QUALITY OF SANDCRETE HOLLOW BLOCKS IN THE FEDERAL CAPITAL TERRITORY, ABUJA.

BY

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DECLARATION

I hereby declare that this thesis has been composed by myself and it is a record of my known research work. It has not been accepted in any publication for a higher degree.

All quotations are distinguished by quotation marks and the sources of information are specifically acknowledged by means of reference.



Aliu, Abdul Azeez

CERTIFICATION

This thesis entitled "Quality of Sandcrete Hollow Blocks Produced in the Federal Capital Territory", Abuja" by Aliu, Abdul Azeez, meets the regulations governing the award of degree of Master of Science (Structural Engineering) of Ahmadu Bello University, and is approved for its contribution to knowledge.

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KASHIM IBRA...

DEDICATION

This thesis is dedicated to Almighty Allah.

ACKNOWLEDGMENT

This project would not have been completed without making references to previous research works and publications.

I would like to acknowledge the authors whose works were quoted. In the same respect, I would like to thank all those that contributed in one way or the other towards the completion of this work. I am therefore expressing my profound gratitude and appreciation to my project supervisor, Dr. S. P. Ejeh (B.Eng., MSc., P.hD., A.M.I.C.E., M.NSE.) Head, Department of Civil Engineering for his encouragement, unfailing support, his various criticisms, suggestions and direction in accomplishing this research work.

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1.0 CHAPTER ONE

1.1 INTRODUCTION

A Sandcrete hollow block can be defined as a block made from a mixture of cement, sand and water. A block is a willing unit, dimensionally larger than bricks and has one or more large cavities passing through it and the solid material is between 50 and 75 percent of the total volume of block calculated from the overall dimension.

The nominal sizes of blocks are as follows: 100mm x 230mm x 460mm, 150mm x 230mm x 460mm and 230mm x 230mm x 460mm.

The specified nominal mixes of Sandcrete hollow blocks are between one part of cement by volume to six or eight parts of sand (1:6, 1:8); with water cement ratio of 0.6 and 0.9.

Sandcrete hollow blocks are either produced manually or by moulding machines. Blocks produced are cured for a minimum period of seven days and a maximum of twenty eight days.

Sandcrete hollow blocks used for walling units are widely used in Nigeria. Because of the fact that Sandcrete hollow blocks constitute a high percentage of concrete work in the building industry, its importance cannot be neglected. Due to high demand of Sandcrete hollow blocks, numerous block making factories sprang up. This project is intended to study the physical properties of Sandcrete hollow blocks produced in the Federal Capital Territory, Abuja for the purpose of testing their quality if they meet the required specified standards.

To obtained general information in respect of material, choice of mix, sizes, manner of curing and mode of production used in producing Sandcrete hollow blocks in the F.C.T. initial site visits were conducted.

The second site visit involved the collection of samples from the selected industries. The territory was divided into five zones and a town was chosen from each zone. A well equipped block industry was chosen from each town where block samples were collected. In each industry fifty (50) samples were collected. In all, two hundred and fifty (250) hollow block samples were collected from the five industries for various standard tests in the laboratory.

1.2 OBJECTIVES

The objectives of this research are to find out:

a) How suitable are the raw materials used for the production of Sancrete hollow blocks.

b) Methods of production and procedures used in different block industries in the F.C.T.

c) The quality of the finished Sandcrete hollow blocks.

d) To compare the results of above with existing international and local standards as well as the results of technical papers.

1.3 SCOPE OF WORK

In order to realise the set objectives, the following form the scope of work:

a) Review of previous work on Sandcrete blocks.

b) Sieve analysis to determine type of sand used.

c) Conduct laboratory tests on samples of Sandcrete hollow blocks collected from block industries. The standard tests conducted are the dry development strength, wet development strength, wet compressive strength, density, moisture movement, drying shrinkage and dimensional measurement.

1.4 LIMITATION

In the course of visits to the various block industries for the collection of necessary information for the research work, one encountered the problem of fluctuation in the price of Sandcrete hollow blocks. This was due to the hike in price of Portland cement and sand.

Also, the workers in the industries were suspicious of the visits being paid to the industries. As a result, they were not willing to divulge the necessary information required from them. This was solved by paying frequent visits to the industries and making friends with the workers.

Some of the industries visited were very remote and transportation became a problem. In the process of conveying the Sandcrete hollow blocks from these remote areas to the laboratory, quite a number of the blocks got broken.

In order to still have the sufficient number of blocks required for the tests. Sand was spread on the floor of the truck before stacking for conveyance and excess Sandcrete blocks were purchased.

1.5 OUTCOME OF RESULTS

From the test results, it was observed that most of Sandcrete hollow blocks produced in the Federal Capital Territory, Abuja are generally low in quality compared to specified standards. The average 28 - day dry development strength of the five industries are 0.86N/mm^2, 0.81N/mm^2, 0.77N/mm^2, 0.81N/mm^2 and 0.83N/mm^2 respectively. While the average values of the wet compressive strength of industries A, B, C, D and E are 0.49N/mm^2, 0.46N/mm^2, 0.46N/mm^2, 0.48N/mm^2 and 0.44N/mm^2 respectively, the average density of the block samples were found to be 1042Kg/m^3, 1060Kg/m^3, 948Kg/m^3, 1020Kg/m^3 and 960Kg/m^2 for industries A, B, C, D and E respectively. However, these values do not meet the specification in the relevant standard.

2.0 CHAPTER TWO

2.1 LITERATURE REVIEW

Sandcrete hollow block is a constituent of three main materials namely: Cement, Sand and Water. Cement is the chemically active constituent and acts as a binding material, but its reactivity only comes into effect on mixing with water. The sand plays no part in the chemical reaction but its usefulness arises from the fact that it is an economical filler material with good resistance to volume changes which takes place during mixing and improves the durability of the block.

The properties of the Sandcrete blocks depend on 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 block itself /9/. Some of the properties of Sandcrete blocks are strength, density, modulus of elasticity, dimensional changes, durability, efflorescence, fire resistance and thermal Conductivity.

Several studies have been carried out on Sandcrete hollow blocks. However, reference materials generally made use of are the Nigeria Industrial standard and British standard specifications for Sandcrete hollow blocks.

2.2 FORM AND SIZE

The shape and size of Sandcrete blocks should be regular to facilitate bonding. British standard 2028, 1364, 1968 defines a block as walling unit

TABLE 1: B.S. 2028 DIMENSIONS FOR SANDCRETE BLOCKS

TYPE	WORK SIZE (MM)		
	LENGTH	HEIGHT	THICKNESS
A, B	390	90 190	75, 90, 100, 140, 190
A	420	215	75, 90, 100, 140, 190, 21
B	440 590	190 215 290 190 215	75, 90, 100, 140, 190, 21
C	390 440 590	190 190 215 290 190 215	60, 75

2.3 COMPRESSIVE STRENGTH

The compressive strength of hollow Sandcrete blocks is of prime importance amongst its other properties. Several factors affect the compressive strength of hollow Sandcrete blocks and the most important factors are: void content, age of cement, amount of cement, water content, fine aggregate, temperature and curing conditions.

According to Iloghalu/8/, who compared the properties of fired building bricks against that of Sandcrete, he stated that the variables that can easily affect the strength of a cement product are many, namely water/binder ratio,

concluded by recommending that the manufacturers of Sandcrete hollow blocks should be mandated by the standard organization of Nigeria to undertake periodical testing so as to ascertain that their products conform with the specifications. Thus, have test certificates attached to their products. In addition, the users of Sandcrete hollow blocks should always demand a certificate of test from producers to ascertain that the blocks being purchased are of good quality.

In a paper titled "soil stabilized compressed blocks for Civil Engineering works" jointly presented by Ola and Awoleye/11/ at the seminar on the use of clay bricks and blocks for the provision of cheaper and durable housing in October 1985 at Zaria, they jointly observed that:

(a) The compressive strength of soil - cement blocks increases appreciably with increase in cement content.

(b) The compressive strength of soil - cement blocks increases appreciably with increase in compactive effort up to a compactive effort of about $8MNm^2$, when subsequent increase is no longer appreciable.

The increase in strength for 3 percent to 9 percent cement content for the local brick sizes are from $0.81MN/m^2$ to $2.30MN/m^2$, $1.12MNm^2$ to $2.60MNm^2$, $1.65MN/m^2$ to $3.65MN/m^2$, $2.1MN/m^2$ to $4.96/m^2$ for compactive effort of $1MNm^2$, $2MN/m^2$, $4MN/m^2$ and $7MN/m^2$ respectively. They/11/ also observed that variations of compressive strength with size of blocks showed that large size blocks appeared to have smaller compressive strength.

Also studies have been carried out into the strength of other walling units. The findings of Florek and Ejeh/7/ are stated below:

(a) Development of dry compressive strength of soilcrete hollow blocks continues over the years since complete hydration of cement mixed with laterite cannot be attained.

(b) The minimum wet to dry compressive strength ratio is 0.4 and the average wet to dry compressive strength ratio for blocks is about 0.65.

Ejeh/5/ in his studies on "compressive strength of soilcrete hollow blocks" made the following findings:

(a) The soilcrete hollow blocks will fully develop its full compressive strength after curing by spraying with water and covering with cellophane materials for about a week.

(b) Soft boards should be adopted as the contact layer for the compressive strength test for soilcrete hollow blocks, this is due to the fact that it gives higher compressive strength than the rest packing materials.

Compressive strength is calculated as crushing load divided by the gross area of the specimen /16/. The compressive strength of the block is in N/mm^2. The British standard specification /16/ gave seven strength categories for type A blocks ranging from $3.5N/mm^2$ -$35N/mm^2$ and for type B blocks two strength categories $2.8N/mm^2$ and $7.0N/mm^2$. According to BS

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2028 /16/ the average compressive strength of type A block is given as 3.5N/mm^2 while the lowest individual block is given as 2.8N/mm^2.

The strength of block when tested in accordance with the Nigerian Industrial standard /22/ should not be less than 3.45N/mm^2 and the weakest individual block in the test sample must not less than 2.59N/mm^2.

However the Federal Ministry of work during an annual conference in Kano 1985 /6/ decided to lower requirements for precast concrete blocks produced in Nigeria due to the fact that the blocks will not be subjected to severe climatic conditions. The ministry recommended that the average compressive strength of 3 blocks should not bee less than 2.1N/mm^2 while the lowest compressive strength of individual block should not be less that 1.7N/mm^2.

2.3.1 EFFECT OF VOID CONTENT ON STRENGTH

If the block is inadequately compacted, air voids will remain in the set sandcrete hollow blocks. According to Jackson /9/ partially compacted block will contain a large percentage of voids and the sandcete strength will drop. On the other hand, water in excess of that required for full hydration produce a somewhat porous structure resulting from loss of excess water even for a fully compacted sandcrete.

2.3.2 EFFECT OF CEMENT ON STRENGTH

The influence of cement on concrete strength for a given mix proportion is determine by its fineness and chemical composition /9/. The gain in strength is rapid at early ages and after 28 days the relative gain in strength is much reduced. It is apparent that cements containing relatively high percentage of tricalcium silicate (c_3s) gain strength much more rapidly than those rich in dicalcium silicate (c_2s), however, at a latter age the difference in the corresponding strength value is small.

2.3.3 EFFECT OF TEMPERATURE ON STRENGTH

Temperature increase affects the sandcrete blocks as it fastens the hydration process. If the block is well cured the temperature increases the rate of gain of early strength since there would be no water loss due to evaporation. When water loss due to evaporation is not replaced, temperature increase would adversely affect the strength of the sandcrete hollow blocks.

Boeck, Chaudhuri and Aggarwal /4/ jointly carried out a study on "Sandcrete hollow blocks for Building - A detailed study on mix composition, strength and their cost' and came out with the following conclusions:

a. The weight as well as the compressive strength of a sandcrete block increases with the increase in cement content, also with the addition of coarse aggregate (5-10mm stone chipping) to sand. The compressive strength is highest with the addition of 45 percent coarse

aggregate. It is always economical to add coarse aggregate than more of cement, for getting higher strength.

b. The compressive strength in the wet state is about 80 percent of the strength in dry state.

c. If sandcrete blocks are tested for compressive strength without bedding their faces with cement- sand mortar, the values obtained are erratic, generally low by about 15 percent.

2.4 DENSITY

The object of compaction of concrete and concrete products is to as much possible reduce air voids leading to increased density of the product. For sandcrete blocks, density is largely a function of aggregate density , size, grading, degree of compaction and the block form.

In general, for a given set of materials and compaction pressure the strength of a concrete block will increase with its density. The British standard specification /16/ states that the block density of type A blocks shall not be less than 1500kg/m^3 and types B and C blocks shall be less 1500kg/m^3.

It has been found that the density of solid or hollow blocks will mainly be determined by the type of aggregate used /7/. Light weight aggregates give units of lower density. Floreck and Ejeh /7/, obtained an average density of 1880kg/m^3 for the solicrete hollow blocks (400mm x 150mmx150mm) produced by Occidental construction company in Zaria.

Appendix B of British standard 2028 /9/, the method for the determination of block density clearly spell out the procedure for the determination of density as follows:

a. Take at random three whole blocks from the sample.

b. Calculate the gross volume of each the three blocks.

c. Weigh each of the three blocks to he nearest 0.05kg.

d. Calculates the block density of each block, using the formula:

$$\text{Block density in kg/m}^3 = \frac{\text{weight}}{\text{Gross Volume.}}$$

e. Report the mean block density of the three blocks to nearest 10kg/m^3

2.5 DRYING SHRINKAGE

Several factors influence the overall drying shrinkage of sandcrete blocks. These include the shape and size, type of cement and finess, relative humidity of the environment, the water- cement ratio, and amount of curing, this, subsequently would lead to dimensional changes of the sandcrete blocks. According to Jackson /9/, the drying shrinkage in concrete is directly proportional to the water-cement ratio and inversely proportional to the aggregate-cement ratio. When concrete which has been allowed to dry out is subjected to a moist condition, it swells, however, the magnitude of this expansion is not sufficient to recover all thee initial shrinkage even after prolonged immersion in water. For a given water-cement ratio, shrinkage increases with increasing cement content.

The British standard specification /16/ specified that the average value of drying shrinkage of the sample shall not exceed the values given in the table 3 below.

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TABLE 3: DRYING SHRINKAGE

BLOCK TYPE	AVERAGE COMPRESSIVE STRENGTH (N/mm^2)	BLOCK DENSITY (kg/m^3)	MAXIMUM DRYING SHRINKAGE (%)
A	Less than 10.5	All	0.05
	10.5 and above	All	0.06
B	less than 7.0	over 625	0.07
	7.0 and above	625 and less	0.09
		All	0.08
C	All blocks	over 625	0.08
		625 and less	0.09

Sandcrete blocks shrink with loss of moisture down to an air dry condition. If moist units are placed in a wall and this natural shrinkage is restrained, as it is often the case, tensile and shearing stress are developed which may result in cracking. Sandcrete blocks should be dried to at least the moisture content limitations of the applied specification before use /12/ From the aforemention, it is imperative that sandcrete blocks produced should be adequately cured and protected from moisture and high temperature from its production stage to usage so as to prevent excessive shrinkage which might subsequently lead to cracking of the sandcrete blocks.

2.6 WATER ABSORPTION

Absorption may be defined as the ability of the concrete block to draw water into its voids. And this is expressed as the ratio of the increase in weight to the weight of the dry sample as a percentage. Sandcrete block which readily absorbs water is susceptible to deterioration.

Iloghalu /8/ in his work, carried out test on water absorption of both solid and perforated bricks and states that in a production factory, the determination of water absorption is used for quality control, because it is much simpler and less time-consuming than the measurement of porosity. This is because absorption tests are good indications of the apparent porosity of brick. For most ceramic the apparent porosity is approximately twice the figure obtained for water absorption. Table 4 below shows the relationship between water absorption and apparent porosity.

The Nigerian Industrial standard 74 /21/ specifies that the average water absorption of common building bricks shall not be more than 25 percent by weight after immersion in water for 24 hours.

TABLE 4: SAMPLE RESULT OF APPARENT POROSITY, WATER ABSORPTION AND BULK DENSITY FROM PRODA DENSE REFRACTORY TEST SAMPLES.

SAMPLE NO	APPARENT POROSITY (%)	WATER ABSORPTION (%)	BULK DENSITY Kg/m^3
1	35.37	20.26	2.27
2	36.36	21.09	2.71
3	36.04	20.95	2.70
4	34.08	19.34	2.68
5	34.45	19.55	2.69

The absorption test immediately gives the idea of how porous and more importantly how permeable a block is. Too porous a brick will cause dampness and also the migration and consequent deposition of soluble salts from the interior of brick to the outside forming whitish colouration known as efflorescence. /8/

Due to the porosity of sandcrete block which arises from the use of water in excess of that required for purpose of hydration in order to make the mix efficiently workable and the difficulty of completely removing air during compaction, sandcrete block absorbs water. Permeability decreases with decreasing water-cement ratio and is affected by both the finess and chemical composition of cement. Coarse cements tend to produce pastes with relatively high porosity /9/

2.7 FIRE RESISTANCE AND THERMAL CONDUCTIVITY

Generally, Sandcrete blocks have good fire resisting properties. Compared to bricks, Sandcrete blocks have low fire resisting properties. However, the degree of fire resistance is dependent on the type and grading of aggregate, cement content, weight, thickness of block and its moisture content.

Concrete blocks of 100mm thickness can provide an adequate resistance of fire up to 2 hours if load bearing and up to 4 hours in non load bearing /9/.

Sound insulation is a function of both sound absorption and sound transmission. Sound absorption is a measure of the ability of a surface to reduce the reflection of incident sound, most surfaces have very little sound absorption while porous or otherwise irregular surface are more effective in this respect.

Studies have also shown that the amount of sound transmitted increases as the density of block decreases while the amount of sound absorbed increases as. the amount and size of voids increase.

2.9 RESISTANCE TO CHEMICAL ACTION

In Sandcrete blocks, sulphate attack cause deterioration of the block and mortar. Efflorescence which is the deposition of soluble salts forming whitish discoloration of surface of block has been known to occur when the hydroxides of sodium, potassium or calcium react with free carbon dioxide. In mortars containing portland cement, the result of this reaction is that the crystals so formed cause expansion in mortar leading to reduced strength. /12/

The Nigerian industrial standard 74:1976 /21/ states that the rate of efflorescence shall not be worse than moderate, that is, when area covered by the salt deposit is greater than 10 percent and less than 50 percent of the area of the bricks surface but unaccompanied by powdering or flaking of the surface.

2.10 SAMPLING

It is essential that before tests are conducted sampling of the blocks must be done so as to obtain a good representative sample of the consignment.

The sample of blocks shall then be marked for future identification of the consignment it represents. The blocks shall then be kept under cover and protected from extreme conditions of temperature, relative humidity and wind until they are required for test /16/.

The British standard specification /16/ gives the number of blocks necessary for each test in the Table shown below:

TABLE 5: BLOCKS NECESSARY FOR EACH TEST

PURPOSE FOR WHICH REQUIRED	NO. OF BLOCKS NECESSARY	
	TYPES A OR B	TYPE C.
Checking and measurement of dimension	10	10
Determination of density	3	3
Determination of strength	10	5
Determination of drying shrinkage and/ or wetting expansion	4	4
Spares	3	3
Total required for full set of tests.	20	15

2.11 MATERIALS

The constituent materials used for the production of sandcrete blocks are sand, which is a chemically inert material, cement, which is a binding material and water which initiates the chemical reaction that produce the binding qualities of cement.

Each of these materials must conform with established specifications so as to achieve reasonable results.

2.11.1 CEMENT

The cement referred to here is the ordinary portland cement. It should conform with the requirements of BS12:1971 Portland cement (ordinary and rapid hardening) or the Nigerian Industrial standard 11: 1974.

The principal requirement is that the cement should be able to produce strong, dense, durable sandcrete block with definite setting and hardening characteristics.

Portland cements are made by calcining a slurry of clay (silica, alimina and iron oxide) with limestone (calcium carbonate), in a rotating kiln. The resulting clinker, with a small proportion of gypsum to retard the setting of cement, is ground to a powder. The finess of which influence the properties of the product /1/. The finer the grinding, the more rapid the rate of hydration. The Nigeria Industrial Standard 11:1974 /20/ specified that the ordinary Portland cement shall have an average specific surface of not less than 2500 cm^2/g. Initial setting time should not be less than 45 minutes and

the final setting time should not be more than 10 hours. It went further to state that the ordinary portland cement should not have an expansion of more than 10mm and if aerated 5mm.

2.11.2 SAND

Sand is the largest ingredient of the sandcrete block mix. It occupies at least 75 percent of the volume of sandcrete block.

The bond between sand and cement is an important factor determining the sandcrete block strength. Bond strength is influenced by the size of the aggregate, its surface texture and cleanliness. A batch of sand containing grains of approximately the same size would have voids between the grains which would eventually affect the strength of the block. A batch containing various grain sizes would result in increased strength because the small grain would fill the voids between the larger grains to make a satisfactory dense material.

A fine coating of impurities, such as silt or clay, on the aggregate can also result in a poor bond. So, it is important that the sand to be used should be as clean as possible and free of deleterious material.

According to the Nigerian Industrial standard /22/ 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.

Sand exposed to rain is able to retain moisture on the surface of the particles. As water is a constituent of sandcrete blocks, it becomes very necessary to know the amount of water which is actually present in sand, This moisture must be allowed for in the calculation of batch quantities /1/.

2.11.3 WATER

Water for production of sandcrete blocks should be reasonably free from impurities such as suspended solids, organic matter and salts, which may adversely affect the setting, hardening and durability of the sandcrete block. Water, in addition to reacting with cement and thus causing it to set and harden, also facilitates mixing, placing and compacting of sandcrete blocks. It is also used for curing purposes. In general, water fit for drinking satisfies this requirement. The use of seawater which contains salt does appear to have some effect on portland cement concrete because it is known to cause surface dampness, effloresences and staining and should be avoided where concrete of good appearance is required /9/

2.12 MIX PRODUCTION

The Nigerian Industrial standard /22/ states that the mix used for sandcrete blocks shall not be less than one part of cement to six parts of sand (1:6) up to a mix of one part of cement and sand of eight parts (1:8) by volume.

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2.13 WATER: CEMENT RATIO

A sandcrete mix containing minimum amount of water required for complete hydration of its cement, if it could be fully compacted, would develop the maximum attainable strength. Depending upon the degree of workability required and the strength, water/cement ratio ranging from 0.6 - 0.9 has been recommended for sandcrete block.

A partially compacted mix will contain large percentage of voids leading to reduced strength. On the other hand, while facilitating compaction, water in excess of that required for full hydration produces a somewhat porous product resulting from loss of excess water /9/.

A low water. cement ratio also reduces the shrinkage of sandcrete blocks and increases its durability and strength.

2.14 PRODUCTION

Sandcrete hollow blocks could be produced manually or mechanically. the cement and the aggregate are first properly blended during the mixing. Water is then added until a homogenous material in which each particle of sand is entirely covered with cement paste is achieved.

The thoroughly blended homogenous material is now deposited in a mould and then compacted, this is followed immediately by the extrusion of the pressed blocks so that the mould can be repeatedly used. The blocks are then released directly unto pallets which are hand loaded.

Since the finished blocks are required to be self supporting and be

able to withstand any movement and vibration from the moment they are extruded, the mix is always drier than the normal concrete mix.

2.15 PROTECTION AND CURING

The need for adequate curing and protection of sandcrete blocks cannot be overemphasized. It is not only good enough to use a good mix in the production of sandcrete blocks but to also cure them adequately. Since newly molded blocks contain free water, it is very necessary to protect them against high temperature. High temperature may result in evaporation of water leaving insufficient water to hydrate cement.

Consequently, this would lead to reduced strength and durability . To prevent surface cracks, sandcrete blocks should be placed under a shed for the first 72 hours so as to protect them from direct sun rays, wind and rains. This should be continued for the next 7 days and during this period, the blocks should be in contact with moisture by sprinkling them with water in the morning and evening. This treatment is know as curing. The main aim of curing is to keep the block saturated until the original water filled space in the fresh concrete paste has been filled by products of hydration /4/. As long as the temperature is favorable and moisture is present, the chemical process of hardening continues at a diminishing rate for an indefinite period.

2.16 APPLICATION

The main uses of bricks and blocks are as units laid in mortar to form walls and piers /1/. Individual blocks when bonded together with mortar is referred to as block work or block masonary. They could also be used for exterior and interior load bearing walls, curtain walls, panel walls, partitions, columns and retaining wall /12/. Use of sandcrete blocks give good insulation properties against heat transfer.

Unlike in-situ concrete, no support is needed to vertical surface during construction and also complex shapes can be built, which in concrete would require equally complex and costly form work.

However, the appearance of walling is much affected by that of mortar. The strength in compression of brickwork and block work can be high, but unless the work is reinforced, tensile strength is usually ignored in design. There is no strength advantage in using very strong mortar with weak blocks, in fact, mortar should generally be weaker than the units /1/.

2.17 SITE SURVEY

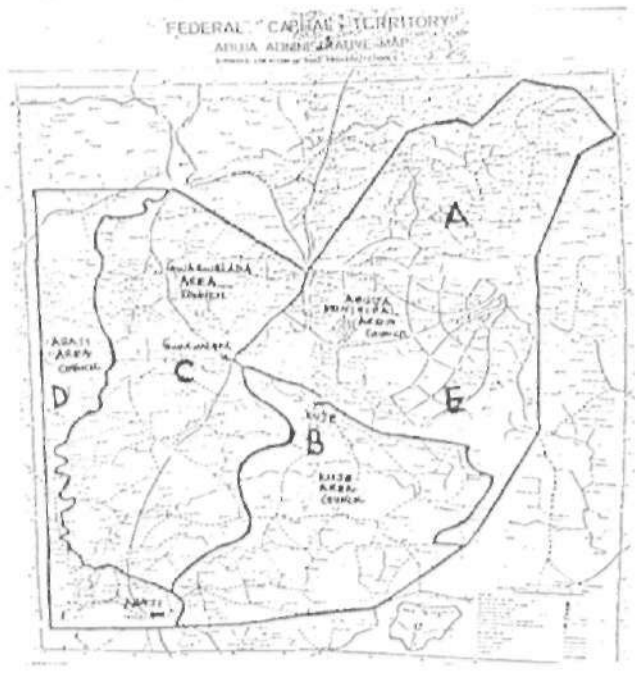
The survey covered the entire Federal Capital Territory as visits were made to the various block industries. For the fact that the Federal Capital Territory, Abuja is made up of four Area councils and this survey was supposed to cover five zones, the biggest amongst the four area councils which is the Municipal area council was divided into two zones. From each zone a town where block industries thrive most was selected.

The towns selected are Kubwa in the North East of Garki, Kuje in the South, Abaji in West, Gwagwalada in the center and Nyanya in the South-East of Garki. About fifty block molding industries were visited.

Prior to this, several preliminary site visits were made to various block making industries in the Federal Capital Territory to collect information on the mix, mode of production, sizes of blocks produced, curing, type of material, cost and number of workers employed by the industry. After the analysis of the data obtained from the various industries, final visits were made to the selected five industries which are fairly scattered within the territory. These industries have large production capacities, moulding machines and are well patronized. The map below shows the Federal Capital Territory and the selected towns where the industries are located.

INDUSTRY A INDUSTRY B

INDUSTRY C INDUSTRY D INDUSTRY E



FEDERAL CAPITAL TERRITORY MAP

2.18 COLLECTION OF SAMPLES

From the selected industries, fifty (50) block samples were randomly selected from each industry. On the whole, two hundred and fifty (250) block samples were collected. In the course of the survey, problems were encountered as some of the block moulders were suspicious and very unfriendly while some were very uncooperative and hostile.

From the various site surveys carried out within the territory, two types of portland cement were commonly used and these are Benue cement and Ashaka cement.

These brands of cement were sold at different prices. More expensive is the Benue cement which was sold for ₦430.00 per 50kg and Ashaka brand sold at ₦400.00 per 50kg bag. It was observed during the site survey that cement was not adequately stored as they are stacked on bare floor in a store.

Tap water was used in all the industries visited but this was not adequately stored as the water was stored in open underground tank made of concrete or sandcrete blocks and this got contaminated with time.

The block moulding machine generally used is the Rosacometta type which vibrates the block during filling and compaction. One block is produced at a time. The survey also revealed that the most commonly used sizes of sandcrete hollow blocks are the 230mm x 230mm x 460mm and 150mm x 230mm x 460mm. On request, the molders could produce the 100mm x 230mm x 460mm size of sandcrete hollow blocks.

In all the industries volume batching was employed. The sand was measured out by using wheel barrow and the mixing of cement and sand was done manually.

Blocks so produced from the mix are placed in the open air immediately after production subjecting them to harsh atmospheric conditions such as severe sunshine, rainfall and wind. The blocks are then cured with water once daily for a period of two to three days before selling. Sometimes due to delay in molding, the mixing water evaporates leaving the sandcrete mixture slightly stiff. To restore workability additional water is added.

The survey also revealed the calibre of people working in the block making industries. These include foreman, operator, mixer, driver, store man, cashier and unskilled laborers.

For identification purpose, the chosen industries are designated as A, B, C, D, and E.

2.19 INDUSTRY A

Industry A represented a block making industry located in Karmo town which is North- East of Garki. This industry has been in existence for five years now and has ever been producing sandcrete blocks consistently.

It was observed that the sand used here was from River Mpape. Two types of block sizes of 230mm x 230mm x 460 and 150mm x 230mm x460 are produced by this industry. The brands of Portland cement used by the

company are the Benue cement and Ashaka cement. These were stacked on bare floor made of cement screed. Water used here was pipe borne water which was stored in open tank and got contaminated with time.

In this industry, a mix of one part of cement to ten parts of sand (1:10) by volume was mostly used. Water was then added until a reasonable consistency was achieved by using manual mixing. Daily, about one thousand two hundred sandcrete blocks of size 230mm x230 x460mm were produced. Blocks produced were then cured for three (3) days by spraying water twice a day. Due to inadequate space, the cured blocks were then stacked above one another five blocks high. The type of machine used for the production of the sandcrete blocks was the vibroblock Rosacometta type. On employment in the block industry are ten (10) workers comprising the foreman, two operators, two mixers, one driver and four unskilled laborers. The hollow sandcrete blocks were sold at the rate of twenty five naira per block and the cost of transportation, loading and off loading was five naira per block.

2.20 INDUSTRY B

This industry B denotes a block making industry located in Kuje town which is about forty (forty) kilometers from Garki, the city centre. Two types of hollow sandcrete blocks are produced by this industry: 150mm x 230mm x 460mm and 230mm x 230mm x 460mm. The survey carried out indicated that the brands of ordinary Portland cement used were Benue cement and

Ashaka cement. These were stacked on bare floor in a store.

For the production of sandcrete blocks, a mix of one part of cement to twelve parts of sand (1:12) by volume was used. Water used is pipe borne which is stored in underground tanks.

On the average, about one thousand three hundred blocks were produced daily using the vibroblock Rosacometta machine. Source of sand was from a pit.

Curing of blocks was done by spraying water twice a day for three days. The cured blocks were then stacked to make space for more blocks to be produced.

The blocks were sold for twenty six naira fifty kobo each. The cost of transportation, loading and off loading per block was six naira.

On employment of the company were ten (10) workers comprising two operators, three mixers, and five unskilled laborers.

2.21 INDUSTRY C

The sand in this industry was obtained from a pit outside the town. This industry is located in Gwagwalada in the center of the Federal Territory and about forty five kilometers from Garki, the city center.

The types of sandcrete hollow blocks of sizes 230mm x 230mm x 460mm and 150mm x 230mm x 460mm were produced by this company. The cement used was from Benue cement company.

A mix of one part of cement to ten parts of sand (1:10) by volume was used. Over nine hundred blocks were produced daily. The blocks were cured for three days by spraying water once daily. The blocks were stacked five blocks high.

The blocks were sold at twenty four naira each. The cost of transportation was seven naira each.

On employment in the block industry are seven workers comprising one foreman, one operator, three mixers and two unskilled laborers.

2.22 INDUSTRY D

This industry is located in Abaji. Abaji is a town located in the West of the Federal Capital Territory, Abuja, and is about 100 kilometers from Garki the city center. According to the manufacturers, the industry is about three years old and had seven workers. The workers are one foreman, one operator, one security man, one cashier, and three unskilled workers.

It was observed that the types of blocks produced by this industry were 150mm x 230mm x 460mm and 230mm x 230mm x 460mm. The brand of cement used was Ashaka. The source of water in the industry was pipe borne stored in an open tank made of sandcrete blocks.

The cement-sand ratio employed by the industry was found to be one part of cement to twelve parts of fine aggregate (1:12) by volume. Manual method of mixing constituent materials was employed by the industry.

The industry produced an average of nine hundred and fifty blocks per day. The mode of curing was by spraying water twice daily for three days. The blocks were sold at the rate of twenty four naira while the cost of transportation was ten naira per block.

2.23 INDUSTRY E

This is located in Nyanya. Nyanya is situated in the south east of the Federal Capital Territory and is about twenty kilometers from Garki, the city center. Fifty blocks samples were randomly selected from this industry and the sand used was gotten from river Ado in Plateau State.

The hollow sandcrete block sizes produced were 100mm x 230mm x 460mm, 150mm x 230mm x 460mm and 230mm x 230mm x 460mm and the cost of 230mm x 230mm x 460mm was twenty seven naira while the cost of transportation was four naira. The brand of cement used was Benue.

The mix was one part of cement to twelve parts of sand (1:12) by volume. One thousand, two hundred blocks were produced daily. The blocks were cured three days by spraying water twice daily. The industry made use of vibroblock Rosacometta type of block molding machine for its production of block.

On employment of the company are ten workers comprising one foreman, one operator, two mixers and six unskilled laborers.

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TABLE 6: SUMMARY OFSITE SURVEY

Industry	Size of Block Produced	Daily prod	Type of m/machine	No.of Employee	No.of Curing Days	Source of Sand	Souce of Water	Mix Ratio
A	150x230x460mm 230x230x460	1200	vibro block rosacometta type	10	3	River Mpape	Tap	1:10
B	150x230x460mm 230x230mm x460mm	1300	"	10	3	Pit	Tap1:10	
C	150 x230 x 460mm 230x230x 460mm	900	"	7	3	Pit	Tap	1:12
D	150x230x460mm 230x230x460mm	950	"	7	3	pit	Tap	1:12
E	100x230x460mm 150x230mmx460mm	1200	"	10	3	River Ado	Tap	1:12

KASHIM IBRAHIM LIBRARY

3.0 CHAPTER THREE

3.1 TEST RESULTS

As stated in the previous chapter, block samples totaling two hundred and fifty in number were collected from five chosen industries in the Federal Capital Territory, Abuja. In each industry, at least fifty (50) block samples were randomly chosen.

These industries were chosen from all the Area Councils with two (2) chosen from the municipal Area council. These locations were Nyanya and Karmo from Municipal Area council, Kuje in Kuje area council, Abaji in Abaji area council and Gwagwalada in Gwagwalada area council. These locations were designated as A, B, C, D and E respectively.

After the collection of the block samples, they were kept under cover in the concrete laboratory of Dantata and Sawoe construction company in Abjua to protect them from extreme whether conditions of temperature and wind before the commencement of laboratory tests.

The test conducted include dry development strength, wet development strength, wet compressive, drying shrinkage, density determination and dimensional measurements. These tests were carried out in accordance with the British standard /16/ and the Nigerian Industrial standard /22/

Silt content and sand classification tests were also performed on the sand samples collected from the various industries.

3.2 DRY DEVELOPMENT STRENGTH

Dry development strength test is used to determine when the strength of the sandcrete block is fully developed. In essence, the test is to ascertain when the sandcrete block is fully ready for use.

Before the tests were conducted, all the samples from the various industries were properly sorted out and marked for identification. The dry compressive strength was obtained by crushing the blocks at various ages to determine the maturing age. The blocks were tested between celotex materials so that it is not in direct contact with the platens of the machine. .Three blocks per age were crushed using the STRASSENTEST machine which has a capacity of 3,000KN. The ages considered were 1,2,7,14,21 and 28 days respectively. The average results for the industries A, B, C, D and E are shown in Tables 7 to 11 respectively. The raw data from which the results were extracted are shown in Appendices A1, A2, A3, A4 and A5.

TABLE 7: DRY DEVELOPMENT STRENGTH OF INDUSTRY A

DATE OF CASTING: 02-09-96

S/NO	AGE (DAYS)	DATE TESTED	LENGTH (mm)	BREADTH (mm)	HEIGHT (mm)	LOAD (KN)	STRENGTH (N/mm^2)
1	1	03-09-96	460	230	219	18.3	0.17
2	3	05-09-96	459	228	220	46.4	0.44
3	7	09-09-96	459	229	219	59.0	0.56
4	14	16-09-96	460	230	219	78.73	0.75
5	21	23-09-96	460	229	220	89.30	0.85
6	28	30-09-96	460	230	220	90.50	0.86

TABLE 8: DRY DEVELOPMENT STRENGTH OF INDUSTRY B

DATE OF CASTING: 03-06-96

S/NO	AGE (DAYS)	DATE TESTED	LENGTH (mm)	BREADTH (mm)	HEIGHT (mm)	LOAD (KN)	STRENGTH (N/mm^2)
1	1	04-06-96	460	229	220	14.33	0.14
2	3	06-06-96	459	230	220	59.83	0.57
3	7	10-06-96	460	230	221	66.60	0.63
4	14	17-06-96	459	229	220	84.43	0.80
5	21	24-06-96	460	230	221	84.03	0.79
6	28	01-07-96	460	230	221	85.23	0.81

TABLE 9: DRY DEVELOPMENT STRENGTH OF INDUSTRY C

DATE OF CASTING: 02-07-96

S/NO	AGE (DAYS)	DATE TESTED	LENGTH (mm)	BREADTH (mm)	HEIGHT (mm)	LOAD (KN)	STRENGTH (N/mm^2)
1	1	03-07-96	460	230	230	14.67	0.14
2	3	05-07-96	459	230	220	58.43	0.55
3	7	09-07-96	460	229	219	63.10	0.60
4	14	16-07-96	459	230	219	72.07	0.68
5	21	23-07-96	460	229	219	76.30	0.73
6	28	30-07-96	460	230	219	81.47	0.77

TABLE 12: COMBINED DRY DEVELOPMENT STRENGTH (N/mm^2)

AGE (DAYS)	INDUSTRY A	INDUSTRY B	INDUSTRY C	INDUSTRY D	INDUSTRY E
1	0.17	0.14	0.14	0.16	0.12
3	0.44	0.57	0.55	0.46	0.31
7	0.56	0.63	0.60	0.56	0.61
14	0.75	0.80	0.68	0.66	0.73
21	0.85	0.74	0.73	0.77	0.79
28	0.86	0.81	0.77	0.81	0.83

The raw data from which the results in the above tables were extracted are shown in Appendices A1 to A5.

3.3 WET DEVELOPMENT STRENGTH

This test was conducted after 28 days of age of the block samples. Randomly selected and properly marked block samples were soaked in water and crushed at the ages of 1, 3,7,14,21 and 28 days. Three sandcrete block samples per age for each industry were crushed. The average strength value at each age for industries A, B, C, D and E are as shown in Tables 13 to 17 respectively. All raw data are as shown in Appendices A6 to A10.

TABLE 12: **COMBINED DRY DEVELOPMENT STRENGTH (N/mm^2)**

AGE (DAYS)	INDUSTRY A	INDUSTRY B	INDUSTRY C	INDUSTRY D	INDUSTRY E
1	0.17	0.14	0.14	0.16	0.12
3	0.44	0.57	0.55	0.46	0.31
7	0.56	0.63	0.60	0.56	0.61
14	0.75	0.80	0.68	0.66	0.73
21	0.85	0.74	0.73	0.77	0.79
28	0.86	0.81	0.77	0.81	0.83

The raw data from which the results in the above tables were extracted are shown in Appendices A1 to A5.

3.3 WET DEVELOPMENT STRENGTH

This test was conducted after 28 days of age of the block samples. Randomly selected and properly marked block samples were soaked in water and crushed at the ages of 1, 3,7,14,21 and 28 days. Three sandcrete block samples per age for each industry were crushed. The average strength value at each age for industries A, B, C, D and E are as shown in Tables 13 to 17 respectively. All raw data are as shown in Appendices A6 to A10.

TABLE 13: WET DEVELOPMENT STRENGTH OF INDUSTRY A

DATE IMMERSED IN WATER: 01-10-96

S/NO	AGE (DAYS)	DATE TESTED	LENGTH (mm)	BREADTH (mm)	HEIGHT (mm)	LOAD (KN)	STRENGTH (N/mm^2)
1	1	02-10-96	460	230	221	33.53	0.32
2	3	04-10-96	460	230	220	52.00	0.49
3	7	08-10-96	459	229	221	52.43	0.50
4	14	15-10-96	460	230	221	60.10	0.57
5	21	22-10-96	461	230	221	62.67	0.59
6	28	29-10-96	460	230	220	74.27	0.70

TABLE 14: WET DEVELOPMENT STRENGTH OF INDUSTRY B

DATE IMMERSED IN WATER: 02-7-96

S/NO	AGE (DAYS)	DATE TESTED	LENGTH (mm)	BREADTH (mm)	HEIGHT (mm)	LOAD (KN)	STRENGTH (N/mm^2)
1	1	03-07-96	461	230	220	32.90	0.31
2	3	05-07-96	460	230	221	45.40	0.43
3	7	09-07-96	460	230	220	56.97	0.54
4	14	16-07-96	460	230	220	46.87	0.44
5	21	23-07-96	460	229	222	65.07	0.62
6	28	30-07-96	460	230	220	72.13	0.68

TABLE 15: WET DEVELOPMENT STRENGTH OF INDUSTRY C

DATE IMMERSED IN WATER: 31-07-96

S/NO	AGE (DAYS)	DATE TESTED	LENGTH (mm)	BREADTH (mm)	HEIGHT (mm)	LOAD (KN)	STRENGTH (N/mm^2)
1	1	01-08-96	460	230	220	29.37	0.28
2	3	03-08-96	460	230	221	44.93	0.42
3	7	07-08-96	460	229	220	48.23	0.46
4	14	14-08-96	459	230	221	62.77	0.59
5	21	21-08-96	460	229	220	70.73	0.67
6	28	28-08-96	460	230	220	63.03	0.60

TABLE 16: WET DEVELOPMENT STRENGTH OF INDUSTRY D

DATE IMMERSED IN WATER: 01-10-96

S/NO	AGE (DAYS)	DATE TESTED	LENGTH (mm)	BREADTH (mm)	HEIGHT (mm)	LOAD (KN)	STRENGTH (N/mm^2)
1	1	02-10-96	460	229	220	39.53	0.39
2	3	04-10-96	460	229	220	45.90	0.43
3	7	08-10-96	460	229	220	52.53	0.50
4	14	15-10-96	460	229	221	53.13	0.50
5	21	22-10-96	460	229	220	61.67	0.58
6	28	29-10-96	459	229	220	66.73	0.63

TABLE 17: WET DEVELOPMENT STRENGTH OF INDUSTRY E

DATE IMMERSED IN WATER: 19-11-96

S/NO	AGE (DAYS)	DATE TESTED	LENGTH (mm)	BREADTH (mm)	HEIGHT (mm)	LOAD (KN)	STRENGTH (N/mm^2)
1	1	20-11-96	462	229	220	32.93	0.31
2	3	22-11-96	460	230	220	44.83	0.42
3	7	27-11-96	460	228	220	45.13	0.43
4	14	04-12-96	461	229	221	49.43	0.47
5	21	11-12-96	461	229	220	56.77	0.54
6	28	18-12-96	460	229	221	63.77	0.61

TABLE 18: COMBINED WET DEVELOPMENT STRENGTH (N/mm^2)

AGE (DAYS)	INDUSTRY A	INDUSTRY B	INDUSTRY C	INDUSTRY D	INDUSTRY E
1	0.32	0.31	0.28	0.39	0.31
3	0.49	0.43	0.42	0.43	0.42
7	0.50	0.54	0.46	0.50	0.43
14	0.57	0.44	0.59	0.50	0.47
21	0.59	0.62	0.67	0.58	0.54
28	0.70	0.68	0.60	0.63	0.61

The raw data results from which the above tables were extracted are shown in Appendices A6 to A10.

3.4 WET COMPRESSIVE STRENGTH

This test is normally conducted to determination the worst condition the sandcrete blocks can be subjected. This test is normally carried out after 28 days age of the block samples.

Ten block samples were randomly selected and measured. They were then immersed in water and allowed to drain under damp sack material before bedding on both faces using a mortar of one part by weight of cement to one part by weight of sand (1:1). After bedding, the sandcrete block samples were then immersed in water. Mortar cubes were also made out of the mortar mix used for bedding, these were also immersed in water.

When the mortar cube had attained the minimum required strength, the compressive strength of each block sample was then determined. The blocks samples were soaked for seven days prior to crushing. The strength indicated against each age is the average strength of three cubes for each industry.

The wet compressive strength test results are shown in Tables 24 to 28 while the mortar cube results are shown in Tables 19 to 23.

TABLE 19: MORTAR CUBES STRENGTH OF INDUSTRY A

DATE IMMERSED IN WATER: 01-10-96

AREA OF CUBE: (70X70)mm^2

S/NO	DATE TESTED	AGE OF CURING (DAYS)	FAILURE LOAD (KN)	AVERAGE STRENGTH N/mm^2)
1	02-10-96	1	19.60	4.00
2	04-10-96	3	87.22	17.80
3	08-10-96	7	146.09	29.81

TABLE 20: MORTAR CUBES STRENGTH OF INDUSTRY B

DATE IMMERSED IN WATER: 02-07-96

AREA OF CUBE : (70X70)mm^2

S/NO	DATE TESTED	AGE OF CURING (DAYS)	FAILURE LOAD (KN)	AVERAGE STRENGTH N/mm^2)
1	03-07-96	1	19.55	3.99
2	05-07-96	3	87.17	17.79
3	09-07-96	7	146.13	30.23

TABLE 21: MORTAR CUBES STRENGTH OF INDUSTRY C

DATE IMMERSED IN WATER: 31-07-96

AREA OF CUBE : (70X70)mm^2

S/NO	DATE TESTED	AGE OF CURING (DAYS)	FAILURE LOAD (KN)	AVERAGE STRENGTH N/mm^2)
1	01-08-96	1	19.70	4.02
2	03-08-96	3	89.28	18.22
3	07-08-96	7	151.11	30.67

TABLE 22: MORTAR CUBES STRENGTH OF INDUSTRY D

DATE IMMERSED IN WATER: 01-10-96

AREA OF CUBE : (70X70)mm^2

S/NO	DATE TESTED	AGE OF CURING (DAYS)	FAILURE LOAD (KN)	AVERAGE STRENGTH N/mm^2)
1	02-10-96	1	19.80	4.04
2	04-10-96	3	93.69	19.12
3	08-10-96	7	151.11	30.84

TABLE 23: MORTAR CUBES STRENGTH OF INDUSTRY E

DATE IMMERSED IN WATER: 19-11-96

AREA OF CUBE : (70X70)mm^2

S/NO	DATE TESTED	AGE OF CURING (DAYS)	FAILURE LOAD (KN)	AVERAGE STRENGTH N/mm^2)
1	20-11-96	1	19.11	3.90
2	22-11-96	3	88.40	18.04
3	26-11-96	7	146.94	30.60

TABLE 24: WET COMPRESSIVE STRENGTH OF INDUSTRY A

DATE IMMERSED IN WATER: 01 -10-96

DATE TESTED: 08-10-96

NO. OF DAYS SOAKED: 7 DAYS

AGE: 35 DAYS

S/NO	SAMPLE NO.	LENGTH (mm)	BREADTH (mm)	HEIGHT (mm)	FAILURE LOAD (KN)	STRENGTH (N/mm^2)
1	A1/08/10/ABJ	461	230	229	46.10	0.43
2	A2/08/10/ABJ	460	230	230	42.20	0.40
3	A3/08/10/ABJ	460	228	229	53.60	0.51
4	A4/08/10/ABJ	459	230	298	60.00	0.57
5	A5/08/10/ABJ	461	239	230	48.40	0.46
6	A6/08/10/ABJ	460	231	229	52.20	0.49
7	A7/08/10/ABJ	460	229	230	49.50	0.47
8	A8/08/10/ABJ	459	230	230	48.00	0.45
9	A9/08/10/ABJ	460	230	230	56.20	0.53
10	A10/08/10/ABJ	460	229	230	57.30	0.54

AVERAGE STRENGTH = $0.49N/mm^2$

STANDARD DEVIATION = $0.05N/mm^2$

COEFFICIENT OF VARIATION = 10.86%

TABLE 25: WET COMPRESSIVE STRENGTH OF INDUSTRY B

DATE IMMERSED IN WATER: 02 -07-96

DATE TESTED: 09-07-96

NO. OF DAYS SOAKED: 7 DAYS

AGE: 35 DAYS

S/NO	SAMPLE NO.	LENGTH (mm)	BREADTH (mm)	HEIGHT (mm)	FAILURE LOAD (KN)	STRENGTH (N/mm^2)
1	B1/09/07/AB	460	230	229	46.20	0.44
2	B2/09/07/AB	461	229	230	42.70	0.40
3	B3/09/07/AB	460	230	230	44.70	0.40
4	B4/09/07/AB	459	230	229	48.80	0.46
5	B5/09/07/AB	459	221	228	56.40	0.54
6	B6/09/07/AB	460	231	230	58.00	0.55
7	B7/09/07/AB	461	230	229	40.90	0.39
8	B8/09/07/AB	460	230	230	43.00	0.41
9	B9/09/07/AB	460	229	230	60.10	0.57
10	B10/09/07/AB	460	230	230	48.20	0.4

AVERAGE STRENGTH = $0.46N/mm^2$

STANDARD DEVIATION = $0.06N/mm^2$

COEFFICIENT OF VARIATION = 13.04%

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TABLE 26: **WET COMPRESSIVE STRENGTH OF INDUSTRY C**

DATE IMMERSED IN WATER: **31 -07-96**

DATE TESTED: **07-08-96**

NO. OF DAYS SOAKED: **7 DAYS**

AGE: **35 DAYS**

S/NO	SAMPLE NO.	LENGTH (mm)	BREADTH (mm)	HEIGHT (mm)	FAILURE LOAD (KN)	STRENGTH (N/mm^2)
1	C1/07/08/KJ	460	230	231	49.10	0.46
2	C2/07/08/KJ	461	230	230	53.40	0.50
3	C3/07/08/KJ	460	230	230	52.30	0.49
4	C4/07/08/KJ	460	230	230	38.80	0.37
5	C5/07/08/KJ	459	230	229	56.00	0.53
6	C6/07/08/KJ	460	230	231	42.30	0.40
7	C7/07/08/KJ	459	229	231	48.00	0.47
8	C8/07/08/KJ	460	229	230	43.00	0.41
9	C9/07/08/KJ	460	228	230	44.20	0.42
10	C10/07/08/KJ	460	230	230	54.40	0.51

AVERAGE STRENGTH = $0.46N/mm^2$

STANDARD DEVIATION = $0.05N/mm^2$

COEFFICIENT OF VARIATION = 10.86%

TABLE 27: **WET COMPRESSIVE STRENGTH OF INDUSTRY D**

DATE IMMERSED IN WATER: **01 -10-96**

DATE TESTED: **08-10-96**

NO. OF DAYS SOAKED: **7 DAYS**

AGE: **35 DAYS**

S/NO	SAMPLE NO.	LENGTH (mm)	BREADTH (mm)	HEIGHT (mm)	FAILURE LOAD (KN)	STRENGTH (N/mm^2)
1	D1/08/10/KJ	459	230	231	48.80	0.46
2	D2/08/10/KJ	460	230	230	47.10	0.45
3	D3/08/10/KJ	460	229	230	46.00	0.44
4	D4/08/10/KJ	460	229	228	44.20	0.42
5	D5/08/10/KJ	459	231	229	53.20	0.50
6	D6/08/10/KJ	461	230	229	51.30	0.48
7	D7/08/10/KJ	459	230	230	50.60	0.48
8	D8/08/10/KJ	461	229	231	49.80	0.47
9	D9/08/10/KJ	460	229	229	45.80	0.43
10	D10/08/10/KJ	460	231	230	53.70	0.51

AVERAGE STRENGTH = $0.46N/mm^2$

STANDARD DEVIATION = $0.04N/mm^2$

COEFFICIENT OF VARIATION = 8.33%

TABLE 28: **WET COMPRESSIVE STRENGTH OF INDUSTRY E**

DATE IMMERSED IN WATER: **19 -11-96**

DATE TESTED: **26-11-96**

NO. OF DAYS SOAKED: **7 DAYS**

AGE: **35 DAYS**

S/NO	SAMPLE NO.	LENGTH (mm)	BREADTH (mm)	HEIGHT (mm)	FAILURE LOAD (KN)	STRENGTH (N/mm^2)
1	E1/26/11/ABJ	461	228	220	43.40	0.41
2	E2/26/11/ABJ	460	230	220	46.60	0.44
3	E3/26/11/ABJ	463	230	221	45.10	0.42
4	E4/26/11/ABJ	462	229	220	50.50	0.48
5	E5/26/11/ABJ	460	230	220	45.00	0.51
6	E6/26/11/ABJ	460	228	229	46.20	0.44
7	E7/26/11/ABJ	460	230	220	49.70	0.49
8	E8/26/11/ABJ	460	229	221	40.90	0.39
9	E9/26/11/ABJ	462	230	220	49.00	0.46
10	E10/26/11/ABJ	463	230	220	42.00	0.39

AVERAGE STRENGTH = 0.44N/mm²

STANDARD DEVIATION = 0.03N/mm²

COEFFICIENT OF VARIATION = 6.82%

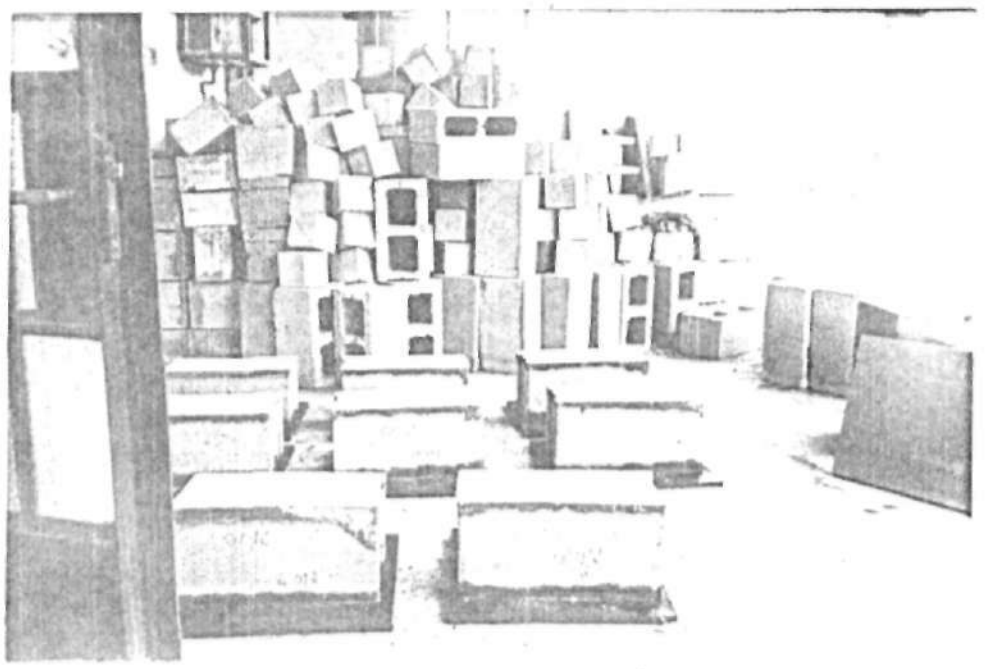


PLATE I: BEDDED BLOCK SAMPLES READY FOR TESTING

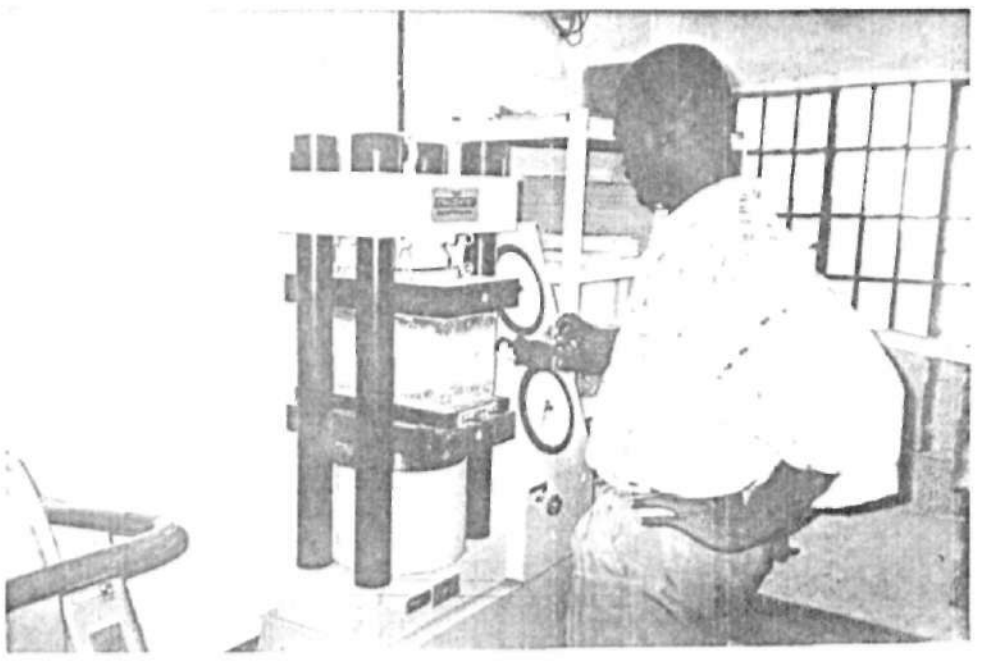


PLATE II: USE OF STRASSENTEST MACHINE TO CRUSH BLOCK SAMPLES

3.5 DRY SHRINKAGE

This test was carried out in accordance with Appendix E of the British standard 2028- specification for precast concrete blocks. The results of the tests are shown below.

TABLES 29: DRY SHRINKAGE FOR INDUSTRY A

S/NO	WET LENGTH (mm)	DRY LENGTH (mm)	AVERAGE WET LENGTH (mm)	AVERAGE DRY LENGTH (mm)	DRYING SHRINKAGE (%)
1	150.06	149.99			
2	150.04	149.98			
3	150.01	149.97	150.04	149.98	0.04

TABLES 30: DRY SHRINKAGE FOR INDUSTRY B

S/NO	WET LENGTH (mm)	DRY LENGTH (mm)	AVERAGE WET LENGTH (mm)	AVERAGE DRY LENGTH (mm)	DRYING SHRINKAGE (%)
1	150.01	149.99			
2	150.03	150.01			
3	150.05	150.02	150.03	150.00	0.02

TABLES 31: DRY SHRINKAGE FOR INDUSTRY C

S/NO	WET LENGTH (mm)	DRY LENGTH (mm)	AVERAGE WET LENGTH (mm)	AVERAGE DRY LENGTH (mm)	DRYING SHRINKAGE (%)
1	150.03	149.99			
2	150.02	149.98			
3	150.05	150.01	150.03	149.99	0.03

TABLES 32: DRY SHRINKAGE FOR INDUSTRY D

S/NO	WET LENGTH (mm)	DRY LENGTH (mm)	AVERAGE WET LENGTH (mm)	AVERAGE DRY LENGTH (mm)	DRYING SHRINKAGE (%)
1	150.04	149.99			
2	150.06	150.02			
3	150.05	150.01	150.05	150.00	0.03

TABLES 33: DRY SHRINKAGE FOR INDUSTRY E

S/NO	WET LENGTH (mm)	DRY LENGTH (mm)	AVERAGE WET LENGTH (mm)	AVERAGE DRY LENGTH (mm)	DRYING SHRINKAGE (%)
1	150.05	150.00			
2	150.03	150.02			
3	150.06	150.01	150.05	150.00	0.03

3.6 WETTING EXPANSION

This test was carried out in accordance with Appendix E of the British standard 2028 - specification for precast concrete blocks. The results of the test are shown below.

TABLE 34: WETTING EXPANSION FOR INDUSTRY A

S/NO	WET LENGTH (mm)	DRY LENGTH (mm)	AVERAGE WET LENGTH (mm)	AVERAGE DRY LENGTH (mm)	WETTING EXPANSION (%)
1	149.99	150.08			
2	149.98	150.05			
3	159.97	150.03	149.98	150.06	0.05

TABLE 35: WETTING EXPANSION FOR INDUSTRY B

S/NO	WET LENGTH (mm)	DRY LENGTH (mm)	AVERAGE WET LENGTH (mm)	AVERAGE DRY LENGTH (mm)	WETTING EXPANSION (%)
1	149.99	150.03			
2	150.01	150.05			
3	150.02	150.07	150.00	150.05	0.03

TABLE 36: WETTING EXPANSION FOR INDUSTRY C

S/NO	WET LENGTH (mm)	DRY LENGTH (mm)	AVERAGE WET LENGTH (mm)	AVERAGE DRY LENGTH (mm)	WETTING EXPANSION (%)
1	149.99	150.07			
2	149.98	150.08			
3	150.01	150.09	149.99	150.08	0.06

TABLE 37: WETTING EXPANSION FOR INDUSTRY D

S/NO	WET LENGTH (mm)	DRY LENGTH (mm)	AVERAGE WET LENGTH (mm)	AVERAGE DRY LENGTH (mm)	WETTING EXPANSION (%)
1	149.99	150.07			
2	150.02	150.09			
3	150.01	150.09	150.01	150.08	0.05

TABLE 38: WETTING EXPANSION FOR INDUSTRY E

S/NO	WET LENGTH (mm)	DRY LENGTH (mm)	AVERAGE WET LENGTH (mm)	AVERAGE DRY LENGTH (mm)	WETTING EXPANSION (%)
1	150.00	150.08			
2	150.02	150.07			
3	150.01	150.08	150.01	150.08	0.05

3.7 DENSITY DETERMINATION

The density was determined in accordance with the specification for precast concrete blocks. (BS2028,1364) as contained in Appendix B.

TABLE 39: DENSITY DETERMINATION

INDUSTRY	DENSITY (kg/m^3)
A	1042
B	1060
C	948
D	1020
E	960

3.8 WATER ABSORPTION

This is known as the ratio of the increase in weight to the weight of the dry sample expressed as a percentage. The test was carried out in accordance with the British standard specification.

The raw data from which the table below was extracted are shown in Appendix A-21

TABLE 40: WATER ABSORPTION

INDUSTRY	WATER ABSORPTION (%)
A	7.42
B	6.84
C	13.80
D	8.60
E	12.48

3.9 SILT CONTENT

The sand samples collected from the five industries were tested for silt content. Sand which contains silt when rubbed between the fingers is soft, smooth and leaves stains on the finger as against clean sand which when compressed between the fingers is coarse.

The silt content test involved the preparation of one percent solution of common salt in water. About 50ml of this solution was placed in a 250ml measuring cylinder. The sand samples was gradually added until the level reached the 100ml mark and more salt solution was added until the total volume of the mixture in the cylinder was 150ml. Covering the cylinder with the palm of the hand, the mixture was vigorously shaken, the repeatedly turned upside down and then allowed to stand for three hours. The silt contained in the sand separated out and this was clearly seen as a layer of different color on top of the sand. The height from above the bottom of the cylinder to the silt surface was measured to be h1 and from the bottom of the cylinder to the sand surface was measured to be h2. Then, the silt content expressed as a percentage by volume of the sand content was calculatated as:

$$\text{silt content} = \frac{h1 - h2 \times 100\%}{h2}$$

The result of the silt content of sand for the different industries are as shown in table 41.

TABLE 41: RESULT OF SILT CONTENT

INDUSTRY	SILT CONTENT (%)
A	4.87
B	5.50
C	5.60
D	7.05
E	5.00

3.10 SIEVE ANALYSIS

Samples of sand used in the five chosen industries were collected and tested to determine their particle size distribution. The resluts are as shown in Tables 42,43,44,45 and 46. Comparison of the test results show that the sand fall parlty within the limits of zone 2 of the British standard 882 /4/.

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TABLE 42: SIEVE AN ANALYSIS OF INDUSTRY A

WEIGHT OF SAND SAMPLE: 1000g

B.S. SIEVE SIZE (mm)	WEIGHT RETAINED (g)	WEIGHT PASSING (g)	PERCENTAGE RETAINED (%)	CUMMULATIVE PERCENTAGE PASSING (%)	CUMMULATIVE PERCENTAGE RETAINED (%)
10.00	0	1000	0	100	0
5.00	0	1000	0	100	0
2.36	3.6	996.4	0.4	99.6	0.4
1.40	50.7	945.7	5.1	94.0	6.0
1.18	106.0	839.7	10.6	84.4	16.0
0.60	363.7	476.0	36.3	48.0	52.0
0.425	106.2	396.8	10.6	37.0	63.0
0.30	100.9	268.9	10.1	27.0	73.0
0.212	94.1	174.8	9.4	17.0	83.0
0.150	86.6	88.2	8.7	9.0	91.0
0.075	67.1	21.1	6.7	2.0	98.0
Receiver	18.2	-	1.87		-

TABLE 43: SIEVE AN ANALYSIS OF INDUSTRY B

WEIGHT OF SAND SAMPLE: 850g

B.S. SIEVE SIZE (mm)	WEIGHT RETAINED (g)	WEIGHT PASSING (g)	PERCENTAGE RETAINED (%)	CUMMULATIVE PERCENTAGE PASSING (%)	CUMMULATIVE PERCENTAGE RETAINED (%)
10.00	0	850	0	100	0
5.00	6.2	843.8	0.73	99	1
2.36	11.2	832.6	1.32	98	2
1.40	60.5	772.1	7.112	91	9
1.18	100.9	671.2	11.87	79	21
0.60	261.7	409.5	30.79	48	52
0.425	100.9	308.6	11.87	36	64
0.30	84.0	224.6	9.88	26	74
0.212	68.1	156.5	8.01	18	82
0.150	56.0	100.5	6.59	12	88
0.075	69.4	31.1	8.16	4	96
Receiver	28.3	-	3.33	-	-

TABLE 44: **SIEVE AN ANALYSIS OF INDUSTRY C**

WEIGHT OF SAND SAMPLE: 1000g

B.S. SIEVE SIZE (mm)	WEIGHT RETAINED (g)	WEIGHT PASSING (g)	PERCENTAGE RETAINED (%)	CUMMULATIVE PERCENTAGE PASSING (%)	CUMMULATIVE PERCENTAGE RETAINED (%)
10.00	0	1000	0	100	0
5.00	12.6	987.4	1.26	99	1
2.36	16.3	971.1	1.63	97	3
1.40	92.6	878.5	9.26	88	12
1.18	101.0	777.5	10.10	78	22
0.60	335.8	441.7	33.58	44	56
0.425	139.4	302.3	13.94	30	70
0.30	98.3	204	9.83	20	80
0.212	76.2	127.8	7.62	13	87
0.150	47.8	80.0	4.78	8	92
0.075	55.9	24.1	5.59	2	98
Receiver	19.9	-	1.99	-	-

TABLE 45: **SIEVE AN ANALYSIS OF INDUSTRY D**

WEIGHT OF SAND SAMPLE: 1200g

B.S. SIEVE SIZE (mm)	WEIGHT RETAINED (g)	WEIGHT PASSING (g)	PERCENTAGE RETAINED (%)	CUMMULATIVE PERCENTAGE PASSING (%)	CUMMULATIVE PERCENTAGE RETAINED (%)
10.00	0	1200	0	100	0
5.00	12.6	1187.4	1.05	99	1
2.36	16.2	1171.2	1.35	98	2
1.40	87.3	1083.9	7.28	90	10
1.18	120.1	963.8	10.01	80	20
0.60	380.6	583.2	31.72	49	51
0.425	160.4	422.8	13.37	35	65
0.30	126.7	296.1	10.56	25	75
0.212	90.8	205.3	7.57	18	82
0.150	76.7	128.6	6.39	11	89
0.075	100.4	28.2	8.37	2	98
Receiver	24.6	-	2.05	-	-

TABLE 46: **SIEVE AN ANALYSIS OF INDUSTRY E**

WEIGHT OF SAND SAMPLE: 1100g

B.S. SIEVE SIZE (mm)	WEIGHT RETAINED (g)	WEIGHT PASSING (g)	PERCENTAGE RETAINED (%)	CUMMULATIVE PERCENTAGE PASSING (%)	CUMMULATIVE PERCENTAGE RETAINED (%)
10.00	0	1100	0	100	0
5.00	0	1100	0	100	0
2.36	19.3	1080.7	1.75	98	2
1.40	88.9	991.8	8.08	90	10
1.18	170.6	821.8	15.51	75	25
0.60	357.3	464.5	32.48	42	58
0.425	147.2	317.3	13.38	19	71
0.30	90.5	226.8	8.23	11	79
0.212	73.1	153.7	6.65	14	86
0.150	59.0	94.7	5.36	9	91
0.075	58.7	36.0	5.33	3	97
Receiver	31.7	-	2.88	-	-

4.0 CHAPTER FOUR

4.1 ANALYSIS AND DISCUSSION OF RESULTS

Results of the various tests carried out were presented in chapter three. In this chapter , the results of the tests are analyzed so as to ascertain the quality of the hollow sandcrete blocks produced in the Federal Capital Territory, Abuja.

The results of the tests carried out on the sandcrete hollow block samples are discussed below.

4.2 STRENGTH

As earlier stated, the strength tests carried out include the dry development strength, wet development strength and the wet compressive strength.

4.2.1 DRY DEVELOPMENT STRENGTH

Figures 1-5 below show the dry development strength as tested for industries A, B, C, D and E respectively. It can be observed from the graphs that the moment when the cement paste has set, the blocks started gaining strength. The rate of gain of strength between 1 to 14 days was rapid. Progressively, it became slower in the following days indicating that hydration of cement is continuous but at a lower rate giving the curve a steady or fairly constant rate.

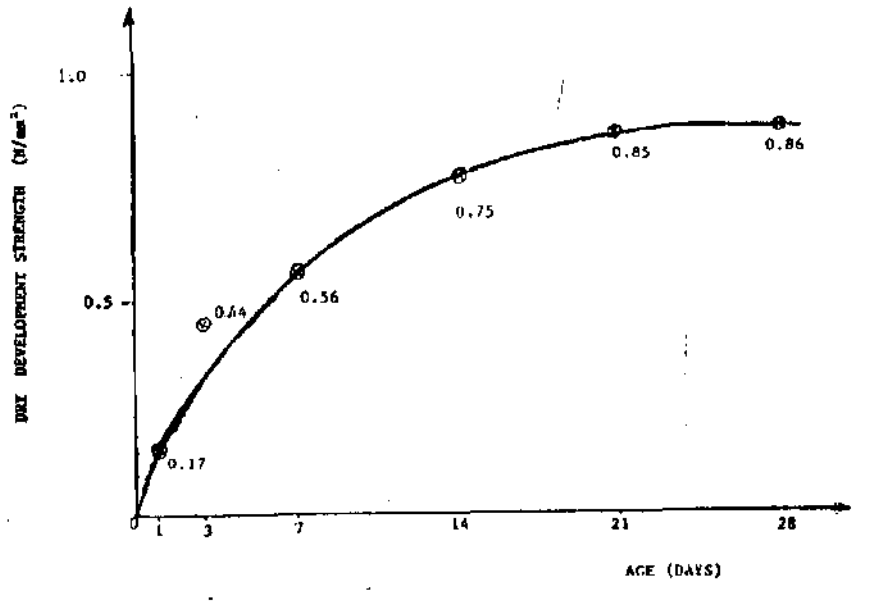


FIG. 1: DRY DEVELOPMENT STRENGTH FOR INDUSTRY A

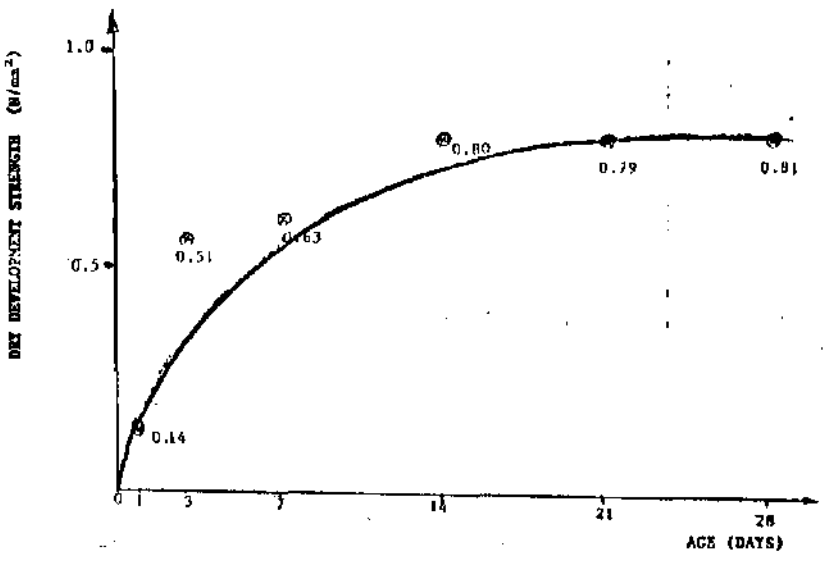


FIG. 2: DRY DEVELOPMENT STRENGTH FOR INDUSTRY B

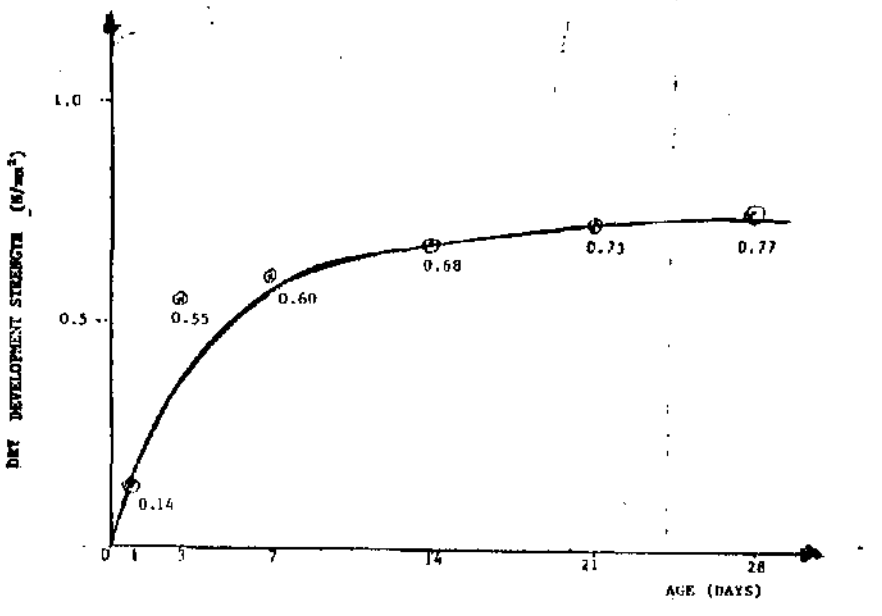


FIG. 3: DRY DEVELOPMENT STRENGTH FOR INDUSTRY C

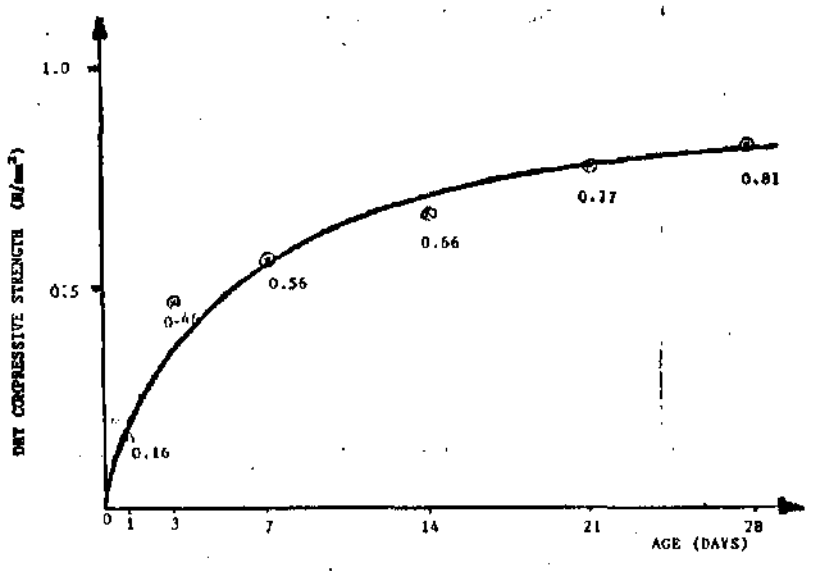


FIG. 4: DRY DEVELOPMENT STRENGTH FOR INDUSTRY D

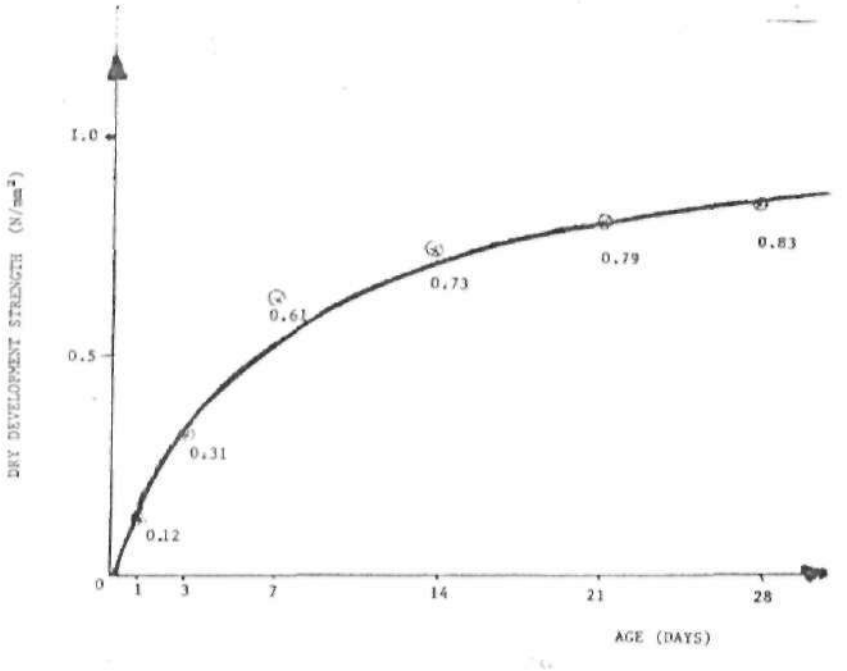


FIG. 5: DRY DEVELOPMENT STRENGTH FOR INDUSTRY E

The average strength at 28 -days are 0.86N/mm^2 , 0.81N/mm^2 , 0.77N/mm^2 , 0.81N/mm^2 and 0.83N/mm^2 for industries A, B, C, D and E respectively. Comparing the strength values obtained in the five industries with the specified value of 3.5N/mm^2 by the British standard /16/, these values are low.

4.2.2 WET DEVELOPMENT STRENGTH

The values of the wet development strength of industries A, B,C, D and E are as shown in figures 6,7,8,9 and 10 respectively.

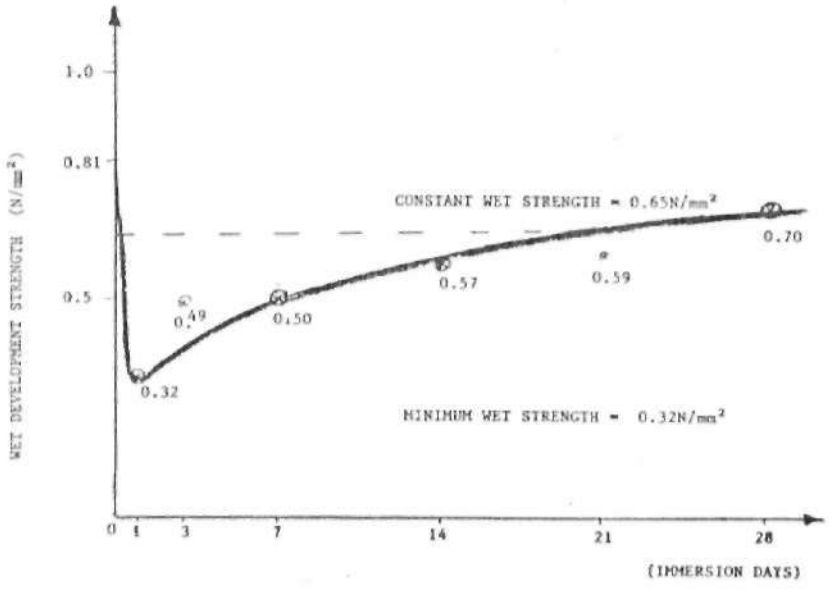


FIG. 6: WET DEVELOPMENT STRENGTH FOR INDUSTRY A

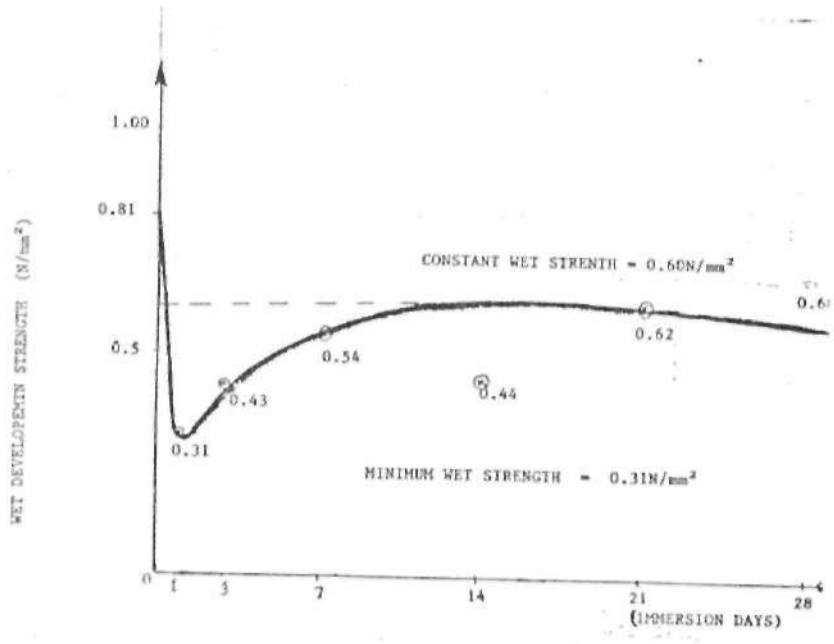


FIG. 7: WET EVELOPMENT STRENGTH FOR INDUSTRY B

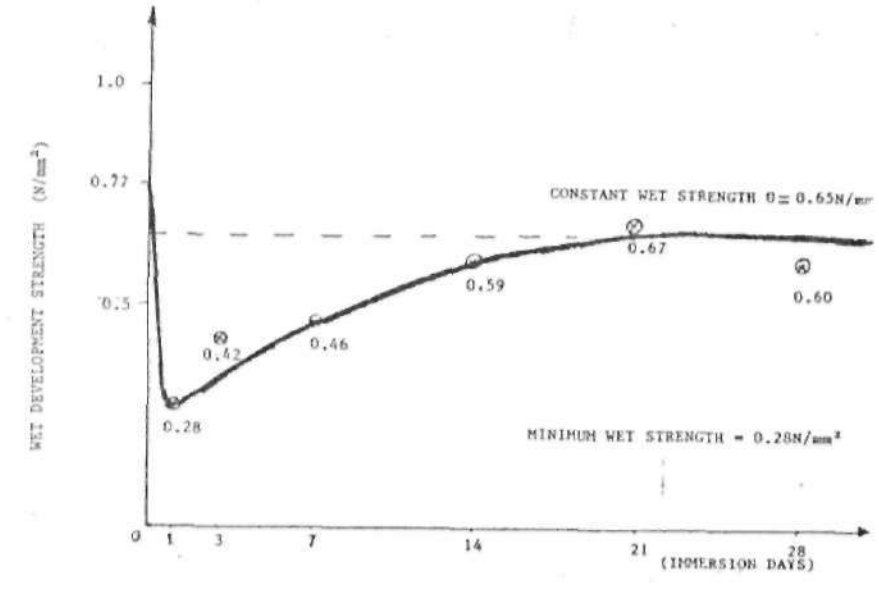


FIG. 8: WET DEVELOPMENT STRENGTH FOR INDUSTRY C

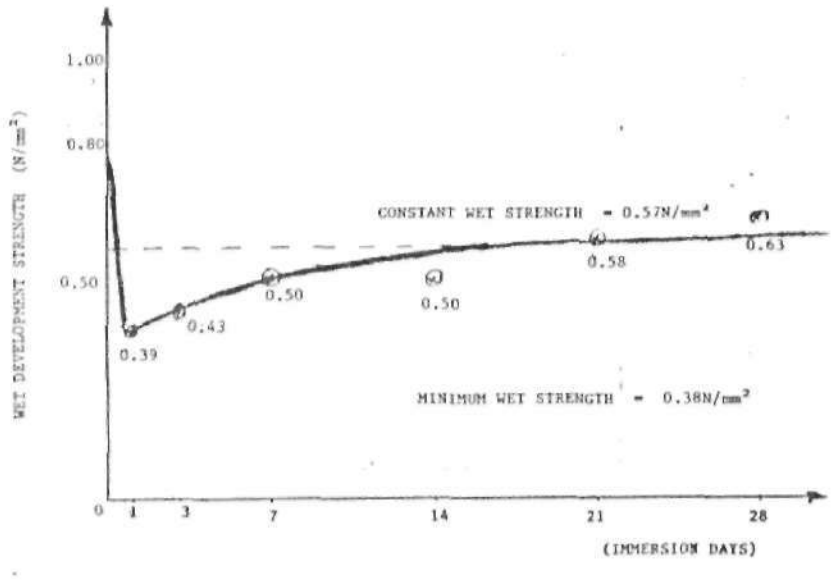


FIG. 9: WET DEVELOPMENT STRENGTH FOR INDUSTRY D

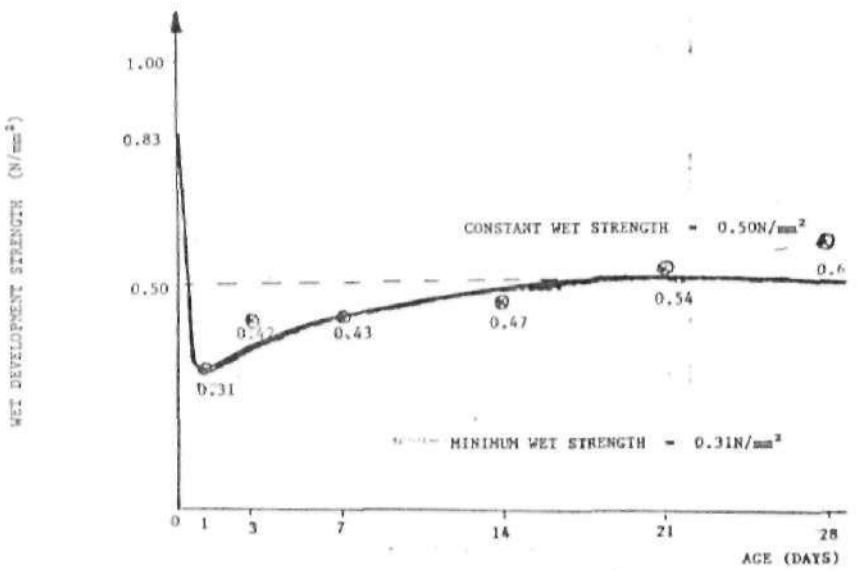


FIG. 10: WET DEVELOPMENT STRENGTH FOR INDUSTRY E

From the test results, the strength of the blocks dropped sharply after soaking block samples in water for 24 hours prior to testing. This gives the blocks the lowest values of 0.32N/mm^2 , 0.31N/mm^2 , 0.28N/mm^2 , 0.39N/mm^2 and 0.31N/mm^2 for industries A, B, C, D and E respectively. As

from the 3rd day, there was a gradual increase in strength as indicated in the graphs up to the 28th day: with the rate of increase diminishing with time. Thus, the values of the wet development strengths of the five industries are lower than the values of the dry development strengths. At 28 days of soaking, the average values of the wet development strengths are 0.70N/mm^2, 0.68N/mm^2, 0.60N/mm^2, 0.63N/mm^2 and 0.61N/mm^2 for industries A, B, C, D and E respectively. These values compared to 2.1N/mm^2 recommended by the Federal Ministry of work and Housing /6/ are low.

It was observed generally that there was a sharp drop in wet development strength before gain in strength in all the industries. This is because on soaking, the cement gel and silt in the sandcrete hollow blocks absorb water which occupies the voids within the blocks causing swelling . The water molecules absorbed act against the cohesive forces and tend to force the gel particles further apart, with resulting swelling pressure. Further more, surface tension of the gel is decreased by the absorption of water with further expansion taking place, hence, the drop in strength values. With time, absorbed water gets into the cement gel and hydration starts as a result of the presence of moisture giving rise to a steady increase in strength.

4.2.3 WET COMPRESSIVE STRENGTH

The value of the average wet compressive strength for ten blocks in each of the five industries are shown in table 47 below.

TABLE 47: WET COMPRESSIVE STRENGTH FOR AS ALL THE INDUSTRIES

INDUSTRY	A	B	C	D	E
STRENGTH (N/mm^2)	0.49	0.46	0.46	0.46	0.44

From table 47 above, the average wet compressive strength of industries A, B, C, D and E are $0.49N/mm^2$, $o.46N/mm^2$, $0.46N/mm^2$, $0.46N/mm^2$, and $0.44N/mm^2$ respectively. The British standard /16/ specified that the average wet compressive strength should be $3.5N/mm^2$ and the lowest individual block strength as $2.8N/mm^2$. The Federal Ministry of work /6/ recommended an average compressive strength of $2.1N/mm^2$ while the lowest compressive strength of an individual block should not be less than $1.7N/mm^2$. The Nigerian Industrial standard /22/ part two: 1974 specified an average strength of $3.45N/mm^2$. The average compressive strength of $0.49N/mm^2$, $0.46N/mm^2$, $0.46N/mm^2$ $0.46N/mm^2$ and $0.44N/mm^2$ of industries A, B, C, D and E are about 23%, 22%,22%,22% and 21% of the $2.1N/mm^2$ value recommended by the Federal Ministry of Works and Housing.

Table 48 below shows the average wet compressive strength of the five industries compared to the specified standards.

TABLE 48: COMPARED VALUES OF WET COMPRESSIVE STRENGTH IN PERCENTAGES

	INDUSTRY A (%)	INDUSTRY B (%)	INDUSTRY C (%)	INDUSTRY D (%)	INDUSTRY E (%)
B.S 2028	14.00	13.14	13.14	13.14	12.57
N.I.S II	14.20	13.33	13.33	13.33	12.75
F.M.W.&H	23.33	21.90	21.90	21.90	20.95

Generally, the coefficients of variation of the block samples from the five industries satisfied the 20% limit specified for concrete structure. The values of the coefficients of variation are 10.86%, 13.04%, 10.86%, 8.33%, and 6..8% for industries A, B, C, D and E, respectively. From these values, it can be seen that the manufacturing process employed by each industry is consistent and as such there is not much variance in the level of production.

4.2.4 RATIO OF WET TO DRY DEVELOPMENT STRENGTH

The ratio of wet development strength at various soaking ages after 28 days of age to the dry development strength at 28 days for the five industries is shown in Table 49 and presented in figures 11, 12, 13,14, and 15 for industries A, B, C, D, and E respectively.

TABLES 49: WET DEVELOPMENT STRENGTH TO DRY DEVELOPMENT STRENGTH RATIO IN PERCENTAGES

DAYS OF IMMERSION AFTER 28 DAYS	F_{WET}/F_{DRY} (28)				
	INDUSTRY A	INDUSTRY B	INDUSTRY C	INDUSTRY D	INDUSTRY E
0	100	100	100	100	100
1	37	38	36	48	37
3	57	53	55	53	51
7	58	67	60	62	52
14	66	54	77	62	57
21	69	77	87	72	65
28	81	84	78	78	73

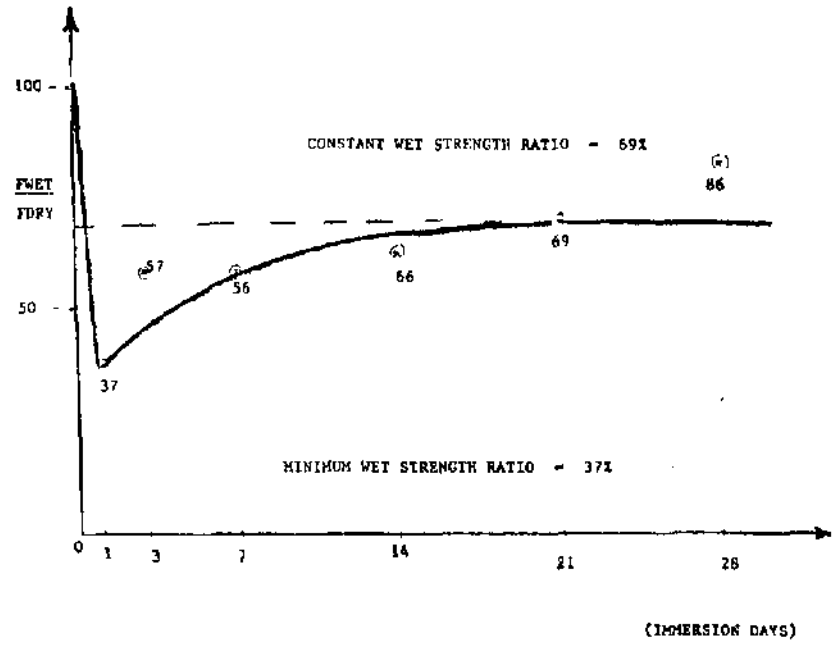


FIG. 11: FWET /FDRY RATIO IN PERCENTAGES FOR SAMPLE A

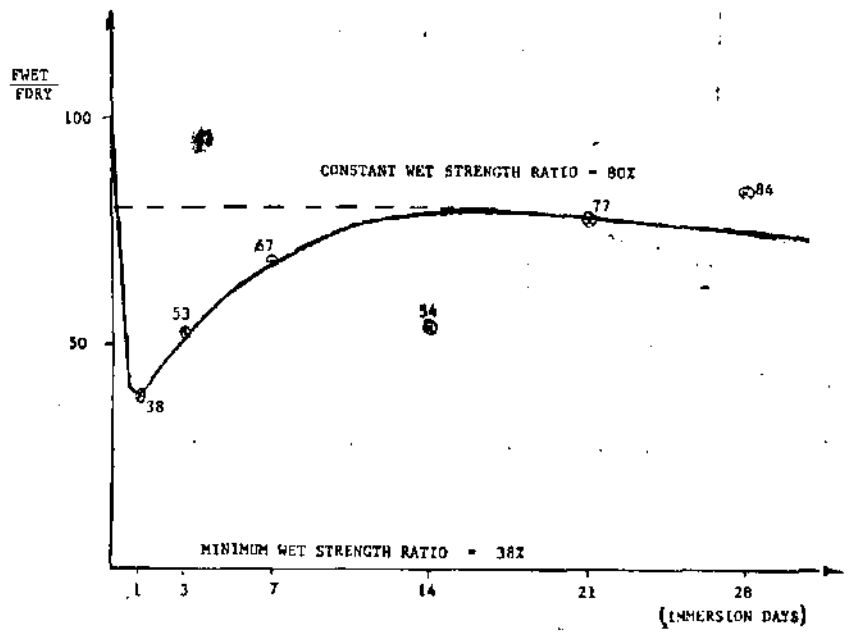


FIG. 12: FWET /FDRY RATIO IN PERCENTAGES FOR SAMPLE B

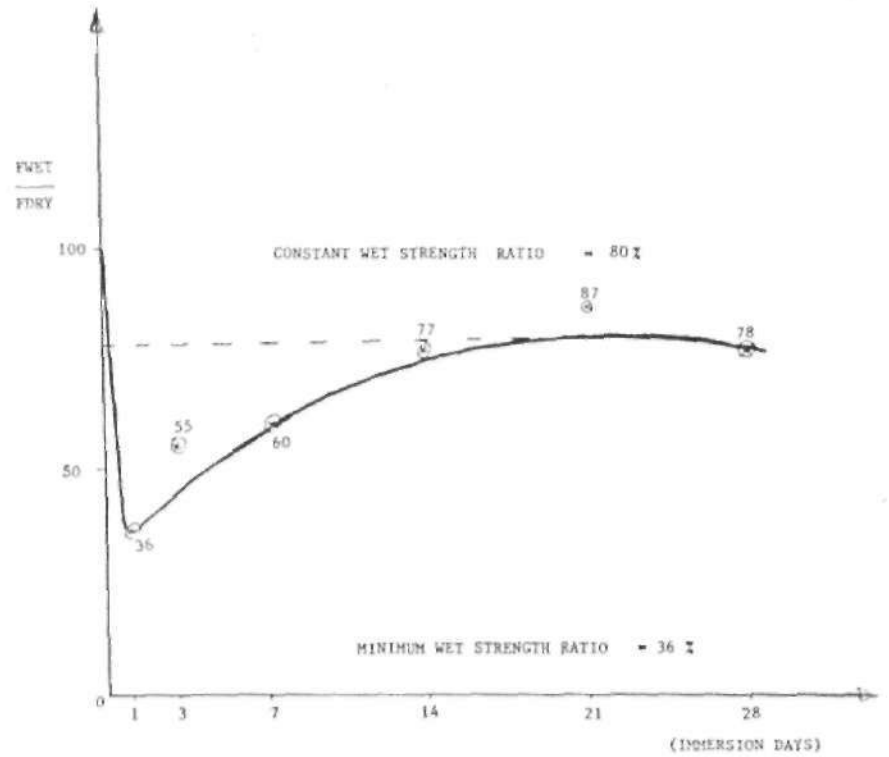


FIG. I3: FWET /FDRY RATIO IN PERCENTAGES FOR SAMPLE C

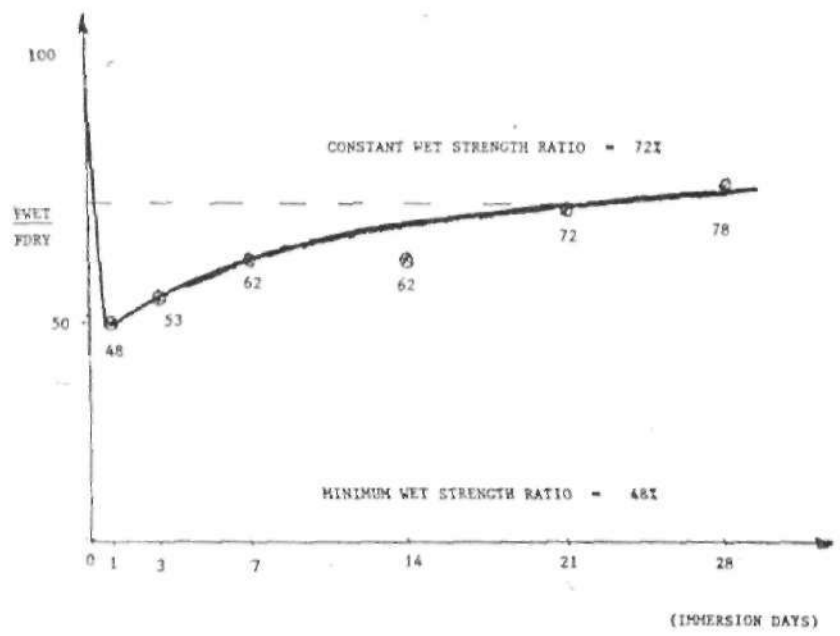


FIG. I4: FWET /FDRY RATIO IN PERCENTAGES FOR SAMPLE D

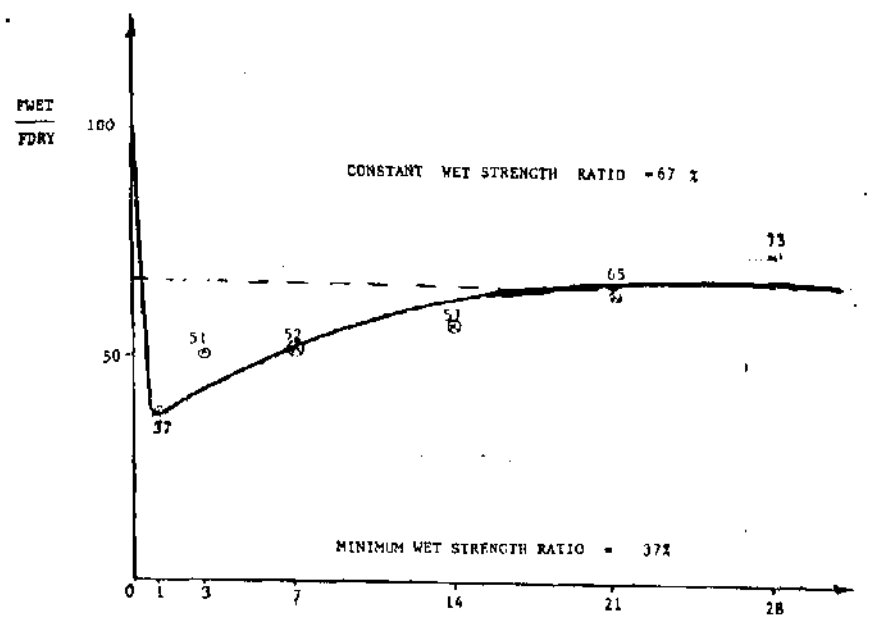


FIG. I5: FWET /FDRY RATIO IN PERCENTAGES FOR SAMPLE E

From the figures above, the wet development strengths of industries A, B, C, D and E dropped to 37%,38%, 36%, 48% and 37% respectively after 24 hours of soaking prior to testing. These gradually increased from 57%, 53%, 55%, 53% and 51% on the 3rd day to 86%,84%,78%, 73% and 73% on the 28th day for industries A, B, C,D and E respectively. The minimum wet strength ratios are 38% and 37% for industries B and E while the constant wet strength ratios are 69%,80% and 67% for industries A, C and D respectively. The industry with the minimum wet strength ratio is industry C.

Generally, the strength of the blocks produced in all the five industries is low. Various factors are responsible for these low strength values. These factors are presence of silt in sand, inadequate curing and compaction, non provision of adequate shade, and wrong proportioning materials.

Presence of silt in sand forms coating on the sand particles, thus,, weakening the bond between sand and cement. This would result in low strength.

From visual inspection of the sand used in industries A, and D, it was discovered that it contained deleterious materials such as leaves and roots of trees. On decomposition, these materials would leave voids in the sandcrete blocks leading to reduced strength.

While the Nigerian industrial standard /22/ recommends the mix of one part of cement to six parts of sand (1:6) by volume: up to eight parts of sand (1:8) as the proportioning for sandcrete hollow blocks, ratios of 1:10. 1:10 and 1:12 were used by industries A, C and E respectively. This grossly inadequate proportioning of sand and cement by all the industries also contributed to the l ow strength of the blocks because for a mix there is an upper limit for the sand content beyond which there would be insufficient cement paste to coat all the particles. As the sand content increases beyond this limit, the strength of the final product decreases.

Poor curing condition is another contributing factor to the low strength of the sandcrete blocks produced in all the industries. The blocks were cured by spraying water for three days as against the minimum of seven

days. The aim of curing is to keep the blocks saturated until the original water filled space in the fresh cement paste has been filled with the products of hydration. So, inadequate curing causes non -uniform development of cementations matrix, which not only decreased the strength but reduced durability, impermeability and abrasion resistance of the sandcrete blocks.

Exposure of the blocks to open air without covering affects the strength of the blocks adversely. This is because they are exposed to harsh conditions of temperature and wind which shortens the hydration process. This affects the strength as a result of high evaporation of mixing and curing water and early stiffening, which are accompanied by increased surface shrinkage and cracking of the sandcrete blocks.

Improper compaction of sandcrete blocks leads to voids in the final product. Ultimately, this will result in low density as experienced in all the industries. This improper compaction is as a result of irregular servicing of the blocks molding machines and fatigue experienced by operator of the machine because of long hours of working.

The addition of water to restore workability as a result of its fall due to loss of moisture during the delay in molding is also another factor responsible for the low strength values in all the industries. This is because water content greater than originally intended would result in reduction of strength and durability of the sandcrete block. This was observed on sites mentioned in chapter 3.

4.3 DENSITY

The average densities are 1042kg/m^3 , 1060kg/m^3 , 948kg/m^3 , 1020kg/m^3 and 960kg/m^3 for industries A, B, C , D and E respectively. The British standard 2028 /16/ specified that the block density of TYPE A blocks shall not be less than 1500kg/m^3 . These values are all below the recommended value. This is as a result of the presence of voids in the sandcrete blocks caused by non uniform compacting pressure resulting in more voids than necessary, thus, resulting in low density.

4.4 DRYING SHRINKAGE AND WETTING EXPANSION

The average values of drying shrinkage are 0.04%,0.02%,0.03%,0.03% and 0.03% for industries A, B, C, D. and E respectively. These values do not exceed the 0.05% specified for TYPE A blocks in the British standard specification 2028/16/

The wetting expansion average values of the sandcrete hollow blocks are 0.05%, 0.03%, 0.06%,0.05% and 0.05% for industries A, B, C, D. and E respectively. All these values conform with the British standard 2028/16/ specification of 0.07% as the maximum wetting expansion value for type A blocks. This shows that the blocks exhibit normal change in volume as their water content changes.

4.5 SAND

The results of the test for the particle size distribution for the five industries are shown in tables 42 -46 in chapter three. Figure 16-20 below show the graphs of the particle size distribution for industries A,B, C, D and E respectively. From the figures below, it can be observed that the sand used in all the industries fall within zone 2 of the British standard sieve sizes. Most of the sand particles fall within medium to coarse sand range.

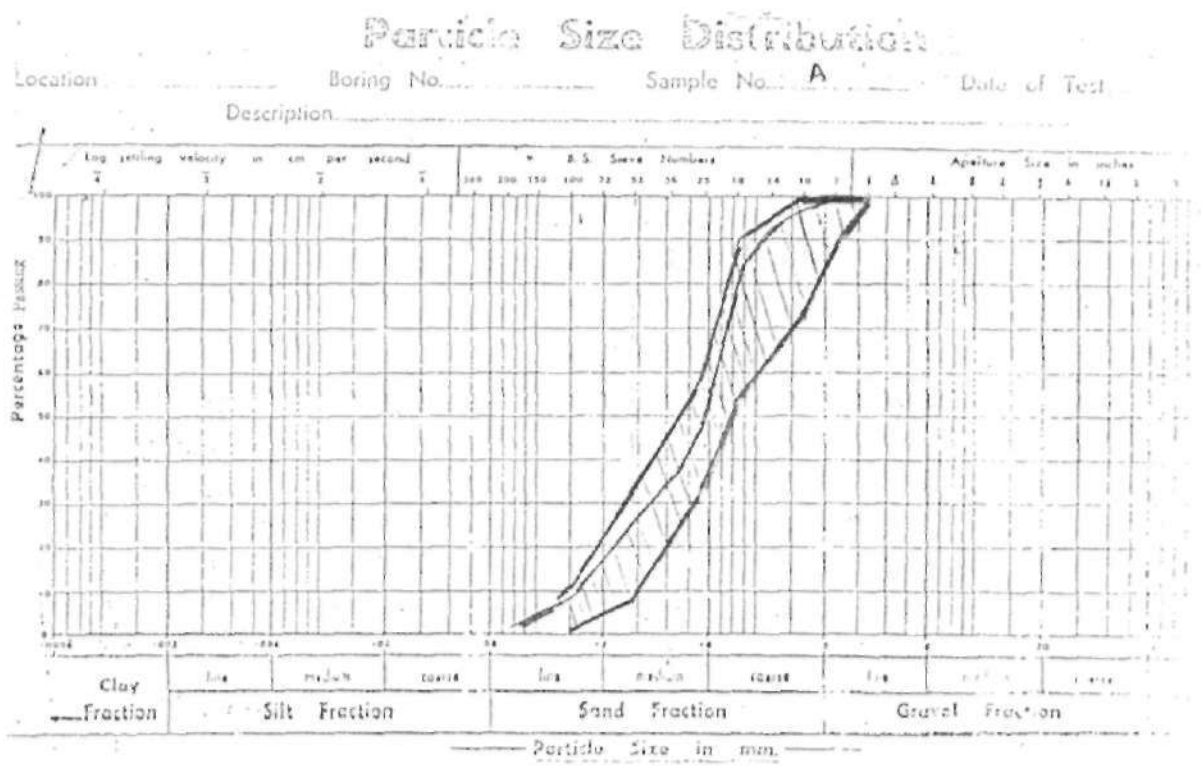


FIG. 16: PARTICLE SIZE DISTRIBUTION CURVE FOR SAMPLE A

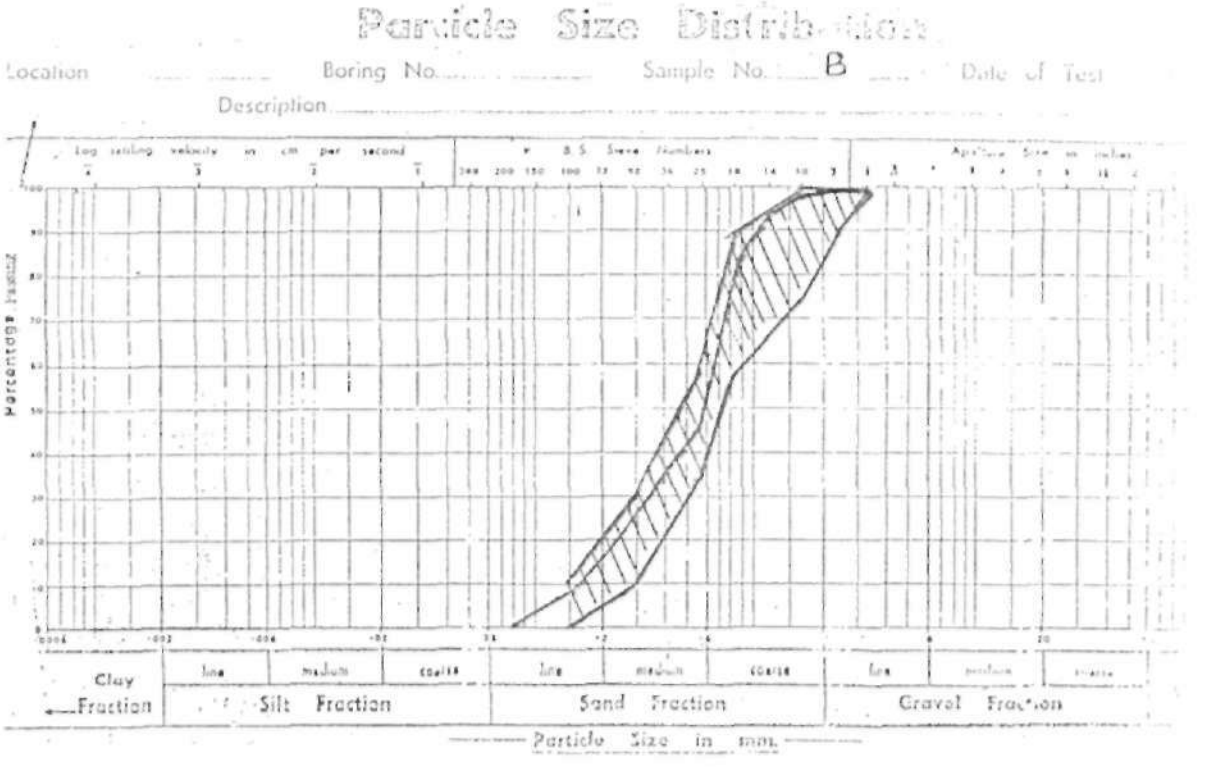


FIG. 17: PARTICLE SIZE DISTRIBUTION CURVE FOR SAMPLE B

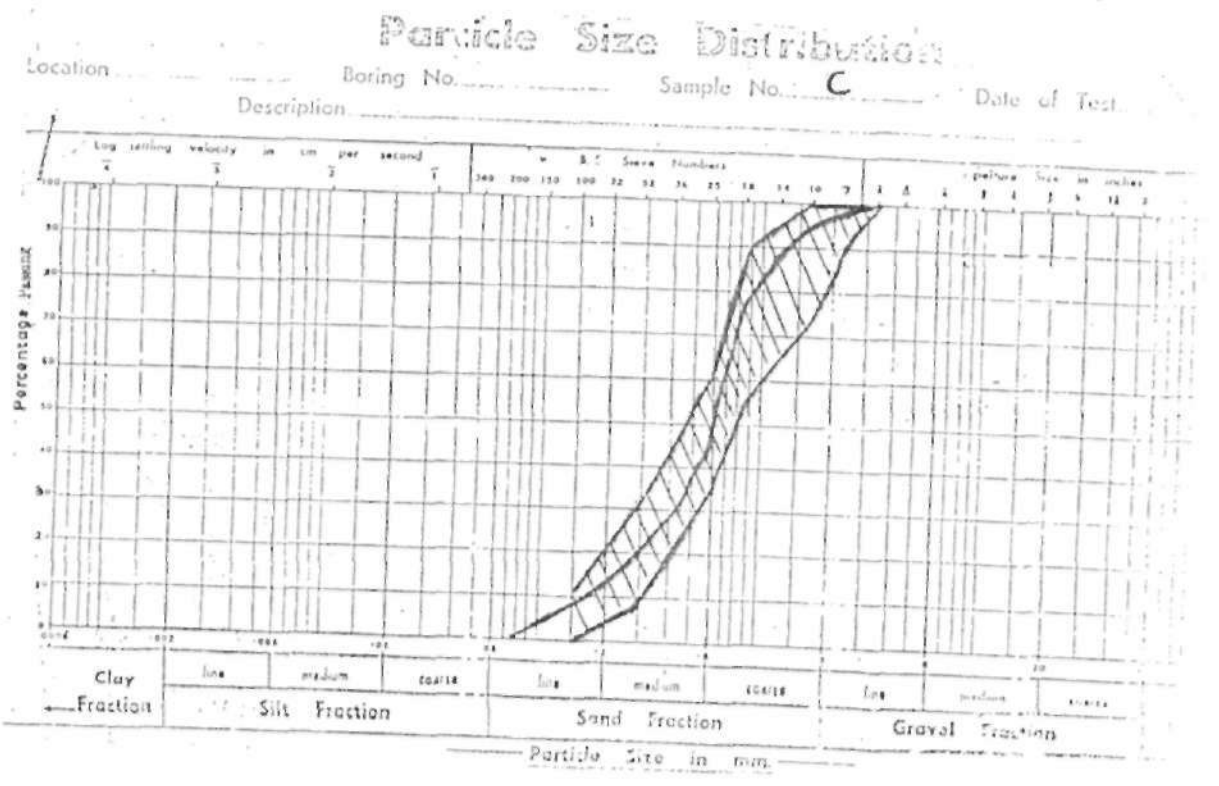


FIG. 18: PARTICLE SIZE DISTRIBUTION CURVE FOR SAMPLE C

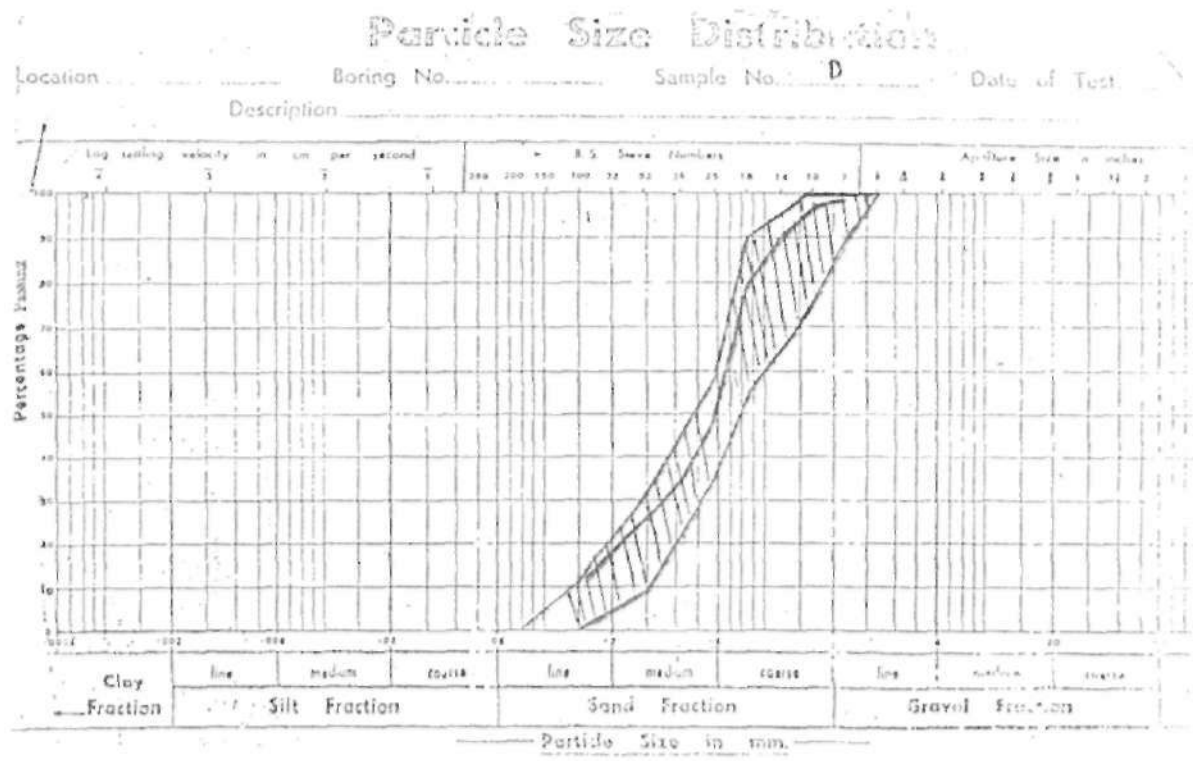


FIG. 19: PARTICLE SIZE DISTRIBUTION CURVE FOR SAMPLE D

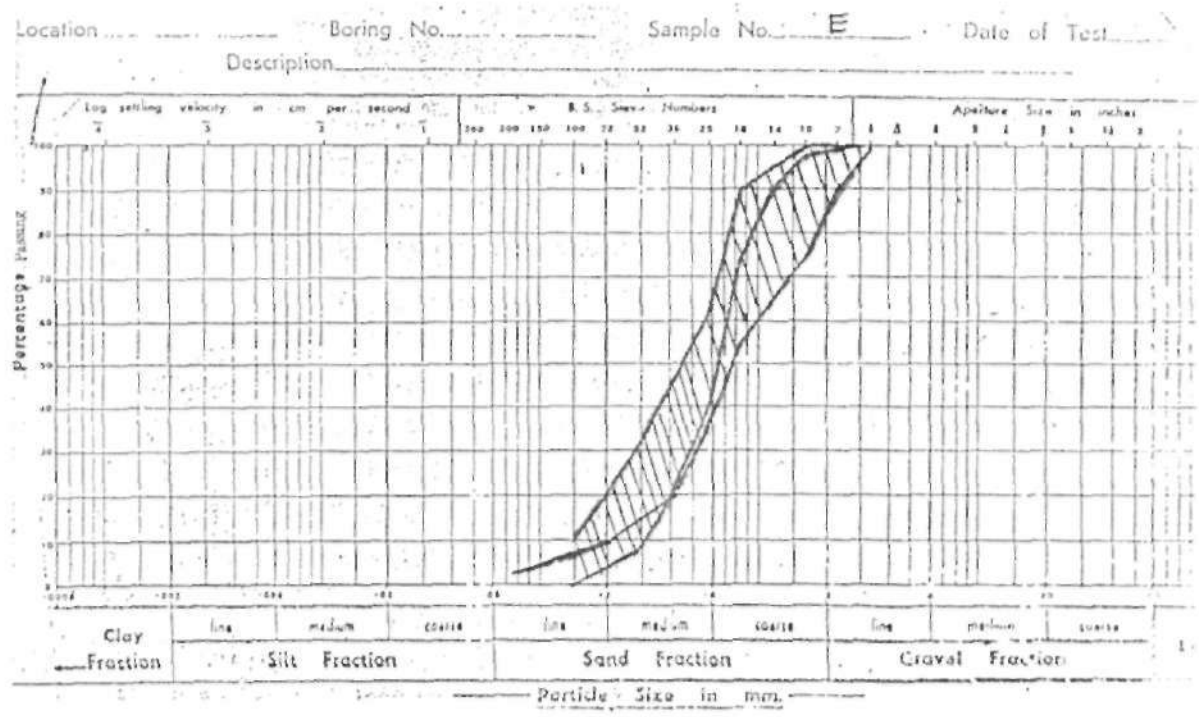


FIG. 20: PARTICLE SIZE DISTRIBUTION CURVE FOR SAMPLE E

The result of the silt content shown in table 42 of chapter three shows the silt content are 4.87%, 5.50%, 5.60%, 7.05% and 5.00% for industries A, B, C, D and E respectively. The Nigerian industrial standard /22/ specifies that the best sand for producing sandcrete blocks is that which falls within zones 1 and 2 of the British standard sieve sizes. It then implies that industries A, B, C, D and E comply with these requirement as they all fall within zone 2 of the B.S sieve sizes.

Industries A, B, C and E meet the silt content requirement as their silt content is less than 6% while industry D which has a silt content 7.05% does not meet the silt content requirement in the specification.

Although the various test results showed that the blocks produced from all the industries do not meet the required standard, industry A appears to have a relatively better strength result than industries B, C, D and E.

The comparison of dry and wet development strengths are shown in figures 21 and 22 respectively.

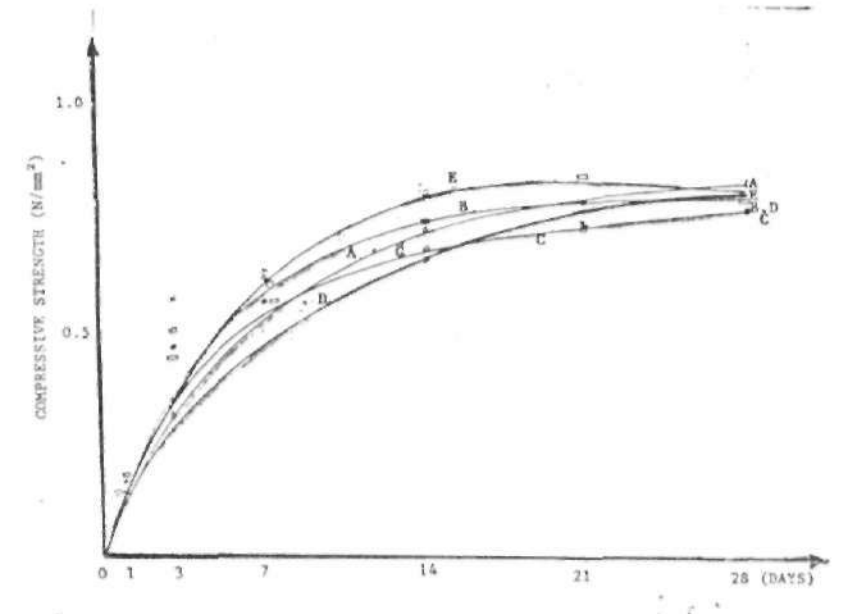


FIG. 21: COMPARISON OF WET DEVELOPMENT STRENGTHS

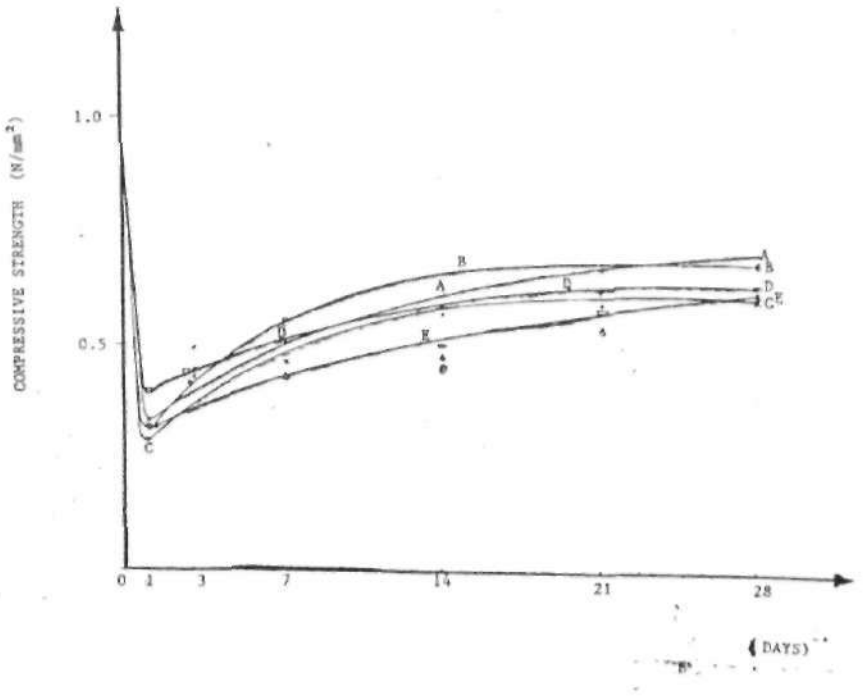


FIG. 22: COMPARISON OF DRY DEVELOPMENT STRENGTHS

It can be seen from figures 21 and 22 that industry A has the best result in terms of dry development strength and wet development strength.

The 28 -days age average dry development strengths are 0.86N/mm^2, 0.81Nmm^2, 0.77N/mm^2, 0.81N/mm^2, and 0.83N/mm^2 for industries A, B, C, D and E respectively. Also the average wet development strength at 28 days age of soaking prior to testing are 0.70N/mm^2 , 0.68N/mm^2, 0.60N/mm^2 , 0.63N/mm^2, and 0.61N/mm^2 for industries A,B,C,D and E respectively. The wet compressive strengths are 0.49N/mm^2, 0.46N/mm , 0.46N/mm , ^{2} 0.46n/mm^2 and 0.44N/mm^2 for industries A, B, C, D and E respectively.

From the aforementioned, industry A can be said to produce relatively better sandcrete hollow blocks when compared to other industries in terms of strength values.

Furthermore, the blocks from industry B are the best in terms of density values. Compared to other industries, industry B has the highest values of 1060kg/m^3 but this is still less than the 1500kg/m ^{3}specified by the B.S 2028 /16/for type A blocks.

5.0 CHAPTER FIVE

5.1 CONCLUSION AND RECOMMENDATIONS

5.2 CONCLUSION:

This thesis is aimed at determining the quality of sandcrete blocks produced in the Federal Capital Territory, Abuja. In the process of determining the quality, the various materials used as well as the methods of production of sandcrete blocks were considered.

The test results presented in previous chapters enable some basic conclusions to be drawn on the quality of sandcrete hollow blocks. It also serves as a guide for future investigations in this area.

(1) The quality of sand used in most of the industries for the production of sandcrete blocks in the Federal Capital Territory, Abuja is generally good.

(2) The dry development strength of the block samples is generally low although the blocks samples attained fairly steady strength from the 7th day to the 28th day. The average dry development strength at 28 days are 0.86N/mm^2 ,0.81N/mm^2 , 0.77N/mm^2 , 0.81N/mm^2 and 0.83N/mm^2 for industries A, B, C, D and E respectively.

(3) Upon immersion in water, the block samples attained a critical condition within 24 hours prior to testing. The values of the average dry development strength at 28 days now dropped to a minimum

average value of 0.32N/mm^2, 0.31N/mm^2 0.28N/mm^2, 0.39N/mm^2 and 0.31N/mm^2 for industries A, B, C D and E respectively.

(4) The wet development strength of the sandcrete block samples began to increase after the first 24 hours of immersion to an average wet development strength of 0.70N/mm^2,0. 68N/mm^2, 0.60N/mm^2, 0.63N/mm^2 and 0.61N/mm^2 at 28 days of curing for industries A, B, C, D and E respectively.

(5) The ratio of the average wet development strength at various soaking ages to the average dry development strength at 28 days was also determined. The constant wet strength ratios are 69%, 80% , 80%, 72% and 65% for industries A, B, C , D and E respectively.

(6) The average compressive strength of the block samples were 0.49N/mm^2, 0.46N/mm^2 , 0.46N/mm^2, 0.46N/mm^2 and 0.44N/mm^2 for industries A, B, C, D and E respectively. When compared with the Federal Ministry of works and housing recommended value of 2.1N/mm^2, these values are low.

(7) The densities of blocks produced in the Federal Capital Territory, Abuja, are lower when compared with the British standard specification of 1500kg/m^3 for type A blocks. The average values

obtained are 1042kg/m^3, 1060kg/m^3, 948kg/m^3, 1020kg/m^3 and 960kg/m^3 for industries A, B, C, D and E respectively.

(8) Most of the sandcrete blocks produced in the Federal Capital Territory, Abjua fall withing the limits of dimension tolerance. The average block size is 218mm x229mm x 460mm.

(9) The mode of curing of the sandcrete blocks was generally poor. The blocks after molding are kept in the open air without proper shade thereby exposing them to direct rays of sun and wind. The blocks are then cured once daily for two or three days instead of 7 days. Maximum strength of the block is not attained as most of the water required for the process of hydration are lost through evaporation.

(10) The mix proportion used does not meet the required specification of one part of cement to six or eight parts of sand (1:6 or 1:8). In most industries, a mix proportion of (1:12) one part of cement to twelve parts of sand is used.

(11) The average values of drying shrinkage for industries A, B, C, D and E are 0.04%,o 02%, 0.03%, 0.03% and 0.03% respectively. These values do not exceed the 0.05% specified for type A blocks in the British standard specification.

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(12) The moisture movement of the blocks are 0.05%, 0.03% 0.06%, 0.05% and 0.05% for industries A, B, C, D and E respectively. The British standard specified 0.07% as the maximum moisture movement for type A blocks. They all conform with the requirements of the British standard specification.

5.3 RECOMMENDATIONS

It has been shown from the analysis of the test results that the quality of the sandcrete hollow blocks produced in the Federal Capital Territory, Abuja, is poor. Efforts should be made to improve the quality of the sandcrete blocks to meet the required standards. The following recommendations are made for improved production and quality of sandcrete blocks.

1. The block manufacturers should be educated on the requirements of good quality sandcrete blocks. They should be made to be aware of strength requirements and the various production steps necessary to be taken to achieve the desired strength.
2. Sandcrete block tests should be conducted in all the states of the Federation so as to determine the strength values in all the states, experts can now discuss and determine what the minimum average strength of sandcrete blocks in the country should be.

3. At periodic intervals, the standard organization of Nigeria should undertake industrial visits to block molding industries in the Federation to collect block samples for tests so as to check if the products meet the required specifications. Industries that meet the specification should be issued with the Nigerian industrial standard certificate and probably given a stamp which they can now use on their products as a sign of good quality.
4. Manufacturers of sandcrete blocks should also be made to be aware that prolonged storage of cement affects its strength. Cement should not be stored longer than six months and not stacked on bare floor.
5. The sandcrete blocks should be well stacked so as to allow reasonable circulation of air around the blocks. They should be cured by watering twice daily for at least seven days and should be placed under shed for seven days so as to protect blocks from the direct rays of sun, rain and wind.
6. The block molding machine should be checked and serviced at specific intervals so that sandcrete blocks of uniform size and strength are produced.
7. The quality of the sandcrete blocks produced in the Federal Capital Territory, Abuja, can be improved upon by using the correct mix proportion .

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APPENDIX A1

INDUSTRY: A

DATE OF CASTING: 2 - 09 - 96

TEST: DRY DEVELOPMENT STRENGTH.

S/No	Date Tested	Sample No.	Length mm	Breath mm	Height mm	Weight mm	Failure Load (KN)	Strength	
								N/MM^2	AVE
1		A1/03/09/ABJ	460	229	220	23.7	12.00	0.11	
2	3-9-96	A2/03/09/ABJ	460	229	221	23.6	17.10	0.16	0.16
3		A3/03/09/ABJ	459	230	222	22.5	21.20	0.20	
4		A4/05/09/ABJ	459	228	222	24.6	51.50	0.48	
5	5-9-96	A5/05/09/ABJ	459	228	221	24.2	45.00	0.42	0.46
6		A6/05/09/ABJ	458	229	220	23.8	53.00	0.49	
7		A7/09/09/ABJ	460	228	221	24.3	62.00	0.58	
8	9-9-96	A8/09/09/ABJ	460	229	220	21.7	58.50	0.55	0.56
9		A9/09/09/ABJ	460	230	220	23.5	57.00	0.56	
10		A10/16/09/ABJ	461	230	220	23.3	70.00	0.66	
11	16-9-96	A11/16/09/ABJ	460	230	220	23.6	69.00	0.66	0.67
12		A12/16/09/ABJ	460	229	221	24.9	71.50	0.69	
13		A13/23/09/ABJ	459	230	222	23.9	79.30	0.75	
14	23-9-96	A14/23/09/ABJ	461	231	230	23.6	80.20	0.75	0.76
15		A15/23/09/ABJ	461	230	231	22.6	83.50	0.79	
16		A16/30/09/ABJ	460	229	221	23.8	81.00	0.77	
17	30-9-96	A17/30/09/ABJ	459	230	230	24.4	86.20	0.81	0.81
18		A18/30/09/ABJ	460	230	220	22.6	90.30	0.86	

APPENDIX A2

INDUSTRY: B

DATE OF CASTING: 03 -06-96

TEST: DRY DEVELOPMENT STRENGTH.

S/No	Date Tested	Sample No.	Length mm	Breath mm	Height mm	Weight mm	Failure Load (KN)	Strength	
								N/MM^2	AVE
1		B1/04/06/AB	460	230	221	23.1	15.00	0.14	
2	4-6-96	B2/04/06/AB	459	229	220	24.8	12.00	0.12	0.13
3		B3/04/06/AB	460	229	220	23.7	16.00	0.15	
4		B4/06/06/AB	460	229	221	23.9	57.00	0.54	
5	6-6-96	B5/06/06/AB	458	230	220	24.9	60.00	0.57	0.57
6		B6/06/06/AB	460	230	220	22.7	62.00	0.58	
7		B7/10/06/AB	460	230	220	24.6	61.00	0.58	
8	10-6-96	B8/10/06/AB	460	230	220	23.8	72.00	0.69	0.63
9		B9/10/06/AB	459	231	220	22.6	65.00	0.62	
10		B10/24/06/AB	459	228	221	24.0	83.00	0.79	
11	17-6-96	B11/24/06/AB	460	229	220	23.9	89.00	0.84	0.80
12		B12/24/06/AB	458	230	220	24.6	81.00	0.77	
13		B13/24/06/AB	461	231	220	24.1	85.00	0.80	
14	24-6-96	B14/24/06/AB	460	230	222	22.8	86.00	0.81	0.79
15		B15/24/06/AB	460	230	222	24.9	80.60	0.76	
16		B16/01/07/AB	459	230	220	24.4	80.20	0.76	
17	01-7-96	B17/01/07/AB	460	230	221	23.6	89.20	0.84	0.81
18		B18/01/07/AB	460	230	221	22.9	86.30	0.82	

APPENDIX A3

INDUSTRY: C

DATE OF CASTING: 02 -07-96

TEST: DRY DEVELOPMENT STRENGTH.

S/No	Date Tested	Sample No.	Length mm	Breath mm	Height mm	Weight mm	Failure Load (KN)	Strength	
								N/MM^2	AVE
1		C1034/07/KJ	460	230	215	23.50	15.00	0.14	
2	3-7-96	C2/03/07/KJ	460	230	218	22.70	10.20	0.09	0.14
3		C3/03/07/KJ	460	229	220	21.80	19.40	0.18	
4		C4/05/07/KJ	460	230	220	22.00	53.00	0.50	
5	5-7-96	C5/05/07/KJ	458	230	220	22.55	62.20	0.59	0.55
6		C6/05/07/KJ	458	229	218	23.00	60.10	0.57	
7		C7/09/07/KJ	460	228	220	24.00	61.70	0.59	
8	9-7-96	C8/09/07/KJ	459	230	218	25.00	70.50	0.67	0.60
9		C9/09/07/KJ	461	228	220	24.80	57.10	0.54	
10		C10/16/07/KJ	460	230	218	23.50	68.20	0.64	
11	16-7-96	C11/16/07/KJ	460	229	219	21.90	72.00	0.68	0.68
12		C12/16/07/KJ	458	230	219	21.95	76.00	0.72	
13		C13/23/07/KJ	459	230	220	25.85	73.40	0.70	
14	23-7-96	C14/23/07/KJ	460	228	216	23.00	75.50	0.72	0.73
15		C15/23/07/KJ	460	228	220	22.50	80.00	0.76	
16		C16/30/07/LJ	458	230	220	22.55	60.10	0.57	
17	30-7-96	C17/30/07/LJ	460	230	218	23.35	85.60	0.81	0.77
18		C18/30/07/LJ	461	230	220	22.50	98.70	0.93	
								0.87	

APPENDIX A4

INDUSTRY: D

DATE OF CASTING: 2 - 9 - 96

TEST: DRY DEVELOPMENT STRENGTH.

S/No	Date Tested	Sample No.	Length mm	Breath mm	Height mm	Weight mm	Failure Load (KN)	Strength N/MM²	Strength AVE
1		D1/03/09/GW	460	230	220	23.20	15.10	0.14	
2	3-9-96	D2/03/09/GW	459	230	220	23.70	18.20	0.17	0.17
3		D3/03/09/GW	460	229	218	23.30	22.10	0.21	
4		D4/05/09/GW	459	228	220	24.70	61.20	0.58	
5	5-9-96	D5/05/09/GW	459	229	219	23.95	32.10	0.30	0.44
6		D6/05/09/GW	460	228	220	24.35	45.90	0.44	
7		D7/09/09/GW	460	230	220	23.50	53.40	0.50	
8	9-9-96	D8/09/09/GW	459	229	218	23.50	58.60	0.56	0.56
9		D9/09/09/GW	458	228	220	23.00	65.00	0.62	
10		D10/16/09/GW	459	230	220	24.10	75.00	0.71	
11	16-9-96	D11/16/09/GW	460	229	220	23.80	80.00	0.76	0.75
12		D12/16/09/GW	460	230	218	23.90	81.20	0.77	
13		D13/23/09/GW	460	228	219	22.90	91.50	0.87	
14	23-9-96	D14/23/09/GW	460	230	220	23.10	88.60	0.84	0.85
15		D15/23/09/GW	459	229	220	23.15	87.80	0.84	
16		D16/30/09/GW	459	230	220	24.50	93.40	0.88	
17	30-9-96	D17/30/09/GW	461	229	220	24.55	86.00	0.81	0.86
18		D18/30/09/GW	460	230	219	24.80	92.00	0.87	

APPENDIX A5

INDUSTRY: E

DATE OF CASTING: 21 - 10 - 96

TEST: DRY DEVELOPMENT STRENGTH.

S/No	Date Tested	Sample No.	Length mm	Breath mm	Height mm	Weight mm	Failure Load (KN)	Strength	
								N/MM^2	AVE
1		E1/22/10/ABJ	463	228	222	21.7	10.10	0.09	
2	22-10-96	E2/22/10/ABJ	463	228	221	21.9	12.30	0.11	0.12
3		E3/22/10/ABJ	460	229	220	22.6	16.10	0.11	
4		E4/24/10/ABJ	462	230	221	22.3	32.30	0.30	
5	24-10-96	E5/24/10/ABJ	460	230	221	21.8	30.10	0.28.	0.30
6		E6/24/10/ABJ	460	228	220	21.9	35.10	0.33	
7		E7/28/10/ABJ	460	229	220	22.7	60.20	0.57	
8	28-10-96	E8/28/10/ABJ	463	229	220	23.0	65.00	0.61	0.61
9		E9/28/10/ABJ	460	230	220	22.8	68.50	0.65	
10		E10/04/11/ABJ	460	229	222	22.9	75.70	0.72	
11	4-11-96	E11/04/11/ABJ	460	228	231	21.5	90.00	0.86	0.73
12		E12/04/11/ABJ	463	228	221	22.8	64.90	0.61	
13		E13/11/11/ABJ	460	228	229	22.9	86.00	0.82	
14	11-11-97	E14/11/11/ABJ	461	228	220	22.6	89.00	0.84	0.79
15		E15/11/11/ABJ	463	228	220	23.1	74.20	0.70	
16		E16/18/11/ABJ	461	229	220	22.9	102.10	0.97	
17	18-11-96	E17/18/11/ABJ	460	230	220	22.7	76.20	0.72	0.83
18		E18/18/11/ABJ	460	230	222	22.8	84.60	0.80	

APPENDIX A6

INDUSTRY: A

DATE IMMERSED IN WATER: 01 - 10 - 96

TEST: WET DEVELOPMENT STRENGTH.

S/No	Date Tested	Sample No.	Length mm	Breath mm	Height mm	Weight mm	Failure Load (KN)	Strength N/MM²	Strength AVE
1		A1/02/10/ABJ	459	230	220	24.8	25.20	0.24	
2	02-10-96	A2/02/10/ABJ	460	230	221	24.2	25.00	0.33	0.32
3		A3/02/10/ABJ	46	230	222	25.6	40.40	0.38	
4		A4/04/10/ABJ	460	231	220	23.9	48.50	0.46	
5	04-10-96	A5/04/10/ABJ	458	229	220	25.7	52.20	0.50	0.49
6		A6/04/10/ABJ	461	230	221	23.9	55.30	0.52	
7		A7/08/10/ABJ	460	22	220	25.0	35.10	0.51	
8	08-10-96	A8/08/10/ABJ	458	230	220	24.8	48.00	0.46	0.50
9		A9/08/10/ABJ	458	230	222	25.6	56.20	0.53	
10		A10/15/10/ABJ	460	229	220	23.8	62.30	0.59	
11	15-10-96	A11/15/10/ABJ	460	231	222	25.7	58.00	0.55	0.57
12		A12/15/10/ABJ	459	230	221	25.2	60.00	0.56	
13		A13/22/10/ABJ	460	229	222	23.9	65.50	0.62	
14	22-10-96	A14/22/10/ABJ	461	230	222	25.6	53.80	0.51	0.59
15		A15/22/10/ABJ	461	230	220	24.8	68.70	0.65	
16		A14/29/10/ABJ	458	229	221	23.8	74.60	0.71	
17	29-10-96	A15/29/10/ABJ	461	230	220	23.9	76.20	0.72	0.70
18		A16/29/10/ABJ	40	230	220	25.6	72.00	0.68	

APPENDIX A7

INDUSTRY: B

DATE IMMERSED IN WATER: 02 - 07 - 96

TEST: WET DEVELOPMENT STRENGTH.

S/No	Date Tested	Sample No.	Length mm	Breath mm	Height mm	Weight mm	Failure Load (KN)	Strength N/MM²	Strength AVE
1		B1/03/07/AB	461	220	230	23.4	23.00	0.22	
2	03-07-96	B2/03/07/AB	460	220	230	24.8	35.10	0.33	0.31
3		B3/03/07/AB	461	221	230	24.4	40.60	0.38	
4		B4/05/07/AB	460	220	229	25.3	43.20	0.41	
5	05-07-96	B5/05/07/AB	459	221	230	23.2	45.00	0.42	0.43
6		B6/05/07/AB	460	220	230	24.8	48.00	0.45	
7		B7/09/07/AB	459	220	230	22.7	45.00	0.43	
8	09-07-96	B8/09/07/AB	460	221	229	25.3	55.20	0.52	0.54
9		B9/09/07/AB	460	220	229	26.5	70.70	0.67	
10		B10/11/07/AB	460	220	230	24.8	45.30	0.43	
11	16-07-96	B11/11/07/AB	461	220	230	24.8	55.10	0.52	0.44
12		B12/11/07/AB	460	220	230	25.7	40.20	0.38	
13		B13/23/07/AB	459	222	230	25.5	65.00	0.62	
14	23-07-96	B14/23/07/AB	460	221	229	25.8	80.60	0.76	0.62
15		B15/23/07/AB	460	222	229	26.8	49.60	0.47	
16		B16/30/07/AB	458	220	229	24.6	65.80	0.63	
17	30-07-96	B17/30/07/AB	461	220	230	26.2	79.90	0.75	0.68
18		B18/30/07/AB	460	220	231	25.5	70.70	0.67	

APPENDIX A8

INDUSTRY: C

DATE IMMERSED IN WATER: 31 - 07 - 96

TEST: WET DEVELOPMENT STRENGTH.

S/No	Date Tested	Sample No.	Length mm	Breath mm	Height mm	Weight mm	Failure Load (KN)	Strength N/MM²	Strength AVE
1		C1/01/08/KJ	459	230	219	25.80	27.40	0.26	
2	01-08-96	C2/01/08/KJ	460	230	220	24.70	32.60	0.31	0.28
3		C3/01/08/KJ	460	229	220	26.80	28.10	0.27	
4		C4/03/08/KJ	458	229	220	24.75	28.00	0.27	
5	03-08-96	C5/03/08/KJ	461	230	220	25.70	62.20	0.59	0.43
6		C6/03/08/KJ	460	230	222	25.95	44.60	0.42	
7		C7/07/08/KJ	460	230	220	26.15	59.90	0.57	
8	07-08-96	C8/07/08/KJ	460	228	220	25.30	36.80	0.35	0.46
9		C9/07/08/KJ	460	229	220	26.90	48.00	0.46	
10		C10/14/08/KJ	458	230	222	27.25	68.70	0.65	
11	14-08-96	C11/14/08/KJ	459	230	221	24.80	66.00	0.63	0.59
12		C12/14/08/KJ	461	230	221	25.60	53.60	0.51	
13		C13/21/08/KJ	460	228	220	25.40	83.20	0.79	
14	21-08-96	C14/21/08/KJ	460	229	221	26.50	63.50	0.60	0.67
15		C15/21/08/KJ	460	229	220	26.80	65.50	0.62	
16		C16/28/08/KJ	459	230	220	25.80	64.60	0.61	
17	28-08-96	C17/28/08/KJ	460	229	220	27.90	68.30	0.65	0.60
18		C18/28/08/KJ	460	230	220	26.40	66.20	0.53	

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APPENDIX A9

INDUSTRY: D

DATE IMMERSED IN WATER: 01 - 10 - 96

TEST: WET DEVELOPMENT STRENGTH.

S/No	Date Tested	Sample No.	Length mm	Breath mm	Height mm	Weight mm	Failure Load (KN)	Strength N/MM²	Strength AVE
1		D1/02/10/GW	459	229	220	25.60	26.30	0.35	
2	02-10-96	D2/02/10/GW	460	230	220	25.80	40.20	0.38	0.38
3		D3/02/10/GW	460	229	220	26.50	42.10	0.40	
4		D1/04/10/GW	459	228	210	27.80	43.40	0.41	
5	04-10-96	D2/04/10/GW	460	229	221	24.50	45.60	0.43	0.43
6		D3/04/10/GW	461	230	220	25.25	48.70	0.46	
7		D1/08/10/GW	459	230	219	25.15	45.40	0.43	
8	08-10-96	D2/08/10/GW	461	230	220	24.85	52.20	0.49	0.50
9		D3/08/10/GW	460	228	220	25.20	60.00	0.57	
10		D1/15/10/GW	460	229	220	26.10	48.10	0.46	
11	15-10-96	D2/15/10/GW	460	229	221	26.00	52.70	0.50	0.51
12		D3/15/10/GW	459	229	221	25.95	58.60	0.56	
13		D1/22/10/GW	461	230	220	29.15	65.40	0.62	
14	22-10-96	D2/22/10/GW	460	230	220	23.90	49.60	0.47	0.58
15		D3/22/10/GW	460	227	220	24.20	70.00	0.66	
16		D1/29/10/GW	459	228	220	26.10	26.10	0.69	
17	29-10-96	D2/29/10/GW	458	229	221	26.15	26.15	0.56	0.63
18		D3/29/10/GW	459	230	220	25.00	25.00	0.66	

APPENDIX A10

INDUSTRY: D

DATE IMMERSED IN WATER: 19 - 11 - 96

TEST: WET DEVELOPMENT STRENGTH.

S/No	Date Tested	Sample No.	Length mm	Breath mm	Height mm	Weight mm	Failure Load (KN)	Strength N/MM²	Strength AVE
1		E1/20/11/ABJ	461	229	220	27.7	20.50	0.19	
2	20-11-96	E2/20/11/ABJ	462	230	220	22.2	40.20	0.38	0.31
3		E3/20/11/ABJ	462	228	220	24.9	38.10	0.36	
4		E4/22/11/ABJ	460	230	231	23.5	43.80	0.41	
5	22-11-96	E5/22/11/ABJ	460	230	220	24.6	45.80	0.43	0.42
6		E6/22/11/ABJ	461	230	220	25.9	44.90	0.42	
7		E7/26/11/ABJ	459	229	221	23.1	45.90	0.44	
8	26-11-96	E8/26/11/ABJ	462	228	220	24.6	40.80	0.39	0.43
9		E9/26/11/ABJ	460	228	220	24.0	48.70	0.46	
10		E10/03/12/ABJ	460	228	222	24.7	45.60	0.43	
11	03-11-96	E11/03/12/ABJ	462	228	221	24.2	50.40	0.48	0.47
12		E12/03/12/ABJ	460	230	220	25.5	52.30	0.49	
13		E13/10/12/ABJ	461	230	220	22.9	65.20	0.64	
14	10-11-96	E14/10/12/ABJ	461	230	221	25.6	45.10	0.43	0.55
15		E15/10/12/ABJ	460	228	220	26.4	60.00	0.57	
16		E16/17/12/ABJ	460	229	222	22.6	65.90	0.63	
17	17-12-96	E17/17/12/ABJ	461	228	220	23.2	56.80	0.54	0.61
18		E18/17/12/ABJ	460	230	220	23.1	68.60	0.65	

APPENDIX A11

INDUSTRY: A

TEST: WET COMPRESSIVE STRENGTH

DATE IMMERSED IN WATER: 01 - 10 - 96

DATE TESTED: 08 - 10 - 96

DATE MORTAR CUBE ATTAINED LEAST STRENGTH: 08 - 10 - 96

S/No.	Sample Number	Length (mm)	Breadth (mm)	Height (mm)	Hollow Size Before Capping	Volume (m^3)	Weight (kg)	Failure Load (kg)	Strength N/mm^3	Average Strength (N/mm^3)
1	A1/08/10/ABI	461	230	229	168x140	0.024	50.20	46.10	0.43	
2	A2/08/10/ABI	460	230	230	170x140	0.024	26.10	42.20	0.40	
3	A3/08/10/ABI	460	228	229	166x136	0.024	25.80	53.60	0.51	
4	A4/08/10/ABI	465	230	228	170x138	0.024	25.20	60.00	0.57	
5	A5/08/10/ABI	461	229	230	170x140	0.024	25.00	48.40	0.46	
6	A6/08/10/ABI	460	231	229	170x140	0.024	24.80	52.20	0.49	0.4
7	A7/08/10/ABI	460	229	230	168x135	0.024	25.20	49.50	0.47	
8	A8/08/10/ABI	459	230	230	168x136	0.024	25.30	48.00	0.45	
9	A9/08/10/ABI	460	230	230	170x136	0.024	25.40	52.20	0.53	
10	A10/08/10/ABI	460	229	230	170x140	0.024	25.80	57.30	0.54	

AVERAGE STRENGTH = 0.49N/mm²

STANDARRD DEVIATION = 0.05N/mm²

COEFFICIENT OF VARIATION = 10.86%

APPENDIX A12

INDUSTRY: B

TEST: WET COMPRESSIVE STRENGTH

DATE IMMERSED IN WATER: 02 - 07 - 96

DATE TESTED: 09 - 07 - 96

DATE MORTAR CUBE ATTAINED LEAST STRENGTH: 09 - 07 - 96

S/No.	Sample Number	Length (mm)	Breadth (mm)	Height (mm)	Hollow Size Before Capping	Volume (m^3)	Weight (kg)	Failure Load (kg)	Strength N/mm^3	Average Strength (N/mm^3)
1	B1/09/07/AB	460	230	229	165x140	0.024	25.80	46.20	0.44	
2	B2/09/07/AB	461	229	230	170x140	0.024	22.60	42.70	0.40	
3	B3/09/07/AB	460	230	230	165x136	0.024	23.40	44.70	0.42	
4	B4/09/07/AB	459	230	229	166x138	0.024	22.80	48.80	0.46	
5	B5/09/07/AB	459	229	228	168x140	0.024	26.20	56.40	0.54	
6	B6/09/07/AB	460	231	230	165x140	0.024	25.80	58.00	0.55	0.5
7	B7/09/07/AB	461	230	229	168x140	0.024	25.60	40.90	0.39	
8	B8/09/07/AB	460	230	230	168x138	0.024	26.10	43.00	0.41	
9	B9/09/07/AB	460	229	230	168x136	0.024	24.80	60.10	0.57	
10	B'0/09/07/AB	460	230	230	168x140	0.024	26.10	48.20	0.46	

AVERAGE STRENGTH = 0.46N/mm²

STANDARRD DEVIATION = 0.06N/mm²

COEFFICIENT OF VARIATION = 13.04%

APPENDIX A13

INDUSTRY: C

TEST: WET COMPRESSIVE STRENGTH

DATE IMMERSED IN WATER: 31 - 07 - 96

DATE TESTED: 08 - 08 - 96

DATE MORTAR CUBE ATTAINED LEAST STRENGTH: 07 - 08 - 96

S/No	Sample Number	Length (mm)	Breadth (mm)	Height (mm)	Hollow Size Before Capping	Volume (m^3)	Weight (kg)	Failure Load (kg)	Strength N/mm^3	Average Strength (N/mm^2)
1	C1/07/08/KI	460	230	231	160x140	0.024	26.40	49.10	0.46	
2	C2/07/08/KI	461	230	230	162x139	0.024	26.10	53.40	0.50	
3	C3/07/08/KI	460	230	230	161x140	0.024	26.40	52.30	0.49	
4	C4/07/08/KI	460	230	230	163x140	0.024	26.80	38.80	0.37	0.4
5	C5/07/08/KJ	459	230	229	160x138	0.024	25.70	56.00	0.53	
6	C6/07/08/KJ	460	230	231	160x138	0.024	25.90	42.30	0.40	
7	C7/07/08/KJ	459	229	231	159x140	0.024	26.00	48.00	0.47	
8	C8/78/08/KJ	460	229	230	162x140	0.024	26.10	43.00	0.41	
9	C9/07/08/KJ	460	228	230	162x140	0.024	26.30	44.20	0.42	
10	C10/07/08/KI	460	230	230	162x140	0.024	25.90	54.40	0.51	

AVERAGE STRENGTH = 0.46N/mm^2

STANDARRD DEVIATION = 0.05N/mm^2

COEFFICIENT OF VARIATION = 10.86%

APPENDIX A14

INDUSTRY: D

TEST: WET COMPRESSIVE STRENGTH

DATE IMMERSED IN WATER: 01 - 10 - 96

DATE TESTED: 08 - 10 - 96

DATE MORTAR CUBE ATTAINED LEAST STRENGTH: 08 -10 - 96

S/No.	Sample Number	Length (mm)	Breadth (mm)	Height (mm)	Hollow Size Before Capping	Volume (m^3)	Weight (kg)	Failure Load (kg)	Strength N/mm^2	Average Strength (N/mm^2)
1	D1/08/10/GW	459	230	231	166x136	0.024	24.90	48.80	0.46	
2	D2/08/10/GW	460	230	230	168x138	0.024	24.70	47.10	0.45	
3	D3/08/10/GW	460	229	230	164x135	0.024	25.10	46.00	0.44	
4	D4/08/10/GW	460	229	228	168x134	0.024	25.30	44.20	0.42	
5	D5/08/10/GW	459	231	229	166x135	0.024	25.80	53.20	0.50	0.4
6	D6/08/10/GW	461	230	229	166x136	0.024	25.10	51.30	0.48	
7	D7/08/10/GW	459	230	230	170x138	0.024	26.20	50.60	0.48	
8	D8/08/10/GW	461	229	231	168x138	0.024	24.70	49.80	0.47	
9	D9/08/10/GW	460	230	229	166x140	0.024	24.20	45.80	0.43	
10	D10/08/10/GW	460	231	230	168x134	0.024	24.80	53.70	0.51	

AVERAGE STRENGTH = 0.46N/mm^2

STANDARRD DEVIATION = 0.04N/mm^2

COEFFICIENT OF VARIATION = 8.33%

APPENDIX A15

INDUSTRY: E

TEST: WET COMPRESSIVE STRENGTH

DATE IMMERSED IN WATER: 19 - 11 - 96

DATE TESTED: 26 - 11 - 96

DATE MORTAR CUBE ATTAINED LEAST STRENGTH: 26 - 11 - 96

S/No	Sample Number	Length (mm)	Breadth (mm)	Height (mm)	Hollow Size Before Capping	Volume (m^3)	Weight (kg)	Failure Load (kg)	Strength N/mm^2	Average Strength (N/mm^2)
1	E1/26/11/ABI	461	228	228	168x138	0.023	24.20	43.40	0.41	
2	E2/26/11/ABI	460	230	230	168x140	0.023	24.10	46.60	0.44	
3	EE/26/11/ABI	463	230	230	164x138	0.023	23.90	45.10	0.42	
4	E4/26/11/ABI	462	229	229	168x140	0.023	24.10	50.50	0.48	0.4
5	E5/26/11/ABI	460	230	230	170x138	0.023	24.00	54.00	0.51	
6	E6/26/11/ABI	460	228	228	170x140	0.023	23.80	46.20	0.44	
7	E7/26/11/ABI	460	230	230	166x136	0.023	24.20	49.70	0.49	
8	E8/26/11/ABI	460	229	229	166x138	0.023	24.30	40.90	0.39	
9	E9/26/11/ABI	462	230	230	168x140	0.023	24.10	49.00	0.46	
10	EE0/26/11/ABI	463	231	230	168x140	0.023	24.20	42.00	0.39	

AVERAGE STRENGTH = 0.44N/mm²

STANDARRD DEVIATION = 0.03N/mm²

COEFFICIENT OF VARIATION = 6.82%

APPENDIX A16

INDUSTRY: A

TEST: MORTAR CUBE STRENGTH

DATE IMMERSED IN WATER: 01 - 10 - 96

S/No.	DATE TESTED	SAMPLE NUMBER	AGE OF CURING (DAYS)	FAILURE LOAD (KN)	STRENGTH (N\mm²)	AVERAGE STREMGTI N\mm²)
1		A1/02/10/ABI	1	20.53	4.19	
2	2-10-96	A2/02/10/ABI	1	19.60	4.00	4.00
3		A3/02/10/ABI	1	18.62	3.80	
4		A4/05/10/ABI	3	85.11	17.37	
5	5-10-96	A5/05/10/ABI	3	89.42	18.25	17.80
6		A6/05/10/ABI	3	87.22	17.80	
7		A7/05/10/ABI	7	143.91	29.37	
8	8-10-96	A8/05/10/ABI	7	139.41	28.45	29.81
9		A9/05/10/ABI	7	154.94	31.45	

APPENDIX A17

INDUSTRY: B

TEST: MORTAR CUBE STRENGTH

DATE IMMERSED IN WATER: 02 - 07 - 96

S/No.	DATE TESTED	SAMPLE NUMBER	AGE OF CURING (DAYS)	FAILURE LOAD (KN)	STRENGTH (N\mm^2)	AVERAGE STREMGTI N\mm^2)
1		B1/03/07/AB	1	19.75	4.03	
2	3-10-96	B2/03/07/AB	1	18.67	3.81	3.99
3		B3/03/07/AB	1	20.29	4.14	
4		B4/05/07/AB	3	91.63	18.70	
5	5-10-96	B5/05/07/AB	3	85.06	17.36	17.79
6		B6/05/07/AB	3	84.82	17.31	
7		B7/09/07/AB	7	143.86	29.36	
8	8-10-96	B8/09/07/AB	7	156.85	32.01	30.23
9		B9/09/07/AB	7	143.62	29.31	

APPENDIX A18

INDUSTRY: C

TEST: MORTAR CUBE STRENGTH

DATE IMMERSED IN WATER: 31 - 07 - 96

S/No.	DATE TESTED	SAMPLE NUMBER	AGE OF CURING (DAYS)	FAILURE LOAD (KN)	STRENGTH (N\mm^2)	AVERAGE STREMGTI N\mm^2)
1		C1/01/08/KJ	1	19.31	3.94	
2	01-08-96	C2/01/08/KJ	1	20.14	4.11	4.02
3		C3/01/08/KJ	1	19.70	4.02	
4		A4/03/08/KJ	3	91.19	18.61	
5	03-08-96	A5/03/08/KJ	3	86.29	17.61	18.22
6		A6/03/08/KJ	3	90.36	18.44	
7		A7/07/08/KJ	7	148.18	30.24	
8	07-08-96	A8/07/08/KJ	7	152.44	31.11	30.60
9		A9/07/08/KJ	7	150.28	30.67	

APPENDIX A19

INDUSTRY: D

TEST: MORTAR CUBE STRENGTH

DATE IMMERSED IN WATER: 01 - 10 - 96

S/No.	DATE TESTED	SAMPLE NUMBER	AGE OF CURING (DAYS)	FAILURE LOAD (KN)	STRENGTH (N\mm^2)	AVERAGE STREMGTI N\mm^2)
1		D1/02/10/GW	1	20.97	4.28	
2	2-10-96	D2/02/10/GW	1	18.42	3.76	4.04
3		D3/02/10/GW	1	19.94	4.07	
4		D4/04/10/GW	3	89.38	18.24	
5	4-10-96	D5/04/10/GW	3	95.94	19.58	19.12
6		D6/04/10/GW	3	95.80	19.55	
7		D7/08/10/GW	7	148.27	30.26	
8	8-10-96	D8/08/10/GW	7	152.45	31.13	30.84
9		D9/08/10/GW	7	152.49	31.12	

APPENDIX A 20

INDUSTRY: E

TEST: MORTAR CUBE STRENGTH

DATE IMMERSED IN WATER: 19 - 11 - 96

S/No.	DATE TESTED	SAMPLE NUMBER	AGE OF CURING (DAYS)	FAILURE LOAD (KN)	STRENGTH (N\mm^2)	AVERAGE STREMGTI N\mm^2)
1		E1/20/11/ABJ	1	19.26	3.93	
2	20-11-96	E2/20/11/ABJ	1	19.06	3.89	3.90
3		E3/20/11/ABJ	1	19.06	3.89	
4		E4/22/11/ABJ	3	89.33	18.23	
5	22-11-96	E5/22/11/ABJ	3	87.27	17.81	18.04
6		E6/22/11/ABJ	3	88.54	18.07	
7		E7/26/11/ABJ	7	148.57	30.32	
8	26-11-96	E8/26/11/ABJ	7	150.28	30.67	30.60
9		E9/26/11/ABJ	7	150.92	30.80	

APPENDIX A-21

CALCULATION OF ABSORPTION OF WATER

INDUSTRY A:

Average weight of 3 blocks air dry = 24.17kg.

Average weights of 3 blocks

Immersed in watere for 48 hours = 25.96kg

∴ Water Absorption = $\frac{25.96 - 24.17}{24.17} \times 100 = 7.42\%$

INDUSTRY B:

Average weight of 3 blocks air dry = 24.45kg.

Average weights of 3 blocks

Immersed in watere for 48 hours = 26.12kg

∴ Water Absorption = $\frac{26.12 - 24.45}{24.45} \times 100 = 6.84\%$

INDUSTRY C:

Average weight of 3 blocks air dry = 21.87kg.

Average weights of 3 blocks

Immersed in watere for 48 hours = 24.89kg

∴ Water Absorption = $\frac{24.89 - 21.87}{21.87} \times 100 = 13.80\%$

INDUSTRY D:

Average weight of 3 blocks air dry = 23.63kg.

Average weights of 3 blocks

Immersed in watere for 48 hours = 25.66kg

∴ Water Absorption = $\frac{25.66 - 23.63}{23.63} \times 100 = 8.60\%$

INDUSTRY E:

Average weight of 3 blocks air dry = 22.15kg.

Average weights of 3 blocks

Immersed in watere for 48 hours = 24.91kg

∴ Water Absorption = $\frac{24.91 - 23.63}{22.15} \times 100 = 12.48\%$

APPENDIX A-23

DETERMINATION OF SILT CONTENT

INDUSTRY A:

Height of Sand + Silt	=	82 ml
Height of Sand	=	78 ml
∴ Height of Silt	=	4 ml
% of Silt	=	$\frac{4}{82} \times 100 = 4.87\%$

INDUSTRY B:

Height of Sand + Silt	=	84 ml
Height of Sand	=	79 ml
∴ Height of Silt	=	5 ml
% of Silt	=	$\frac{5}{84} \times 100 = 5.95\%$

INDUSTRY C:

Height of Sand + Silt	=	83 ml
Height of Sand	=	75 ml
∴ Height of Silt	=	8 ml
% of Silt	=	$\frac{8}{83} \times 100 = 5.88\%$

INDUSTRY D:

Height of Sand + Silt	=	89 ml
Height of Sand	=	82 ml
∴ Height of Silt	=	7 ml
% of Silt	=	$\frac{7}{89} \times 100 = 7.87\%$

INDUSTRY E:

Height of Sand + Silt	=	80 ml
Height of Sand	=	76 ml
∴ Height of Silt	=	4 ml
% of Silt	=	$\frac{4}{80} \times 100 = 5\%$