Journal of Engineering Research and Reports

20(4): 106-116, 2021; Article no.JERR.66642
ISSN: 2582-2926

Factorial Design of Concrete Production in Hot and Warm Humid Zones in South East Nigeria

M. Odoanyanwu Ndubuisi[1*], H. Ivoke Ifeanyichukwu[1] and C. Odom Uzodimma[2]

[1]Department of Architecture, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria.
[2]Department of Architectural Technology, Akanu Ibiam Federal Polytechnic, Unwana, Ebonyi State, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JERR/2021/v20i417300
Editor(s):
(1) Dr. Djordje Cica, University of Banja Luka, Bosnia and Herzegovina.
Reviewers:
(1) Bartosz Marek Zegadło, Siedlce University of Natural Sciences and Humanities, Poland.
(2) Dung Nguyen Trong, Hanoi National University of Education, Vietnam.
Complete Peer review History: http://www.sdiarticle4.com/review-history/66642

Review Article

Received 15 January 2021
Accepted 19 March 2021
Published 25 March 2021

ABSTRACT

This study narrates the quality of concrete production as slump wet in warm and hot zones. The quality of concrete mixture is of inevitable concern to all stakeholders in the construction industry in the zones when the climatic conditions of the zones are considered. Absence of National standards, environmental and climatic conditions and other factors are the main factors that affect the quality of concrete produced in the area. The affected mix ratio is examined and all the prevailing construction/production practices are considered. All necessary measures for improving the quality of concrete produced are surveyed considering the relationships between various variables used in the mixture. Three major factors (variables) that are found to be influencing the quality of concrete in the south east, Nigeria. The absence or lack of implementing the existing building code, climatic conditions in the zones and types of construction materials available, all remain the major variable influencing the quality of present concrete production in the zones of south east, Nigeria.

Keywords: Concrete; factorial design; aggregate; water; slump wet; cement.

**Corresponding author: Email: mn.odoanyanwu@unizik.edu.ng;*

1. INTRODUCTION

Structural industry plays an active role in the fixed capital formation of any economy. It accounts for over sixty percent of the Gross Fixed Capital Formation of any nation, Ezeokonkwo [1]. The construction industry thus is very strategic in its contribution to the gross domestic product of a country [2]. From the foregoing, it has a very high capacity of generating growth and inducing multipliers effects on a nation's economy.

The equatorial climate includes two subgroups, the tropical rain forest and the savannah, differentiated by the amount of rain. There are two seasons in this country, the wet season and the dry season, also based on the rainfall [3].

However, current events in construction industry in Nigeria are inducing negative effects within the industry. For instance the issue of collapse of buildings has been persistent in the country in recent times and the need to proffer solutions to avert future occurrences become obvious. Over the last ten years, the incidence of building collapse has become so alarming and worrisome and it does not show any sign of abating. Each collapse carries along with it tremendous effects that cannot be easily forgotten by any of its victim. These effects include loss of human lives, economic waste, loss of jobs, incomes, loss of trust, dignity and exasperation of crises among stakeholders and environmental disasters [4]. It is believed that any pursuit in human life has its cost, but the cost being paid in South-Eastern Nigeria due to incessant incidents of building collapse cannot be comprehended and quantified [5].

Buildings are structures which provide shelter for man, his properties, and activities. As such, they must be properly planned, designed and constructed to obtain desired satisfaction from the environment. Major factors observed during building construction include; the functional performance requirements of durability, adequate stability to prevent structural failure, discomfort to the users, resistance to climatic conditions and use of good quality materials. The styles of building construction are constantly changing with the introduction of new materials and techniques of construction. Consequently, the work involved in the design and construction stages are largely those of selecting materials, component and structures that will meet the expected building standards and aesthetics on an economic basis [6].

A general survey shows that most of modern buildings in the south eastern Nigeria have concrete as their major component. It then becomes pertinent that the quality of concrete materials required for concrete used in the construction process must be of paramount importance. Many building failures are mostly linked to the use of substandard materials, poor workmanship and inefficient management in the production process. Experts have canvassed the assessment of quality of materials and the level of workmanship utilized in concrete production on project sites. According to Amana [7], there is also a need for an accurate assessment of quality, strength and variability of the materials used in forming the structural components [8].

He further observed that a good example of how quality, strength and variability play out in our environment is in the wide variability of the quality of concrete used in our construction sites.

Imaga [9] is of the opinion that enterprises in developing countries do not appear to pay sufficient attention to the areas of quality standards, definition and proper inspection of products produced in their organization. A critical look at this, now reminds us that the quality of a product is determined by the character it possesses. It then becomes imperative that the producers and professionals involved in the construction process must decide ahead of time what the characteristics of their product should possess and have integrated into the design and specification of quality of concrete that should be employed in projects [10].

Quality therefore is defined as pre-determined standards (basis) sets to ensure a minimum level of requirement for achievable out-come. These predetermined standards are seen as an agreed reputable way of doing something. It is a published document that contains a technical specification or other precise criteria designed to be used consistently as a rule, guideline or definition.

Furthermore standards help to make life simpler and increase reliability and the effectiveness of many goods and services we use. Standards are created by bringing together the experience of all interested parties such as the producers, sellers, users and regulators of a particular material, product, process or service. Through these, the quality of any product now becomes achievable in the actual production process in construction sites. This study is therefore an effort to evaluate the quality control management of concrete works in building construction projects within the study area [11].

The research method used in this work is the application of Factorial design Analysis of Mathematical Models for input factors that is the cement variables, water content variables, fine aggregate variables and coarse aggregate variables to form a slump wet response parameter in the studied zone. The factorial design method is used to study the relative influence of each of the factors on the slumps (workability) of concrete, density and compressive strength for each climatic season, quasi or mono factorial models were obtained. From the analysis, it is possible to make the following deductions on the influence of the different factors over the workability density and strength of concrete.

2. COMPUTER ANALYSIS OF THE EXPERIMENTAL RESULTS FROM THE TWO ZONES

After experimentally generating data on Tables 1 and 2, the data was subjected to electronic simulation with Minitab software and the following results with appropriates tables and figures were obtained.

3. FACTORIAL DESIGN ANALYSIS FOR CEMENT QUANTITY, WATER CONTENT RATIO, AGGREGATES AND THE WET SLUMP BUILDING PRODUCTION PROCESS EXPERIMENT

Table 3 shows the estimated effect, coefficients, some of errors of the coefficients, T statistics of the coefficients and the probability value of the coefficients using factorial design method. The model developed shows correlations of the determinant (R-Sq) of the independent variables (cement quantity, water content ratio, aggregates) to response variable (wet slump) to be 60.94%.

Table 4. shows the observation, fit and residual in the response parameter. The difference between the actual response and the fit is the residual values. However, the response value X denotes an observation whose X value gives it large leverage.

Fig. 1 shows the effect analysis of the factors (cement quantity, water content ratio, aggregates) used to achieve the response variable (wet slump). It shows that coarse aggregates have more effect on the wet slump.

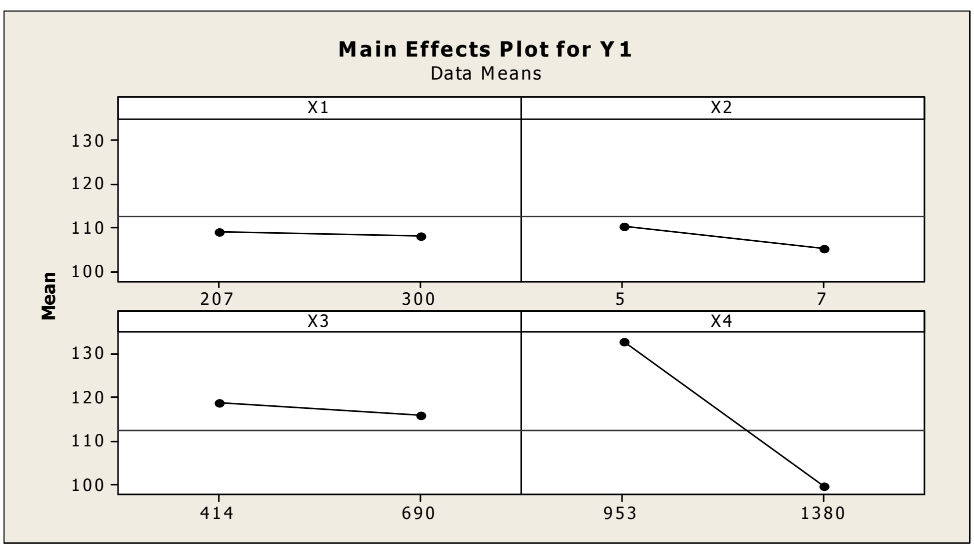

Fig. 1. Main effects plot for the factors to the response experimental parameters

Table 1. Values of results from hot humid zone (Awka)

Level of factors and test	X_1 = C Cement kg/m^3	X_2= w water content kg/m^3	X_3 = Fa fine paragraph kg/m^3	X_4 = Ca coarse Aggregate kg/m^0	Slump Swet (mm)
Xnar Highest level (+)	300	7	690	1380	
Xim Lowest level (-)	207	5	414	953	
Xer Central Level (0) average	254	6	552	1167	
δInterval of Change Δ	46	1	138	213	
Test No	X_1	X_2	X_3	X_4	Y_1
1	207	5	414	953	88
2	207	7	690	953	109
3	207	5	690	953	160
4	207	5	690	953	156
5	300	7	414	953	65
6	300	5	690	1380	81
7	207	7	690	1380	99
8	207	7	690	1380	50
9	207	6	552	1167	67
10	300	7	552	1167	62
11	254	5	552	1167	82
12	254	7	552	1167	93
13	254	6	414	953	166
14	300	5	690	953	157
15	207	7	414	1380	110
16	254	6	552	1167	179
17	207	5	414	953	105
18	207	5	690	953	101
19	254	7	552	1167	95
20	254	5	552	1167	90
21	254	7	690	953	89
22	254	6	414	1167	102
23	254	6	552	1380	105
24	254	6	552	953	195
25	254	6	552	1167	165

Source: Researcher's Field Work, 2021

Table 2. Values of result obtained from experiment in warm humid zone (Owerri)

	Level (of Factors and tests)	$X_{1=}$ C Cement $Kg.m^3$	X_2 = c Water Cement Kg/m^3	X_3 = Fine Aggregate Kg/m^3	X_4 Coarse Aggregate	Slump S_{wet}
	Highest Level (+)	300	.7	690	1380	
Xmin	Lowel level (-)	207	.5	414	953	
Xmin	Control level(0)	254	.6	552	1167	
△	Interval of Cha△ge	46	.1	138	213	Y_1
S/N0						
1		-	-	-	-	90
2		+	+	-	-	115
3		-	+	-	-	165
4		-	+	-	-	160
5		+	+	-	-	141
6		+	-	+	+	75
7		-	+	+	+	105
8		+	+	+	+	165
9		-	0	0	0	76
10		+	0	0	0	65
11		0	-	0	0	91
12		0	+	0	0	70
13		0	0	-	-	168
14		+	-	+	-	161
15		-	+	-	+	113
16		0	0	0	0	175
17		-	-	-	0	109
18		-	+	-	0	100
19		0	+	0	0	96
20		0	-	0	0	105
21		+	+	0	0	102
22		0	0	-	0	106
23		0	0	0	+	95
24		0	0	0	0	105
25		0	0	0	0	99

Source: Researcher's Field Work, 2021

Table 3. Estimated effects and coefficients for the experimental variables

Term	Effect	Coef	SE Coef	T	P
Constant	121.3	12.65	9.59		0.000
X1	107.9	54.0	40.30	1.34	0.210
X2	10.7	5.3	19.66	0.27	0.792
X3	-177.3	-88.6	70.36	-1.26	0.236
X4	-62.8	-31.4	18.66	-1.68	0.123
X1*X2	-237.1	-118.5	63.49	-1.87	0.091
X1*X3	20148.3	10074.1	8027.31	1.25	0.238
X1*X4	211.1	105.5	78.17	1.35	0.207
X2*X3	20216.4	10108.2	8046.47	1.26	0.238
X2*X4	-48.6	-24.3	55.69	-0.44	0.672
X3*X4	-118.9	-59.5	73.89	-0.80	0.440
X1*X2*X3	89.7	44.9	24.27	1.85	0.094
X1*X2*X4	-124.6	-62.3	66.89	-0.93	0.374
X1*X3*X4	20047.3	10023.7	7986.24	1.26	0.238
X2*X3*X4	20329.7	10164.8	8088.49	1.26	0.237

Table 4. Observations and residuals of the experimental variables

Obs	Std Order	Y1	Fit	SE Fit	Residual	St Residual
1	1	88.000	96.500	27.427	-8.500	-0.31
2	2	109.000	109.000	38.787	-0.000	* X
3	3	160.000	140.217	22.334	19.783	0.62
4	4	156.000	140.217	22.334	15.783	0.50
5	5	65.000	65.000	38.787	-0.000	* X
6	6	81.000	81.000	38.787	0.000	* X
7	7	99.000	74.500	27.427	24.500	0.89
8	8	50.000	74.500	27.427	-24.500	-0.89
9	9	67.000	67.000	38.787	0.000	* X
10	10	62.000	62.000	38.787	-0.000	* X
11	11	82.000	117.791	23.234	-35.791	-1.15
12	12	93.000	125.791	23.234	-32.791	-1.06
13	13	166.000	180.767	33.358	-14.767	-0.75
14	14	157.000	160.731	38.463	-3.731	-0.75
15	15	110.000	110.000	38.787	0.000	* X
16	16	179.000	121.791	12.794	57.209	1.56
17	17	105.000	96.500	27.427	8.500	0.31
18	18	101.000	140.217	22.334	-39.217	-1.24
19	19	95.000	125.791	23.234	-30.791	-0.99
20	20	90.000	117.791	23.234	-27.791	-0.89
21	21	89.000	96.384	37.504	-7.384	-0.75
22	22	102.000	102.000	38.787	-0.000	* X
23	23	105.000	91.597	26.783	13.403	0.48
24	24	195.000	152.126	18.097	42.874	1.25
25	25	165.000	121.791	12.794	43.209	1.18

Fig. 2 reveals the interaction of the variable to the wet slump mix. It's the experimental mix design of the cement and the aggregates to form the wet slump for building production process.

Fig. 3 shows the contour 3-dimensional view plot of the factors and the response variables. It also reveals the effect of the factors to the response variables of the experiment.

Fig. 4. shows the surface 3dimensional view plot of the factors and the response variables. It also reveals the effect of the factors to the response variables of the experiment.

Fig. 5 shows the contour 3-dimensional view plot of the cement quantity, water content and the wet slump response variable. It reveals the effect of the cement and water content to the wet slump (response variables) of the experiment. It shows that increase in cement quantity will increase the wet slump response, while decrease in water content will increase the wet slump and makes it more solid for building production process.

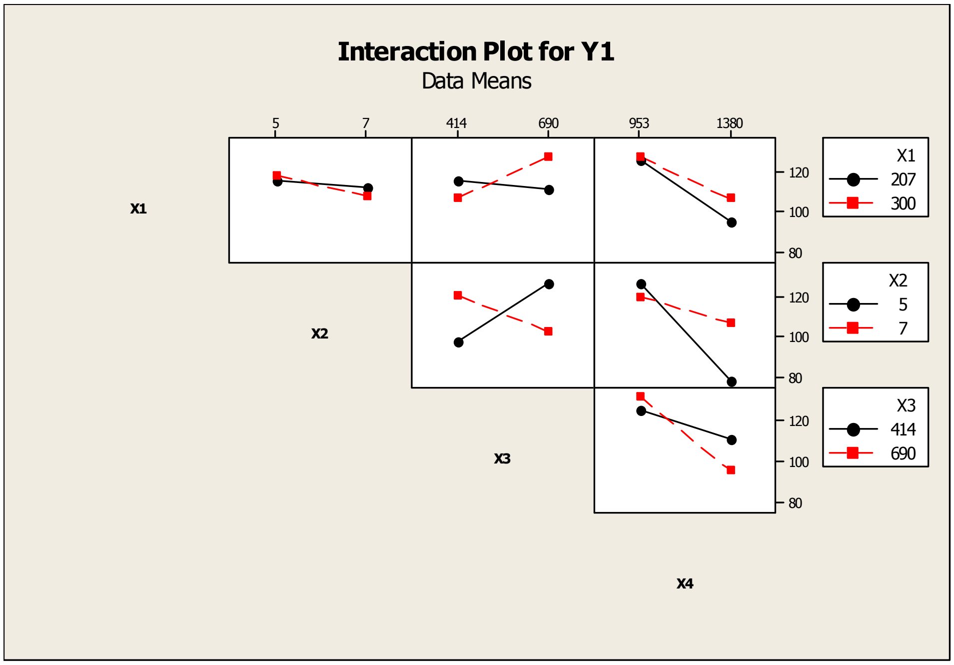

Fig. 2. Interaction plot for variable

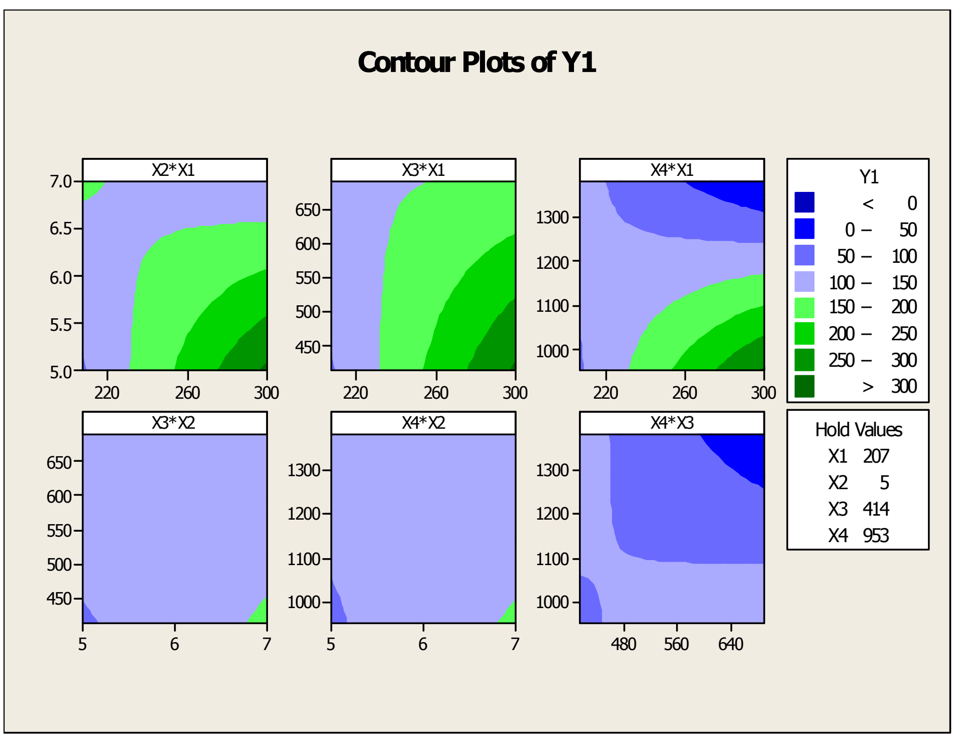

Fig. 3. Contour plots of the factors to the response experimental parameters

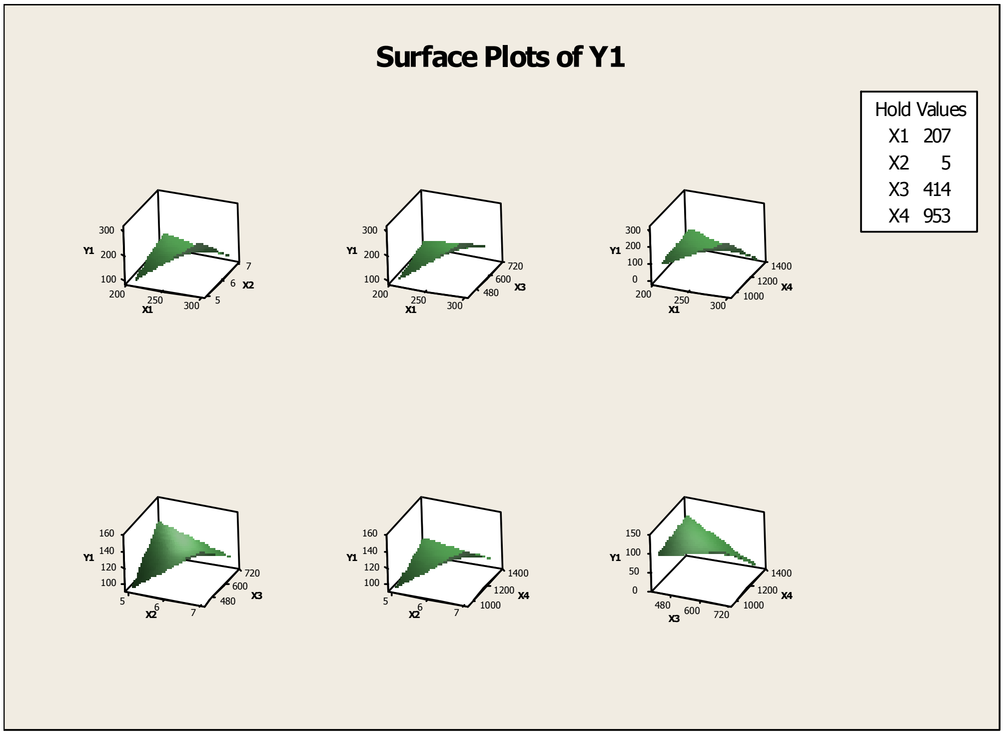

Fig. 4. Surface plots of the factors to the response experimental parameters

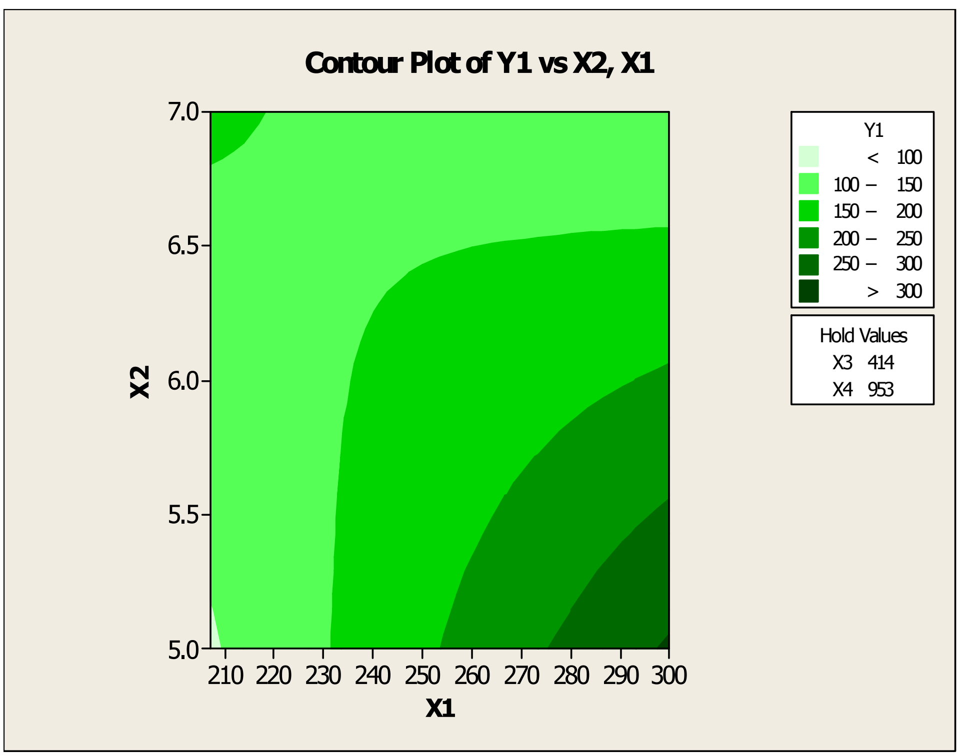

Fig. 5. Contour plot of the factors to the response experimental parameters

Fig. 6 shows the response surface 3-dimensional view plot of the cement quantity, water content and the wet slump response variable. It reveals the effect of the cement and water content to the wet slump of the experiment. It shows that increase in cement quantity will increase the wet slump response, while decrease in water content will increase the wet slump and makes it more solid for building production process.

3.1 Response Optimization

Fig. 7 shows the optimization response of the cement quantity, water content ratio, fine aggregates, coarse aggregates and the wet slump used in the experiment. It further revealed the effects and the interactions of the factors and the response variables. The model developed shows the optimal solutions for the factors and the response variable. The optimal solutions of the factors are; cement quantity 285.1943, water content ratio 5.1616, fine aggregate 656.5455 and coarse aggregate 181.5960. The optimal solution for the response variables (slump wet) is 112.6046. The optimal solutions have an optimal desirability of 99.835%. the desirability solution shows that the optimal solution is achievable and can appraise the experimental mix design for building production process in Hot and Warm humid zone in South East, Nigeria.

4. DISCUSSION OF SLUMP AND STRENGTH RESULTS FOR OPTIMIZATION OF FACTORS OF CONCRETE WORKABILITY

On the basis of the derived mathematical model for the slumps (workability) and strength of concrete in a Hot and Warm humid zone as functions of quantity of cement, water-cement ratio and quantity of aggregates, it is possible to optimize the composition of the concrete mix by varying the independent factors (variables) for various seasons within the zones through Box Wilson's composite mathematical method. From the regression equations the following optimum values for factors X_1 and X_2 and X_3 and X_4 were obtained for the Hot and Warm humid zones as $Y_1 = 112.6046$.

After electronic (computer) manipulations of the data generated from the experiments the following graphs (1 – 7) are generated for a better understanding of interactions between the factors and values generated as a result.

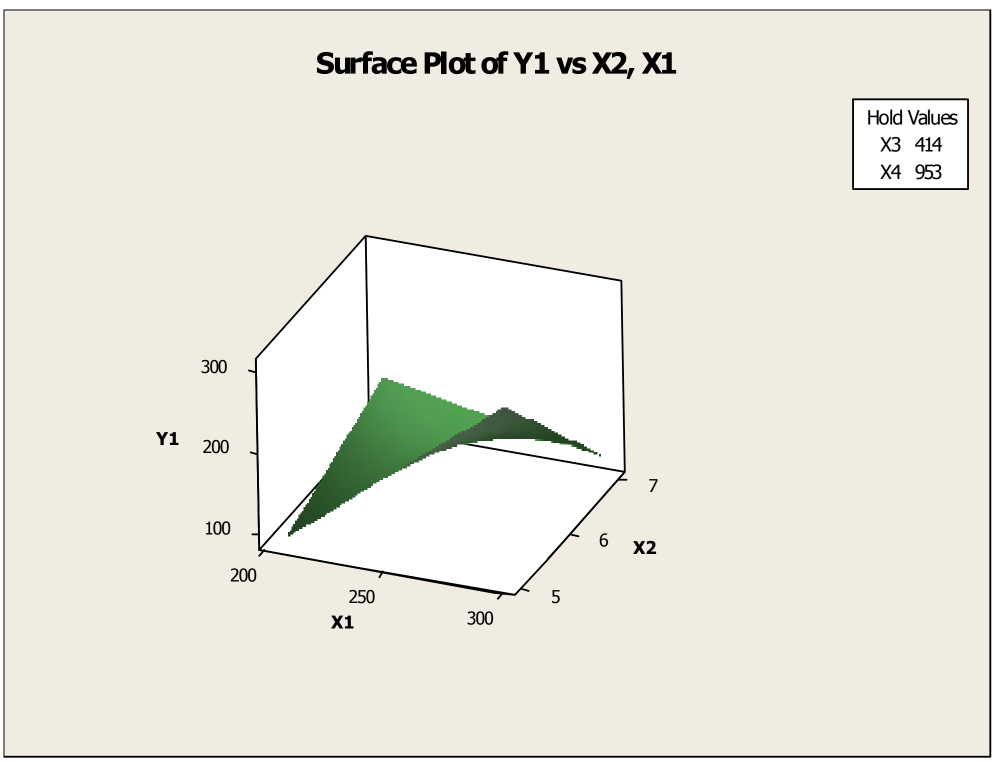

Fig. 6. Surface plot of the factors to the response experimental parameters

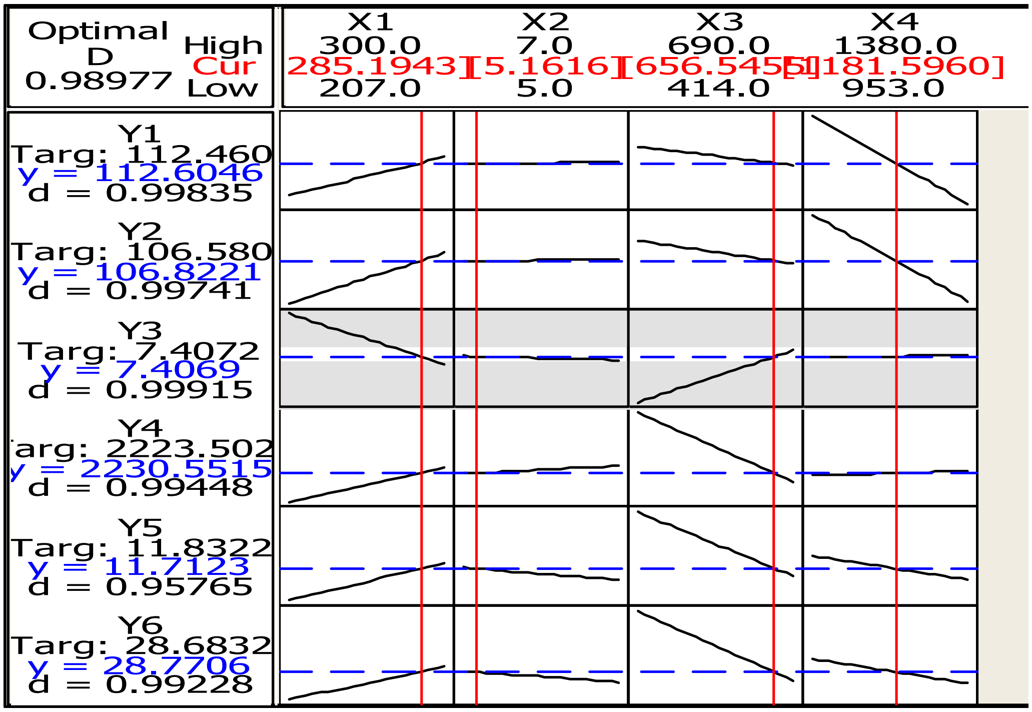

Fig. 7. Optimization plot

5. CONCLUSION

The factors affecting the quality of concrete works were established as i) temperature, 2) relative humidity as seen from the experiments carried out which depicted that these affect the workability of concrete and thereby affecting the strength of concrete produced on project sites, as shown in the experiments performed. Factorial design based on optimal mathematical models, it is possible to analyze accurately the positive effects of the various factors responsible for better slumps (workability) and strength of concrete produced and to optimize those factors for quick determination of the optimum factorial composition of concrete for any given climatic condition.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Ezeokonkwo JU. Quality Control in Construction, Project. Effective Building Procurement and Delivery in Nigerian Construction Industry. Rex Charles and Patrick Ltd. Nimo Anambra State. 2002;85-101.
2. Ezeokonkwo JU. the impact of project overload in construction based organisations. Nnamdi Azikiwe University Awka; 2016.
3. Adamson B, Olle A. Design for climatization; houses in warm-humid areas Lund: LCHS. 1993;5
4. Edeh, et al. Analysis of Environmental Risk factors affecting Rice farming in Ebonyi State, South Eastern Nigeria; 2011.
5. Ezeokonkwo JU. An Evaluation of risk management practices in the process of construction projects in Anambra State, Nigeria. Nnamdi Azikiwe University Awka; 2020.
6. Obiegbu ME. The professional builder. magazine published by Nigerian Institute of Building; 2007.
7. Aman A. Assessment of the quality strength and variability of the consturtion materials. Nigerian Institute of Structural Engineers Conference. 2010;10-12.
8. Ezeokonkwo JU. Assessment of quality control of concrete production works in the hot and warm humid zones of South East Nigeria. Nnamdi Azikiwe University Awka; 2015.

9. Imaga, theory and practice of production management. afritrade International Limited Publishers. 8/10 Broad Street 10th Floor Western House; 1994.
10. Dung Nguyen Trong. Z-AXIS deformation method to investigate the influence of system size, structure phase transition on mechanical properties of bulk nickel, Materials Chemistry and Physics. 2020;123275
Available:28 May 2020
11. Alexina de Roux. Climatic building design in warm-humid areas. Passive and active houses, Paris, France; 2020

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/66642