International Journal of Recent Engineering Science (IJRES) Volume 6 Issue 3, 09-18, May-Jun 2019
ISSN: 2349 – 7157 / doi: 10.1445/23497157/IJRES-V6I3P102

Prediction of Cost of Chikoko-Cement Concrete Using Osadebe's Regression Polynomial

J. I. Arimanwa[1] and S. Sule[2]

[1] (Department of Civil Engineering, Federal University of Technology, P.M.B. 1526, Owerri, Nigeria)
[2] (Department of Civil and Environmental Engineering, University of Port Harcourt P.M.B. 5323, Rivers State, Nigeria)

Abstract

In this paper, Osadebe's regression polynomial is used to predict the cost of chikoko-cement concrete. The cost model was formulated based on the unit costs of the component materials. The expected cost values were compared with the observed cost values and were found to coincide at all points of observation. The reliability of the model was assessed using F-statistic at a 5% level of significance and was found to be adequate. A computer program written in BASIC language was invoked to select the optimum mix ratios corresponding to the desired overall cost value and vice versa. The computer program is simple and requires less effort to achieve the desired results.

Keywords:

Chikoko-cement concrete, Level of significance, Mix ratios, observed cost, Osadebe's regression theory, Overall cost, Predicted cost

I. INTRODUCTION

The increase in the population of Nigerians in recent times, coupled with the recent rise in the price of cement, has reduced the pace of infrastructural developments in Nigeria as most citizens of Nigeria cannot afford their decent shelters [1-3]. Nigeria is a country where different local buildings and construction materials, such as stones, sand, laterite, and timber abound. Nevertheless, the search for decent shelter is a source of concern [4]. Concrete has been rated as the most universal of all structural materials in the world [5].

The quest for decent accommodation amid the present economic situation in Nigeria is on the increase [6]. This scenario is directly proportional to the rise in the local demand for cement by both the local and urban dwellers. According to Johnarry [13], the increase in the number of cement factories here and there to increase the availability of cement cannot still provide a lasting solution to the problem of scarcity of cement in Nigeria. According to him, even an effort by the Federal Government of Nigeria to engage in the importation of cement is always a difficult task as it always involves high foreign exchange.

The search for cement replacement materials in concrete production now becomes an issue to contend with, as that appears to be the only way out of the present housing problem in Nigeria.

The potential of chikoko clay as a partial replacement for cement in concrete production has been studied by some researchers [8-9]. The addition of chikoko clay in concrete will increase the number of component materials and will eventually make it difficult to identify the cheapest mix ratios that will produce the desired strength. Concrete structures and houses perform better in service when the component materials are blended in optimum proportions. The use of laboratory trial mixes is practically not economical [10].

In this paper, a mathematical model is developed based on Osadebe's regression technique to predict the overall cost of chikoko-cement concrete. A BASIC computer program is invoked to facilitate quick selection of the best mix ratios corresponding to a desired overall cost value and vice versa.

II. MATERIALS AND METHODS

The cement used as a binder is ordinary Portland cement, with properties meeting the requirements of [11]. The water used was clean and free from any form of organic matter. The fine aggregate was sharp river sand obtained from Otamiri River at the Federal University of Technology, Owerri, Imo State. The maximum size was 5mm. The provisions of [12] carried out grading and properties. The granites used as coarse aggregates were obtained in bags at Ihiagwua in Imo State. They were washed correctly and sundried for two weeks to remove dirt before concreting. The maximum size was 20mm. The chikoko clay was obtained in bags from the mangrove swamps of the Eagle's Island in Port Harcourt, Rivers State. It was sundried for three weeks, after which it was ground and sieved to obtain particles of fineness close to that of cement. An oxide composition test was carried out on a dry chikoko clay sample to ascertain its pozzolanic properties (Table 1).

III. DEVELOPMENT OF COST MODEL

According to Obam and Osadebe [1], the overall cost for a 5-component mixture can be approximated by a polynomial function as follows:

$$Y = \alpha_1 Z_1 + \alpha_2 Z_2 + \alpha_3 Z_3 + \alpha_4 Z_4 + \alpha_5 Z_5 + \alpha_{12} Z_1 Z_2 + \alpha_{13} Z_1 Z_3 + \alpha_{14} Z_1 Z_4 + \alpha_{15} Z_1 Z_5 + \alpha_{23} Z_2 Z_3 + \alpha_{24} Z_2 Z_4 + \alpha_{25} Z_2 Z_5 + \alpha_{34} Z_3 Z_4 + \alpha_{35} Z_3 Z_5 + \alpha_{45} Z_4 Z_5 \quad (1)$$

Where: Y = overall cost corresponding to a particular point of observation,

Z_i, Z_j, Z_{ij} = predictor variables, α_i, α_{ij} = coefficients of the cost model

Consider S_i and Z_i to be the actual ratio and fractional portions of the mixture.
If the mixture is assumed to have a total volume denoted by S, then:

$$S_1 + S_2 + S_3 + S_4 + S_5 = S \quad (2)$$

Dividing both sides of equation (2) by S yields:

$$S_1/S + S_2/S + S_3/S + S_4/S + S_5/S = 1 \quad (3)$$

Let:

$$S_i/S = Z_i \quad (i = 1, 2, 3, 4, 5) \quad (4)$$

Equation (3) now becomes:

$$Z_1 + Z_2 + Z_3 + Z_4 + Z_5 = 1 \quad (5)$$

Where: Z_1, Z_2, Z_3, Z_4 *and* Z_5 = fractional portion of water, cement, chikoko, sand and coarse aggregate, respectively

A. Coefficients of the cost function

For the nth point of observation, $y^{(n)}$ the vector of the corresponding predictor variables is:

$$Z^{(n)} = [Z_1^{(n)}, Z_2^{(n)}, Z_3^{(n)}, Z_4^{(n)}, Z_5^{(n)}] \quad (6)$$

The response function $Y^{(n)}$ corresponding with the predictors $Z_i^{(n)}$ at the nth point of observation is given by:

$$Y^{(n)} = \sum_{i=1}^{5} \alpha_i Z_i^{(n)} + \sum_{1 \le i \le j}^{5} \alpha_{ij} Z_i^{(n)} Z_j^{(n)} \quad (7)$$

Where: $1 \le i \le j \le 5$ *and* $n = 1, 2, 3, \ldots, 15$

Putting equation (7) in matrix form yields:

$$[y^{(n)}] = [Z^{(n)}][\alpha] \quad (8)$$

The constant coefficients α_i in equation (8) are obtained from equation (8) as follows:

$$[\alpha] = [Z^{(n)}]^{-1}[Y^{(n)}] \quad (9)$$

The actual proportions $S_i^{(n)}$ and their corresponding fractional portions $Z_i^{(n)}$ are presented in Table 2. The $Z^{(n)}$ values are used to determine $Z^{(n)}$ matrix and $Z^{(n)}$ matrix inverse (Tables 3 and 4). The values of $Y^{(n)}$ the matrix are obtained from Table 6.

According to Obam and Osadebe, the number of experiments required to model the overall cost function as a quadratic surface is given by:

$$N = \frac{(q + n - 1)!}{n!(q - 1)!} \quad (10)$$

Where: n, q = Degree of the polynomial and number of concrete components, respectively
One cubic meter of chikoko-cement concrete weighs 2400 Kg. Therefore, the observed overall cost of chikoko-cement concrete per observation point is given by:

$$OC = \frac{2400}{TZT} * \begin{pmatrix} S_1 * CW + S_2 * CC + S_3 * CCH \\ + S_4 * CS + S_5 * CG \end{pmatrix} \quad (11)$$

Where: $CCC, CW, CC, CCH, CS, CG =$ the overall cost of concrete, cost of water, cost of cement, cost of chikoko, cost of sand, and cost of coarse aggregate, respectively.

$$TZT = S_1 + S_2 + S_3 + S_4 + S_5 \quad (12)$$

Table 1, Oxide Composition of Chikoko Clay

CaO	SiO_2	$Al2O_3$	Fe_2O_3	MgO	Na_2O	K_2O	SO_3	TiO_2	ZnO	LoI
9.85	41.21	10.15	2.31	5.02	1.97	8.17	0.08	0.72	0.09	6.51

Source: Authors' experiment

Table 2, Actual mix ratios and component fractions based on Osadebe's second degree polynomial

S/N	Actual Mix Ratios					Component's Fractional Portion				
	S1	S2	S3	S4	S5	Z1	Z2	Z3	Z4	Z5
1	0.52601	0.947	0.053	2.1	4.2	0.06721305	0.121006745	0.006772289	0.268335972	0.536671944
2	0.566	0.91901	0.081	2.02	4.04	0.074219677	0.120509939	0.010621544	0.264882947	0.529765893
3	0.589	0.823	0.17701	1.91	3.82	0.080475365	0.112446902	0.024184965	0.260964256	0.521928512
4	0.611	0.889	0.111	2.1601	4.32	0.075515072	0.109873812	0.013718777	0.266972352	0.533919986
5	0.596	0.846	0.154	2.15	4.301	0.074064869	0.105132347	0.019137567	0.267180316	0.534484901
6	0.546005	0.933005	0.067	2.06	4.12	0.070671019	0.120761557	0.008672005	0.266631806	0.533263612
7	0.557505	0.885	0.115005	2.005	4.01	0.07362222	0.1168701	0.01518717	0.264773503	0.529547006
8	0.568505	0.918	0.082	2.13005	4.26	0.071433194	0.115347573	0.010303378	0.267642807	0.535273049
9	0.561005	0.8965	0.1035	2.125	4.2505	0.070686656	0.112959042	0.013041005	0.267750099	0.535563198
10	0.5775	0.871005	0.129005	1.965	3.93	0.077283269	0.116561236	0.017263945	0.26296385	0.5259277
11	0.5885	0.904005	0.096	2.09005	4.18	0.074886541	0.115034507	0.012215986	0.265958564	0.531904402
12	0.581	0.882505	0.1175	2.085	4.1705	0.074140194	0.112614616	0.014993929	0.266062486	0.532188775
13	0.6	0.856	0.144005	2.03505	4.07	0.077870956	0.111095897	0.018689678	0.264118816	0.528224653
14	0.5925	0.8345	0.165505	2.03	4.0605	0.077118263	0.108616355	0.021541701	0.264219534	0.528504146
15	0.6035	0.8675	0.1325	2.15505	4.3105	0.074791952	0.107509558	0.016420768	0.26707605	0.534201672
Checkpoints for model validation										
16	0.560336667	0.896336667	0.10367	2.01	4.02	0.073822308	0.118089081	0.013658144	0.264810156	0.529620311
17	0.575336667	0.886333333	0.11367	2.0567	4.113333333	0.074281334	0.114433907	0.014675858	0.265539169	0.531069731
18	0.57767	0.894	0.106	2.1367	4.273666667	0.072316894	0.111917363	0.013269844	0.267487505	0.535008394
19	0.5730025	0.8945025	0.1055025	2.047525	4.095	0.074266099	0.115935290	0.013674040	0.265377017	0.530747554

20	0.5805025	0.87625	0.1237525	2.080025	4.16025	0.074225653	0.112041254	0.015823550	0.265961324	0.531948220
21	0.5692525	0.8837525	0.1162525	2.045	4.09025	0.073885644	0.114705904	0.015088894	0.265429036	0.530890521
22	0.551755	0.9090025	0.0910025	2.0325	4.065	0.072131814	0.118835351	0.011896902	0.265711977	0.531423955
23	0.5767525	0.8655	0.1345025	2.0775	4.1555	0.073850268	0.110822939	0.017222371	0.266013466	0.532090955
24	0.563604	0.905002	0.095002	2.05802	4.116	0.072839377	0.116961167	0.012277923	0.265975568	0.531945966
25	0.577602	0.884802	0.115202	2.06802	4.1362	0.074224482	0.113701077	0.014803980	0.265749967	0.531520494
26	0.573603	0.887601	0.112402	2.07602	4.1522	0.073521635	0.113768367	0.014407140	0.266094117	0.532208742
27	0.586101	0.879002	0.121002	2.07403	4.1482	0.075060944	0.112572271	0.015496518	0.265617446	0.531252822
28	0.5652535	0.8865515	0.1134525	2.053	4.10625	0.073176639	0.114771265	0.014687344	0.265777462	0.531587289
29	0.5744525	0.891002	0.1090015	2.07752	4.1552	0.073580063	0.114126030	0.013961707	0.266103902	0.532228299
30	0.5660045	0.9037005	0.0963	2.12302	4.2463	0.071327198	0.113883237	0.012135609	0.267540397	0.535113559

Where:

S_1 = actual proportion of water

S_2 = actual proportion of cement

S_3 = a proportion of chikoko

S_4 = actual proportion of sand

S_5 = actual proportion of granite

Z_1 = fractional portion of water

Z_2 = fractional portion of cement

Z_3 = fractional portion of chikoko

Z_4 = fractional portion of sand

Z_5 = fractional portion of granite

Table 3, Zn Matrix Based on Osadebe's Second Degree Polynomial

Z_1	Z_2	Z_3	Z_4	Z_5	Z_1Z_2	Z_1Z_3	Z_1Z_4	Z_1Z_5	Z_2Z_3	Z_2Z_4	Z_2Z_5	Z_3Z_4	Z_3Z_5	Z_4Z_5
0.06721305	0.121006745	0.006772289	0.268335972	0.536671944	0.008133232	0.000455186	0.018035679	0.036071358	0.000819493	0.032470463	0.064940925	0.001817249	0.003634497	0.144008388
0.074219677	0.120509939	0.010621544	0.264882947	0.529765893	0.008944209	0.000788328	0.019659527	0.039319054	0.001280002	0.031921028	0.063842055	0.002813466	0.005626932	0.140325951
0.080475365	0.112446902	0.024184965	0.260964256	0.521928512	0.009049205	0.001946294	0.021001194	0.042002387	0.002719524	0.029344622	0.058689244	0.006311411	0.012622823	0.136204686
0.075515072	0.109873812	0.013718777	0.266972352	0.533919986	0.008297129	0.001035974	0.020160436	0.040319006	0.001507334	0.02933327	0.058663824	0.003662534	0.007324729	0.142541875
0.074064869	0.105132347	0.019137567	0.267180316	0.534484901	0.007786614	0.001417421	0.019788675	0.039586554	0.002011977	0.028089294	0.056191652	0.005113181	0.01022874	0.142803845

0.070671019	0.120761557	0.008672005	0.266631806	0.533263612	0.008534342	0.000612859	0.018843141	0.037686283	0.001047245	0.032198872	0.064397744	0.002312232	0.004624465	0.14218504
0.07362222	0.1168701	0.01518717	0.264773503	0.529547006	0.008604236	0.001118113	0.019493213	0.038986426	0.001774926	0.030944106	0.061888212	0.00402116	0.008042321	0.140210016
0.071433194	0.115347573	0.010303378	0.267642807	0.535273049	0.008239645	0.000736003	0.01911858	0.038236263	0.00118847	0.030871948	0.061742447	0.002757625	0.005515121	0.143261981
0.070686656	0.112959042	0.013041005	0.267750099	0.535563198	0.007984697	0.000921825	0.018926359	0.037857172	0.001473099	0.030244795	0.060496706	0.00349173	0.006984282	0.143397099
0.077283269	0.116561236	0.017263945	0.26296385	0.5259277	0.009008233	0.001334214	0.020322706	0.040645412	0.002012307	0.030651391	0.061302783	0.004539793	0.009079587	0.138299973
0.074886541	0.115034507	0.012215986	0.265958564	0.531904402	0.008614536	0.000914813	0.019916717	0.039832481	0.00140526	0.030594412	0.061187361	0.003248946	0.006497737	0.141464531
0.074140194	0.112614616	0.014993929	0.266062486	0.532188775	0.008349269	0.001111653	0.019725924	0.039456579	0.001688536	0.029962525	0.059932234	0.003989322	0.007979601	0.141595469
0.077870956	0.111095897	0.018689678	0.264118816	0.528224653	0.008651144	0.001455383	0.020567185	0.041133359	0.002076347	0.029342517	0.058683592	0.004936296	0.009872349	0.13951407
0.077118263	0.108616355	0.021541701	0.264219534	0.528504146	0.008376305	0.001661259	0.020376151	0.040757322	0.002339781	0.028698563	0.057404194	0.005691738	0.011384879	0.139641119
0.074791952	0.107509558	0.016420768	0.26707605	0.534201672	0.00804085	0.001228141	0.019975139	0.039953986	0.00176539	0.028713228	0.057431786	0.004385594	0.008772002	0.142672472

Table 4: Inverse of Zn Matrix Based obtained from Table 3

Z_1	Z_2	Z_3	Z_4	Z_5	Z_1Z_2	Z_1Z_3	Z_1Z_4	Z_1Z_5	Z_2Z_3	Z_2Z_4	Z_2Z_5	Z_3Z_4	Z_3Z_5	Z_4Z_5
68861.88734	83391.0578	9356.830938	3585.275594	141.8630848	-151583.542	50824.56129	-31433.89793	-6251.99463	-55890.59649	34612.02133	6883.617923	-11613.02714	-2309.333517	1426.276382
1417.537624	2467.210281	2531.776741	15219.10693	711.2766514	4250.284477	4297.382545	-9770.758848	-1943.337219	5557.916002	-12653.17904	-2516.456702	-12802.14894	-2545.795133	5780.184632
24460.8499	55223.9781	31172.00764	8114.437185	400.0677064	-73978.00843	57106.22897	-27791.28067	-5527.501822	-83280.21351	40581.72919	8070.867617	-31347.89137	-6233.74759	3029.477063
204318116	686446898	132899063.7	372509686.6	358016334	-749135171.9	329939076.5	551918114.2	-541027436.3	-604335940.7	-1012238772	992194695.5	446121802.1	-437238796.4	-730387668.7
50731986.81	170433209.4	33248863.52	92726776.03	89582309.62	-186003587.8	82233482.32	137213212.8	-134854827.1	-150618908.4	-251646212.7	247303494.7	111330631.3	-109397106.7	-182283322.8
-90092.[illegible]	-57128.[illegible]	-21635.[illegible]	-33581.[illegible]	-1492.0[illegible]	143211.6885	-90801.39295	109338.2428	21746.64636	70789.29429	-85351.42743	-16974.63195	54152.90492	10768.68321	-12948.98849

-8613.0 95675	72858 0084	18318 5965.7	-440.44 41056	73401 7891.5	18045 7548.1	73301 6952	18096 2694.1	16424 31815
16186. 00438	44118 5117.1	10742 6559	-1674.1 54381	43467 8235.3	11068 1745.3	43004 8691.7	11300 3066.9	98404 9480.1
81395. 17737	-44846 9497.9	-11014 3645.2	-8418.8 95548	-44684 5312.9	-11094 6960.6	-44117 4252.8	-11374 9553.5	-10031 74771
-30524. 55231	-10037 61982	-24152 8862	3772.0 33796	-99292 0807.9	-24693 4067.8	-98249 4737.7	-25216 5936.5	-22302 03273
-15348 2.7544	10202 20648	24760 9968.4	18966. 46982	10205 99222	24749 8020.8	10077 99342	25380 3262.2	22732 93047
28765 3.3305	61612 3628.1	14481 6413.9	71898. 48811	60276 3130.3	15139 1981.8	58966 8434.2	15806 2400.8	13583 61013
24683. 90237	55130 6658.3	12972 3004.6	-1571.1 69013	53881 0194.7	13596 5529.8	53451 1271.4	13812 1671.5	12161 06039
12410 6.2024	-56030 6802.8	-13297 9709.6	-7899.5 66103	-55379 0774.7	-13626 6415.1	-54823 9088.4	-13900 8672.6	-12395 14785
-23289 8.6329	-33881 5525	-77875 114.03	-29984. 72891	-32749 2090	-83461 008.03	-32119 4025	-86683 596.57	-74160 9265.6
43946 5.4863	77129 6593.9	17518 7973.1	67597. 15573	74850 6806.7	18631 0297.8	73422 3502.7	19354 4722.9	16817 09131
-1023.1 [illegible]	-35846 [illegible]	-89356 [illegible]	-43.799 [illegible]	-35700 [illegible]	-90090 [illegible]	-35725 [illegible]	-89965 [illegible]	-80577 [illegible]
-22492. [illegible]	-37020 [illegible]	-93883 [illegible]	-1107.1 [illegible]	-37728 [illegible]	-90365 [illegible]	-37599 [illegible]	-90999 [illegible]	-83694 [illegible]
-74689. [illegible]	-13513 [illegible]	-32142 [illegible]	-15924. [illegible]	-13173 [illegible]	-33832 [illegible]	-12885 [illegible]	-35316 [illegible]	-29909 [illegible]
-27434 [illegible]	-70166 [illegible]	-16297 [illegible]	-81086. [illegible]	-68905 [illegible]	-16913 [illegible]	-67418 [illegible]	-17662 [illegible]	-15409 [illegible]
-17541 [illegible]	-21188 [illegible]	-47062 [illegible]	-14083. [illegible]	-20324 [illegible]	-51271 [illegible]	-19987 [illegible]	-52984 [illegible]	-45867 [illegible]

B. Cost analysis of chikoko-cement concrete mixes

The unit costs of the component materials are as follows:

Water =₦3.20, Cement =₦30.00, Sand =₦1.60, Chikoko =₦4.00, and Granite =₦8.00.

The quantities and the overall cost of component materials per cubic meter of chikoko-cement concrete are given in Tables 5 and 6, respectively.

Table 5, Quantities of materials in kg per cubic meter of chikoko-cement concrete

S/No	Water	Cement	Chikoko	Sand	Granite
1.	161.311	290.416	16.253	644.006	1288.013
2.	178.127	289.224	25.492	635.719	1271.438
3.	193.141	269.873	58.044	626.314	1252.628
4.	181.236	263.697	32.925	640.734	1281.408
5.	177.756	252.318	45.930	641.233	1282.764
6.	169.610	289.828	20.813	639.916	1279.833
7.	176.693	280.488	36.449	635.456	1270.913
8.	171.440	276.834	24.728	642.343	1284.655

9.	169.648	271.102	31.298	642.600	1285.352
10.	185.480	279.747	41.433	631.113	1262.226
11.	179.728	276.083	29.318	638.301	1276.571
12.	177.936	270.275	35.985	638.550	1277.253
13.	186.890	266.630	44.855	633.885	1267.739
14.	185.084	260.679	51.700	634.127	1268.410
15.	179.501	258.023	39.410	640.983	1282.084
Control points					
16.	177.174	283.414	32.780	635.544	1271.089
17.	178.275	274.641	35.222	637.294	1274.567
18.	173.561	268.602	31.848	641.970	1284.020
19.	178.239	278.245	32.818	636.905	1273.794
20.	178.142	268.899	37.977	638.307	1276.676
21.	177.326	275.294	36.213	637.030	1274.137
22.	173.116	285.205	28.553	637.709	1275.417
23.	177.241	265.975	41.334	638.432	1277.018
24.	174.815	280.707	29.467	638.341	1276.670
25.	178.139	272.883	35.530	637.800	1275.649
26.	176.452	273.044	34.577	638.626	1277.301
27.	180.146	270.173	37.192	637.482	1275.007
28.	175.624	275.451	35.250	637.866	1275.809
29.	176.592	273.902	33.508	638.649	1277.348
30.	171.185	273.320	29.125	642.097	1284.272

Table 6, cost of materials per m^3 of chikoko-cement concrete

S/No	Water	Cement	Chikoko	Sand	Granite	Total cost (₦)
1	516.1962	8,712.486	65.01397	1,030.41	10,304.1	20,628.21
2	570.0071	8,676.716	101.9668	1,017.151	10,171.51	20,537.35
3	618.0508	8,096.177	232.1757	1,002.103	10,021.03	19,969.53
4	579.9558	7,910.914	131.7003	1,025.174	10,251.26	19,899.01
5	568.8182	7,569.529	183.7206	1,025.972	10,262.11	19,610.15
6	542.7534	8,694.832	83.25125	1,023.866	10,238.66	20,583.36
7	565.4187	8,414.647	145.7968	1,016.73	10,167.3	20,309.9
8	548.6069	8,305.025	98.91243	1,027.748	10,277.24	20,257.54
9	542.8735	8,133.051	125.1936	1,028.16	10,282.81	20,112.09
10	593.5355	8,392.409	165.7339	1,009.781	10,097.81	20,259.27
11	575.1286	8,282.485	117.2735	1,021.281	10,212.56	20,208.73
12	569.3967	8,108.252	143.9417	1,021.68	10,218.02	20,061.3

13	598.0489	7,998.905	179.4209	1,014.216	10,141.91	19,932.5
14	592.2683	7,820.378	206.8003	1,014.603	10,147.28	19,781.33
15	574.4022	7,740.688	157.6394	1,025.572	10,256.67	19,754.97
Control points						
16	566.9556	8,502.416	131.1182	1,016.871	10,168.71	20,386.07
17	570.481	8,239.238	140.8882	1,019.67	10,196.54	20,166.82
18	555.3937	8,058.05	127.3905	1,027.152	10,272.16	20,040.15
19	570.364	8,347.344	131.2714	1,019.048	10,190.35	20,258.38
20	570.0534	8,066.969	151.9067	1,021.291	10,213.4	20,023.63
21	567.4421	8,258.828	144.854	1,019.247	10,193.1	20,183.47
22	553.9723	8,556.149	114.2109	1,020.334	10,203.34	20,448
23	567.1705	7,979.251	165.3354	1,021.492	10,216.15	19,949.39
24	559.4064	8,421.204	117.8681	1,021.346	10,213.36	20,333.19
25	570.044	8,186.478	142.1182	1,020.48	10,205.19	20,124.31
26	564.6462	8,191.322	138.3085	1,021.801	10,218.41	20,134.49
27	576.4681	8,105.203	148.7666	1,019.971	10,200.05	20,050.46
28	561.997	8,263.534	140.9991	1,020.585	10,206.47	20,193.59
29	565.0953	8,217.073	134.033	1,021.839	10,218.78	20,156.82
30	547.7933	8,199.597	116.5018	1,027.355	10,274.18	20,165.43

C. Cost model development

The values of $y^{(n)}$ in Table 6 are substituted into equation (9) to yield the cost coefficients as follows:

α_1 = 29601.03149, α_2 = 501171.8682,

α_3 = 784745.5018, α_4 = 1039598.594,

α_5 = -558813.1753, α_{12} = -662531.733,

α_{13} = -1058144.401, α_{14} = 56149.64063,

α_{15} = 83209.40186, α_{23} = 9269.149098,

α_{24} = -9282247.803, α_{25} = 3612494.469,

α_{34} = -10590578.33, α_{35} = 3669474.146,

α_{45} = 335449.375

The obtained coefficient values are now substituted into equation (1) to yield:

$$Y = 29601.03149Z_1 + 501171.8682Z_2 + 784745.5018Z_3 + 1039598.594Z_4 - 558813.1753Z_5 - 662531.733\,Z_1Z_2 - 1058144.401Z_1Z_3 + 56149.64063Z_1Z_4 + 83209.40186Z_1Z_5 + 9269.149098Z_2Z_3 - 9282247.803Z_2Z_4 + 3612494.469Z_2Z_5 - 10590578.33Z_3Z_4 + 3669474.146Z_3Z_5 + 335449.375Z_4Z_5 \qquad (13)$$

Equation (13) is the mathematical model for predicting the overall cost of chikoko-cement concrete based on Osadebe's second-degree polynomial equation.

D. Test of the goodness of fit of the model

Equation (13) is tested for adequacy against the control points at a 95% confidence level using F-statistic, and the results are presented in **TABLE 7**.

Table 7, F-statistics test for control points

Control point	y_o	y_p	$y_o - \bar{y}_o$	$y_p - \bar{y}_p$	$(y_o - \bar{y}_o)^2$	$(y_p - \bar{y}_p)^2$
C_1	20,386.07	20,386.07	211.790	211.788	44855.004	44854.355
C_2	20,166.82	20,166.82	-7.460	-7.458	55.652	55.615
C_3	20,040.15	20,040.15	-134.130	-134.132	17990.857	17991.268
C_4	20,258.38	20,258.38	84.100	84.096	7072.810	7072.216
C_5	20,023.63	20,023.63	-150.650	-150.652	22695.423	22695.884
C_6	20,183.47	20,183.47	9.190	9.187	84.456	84.410
C_7	20,448.00	20,448.00	273.720	273.722	74922.638	74923.989
C_8	19,949.39	19,949.40	-224.890	-224.884	50575.512	50572.604
C_9	20,333.19	20,333.19	158.910	158.908	25252.388	25251.901
C_{10}	20,124.31	20,124.31	-49.970	-49.967	2497.001	2496.654
C_{11}	20,134.49	20,134.49	-39.790	-39.793	1583.244	1583.446
C_{12}	20,050.46	20,050.46	-123.820	-123.818	15331.392	15330.782
C_{13}	20,193.59	20,193.59	19.310	19.309	372.876	372.856
C_{14}	20,156.82	20,156.83	-17.460	-17.456	304.852	304.696
C_{15}	20,165.43	20,165.42	-8.850	-8.857	78.323	78.438
Σ	20174.280	20174.281		Σ	263672.427	263669.112

The F- statistics is given by:

$$F = S_1^{\ 2} / S_2^{\ 2} \qquad (14)$$

S_1 , S_2 = larger and smaller value of the sample variances, respectively

Let: y_o , y_p = observed and predicted cost of chikoko-cement concrete mixes, respectively

$$\bar{y}_o = \frac{\Sigma y_o}{n}\ ; \quad \bar{y}_p = \frac{\Sigma y_p}{n}$$

Using Equation (14), S_o^2 and S_p^2 are determined as follows:

$$S_o^{\ 2} = \frac{263672.427}{14} = 18833.75;$$

$$S_o^{\ 2} = \frac{263733.976}{14} = 18838.14$$

Using equation (14),

$$S_o^{\ 2} = \frac{18838.14}{18833.75} = 1.00023$$

From Fisher table, $F_{\ 0.95}(14,14) = 2.4$.

The calculated value of $F < F$ value obtained from the standard statistical table, showing that the model is adequate and can be used to predict the overall cost of chikoko-cement concrete.

IV. CONCLUSION

A regression model has been developed to predict the cost of chikoko-cement concrete using Osadebe's regression technique. The F-statistic results showed that the cost model is adequate.

The predicted cost values were found to coincide with the observed values at all points of observation, showing that the model is reliable and can be used to predict the overall cost of chikoko-cement concrete. The overall cost of chikoko-cement concrete mixes is a function of the proportion and unit costs of the component materials: water, cement, chikoko mud, sand, and coarse aggregate, respectively. With the model, any desired value of cost that falls within the region of the observed overall cost values, given any mix ratio, can be obtained with ease.

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