[Chijioke et. al., Vol.6 (Iss.6): June 2018]
(Received: May 30, 2018 - Accepted: June 29, 2018)
ISSN- 2350-0530(O), ISSN- 2394-3629(P)
DOI: 10.29121/granthaalayah.v6.i6.2018.1392

INTERNATIONAL JOURNAL OF RESEARCH – GRANTHAALAYAH
A knowledge Repository

Science

PREDICTING THE COMPRESSIVE STRENGTH OF PBA – CLAY REFRACTORY BRICKS USING RESPONSE SURFACE METHOD

Chijioke C. [*1], **Okoye P.**[2], **Igwegbe W. E.** [3], **Ugwuegbulam J.C.** [4]
[1, 3, 4] Civil Engineering Department Federal Polytechnic Nekede Owerri
[2] Mechanical Engineering Department Federal Polytechnic Nekede Owerri

Abstract

The importation of refractory materials is one of the biggest challenges industries faced in third world countries, of which Nigerian is one of them. The addition of palm bunch ash to clay in the production of clay bricks is one of the ways refractory materials are produced. The clay used here was Nsu clay. This work looked at the compressive strength of refractory bricks which is one of the properties of refractory materials. The work eliminates the traditional methods of trial and error and the rigorous mathematical analysis associated with the formation of some regression models in the prediction of some properties of refractory bricks. This was achieved by the use of Surface Response method. A regression model to predict the strength of a refractory brick was formulated, the model was found to be adequate based of the analysis of variance in which the Rsq, Rsq (adjusted) and Rsq (prediction) were found to be adequate, hence the model can be used to predict the compressive strength of refractory bricks. The optimal compressive strength was found to be 30.1513KN/m2 at a ratio of 1:0.2570 at a water/clay ratio of 4.2590. Also, from the results it can be seen that the compressive strength of bricks decrease with increase in the percentages of palm bunch ash.

Keywords: Clay; Refractory; Brick; Compressive Strength; Palm Bunch Ash.

Cite This Article: Chijioke C., Okoye P., Igwegbe W. E., and Ugwuegbulam J.C. (2018). "PREDICTING THE COMPRESSIVE STRENGTH OF PBA – CLAY REFRACTORY BRICKS USING RESPONSE SURFACE METHOD" *International Journal of Research - Granthaalayah*, 6(6), 472-479. https://doi.org/10.29121/granthaalayah.v6.i6.2018.1392.

1. Introduction

Nigeria is a third world country in dire need of cutting edge technology. The use of refractory materials such as bricks is very essential in the metallurgical industries as iron and steel industries. Almost all the metallurgical processes are heat generating system, which require refractory materials that can withstand both physical and chemical action of molten materials (Hassan et al 2014). The chief material in the production of refractory material is clay. Clay is made into refractory material by cutting molded clay into various shapes and fired in the kiln. The firing processes transform the clay into the intending use with very high compressive strength and

 ISSN- 2350-0530(O), ISSN- 2394-3629(P)
DOI: 10.5281/zenodo.1313134

excellent weathering qualities. Without refractory materials it will be very difficult to develop heavy industries and the necessary power production required for industrialization (Marwa et al 2009). Often times, admixtures such as palm bunch ash are added to raw mixes of burnt bricks in order to modify the properties or reduce the cost of the final product (Onwuka et al 2014). The addition of ash to bricks produces clay refractory. The term refractory means hard to fuse (Malu et al 2007).). Refractory materials are generally employed for the construction of furnace flues, crucible etc. used in high temperature operations because of their resistance to the corrosive action of glasses and slag present therein. The use of software to develop a model for the prediction of the compressive strength of refractory bricks is aimed at producing refractory bricks which is of optimal value, without passing through the rigorous tradition methods which is cumbersome, material wasting and time wasting.

2. Materials and method

2.1. Material

The unprocessed dry clay called Nsu clay was obtained from Isu Ihime Mbano L.G.A. of Imo State Nigeria. The palm bunch ash was obtained by burning palm bunch, a waste product from palm oil mill at Ada Palm in Ugwuta in Imo State Nigeria in the open air.

2.2. Material Preparation

The unprocessed clay was made into a slip by adding water to it, it later crushed, mashed, washed and stirred. It was later made to pass through a BS sieve with $300\mu m$ and filtered to remove oversized quartz, such as vegetables and other unwanted materials. The filtration process was repeated several times until all the clay powder was washed off completely. The filtered slip was allowed to settle after a little alum was added to fasten settlement process. After sedimentation the top was carefully filtered off leaving a slimy pest behind. Lastly the clay was dried in the sun and grounded with mortar and pestle to increase its compacting properties as well as aid proper blending with the ash.

The palm bunch ash was dried in the sun and was burnt completely in the open in an open drum. The ash from the process was then made to pass through BS sieve of $212\mu m$. The water used was a clean pipe borne water obtained from municipal water supply.

2.3. Methods

The mix proportioning refers as the mix ratios of the various components in the mixture, and was done using Surface Response Method. The total number of components are three (water, clay and palm bunch ash), so a total of twenty (20) mixes was generated by the software. The mix ratios are as seen in table 1.0. X_1, X_2 and X_3 represent the mix ratio of water/clay ratio, clay/clay ratio and palm ash/clay ratio respectively.

[Chijioke et. al., Vol.6 (Iss.6): June 2018] ISSN- 2350-0530(O), ISSN- 2394-3629(P)
(Received: May 30, 2018 - Accepted: June 29, 2018) DOI: 10.5281/zenodo.1313134

Table 1: Mix ratios from response surface

S/N	X_1	X_2	X_3
1	4.05556	1.0000	0.111111
2	4.13793	0.9999	0.149425
3	4.18648	1.0000	0.165501
4	4.20588	0.9999	0.176471
5	4.22646	1.0000	0.180575
6	4.26829	0.9999	0.219512
7	4.27711	1.0000	0.204819
8	4.28395	1.0000	0.234568
9	4.28571	1.0000	0.242236
10	4.30303	0.9999	0.212121
11	4.31707	1.0000	0.219512
12	4.32653	1.0000	0.224490
13	4.35897	0.9999	0.282051
14	4.37500	1.0000	0.250000
15	4.43421	1.0000	0.315789
16	4.44325	0.9999	0.310693
17	4.45408	1.0000	0.275510
18	4.47815	1.0000	0.285347
19	4.48387	0.9999	0.290323
20	4.60000	1.0000	0.333333

2.4. Production of Palm Bunch Ash – Clay Bricks

For each mix ratios the masses were carefully measured out using weighing balance. The clay and the ash were thoroughly in the dry state and water was added, gradually the mixed raw material was thoroughly mixed together to increase the plasticity and binding properties of the clay. When the required plasticity is obtained, the raw material mixture is cast using small moulds.

2.5. Drying Process

The cast bricks were air dried for 72 hours after which the samples were placed in a kiln for drying. The drying was carried out in order to avoid the formation of steam within the body.

2.6. Firing Process

Firing was done in an electric furnace in the laboratory, the sample were fired from $0^{O}C$ to $1200^{O}C$ and soaked at that temperature for 1 hour. The firing schedule is as follows;

Table 2: Firing schedule

Temperature	Total time taken
$0^{O}C$ to $900^{O}C$	2 hours
$900^{O}C$ to $1000^{O}C$	2 minutes
$1000^{O}C$ to $1100^{O}C$	10 minutes
$1100^{O}C$ to $1200^{O}C$	7 minutes then soaked.

2.7. Cold Crushing Strength

The cold crushing strength was determined by applying uniaxial load on the specimen in cold condition. The metallurgical mounting press was used to produce this load through the hydraulic ram. The load at which the samples fracture are noted from the dial gauge. The crushing strength can be calculated from the equation;

$$cold\ crushing\ strength\ \sigma = \frac{force\ (F)}{cross\ sectional\ area\ of\ punch\ (A)} \quad 1$$

$$cold\ crushing\ strength\ \sigma = \frac{load \times 9.81}{cross\ sectional\ area\ of\ punch\ (A)} \quad 2$$

3. Chemical Analysis of Nsu Clay

The chemical analysis was carried at the PRODA laboratory Enugu and is as presented in table 3

3.1. Results and Analysis

Table 3: Chemical analysis of Nsu clay

Compound	Chemical composition in percentage (%)
CaO	4.87
MgO	5.21
Fe_2O_3	1.76
Na_2O	0.92
K2O	1.68
Al_2O_3	24.74
P_2O_5	0.51
TiO_2	0.69
SO_3	1.1
SiO_2	46.44
Loss in ignition	9.6

Table 4: Compressive strength

S/N	X_1	X_2	X_3	Compressive strength (KN/m^2)
1	4.05556	1.0000	0.111111	29.0652
2	4.13793	0.9999	0.149425	26.4391
3	4.18648	1.0000	0.165501	25.8480
4	4.20588	0.9999	0.176471	25.6961
5	4.22646	1.0000	0.180575	23.7042
6	4.26829	0.9999	0.219512	23.5122
7	4.27711	1.0000	0.204819	23.4500
8	4.28395	1.0000	0.234568	21.6642
9	4.28571	1.0000	0.242236	21.5578
10	4.30303	0.9999	0.212121	21.0700
11	4.31707	1.0000	0.219512	20.8198
12	4.32653	1.0000	0.224490	20.7169

ISSN- 2350-0530(O), ISSN- 2394-3629(P)
(Received: May 30, 2018 - Accepted: June 29, 2018)
DOI: 10.5281/zenodo.1313134

13	4.35897	0.9999	0.282051	20.7169
14	4.37500	1.0000	0.250000	20.6281
15	4.43421	1.0000	0.315789	20.5600
16	4.44325	0.9999	0.310693	19.6100
17	4.45408	1.0000	0.275510	18.4059
18	4.47815	1.0000	0.285347	17.9501
19	4.48387	0.9999	0.290323	16.7242
20	4.60000	1.0000	0.333333	15.0100

3.2. Analysis of Results

The following terms cannot be estimated and were removed:
X2*X2

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	8	220.122	27.5153	67.93	0.000
Linear	3	163.748	54.5827	134.76	0.000
X1	1	2.883	2.8826	7.12	0.022
X2	1	0.491	0.4905	1.21	0.295
X3	1	0.698	0.6981	1.72	0.216
Square	2	3.885	1.9423	4.80	0.032
X1*X1	1	1.324	1.3245	3.27	0.098
X3*X3	1	0.657	0.6571	1.62	0.229
2-Way Interaction	3	2.765	0.9218	2.28	0.137
X1*X2	1	0.952	0.9523	2.35	0.153
X1*X3	1	1.037	1.0365	2.56	0.138
X2*X3	1	0.352	0.3517	0.87	0.371
Error	11	4.455	0.4050	-	-
Total	19	224.578	-	-	-

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.636425	98.02%	96.57%	91.51%

Coded Coefficients

Term	Effect	Coef SE	Coef	T-Value	P-Value	VIF
Constant	-	20.944	0.311	67.25	0.000	-
X1	-30.73	-15.36	5.76	-2.67	0.022	365.25
X2	0.474	0.237	0.215	1.10	0.295	2.09
X3	14.85	7.43	5.66	1.31	0.216	432.16
X1*X1	-64.6	-32.3	17.9	-1.81	0.098 c	-
X3*X3	-37.1	-18.6	14.6	-1.27	0.229	1031.74
X1*X2	3.63	1.82	1.18	1.53	0.153	15.41
X1*X3	103.5	51.8	32.4	1.60	0.138	4466.63
X2*X3	-1.90	-0.95	1.02	-0.93	0.371	14.52

 ISSN- 2350-0530(O), ISSN- 2394-3629(P)
DOI: 10.5281/zenodo.1313134

Regression Equation in Uncoded Units

$$Y = 528371 - 130074X_1 - 534737X_2 + 163925X_3 - 436X_1^2 - 1504X_2^2 + 133415X_3^2 + 1711X_1X_3 - 170605X_2X_3 \quad 3$$

Equation 3 in the model equation for the prediction of the compressive strength of refractory bricks.

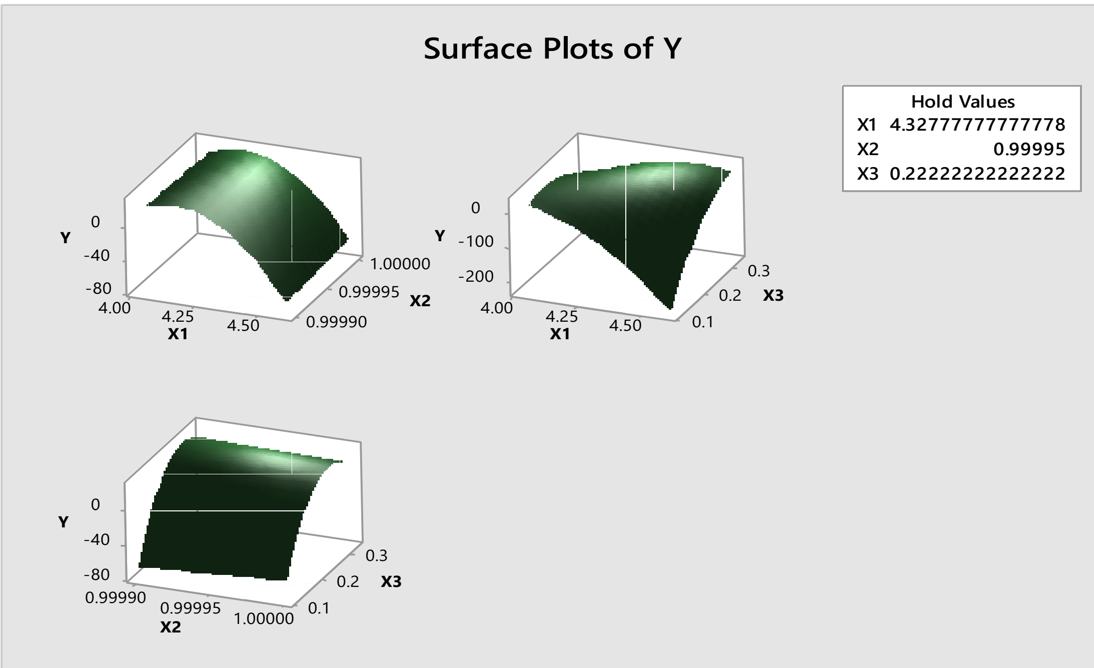

Figure 1: The interactions between the various mixes and the compressive strength

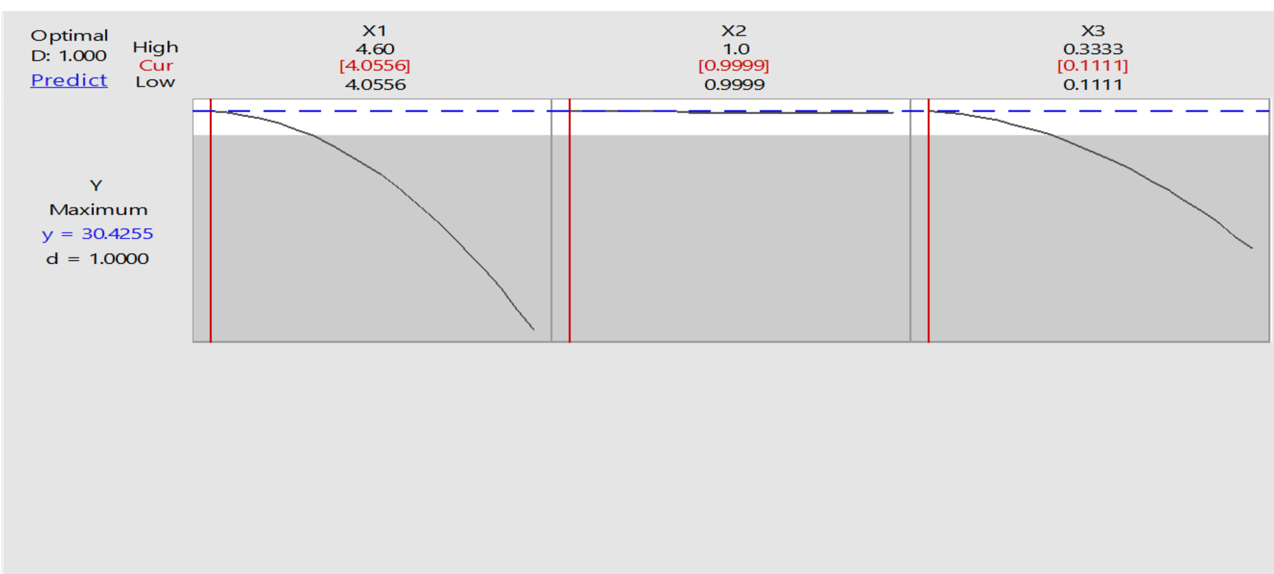

Figure 2: The maximum compressive strength (30.4255KN/m^2) at mix ration of 1.000:0.1111 and water/clay ratio of 4.0556

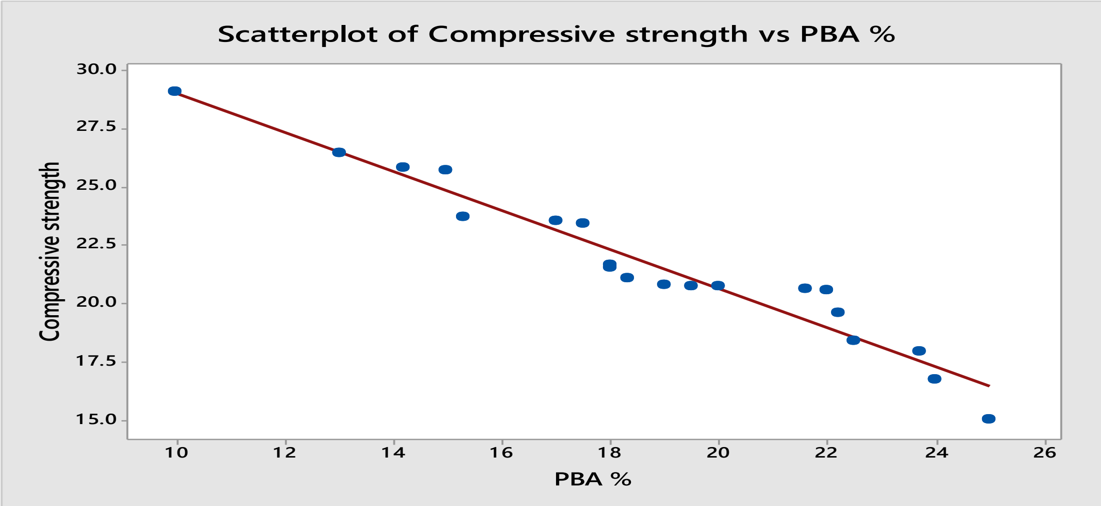

Figure 3: The graph of percentage of PBA against compressive strength

3.3. Discussion of Results

Twenty mixes were used based on the number generated by the software. From the results it can be seen that the addition of palm bunch ash to clay bricks reduces the compressive strength of the brick, this is because as more ash is added more pores are created which in turn reduces the compressive strength. The ash is added to the brick to enhance their properties. The interaction between the mixes and the compressive strength is as shown in fig 1.0. The figure shows all the interactions against the compressive strength. The figure shows the interaction that can give the maximum and the minimum compressive strength. The maximum compressive strength of strength 30.4255KN/m^2 at mix ration of 1.000:0.1111 and water/clay ratio of 4.0556 was achievable. The graph on figure 3 shows that as the percentage of palm bunch increases the lower the compressive strength of the refractory bricks produced. From the analysis of the results the Rsq value is 98.02% which means that the model can be use to predict responses from the various mixes, hence the model can be used to predict the compressive strength of refractory bricks. The Rsq(adj)) value is 96.57% which shows how well the model predicts new observations. The Rsq(pred) value is 91.51% which is okay.

3.4. Conclusion

The addition of palm bunch ash to bricks reduces the compressive strength of refractory brick. This is because as more ash is added to the brick more pores are created which in turn reduce the compressive strength of the refractory material. This pores are created when the ash are burnt off during the sintering process. The use of Surface Response Method reduces the rigorous mathematical analysis encountered in the formation of regression models. A regression model that can be used to predict the compressive strength of refractory bricks was developed based on the mixes produce. From this, refractory clay bricks with desired compressive strength can be produced locally and this will go a long way in discouraging the importation of refractory materials for our industries; hence reduce the stress on our local currency. This will also encourage the growth of our local industries.

ISSN- 2350-0530(O), ISSN- 2394-3629(P)
(Received: May 30, 2018 - Accepted: June 29, 2018)
DOI: 10.5281/zenodo.1313134

References

[1] Hassan M.A., Yami A.M., Raji A., and Ngala M. J. (2014); 'Effects of Sawdust and Rice Husk Additives on Properties of Local Refractory Clay', The International Journal of Engineering and Science (IJES), Volume 3, Issue 8, Pages 40-44.

[2] Elngar M. A.G., Mohamed F. M., El-Bohy S. A.H., Sharaby C. M., and Shalabi M. E. H. (2009); 'Factors Affected the Performance of Fire Clay Refractory Bricks', Górnictwo i Geoinżynieria, Rok 33, Zeszyt 4.

[3] Onwuka D.O., Chijioke C., Ibearugbulam O. H., Obilonu A. N, and Adinna B.O, (2014); 'Computer Program for the Determination of Optimum Compressive Strength of PBA – Clay Refractory Bricks', International Journal of Scientific and Research Publications, Volume 4, Issue 3.

[4] Malu, A. and Babson, A. (2007); 'Production Insulation Refractory Bricks with Kaolin and Saw Dust', Journal for Engineering and Applied Science, 2 (12), Pp 1697 – 199.

*Corresponding author.
E-mail address: cjuc2000@ gmail.com