.035	0.043	0.075	0.140	0	28.01
12	0.0580848	0.1255887	0.2825746	0.533752	0.007	0.016	0.031	0.035	0.067	0.151	11.47	25.2
13	0.046883	0.1030397	0.2833591	0.5667182	0.005	0.013	0.027	0.029	0.058	0.161	19.62	16.49
14	0.0614334	0.1365188	0.2901024	0.5119454	0.008	0.018	0.031	0.040	0.070	0.149	0	25.72
15	0.066092	0.1436782	0.2873563	0.5028736	0.009	0.019	0.033	0.041	0.072	0.145	2.10	26.86
16	0.054683	0.1163467	0.2763234	0.5526469	0.006	0.015	0.030	0.032	0.064	0.153	0	22.16
17	0.0520446	0.1115242	0.2788104	0.5576208	0.006	0.015	0.029	0.031	0.062	0.155	33.17	25.06
18	0.0577889	0.1256281	0.2826633	0.5339196	0.007	0.016	0.031	0.036	0.067	0.151	0	25.26
19	0.0549055	0.120012	0.2850285	0.540054	0.007	0.016	0.030	0.034	0.065	0.154	15.55	22.76
20	0.0503205	0.1109115	0.2842106	0.5545574	0.006	0.014	0.028	0.032	0.062	0.158	0	16.96

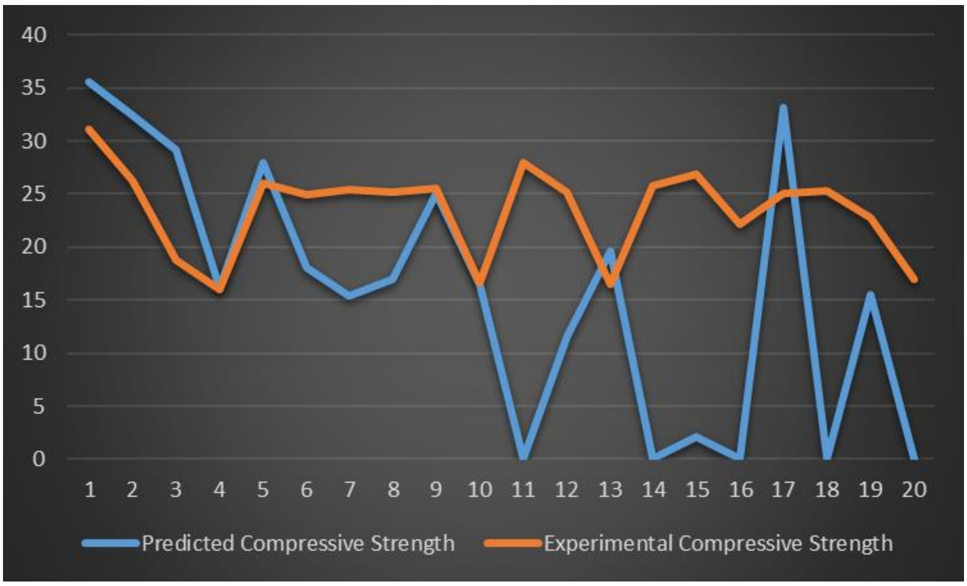

Figure 2: Graph showing the model and experimental results.

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7. OPTIMIZATION RESULT

The optimized mix ratios produced by the optimixer based on the matrix's component proportion values are shown in Table 6. According to the optimized results, mix 17 will yield the highest strength of 40.99 N/mm^2 from a water, cement, sand and coarse aggregate (at 88% coarse aggregate + 12% polystyrene) of 0.462, 1, 2.42 and 4.68 respectively. This optimized results conforms to [8] and [9]. At 12% partial replacement of the coarse aggregates, this indicates that the optimized mix can produce a compressive strength suitable for residential and commercial structures. All other mixes produced suitable results as well suitable enough for residential applications and as wall partitions in high rise buildings.

Table 6: Optimization result

SN	Water	Cement	Sand	Coarse aggregate	Compressive Strength	COST/cum	UCB
					N/Square mm	Naira	Naira
1	0.449	1	2.77	5.52	36.31758	14788.08	189.26
2	0.452	1	2.72	5.42	37.05067	14736.59	188.6
3	0.456	1	2.67	5.32	37.80091	14680.26	187.88
4	0.458	1	2.61	5.18	38.61263	14630.42	187.24
5	0.462	1	2.56	5.08	39.40137	14562.53	186.37
6	0.466	1	2.51	4.98	40.20902	14488.45	185.42
7	0.468	1	2.45	4.84	41.08766	14419.2	184.54
w8	0.452	1	2.65	5.22	37.76502	14702.19	188.16
9	0.456	1	2.6	5.12	38.53668	14639.81	187.36
10	0.462	1	2.49	4.88	40.18366	14513.83	185.75
11	0.449	1	2.64	5.16	37.68624	14719.77	188.38
12	0.453	1	2.59	5.06	38.45907	14657.42	187.59
13	0.464	1	2.43	4.74	41.06522	14450.18	184.93
14	0.455	1	2.53	4.92	39.29551	14610.9	186.99
15	0.459	1	2.48	4.82	40.10764	14535.85	186.03
16	0.45	1	2.58	5	38.37975	14683.63	187.92
17	0.462	1	2.42	4.68	40.98944	14476.99	185.28
18	0.456	1	2.47	4.76	40.02962	14567.3	186.43
19	0.447	1	2.57	4.94	38.29866	14718.86	188.37
20	0.451	1	2.52	4.84	39.09194	14651.39	187.51

8. CONCLUSION AND RECOMMENDATION

The trial-and-error mix method has not been effective due to the difficulty of determining the ideal mix proportion, especially when more components are involved, such as when Expanded Polystyrene Beads were used to partially replace aggregate. According to the findings of this study, employing a mathematical model is therefore more effective and accurate. Without the need for additional trial mixes, this model makes it simple to replicate the mix proportions necessary to achieve the desired compressive strength for lightweight concrete performance. This will invariably reduce the environmental and financial cost for construction. This is in line with the United Nations sustainable development goal (SDG) 11, which advocates for sustainable cities and communities, by providing affordable housing. In any case, it is suggested that further examinations ought to be completed with bigger blend proportions, in other to find out the best advanced compressive strength for polystyrene lightweight concrete, substantial enough to provide higher strength properties.

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