Original Research Article

COMPARATIVE ANALYSIS ON THE FACTORIAL EFFECT OF CURING AGE ON SOME MAJOR PROPERTIES OF SANCRETE BLOCK PRODUCED IN THE WARM HUMID CLIMATE OF NIGERIA

ABSTRACT

Quality of a composite material like Sandcrete block is basically a function of the basic properties of the constituent ingredients, mix ratio relationship, production characteristics. This study therefore, investigates compressive strength property of sandcrete blocks produced and compares the effects of curing ages on it in Owerri Metropolis. Field survey was conducted in the area to determine the production characteristics of the blocks marketed in the area. Based on the prevalent nominal mix ratio of the block, mix design on the constituent ingredients of the block based Box-wilson symmetric composite plan B_3 was adopted. Results of the strength from each experimental set of the design were used to form the polynomial regression models of blocks cured at various ages. Findings show that the average compressive strengths of the 7-day, 14-day, and 28-day old cured blocks are 1.578 N/mm^2, 1.604N/mm^2, and 1.975N/mm^2. Mono-factorial analyses on the final models left with significant coefficients were carried out to know the effect of change in content of the independent factors on the objective function for blocks cured at 7-day, 14-day, and 28-day ages respectively. As a result, cement and water factors has stronger effect on the strength of the block than sand factor. The nature of their influences is positive, and more linear than quadratic and mutual interaction relationships. The relationship of mutual interaction between the cement and water factors is seen only in the models of the 7-day and 28-day curing ages in the study. Since the strength of the block increases with increase in the age of curing, it therefore recertifies the standard practice of 28-day curing age for improved quality of sandcrete block in the industry, as well as recommending factorial analyses on the effects of the independent factors of the mix designed blocks cured age 28-day age, for optimized quality of the blocks produced in the study area.

Key words: Sandcrete Block, Mix Design, Box-wilson Symmetric Composite Plan, Model, Factorial Analysis, and Quality of the Block.

INTRODUCTION

Sandcrete block is one of the basic construction materials widely used as walling units in Nigeria (Ikechukwu, 2015). It is composite in nature, a modern or conventional material of standard and marketable sizes usually applied in multiple and interrelated pattern in a building. Sandcrete block is obtained by mixing cementations materials, water, cement and sand in the right proportion. The mixture when placed in standard forms, cured for a period of time will harden to form strong units of sandcrete block. The hardening process of the block is caused by chemical reaction between water and cement material, which continues for a long time and consequently makes the block, becomes stronger with the increasing age of curing until it optimizes. The quality of sandcrete blocks produced however differs from one manufacturer to the other because of noncompliance with the stipulated standard that regulates the quality of sandcrete block production (Ikechukwu, 2016 and Anosike et al, 2 012). As a walling unit, it can serve as load or non bearing wall. It helps to enclose and/or divide spaces in a building, as well transmits some dead loads down to the foundation of the building where it functions as a load bearing wall. In general, apart from its ability to enclose spaces and helps in transmitting some loads, it should be able to withstand and moderate the external agents and the environment respectively, for the safety and comfort of the interiors and occupants respectively.

RESEARCH METHODOLOGY

The method adopted in this scientific investigation is based on the research designs of field survey and design of experiment. The basic information derivative of the design of the sandcrete mix is in the quantitative forms which reflect the antecedence of the characteristics of the block production in the study area, as well as provide information on the values of compressive strength of the blocks of different mix design respectively.

Data gathered from the field survey in the study area were used as basis for the design of sandcrete mixes using Box-wilson symmetric composite plan B_m in the design experiments, applied by okereke (2004). With the results of the experiment as objective functions which depend on the mix design effect of the independent factors (cement, water and sand) in the study, the block productions with river sharp sand aggregates (2.36mm > Dia > 0.425mm) were formed into Multiple regression models of different curing age. Subsequently, Fisher's distribution test analyses were carried out on the models for adequacy (Okereke, 1991; and Raissi, 2009). The models that were confirmed adequate were consequently subjected to student'tʼ test for test of significances of the constituent coefficients in the models.

Further analysis for the mono-factorial effect of the independent factors on the final models of the blocks of different curing age (7-day, 14-day and 28-day ages) were carried out to determine the degrees of effects of the changes in the predictive factors of the respective model, for optimized mix design of the block.

DATA PRESENTATION AND ANALYSES

Regression Models for the Compressive Strength of Manually Produced Sandcrete Blocks with Hard Sand Mix in the WHC

$$R_{D7(hs)} = b_0 + b_1x_1 + b_2x_2 + b_{11}x_1^2 + b_{12}x_1x_2$$
$$= 1.578 + 0.075x_1 + 0.046x_2 + 0.061x_1^2 + 0.30x_1x_2 \quad \ldots(1.0)$$

$$R_{D14(hs)} = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_{11}x_1^2 + b_{22}x_2^2$$
$$= 1.604 + 0.061x_1 + 0.047x_2 + 0.033x_3 + 0.079x_1^2 + 0.029x_2^2 \quad \ldots(2.0)$$

$$R_{D28(hs)} = b_0 + b_1x_1 + b_2x_2 + b_{11}x_1^2 + b_{12}x_1x_2$$
$$= 1.975 + 0.085x_1 + 0.054x_2 + 0.062x_1^2 + 0.034x_1x_2 \quad \ldots(3.0)$$

Table 1.0. Results of the Factorial Analysis on Model (Equ. 1.0)
$R_{D7} = 1.578 + 0.075X_1 + 0.046X_2 + 0.061X_1^2 + 0.30X_1X_2$

S/N	FACTORS	LEVELS	X_{ij}	X_{ij}	X_{ij}	X_{ij}	REMARKS
1	X_1		X_2 , X_3	X_2 , X_3	X_2 , X_3	X_2 , X_3	
		-1	-1 , -1	-1 +1	+1 -1	+1 +1	
			0.286	0.286	-0.314	-0.314	
		+1	-1 , -1	-1 +1	+1 -1	+1 +1	
			-0.164	-0.164	0.436	0.436	
2	X_2		X_1 , X_3	X_1 , X_3	X_1 , X_3	X_1 , X_3	
		-1	-1 , -1	-1 +1	+1 -1	+1 +1	
			0.254	0.254	-0.346	-0.346	
		+1	-1 , -1	-1 , +1	+1 , -1	+1 , +1	
			-0.254	-0.254	0.346	0.346	
3	X_3		X_1 , X_2	X_1 , X_2	X_1 , X_2	X_1 , X_2	
		-1	-1 , -1	-1 , +1	+1 , -1	+1 , +1	
			0.00	0.00	0.00	0.00	
		+1	-1 , -1	-1 , +1	+1 , -1	+1 , +1	
			0.00	0.00	0.00	0.00	

Legend: X_1 - Cement, X_2 - Water, X_3 - Sand

i. Effects of Cement (X_1) on Compressive Strength ($R_{7(hs)}$)

According to Fig.1a, Factor x_1 (cement) has positive and negative effects on the compressive strength of the sandcrete block produced with hard sand (Fig.1a). Every increase in cement content results in increase in the strength,when water factor is at maximum level. The effect in the property is seen to be stronger when cement content is at average to maximum levels.

However, when water factor is at minimum level, increase in the cement content results to decrease in strength. Besides, the influence of change in the content of water in the mix is more significant when water is at maximum level in the experiment.

ii. Effects of Water (X_2) on Compressive Strength ($R_{7(hs)}$)

In Fig.1b, change in the content of water is directly proportional to its effect on compressive strength of the block when cement content is at maximum level in the mix while; the change in the water content is inversely proportional to its influence on the strength when cement content is at minimum level. Besides, the effect of change in water content on the property of the block is more significant when cement factor is at maximum level in the mix than at minimum level.

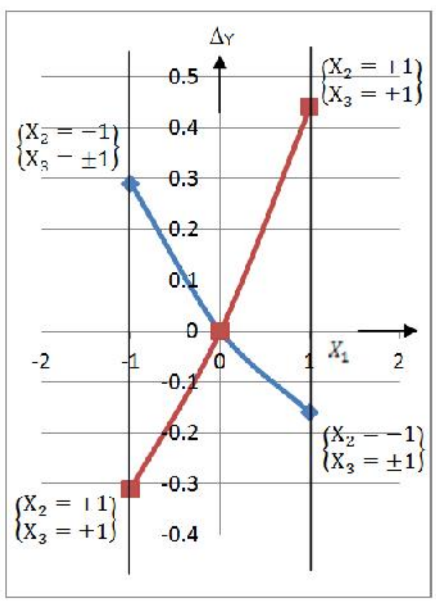

Fig. 1a. Effect of Cement (X_1) on ($R_{7(hs)}$)

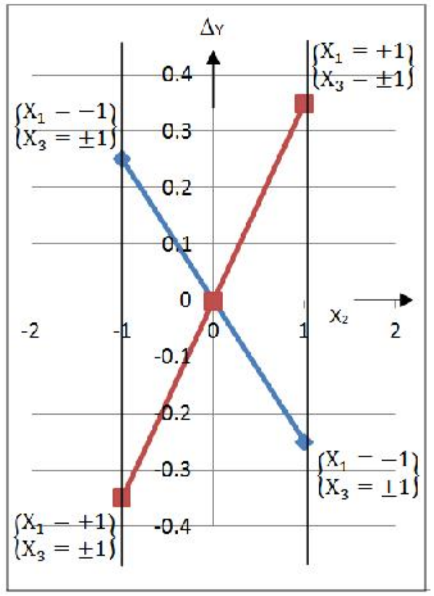

Fig. 1b. Effect of Water (X_2) on ($R_{7(hs)}$)

Table 2.0. Results of the Factorial Analysis on Model (Equ. 2.0)

$$R_{D14} = 1.604 + 0.061X_1 + 0.047X_2 + 0.033X_3 + 0.079X_1^2 + 0.029X_2^2$$

S/N	FACTORS	LEVELS	X_{ij}	X_{ij}	X_{ij}	X_{ij}	REMARKS
1	X_1		X_2 , X_3	X_2 , X_3	X_2 , X_3	X_2 , X_3	
		-1	-1 , -1	-1 , +1	+1 , -1	+1 , +1	
			0.018	0.018	0.018	0.018	
		+1	-1 , -1	-1 , +1	+1 , -1	+1 , +1	
			0.14	0.14	0.14	0.14	
2	X_2		X_1 , X_3	X_1 , X_3	X_1 , X_3	X_1 , X_3	
		-1	-1 , -1	-1 , +1	+1 , -1	+1 , +1	
			-0.018	-0.018	-0.018	-0.018	
		+1	-1 , -1	-1 , +1	+1 , -1	+1 , +1	
			0.076	0.076	0.076	0.076	
3	X_3		X_1 , X_2	X_1 , X_2	X_1 , X_2	X_1 , X_2	
		-1	-1 , -1	-1 , +1	+1 , -1	+1 , +1	
			-0.033	-0.033	-0.033	-0.033	
		+1	-1 , -1	-1 , +1	+1 , -1	+1 , +1	
			0.033	0.033	0.033	0.033	

Legend: X_1 - Cement, X_2 - Water, X_3 - Sand

i. Effects of Cement (X_1) on Compressive Strength ($R_{14(hs)}$)

Cement factor (x_1) in Fig.2a has positive and negative effects on compressive strength of the block produced with hard sand at any respective quantity of cement and water factors in the mix. The positive effect however, is stronger in the experiment than the negative effect. Increase in the cement content from minimum (-) to average (0) levels results to decrease in the strength. When the increase goes beyond average level towards the maximum level, the strength however increases at a higher rate.

ii. Effects of Water(X_2) on Compressive Strength ($R_{14(hs)}$)

At all levels of cement and sand factors in Fig.2b every increase in the water content from minimum to average levels leads to increment in strength value. As the increase in water content goes beyond the average level towards the maximum levels, the strength however, increases proportionally at a higher rate.

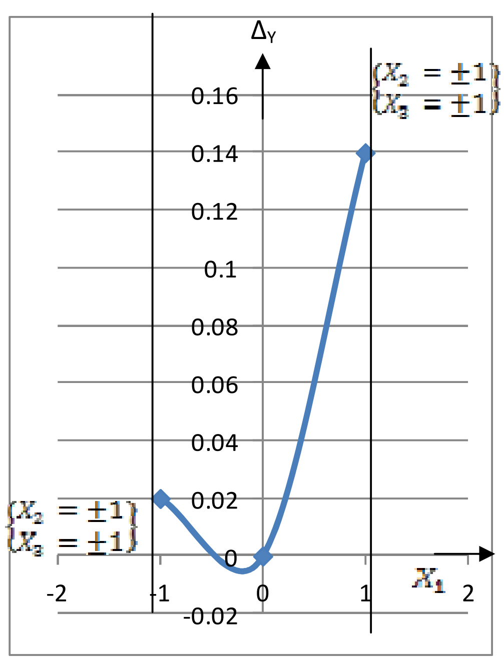

Fig. 2a. Effect of Cement (X_1) on ($R_{14(hs)}$)

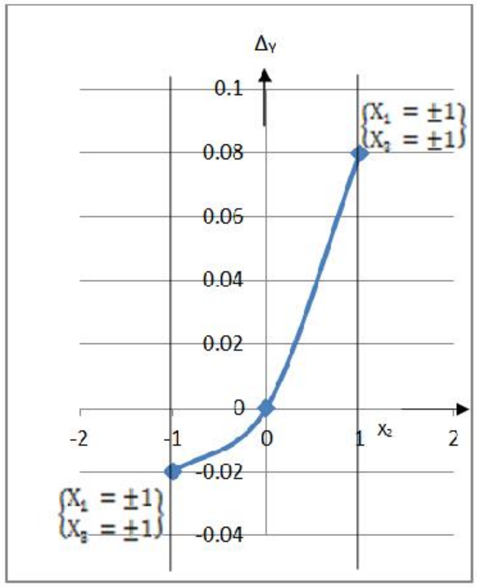

Fig. 2b. Effect of Water (X_2) on ($R_{14(hs)}$)

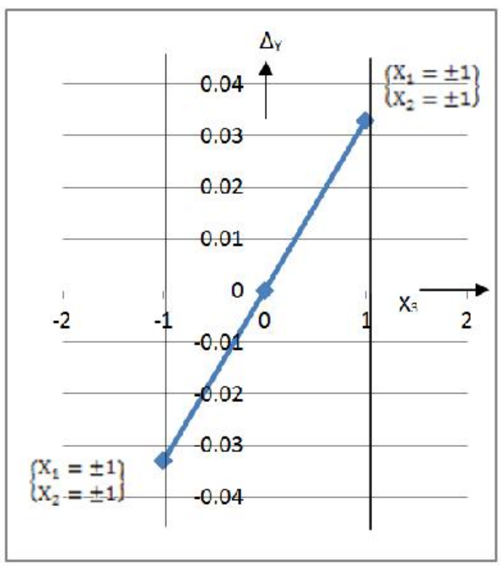

Fig. 2c. Effect of Sand (X_3) on ($R_{14(hs)}$)

iii. Effects of Sand (X_3) on Compressive Strength ($R_{14(hs)}$)

In Fig.2c, Sand factor (x_3) has absolute positive effect on the compressive strength of the block. Any increase in sand content results to a corresponding increase in the strength. The effect on the property is constant at all levels of cement and water factors.

Table 3.0. Results of the Factorial Analysis on Model (Equ. 1.0)

$$R_{D28} = 1.975 + 0.085X_1 + 0.054X_2 + 0.062X_1^2 + 0.034X_1X_2$$

S/N	FACTORS	LEVELS	X_{ij}	X_{ij}	X_{ij}	X_{ij}	REMARKS
1	X_1		X_2 , X_3	X_2 , X_3	X_2 , X_3	X_2 , X_3	
		-1	-1 , -1	-1 +1	+1 -1	+1 +1	
			0.011	0.011	-0.057	-0.057	
		+1	-1 , -1	-1 , +1	+1 , -1	+1 , +1	
			0.113	0.113	0.181	0.181	
2	X_2		X_1 , X_3	X_1 , X_3	X_1 , X_3	X_1 , X_3	
		-1	-1 , -1	-1 , +1	+1 , -1	+1 , +1	
			-0.020	-0.020	-0.088	-0.088	
		+1	-1 , -1	-1 , +1	+1 , -1	+1 , +1	
			0.020	0.020	0.088	0.088	
3	X_3		X_1 , X_2	X_1 , X_2	X_1 , X_2	X_1 , X_2	
		-1	-1 , -1	-1 , +1	+1 , -1	+1 , +1	
			0.00	0.00	0.00	0.00	
		+1	-1 , -1	-1 , +1	+1 , -1	+1 , +1	
			0.00	0.00	0.00	0.00	

Legend: X_1 - Cement, X_2 - Water, X_3 - Sand

i. Effects of Cement (X_1) on Compressive Strength ($R_{28(hs)}$)

According to Fig.3a, cement factor (x_1) has positive and negative effects on compressive strength of the block produced with hard sand depending on the cement content and the content of water factor in the mix. This positive effect however, is stronger in the experiment than the negative effect. Increase in the cement content from minimum (-) to average (0) levels results to decrease in the strength when the water content in the mix is at minimum level. If the increase exceeds average level tending to maximum level, the strength however increases at a higher rate.

Nevertheless, when the water content in the mix is at maximum level, every increase in the cement content from minimum to average level leads to the increase in strength. As the increase in cement content goes beyond the average level towards the maximum levels, the strength however, increases at a higher rate.

ii. Effects of Water (X_2) on Compressive Strength ($R_{28(hs)}$)

Water factor (x_2) in Fig.3b has absolute positive effect on the compressive strength of the block. Any increase in water content results to a corresponding increase in the strength. The effect on the property due to changes in water content is more significant when the cement content in the mix is at maximum level than when at minimum level.

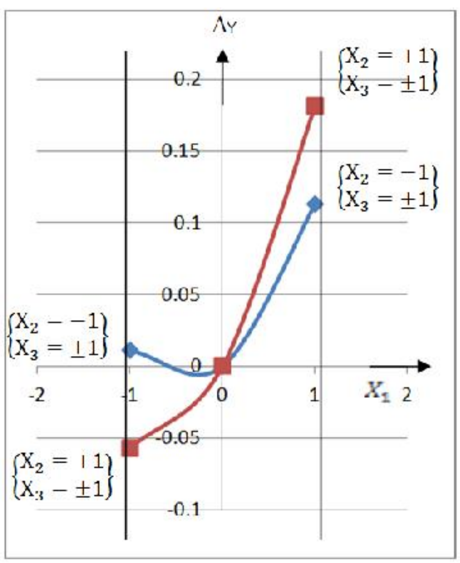

Fig. 3a. Effect of Cement (X_1) on ($R_{28(hs)}$)

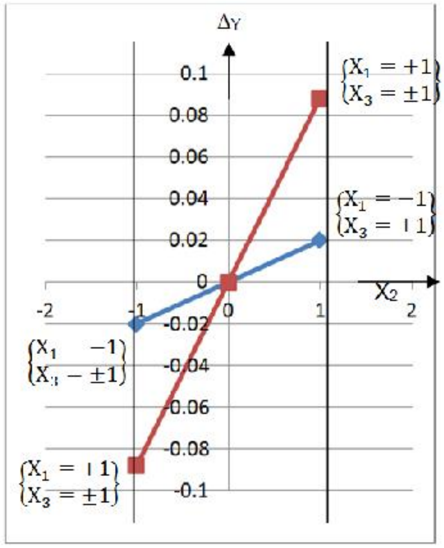

Fig. 3b. Effect of Water (X_2) on ($R_{28(hs)}$)

DISCUSSION OF FINDINGS, RECOMMENDATIONS AND CONCLUSION

Models for all the respective curing ages in the study are mixed in nature, in respect to the characteristics of the constituent ingredients of the sandcrete mix. The models are characterized by combination of linear, quadratic and mutual interaction relationships of the respective ingredients.

Findings show that blocks designed and cured at 7-day, 14-day, and 28-day ages have compressive strength of 1.578 N/mm^2, 1.604N/mm^2, and 1.975N/mm^2 respectively, at neutral values of the experiments in their respective models. The average strength at the 7-day age is the least while; the average strength at the 28-day age is the highest in value.

Change in the quantity of cement factor is the most significant to the strength followed by change in water factor. Nevertheless, sand factor is the less significant in the experiments especially, in the 7-day and 28-day curing ages. Hence, significant mutual interaction relationships exist only between cement and water factors in the experiments. Changes in them therefore have effects on the strength of the block especially, on the 7-day and 28-day cured blocks. Besides, the cement factor has influence of quadratic relationship in the models of the mix design.

It is therefore recommended that sandcrete mix be designed with strong emphases on cement and water ingredients for optimum factorial combinations towards high quality blocks in the study area. To complement the mix design effort, blocks should always be cured up to 28 days for effective strength development in the industry.

In conclusion, although the 28-day curing age of sandcrete block as one of the standard production characteristics for improved block work in the industry is confirmed, factorial analysis on models of designed sandcrete mix forms basis for regulating and improving more on the properties of the block to meet up with desired qualities, as the case may be.

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