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Assessment of Materials and Process Variables on Regulatory Compliance of Sandcrete Blocks: A Case Study of Ogbomoso, Nigeria.

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Abstract
The resulting pressure due to steady population growth has increased interest in the use of sandcrete blocks as load and non-load bearing walling unit especially in Nigeria. The haphazard production of sandcrete blocks within the study area has necessitated investigations into assessing the degree of compliance requirements stipulated by regulatory bodies. Therefore, the aim of this paper is to investigate variability in strength characterization of sandcrete blocks and the roles played by materials and process variables, as well as to establish the degree of compliance with the required regulatory specifications. The methods adopted include field survey, oral interviews, and completion of structured questionnaires. Also, representative soil and sandcrete block samples were collected for sieve analysis, compressive strength and density tests. The results show that the grading curves obtained from the representative soil samples used in the production contains wide range of grain sizes. The ranges of values obtained for compressive strength are 0.26 - 1.62 N/mm^2 and 0.35 - 1.66 N/mm^2, for six and nine inches blocks respectively, compared to the required regulatory standard of between 2.5 and 3.45 N/mm^2. Corresponding density values are 1.95 - 2.05 g/cm^3 and 1.67 - 2.02 g/cm^3, compared to the required minimum density value of 1.5 g/cm^3. The sandcrete blocks appear to possess adequate density values however the compressive strength has an over-riding influence due to its domineering determining factor for flexural members. Factors which include profit orientation, mix ratio, period of curing, and level of literacy, appear to have been responsible for the observed sub-standard products. Enforcement of compliance monitoring and basic education are recommended to ensure improved production of good quality sandcrete blocks.

I. Introduction

The Nigerian Industrial Standard (NIS) 87:2000 defines sandcrete block as composite material made up of cement, sand and water, molded into different sizes. The interest in the use of sandcrete blocks as load and non-load bearing walling units in most West African countries appears to be on the increase, partly because of the increasing population growth, coupled with its flexibility and fire resistant capabilities. Possible factors that can affect the properties of sandcrete blocks have been broadly categorized into two namely Chance and Assignable factors (NIS 87: 2000**)**. The former are related to less controllable environmental factors such as temperature, noise etc., while the latter are largely man-made factors induced by machine, material constituent, and the degree of quality control observed during production, with possible consequences for the strength, durability and workability of the product. Of particular importance is the compressive strength of sandcrete blocks, with regulatory minimum strength specification of between 2.10 - 3.45 N/mm^2 (NIS 87: 2000; RCRD, 1979; BS 2028 (1978); ASTM C145-75 (1975) and ASTM C90-75 (1975). The compressive strength has direct proportionality to the density, thermal conductivity and acoustic properties of sandcrete blocks, and a domineering influence as a determining factor for flexural members.

In Nigeria, approximately 90 % of the building formworks are constructed by employing the use of sandcrete blocks (Baiden and Tuuli, 2004; Anosike and Oyebade, 2012). Therefore, as part of regulatory efforts to prevent building collapse and ensure safety, Standard Organization of Nigeria (SON) prescribed sets of minimum standards as regulatory measures. Authors including Afolayan, *et. al.,* 2008; Banuso and Ejeh, 2008; Aiyewalehinmi and Tanmola, 2013, Mahmoud, *et. al.,* 2010 as well as Baiden and Tuuli, 2004, respectively worked on the characterization of sandcrete blocks in Ondo, Kaduna, Akure, Yola States of Nigeria and Ghana. The results showed wide variations in the strength properties of sandcrete blocks, largely reflecting site specific influences. Hence, the aim of this study is to investigate variability in strength characterization of sandcrete blocks and the roles played by materials and process variables, as well as to establish the degree of compliance with the required regulatory specifications in the ancient town of Ogbomoso, Nigeria, The town is largely dominated by residents with distinct and varied socio-economic background, and hence considered to be representative of typical semi urban towns in Nigeria,

II. Materials and methods

The case study area for this work is Ogbomoso North Local Government Area (LGA), Oyo state, Nigeria (Figure 1). Ogbomoso is a cosmopolitan ancient town with a population of approximately 172,000 (NPC, 2010), and bounded in the south by Ogbomoso South Local Government Area (LGA). The western and eastern boundaries are delineated by the boundaries of Surulere and Ori-Ire LGAs, respectively. For the purpose of this study, Ogbomoso North LGA is divided into five zones based on the geographical area where the industry is located. The locations of registered sandcrete block industries within the study area are shown in Figure 1.

The methods adopted in this work include field survey, collection of representative sandcrete block samples, and laboratory tests. All the sites were visited for observations, and where appropriate, oral interviews and/or completion of structured questionnaire were conducted to obtain primary data about the sourcing of the materials, quality assurance and production processes including mix ratio, method of mixing, method of compaction, length and period of curing, number of blocks produce per bag of cement, types of cement and source(s) of water used in the production.

All the sandcrete block industries located within each zone acquires their materials from a single source within the zone through individual contractors. Hence, 30 representative pieces of six and nine inches of sandcrete block specimens were collected from a single industry within each zone of the area of study. These samples are considered to be representative of the respective zones. In addition, soil samples used in the production of sandcrete blocks were also collected from each of the zones. The laboratory tests carried out include sieve analysis to characterize the soil materials across the zones, as well as compressive strength and density tests. The detailed descriptions of the tests are contained in the BS 1377 (1990) guidelines.

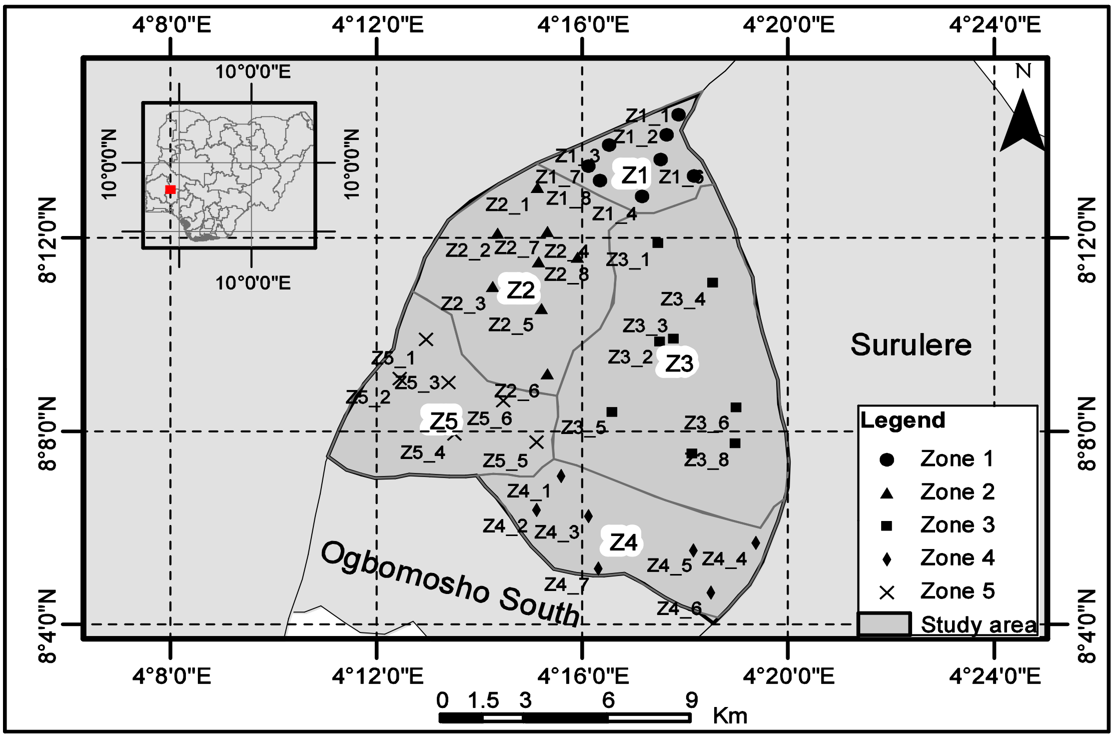

Figure 1: Map of the study area

III. Results and discussions

The results of the data obtained from the field observations, oral interviews and questionnaire for zones 1 - 5 are summarized and presented in Table 1. The grain size distribution curves for the representative soil samples obtained from the five zones are shown in Figure 2. The ranges of values for the compressive strength and the density obtained for all the samples for the five zones are presented in Table 2, while their respective average values for the compressive strength of the sandcrete blocks obtained for zones 1 – 5 for the 3rd, 7th 14th, 21st and 28th day and the corresponding average density values are presented in Figures 3 and 4, respectively.

Table 1: Summary of the field surveys and questionnaire

S/N	Method of production	Mix ratio	No of block produced by bag		Years of exp-erience (Years)	Mode of curing	Period of curing (Days)	Sources of sand materials	Water Source	Type of cement
			6"	9"						
Z1_1	Mechanical	1:14	48	39	> 7		4			Diamond
Z1_2	Mech & Manual	1:15	50	40	5		4			
Z1_3	Mechanical	1:14	49	38	3		4			Diamond
Z1_4	Mechanical	1:16	52	42	5		4			Burham
Z1_5	Manual	1:17	54	44	2		5			
Z1_6	Manual	1:15	49	41	6		4		Well	
Z1_7	Mechanical	1:18	57	46	5		4			Diamond
Z1_8	Mech & Manual	1:16	52	42	6		4			
Z2_1	Mechanical	1:14	52	40	5		4			
Z2_2	Mech & Manual	1:14	52	40	4		3			
Z2_3	Mech & Manual	1:14	45	40	6		3			
Z2_4	Mechanical	1:10	50	40	5		5		Borehole	
Z2_5	Mech & Manual	1:10	50	30	2		4			Elephant
Z2_6	Manual	1:12	48	32	5		5			
Z2_7	Manual	1:10	50	35	7		3			
Z2_8	Mech & Manual	1:10	50	3	6		4			Diamond
Z3_1	Mechanical	1:12	50	34	> 6	Wetting	3	Quarry		Burham
Z3_2	Manual	1:10	50	30	4		3			Elephant
Z3_3	Mech & Manual	1:12	52	35	3		4			Dangote
Z3_4	Mechanical	1:10	48	34	7		3			
Z3_5	Mechanical	1:10	50	30	8		3			Diamond
Z3_6	Mechanical	1:12	50	32	3		4			Elephant
Z3_7	Manual	1:14	50	37	3.5		3			Diamond
Z3_8	Manual	1:10	50	40	5		3		Well	Elephant
Z4_1	Mechanical	1:10	52	34	6		3			Dangote
Z4_2	Manual	1:14	48	30	3		3			
Z4_3	Mech & Manual	1:16	50	35	7		4			Diamond
Z4_4	Mechanical	1:13	46	34	4		3			
Z4_5	Manual	1:14	47	30	3		3			Elephant
Z4_6	Manual	1:12	44	32	2		4			Burham
Z4_7	Mech & Manual	1:15	50	35	7.5		4			Elephant
Z5_1	Mechanical	1:14	48	45	4		4			Dangote
Z5_2	Manual	1:14	48	45	16		5			Elephant
Z5_3	Mech & Manual	1:13	46	44	13		4			Diamond
Z5_4	Mechanical	1:12	44	40	3		6			
Z5_5	Mechanical	1:14	48	45	18		4			Elephant
Z5_6	Mechanical	1:10	42	39	13		3			

The compressive strength of the representative test specimen obtained from each zone increases proportionally with respect to the number of days of curing after production (Figure 3). In addition, Table 2 indicates that none of the sandcrete block samples attained the minimum acceptable regulatory standards of 2.10 - 3.45 N/mm^2. There is also a shortfall from the NIS 87: 2000 minimum required strength of 2.5 N/mm^2 at the age of 28 days for both the 6-inch and 9-inch sandcrete blocks. The minimum and maximum strength values obtained are approximately 10 % and 66 % of the 2.5 N/mm^2 NIS 87: 2000 required standard.

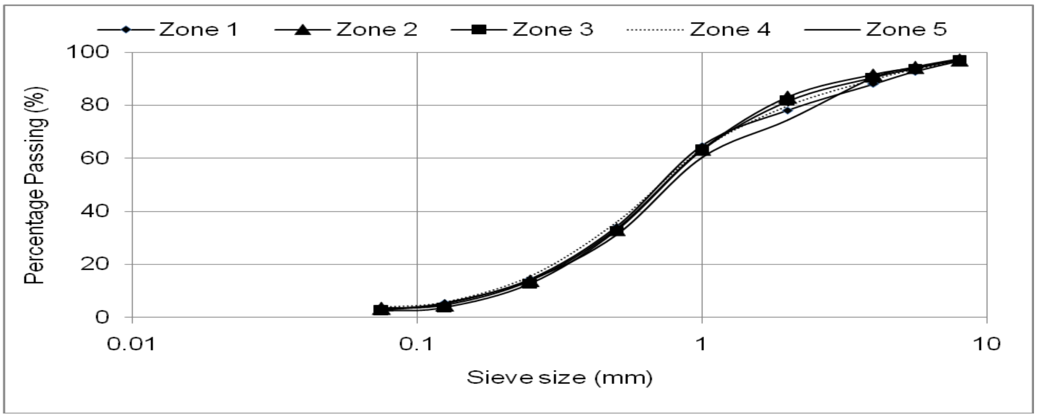

Figure 2: Soil grading curves for the five zones

Table 2: Ranges of values of compressive strength and density of sandcrete blocks

Zone	**Compressive Strength (N/mm^2)**		**Density (g/cm^3)**	
	6-Inch Block	9-Inch Block	6-Inch Block	9-Inch Block
1	0.37 - 0.70	0.37 - 0.74	2.05 - 2.04	1.98 - 2.02
2	0.61 - 1.62	0.56 - 1.66	1.95 - 1.97	1.67 - 2.02
3	0.31 - 0.63	0.38 - 0.70	2.03 - 2.01	1.98 - 2.02
4	0.29 -0.70	0.38 - 0.71	2.02 - 2.11	1.92 - 2.06
5	0.26 - 0.49	0.35 - 0.60	1.82 - 2.02	1.92 - 2.02

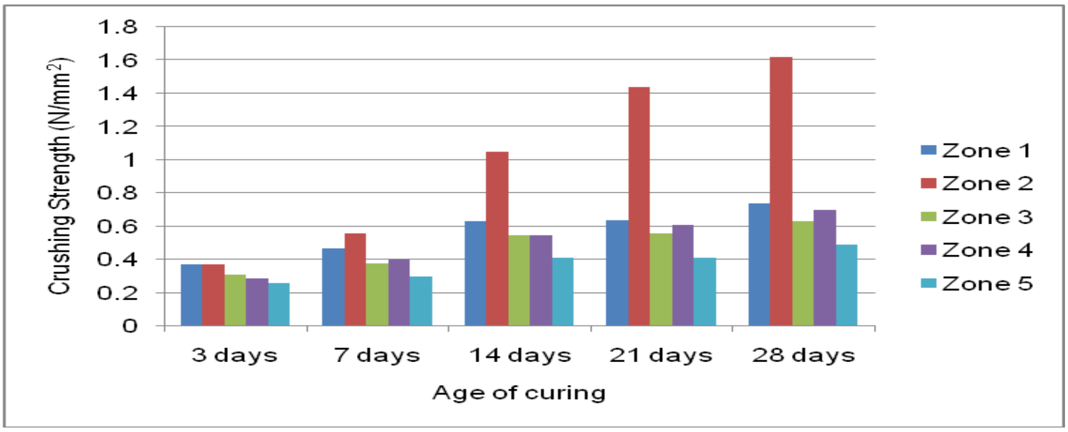

Figure 3a: Compressive strength of 6-inch sandcrete blocks

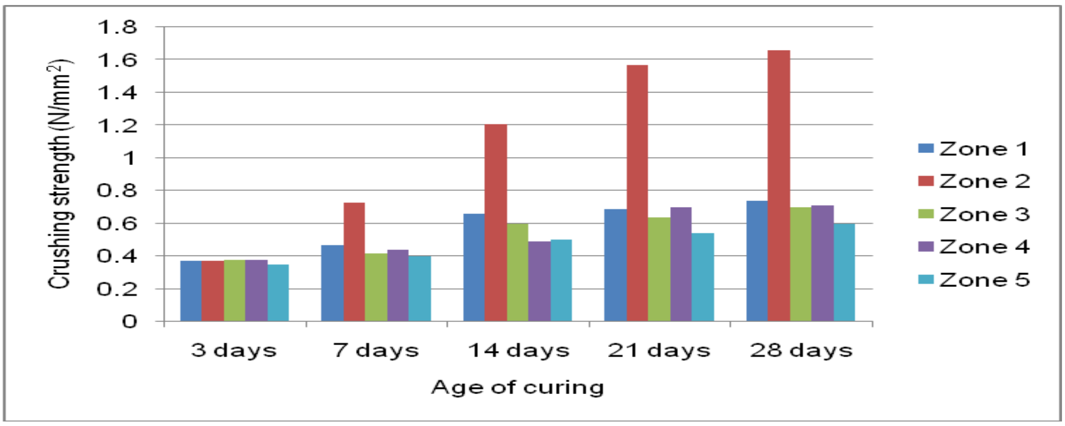

Figure 3b: Compressive strength of 9-inch sandcrete blocks

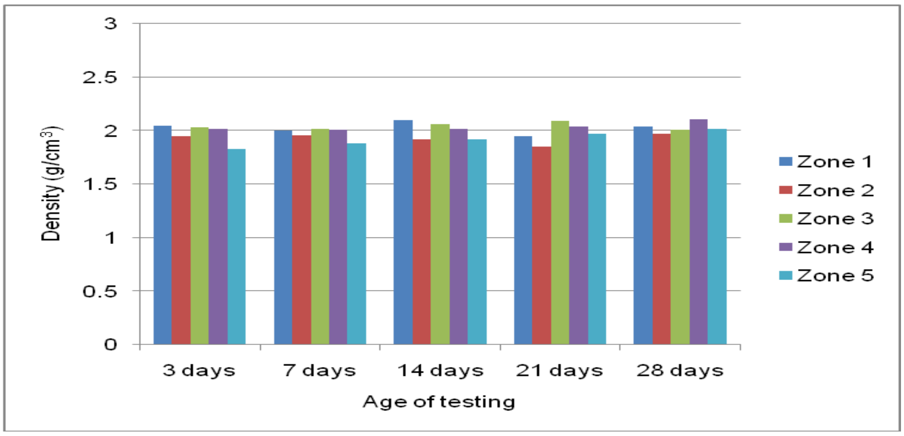

Figure 4a: Density values for 6-inch sandcrete blocks

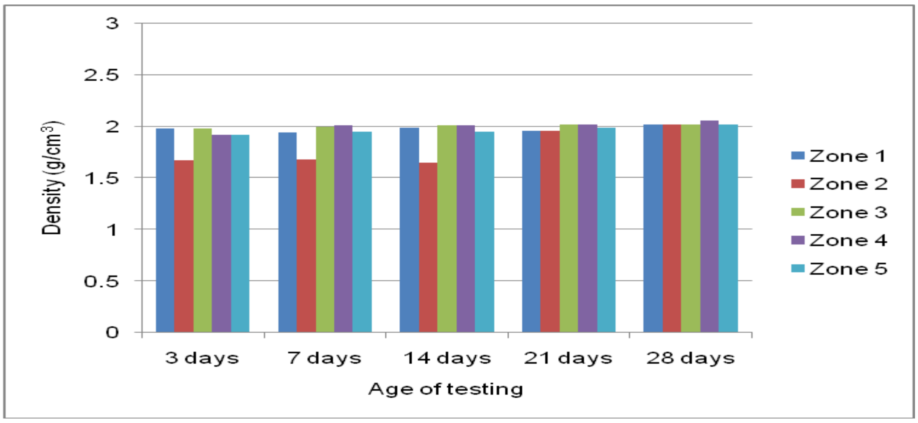

Figure 4b: Density values for 9-inch sandcrete blocks

Based on Figure 3, Zone 2 has significantly higher values, compared to other zones, though generally less than the required regulatory requirements. The ranges of values obtained for densities of the sandcrete block samples are also presented in Table 2, and it shows that the values are above the minimum regulatory density value of 1.5 g/cm^3 (NIS 87: 2000). Although, the sandcrete blocks appear to show adequate density values, however the compressive strength has an over-riding influence due to its domineering determining factor for flexural members.

Generally, the main materials used in the manufacture of sandcrete blocks are aggregate, cement and water. The oral interview and questionnaire conducted (Table 1) shows that the main aggregate used in all the five zones is sharp sand. All the block industries in the five zones acquire their sand from a single source through individual contractors. The grading curves obtained from the representative soil samples (Figure 1) indicate that the sands contain wide range of grain sizes. Therefore, it is generally expected that well graded sharp sand will have higher crushing strength because of its grain size which tends to produce strong bond with the cement. Consequently, it is expected that the resulting bond will lead to strong strength development within the sandcrete blocks. Also, Table 1 shows that the block manufacturers in all the five zones make use of Ordinary Portland of different brand, which contains calcium silicate compounds, with capability to set and harden when combined with water, induced by chemical reaction known as hydration. Generally, Ordinary Portland cement is considered to be a good binder with sufficient adhesive and cohesive properties required for efficient bonding. Although, instances of occurrence of temperatures significantly above room temperature may cause false setting of concrete which may lead to reduction in the strength of sandcrete block (Hurley and Pritchard, 2005).

The oral interview and questionnaire conducted and summarized in Table 1 shows that approximately 98 % of the manufacturers obtained the water used in the production of the sandcrete blocks from shallow wells. Water is required in order to cause hydration of cement, and consequently leads to strength development of the sandcrete block. Recent researches (Oladejo, 2007; Adewuyi, 2011) carried out physico-chemical characterization of shallow wells in Ogbomoso, and concluded that the waters have similarities in their chemical composition with the exception of pockets of anomalous concentrations which are attributed to local anthropogenic activities. Furthermore, similar geo-hydrologic conditions and land use pattern may further suggest that the well waters have similar qualities, though this was not confirmed during this work. In addition, well water serves as the major source of domestic water in all the neighborhoods, and this may indicate that it is of a fairly good quality. Hence, the quality of the water is not considered to have differential or derogatory effects on the quality or the variability of the strength of sandcrete blocks within the study area.

Table 1 shows that the methods employed for production are of two types, namely the use of manual mould and use of mechanical mould. The manual mould pre-dates the mechanical operation, and does not give proper compaction, and normally associated with occurrence of micro distortion due to poor separation of the mould and the block. These consequently result in relative weakness of the block. Approximately 14 % of the block industries use the manual mould within the study area. Conversely, the mechanical mould gives adequate compaction and produces block at faster rate, and at a relatively higher strength. Approximately 79 % of the block industries visited used this mechanical mould only while 7 % tend to combine the use of both the manual and mechanical at different proportions. In this work, the observed strength distribution of sandcrete block samples does not correlate with the distribution of types of mould usage. Therefore, the use of different types of mould is not considered as the major reason for the observed differential and comparatively low compressive strength within the study area.

The ranges of mix of cement to aggregate used (mix ratio) based on the questionnaire are presented in Table 3. The BS 2028 (1978) specifies the range of allowable mix ratio to be between 1:6 and 1:8. It is obvious (Table 3) that none of the sandcrete block produced within the study area meets this specification, and this appears to have significantly contributed to the observed reduced values of compressive strength as presented in Tables 2. It is apparent from the tables (Table 2 and 3) that the entire sandcrete blocks produced within the study area largely deviated from the mix ratio specified by the regulatory bodies.

The compressive strength of sandcrete block tend to increase proportionally to the length of period of curing (Figure 3) partly because of continuous enhancement of the process of hydration with increasing time. Table 3 therefore suggests that there is high potential for reduction in the strength of sandcrete blocks due to significant reduction in the length of curing. In addition, the method employed by the entire manufacturers within the study area is wetting. For effectiveness, it is required that wetting is carried out at a minimum of twice per day, contrary to the observed practice of once per day, which may further contribute to the observed low strength.

Other parameters considered in this assessment of variability of strength of sandcrete blocks include attitude to profit making and level of formal education. The oral interviews reflect that the entire sandcrete block manufacturers within the study area are largely driven by profit, with little consideration for the strength and quality of their products.

Table 3: Mix ratio and period of curing of sandcrete blocks

Zone	Mix Ratio	Period of curing (Days)
Zone 1	1:14 to 1:18	3 - 5
Zone 2	1:10 to 1:14	3 - 5
Zone 3	1:10 to 1:14	3 - 5
Zone 4	1:10 to 1:16	3 - 5
Zone 5	1:10 to 1:14	3 - 6

The average number of sandcrete blocks produced per bag is 43, rather than the preferred range of between 25 and 30. Also, majority of the block makers visited in the five zones are semi-illiterates, and appear to lack the necessary rudimentary knowledge about sandcrete block making, but largely rely on a trial-and-error approach and experience. Therefore, little or no appreciation is given to the need to adhere to the required regulatory standards and consequently safety.

IV. Conclusions

In this work, assessment of impact of material and process variables on the strength of sandcrete block was carried out, including the degree of compliance between the measured strength and the standard specifications. It was observed that a monolithic source exist where the manufacturers within each zone acquire their coarse aggregates from the same source through individual contractors. The sand materials generally contain wide range of grain sizes and appear to be suitable for the production of the sandcrete blocks. The same water source is used both for the sandcrete block production and domestic supply within the neighborhoods and therefore, the quality of the water is considered not likely to have any significant derogatory effects on the strength of the sandcrete blocks. The compressive strength of the sandcrete blocks varied across the zones and generally lower than the regulatory guidelines. The sandcrete block samples obtained from zone 2 and zone 5 respectively have highest and lowest values of compressive strength. The ranges of values obtained for the density appears to be adequate, but this is likely to be overridden by the more important compressive strength. Factors which include profit orientation, mix ratio, period of curing, and level of literacy, appear to have been responsible for the sub-standard products. It is therefore recommended that enforcement of compliance monitoring with the standard specifications and basic education will be required to ensure improved production of good quality sandcrete blocks within the study area.

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