QUALITY OF SANDCRETE HOLLOW BLOCKS IN PLATEAU STATE

BY

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DECLARATION

I declare that the work in this dissertation entitled **QUALITY OF SANDCRETE HOLLOW BLOCKS IN PLATEAU STATE** has been carried out by me in the Department of Civil Engineering. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of the project thesis was previously presented for another degree or diploma at this or any other Institution.

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CERTIFICATION

This dissertation entitled **"QUALITY OF SANDCRETE HOLLOW BLOCKS IN PLATEAU STATE"** meets the regulation governing the award of the degree of **Master of Science (MSc)** in Civil Engineering of Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This dissertation is dedicated to
my late Mother ,Father and elder Brother:
Alhaji Bala Musa Zakariyya

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ABSTRACT

Sandcrete hollow blocks are widely used in Plateau State. The quality of these blocks produced, however, differs from each manufacturer due to different methods employed in the production and the properties of the constituent materials. This research work focuses on the impact of quality control practices by manufacturers on the quality of blocks produced in the state. General survey of the entire state was conducted to determine the number of block industries in the state and 121 block manufacturing industries were observed. Five (5) block industries were selected randomly for the studies. 300 Sandcrete blocks of average sizes of 450 x 230 x 230mm were purchased from the manufacturers and tested for dry and wet development compressive strength; and wet compressive strength after 28 days, the density, water absorption, dry shrinkage, wetting expansion and dimension tolerance of the blocks were also determined. Sand (fine aggregates) material samples were also taken from the manufacturers and tested for grading, silt and clay contents. Cement samples used for the manufacturing of these blocks were collected and tested for setting times, standard consistency and soundness. The mix ratio and method of curing were also considered. The research work confirmed that, the highest dry and wet development compressive strength values were found to be 0.75N/mm^2 and 0.62N/mm^2 respectively. The highest wet compressive strength was found to be 0.86N/mm^2. The sand materials fell within zone 1 and 2 of the British standard sieve, and the silt and clay contents were found to be less than 6% as specified by BS EN 1377-2:1990, which are adequate for good mix. The cement consistency was found to be 30.5% which is within the BS EN 196-6:2010 requirement, the initial setting time was found to be 48minutes and the final setting time was found to be 2hours 47minutes, which is within the recommendations of BS EN 196-:2008. The soundness was found to be 1.2mm, which is within the recommendations of 12mm specified by BS EN 196-3:2008. The blocks produced are therefore less than the local and international standard requirements and therefore, unsuitable for use as a load bearing wall.

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CHAPTER ONE

INTRODUCTION

1.1 Background Information

Sandcrete hollow block is one of the most common building materials used in most building constructions that require walling units in many countries of the world; Nigeria inclusive. Sandcrete hollow block is made from the mixture of cement, sand (fine aggregate) and water in a standard specified mix proportion. It has the following nominal standard sizes of:

450mm x230mm x 100mm

450mm x230mm x150mm

450mm 230mm x 230mm NIS 87: (2006)

British Standard (BS EN 77-3) : 2006, defines block as a masonry unit of larger size in all dimensions than specified for bricks but no dimension should exceed 650mm nor should the height exceed either its length or six times its thickness.

Sandcrete hollow block is either produced manually or by moulding machine. The manual production suffers the problem of less compaction and therefore less strength after curing. The machine moulding when produced according to the standards, suppose to attain strength of not less than 3.45 N/mm^2 for mean strength and 2.59 N/mm^2 for the lowest individual strength BS EN 77-3:2006. The Federal Ministry of Works (1979), recommends 2.1 N/mm^2 for mean strength and 1.7N/mm^2 for the lowest individual strength; Though not in accordance with BS EN 771-3:2006. Sandcrete hollow block is still playing important role in the provision of walling unit.

1.2 Statement of the Problem

Most of the sandcrete hollow blocks produced in Plateau state are produce without reference to any standard. The quality of these sandcrete hollow blocks produced in the state commercially, however, need to be checked and be sure that they meet the minimum specified international standards. This research work therefore, tried to investigate the quality or physical properties of sandcrete hollow blocks produced in the state commercially for the purpose of determining its quality and suitability as a building unit.

1.3 Justification of the Study

Most of the blocks produced in Plateau State are somehow substandard; this contributes to the deteriorations of buildings in the state. Therefore, investigations to determine the quality of blocks produced in the state could not be over emphasized.

The standard compressive strength of sandcrete hollow block can only be achieved when its production is done in accordance with the BS or NIS standard. The final compressive strength of sandcrete hollow block can be as high as 3.5N/mm^2, but 3.45N/mm^2 is the BS recommended compressive strength. Thus, the research will find out whether the strength of the blocks produced in the state are not up to standard.

1.4 **Aim and Objectives**

This research work is aimed at assessing the quality of sandcrete hollow blocks produced commercially in Plateau State with the following objectives.

i. To carry out survey of the manufacturing block industries in Plateau State.

ii. To determine the particle size distribution by sieve analysis and silt and clay content of the sand materials used for the production of these blocks.

iii. To determine the varying mix proportion used by the block producing industries and compare with the standards.
iv. To determine the dry and wet compressive strengths of the sandcrete blocks produced with age, in the state and compare with the international and local standards.
v. To determine the density of the finished sandcrete blocks.

1.5 Scope of the Study and Limitation

This research work intended to:

i. Review the previous type of research works done on sandcrete hollow blocks here in Nigeria, some neighboring countries and internationally.
ii. Determine the properties of the materials used for the production of these blocks and compare with the standard.
iii. Determine the dry and wet strengths of the blocks.
iv. The chemical properties aspect of the blocks is not considered in this study.

1.6 Description of The Study Area

Plateau state, which was created in February 1976, is the twelfth largest state in Nigeria and is roughly located in the center of the country. It is geographically unique in Nigeria because it is totally surrounded by the Jos plateau, having the Jos plateau totally in its central and northern part. Its capital is Jos. Map of Plateau state with its seventeen local governments is shown below.

Plateau state is celebrated as the Home of peace and tourism". It has a population of around 3.5 million people (2006 census). Plateau state is sharing boundaries with Bauchi state to the North East, Kaduna state to North West, Nasarawa state to the south west and Taraba State to the east. It is located in the middle belt, of the country, with an area of 26,899 square kilometers and named after the Jos plateau, a mountainous area in the north of the state with captivating rock formations. Rocks are scattered across the grasslands, which cover the entire plateau.

Plateau state is situated almost at the geographical centre of Nigeria and about 179 kilometers (111miles) from Abuja, the nation's capital. Jos is linked by road, rail and air to other states of the country. It is located between latitude 08^{o} 24^{I} N and latitude 008^{o} 32^{I} and 010^{o} 38^{I} east.

The mean annual rainfall varies from 132cm in the southern part to 146cm on the plateau, www.plateaustategovt.net (2016). The Jos plateau makes source of many rivers in northern Nigeria including the Kaduna, Gongola, Hadeja and Yobe rivers.

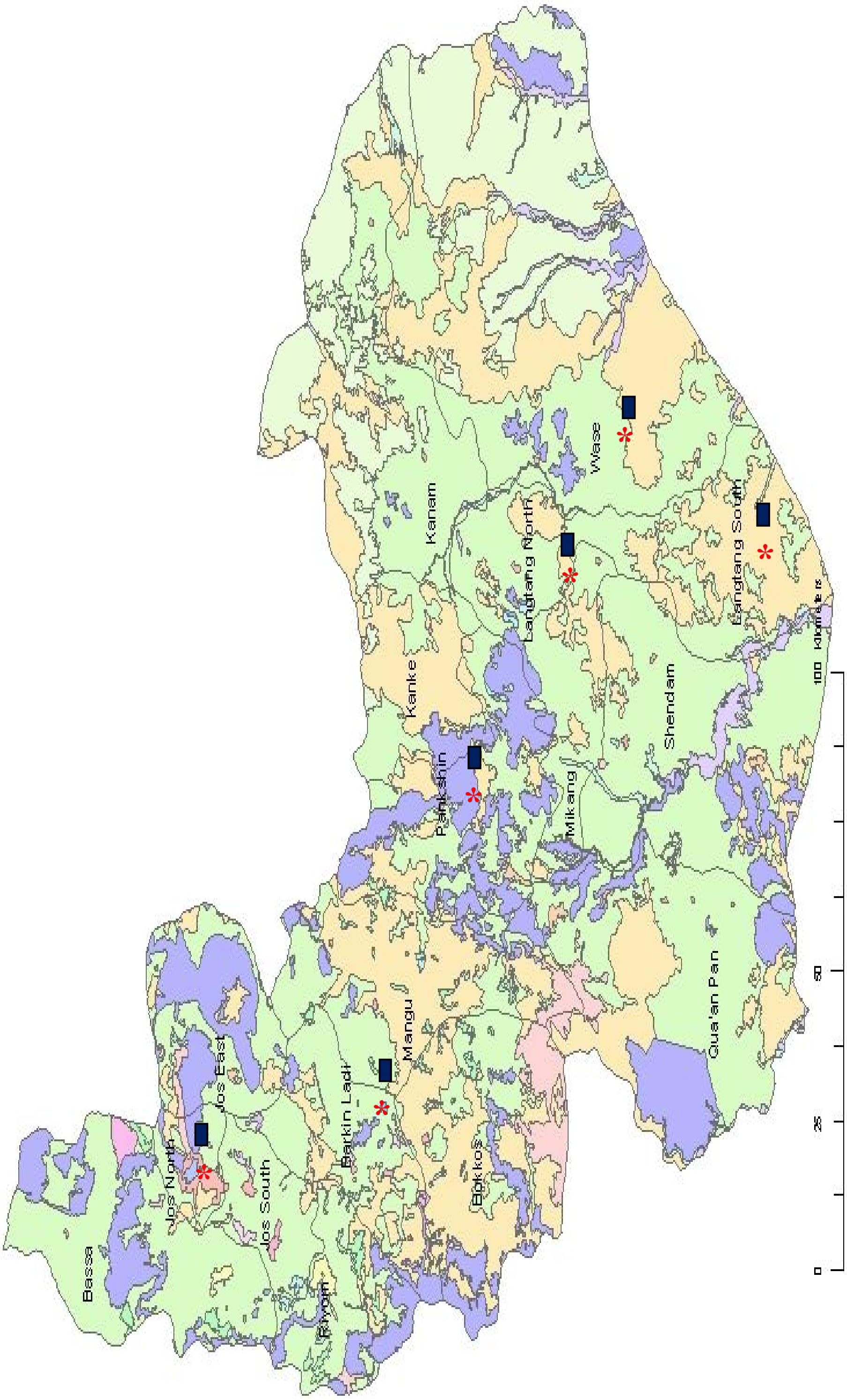

Plate I: Map of Plateau State local government areas with the local Governments selected for the studies in red * and black blocks.

CHAPTER TWO

LITERATURE REVIEW

2.1 Sandcrete Hollow Blocks

The use of sandcrete hollow blocks in building construction, especially in shelter provision as stressed by Omopariola (2014), as a walling unit in Nigeria, has come a long way. It is as old as the construction industry itself. For a long time until perhaps a few years ago, these blocks were manufactured in many parts of this country without any reference to any specification either to suit local building requirements or for good quality work. It is interesting to observe that the situation has changed, as the Standard Organization of Nigeria now has a document in place giving the specification both for the manufacture and use of these blocks in Nigeria, (SON 1976). Therefore, studies have been carried out by different researches from various parts of this country to determine its quality in comparison with the quality set by the local and international standards.

Ejeh and Banuso (2008), assessed the quality of sandcrete blocks produced in Kaduna state and concluded that the blocks were of lower quality when compared with the BS and NIS standards. A research work carried out by Afolayan et al (2008) indicated that the compressive strengths of sandcrete hollow blocks produced in Ondo State of Nigeria were sub-standard. Abdullahi (2005) studied the compressive strength of sandcrete blocks produced in some parts of Minna, Niger State, and discovered that they were below the minimum standard requirement. Florek (1985) also said that the quality of sandcrete hollow blocks produced in Kaduna, Zaria, Saminaka, Ikara, Bauchi and Mubi were very low compared to the standard. Omoreregie (2012) also reported that investigations into the compressive strength of blocks were carried out in Benin City, Ekpoma, Ughelle, Effurum and Warri town, and the results also revealed low compressive strength as compared to the standerd. The standard compressive strength, when produced by machine moulding and under the standard production requirement is 2.9N/mm^2, BS EN 771-3:2006. Measured strength of commercially available sandcrete blocks in Nigeria was found to be between 0.5 and 1 N/mm^2, which is well below the 3.45N/mm^2 (BS) and 2.5N/mm2, NIS (2007) that is legally required. This may be due to the need of the manufacturers to keep the price low, and since the main cost- factor is the Portland cement, they reduce that, which results in a block that behaves more like loose sand. Most of the manufacturing industries do not care to provide adequate enabling environment for the production of sandcrete blocks. They are, in most cases, trying to maximize their profit. The manufacturing of sandcrete hollow block was always in the hands of the illiterates, sandcrete blocks depend on some variables during production which are: amount of cement, fine aggregate, water, degree of compaction, curing condition and etc". Frank (1982), observed that "the physical properties of sandcrete hollow blocks are affected to high degree by the properties of the constituent materials" that is cement, aggregate and water. Oyekan and Kamiyo (2011), The material constituents, their mix, presence of admixtures, if needed, and the manufacturing process are important factors that determine the properties of sandcrete blocks.

These conventional constituent materials; cement, sand (fine aggregate) and water, are discussed as follow:

2.2 Cement

This binds the other constituent materials together and also fills up the voids in between them in the presence of water. Ma'aruf et al (2017) observed that 'the cement glues the aggregates (sand) together, fills voids with it and makes it flow freely'. Therefore, it is the most essential constituent material of sandcrete blocks. Neville (2012), stressed the fact that cement binds aggregates together and fills up the voids in between them. It has been observed that Ordinary Portland Cement (OPC) is the most common cement generally used in this country for building construction and it comes in different brands; from Dangote, Sokoto, Ashaka cements etc.

Whichever brand of cement is used in the production of sandcrete block, it should meet the BS EN 197-1:2011 and NIS 87:2004 requirements. These codes specify the following physical properties of cement.

i. The soundness expansion should not be more than 10mm and 5mm if aerated.
ii. The fineness of an average specific surface of range bewteen200 and 300 cm^2/g
iii. Initial setting time should not be less than 45 minutes and final setting time of more than 10hrs, BS 12(1996).

The Portland cement that is commonly used in Nigeria in the manufacture of sandcrete blocks is often deficient in basic characteristics such as soundness, leading to excessive change in volume, particularly expansion of the cement paste after setting, as reported by Omoregie (2012).

Cement is the most important material for the production of sandcrete hollow blocks, because it binds the other constituent materials together in the presence of water into a cohesive strong mass. Ola and Owoleye (2002), after their tests concluded that the compressive strength of sandctete blocks increase appreciably with increase in cement content.

The principal requirement is that the cement should be able to produce strong, dense, durable sandcrete hollow block with definite setting and hardening characteristics. The cement should conform to the standard recommendations of BS EN 197-1: 2011and NIS 87:2004, Portland cement (ordinary and rapid hardening).

2.3 Aggregate

According to NIS 87:2004, the sand to be used for producing sandcrete blocks shall be approved clean, sharp, fresh water or pit sand free from clay, loam, dirt, organic or chemical matter of any description and shall mainly pass through 4.70mm or fall within zones 1 and 2 of British standard test sieves.

Abdullahi (2005), said ‘The most widely used aggregates for moulding sandcrete blocks is the natural sharp sand usually from the riverbed’. BS EN 12620:2013, specifies that the maximum quantity of clay, silt and fine dust should not be more than 6% . The grading for sizes and the shape of particles are important, because they affect the workability of the mix as well as the density and impermeability of sandcrete hollow block. Jackson and Dhir (1996), said aggregate from some parents rock should not be used for sandcrete block because they may be physically and chemically unsuitable. In general, aggregate to be used in any construction work or manufacturing should conform to the standards.

2.4 Water

BS EN 1008:2002 specifies that, the suitable water for making concrete block should be water that is free from any chemical composition and acceptable for drinking, whether treated for distribution through the public supply or untreated. It went on to state that the use of seawater causes a moderates reduction in strength, surface dampness and efflorescence attack on sandcrete blocks.

Sea water has a maximum concentration of 3.5% salts in its compositions; hence it is not advisable to use seawater as mixing water, Association of Portland Cement (APC), (1980).

The quality of water affects the hydration of cement, while the quality of water adversely affects the strength of sandcrete blocks. Nasa (1980), said the strength of sandcrete block at a given age depends upon the water/cement ratio. The amount of water used should be the minimum necessary to give sufficient workability for full compaction of the block. Umar (2006), said When the water quality is in doubt, it is necessary to test both it nature and extent of contamination according to BS EN 1008:2002 before use. Cement and Concrete Association (1980) indicated that the 28 days strength could be reduced by as much as 20% if seawater is used as mixing water. Plateau State is blessed with rivers that run through most of its local governments. Manufacturers of blocks in the state rely mostly on these rivers for their source of mixing water especially during the raining season. In the dry season, some of these rivers lack adequate water and manufacturers then use bore holes for their water supply, as confirmed by the manager of the industry. Where bore-hole is not available, like in Kanke local government headquarters, manufacturers usually buy water from water tankers, sourced from Pankshin local government area, which is about 35km away, where there is pipe-borne water and bore-holes.

2.5 Mix Proportion

The British Standard; BS EN 771-3:2006 specifies that the mix ratio used for sandcrete hollow block production shall be not richer than one part by volume of cement to six parts (1:6) of combined fine and coarse aggregate except that it may be increased to 1:4 where thickness of the web of block is 25mm or less. Ahmed (1996), stated that, the strength of block decreases with increase in the mix ratio. He observed that the strength of block after 28 days with a mix proportion of 1:4, 1: 5, 1:7 and 1:8 were 0.904, 0.548, 0.259 and 0.176 N/mm^2 respectively. Hence, the richer the mix proportion, the higher the crushing strength of the blocks produced from the mix. Andrew and William (2006), stated that if cement content of a mix for sandcrete block production is increased, the strength usually increases, but if the block with a higher cement content was less compacted than the lesser block, then the strength of the rich block may be lower. Cement and concrete association (1980), confirmed the undesirability of using mix proportions richer than the nominal ratio of 1:6 to achieve good quality blocks. This causes a great loss of economy in using mix of higher cement content. John (1999), stated that it is possible to decrease the cement to sand and still retain the strength requirements of the block, provided that well graded sand is used under effective vibration and optimum workability.

2.6 Water/Cement Ratio

Sandcrete block mixtures are usually specified in terms of the dry-volume ratios of cement to sand. Depending on the applications, the proportions of the ingredients in the block can be altered to produce specific changes in its properties, particularly strength. The amount of water added to these mixtures is about 0.5 to 1 times the volume of the cement, according to the operator of the industry. For high-strength block, the water content is kept low, with just enough water added to wet the entire mixture.

The strength of sandcrete block at a given age is assumed to depend primarily on two factors: the water/cement ratio and the degree of compaction, Neville (2012). The net water/cement ratio depends on the rate of absorption at the time of mixing and not only on the moisture content of the aggregate. A well-graded aggregate with a minimum volume of voids will required only a moderate amount of cement and produce a block with small drying shrinkage, high durability and strength, Neville (2012). Umar (2006) in his test observed that the strength of sandcrete hollow block increased as the water/cement ration increase from 0.45 to 0.50 and decreases as the water/cement ratios increases to 0.65 because of the increase in void content.

Neville (2012) said, the amount of water in a mix must be controlled if high strength quality blocks are to be produced.

2.7 Block Production

Sandcrete hollow blocks are produced either manually or mechanically. The manual production suffers less compressive strength due to poor mixing and manual compaction. Ali (2006) reported that, 'The machine production, produces better quality blocks due to the effective compaction through vibration of the mix during filing in the mould and compression by the weight of the rammer'.

2.8 Curing

Curing has been described as the process of preventing the loss of moisture from the block while maintaining a satisfactory temperature regime, (Sheikh & Hamza 2010). Adequate curing of block is essential to ensure sufficient hydration of the cement, Obede, (1990). During curing period, the originally water filled space in the cement – sand mix, is gradually replaced by gel product of hydration. This practice promotes the development of compressive strength and dimensional stability of the block. After the block has been cast, the surface should be kept moist so that it can achieve its maximum strength and not shrink too much due to drying out, which results in cracks, Nasa (1980). The method of curing employed can significantly affect the properties of the blocks. Being concrete product, strength can only be gained if blocks are subjected to condition in which moisture is retained long enough for setting of the cement, Shettima (2006). If curing is efficient, the strength of the concrete block increases with age. This increase is rapid at early ages and then continues more slowly for an indefinite period, Shettima (2006). Cement curing increases the impermeability and durability of the sandcrete block, as stated by the Cement and Concrete Association (1980).

Curing takes place about twenty-four hours after the production of the blocks for about seven days and then allow to dry slowly. Andrew and William (1996) observed the blocks will be ready for use in about four week.

2.9 Storage

It was observed that, at the end of curing, the blocks are normally stockpiled on a raised platform of old blocks, in most o the industries in Plateau state, to keep it free from contact with the ground. Covering the stockpiled blocks with a tarpaulin, Kraft paper or other weather tight coverings provides protection from rain. The moisture content of the blocks must be kept low to minimize subsequent shrinkage movement, Obende (1990). Sandcrete blocks should not be wet before using them except in extremely hot, dry weather when it may be dampened by applying water with a brush, CC Asso (1980).

2.10 Form and Size

There are three basic forms of sandcrete blocks: solid, cellular and hollow. A solid block has no formed holes or cavities other than the voids of the constituent materials, while cellular and hollow blocks have one or more formed holes or cavities which in hollow blocks pass right through them, according to Amodu (1998). BS EN 771-3: 2026:, said "A block is considered solid when the solid material is not less than 75% of total volume of the block calculated from the overall dimensions". Also a hollow block is obtained when there are one or more large cavities, which pass through the block, and the solid material is between 50% and 75% of the total volume of the block calculated from the overall dimension. A cellular block is formed when the block has one or more moulded cavities, which do not effectively pass through the block and the solid material is between 50% and 75% of the total volume of the block calculated from the overall dimension.

In modern construction industries, blocks are invariably hollow. Frank (1982) said, apart from the economy of material, the hole reduces the risk of interior dampness into the building wall and also improves thermal resistance and heat insulation within the walls. However, solid blocks bear high strength than hollow or cellular type of the same concrete mix quality.

British Standard BS EN 771-3: 2006, states that block is a masonry unit of a large size in dimensions than specified for bricks but no dimension should exceed 650mm nor should the height exceed either its length or six times its thickness. BS EN 771-3:2006, specifies the dimensions of blocks as shown in table 1 and NIS in table 2.

Table 2.1: Block dimensions

BLOCK	Length x HeIght		Thickness (Work size) mm
	Co-coordinating size (mm)	Work size (mm)	
TYPE A	400 x 100 400 x 200	390 x 90 390 x 190	75,90,100 140 and 190
	450 x 225	440 x 215	75,90,100,140,190 & 215
TYPE B	450 x 200 450 x 225 450 x 300 600 x 200 600 x 225	440 x 190 440 x 215 440 x 290 440 x 190 590 x 190 590 x 215	75,90,100 140,190 and 215
TYPE C	400 x 200 450 x 200 450 x 225 450 x 300 600 x 200 600 x 225	390 x 190 440 x 190 440 x 215 440 x 290 590 x 190 590 x 215	60 and 75

Source: BS EN 771-3:2006.

NIS 87:2004 defines sandcrete block as a composite material made up of cement, sand and water, moulded into different sizes. According to them, they are masonry units which when used in its normal aspect exceeds the length or width or heights specified for bricks. The block can, therefore, be made either in solid and hollow rectangular types (for normal wall) or decorative and perforated in different designs, patterns, shapes, sizes and types (for screen wall or sun breakers).

Table 2.2 Types of sandcrete blocks and their usage

Type	Work size (mm)		
Solid blocks	Length x Heigth x Thickness	Web Thickness	Usage
	450 x 225 x 100	25	For non-load bearing and partition walls Hollow
	450 x 225 x 113	25	For non-load bearing and partirion walls
	450 x 225 x 150	37 – 50	For load bearing walls Hollow
	450 x 225 x 225	50	Forload bearing walls

Source: NIS 587: 2007

2.11 Physical Properties of Sandcrete Blocks

Jackson & Dhir (1980) asserted that 'The physical properties of sandcrete hollow blocks depend to a varying degree on the type and proportions of the constituent materials, the manufacturing process, and the mode and duration of curing employed, as well as on the form and size of the sandcrete block'. All of these can vary greatly and subsequently affect the properties of sandcrete blocks,

2.12 Compressive Strength:

Compressive strength is the most common measure for judging the overall picture of the quality of sandcrete hollow blocks as a walling and load bearing in building structures, Frank (1982). The , Portland Cement Association (PCA) (1980) said that the compressive strength of sandcrete hollow block is influenced principally by the type and amount of cement, the type and grading of aggregate, degree of compaction, age of the specimen, curing procedures and moisture content at the time of test.

The PCA (1980) stated that different types of cement have different strength-producing characteristic and that the strength of sandcrete block increases with the cement content. It usually depends on the strength of cement paste and the bond between the cement and the aggregate. This bond is affected greatly by the texture and the cleanliness of aggregate. The strength also decreases as the amount of sand in a mix increases beyond the level needed to fill voids in the coarse aggregate because of increased water requirement and then effect on the water-cement ratio.

Murdock (1980) observed that, lack of proper curing results in a premature dry and loss of about 40% strength. Sandcrete hollow blocks will continue to gain strength as long as moisture is available and temperature is satisfactory. Orchard (1996), observed that the amount of water absorbed would not cause much decreases in the strength of hollow sandcrete block. He also observed that most concrete blocks are about 15% stronger when dry than wet,

British standard, BS EN 771-3: 2006, recommends the values of average compressive strength for type A and B blocks as shown in Table 3 below.

Table 2.3: Average compressive strength of type A and B blocks

Block type and Designation	Minimum compressive strength	
	Average of 10 blocks N/mm^2	Lowest individual block N/mm^2
A (3.5)	3.5	2.8
A (7)	7.0	5.6
A (10.5)	10.5	8.4
A (14)	14.0	11.2
A (21)	21.0	16.8
A (28)	28.0	22.4
A (35)	35.0	28.0
B (2.8)	2.8	2.25
B (7)	7.0	5.6

Source: BS EN 771-3: 2006.

Thus, the minimum average compressive strength recommended by the British Standard for type A block is 3.5 N/mm^2, while that of lower individual block strength is 2.8 N/mm^2. Similarly, the Nigerian industrial standard recommends an average strength of 3.45 N/mm^2 and 2.76 N/mm^2 for load and non-load bearing sandcrete block respectively NIS 87(2004).

The results of average wet compressive strength test carried out on sandcrete hollow blocks at Katsina, Bauchi, Gombe, Benue and Kogi States as well as the Federal Capaital Territory, Abuja were 0.88, 1.04, 0.45, 0.44 and 0.49 N/mm^2 respectively as reported by Shettima (2006) and observed by Muojekwu (2000), Duna (1998), Abbas (1997), Amodu (1998) and Aliu (1998).These values are less than the average strength of 3.5 N/mm^2 recommended by Nigerian Industrial standards, NIS 87 (2004). With the high demand of sandcrete hollow blocks presently in the state and the numerous block-moulding Industries springing up, the quality of sandcrete blocks needs to be checked and standardise.

2.13 Density

Orchard (1996), said that maximum density is obtained when the mix used is of adequate workability. Nasa (1980), also said that there is a close correlation between the strength at a given age (for a particular aggregate/cement ratio) and the density. He said they both increase as the proportion of fine aggregate is increased. Jackson & Dhir (1996) stated that the typical range for dry density sandcrete block is usually given as 500 – 2100 kg/m^3, But BS EN 771-3: 2006, specifies that the block density of type A blocks whether solid, hollow or cellular, shall not be less than 1500 kg/m^3 when determined according to the standard, and similarly the density of type B and C blocks shall be less than 1500kg/m^3.

2.14 Dry Shrinkage and Moisture Movement

This is another important property of sandcrete hollow block, it is a dimensional change occurring in sandcrete blocks owing to variation in the ambient moisture and temperature conditions, according to Jackson & Dhir (1996).

The drying shrinkage is the reduction in length obtained when a saturated sample is dried under certain conditions, while the moisture movement is the increase in length of the sample when again saturated.

Orchard (1962) said that, ‘the properties of cement have little effect on the shrinkage of concrete’. But Neville (2012) said that cement deficient in gypsum can exhibit high shrinkage. He also said that entrainment of air has virtually no effect on shrinkage. Dry shrinkage and moisture movement can be controlled by thorough or proper production and handling of the blocks. When produced, the block should be properly cured to avoid dimensional changes that may cause cracks on walls.

Murdock (1960), said that the use of excess mixing water leads to high shrinkage. He also said that drying shrinkage generally decreases as the strength of the aggregate increases.

2.15 Fire Resistance

Sandcrete blocks are generally good for fire resistance properties. However, Shettima (2006), mentioned in his write up that, the actual fire-endurance is controlled by numerous factors, which include: the type and grading of aggregates, cement content in the mix, weight and thickness of the block and its moisture content. Jackson & Dhir (1996), stated that ‘as a general rule, most sandcrete blocks of 100mm thickness can provide an adequate resistance to fire for up to two hours if load-bearing or up to four hours if non-load bearing’,

2.16 Thermal conductivity

The thermal conductivity of a concrete block is largely dependent on its density. It is observed that aerated concrete and lightweight concrete blocks have relatively low thermal conductivities. The lighter and more porous the blocks, the better will be its insulating value, Obende (1990).

2.17 Efflorescence

Efflorescence usually occurs at the time the walls are drying out after construction. It is the formation of salt deposit on the surface of the block walls because of a reaction between the free calcium hydroxide [$Ca(OH)_2$] brought to the surface and atmospheric carbon dioxide to form a white deposit of calcium carbonate. Neville (2012), stated that, efflorescence is the salt coating on the surface of sandcrete hollow block which may appear in due course as a white deposit on the surface of the block walls,

CHAPTER THREE

METHODOLOGY

3.1 Survey of Existing Block Industries

The methodology involves general survey of the entire state to determine the total number of 121 functional block industries and spread all over the state. The state has seventeen Local Government Areas and they were divided into four different zones. These zones are: North East Zone, North West Zone South West Zone and South East Zone. Five block industries were selected, based on consistency in production; two from North East Zone and one from each of the other Zones. Three(3) number of block samples were collected per ages of 1, 3, 7, 14 and 28 days of curing; that is, fifteen (15) numbers of blocks per industry. The fifteen (15) number of blocks, were used for the test of Dry development compressive strength, Wet development compressive strength, Wet compressive strength and Density of these block samples. That is, 60 pieces of sandcrete hollow block samples of size 450mm x 230mm x 230mm were purchased from each of the five selected block industries. A total number of 300 blocks, produced by the block industries, were purchased and collected for laboratory test. 'Tippett's (2004), 'random sampling technique' was adopted for selection of these block specimen. Sand materials used by the block industries, were also collected. Laboratory tests were performed on the samples collected in accordance with the relevant code of practice.

The following listed laboratory tests were conducted:

i. Dry development compressive strength.

ii. Wet development compressive strength.

iii. Wet compressive strength

iv. Density determination.

v. Sieve analysis, Clay and silt content and Cement test.

3.2 Summary of the excising functional block industries

Extensive survey of the existing block industries in the entire state was conducted between February and May 2016. This was done to obtain detail information on sandcrete hollow blocks production in the state and to ascertain the number and spread of block industries across the entire state. After general survey of the entire state, it was observed that there were one hundred and twenty one total number of block functioning industries within the state, the breakdown of which is shown in the table below:

Table 3.1: Local Government Areas with Number of Block Industries(functional).

	Local government	**Number of block industries**
1	Barkin Ladi	8
2	Bassa	3
3	Bokkos	5
4	Jos East	9
5	Jos South	8
6	JOs North	11
7	Kakem	7
8	Kanke	6
9	Langtan North	13
10	Langtan South	7
11	Mangu	6
12	Mikang	3
13	Pankshin	8
14	Qua'an Pan	5
15	Riyom	6
16	Shendam	9
17	Wase	7
-	TOTAL	121

Personal survey (2016)

3.3 North East Zone (zone A)

This zone comprises of 5 Local Governments; Jos north, Jos east, Barkin Ladi, Kanke and Kanem Local Government areas. Each of these local government towns were visited and after careful investigation it was discovered that all the local governments in this zone A have thirty five (35) functional block industries. Jos North Local government has the highest number of eleven (11) block industries, Jos East Local Government has nine (9) block industries, Kanem Local Government has seven (11) block industries, Mangu Local Government has eight (8) block industries while Kanke local government, which was created just recently has only six (6) block industries. The block industries in this zone A, were using mechanized Rosacometer type of moulding machines for the production of sandcrete hollow blocks in the commercial quantities. All the block industries in this zone A were using Lister type of diesel engines with water-cooling system to drive the Rosacometer mouding machine for the production of the sandcrete blocks. Other production materials that were seen in all the industries of this zone A, were shovels, wheel barrows, head pans, buckets and diesel oil drum containers, tipping trucks and an average of two delivery vans per each block industry.

It was observed that all the block industries in the zone A, used ordinary Portland cement of Burham, and Dangote cements. The cost of a bag of Ashaka cement of 50kg at the time of the visit, was ₦1750 including delivery to site. Dangote cement was sold at ₦1800 per 50kg.

The industries in this zone A use mostly sharp sand for the production of their blocks which were sourced from river banks of Pan-shanu and Gumau of Bauchi state: Jos north and Jos east were using sand from the neighboring rivers of Gumau and Pan-shanu. Kanke and Kanem local governments sourced their sharp sand from the bank of river Dankan in Amper, Kanke local government area and river Zai in Kanem local government area respectively. Mangu local government block industries, use river Mangu bank for the source of their sand.

The sand materials are usually delivered to the site using the common tipping truck owned by a different individual. In Jos north and Jos east, a truck of tree cubic metre ($3m^3$) of sand, was sold at ₦17200 and ₦15300. In kanke and kanem, the sand of $3m^3$, was sold at N15500 and N12300 respectively, while in Mangu which is within the town, the $3m^3$, of sand,was sold at ₦11600 per truck. These sands were heaped at open spaces within the site from where they are measured out, with a wheel barrow, to the mixing point, which was closer to the moulding machine.

The water used in this zone, especially in Jos north and Jos east, is portable water, which is supplied from the mains. The monthly rate of water bill of ₦3000 was fixed. In Mangu, Kanke and Kanem the water is purchased from water tankers. The cost of the water tanker ranges between ₦4000 and ₦6000 per one hundred and seventeen (117lts) of depending on the distance, from the industry to the source of the water. All the industries have reservoirs in form of an underground concrete tank for water storage and usage. Refer to table 6 on page 39.

The labour force in each of the block industries of this zone A averaged to seventeen workers, depending on the number of blocks to be produced per day. These workers include foremen, site guards, and drivers, skilled and unskilled laborers. The foremen and the guards as well as the drivers were paid on fixed monthly salary basis. While the machine operator who is classified as skilled worker and his team of unskilled workers were paid ₦20 per unit of block produced. The labour ranges from ₦500 to ₦650 per bag of cement used. A unit of a 450 x 225 x 225 block is costing ₦195 to be produced averagely according to the factory manager.

In all the industries in this zone A, the mixing operation of cement and sand materials are carried out manually. Batching by volume method is adopted in this zone A. But, none of the industries visited uses concrete mixer for mixing sand and cement. Therefore, all the mixing operations were done manually using shovels. An average of five wheelbarrows of sand is mixed with one bag of 50kg of cement. This was later measured to about 1:10 mix. It was observed that almost all the industries added the mixing water without reference to any standard at various stages of the mix, until acceptable workability is achieved.

The common sizes of sandcrete hollow blocks produced in this zone were 450mm x 225mm x 225mm size and 450mm x 225mm x 150mm size. On special request, 450mm x 225mm x 100mm size are sometimes produced. The average number of daily production per industry ranges between 1000 and 1500 for 450mm x 225mm x 225mm size of blocks.

The curing of blocks in this zone starts after twenty-four hours of production. The blocks are immediately wet with water by sprinkling twice a day. Average curing period ranges from 3-7 days per industry. Thereafter the blocks are set for sale. The price of 450mm x 225mm x 225mm size of block ranges between ₦190-₦210 including the cost of delivery to the site within the town, at the time of the survey.

3.4 North West Zone (zone B)

This zone (zone B), comprises of 5 Local Government areas: Bassa, Jos south, Riyom, Barkin Ladi and Bokkos local government areas. Each of these local government headquarters was visited and after careful investigations, it was discovered that there were twenty-three (23) machine block industries and eight (8) manual block industries in this zone B. The highest number of block industries was located in Jos South Local government which has eight machine block industries, with Bassa local government having the least block industries of only three (3) machine and five (5) additional manual block industries within Bassa town. Barkin ladi has eight machine block industries and three additional manual block industries; Bokkos has five block industries and two additional manual industries.

The workforce in this zone B ranges between 9 and 12 workmen per block industry: Jos south has the industry with the highest number of 12 workers per industry while Bassa has the least of 9 workers per industry.

The block industries in this zone B were also using mechanized Rosacomenter type of moulding machine to produce the sandcrete hollow blocks in the commercial quantities. They also use liter type of diesel engine with water-cooling system to drive the Rosacometer machine. Other materials that help in the block production are tipping trucks, delivery vans, shovels and whell barrows. Dangote and Burham Portland cements are the main type of cement used by the block industries in this zone as observed during the survey. The cost of Dangote cement in this zone was ₦1850 per 50kg bag while that of Burham cement was ₦1750 per 50kg bag as confirmed by the manager of the industry in Barkin Ladi.

The sand materials for block production in this zone were observed to be clean and sharp. A sand material used for block production in Jos south is sourced from the bank of River Kaduna and its tributary through vom. Riyom block industries sourced their sand materials from the bank of River Werran through Bochi. Bokkos sourced its sand materials from the banks of Rivers Daffo and Masari. Barkin Ladi has the bank of river Foron From which the sand materials were obtained. Industries in Bassa local government were obtaining part of their sand materials from the bank of River Gambo through Jere and Limoto towns. An $8m^3$ truck of sand material cost averagely ₦15000.

All the block industries in this zone B rely mostly on close-by Rivers for their water for mixing, with the exception of Jos south where there was pipe born water in addition to the distributaries of Kaduna River through vom town.

In all the industries in this zone B, mixing of cement-sand materials is carried out manually using wheel barrows to measure the sand. Water is added indiscriminately along stages of the mixing. The average mix ratio in this zone B is 1:9 for block size of 450mm x 225mm x 225mm. Another size of block produced in this zone includes 450mm x 225mm x 150mm with the same cement/sand ratio.

The blocks produced within this zone are immediately exposed to the air for curing with water by sprinkling twice a day. The curing of these blocks produced starts a day after casting and last for 3 to 4 days before selling. The price of 450mm x 225mm x 225mm size of block ranges from ₦220 to ₦240 during the time of the survey.

3.5 South West Zone (zone C)

This zone C, comprises of 4 local governments which includes Qua'an-pan, Shendam, Pankshin and Mikang local government areas. These local governments were also visited to ascertain the number of block industries. The commercial block industries were found in all the local government headquarters, with Shendam local government having nine (9) machine and three (3) manual block industries. Mikang local government has three (3) machine and four manual block industries, all in Tunkus town. Pankshin has eight machine (8) and three (3) block industries all in Pankshin town. There are therefore, twenty (20) machine block industries all together in this zone C. All of them used Rosacometer type of moulding machine for the production of sandcrete hollow blocks. Other materials like tipping trucks, wheelbarrows, shovels buckets and etc are being used in the production and delivery of these blocks.

It was observed that all the industries in this zone were using either Dangote or Burham Portland cements for production of the blocks. A 50kg bag of Dangote Portland cement was sold at ₦1950 and ₦1930:00 in Mikang and Pankshen local government areas respectively. Burham Portland cement of 50kg cost ₦1910. All the block industries stacked cement on ordinary concrete floor in their site store made of zinc sheets and concrete floor. The industries buy their Dangote Portland cement from the Pankshanu and Mikang markets. The block industries in this zone C also used sharp river sands for the sandcrete block production, which are bought from the neighboring river banks. Qua'an block industries buy their sand materials from the banks of rivers Yuli and Dep villages. Shendam block industries buy their sand materials from the bank of river Shemakar through Kolong town. Parkshen block industries buy their sand materials from the bank of rivers Dankan in Kanke local government and river Pushit from Pankshen local government area. One industry combine crushed stone dust with sand material when the sharp sand is too coarse for effective workability and high yield strength as confirmed by the industry's manager in Pankshen town. The cost of the sharp river sand ranges between ₦13, 000.00 to ₦16, 000:00 per 8m^3 truck capacity, depending on the distance from the source of the sand to the industry, while stone dust was sold at ₦30, 000:00 for an 8m^3 truck capacity.

Block industries in this zone c use river and pipe-borne water for the production of sandcrete hollow blocks, as observed in parkshen and shendam, while other industries rely on either borehole supply or buy from water tankers at the cost of ₦7000:00 per 32000lts capacity.

There is an average of 13 workers per industry in this zone as observed during the survey. The moulding machine operators and their teams are paid in unit rate of ₦35 per block produced of either 450 x 225 x225mm or 450 x 225 x 150mm.

The mixing operations of the constituent materials in this zone are done manually. The batching was done based on one bag of cement to two wheel barrow of sand, which was later confirmed to be mix ratio of between 1: 9 to 1:10, as confirmed by the load of worker of the industries. The addition of water was done without any standard reference; therefore, water was added until sufficient workability was achieved.

Two common sizes of blocks are produced in this zone. These are 450mm x 225mm x 225mm and 450mm x 225mm x 150mm sizes as observed during the survey.

Curing starts when the sandcrete blocks are one day old after production by sprinkling water twice a day and last for three to five days. One of the curing periods may sometime be skipped when there was rainfall. A unit of 450mm x 225mm x 225mm was sold at the range of ₦185 to ₦190:00 according to the factory managers. The cost of delivery to the site is also inclusive.

3.6 South East Zone (zone D)

This zone D, comprises of Langtang North, Langtang South and Wase local government areas. These local government headquarters were also visited to ascertain the number of functional block industries in the zone. The commercial block industries were all found in the local government headquarters, with Langtang North local government having the maximum number of thirtene (13) machine block industries and two manual block industries within the Langtng town. Langtang South has seven functional block industries, only five (5) were working during the time of the survey.

In Wase Local Government, there were four (4) block industries, but only three were functional. The industries in this zone D also used Rosacometer type of molding machine for the production of sandcrete hollow blocks. Other materials in the production of the blocks were: shovels, wheelbarrow, seven delivery vans etc. it was also observed that industries in these Local Governments commonly used Dangote brand of cement for the production of their blocks. A 50kg bag of cement cost ₦1850 and the cement are normally bought from Lang-tang north. It was reported by the workers and personally observed, that cements were stacked by the industries in roofing sheets stores at the site before production come.

The industries in this zone D also used coarse sand in block production which is sourced from either river Kurmi or river Bululluga along Langtang north road to Wase and river Kemsangi in Dengi Kanam local government. The cost of a $6m^3$ tipping truck ranges between ₦12, 500:00 and ₦13, 500:00, depending on the season of the year and the distance from the river bank to factory.

The industries in this zone D use portable water for the production of sandcrete blocks. The water was obtained from river kurimi and river Bullunga winthin Langtang north and south respectively. One of the industries in Langtang North, uses bore-hole water for the supply of water for production of blocks.

The mixing of cement and sand in this local government is carried out manually. Batching by volume method is also adopted here. None of the industries was using concrete mixer. An average of six wheel barrows of sand material was mix with one bag of 50kg cement. This was later measured to be 1:12 mix ratio. Water was observed to be added without any standard reference, it was therefore added at various stages of the mix until acceptable workability is achieved.

The common sizes of sandcrete hollow blocks produced in this local government were 450mm x 225mm x 225mm and 450mm x 225mm x 150mm. The average number of daily production per industry ranges between 700 and 1200 for 450mm x 225mm x 225mm size of block.

Curing of blocks in this Local Governments also start immediately after twenty four hours of production. The blocks are then exposed to the dry weather condition for a period of three to seven days after which the blocks are set for sale. A unit of 450mm x 225mm x 225mm size of block cost between ₦180 and ₦195 and ₦140:00 to ₦155:00 for 450mm x 225mm x 150mm including cost of delivery to site.

At the end of the site survey, the number and spread of sandcrete block industries in Plateau state were found to be one hundred and twenty one. The summary of the entire zones is shown in table 5 below.

Table 3.2: summary of site survey of sandcrete hollow blocks in plateau state.

ZONE	LOCAL GOVERNMENTS	NO. OF BLOCK INDUSTRIES	TYPE OF CEMENT USED / COST PER 50Kg BAG	TYPE OF SAND USED AND COST PER TRIP OF 4M 3	AVERAGE MIX RATIO	COST RANGE PER UNIT OF BLOCK	METHOD OF PRODUCTION
NORTH EAST ZONE (A)	JOS NORTH, JOS EAST, MANGU, KANKE & KANAM.	35	Dangote-N1850:00	River sand N12500-N175000	1:10	N220-N240	Mechanical
NORTH WEST ZONE (B)	BASSA, BOKKOS, BARKIN LADI, JOS SOUTH &RIYOM	23	Dangote-N1850:00	River sand N12000-N15000 Sand dust/30000	1:10	N220-N240	Mechanical
SOUTH WEST ZONE (C)	MIKANG, SHENDAM, QUA'AN-PAN & PANKSHIN.	20	Dangote-N1930:00	River sand N12000-N16000	1:10	N180-190	Mechanical
SOUTH EAST ZONE (D)	LANGTANG NORTH, LANGTANG SOUTH & WASE.	22	Dangote-N1850:00	River sand N11500-13500	1:12	N230-N250	Mechanical

Five reputable block industries, one per zone, were selected based on randomness, capacity and consistency in production as well as level of organization of the industry in enhancing performance and competitiveness.

The industries chosen were designated as I, II, III, IV and V. These numbers were only used for identification and they have nothing to do with the quality of blocks produced in the industries. The five industries comprised of two from north east zone (Jos North and Kanke) and one each from North West zone (Barkin Ladi), south west zone (Shendam) and south East zone(Wase). The selection of these industries was done through the state's map, as can be seen in the map on page 5 above. These industries are discussed as follows:

3.7 Industry I

This industry is located in North East zone A of Plateau State. The Industry is known as A. S. Mohammed block industry, located in Jos North Local Government of the state along Farin gada road, opposite university of Jos student's village. It was established in 1982 and is considered as one of the pioneers block industries in Jos. Production of sandcerete hollow blocks has been consistent since from its inception.

The industry has a workforce of twenty three men comprising of one site foreman, one sales man, 3 drivers, two site guards and two moulding machine operators with their team of seven unskilled labour men each. While all others are on fixed salary remuneration, each of the moulding machine operators with his seven team of unskilled labour receive ₦500 for every bag of cement used for any size of block produced. The machine operators received ₦150:00, the mould feeder receives ₦80:00 and other unskilled labour men receive ₦45.00 per person for every bag of cement used in the production of block, irrespective of the size. The industry has two functional Rosacometta type of moulding machine at the time of the visit. Other production tools, according to the industry's manager, include wheelbarrows, shovels, buckets and wooden pallets. The industry, according to him, also has three delivery vehicles: A Peugeot pick-up with a capacity of 200 number of blocks, a 'Tata' pick-up that has a capacity of 300 blocks and a Daff tipper that carries 350 pieces of blocks. The industry used Ashaka, Burhan and Dangote brands of Portland cements for the production of the sandcrete hollow blocks. The cements are sourced from within the town and sometimes from Benue state direct. The industry uses sharp sand, sourced from the rivers of Gumau and Panshanu in Bauchi state. The price of a trip of sand is also given in Table 3.2 above, depending on the capacity of the truck and distance to the site.

The industry buys water from water tankers at the cost of ₦4000 per 3200 litres in addition to pipe borne water. Volume by batching method of mixing is being used in the industry. The manager confirmed that the ratio of 1:10 of cement sand is being used. According to the foreman, the water added was not measured, but added until reasonable workability is achieved. The number of blocks produced in a batch of 50kg bag of cement is between 30 to 35 numbers of blocks for 460mm x 225mm x 225mm size and 50 to 55 numbers of blocks for 460mm x 225mm x 150mm size. On special request, about 60 numbers of 460mm x 225mm x 100mm size are also produced in a batch of 50kg bag of cement.

The daily average production in the industry is about 1400 pieces of 460mm x 225mm x 225mm size and about 2000 pieces of 460mm x 225mm x 150mm size of blocks.

Curing of blocks is done for a period of 3 to 5 days by spraying water on it between morning and evening depending on the season of the year. Thereafter the blocks are stocked in rows of five pieces at open space ready for sale at a rate of ₦1150 for a

460mm x 225mm 150mm and N190 for 460mm x 225mm 225mm size of block. This cost, include the cost of delivery within the town.

3.8 Industry II

This industry is also located within the North east zone B of plateau state at Kwal, the kanke local government headquarters along Pankshen - Amper road. It was established in 1992 and was using manual production. The industry is known as Ekeduma block industry. This block industry later became a modern one by bringing in Rosacometre machine with all other accessories. It is one of the prominent pioneer block industries in this local government, it is considered because of its consistency in block production and level of organization.

The industry has a workforce of 18 men comprising of one site foreman one driver, one site guard one sales lady and two moulding machine operators with their team of unskilled labour. Each of the moulding machine operators with his six team of unskilled labour receive ₦495 for every bag of cement used for any size of block produced. The machine operators received ₦250:00, the mould feeder receives ₦35.00 and other six unskilled labour men received ₦30.00 per person for every bag of cement used for the production of block irrespective of the size.

The industry has two functional Rosacometta type of moulding machine, according to the industry's manager, at the time of the visit. Other operation ancillaries and tools according to him, include a Mazda pick-up model of delivery van with a capacity of 200 numbers of blocks, two subsurface concrete tanks which were observed during site survey, two wheel barrows, shovels, buckets and about 200 wooden pallets.

The industry uses only Ashaka and Dangote Portland cements for production of the blocks. The cements are sourced from either Pankshen or langtang towns where there were cement depots. According to the foreman, cement transportation is being taking care by the industry.

The industry uses sharp sand sourced from river Dankan in Kwal and Amper of Kanke local government area respectively. The price of a truck is given on table 3.2 depending on the distance from where it was sourced.

The industry only depends on river Kaduna for its water supply, for the production of sanderete blocks. A water tanker of 3200 liters cost between ₦4000 and ₦6000. The ratio of one part of cement to twelve parts of sand materials (1:12) is being used, according to the industry's manager. The number of blocks produced in a batch of 50kg bag of cement was about 35 numbers of blocks for 460mm x 225mm x 225mm size and 50 to 60 number of blocks for 460mm x 225mm x 150mm size.

The average daily production in the industry was about 560 pieces or units of 460mm x 225mm x 225mm size and about 830 pieces of 460mm x 225mm x 150mm size of blocks, according to the industry's machine's operator.

Curing of blocks is done for a period of 3 to 5 days by spraying water between morning and evening time, according to the industry's manager. Thereafter, the blocks are stacked in rows of 10 pieces at open space ready for sale at the rate of ₦190 for a 460mm x 225mm x 225mm size and ₦155 for a 460mm x 225mm x 150mm size. These include cost of delivery within Kanke local government only.

3.9 Industry III

Industry III is located in zone C of the state in Barkin Ladi Local Government along Jos-Mangu road. The industry was established in the year 1976. The industry chosen in this local government is known as BK block industry. It has staff strength of eleven workers which comprise of a site foreman, a site security guard, a store keeper who is also the sales man, a driver and a moulding machine operator with his team of six unskilled labour men, according to the industry's manager. The moulding machine operator and his team men are paid ₦450:00 per unit of block of size 460mm x 225mm x 225mm and 460mm x 225mm x 150mm. The industry has only one Rosacometta type of moulding machine. Other accessories and equipment were underground block filled with concrete tank, two wheel barrows, shovels, buckets, about 1000 wooden pallets and a water pump generator of Honda brand used for pumping water from River Foron for mixing cement and curing of blocks.

The industry uses Burham and Dangote ordinary Portland cements for block production, which are usually purchased from within Barkin Ladi at the cost of ₦2750:00 and ₦2800:00 respectively, per 50 kg bag, and sometimes from Mangu local Government at the cost of ₦2850:00 and ₦2850:00 respectively, per bag of 50kg, according to the industry's manager.. The cements are usually stockpiled on planks and on hard concrete floor at the site store as observed during the survey.

The industry uses sharp sand for the production of the blocks. The sands are sourced from River Foron which is just about one kilometer from the site at the cost of ₦11,000:00 per tipping truck of four cubic metres capacity.

The industry uses River Foron tributary water by pumping using a Honda pumping machine. The industry uses ratio 1:10 for cement and sand mix. The industry produces about 50 of 460mm x 225mm x 225mm pieces of block per 50kg bag and 60 pieces of 450mm x 225mm x 150mm per bag of cement. The average daily production in this industry was about 460 and 580 pieces of 460mm x 225mm x 225mm size and 460mm x 225mm x 150mm size respectively as confirmed by the machine operator of the industry.

The blocks were then cured for about 3 to 7 days by spraying water in the morning and evening time. Immediately after this curing, the blocks were then ready for sale. A block of size 460mm x 225mm x 225mm was sold at ₦1800:00 and ₦145 for 460mm x 225mm x 150mm size. The cost of loading, and offloading and delivery were inclusive.

3.10 Industry IV

This industry is located in zone D of the state, in Shendam local government area. The block industry considered here is known as Aloi block industry limited, located at No.7 shendam road Shendam.

This block industry was established in 1989 with only 6 staff strength then, but has up to 29 staff strength now. The workers that are on fixed monthly salary now comprised of the site foreman, 3 drivers, 2 security guards, a store keeper, a sales man whom they called accountant, and 3 moulding machine operators with their teams of 6 unskilled labour men, according to the industry's manager.

The industry has three Rosacometta of moulding machines and three lister machines. All the three were working at the time of the visit. Two of the moulding machines were operated with Vikki diesel engines with water-cooling system. Other production materials or tools were shovels, six wheel barrows, buckets and water pump generator. The industry has two tipping trucks as delivery vans with a Pickup of 200 number of blocks capacity.

Dangote brand of Portland cement is the main cement used for block production in this industry. The cements were sourced from Makurdi town of Benue state. The sand materials used for the production of these blocks are sourced from river Kolong of Shendam. The cost of a four cubic metre capacity tipping truck was ranging between ₦13500:00 to ₦15000:00. The industry uses river water for mixing that was sourced from river Kolong by a tanker of 5000 liters capacity at the rate of ₦6500. The industry has a reinforced concrete suubsurface tank for water reservation.

In this industry, the mixing proportion was observed to be one part of cement to twelve parts of sand (1:12). Mixing is done manually using shovel to mix the cement and sands. Mixing water was added without reference to any standard until acceptable workability is achieved as confirmed by the industry's manager.

Average of 35 number of blocks of size 460mm x 225mm x 225mm were produced per 50kg bag of cement. Similarly, about 55 numbers of blocks of 460mm x 225mm x 150mm size of block were produced per 50kg bag of cement. The average daily production capacity in the industry were 1000 of 460mm x 225mm x 225mm size and 1600 of 460mm x 225mm x 150mm size of blocks respectively.

Curing of blocks is done by spraying water twice a day, for a period of three (3) to five (5) days. The cured block are stacked in rows of 5 to provide space for more blocks to be produced. The cured blocks are sold at the price of ₦190 and ₦155 per 460mm x 225mm x 225mm and 460mm x 225mm x 150mm size respectively. These include cost of delivery within Shandam local government only.

3.11 Industry V

This industry was chosen in zone E and the industry chosen is Danburan block industry, which is situated at No 3 Kunbul road, Wase local government area. The industry was established in 2003 and has been in production with staff strength of 12 workers. This comprised of the manager, site guard, a driver and a moulding machine operator and his team of eight unskilled labourers. The manager, site driver and site guard are on fixed monthly salary. While the machine operator with his team of workers are on contract basis and are paid ₦300 for every bag of cement used for block production irrespective of the size of block. About 40 blocks are produced per each bag of 50kg cement of 460mm x 225mm x 225mm size and about 50 blocks per bag of 50kg blocks for 460mm x 225mm x 150mm size. Average daily production of 460mm x 225mm x 225mm ranges between 400 and 600 number of blocks and about 500 to 700 blocks of size 460mm x 225mm x 150mm daily, as explained by the industry's manager. It was observed that only a particular size of block is produced in a day.

The industry has only one Rosacometta type of moulding machine. Other auxiliary production tools and accessories are shovels, wheel barrows, buckets, wooden pallets, water pump generator and a Peugeot pick-up van.

This industry uses Dangote brand of Portland cement for the production of blocks. The cements are purchased from either Langtang or Dangi in Kanem local government area where there is a depot of Dangote brand of cement.

The industry sourced its production sand from river Wase at the cost of ₦8000 per tractor container. The sands are also sharp, coarse and brownish in colour. The industry sourced its water for mixing from a bore hole for its water supply. It was observed that the water was clean and acceptable for block production.

The proportion of cement to sand used by this industry according to the industry's manager is one part of cement to twelve parts of sand by volume,that is 1:12.The industry cures blocks from four to seven days, by spraying water twice daily within morning and evening hours. The cured blocks are stacked in rows of five blocks high. Thereafter the blocks are open for sale. The blocks were sold at ₦190 and ₦155 for 640mm x 225mm x 225mm and 640mm x 225mm x 150mm sizes respectively. This price includes cost of delivery within the town.

A summary of the activities in the selected industries are presented in the Table 3.3 below:

Table 3.3: Summary of site survey of the five block industries

INDUSTRY	YEAR OF ESTABLISHMENT	NO. OF WORKERS	MODE OF PRODUCTION	CEMENT TYPE	METHOD OF BATCHING	SIZE OF BLOCK PRODUCED (mm)	DAILY PRODUCTION	CURING DAYS	SOURCE OF SAND	SOURCE OF WATER	MIX RATION
I	1982	23	Mechanical	Ashaka Burham & Dangote	Volume batching	460x225x225 460x225x150	1400 of 450x225x225 & 2000 of 450x225x 150	3 to 5	Rivers Gunt & panshanu	Pipe born water & water tank	1:12
II	1992	18	Mechanical	Ashaka & Dangote	Volume batching	460x225x225 460x225x150	560 of450x225x225 830of450x225x150	3 to 5	Rivers jadan & Dankan	River Kaduna	1:12
III	1976	11	Mechanical	Burham Dangote	Volume batching	460x225x225 460x255x150	460 of 460x225x225 580-600 450x225x150	3 to 7	River foron	River Foron	1:11
IV	1989	23	Mechanical	Dangote	Volume batching	460x225x225 460x225x150	1000of450x225x225 1600 of 450x225x150	3 to 5	River kolong	River kolong	1:12
V	2003	12	Mechanical	Dangote	Volume batching	460x225x225 460x225x150	400-600 of 450x225x225 500-700 of 450x225x150	3 to7	River wase	Borehole & water Tanker	1:12

3.12 The Block Sample Test

After the site survey and collection of information about the five selected block industries, sixty (60) block samples were randomly selected (NIS 87: 2000) from each of the selected industries. Therefore, a total number 300 blocks, were collected from the five block industries. Sand materials used by the block industries for the bock production, were also collected and conveyed to the material Laboratory of the Civil Engineering Department of kaduna Polytechnic, for experimental investigations.

The following tests were conducted on the samples in accordance with BS EN 12620-201 and NIS 87:2004. These tests included:

Sieve analysis, silt and clay content of the sand materials.

Cement tests.

Dry development compressive strength.

Wet development compressive strength.

Wet compressive strength.

Density of the block samples.

Water absorption of the blocks.

Dry shrinkage and wetting expansion of the blocks.

3.13 Sieve Analysis

Sieve analysis was carried out on the sand materials used for the block production in all the five industries. The test was conducted in accordance with BS 812-103.1: 2000. The test results are shown in Tables 3.4, while the raw data from which the results were extracted are shown in appendix A1 to A5.

Table 3.4: Sieve analysis of industry i, ii, iii, iv and v sand

BS. SIEVE SIZE (mm)	CUMULATIVE PERCENTAGE PASSING (%)				
	INDUSTRIES				
	I	II	III	IV	V
9.5	100	100	98.7	100	98.7
4.75	96.5	97.4	93.9	95.2	95.4
2.38	75.6	96.5	81	81	91.1
1.18	40	85.3	55.4	46.3	78.2
0.6	14.7	60	14.6	17.6	39.6
0.3	3.5	24.4	2.3	4.6	4.9
0.15	2.6	3.5	0.9	0.9	0
PAN					

3.14 Silt Content

The silt contents of the sand collected from the five industries were determined in accordance with BS 812: part 2, 1979.

The results of the silt content recorded for the five industries are shown in Table .9 below and the raw data of the results are given in the appendix. Each result is an average of two values.

Table 3.5: Silt content of the five block industries

INDUSTRY	**SILT CONTENT (%)**
I	0.88
II	0.89
III	0.88
IV	0.90
V	0.90
CODE REQUIREMENT **: 6%** MAXIMUM	

3.15 Cement Test

It was observed that Dangote ordinary Portland cement is the brand of cement that is mostly used in the production of sandcrete block in Plateau state, therefore, this cement was also tested to determine its suitability in the production of the blocks.

The following physical properties were checked in accordance with the requirement of BS EN 196 -3:2008. These properties' results are shown in the Tables below:

Table: 3.6 Cement setting time test**:**

Industry label	Weight of cement		Depth of penetration(mm)	Initial time (min.)	Final time (min.)	Water/cement (%)
I	400	120	13.0	45	3hr :45	30.0
II	400	121	10.70	43	3hr :41	30.3
III	400	122	6.50	47	3hr :30	30.5
IV	400	123	5.00	45	2hr :50	30.7
V	400	120	7.00	1hr 45	2hr :47	30.0

Table 3.7: Cement standard consistency test**:**

Industry	WEIGHT OF CEMENT(g)	WEIGHT OF WATER(g)	DEPTH OF PENETRATION OF PLUNGER(mm)	STANDARD CNSISTENCY (%)
I	400	120	13.0	30.0
II	400	121	10.2	30.3
III	400	122	6.5	30.5
IV	400	120	12.4	30.8
V	400	120	6.8	30.0

Table: 3.8 Cement soundness test result

Industry	Weight of cement(g)	Volume of water(ml)	Water/cement (%)	Dist b/w pointers before heating(l_1)	Dist. b/w pointers after heating(l_2)	Expansion (mm)
I	400	120	30.0	28.0	29.5	1.5
II	400	121	30.3	36.0	37.5	1.5
III	400	122	30.5	27.0	28.0	1.0
IV	400	123	30.7	22.0	23.5	1.5
V	400	120	30.0	16.0	17.0	1.0

Average expansion=1.3mm

3.16 Dry Development Compressive Strength

Dry development strength test is used to determine the strength of sandcrete hollow blocks in the dry state. The blocks were tested at the ages of 2, 3, 7, 14, 21 and 28 days of maturity in accordance with appendix C of BS EN 771-3: 2006. Three samples of block were tested at each of the ages. The average result for the five industries that is industries I, II, III, IV, and V are shown in Table 3.13 on the next page.

Table 3.9: Summary of dry development compressive strength of the five block industries

AVERAGE DRY COMPRESSIVE STRENGTHS OF SANDCRETE BLOCKS OF THE FIVE INDUSTRIES (N/mm^2)					
AGE (DAYS)	AVERAGE DRY COMPRESSIVE STRENGTHS OF THE INDUTRIES (N/mm^2)				
	I	II	III	IV	V
2	0.13	0.07	0.08	0.16	0.12
3	0.17	0.09	0.10	0.21	0.16
7	0.21	0.13	0.15	0.26	0.28
14	0.26	0.16	0.20	0.30	0.41
21	0.29	0.19	0.24	0.33	0.52
28	0.30	0.21	0.28	0.38	0.57

3.17 Wet Development Compressive Strength

The wet development compressive strength is the strength determined under wet curing of the blocks at various ages after 28days of age. The blocks were immersed in water after 28 days of normal curing and tested at the ages of 2, 3, 7, 14, 21 and 28 days. Three sandcrete block samples per age of immersion were tested. The average of the three is taken as the strength for that soaked age.

The significance of this test is to determine the effect of soaking time on the strength of the blocks. The results of this test are shown in Table 3.14 below. The raw data from which the results were obtained are given in the appendix A11 to A15.

Table3.10: Summary of wet development compressive strength of the five block industries.

WET DEVELOPMENT `COMPRESSIVE STRENGTH (N/mm^2)					
AGE (DAYS)	AVERAGE COMPRESSIVE STRENGTH (N/mm^2)				
	I	II	III	IV	V
2	0.20	0.03	0.24	0.08	0.08
3	0.29	0.44	0.32	0.19	0.17
7	0.48	0.52	0.53	0.38	0.38
14	0.52	0.55	0.57	0.59	0.62
21	0.54	0.57	0.59	0.50	0.48
28	0.55	0.6	0.62	0.55	0.52

3.18 Wet Compressive Strength

Wet compressive strength test is meant to determine the worst condition the sandcrete hollow blocks can be subjected to under normal practical condition such as submerging of the foundation and general over flooding of the structure.

Ten block samples were randomly selected and tested in accordance with appendix C of the BS EN 771-3:2006. In this test, the two faces of the blocks were bedded with mortar made up of one water and crushed at the ages 2, 3,7,21 and 28days. Mortar cubes of the 1:3 mixes, were cast from the mortar used for the bedding and later cured until enough minimum strength of 28 days was obtained by the standard.

The wet compressive strength test results are shown on Tables 3.15, 3.16, 3.17, 3.18 and 3.19 for industries I, II, III, IV and V respectively below. The raw data from which the results were obtained are shown in appendix A18 to A23.

Table 3.11: Wet compressive strength of industry I

WET COMPRESSIVE STRENGTH (N/mm^2)	
S/NO	STRENGTH (N/mm^2)
SA-01	0.66
SA-02	0.60
SA-03	0.67
SA-04	0.71
SA-05	1.12
SA-06	0.79
SA-07	1.35
SA-08	0.59
SA-09	0.73
SA-010	0.71
Average strength : 0.79 Standard deviation : 0.26 Coefficient of variation : 32.9%	

Table 3.12: Wet Compressive Strength of Industry II

WET COMPRESSIVE STRENGTH (N/mm^2)	
S/N0	STRENGTH N/mm^2
SB-01	0.39
SB-02	0.47
SB-03	0.46
SB-04	0.49
SB-05	0.52
SB-06	0.43
SB-07	0.41
SB-08	0.49
SB-09	0.47
SB-10	0.61
Average strength = 0.47 Standard deviation = 0.06 Coefficient of variation = 12.77%	

Table 3.13: Wet compressive strength of industry III

WET COMPRESSIVE STRENGTH (N/mm^2)	
S/NO	STRENGTH (N/mm^2)
SE-01	0.86
SE-02	0.81
SE-03	0.76
SE-04	1.10
SE-05	1.19
SE-06	0.53
SE-07	1.04
SE-08	0.57
SE-09	1.72
SE-10	0.53
Average strength = 0.91 Standard deviation = 0.35 Coefficient of variation = 38.5%	

Table 3.14: Wet Compressive Strength of Industry IV

WET COMPRESSIVE STRENGTH (N/mm^2)	
S/NO	STRENGTH (N/mm^2)
SD-01	0.52
SD-02	0.66
SD-03	0.46
SD-04	0.62
SD-05	0.57
SD-06	0.85
SD-07	0.52
SD-08	0.33
SD-09	0.51
SD-10	0.43
Average strength = 0.55 Standard deviation = 0.13 Coefficient of variation = 24.13%	

Table 3.15: Wet Compressive Strength of Industry V

WET COMPRESSIVE STRENGTH (N/mm^2)	
S/NO	STRENGTH (N/mm^2)
SE-01	0.45
SE-02	0.43
SE-03	0.51
SE-04	0.38
SE-05	0.40
SE-06	0.50
SE-07	0.43
SE-08	0.46
SE-09	0.52
SE-10	0.38
Average strength = 0.45 Standard deviation = 0.49 Coefficient of variation = 10.93%	

3.19 DENSITY OF THE BLOCK

The density of the blocks was determined in accordance with BS EN 771-3: 2006, using three block samples selected randomly from each of the five block industries. The results are shown in Table 33 on the next page:

Table 3.16: Density Of The Block Samples of the Five Industries

INDUSTRY	SAMPLE S/NO	DENSITY (kg/m^3)	AVERAGE DENSITY (kg/m^3)
I	SA_D-01	890	
	SA_D-02	916	928
	SA_D-03	979	
II	SB_D-01	904	
	SB_D-02	958	937
	SB_D-03	950	
III	SC_D-01	875	
	SC_D-02	917	916
	SC_D-03	955	
IV	SD_D-01	858	
	SD_D-02	905	891
	SD_D-03	909	
V	SE_D-01	905	
	SE_D-02	897	910
	SE_D-03	927	

3.20 WATER ABSORPTION

This is the ratio of the difference between the dry weight and wet weight to the weight of the dry sample expressed as a percentage. The test was carried out in accordance with the Nigerian industrial standard NIS. 74:1976 using three block samples chosen at random in each of the five block industries. The blocks were allowed to attained 28 days of age before the test. The results of this test are shown in Table 3.21 below, while the raw date of the results are shown in appendix.

Table 3.17: Water Absorption of the Five Block Industries:

INDUSTRY	WATER ABSERPTION (%)
I	7.16
II	8.52
III	7.12
IV	4.54
V	5.92
CODE REQUIREMENT – 25% MAXIMUM (BS EN 771-3:2006)	

3.21 Dry Shrinkage and Wetting Expansion

Three block samples were randomly selected from each of the five block industries and were tested in accordance with BS EN 771-3:2006. The average results of the test are shown in table 3.22 below.

Table 3.18: Dry Shrinkage And Wetting Expansion of the Five Industries

INDUSTRY	I	II	III	IV	V
DRY SHRINKAGE (%)	0.03	0.05	0.03	0.05	0.04
WETTING EXPNSION (%)	0.06	0.07	0.05	0.07	0.07
CODE REQUIREMENTS (BS EN 771-3:2006)	DRY SHRINKAGE – 0.06 MAX WETTING EXPANSION – 0.07 MAX				

CHAPTER FOUR

ANALYSIS AND DISCUSSION OF RESULTS.

4.1 Particle Size Distribution.

The sieve analysis results of the sand materials used for the production of the block samples are shown in Tables 3.4 to 3.8 and plotted in figure 4.1 below:

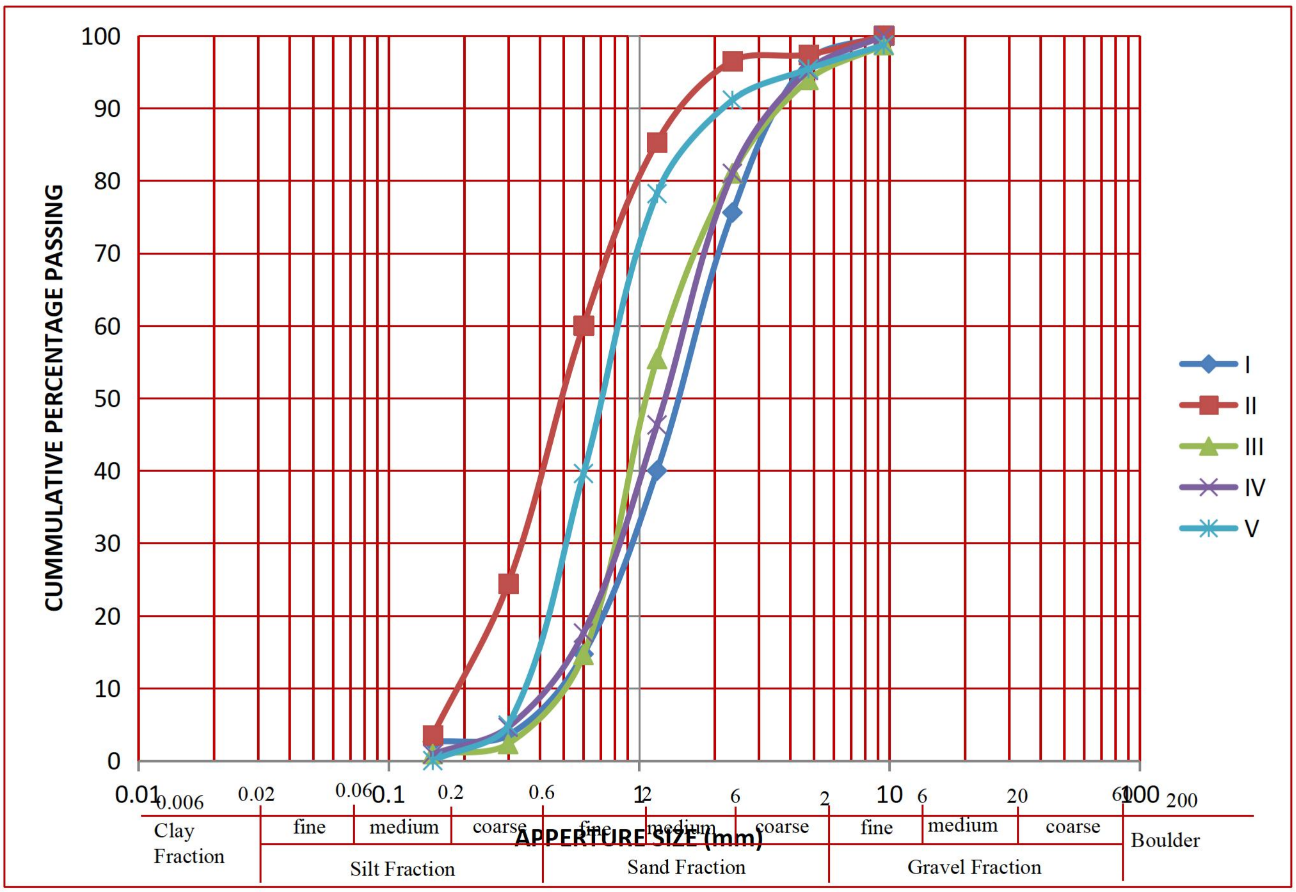

Figure 4.1: Particle Size Distribution for Industries I, II, III, IV and V

Figure 4.1 showed that the sand samples for all the five industries fell within the coarse and medium sand materials. The results showed that the sand materials used in all the industries fell into zone 2. They are therefore, suitable for rich mixes.

Nigerian industrial standard NIS 87 (1974) specifies that the best sand for the production of sandcrete blocks should be that which falls within zone 1 and 2 of the British standard sieve sizes. The results of the sieve analysis of all the five block industries obtained were within zones 1 and 2. Therefore, the sand materials used for the block production in the state complied with grading requirement of the standards.

4.2 Silt Content

The silt content for industries I, II, III, IV and V were found to be 0.88, 0.89, 0.90 and 0.90 respectively. All these values were less than 6% silt content limit specified by BS EN 1377-2:1990. Therefore the silt content is adequate. Excess silt content will interfere with the process of hydrations of cement and the development of good bond between the sand aggregate and cement paste, Neville (1995).

4.3 Cement result

The standard consistency was found to be 30.5% which is within the requirement of BS EN 196-6:2010. The initial setting time was found to be 48 minutes and the final setting time was found to be 2hours 47minutes which is also within the recommendations of BS EN 196-3:2008 which stated that the initial and final setting times should not be more than 2hours and 10hours respectively. Therefore, the consistency is adequate.

The soundness of the cement was found to be 1.2mm, which is not more than 12mm given by the standard (BS EN196-3:2008).

4.4 Dry Development Compressive Strength

The results of the dry development compressive strength tests of the sandcrete hollow blocks for industries I,II,III,IV and V are shown in Table 3.13 and plotted in figures below.

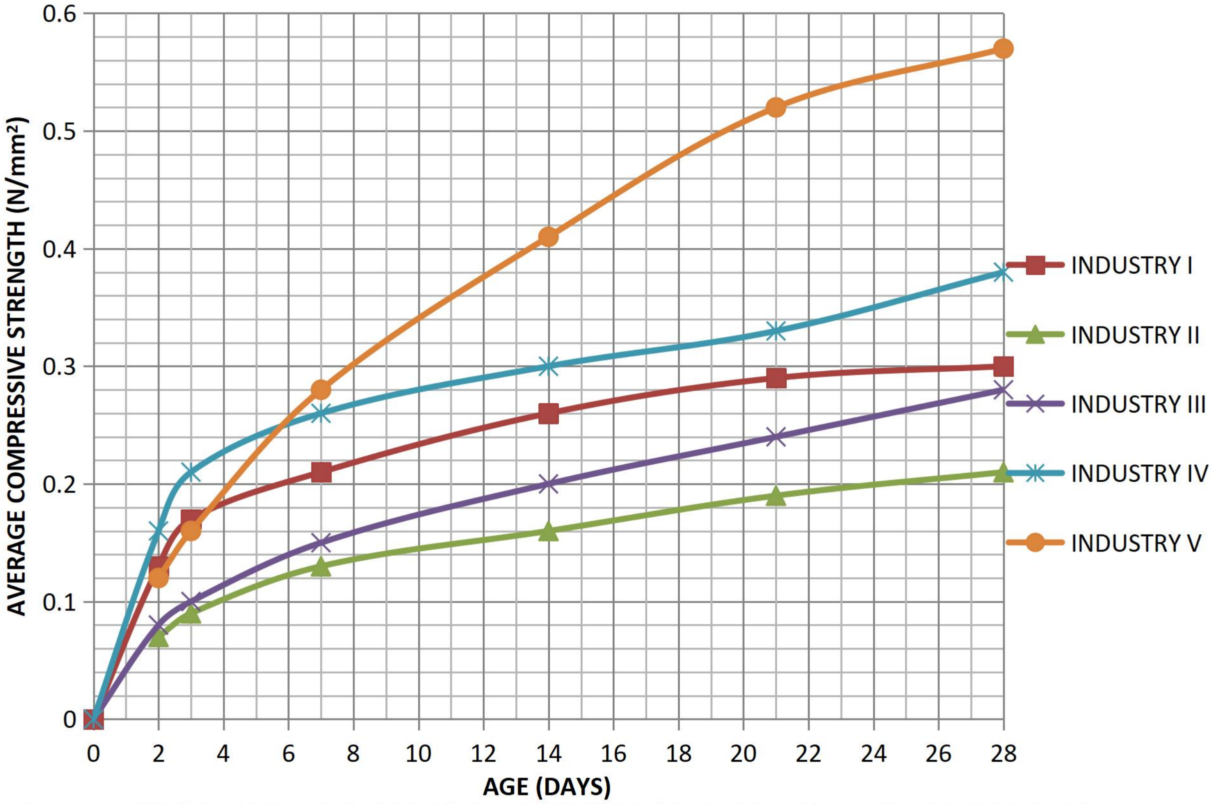

Figure:4.2 SUMMARY OF DRY DEVELOPMENT COMPRESSIVE STRENGTH OF THE FIVE INDUSTRIES

It was observed that all the graphs plotted resembled the usual pattern of strength development of concrete materials subjected to compressive strength test. In the whole industries the rate of strength development was observed to be increasing rapidly and continuously until it reaches the high value at 28 days of curing. Hydration of cement is always accompanied with adequate curing, but as was observed in all the five industries, the method of curing is inadequate. This has definitely affected the strength development of the block produced. Hydration of cement can only take place in water filled capillaries. Any loss of water by evaporation from the capillaries affects the strength development of the sandcrete block as observed by Neville (2012). The values of average dry development strength at 28 days are 0.3N/mm^2, 0.21 N/mm^2, 0.28N/mm^2, 0.38 N/mm^2, and 0.57 N/mm^2 for industries I, II, III, IV and V respectively. These values are very low when compared with 3.5 N/mm^2 average strength, specified by the British standard and 3.45 N/mm^2 recommended by the Nigerian industrial standard, BS EN 771-3:2006 and N1S 87 (2004). The highest strength of 0.57 N/mm^2 observed in industry E sample is just 16.3% of the 3.5 N/mm^2 of the British standard. This shows that, the compressive strength of commercially produced sandcrete hollow blocks in Plateau state are generally low.

4.5 Wet Development Compressive Strength

The values of the wet development compressive strength of the five industries: I, II, III, IV and V are shown in Table 3.14 and plotted in the figure 4.2 below:

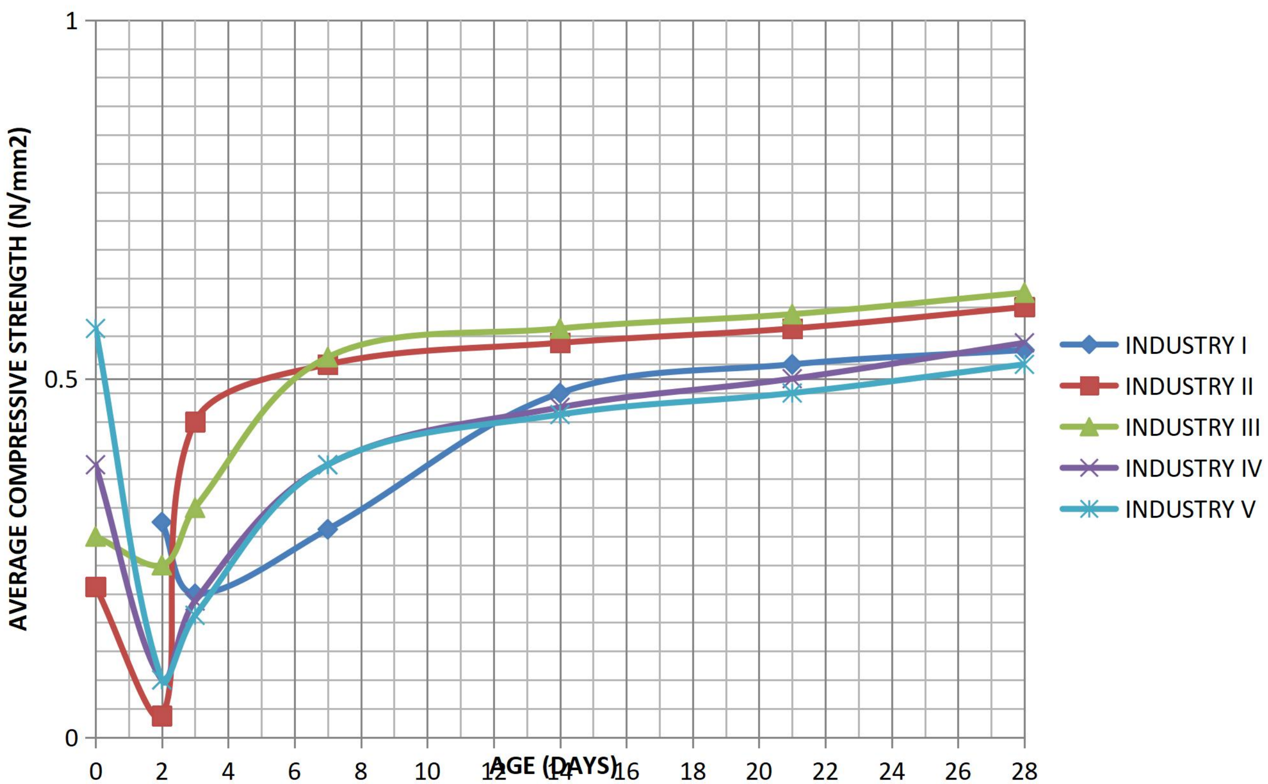

Figure: 4.3 Summary Of Wet Development Compressive Strength Of The Five Industries

The test results of the wet development compressive strength for all the five industries showed that the strength of sandcrete blocks dropped sharply after immersion in water for 48 hours from the initial 28 days old strength. These gave the blocks strength values of 0.55N/mm^2, 0.6/mm^2, 0.62N/mm^2, 0.55N/mm^2 and 0.52N/mm^2 for industries I, II, III, IV and V respectively. This sharp dropped in strength values was due to high water absorption of the sandcrete blocks that occurred when the block samples were immersed in water. The rate of water absorption was rapid within the 48 hours of immersion, giving rise to the sharp drop in strength, from lower to higher values as shown in the strength curves above. The strength values later improved gradually at the end of the 28 days of Soaking as against the 2 days old immersion. This did not meet the standard too.

4.6 Wet compressive strength

The values of the average wet compressive strength of the sandcrete hollow block samples that were shown in Tables 3.15,3.16,3.17,3.18 and 3.19 were 0.79 N/mm^2, 0.47 N/mm^2, 0.91 N/mm^2, 0.55 N/mm^2, and 0.45 N/mm^2 for industries I, II, III, IV and V respectively. These values are below the specified standard values given by BS EN 771-3:2006 of 3.45N/mm^2 and that of the Nigerian Industrial Standard NIS 87: 2004 of 2.9 N/mm^2.

When the values of these wet compressive strengths obtained are compared with the BN ES and NIS above, there was a general short fall of average strength of about 82%. Therefore, the low value of the average compressive strength of each of the industries is extremely unacceptable as compared with the standard values.

However, the values of the coefficient of variation of industries II and V obtained as 12.77% and 10.93%, were within the 20% limit specified for concrete structure by the

Nigerian Society of Engineers (2000). But the values of the Coefficient of Variation for industries I, III and IV obtained as 32.9%, 38.5% and 24.13% respectively were above the 20% limit. This shows that there is much variation of strength in those industries. Neville (2012), reported that' Variation in strength of sandcrete block arises from inaccurate volume batching of aggregate, inadequate mixing, insufficient compaction and irregular curing.

From these results, it can be stated that the manufacturing processes in industries I, III and IV are not consistent in variation of the production processes. However, there is no much variation in the level of consistency in production process for industries II and V.

4.7 Summary of strength results

From figure 4.1, it can be seen that industry V consistently produced the highest strength values among the five industries, while industry II showed the least values of the dry development strength. In figure 4.1, industry V gave the least strength values when compared with the other industries. The results of the average wet compressive strength recorded were 0.91, 0.99, 0.97, 0.36 and 0.21 N/mm^2 for industries I to V respectively. Therefore industry V produced blocks of least strength of wet compressive strength but industry II produced the highest wet compressive strength of 0.99 N/mm^2. However, none of these strength values satisfies the standard requirements of 2.9 N/mm^2 and 3.45 N/mm^2 for BS EN 771:2006 and NIS 87:2004, respectively.

4.8 The Sandcrete Block Density

The results of the average densities shown in Table 3.2 , for the five(5) block industries are 928kg/m^3, 937 kg/m^3, 916 kg/m^3, 891 kg/m^3 and 910 kg/m^3 for industries I,II,III,IV and V respectively. From these results, the average density of the five block industries is 916.4 kg/m^3. This value is less than the 1500 kg/m^3 specified by BS EN 771-3:2006 as the minimum average density for type A block whether solid, hollow or cellular. However, they can be considered for types B and C blocks, which are less than 1500 kg/m^3 and not less than 625g/m^3 as recommended by the standard. The blocks in Plateau state are generally type C blocks. Therefore the density is adequate.

However the low density values recorded in the industries may be as a result of inadequate compactive effort of the moulding machine and low cement in the mixture resulting to more voids, less density and low strength values.

4.9 Water Absorption

The water absorption for the five industries has shown in table 3.21, are 7.16%, 8.52% 7.12%, and 4.54% and 5.92% for industries I, II, III, IV and V respectively. From these results, the average water absorption for the five industries is 6.65%. This value is within the 12% limit for water absorption specified by NIS 87:2004 for burnt clay bricks

Water absorption gives an apparent porosity and effects of compaction of the blocks, as observed by Shettima (2006).

4.10 Dry Shrinkage and Wetting Expansion

The average values of percentage drying shrinkage shown in table 3.22 are 0.03%, 0.05%,0.03%, 0.05% and 0.04% for industries I,II,III,IV and V respectively. These values are within the 0.06% value specified for blocks that are said to be Type A blocks in BS EN 771-3:2026.

The wetting expansion of industries I, II, III, IV and V as 0.06%, 0.067, 0.05%, 0.07% and 0.07% are all within the 0.07% wetting expansion limit specified in BS EN 771-3: 2006 for type A blocks.

The results of the drying shrinkage and wetting expansion showed that all the blocks exhibit normal dimensional changes as water content changes.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

This research work considered the materials and method of production of sandcrete hollow blocks produced in Plateau state. All the tests and analyses carried out were aimed at determining the quality of the sandcrete hollow blocks produced in the state. The following conclusions are therefore reached:

i. There were 121 block industries observed in Plateau state.

ii. The sand material used for the production of the sandcrete hollow blocks in all the industries considered were generally sharp and clean materials. They are mainly graded into zone 1 and 2 of the grading standard of BS EN: 2013 12620 812:part 103 and complied with the requirement of the NIS standard for blocks production.

iii. Results of the silt content of the sand materials were all within the 6% limit specified by BS EN 12620:2013. Therefore the silt content is adequate.

iv. The proportion of sand material in the mix for the production of blocks in all the industries was too high. All the industries were using between 1:10 to 1:12 mix ratio of cement to sand, instead of the recommended standard of 1:6 to 1:8 as specified by the standards.

v. The curing method and duration of curing in all the five industries, was done by spraying water twice in a day and for duration of two to five days in an open place. This is actually inadequate to allow for effective development of the cement gel.

vi. All the five industries were using Ordinary Portland Cement (Dangote brand). From the results of the cement tests obtained for setting time, standard consistency and soundness, all conformed to BS EN 197-3:2005.

vii. The maximum twenty eight (28 day) dry development compressive strengths of the blocks for all the five industries were found to be less than the minimum average strength recommended by the established standards. From the analysis, industry V had the highest 28days dry development strength of 0.57N/mm^{2,} while industry II had the least compressive strength value of 0.21N/mm^2. These values were less than the 2.5N/mm^2 minimum average strength for individual block as specified by the Standards.

viii. The average wet compressive strength values were 0.91, 0.99, 0.97, 0.36 and 0.21N/mm^2 for industries I to V respectively. These strength values fell below the minimum national and international standards prescribed for type C sandcrete blocks.

ix. The values of the coefficient of variation of 32.9%, 38.5%, and 24.13% for industries I, II and IV are too high when compared with the 20% limit specified for sandcrete blocks, as stated by Shettima (2006). This implies that these industries were not consistent in the variation of their strength, but there is no much variation in the level of production process in industries B and E.

x. The average density of blocks produced in the state was 916.4Kg/m^3. This value is less than 1500Kg/m^3 but greater than 675Kg/m3 as specified by the standard for type C blocks; BS EN 771-3:2006. This means that the density value is adequate.

xi. The values of the drying shrinkage and wetting expansion of all the five industries were within the limit specified by the standard for type C blocks. Therefore, all the blocks exhibit normal dimensional changes as water content changed.

5.2 RECOMMENDATIONS

These recommendations are either corrective or preventive aiming at improving the quality of sandcrete hollow blocks, produced commercially in the state, to meet the requirement of national and international standards.

From the analysis and conclusion made, the following recommendations are suggested:

1. Manufacturers of sandcrete hollow blocks should be enlightened through workshops and seminars to emphasize the need of producing blocks that meet the standard requirements, and the consequences of producing sub standard blocks.
2. The Federal Government in collaboration with COREN and NSE should constitute a powerful regulating body which will be monitoring the production of sandcrete blocks in the whole nation, with a powerful supervising team. This regulating body should be given the responsibility of testing and issuing a certificate of test passed, to enable the end users to demand for it when burying the blocks.
3. The block moulding machines as well as the driving engine device should be properly checked and service when due or on routine basis to improve the efficiency of the machines.
4. Curing should be done according to the standard specifications.
5. Proper adherence to standard procedure of block production is highly recommended.

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APPENDIXES

APPENDIX A1

SIEVE ANALYSIS OF INDUSTRY I

WEIGHT OF SAND SAMPLE: 1000g

BS SIEVE SIZE (mm)	WEIGHT RETAINED (g)	CUMMULATIVE WEIGHT RETAINED (g)	WEIGHT PASSED (g)	CUMMULATIVE PARCENTAGE PASSING	CUMMULATIVE PERCENTAGE RETAINED
9.5	0	0	1000	100	0
4.75	35	35	965	97	4
2.38	209	244	756	76	24
1.18	356	600	400	40	60
600μm	253	853	147	15	85
300 μm	112	965	35	4	96
150 μm	9	974	26	3	97
PAN	1	975	25	2	98

APPENDIX A2

SIEVE ANALYSIS OF INDUSTRY II

WEIGHT OF SAND SAMPLE: 1000g

BS SIEVE SIZE (mm)	WEIGHT RETAINED (g)	CUMMULATIVE WEIGHT RETAINED (g)	WEIGHT PASSED (g)	CUMMULATIVE PARCENTAGE PASSING	CUMMULATIVE PERCENTAGE RETAINED
9.5	13	13	987	99	1
4.75	48	61	939	94	6
2.38	129	190	810	51	19
1.18	256	446	554	55	45
425μm	408	854	146	15	85
300 μm	123	977	23	2	98
150 μm	14	991	9	1	99
PAN	1	992	8	1	99
FINENESS MODULUS					4.52

APPENDIX A3

SIEVE ANALYSIS OF INDUSTRY III

WEIGHT OF SAND SAMPLE: 1000g

BS SIEVE SIZE (mm)	WEIGHT RETAINED (g)	CUMMULATIVE WEIGHT RETAINED (g)	WEIGHT PASSED (g)	CUMMULATIVE PARCENTAGE PASSING	CUMMULATIVE PERCENTAGE RETAINED
9.5	51	51	949	95	5
4.75	63	114	886	87	11
2.38	142	256	744	74	26
1.18	289	545	455	46	55
600µm	248	793	207	21	79
300 µm	169	962	38	4	96
150 µm	35	997	3	1	100
PAN	1	998	2	0	100
FINENESS MODULUS					4.72

APPENDIX A4

SIEVE ANALYSIS OF INDUSTRY IV

WEIGHT OF SAND SAMPLE: 1000g

BS SIEVE SIZE (mm)	WEIGHT RETAINED (g)	CUMMULATIVE WEIGHT RETAINED (g)	WEIGHT PASSED (g)	CUMMULATIVE PARCENTAGE PASSING	CUMMULATIVE PERCENTAGE RETAINED
9.5	0	0	1000	100	0
4.75	48	48	952	95	5
2.38	142	190	570	81	19
1.18	347	537	463	46	54
425µm	287	824	174	17	82
300 µm	130	954	44	4	95
150 µm	37	991	7	1	99
PAN	6	997	1	0	100
FINENESS MODULUS					4.54

APPENDIXA5

SIEVE ANALYSIS OF INDUSTRY V

WEIGHT OF SAND SAMPLE: 1000g

BS SIEVE SIZE (mm)	WEIGHT RETAINED (g)	CUMMULATIVE WEIGHT RETAINED (g)	WEIGHT PASSED (g)	CUMMULATIVE PARCENTAGE PASSING	CUMMULATIVE PERCENTAGE RETAINED
9.5	13	13	987	99	1
4.75	33	46	954	95	5
2.38	43	89	911	91	9
1.18	129	218	782	78	22
425μm	386	604	396	40	60
300 μm	347	951	49	1	95
150 μm	49	1000	0	0	100
PAN	0	1000	0	0	100
FINENESS MODULUS					3.92

ININDUSTRY: I **APPENDIX A6**

LOCATION: JOS NORTH

DATE OF CASTING: 30/07/11

TYPES OF TEST: DRY DEVELOPMENT COMPRESSIVE TEST

S/No	Date tested	Age of blocks days(s)	Length (mm)	Breath (mm)	Height (mm)	Hollow size (mm)	Gross area (m^2)	Volume (m^3)	Weight (kg)	Failure load (kn)	Density (kg/m^3)	Strength (n/mm^2)	Average strength (n/mm^2)
			459	229	230	155x123	0.1051	0.0242	19.1	5.0	789	0.09	
2.	1/0812	2	458	229	230	150x123	0.1049	0.0241	19.1	6.0	793	0.10	0.09
3.			459	230	230	156x123	0.1056	0.0243	19.2	6.0	790	0.10	
4.			458	229	226	157x124	0.1049	0.0237	20	10.0	844	0.17	
5.	2/8/12	3	458	229	232	150x122	0.1049	0.0243	19.2	9.0	790	0.16	0.17
6.			459	229	222	150x122	0.1051	0.0233	1909	10.1	854	0.17	
7.			459	228	223	152x123	0.1049	0.0233	20	12.0	858	0.21	
8.	6/8/12	7	459	228	225	152x123	0.1047	0.0236	20	11.0	848	0.19	0.21

APPENDIX A7

INDUSTRY: II

LOCATION: KANKE

DATE OF CASTING: 16/6/12

TYPES OF TEST: DRY DEVELOPMENT COMPRESSIVE TEST

S/No	Date tested	Age of blocks days(s)	Length (mm)	Breath (mm)	Height (mm)	Hollow size (mm)	Gross area (m^2)	Volume (m^3)	Weight (kg)	Failure load (kn)	Density (kg/m^3)	Strength (n/mm^2)	Average strength (n/mm^2)
1.	18/6/12	2	457	230	230	160x125	0.1051	0.0242	20.1	4.0	831	0.07	0.07
2.			460	229	230	160x125	0.1053	0.0242	20.5	4.0	851	0.07	
3.			459	228	230	155x120	0.1047	0.0241	20.5	5.0	851	0.08	
4.	19/6/12	3	460	230	216	155x120	0.1058	0.0229	20.8	6.0	908	0.10	0.10
5.			460	230	216	155x120	0.1058	0.0229	20.5	5.5	895	0.10	
6.			460	230	216	155x125	0.1059	0.0229	20.6	5.5	900	0.10	
7.	23/6/12	7	457	227	215	155x125	0.1037	0.0223	20.8	5.0	933	0.09	0.11
8.			457	230	215	155x125	0.1051	0.0226	20.5	7.0	907	0.12	
9.			460	230	215	155x125	0.1058	0.0228	21.0	6.5	921	0.11	
10.	30/6/12	14	455	230	222	155x120	0.1047	0.0232	21.0	7.0	905	0.13	0.14
11.			450	228	225	155x120	0.1026	0.0231	21.0	8.0	909	0.14	
12.			450	228	225	155x120	0.1026	0.0231	20.8	8.5	900	0.14	
13.			452	225	224	156x120	0.1017	0.0228	21.0	9.0	921	0.21	

14.	14/7/12	21	450	228	226	157x120	0.1026	0.0232	21.0	11.0	905	0.21	0.19
15.			452	225	225	157x120	0.1017	0.0229	21.0	12.0	917	0.21	
16.	21/7/12	28	457	230	228	155x125	0.1051	0.0240	21.5	12.0	896	0.21	0.21
17.			457	228	227	155x125	0.1042	0.0237	21.0	12.0	886	0.21	
18			459	227	230	156x123	0.1042	0.0240	21.0	12.0	875	0.21	

APPENDIX A 8

INDUSTRY: III

LOCATION: BARKIN LADI

DATE OF CASTING: 30/07/11

TYPES OF TEST: DRY DEVELOPMENT COMPRESSIVE TEST

S/No	Date tested	Age of blocks days(s)	Length (mm)	Breath (mm)	Height (mm)	Hollow size (mm)	Gross area (m^2)	Volume (m^3)	Weight (kg)	Failure load (kn)	Density (kg/m^3)	Strength (n/mm^2)	Average strength (n/mm^2)
1.	01/08/12	2	459	225	225	170x142	0.1033	0.0232	20	4.0	862	0.07	0.08
2.			460	223	222	155x127	0.1026	0.0228	19.5	5.0	868	0.09	
3.			460	229	220	155x125	0.1053	0.02432	20.5	4.5	884	0.08	
4.	2/08/12	3	460	225	220	160x125	0.1035	0.0228	20.0	4.0	877	0.7	0.09
5.			460	225	220	160x125	0.1035	0.0228	21.0	5.0	921	0.09	
6.			459	225	220	160x125	0.1033	0.0227	20.0	6.0	881	0.10	
7.	6/08/12	7	460	223	222	165x125	0.1026	0.0228	21.0	9.0	921	0.16	0.15
8.			458	225	220	165x125	0.1031	0.0227	21.0	8.0	925	0.14	
9.			459	229	220	165x125	0.1051	0.0231	22.0	8.5	952	0.14	
10.	13/08/12	14	460	225	220	160x130	0.1035	0.0228	23.0	12.0	1009	0.21	0.21
11.			460	225	220	160x130	0.1035	0.0228	22.0	13.0	965	0.23	
12.			459	225	228	160x133	0.1033	0.0236	21.8	11.5	924	0.19	

13.	20/08/12	21	458	228	220	155x127	0.1044	0.0230	21.0	14.0	913	0.24	0.24
14.			459	230	223	155x128	0.1056	0.0235	22.0	13.0	936	0.23	
15.			460	225	220	156x128	0.1035	0.0228	22.0	15.0	987	0.26	
16.	27/08/12	28	460	223	225	170x142	0.1026	0.0231	22.5	20.0	952	0.35	0.35
17.			459	229	225	155x127	0.1051	0.0237	20.0	19.0	844	0.33	
18			460	225	225	165x122	0.1035	0.0233	21.0	22.0	901	0.38	

APPENDIX A9

INDUSTRY: IV

LOCATION: WASE

DATE OF CASTING: 5/5/11

TYPES OF TEST: DRY DEVELOPMENT COMPRESSIVE TEST

S/No	Date tested	Age of blocks days(s)	Length (mm)	Breath (mm)	Height (mm)	Hollow size (mm)	Gross area (m^2)	Volume (m^3)	Weight (kg)	Failure load (kn)	Density (kg/m^3)	Strength (n/mm^2)	Average strength (n/mm^2)
1.	7/5/12	2	458	230	220	156x136	0.1053	0.0232	19.8	5.0	852	0.09	0.12
2.			462	231	231	155x134	0.1067	0.0247	21.1	8.0	854	0.14	
3.			460	230	227	156x136	0.1058	0.0240	20.1	8.0	838	0.14	
4.	8/5/12	3	461	227	230	165x147	0.1047	0.0241	20.8	12.0	863	0.21	0.22
5.			460	230	227	165x136	0.1058	0.0240	21.1	15.0	879	0.26	
6.			461	229	220	158X136	0.1056	0.0232	20.8	11.5	897	0.20	
7.	12/5/12	7	461	230	230	157x132	0.1060	0.0244	21.8	16.0	893	0.28	0.29
8.			461	230	229	157x132	0.1060	0.0243	21.8	17.0	897	0.30	
9.			460	230	230	157x132	0.1058	0.0243	21.8	16.5	897	0.28	
10.	19/5/12	14	461	229	229	156x132	0.1056	0.0242	21.0	18.0	868	0.31	0.30
11.			461	230	229	156x136	0.1060	0.0244	21.0	16.0	861	0.28	
12.			461	230	230	156x136	0.1060	0.0244	21.5	17.0	881	0.30	
13.			459	229	231	156x120	0.1051	0.0243	21.0	18.0	864	0.33	

14.	26/5/12	21	460	229	230	156x122	0.1053	0.0242	22.0	19.1	909	0.34	0.33
15.			460	230	230	156x120	0.1058	0.0243	22.0	19.2	905	0.31	
16.	2/6/12	28	459	229	229	157x122	0.1051	0.0241	22.5	28.8	913	0.51	0.51
17.			460	229	230	156x120	0.1053	0.0242	21.9	29.0	905	0.52	
18			459	229	230	156x130	0.1051	0.0242	22.2	28.9	917	0.51	

APPENDIX A10

INDUSTRY: V

LOCATION: SHENDAM

DATE OF CASTING: 5/5/11

TYPES OF TEST: DRY DEVELOPMENT COMPRESSIVE TEST

S/No	Date tested	Age of blocks days(s)	Length (mm)	Breath (mm)	Height (mm)	Hollow size (mm)	Gross area (m^2)	Volume (m^3)	Weight (kg)	Failure load (kn)	Density (kg/m^3)	Strength (n/mm^2)	Average strength (n/mm^2)
1.	7/5/12	2	452	226	217	167x137	0.1022	0.0222	19.2	7.0	865	0.12	0.12
2.			459	227	222	168x136	0.1042	0.0231	19.6	7.3	849	0.13	
3.			452	226	217	167x138	0.1022	0.0231	19.1	6.9	827	0.12	
4.	8/5/12	3	453	230	218	167x137	0.1042	0.0227	19.9	8.3	877	0.15	0.14
5.			456	229	220	168x136	0.1044	0.0230	20.0	8.0	870	0.14	
6.			457	229	220	168X136	0.1047	0.0230	20.0	8.1	870	0.14	
7.	12/5/12	7	457	230	220	167x138	0.1051	0.0231	20.3	15.0	879	0.26	0.24
8.			459	230	222	169x139	0.1056	0.0234	20.7	18.0	885	0.31	
9.			460	230	222	168x137	0.1058	0.0235	20.5	14.7	872	0.24	
10.	19/5/12	14	460	229	222	168x136	0.1053	0.0234	20.9	23.0	893	0.40	0.41
11.			460	230	219	169x137	0.1058	0.0232	20.8	26.0	896	0.45	
12.			460	232	220	167x137	0.1057	0.0235	20.8	21.3	885	0.37	
13.			459	230	222	168x136	0.1056	0.0234	21.9	29.0	8936	0.51	

14.	26/5/12	21	459	229	217	168x137	0.1051	0.0228	22.0	30.0	965	0.52	0.52
15.			460	230	220	169x137	0.1058	0.0233	22.0	30.0	944	0.52	
16.	02/6/12	28	460	230	220	170x137	0.1081	0.0233	22.0	34.0	944	0.39	0.57
17.			460	230	219	168x140	0.1058	0.0232	22.0	32.2	948	0.56	
18			459	232	220	167x136	0.1065	0.0234	21.9	31.9	936	0.56	

APPENDIX A11

INDUSTRY: I

LOCATION: JOS NORTH

DATE OF IMMERSION: 28/8/11

TYPES OF TEST: WET DEVELOPMENT COMPRESSIVE TEST

S/No	Date tested	Age of blocks days(s)	Length (mm)	Breath (mm)	Height (mm)	Hollow size (mm)	Gross area (m^2)	Volume (m^3)	Weight (kg)	Failure load (kn)	Density (kg/m^3)	Strength (n/mm^2)	Average strength (n/mm^2)
1.	30/8/12	2	450	227	227	155x120	0.1022	0.0232	20.6	16.0	888	0.28	0.29
2.			455	228	230	156x122	0.1037	0.0239	21.0	15.0	879	0.26	
3.			459	226	229	155x120	0.1033	0.0236	21.1	18.4	890	0.32	
4.	31/5/12	3	460	230	229	156x122	0.1058	0.0242	21.8	31.2	901	0.58	0.56
5.			459	230	229	156x122	0.1056	0.0242	22.0	33.0	909	0.54	
6.			460	230	229	157X120	0.1058	0.0242	22.0	32.2	909	0.56	
7.	4/9/12	7	458	230	230	156x122	0.1053	0.0242	22.0	45.6	909	0.79	0.80
8.			459	228	229	155x120	0.1047	0.0240	22.0	46.3	917	0.81	
9.			458	229	228	150x122	0.1049	0.0239	21.9	46.5	916	0.81	
10.	11/9/12	14	460	230	230	155x120	0.1058	0.0243	22.0	29.0	905	0.85	0.83
11.			459	230	220	155x122	0.1056	0.0232	22.0	47.8	948	0.83	
12.			459	230	230	156x125	0.1056	0.0243	22.1	46.6	910	0.81	
13.			460	230	220	156x125	0.1059	0.0233	22.8	49.2	979	0.86	

14.	18/9/12	21	460	230	220	156x125	0.1058	0.0233	22.6	49.5	970	0.87	0.87
15.			460	230	220	156x125	0.1058	0.0233	22.6	49.3	970	0.88	
16.	25/9/12	28	458	225	228	157x128	0.1031	0.0235	23.0	54.3	979	0.91	0.91
17.			460	230	227	157x130	0.1058	0.0240	22.8	53.1	950	0.94	
18			460	230	228	157x130	0.1058	0.0241	23.0	52.4	954	0.92	

APPENDIX A12

INDUSTRY: II

LOCATION: KANKE

DATE OF IMMERSION: 21/7/12

TYPES OF TEST: WET DEVELOPMENT COMPRESSIVE TEST

S/No	Date tested	Age of blocks days(s)	Length (mm)	Breath (mm)	Height (mm)	Hollow size (mm)	Gross area (m^2)	Volume (m^3)	Weight (kg)	Failure load (kn)	Density (kg/m^3)	Strength (n/mm^2)	Average strength (n/mm^2)
1.	8/10/11	2	452	226	225	155x120	0.1022	0.0230	20.8	18.0	904	0.31	0.30
2.			459	227	230	156x125	0.1042	0.0240	21.0	16.0	875	0.28	
3.			460	229	229	156x120	0.1053	0.0241	21.0	18.0	871	0.31	
4.	11/10/11	3	460	228	225	156x126	0.1049	0.0236	21.5	31.0	911	0.54	0.54
5.			458	229	225	157x125	0.1049	0.0236	21.5	29.0	911	0.51	
6.			460	230	227	156X130	0.1058	0.0241	21.0	32.2	871	0.56	
7.	15/10/11	7	461	227	230	157x120	0.1047	0.0241	21.8	33.5	905	0.77	0.77
8.			460	228	229	156x125	0.1047	0.0240	22.0	34.4	917	0.78	
9.			459	227	230	157x120	0.1042	0.0240	22.1	33.9	921	0.77	
10.	29/10/11	14	458	225	229	156x125	0.1031	0.0236	22.6	48.0	958	0.84	0.83
11.			460	227	230	156x125	0.1044	0.0240	22.3	47.0	929	0.82	
12.			459	229	230	157x120	0.1051	0.0242	22.0	47.3	938	0.83	
13.			460	229	228	156x120	0.1053	0.0240	22.8	52.0	917	0.91	

14.	5/11/11	21	458	230	228	157x125	0.1053	0.0240	22.6	54.0	950	0.95	0.93
15.			458	230	229	157x125	0.1053	0.0241	22.9	52.8	938	0.92	
16.	12/11/11	28	460	230	229	156x120	0.1056	0.0242	23.0	53.1	946	0.98	0.99
17.			460	230	229	156x120	0.1056	0.0242	23.0	53.2	950	1.00	
18			459	230	230	156x120	0.1056	0.0243	23.0	54.1	950	0.99	

APPENDIX A13

INDUSTRY: III

LOCATION: BARKIN LADI

DATE OF IMMERSION: 28/5/12

TYPES OF TEST: WET DEVELOPMENT COMPRESSIVE TEST

S/No	Date tested	Age of blocks days(s)	Length (mm)	Breath (mm)	Height (mm)	Hollow size (mm)	Gross area (m^2)	Volume (m^3)	Weight (kg)	Failure load (kn)	Density (kg/m^3)	Strength (n/mm^2)	Average strength (n/mm^2)
1.	30/5/12	2	460	230	227	157x125	0.1058	0.0240	21.0	18.0	875	0.32	0.33
2.			459	230	227	157x125	0.1058	0.0240	21.0	18.0	875	0.32	
3.			459	230	228	157x125	0.1058	0.0310	22.0	19.0	709	0.34	
4.	31/8/12	3	458	229	226	156x120	0.1049	0.0238	22.0	33.0	924	0.58	0.58
5.			459	229	225	156x121	0.1051	0.0236	22.0	22.0	932	0.57	
6.			457	229	229	157X125	0.1046	0.0240	22.0	33.2	916	0.58	
7.	4/1912	7	460	229	230	156x120	0.1053	0.0242	22.1	45.5	909	0.80	0.82
8.			460	229	229	157x125	0.1053	0.0241	21.8	47.4	905	0.83	
9.			460	229	229	156x120	0.1044	0.0240	22.0	45.9	917	0.82	
10.	11/9/12	14	459	229	229	155x125	0.1051	0.0231	22.0	49.0	952	0.87	0.87
11.			459	230	220	155x125	0.1056	0.023	22.0	48.0	957	0.85	
12.			460	230	220	157x120	0.1058	0.0243	21.8	50.3	897	0.89	

13.	18/9/12	21	460	230	230	158x125	0.1058	0.0243	22.0	53.0	905	0.94	0.95
14.			460	230	230	156x120	0.1053	0.0242	22.1	53.0	913	0.94	
15.			460	230	230	156x121	0.1056	0.0242	22.3	53.8	922	0.95	
16.	25/9/12	28	459	229	229	155x120	0.1056	0.0242	22.5	55.1	930	0.98	0.97
17.			459	229	229	156x120	0.1056	0.0242	23.1	54.2	955	0.96	
18			459	229	229	156x120	0.1056	0.0242	23.1	55.1	955	0.97	

APPENDIX A14

INDUSTRY: IV

LOCATION: WASE

DATE OF IMMERSION: 2/6/12

TYPES OF TEST: WET DEVELOPMENT COMPRESSIVE TEST

S/No	Date tested	Age of blocks days(s)	Length (mm)	Breath (mm)	Height (mm)	Hollow size (mm)	Gross area (m^2)	Volume (m^3)	Weight (kg)	Failure load (kn)	Density (kg/m^3)	Strength (n/mm^2)	Average strength (n/mm^2)
1.			458	230	220	156x136	0.1053	0.0232	19.9	4	858	0.07	
2.	4/6/12	2	462	231	231	155x134	0.1067	0.0247	21.3	5.0	822	0.09	0.08
3.			460	230	227	156x136	0.1058	0.0240	20.6	4.5	858	0.08	
4.			461	227	230	165x147	0.1047	0.0241	20.9	4.0	867	0.07	
5.	5/6/12	3	460	230	227	165x136	0.1058	0.0240	21.2	5.0	883	0.09	0.09
6.			461	229	220	158X136	0.1056	0.0232	21.2	6.0	914	0.10	
7.			461	230	230	157x132	0.1066	0.0244	21.8	9.0	893	0.16	
8.	9/6/12	7	461	230	229	157x132	0.1060	0.0243	21.8	8.0	897	0.14	0.15
9.			460	230	230	157x132	0.1058	0.0243	21.8	8.0	897	0.14	
10.			461	229	229	156x132	0.1056	0.0242	21.9	12.0	905	0.21	
11.	16/6/12	14	461	230	229	156x136	0.1060	0.0244	22.0	13.0	902	0.23	0.21
12.			461	230	230	156x136	0.1060	0.0244	22.0	11.0	902	0.19	
13.			459	229	231	156x120	0.1051	0.0243	22.1	14.0	905	0.24	

14.	23/6/12	21	460	229	230	156x122	0.1053	0.0242	22.1	14.0	913	0.23	0.24
15.			460	230	230	156x120	0.1058	0.0243	22.1	14.10	909	0.26	
16.	30/6/12	28	459	229	229	157x122	0.1057	0.0241	22.1	20.0	917	0.35	0.36
17.			460	229	230	156x120	0.1053	0.0242	22.0	19.0	909	0.36	
18			459	229	230	156x130	0.1051	0.0242	22.0	22.0	909	0.38	

APPENDIX A15

INDUSTRY: V

LOCATION: SHENDAM

DATE OF IMMERSION: 2/6/12

TYPES OF TEST: WET DEVELOPMENT COMPRESSIVE TEST

S/No	Date tested	Age of blocks days(s)	Length (mm)	Breath (mm)	Height (mm)	Hollow size (mm)	Gross area (m^2)	Volume (m^3)	Weight (kg)	Failure load (kn)	Density (kg/m^3)	Strength (n/mm^2)	Average strength (n/mm^2)
1.			452	226	217	176x137	0.1022	0.0222	20.10	41.0	905	0.07	
2.	4/6/12	2	459	227	222	168x136	0.1042	0.0231	20.50	51.0	888	0.09	0.08
3.			452	230	217	167x138	0.1022	0.0231	20.50	41.0	888	0.07	
4.			453	230	218	167x137	0.1042	0.0227	20.8	6.0	916	0.10	
5.	5/6/12	3	456	229	220	168x136	0.1044	0.0230	20.8	5.5	904	0.10	0.1
6.			457	229	220	118X136	0.1047	0.0230	20.5	5.5	891	0.10	
7.			457	230	220	167x138	0.1051	0.0231	20.8	5.0	900	0.09	
8.	9/6/12	7	457	230	222	169x139	0.1056	0.0234	20.5	7.0	876	0.12	0.11
9.			460	230	222	168x137	0.1058	0.0235	21.0	6.5	894	0.11	
10.			460	230	222	168x136	0.01053	0.0234	21.0	7.5	897	0.13	
11.	16/6/12	14	460	232	219	169x137	0.01058	0.0232	21.0	8.0	905	0.14	0.14
12.			460	230	220	167x137	0.0157	0.0235	20.8	8.0	885	0.14	

13.	23/6/12	21	459	230	222	168x136	0.1057	0.0234	21.0	9.0	897	0.16	0.16
14.			459	229	227	168x137	0.1056	0.0228	21.0	11.0	921	0.19	
15.			460	230	220	169x137	0.1051	0.0233	21.0	12.0	901	0.21	
16.	30/6/12	28	460	230	220	170x137	0.1052	0.0233	21.0	12.0	901	0.21	0.21
17.			460	230	219	168x140	0.1058	0.0232	21.5	12.0	927	0.21	
18			459	232	220	167x136	0.1065	0.0234	21.0	12.0	897	0.21	

APPENDIX A18

INDUSTRY: I

TYPE OF TEST: WET COMPRESSIVE STRENGTH

DATE IMMERSED IN WATE: 8-01-13

DATE TESTED: 5-02-13

S/NO	SAMPLE NUMBER	LENGTH (MM)	BREADTH (MM)	HEIGTH (MM)	GROSS AREA (M^2)	FAILURE LOAD (KN)	STRENGTH (N/mm^2)
	A_1 05-02	450	227	227	0.1022	70	0.65
	A_2 05-02	455	228	230	0.1037	64	0.60
	A_3 05-02	460	230	229	0.1058	92	0.67
	A_4 05-02	459	228	229	0.1047	75	0.71
	A_5 05-02	458	229	229	0.1049	118	1.12
	A_6 05-02	460	230	230	0.1058	33	0.79
	A_7 05-02	459	230	220	0.1056	145	1.35
	A_8 05-02	459	230	230	0.1056	62	0.59
	A_9 05-02	458	225	228	0.1031	85	0.73
	A_{10} 05-02	460	230	227	0.1058	75	0.71

APPENDIX A19

INDUSTRY: II

TYPE OF TEST: WET COMPRESSIVE STRENGTH

DATE IMMERSED IN WATER: 8-01-13

DATE TESTED: 5-02-13

S/NO	SAMPLE NUMBER	LENGTH (MM)	BREADTH (MM)	HEIGTH (MM)	GROSS AREA (M^2)	FAILURE LOAD(KN)	STRENGTH (N/mm^2)
1	B_1 05-02	460	228	225	0.1049	40	0.38
2	B_2 05-02	460	228	225	0.1049	50	0.47
3	B_3 05-02	460	228	225	0.1049	48	0.46
4	B_4 05-02	459	227	230	0.1042	52	0.49
5	B_5 05-02	459	228	230	0.1047	55	0.52
6	B_6 05-02	460	228	225	0.1049	45	0.43
7	B_7 05-02	459	228	230	0.1047	43	0.41
8	B_8 05-02	460	228	225	0.1049	52	0.49
9	B_9 05-02	458	225	229	0.1031	50	0.47
10	B_{10} 05-02	459	229	230	0.1051	65	0.61

APPENDIX A20

INDUSTRY: III

TYPE OF TEST: WET COMPRESSIVE STRENGTH

DATE IMMERSED IN WATER: 8-01-13

DATE TESTED: 5-02-13

S/NO	SAMPLE NUMBER	LENGTH (MM)	BREADTH (MM)	HEIGTH (MM)	GROSS AREA (M^2)	FAILURE LOAD(KN)	STRENGTH (N/mm^2)
1	C_1 05-02	460	230	227	0.1058	90	0.86
2	C_2 05-02	459	230	227	0.1058	85	0.81
3	C_3 05-02	458	229	226	0.1049	80	0.76
4	C_4 05-02	460	229	230	0.1053	115	1.10
5	C_5 05-02	460	229	229	0.1053	125	1.19
6	C_6 05-02	460	229	229	0.1053	55	0.53
7	C_7 05-02	459	230	229	0.1058	110	1.04
8	C_8 05-02	460	229	230	0.1053	60	0.57
9	C_9 05-02	460	229	229	0.1053	180	0.72
10	C_{10} 05-02	457	228	229	0.1046	55	0.53

APPENDIX A21

INDUSTRY: IV

TYPE OF TEST: WET COMPRESSIVE STRENGTH

DATE IMMERSED IN WATER: 8-01-13

DATE TESTED: 5-02-13

S/NO	SAMPLE NUMBER	LENGTH (MM)	BREADTH (MM)	HEIGTH (MM)	GROSS AREA (M^2)	FAILURE LOAD(KN)	STRENGTH (N/mm^2)
1	D_1 05-02	461	227	230	0.1047	55	0.52
2	D_2 05-02	460	230	227	0.1058	70	0.66
3	D_3 05-02	460	230	228	0.1058	48	0.46
4	D_4 05-02	461	230	229	0.1060	65	1.62
5	D_5 05-02	460	230	230	0.1058	60	1.57
6	D_6 05-02	459	229	231	0.1051	90	0.85
7	D_7 05-02	460	229	230	0.1053	55	1.52
8	D_8 05-02	460	230	229	0.1058	35	0.33
9	D_9 05-02	460	229	231	0.1053	52	0.51
10	D_{10} 05-02	459	229	230	0.1051	45	0.43

APPENDIX A22

INDUSTRY: V

TYPE OF TEST: WET COMPRESSIVE STRENGTH

DATE IMMERSED IN WATER: 8-01-13

DATE TESTED: 5-02-13

S/NO	SAMPLE NUMBER	LENGTH (MM)	BREADTH (MM)	HEIGTH (MM)	GROSS AREA (M^2)	FAILURE LOAD(KN)	STRENGTH (N/mm^2)
1	E_1 05-02	460	230	228	0.1053	50	0.45
2	E_2 05-02	459	230	227	0.1053	45	0.43
3	E_3 05-02	460	229	228	0.1053	43	0.51
4	E_4 05-02	460	230	229	0.1053	40	1.38
5	E_5 05-02	459	229	229	0.1053	42	1.40
6	E_6 05-02	460	230	228	0.1053	52	0.50
7	E_7 05-02	460	230	229	0.1053	45	1.43
8	E_8 05-02	459	229	230	0.1053	48	0.46
9	E_9 05-02	460	230	230	0.1053	55	0.52
10	E_{10} 05-02	459	229	230	0.1053	40	0.38

APPENDIX 23

WATER ABSORPTION FOR THE FIVE BLOCK INDUSTRIES

INDUSTRY	SAMPLE NUMBER	DRY WEIGHT W1(kg)	WET WEIGTH W_2 (kg)	WATER ABSORPTION $\underline{(W_2\text{-}W1)}$% W_1X100	AVERAGE WATER ABSORPTION (%)
I	A_1WA	22.0	23.0	4.55	7.61
	A_2WA	22.0	22.8	3.64	
	A_3WA	20.5	23.5	14.63	
II	B_1WA	21.5	22.9	6.51	8.52
	B_2WA	21.0	23.0	9.52	
	B_3WA	21.0	23.0	9.52	
III	C_1WA	22.0	22.8	3.64	7.12
	C_2WA	22.0	23.7	7.73	
	C_3WA	21.0	23.1	10.00	
IV	D_1WA	22.0	22.9	4.10	4.54
	D_2WA	21.9	23.0	5.02	
	D_3WA	22.2	23.2	4.50	
V	E_1WA	22.0	23.1	5.00	5.90
	E_2WA	22.0	23.4	6.36	
	E_3WA	21.9	23.3	6.39	

APPENDIX 24

DRYING SHERINKAGE AND WETTING EXPANSION OF THE FIVE BLOCK INDUSTRIES

INDUSTRY	SAMPLE NUMBER	DRY LENGTH BEFORE IMMERSING L_1(mm)	WEILENGTH AFTER IMMERSION L_2 (MM)	OVER DRY LENGTH L_3 (MM)	DRY (%) SHRINKAGE $(L_3-L_1)/L_3 X10^2$	WETTING EXPANSION $(L_2-L_1)/L_3 X10^2$ %	AVERAGE DRY SHENKAGE (%)	AVERAGE WETTING EXPANSION (%)
	A_1WA	100.00	100.05	100.02	0.02	0.05		
I	A_2WA	100.03	100.09	100.06	0.03	0.06	0.03	0.06
	A_3WA	99.99	100.06	100.03	0.04	0.07		
	B_1WA	100.28	100.36	100.35	0.06	0.08		
II	B_2WA	100.15	100.23	100.20	0.05	0.08	0.05	0.08
	B_3WA	99.58	99.65	99.61	0.03	0.07		
	C_1WA	100.02	100.07	100.05	0.03	0.05		
III	C_2WA	100.00	100.08	100.06	0.06	0.08	0.03	0.06
	C_3WA	100.03	100.07	100.04	0.01	0.04		
	D_1WA	99.90	99.95	99.93	0.03	0.05		
IV	D_2WA	99.37	99.95	99.98	0.11	0.08	0.07	0.07
	D_3WA	100.85	100.92	100.91	0.06	0.07		
	E_1WA	100.04	100.10	100.02	0.02	0.06		
V	E_2WA	99.92	99.98	99.95	0.03	0.06	0.02	0.07

	E_3WA	100.10	100.18	100.15	0.05	0.08		

Plate I:

Block sample Crushing during Dry Development Compressive Test.