QUALITY OF SANDCRETE HOLLOW BLOCKS PRODUCED IN BENUE STATE

BY

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DECLARATION

I hereby declare that this thesis is a record of my own research work. It has not been presented by me in any previous application for a higher degree.

Abbas Yakubu

CERTIFICATION

The thesis entitled "Quality of Sandcrete Hollow Blocks Produced in Benue State" by Abbas Yakubu meets the regulations governing the award of the degree of Master of Science of Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

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DEDICATED TO:

My late parents

Alhaji Yakubu Adaji

and

Hajiya Ajuji Adejoh

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ABSTRACT

The project is a study of the physical properties of sandcrete hollow blocks produced in Benue State for the purpose of ascertaining their quality. Following a careful site survey of thirty block industries across the state, five block industries were chosen for assessement and about fifty blocks were randomly selected from each of them. Majority of the block industries visited produced their blocks using block moulding machines. With an average staff strength of ten, an average of eight hundred blocks were produced daily. The average price of each block is twenty five naira only. Quality assessement was done in the Civil Engineering laboratory of the University of Agriculture, Makurdi. The assessement was based on physical tests done on the blocks in accordance with the British Standard 2028 (Precast Concrete Blocks)/10/. The factors assessed were wet compressive (bedded) strength, dry and wet development strengths, density, dimensional tolerance, raw materials, mix, mixing process, manner of curing, drying shrinkage and wetting expansion. It was observed from the results of the tests that the 7th day wet compressive (bedded) strength averaged 0.420N/mm^2, with a maximum of 0.45N/mm^2 and a minimum of 0.40N/mm^2. The 28 day dry development strength ranged from 0.49-0.63N/mm^2 with and average of 0.57N/mm^2.

Apparently, these strength values are rather low when compared with the standard codes such as the Federal Ministry of Works/12/ which recommends 2.1 N/mm^2 and the lowest individual strength of 1.7N/mm^2. However, the values are close to those obtained in related works such as 0.58N/mm^2 for dry development and 0.39N/mm^2 for wet development strengths in Kano State/9/.

TABLE OF CONTENTS

Content	Page

CHAPTER ONE

1.0 INTRODUCTION

1.1 PREAMBLE

By definition, sandcrete hollow blocks are made from a mixture of cement, sand and water. Sand is chemically inert, cement is a binding material and water initiates the chemical reactions that produce the binding qualities of cement. These blocks are walling units dimensionally larger than bricks and have one or more cavities passing through them with a solid material between 50 to 75 percent of the total volume of the block calculated from the overall volume. Their nominal sizes are 230 x 230 x 460mm, 150x 230 x 460mm and 100 x 230 x 460mm. The specified nominal mixes for these blocks are one part of cement to six or eight parts of sand by volume, with water-cement ratio of 0.60 to 0.90/11/. There are two main types of these blocks namely - aggregate and aerated blocks with different methods of production. Additives and/or admixtures are sometimes used on these blocks to extend the product range. The production of these blocks is not very complicated. They are either produced manually or by moulding machines and are cured for a minimum period of seven days and a maximum period of 28 days before use. Sandcrete hollow blocks are extensively in use throughout Nigeria for a very long time and are rapidly replacing bricks and mud blocks as masonry units.

This project is intended to study the physical properties of sandcrete hollow blocks produced in Benue State for the purpose of evaluating their quality. The choice of mix, the process of mixing and the manner of curing and drying will all have to meet with the various specifications of the recommended standards. The quality of blocks is basically determined by strength. The strength of blocks is usually determined by either compressive, tensile or transverse tests. This study emphasizes on the compressive strength of sandcrete hollow blocks. Compressive strength of blocks can be defined as the maximum compressive stress which the blocks are capable of developing, based on the original area of cross-section before failure.

1.2 OBJECTIVES

The objectives of this research are to study the followings:

a) the quality of the raw materials used for producing the blocks.

b) the production procedures for the different block industries in the State;

c) the quality of the finished products from the different industries, and

d) to compare the findings above with existing international and local standards as well as the results of technical reports.

1.3 SCOPE OF WORK

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

a) a review of previous work on sandcrete hollow blocks;

b) survey of existing block industries in the State for data collection, and

c) experimental investigations on samples of sand and blocks for the various block industries.

1.4 TEST RESULTS

It was observed from the test results that the sandcrete hollow blocks produced in Benue state are generally low in quality when compared with standard local and international codes. For example, the average wet compressive (bedded) strength of the blocks is 0.42N/mm², the average 28 day wet and dry development strengths are 0.59N/mm² and 0.57N/mm², respectively. But the Nigerian Industrial standard recommends an average of 3.45 N/mm² and the lowest individial strength of 2.59N/mm²/11/. Also, the Federal Ministry of Works recommends an average of 2.1N/mm² and the lowest individual strength of 1.7N/mm²/12/. In addition, the British standard 2028 recommends an average of 3.5N/mm² and the minimum individual strength of 2.8N/mm²/10/.

The density of the blocks is expected to be about 1500kg/m³/10/ but the average density for the blocks tested is 1117kg/m³. Nevertheless, the drying shrinkage and watting expansion are within satisfactory region. Dimensional measurements show that the average dimensions of the blocks (458 x 228x218)mm are within acceptable range.

CHAPTER TWO

LITERATURE REVIEW -SANDCRETE HOLLOW BLOCKS

The strength of a material is usually determined by either compressive, tensile or transverse tests. This study emphasises on the compressive strength of sandcrete hollow blocks. Compressive strength of a material can be defined as the maximum compressive stress which a material is capable of developing, based on the original area of cross-section before failure.

The compressive strength of materials like sandcrete hollow blocks depends on the method of curing and percentage of cement and water content. It also depends on mix, compaction pressure, the method of preparing the blocks for testing. However, materials usually have lower strengths when tested wet than when tested in the dry state. The ratio between the wet and the dry strengths usually known as the wet/dry stength varies a bit depending on the material in question, compaction and the percentage of cement. It is much easier to standardise the wet condition for testing; in testing dry it is found that the temperature of drying has a marked effect upon the strength. However, wet compressive strength tests represent the worst conditions in practice and are therefore the safer to use and have accordingly been considered to be the better tests to apply for general purposes. A minimum wet strength of about $1.4N/mm^2$1/ has been recommended by several building authorities throughout the world for most sandcrete hollow blocks.

Professor ADEPEGBA of University of Lagos on his paper presented on the 7th Biennial Conference of the West African Science Association observed the followings: in his work he compared the structural properties of cement-stabilised laterite (latecrate) and that of cement-stabilised sand (sandcrete). About 1000 test specimens including 100mm cubes, 150mm diameter cylinders and modules of rapture beams were tested and he concludes with the followings:/2/.

a) "The strength of cement-stablised laterite and cement-stabilised sand increases with increasing cement content. At high cement content, that is 9% cement content, the granules of cement stabilised sand behaves elastically whereas granules of cement stabilised laterite do not show elasticity/2/.

b) The strength of cement-stablised laterite does not increase unformity, rather there are minimum and maximum strength/2/.

c) The compressive as well as the tensible strength of laterite are higher than those of sandcrete for cement content lower than 22%, thereafter the strength of sandcrete are higher/2/.

d) Structures constructed with sandcrete and tested in bending failed suddenly and without any warning, whereas structures constructed with laterite exhibited reasonable deflection before failure/2/.

e) Latecrete appears to be a structurally superior material than sandcrete which is now the most common building material in most developing countries where laterite is available"/2/.

He also observed that the most economic range of the use of these stabilised soil lies between 0 - 10% cement content. About 21% cement content, latecrete lag behind sandcrete and at about 27% cement content the strength of sandcrete doubles that of latecrete. He indicated that some other important factors affect the strenth of cement-stabilised soil such as cement content, particle of soil, type of soil, uniformity of mix, airing period and condition of curing/2/.

There has been an attempt to replace sand in the normal concrete by laterite fines, which is referred to as laterised concrete. In his research, cement, laterite fines and gravel were mixed in the following proportion by weight - 1:1:2, 1:1½: 3, 1:2:4 and he observed the followings//3/.

a) Laterised concrete requires more water than normal concrete/3/.

b) In considering the compressive strenth with w/c ratio, the laterised concrete will be too dry if the w/c ratio is less than 0.50 and too wet if higher than 1.0 for the mix proportions (1:2:4, 1:1:5:3, and 1:1:2), whereas it was possible to consider that of concrete between the w/c ration of 0.3 and 1.2/3/.

c(i) The minimum and naximum w/c ratio for 1:2:4 mix by weight of laterised concrete are 0.65 and 0.95, respectively/3/.

c(ii) For 1:1½ :3 and 1:1:2 mix are 0.55 and 0.85, respectively/3/.

d) For practical purposes, a w/c ratio of about 0.75 is recommended for 1:2:4 mix by weight since this would yield a compressive strength of 18.5N/mm² in 28 days and w/c ratio of about 0.65 for 1:1:5:3 and would yield compressive strength of about 21.45N/mm² and 23.59N/mm² for 1:1:2 in 28 days. In this test, it was observed that the compressive strength at 7 days was about 40-60% that of 28 days, whereas at 14 days the compressive strength was about 70-80% that of 28 days/3/.

The Building Research Liaison Services in Melbourne reported that the compressive strength of the masonry depends on the compressive strength of the masonry units and the mortar between them. Very strong mortar will not reinforce weak units. It is pointless to match the strengths of mortar and masonry units if the adhesion between the two is poor/4/.

The National Building Studies, London 1953 proposed that in dealing with clay bricks, it is best tested (compressive strength) by filling the frogs with cement mortar and the top bottom faces made plane and parallel with mortar. However, with sand-lime bricks the faces and frog outline are by virtue of the process of manufacture, sharp and square and there is no difficulty in determining the area of application of load. The ratio between the wet and dry strengths, usually known as the wet/dry strength ratio is rather low for sand-lime bricks, ranging from 0.6 - 0.75. Sandlime bricks are practically saturated after soaking in water for 24 hours which is the standard time for soaking for the wet compressive strength/5/.

However, the same Building Studies Special Report No.4 says that the strength of dry sand-lime bricks and concrete bricks is from 30 - 50% higher than when saturated. The two type of bricks differ in their respect from clay bricks which do not vary much in strength between the two extremes. In the compressive strength test, twelve bricks are usually tested after soaking in water for 24 hours. The uniformity of such results are calculated as the average of the lowest 7 values (or the lowest 60% of the sample if other than twelve bricks are tested), expressed as a percentage of the average of the whole sample/5/.

In another bulletin No.1, the National Building Studies, London has this to say about the compressive strength of clay building units. The bricks are tested for compressive strength by filling the frogs with 1:1½:5 cement mortar and compressed between thin plywood sheets. The cubes of the mortar are required to reach a strength between 27.59 and 41.38 MN/m^2 before the bricks are tested in compressive machine.

- The lowest wet strength ($1.39 N/mm^2$) in the test result was obtained when the blocks are put in water after an age of 12 hours for a day prior to drying and re-immersing for testing while the highest wet strength ($2.51 N/mm^2$) was obtained when the blocks are put in water after an age of 24 hours for 7 days. For practical purpose, the curing of the blocks should be after 24 hours of age and put in water for 3 days prior to drying and immersing for test. Blocks of specimen put in water after an age of 24 hours for 3 days increased the minimum wet strength. There is an increase in strength of between 70 - 60% over and above those cured in water after 48 hours referred to above if the specimen were sprayed with water/8/.

For the standard purpose, a sample size of ten blocks for the compressive strength test is proposed with the lowest individual wet strength of $1.5 N/mm^2$ and an average wet strength of $2.0 N/mm^2$/8/.

Lunt /7/ put forward that a minimum wet compressive strength of about $1.4 N/mm^2$ has been recommended by several building authorities throughout the world for stabilised soil blocks. The average value of $2.0 N/mm^2$ could be more exact when compared to $2.10 N/mm^2$ as proposed by FMW since $2.0 N/mm^2$ is about the same as $2.10 N/mm^2$.
Musa /9/ found that the overall dry development strength value for Kano State is $0.58 N/mm^2$ and the wet development strength is $0.39 N/mm^2$ (that is, about 67% of the dry development strength value).
According to the British Standard/10/, the average compressive strength of the sample and the corresponding lowest compressive strength of any individual block shall not be less than $3.5 N/mm^2$ and $2.8 N/mm^2$, respecitvely. The strength for blocks when tested in accordance with the NIS/11/ should not be less than $3.45 N/mm^2$ and the weakest individual block in the test sample must not be less than $2.59 N/mm^2$.

It was pointed out that bricks from a single source may vary widely in strength and it is not unusual for a batch of twelve common bricks with a mean strength of about 20.69MN/m2. Due to these variations, it is a mistake to attach too much importance to small differences between the figures that may be reported for alternative of bricks. This may be due to some part to the random imperfections in their structure (atomic structure)/6/.

The mortar to be used should not be stronger than the blocks themselves, as weak mortar accommodates movement and so reduces the possibility of cracking of the blocks. The use of weak mortar is normal practice for other materials of relatively high strinkage, such as certain classes of calcium silicate bricks or concrete blocks. The Building Research Establishment also carried out an experiment on two Ghanian Soils with lime as a stabilising material/7/. The results show that the improvements in strength of Kumasi and Fumesua soil blocks were oberved from 1.05 - 3.55N/mm² and 0.7 - 3.05N/mm², respectively as their compaction pressure was increased.

According to STEPHEN/8/, the sandcrete/soilcrete hollow block will fully develop its dry compressive strength after curing by spraying with water and covering with water proof materials for about a week. The hydration process at this time can be said to be partially completed although it still continues it diminishes with time for the dry strength. Furthermore, he concluded that the soilcrete hollow blocks have a ratio of average wet compressive strength to dry of 0.65. When the blocks are better cured, the constant wet compressive strength to dry strength could be up to 0.8N/mm² and fairly cured could be up to 0.6N/mm². The value of the ratio could drop as low as 0.4 when the curing period is bad. Practically, a value of 0.70 ratio could be obtained when the curing is moderate. The value of 0.65 ratio of constant wet strength to dry strength is good enough to be representative value since it is the average value. Moreso, he concluded that soilcrete hollow blocks have a minimum wet compressive strength to dry compressive strength ratio of 0.42 was the average ratio value for the different percentages of the cement content. It is therefore representative for the soilcrete hollow blocks. In addition, he stated that for the purpose of laboratory tests, the immersion period of 24 hours in water prior to testing for the wet compressive strength should be adopted for the soilcrete hollow blocks. The 24-28 hours immersion in water is critical in the wet compressive strength of the blocks. Since this immersion period gives the minimum wet compressive strength value, it therefore presents the worst conditions. The worst conditions here could be that after using the blocks for building, especially during rainy season, it rained overnight and the whole site is flooded with rain water for at least one day. The lowest wet compressive strength of the blocks or the lowest bearing capacity of the masonry wall will be envisaged practically in such cases. The minimum wet compressive strength is always seen as the lowest part of the graph in the wet compressive strength. Finally, he concluded that for standard curing, when other factors are tested, the blocks should be, after 24 hours of age put in water for 3 days and dried in atmospheric conditions until it is 27 days of age. The curing as applied to 8% cement content blocks by putting in water after an age of 6, 12, 24 and 48 hours for 1, 3, and 7 days and dried before immersion for 24 hours prior to testing showed that putting the blocks after 6 and 12 hours of age in water do not increase the strength much, rather it is more or less the same. Test results show that the increase in wet strength ranges from 30 - 40% for the age of 6 and 12 hours.

However, the Federal Ministry of Works agreed on an average compressive strength of $2.1N/mm^2$ and the lowest individual strength of $1.7N/mm^2$/12/. But Ezetah/13/ found the average dry development strength at 28 days to be $2.35N/mm^2$ and the wet development strength at 28 days of $1.37N/mm^2$. Florek/14/ found the average compressive strength of $2.43N/mm^2$ for some sandcrete hollow blocks tested in Northern Nigeria.
Recently, Alaaga and Alhassan/15/produced blocks of 1:3:6 mix and found the compressive strength at 28 days to be $3.5N/mm^2$. To attain such a high strength they had to mix the sand and cement with gravels of up to 10mm size.

According to the Nigerian Industrial Standard (1974)/11/, the sand to be used for producing sandcrete hollow 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 (BS 882). If Lagoon sand is used this unit must be properly washed to approval of Engineer or Architect.

CHAPTER THREE

3.0 METHOLODOGY AND EXPERIMENTAL SET UP

The method employed is broken down into three:

(i) Survey of existing industries and collection of samples

Although, there are many existing industries in Benue State, thirty of them were visited for information on mix proportion, production capacity, curing, materials used, type of equipment, cost per block, the size and experience of the workers.

From observation, twenty four of the block industries visited use block moulding machines for production while the remaining six produce the blocks manually. Most of these industries use a mix of one part of cement to ten parts of sharp sand and two parts of plaster sand by volume for producing the blocks. On average, the size of workers is ten with only one or two skilled men and the remaining are unskilled labourers. The production usually commences around seven O'clock in the morning and continues until about six O'clock in the evening. Between eight hundred to over a thousand blocks are produced daily and are sold at an average of Twenty five Naira only. In all the industries visited, curing periods range from one to three days depending on the demand for the blocks. The cement used in all these industries is Benue cement, the sand from the Benue River, and the water from Water Board. For the collection of block samples, five prominent block industries are selected from the thirty visited. Basically, these five are selected because they have better production machines, large production capacity, more experienced workers and are fairly scattered within the state. They are located within the following places:

i. Gbajiba town about fifty kilometres North-East of Makurdi and labelled A.

ii. Otukpo town about ninety kilometres South-West of Makurdi and labelled B.

iii. Gboko town about eighty kilometres South-West of Makurdi and labelled C.

iv. Alaide town about sixty kilometres South of Makurdi and labelled D.

v. Makurdi town, the headquarter of Benue State and the most propulated; labelled E.

The labelling (A,B, C, D and E) are only for identification and has nothing to do with the quality of blocks.
In each industry, fifty blocks were randomly chosen and a total of two hundred and fifty blocks are tested.

Industry A

This uses silty sand in producing the blocks and the cement is Benue Cement. A mix ratio of one part of cement to twelve parts of sand (1: 12) by volume is used. About one thousand blocks are produced daily using the moulding machine and cured for three days by spraying water once a day. The blocks are sold for Twenty five naira each.

The owner of the industry and his workers are not Engineers, but learnt to produce blocks by experience. They are ignorant of the standard requirements of their finished products. The staff strength is ten. Two moulding machines are used. Water is supplied by water tanker from Water Board.

Industry B

On special orders, sand is mostly transported from Makurdi to this industry for producing blocks and the cement is Benue Cement. For normal production, the sand is taken from a place outside the town. The industry uses a mix ratio of one part of cement to ten parts of sharp sand and two parts of plaster sand by volume. But for special orders, a mix ratio of 1:10 is used. On average, over one thousand blocks are produced daily by use of block moulding machines and a workforce of twelve. The blocks are cured for a maximum of three days by spraying with water once a day and stacked over five blocks high because of inadequate space. The blocks are sold at Twnety five naira fifty kobo. The operators of the industry learnt production by experience. Two moulding machines are used. Water is supplied from Water Board in tankers.

Industry C

The sand, visibly lateritic in nature, is obtained from a pit outside the town and the cement is Benue Cement. A mix ratio 1:10 by volume is mostly used to produce about one thousand blocks which are cured for three days and sold at Twenty four naira fifty kobo each. The workforce is ten and no engineers amongst them. The required quality is unknown to them because through experience they simply adopt the mix ratio that has been used by previous block makers, having in mind quantity as their goal. Two moulding machines are used. Water is supplied from the water Board.

Industry D

Sharp sand is usually obtained from Makurdi for producing blocks and the cement is Benue Cement. A mix ratio of 1:12 by volume is mostly used and the production capacity is about eight hundred. With a workforce of eight, the blocks are cured for two days depending on the demand. Each block is sold at Twenty five naira. The block makers learnt production by experience and not through formal education. Two moulding machines are used. Water is supplied from Water Board.

Industry E

This uses sharp sand that is obtained from the River Benue for producing the blocks and the cement is Benue Cement.

A mix ratio of one part of cement to ten parts of sharp sand is used. With three block moulding machines and a labour force of fifteen workers, nearly two thousand blocks are produced daily and are cured for three days by spraying water once daily. The blocks are sold at Twenty four naira, fifty kobo each. There are no engineers in this industry. The owner and his workers learnt production through experience. They are ignorant of the various specifications of the approved standards. Nevertheless, this industry has the highest work force, production capacity, best quality sand, and more experienced workers than others.

ii) From the information on the survey conducted, five major industries are selected from which samples of blocks are taken for detailed studies. These studies include:

a) Sieve analysis of sand

b) Experimental analysis of the block samples to ascertain the physical and mechanical properties of the blocks.

c) Comparative analysis using local and international standards and works of previous studies.

3.1 Materials

(a) Cement - the cement is Benue cement.

(b) Water - tap water is used for the block production in all the industries.

(c) Sand - Sieve analysis and silt content tests were done on the sand samples collected from all the industries and the results are as follows:-

(i) Sieve Analysis

The results obtained from the sieve analysis for all the industries are as follows (Tables 1- 5):

TABLE 1 - SIEVE ANALYSIS FOR INDUSTRY A

BS Sieve size (mm)	Weight Retained (g)	Cumm.wt Retained (g)	Cumm.Percentage weight Retained (g)	Percentage passing (%)
20.00	-	-	-	100.00
9.50	60	60	1.5	98.50
6.30	88	148	3.7	96.30
2.00	92	240	6.0	94.00
1.40	56	296	7.4	92.60
1.18	156	452	11.3	88.70
0.60	428	880	22.0	78.00
0.425	796	1676	41.9	58.10
0.30	716	2392	59.8	40.20
0.212	728	3120	78.0	22.00
0.150	360	3480	87.0	13.00
0.063	340	3820	95.5	4.50
Receiver	20	3840		

TABLE 2 - SIEVE ANALYSIS FOR INDUSTRY B

BS Sieve size (mm)	Weight Retained (g)	Cumm.wt Retained (g)	Cumm.Percentage weight Retained (g)	Percentage passing (%)
20.00	-	-	-	100.00
9.50	20	20	0.5	99.5
6.30	84	104	2.6	97.4
2.00	272	376	9.4	90.6
1.40	152	528	13.2	86.8
1.18	124	652	16.3	83.7
0.60	1944	2596	64.9	35.1
0.425	520	3116	77.9	22.1
0.30	308	3424	85.6	14.4
0.212	196	3620	90.5	9.5
0.150	212	3832	95.8	4.2
0.063	60	3892	97.3	2.7
Receiver	7	3899		

TABLE 3 - SIEVE ANALYSIS FOR INDUSTRY C

BS Sieve size (mm)	Weight Retained (g)	Cumm.wt Retained (g)	Cumm.Percentage weight Retained (g)	Percentage passing (%)
20.00	-	-	-	100.00
9.50	80	80	2.0	98.0
6.30	24	104	2.6	97.4
2.30	404	508	12.7	87.3
1.40	124	632	15.8	84.2
1.18	84	716	17.9	82.1
0.60	848	1564	39.1	60.9
0.425	724	2288	57.2	42.8
0.30	248	2536	63.4	36.5
0.212	116	2652	66.3	33.7
0.150	132	2784	69.6	30.4
0.063	336	3120	78	22.0
Receiver	10	3130		

TABLE 4 - SIEVE ANALYSIS FOR INDUSTRY D

BS Sieve size (mm)	Weight Retained (g)	Cumm.wt Retained (g)	Cumm.Percentage weight Retained (g)	Percentage passing (%)
20.00	-	-	-	100.00
9.50	36	36	0.90	99.1
6.30	72	108	2.7	97.3
2.00	832	940	23.5	76.5
1.40	152	1092	27.3	72.7
1.18	152	1244	31.1	68.9
0.60	1464	2708	67.7	32.3
0.425	476	3184	79.6	20.4
0.30	192	3376	84.4	15.6
0.212	232	3608	90.2	9.8
0.150	220	3828	95.7	4.3
0.063	68	3896	97.4	2.6
Receiver	14	3910		

TABLE 5 -- SIEVE ANALYSIS FOR INDUSTRY E

BS Sieve size (mm)	Weight Retained (g)	Cumm.wt Retained (g)	Cumm.Percentage weight Retained (g)	Percentage passing (%)
20.00	-	-	-	100.00
9.50	-	-	-	100.00
6.30	-	-	-	100.00
2.00	308	308	7.7	92.3
1.40	180	488	12.2	87.8
1.18	88	576	14.4	85.6
0.60	1820	2396	59.9	40.1
0.425	712	3108	77.7	22.3
0.300	356	3464	86.6	13.4
0.212	180	3644	91.1	8.9
0.150	176	3820	95.5	4.5
0.063	116	3936	98.4	1.6
Receiver	24	3960		

(ii) Silt Content - The test was done according to BS 812:1:1975 For each sample of sand a one percent solution of common salt in water was prepared, and 50ml of it was put into a measuring cylinder. The sample of sand was then added until the cylinder contained 100ml of the mixture. A further 50ml of the salt solution was added and after the cylinder had been vigorously shaken, it was placed on a level surface for the sand surface to level up and allowed to stand for three hours. The silt content could be seen clearly as a layer of a different colour and texture on top of the sand. The silt content was calculated as follows:

$$\text{silt content} = \frac{h_2 - h_1}{h_1} \times 100\%$$

Where h_1 = height of the sand surface from the bottom of the cylinder, and h_2 = height of the silt surface.

The results obtained from the silt content analysis are as follows (Table 6):

Table 6- Silt content:

Industry	A	B	C	D	E
Silt content (%)	6	5	20	5	4

3.2 Experimental Analysis of the Block Samples

Fifty blocks were selected at random from each of the industries A, B, C, D, and E making a total of two hundred and fifty blocks for the test. The tests were carried out in the Civil Engineering laboratory of the University of Agriculture, Makurdi between the beginning of March and ending of April, 1992.

The following tests are the tests carried out to ascertain the quality of the blocks:

(i) dry and wet development strength test,

(ii) Wet compressive (bedded) strength test,

(iii) density,

(iv) drying shrinkage and wetting expansion,

(v) dimensional measurements/tolerance.

(i) <u>Dry development compressive Strength test</u>

Freshly produced blocks were lifted from the industries after they were cured for three days. In the laboratory environment, the blocks were left to dry as if still in the block industry. They were then tested for dry development strength according to BS 2028/10/and NIS/11/. In brief, the dry development strength test is done by crushing the blocks on the same day they reached the laboratory and after drying for 7, 14, 21 and 28 days. For each specified period, three blocks are crushed and the average strength recorded. The significance of this test is to study the strength behaviour of the blocks in the conditions they are normally produced, cured and dried by the commercial block makers, without subjecting them to further curing beyond the three day period done at the site. Find the results of the tests in Tables 7 - 11 below. For the raw data, see the appendix (Tables 38 - 42).

TABLE 7- DRY DEVELOPMENT COMPRESSIVE STRENGHT FOR INDUSTRY A

S/NO	AVERAGE LENGHT (mm)	AVERAGE BREADTH (mm)	AGE Days	AVERAGE FAILURE LOAD (KN)	AVERAGE DRY COMPRESSIVE
1	458	227	3	23	0.22
2	458	228	7	27	0.26
3	457	228	14	44	0.42
4	458	227	21	48	0.46
5	458	227	28	52	0.50

TABLE 8 - DRY DEVELOPMENT COMPRESSIVE STRENGHT FOR INDUSTRY B

S/NO	AVERAGE LENGHT (mm)	AVERAGE BREADTH (mm)	AGE Days	AVERAGE FAILURE LOAD (KN)	AVERAGE DRY COMPRESSIVE
1	457	228	3	34	0.33
2	458	228	7	47	0.45
3	456	228	14	49	0.47
4	457	228	21	57	0.55
5	459	228	28	61	0.58

TABLE 9 - DRY DEVELOPMENT COMPRESSIVE STRENGHT FOR INDUSTRY C

S/NO	AVERAGE LENGHT (mm)	AVERAGE BREADTH (mm)	AGE Days	AVERAGE FAILURE LOAD (KN)	AVERAGE DRY COMPRESSIVE
1	458	228	3	35	0.33
2	457	227	7	53	0.51
3	458	227	14	57	0.55
4	458	228	21	65	0.62
5	457	228	28	65	0.63

TABLE 10 DRY DEVELOPMENT COMPRESSIVE STRENGHT FOR INDUSTRY D

S/NO	AVERAGE LENGHT (mm)	AVERAGE BREADTH (mm)	AGE Days	AVERAGE FAILURE LOAD (KN)	AVERAGE DRY COMPRESSIVE
1	457	228	3	21	0.20
2	456	228	7	33	0.31
3	457	228	14	43	0.41
4	458	228	21	49	0.47
5	458	228	28	51	0.49

TABLE 11 DRY DEVELOPMENT COMPRESSIVE STRENGHT FOR INDUSTRY E

S/NO	AVERAGE LENGHT (mm)	AVERAGE BREADTH (mm)	AGE Days	AVERAGE FAILURE LOAD (KN)	AVERAGE DRY COMPRESSIVE
1	458	228	3	30	0.29
2	457	227	7	39	0.38
3	458	227	14	54	0.52
4	458	228	21	61	0.58
5	457	228	28	65	0.63

(ii) Wet development compressive strenght test

After 28 days of production, the block samples are lifted from the industry and cured for the periods specified before crushing. The wet development strenght is obtained by crushing the blocks after soaking in water for 1,3,7,14,21, and 28 days. For each specified period, three blocks are crushed and the average strength recorded. The significance of this test to study the strength behaviour of the blocks after subjecting them to further curing unlike the condition which they are normally subjected to on site. This test is expected to reveal the effect of inadquate curing period, which is further hydration. The results of this test are on Tables 12-16 below. However, the raw data are on tables 43-47 in the appendix.

TABLE 12 - WET DEVELOPMENT COMPRESSIVE STRENGHT FOR INDUSTRY A

S/NO	AVERAGE LENGHT	AVERAGE BREADTH (mm)	AGE Days	AVERAGE FAILURE LOAD (KN)	AVERAGE WET COMPRE. STREN.
1	459	224	1	21	0.20
2	460	230	3	22	0.21
3	460	230	7	34	0.32
4	460	229	14	42	0.42
5	459	230	21	52	0.49
6	460	229	28	57	0.54

TABLE 13 - WET DEVELOPMENT STRENGTH FOR INDUSTRY B

S/NO	AVERAGE LENGTH	AVERAGE BREADTH	AGE (days)	AVERAGE LOAD (KN)	AVERAGE WET COMPRE. STRENGTH
1	460	229	1	32	0.30
2	459	230	3	35	0.33
3	459	229	7	50	0.47
4	460	230	14	57	0.54
5	460	229	21	58	0.55
6	460	230	28	59	0.56

TABLE 14 - WET DEVELOPMENT STRENGTH FOR INDUSTRY C

S/NO	AVERAGE LENGTH	AVERAGE BREADTH	AGE (days)	AVERAGE LOAD (KN)	AVERAGE WET COMPRE. STRENGTH
1	460	229	1	29	0.28
2	459	229	3	30	0.29
3	459	230	7	43	0.41
4	459	229	14	53	0.51
5	460	230	21	61	0.57
6	460	229	28	62	0.59

TABLE 15 - WET DEVELOPMENT STRENGTH FOR INDUSTRY D

S/NO	AVERAGE LENGTH	AVERAGE BREADTH	AGE (days)	AVERAGE LOAD (KN)	AVERAGE WET COMPRE.STRE
1	460	229	1	34	0.32
2	460	229	3	35	0.33
3	460	229	7	48	0.45
4	460	230	14	59	0.56
5	460	229	21	61	0.58
6	459	230	28	62	0.59

TABLE 16 - WET DEVELOPMENT STRENGTH FOR INDUSTRY E

S/NO	AVERAGE LENGTH	AVERAGE BREADTH	AGE (days)	AVERAGE LOAD (KN)	AVERAGE WET COMPRE.STRE
1	459	230	1	40	0.38
2	460	229	3	42	0.40
3	460	230	7	57	0.54
4	460	229	14	61	0.57
5	460	230	21	71	0.67
6	459	229	28	71	0.68

(iii) Wet Compressive (bedded Stength Test

Ten blocks are selected at random and tested in accordance with Clause 16 of BS 2028/10/. In the dry and wet development test, the faces of the blocks are not bedded with mortar. In this test the two faces of the blocks are bedded mortar made up of a part of cement to a part of sand (1:1) by volume. The curing period and crushing age are determined by the age on which the 75mm mortar cubes attain a minimum strength of 27.58N/mm² and a maximum of 41.38N/mm. In this test the mortar cube attained a strength of 30.46mm² in 7 days (See Table (17). Hence, the blocks were crushed after 7 days. The results of the test are shown on Tables 18-22 below. The raw data are on tables in the appendix. The average wet compressive (bedded strengths, for industries A, B, C, D, and E are 0.42, 0.45, 0.40 and 0.41N/mm², respectively. The average standard deviations are 0.01, 0.04, 0.02 and 0.02N/mm² with coefficient of various of 2.40, 8.90, 5.0 and 4.90 percent for A,B,C,D and E, respectively.

TABLE 17 - WET COMPRESSIVE STRENGTH OF 75mm MORTAR CUBE (1:1 MIX)

S/NO	Age (days)	Failure Load (KN)	Wet Strength (N/mm²)	Average wet Strength
1		124	22.04	
2	2	126	22.40	
3		120	21.33	21.92
4		140	24.89	
5	5	146	25,96	
6		144	25.60	25.48
7		172	30.58	
8	7	170	30.22	
9		172	30.58	30.46

TABLE 18 - WET COMPRESSIVE (BEDDED) STRENGTH FOR INDUSTRY A

S/NO	LENGTH	BREADTH	FAILURE	WET COMPRE.
1	460	230	42	0.40
2	458	228	46	0.44
3	460	230	44	0.42
4	460	231	45	0.41
5	460	228	45	0.43
6	460	230	42	0.40
7	458	230	46	0.44
8	460	230	45	0.43
9	458	228	44	0.42
10	460	230	44	0.42

TABLE 19 - WET COMPRESSIVE (BEDDED) STRENGTH FOR INDUSTRY B

S/NO	LENGHT (mm)	BREADTH (mm)	FAILURE LOAD(KN)	WET COMPR.
1	460	230	56	0.53
2	458	228	40	0.38
3	460	230	48	0.45
4	458	231	42	0.40
5	460	228	48	0.46
6	460	230	46	0.43
7	460	228	48	0.46
8	460	230	50	0.47
9	458	230	44	0.42
10	460	230	48	0.45

TABLE 20 - WET COMPRESSIVE (BEDDED) STRENGTH FOR INDUSTRY C

S/NO	LENGHT	BREADTH	FAILURE	WET COMPR
1	460	230	40	0.38
2	458	230	44	o.42
3	458	230	42	0.40
4	460	231	44	0.41
5	460	230	42	0.40
6	460	229	42	0.40
7	461	230	40	0.38
8	459	230	44	0.43
9	458	230	44	0.42
10	460	230	42	0.40

TABLE 21- WET COMPRESSIVE(BEDDED)STRENGTH FOR INDUSTRY D

S/NO	LENGHT (mm)	BREADTH (mm)	FAILURE LOAD (KN)	WET STRE
1	459	230	40	0.38
2	458	230	44	0.42
3	460	230	44	0.42
4	460	230	42	0.40
5	460	228	46	0.44
6	460	230	40	0.38
7	459	228	42	0.40
8	458	230	44	0.42
9	460	230	42	0.40
10	460	230	40	0.38

TABLE 22 - WET COMPRESSIVE(BEDDED)STRENGTH FOR INDUSTRY E

S/NO	LENGHT (mm)	BREADTH (mm)	FAILURE LOAD (KN)	WET STRE
1	460	230	40	0.38
2	459	228	46	0.44
3	458	230	44	0.42
4	460	230	46	0.43
5	460	230	44	0.42
6	460	228	46	0.44
7	460	230	42	0.40
8	460	230	44	0.40
9	458	230	44	0.42
10	459	230	40	0.38

(vi) DENSITY

Fifteen blocks from each industry were selected at random, measured and weighed in accordance with Clause 16 of the British Standard 2028/10/. The results obtained are shown below on tables 23-27. The significance of this test is to ascertain that the densities of the blocks conform with the required standard specifications. See the raw data of results in table 48-52 in the appendix.

TABLE 23 - DRY DENSITY FOR INDUSTRY A

S/No	ave.wt (kg)	ave.vol (m)	age (days)	ave.days dens (kg/m^3)
1	23.15	0.0228	3	1020
2	23.34	0.0228	7	1023
3	24.85	0.0225	14	1100
4	25.33	0.0226	21	1102
5	25.35	0.0228	28	1110

TABLE 24 - DRY DENSITY FOR INDUSTRY B

S/No	ave.wt (kg)	ave.vol (m)	age (days)	ave.days dens (kg/m^3)
1	24.73	0.0230	3	1075
2	25.00	0.0231	7	1082
3	25.12	0.0230	14	1091
4	25.28	0.0231	21	1094
5	25.80	0.0231	28	1117

TABLE 25 - DRY DENSITY FOR INDUSTRY C

S/No	ave.wt (kg)	ave.vol (m)	age (days)	ave.days dens (kg/m³)
1	21.80	0.0228	3	956
2	22.42	0.0227	7	986
3	22.68	0.0227	14	1000
4	24.60	0.0228	21	1078
5	25.17	0.0227	28	1106

TABLE 26 - DRY DENSITY FOR INDUSTRY D

S/No	ave.wt (kg)	ave.vol (m)	age (days)	ave.days dens (kg/m³)
1	23.52	0.0227	3	1036
2	23.89	0.0228	7	1046
3	24.00	0.0227	14	1056
4	24.62	0.0229	21	1073
5	25.18	0.0227	28	1111

TABLE 27 - DRY DENSITY FOR INDUSTRY E

S/No	ave.wt (kg)	ave.vol (m)	age (days)	ave.days dens (kg/m³)
1	24.17	0.0228	3	1060
2	24.37	0.0227	7	1072
3	24.73	0.0230	14	1074
4	24.88	0.0229	21	1095
5	25.95	0.0229	28	1143

(v-) DRYING SHRINKAGE

Three blocks were randomly selected from each of the five industries and tested in accordance with Clause 16 of the British Standard 2028x(1985)/10/. The significance of this test is to study the shrinkage tolerance of the blocks. The results obtained are shown below in tables 28-32

TABLE 28 - DRYING SHRINKAGE FOR INDUSTRY A

S/NO	wet length (mm)	dry length (mm)	ave wet length(mm)	wet dry length(mm)	drying Shrink
1	150.05	149.99			
2	150.06	149.98			
3	150.04	149.97	150.05	149.98	0.05

TABLE 29 - DRYING SHRINKAGE FOR INDUSTRY B

S/NO	wet length (mm)	dry length (mm)	ave wet length(mm)	wet dry length(mm)	drying Shrink
1	150.03	149.99			
2	150.04	149.98			
3	150.05	150.0I	150.04	149.99	0.03

TABLE 30 - DRYING SHRINKAGE FOR INDUSTRY C

S/NO	wet length (mm)	dry length (mm)	ave wet length(mm)	wet dry length(mm)	drying Shrink
1	150.01	149.97			
2	150.03	149.99			
3	150.04	149.97	150.03	149.03	0.03

TABLE 31 - DRYING SHRINKAGE FOR INDUSTRY D

S/NO	wet length (mm)	dry length (mm)	ave.wet length(mm)	ave.dry length(mm)	drying shr (%)
1	150.03	149.99			
2	150.05	149.98			
3.	150.06	150.98	150.05	149.98	0.05

TABLE 32 - DRYING SHRINKAGE FOR INDUSTRY E

S/NO	wet length (mm)	dry length (mm)	ave.wet length(mm)	ave.dry length(mm)	drying shr (%)
1	150.05	150.00			
2	150.03	150.02			
3.	150.06	150.98	150.05	150.00	0.05

(vi) WETTING EXPANSION

Three blocks were tested accordingly/10/ and the results are shown below in tables 33-37. The significance of this test is study the behaviour of the blocks when subjected to a continously wet environment, such as flood times.

TABLE 33 - WETTING EXPANSION FOR INDUSTRY A

S/No.	dry length (mm)	wet length (mm)	ave.dry length (mm)	ave.wet length (mm)	wetting exp (%)
1	149.99	150.07			
2	149.98	150.08			
3	149.97	150.07	149.98	150.07	0.06

TABLE 34 - WETTING EXPANSION FOR INDUSTRY B

S/No.	dry length (mm)	wet length (mm)	ave.dry length (mm)	ave. wet length (mm)	wetting exp (%)
1	149.99	150.06			
2	149.98	150.07			
3	150.01	150.07	149.99	150.07	0.05

TABLE 35 - WETTING EXPANSION FOR INDUSTRY C

S/No.	dry length (mm)	wet length (mm)	ave.dry length (mm)	ave..wet length(mm)	wetting exp (%)
1	149.97	150.08			
2	149.99	150.09			
3	149.97	150.08	149.98	150.08	0.07

TABLE 36 - WETTING EXPANSION FOR INDUSTRY D

S/No.	dry length (mm)	wet length (mm)	ave.dry length (mm)	ave. wet length(mm)	wetting exp (%)
1	149.99	150.07			
2	149.98	150.08			
3	149.98	150.08	149.98	150.08	0.07

TABLE 37 - WETTING EXPANSION FOR INDUSTRY E

S/No.	dry length (mm)	wet length (mm)	ave.dry length (mm)	ave. wet length(mm)	wetting exp (%)
1	150.00	150.05			
2	150.02	150.07			
3	149.98	150.06	150.00	150.06	0.04

(vii) Dimensional Measurements/Tolerance

These measurements were done in accordance with the British Standard 2028/10/. The results obtained are shown on Tables 38-42 in the appendix. The significance of this study is to assess the various dimensional tolerances achieved by the industries as compared with the limits set by the code. The average dimensions for the blocks are length 458mm, breadth 228mm and height 218mm.

(viii) Blocks made to the Nigerian Industrial Standard Specifications

Three blocks were produced according to the Nigeria Industrial Standard's Specifications/11/for the purpose of comparing with the commercially produced blocks. The blocks were tested after 28 days according to the compressive (bedded strength test. The results obtained are shown below on Table 37A The average strength is $2.33N/mm^2$.

Table 37A: 28 day wet compressive (bedded) strength for 1:6 mix blocks

S/No	L(mm)	B(mm)	Failure Load(KN)	wet str.
1	450	225	218	2.15
2	450	225	233	2.33
3	450	225	258	2.55

CHAPTER FOUR

4.0 ANALYSIS AND DISCUSSION OF RESULTS

4.1 Materials

(i) Sieve Analysis of Sand

Tables 1 - 5 are here translated into figures 1 - 5 for the five industries, respectively.

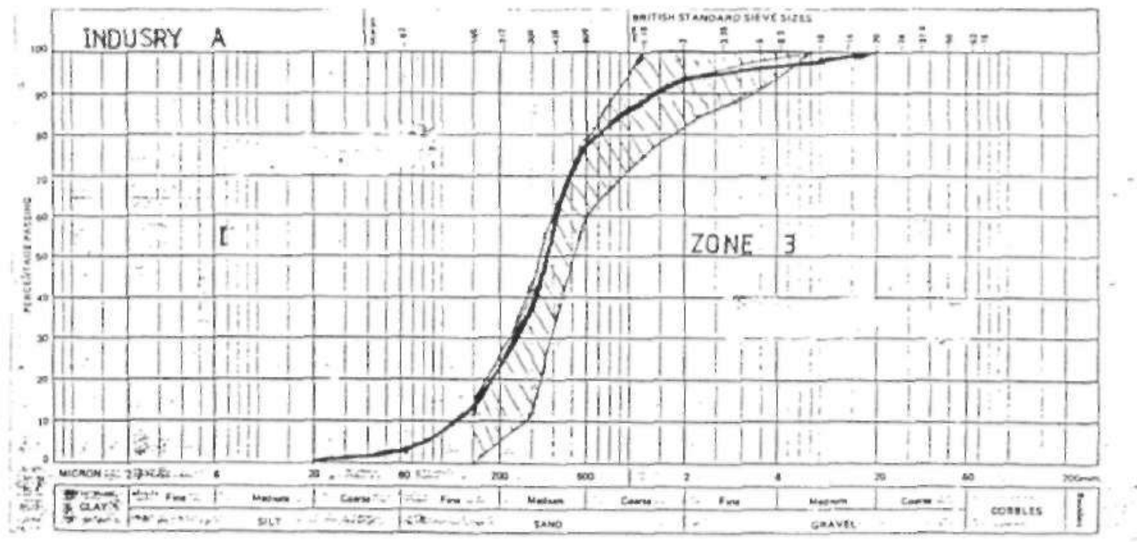

FIGURE 1

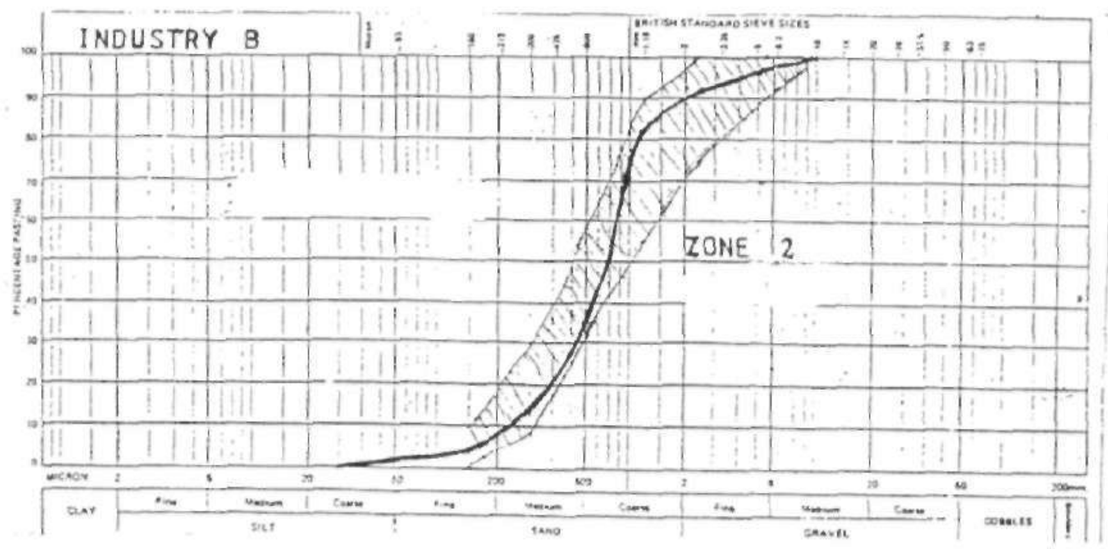

FIGURE 2

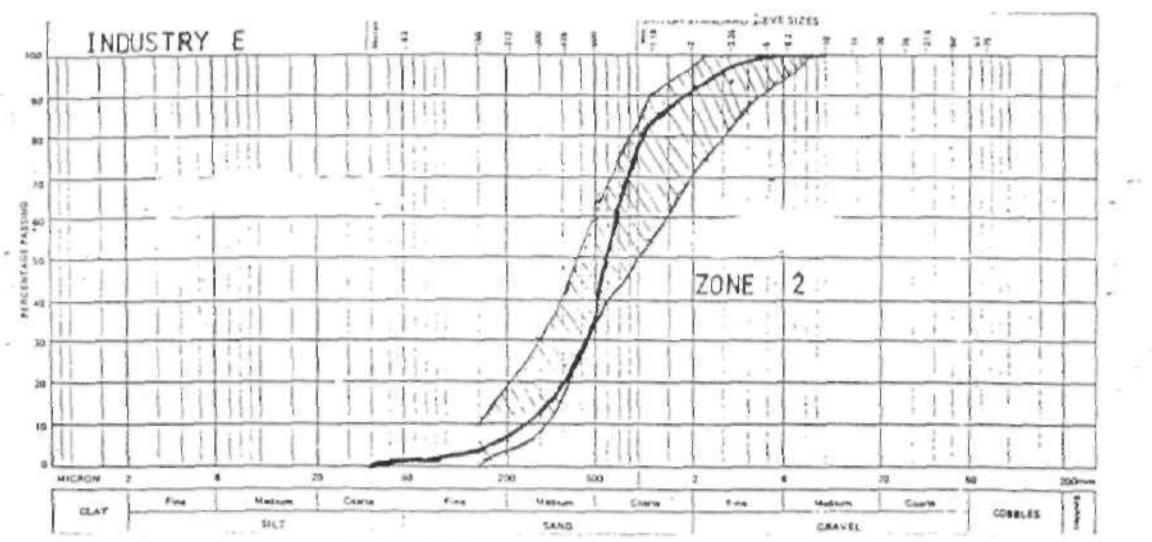

FIGURE 5

According to NIS: 1974/11/the sand to be used for producing sandcrete blocks shall be approved clean, sharp, fresh waster or pit sand free from clay, loam, dirt, organic or chemical matters of any description and shall mainly pass through 4.70mm or fall within zones 1 and 2 of British Standard Test Sieves.

Figures 1 - 5 show that the sand used in A,B,C. D and E fall within zones 3,2,4,1 and 2, respectively. Generally, the sand in all the industries is not clean, contains clay, and silty materials. Sand in A and C does not meet with the standard requirement. The sand in B,D and E fall within satisfactory region, yet they are not visibly clean or pure.

In most blocks, the strength is controlled by the bond between the cement paste and the sand particles. The presence of impurities has adverse effect on the ability of sand to perform its role in the sandcrete block satisfactorily. Their fine particles form coatings on the particles of medium and coarse sand particles, thus weakening the bond with the cement paste, thus reducing the strength of the blocks. Generally, the sand contains a wide range of grain sizes as shown on figures 1-5. The grading of the sand influences the void content thus influencing the strength. Strength decreases as the void content of the block increases. If all the particles are clean and sharp, the small grains will fill up the spaces between the larger grains to make a satisfactory dense materials; but this is not in the case of the sand used in the state. The sand content and the maximum particle size have effects on the strength. For a particular maximum size, there is an upper limit, for the sand content beyond which there will be insufficient cement paste to coat all the particles. As the sand content decreases from this limit, the strength usually decreases. The probable reason for this effect is that with a higher sand content, more water is absorbed in to the sand, thus reducing the free-water content and increasing the strength. The sand used in Kano State fall within zone 1 of the BS Sieves but the strength values are low because of impurities present in it/9/.

(ii) Silt Content

The silt contents of the sand used for producing the blocks in industries A, B, C, D and E are 6,5, 20, 5 and 4 percent respectively (See Table 6).

According to the British Standard (1985) 2028/10/ and the Nigerian Industrial Standard (1975)/11/, the maximum allowable silt content in sand for producing satisfactory sandcrete blocks is 6 percent. Hence, besides the sand used in industry C, all the other industries use sand with acceptable silt content.

The presence of silts has adverse effect on the ability of sand to perform its role in the sandcrete block satisfactorily. Their fine particles form coatings on the particles of medium and coarse sand particles, thus weakening the bond with the cement paste.

4.2. Experimental Analysis

(i) Dry Development Strength

The results of the dry development strength tests (Tables 7-11) are here translated into figures 6 - 11 by plotting the graphs of strength against age.

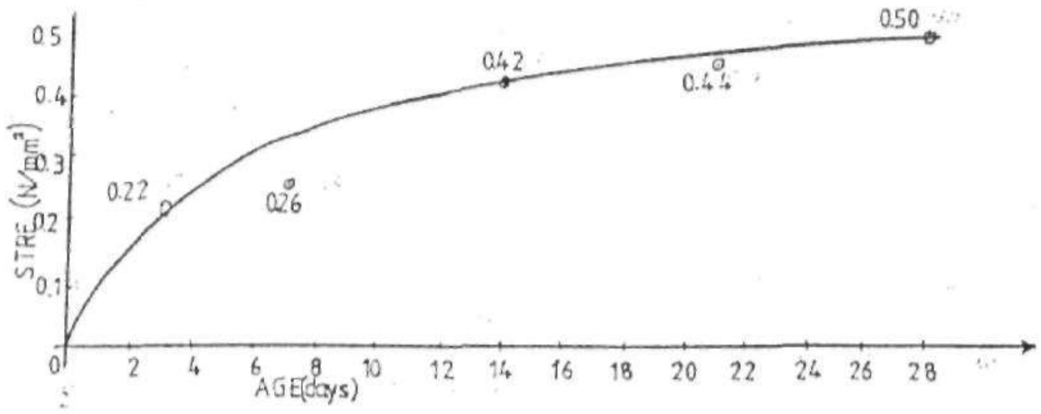

FIGURE 6 - DRY DEVELOPMENT STRENGTH FOR INDUSTRY A

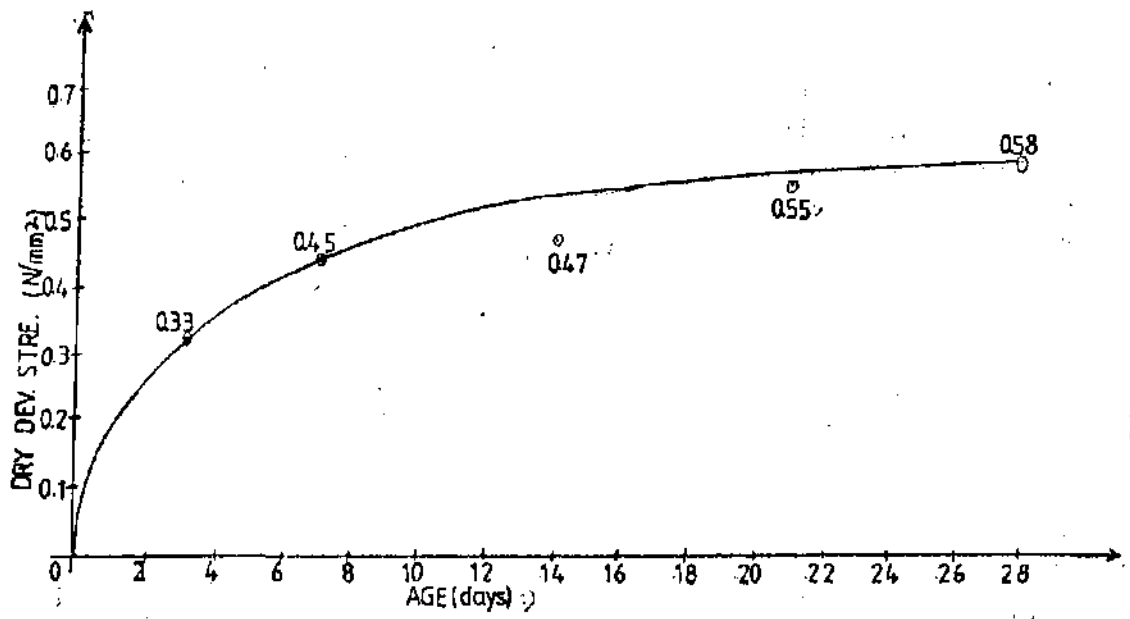

FIGURE 7 - DRY DEVELOPMENT STRENGTH FOR INDUSTRY B

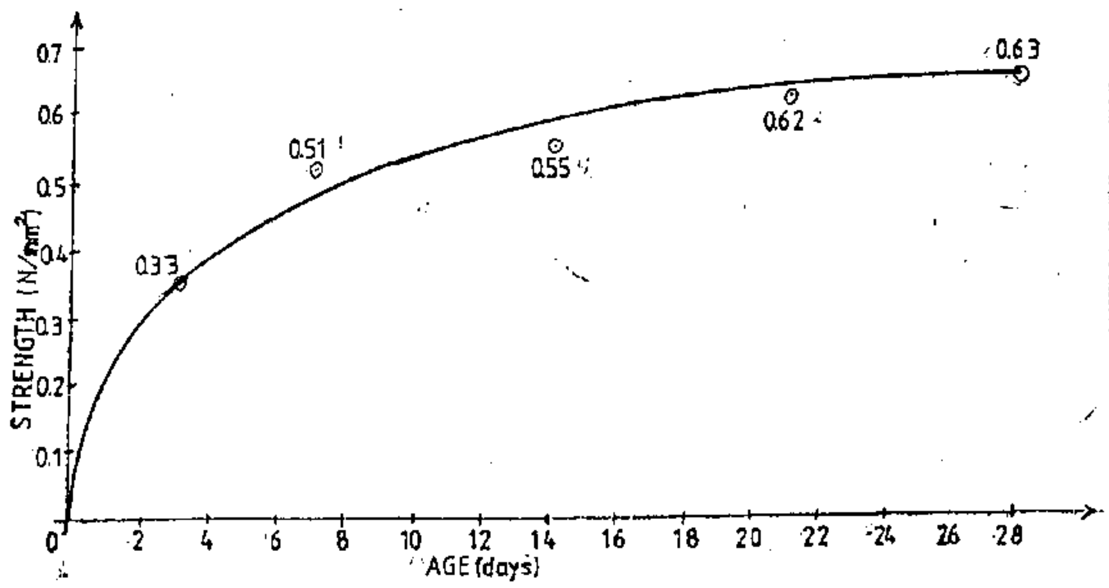

FIGURE 8 - DRY DEVELOPMENT STRENGTH FOR INDUSTRY C

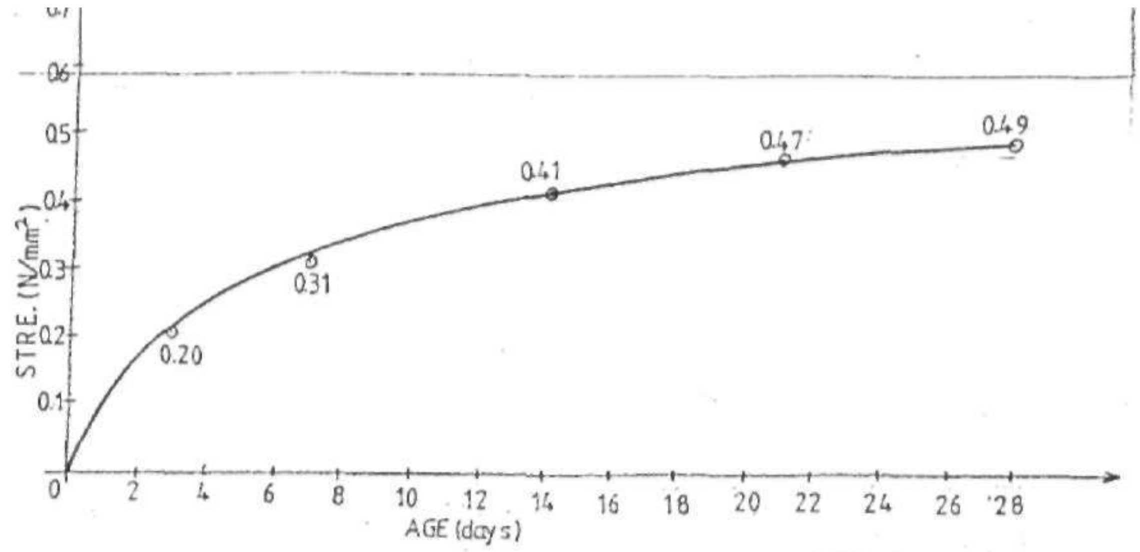

FIGURE 9 - DRY DEVELOPMENT STRENGTH FOR INDUSTRY D

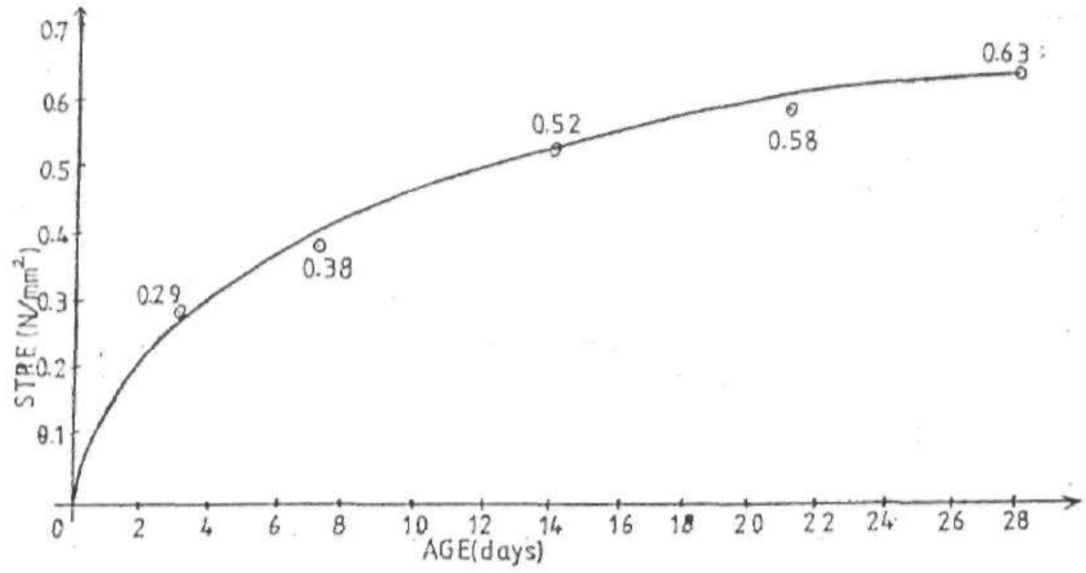

FIGURE 10 DRY DEVELOPMENT STRENGTH FOR INDUSTRY E

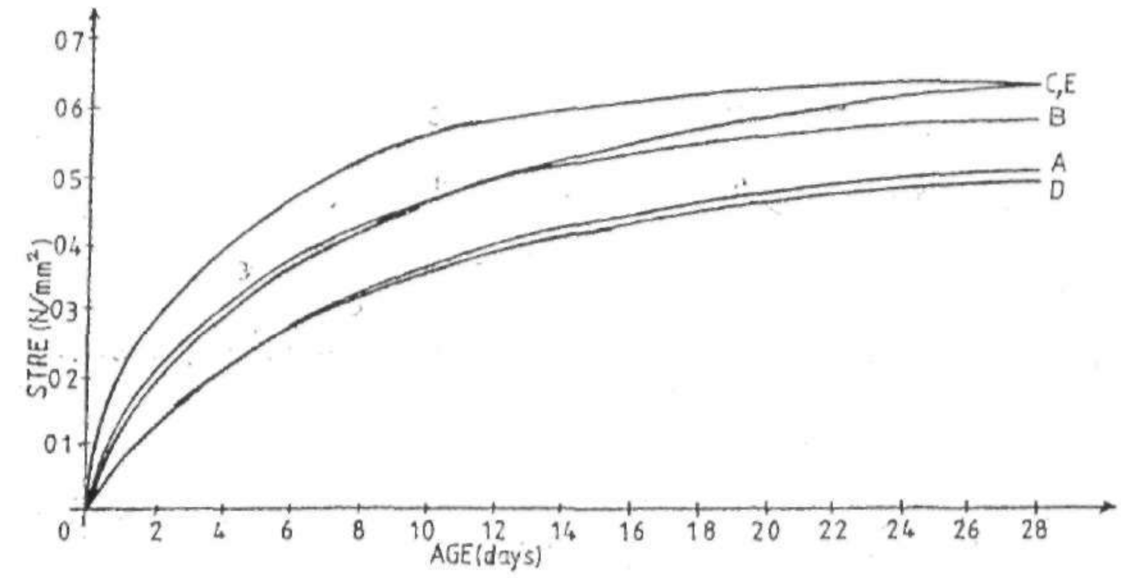

FIGURE 11 DRY DEVELOPMENT STRENGTH COMPARED

In all the industries the graphs are parabolic as earlier obtained in the works of STEPHEN (1982)/8/ and MUSA (1994)/9/. The probable reason for the parabolic curve is that from time to time when the cement paste has set, concrete starts to gain strength. The rate of gain is rapid at first, but it becomes progressively slower. Thus, the graph of strength against age is a parabolic curve. It also indicates that hydration is continuous, but at a diminishing rate. With Ordinary Portland Cement, the block gains little strength after it is twenty-eight days old, and, at an age of seven, its strength, is approximately two-thirds of its 28 day strength/11/. For this work, the average 28 - day dry development strength is $0.57N/mm^2$ with a maximum and minimum values of 0.63 and $0.49N/mm^2$, respectively. The average 7 - day strength is $0.38N/mm^2$ which is about 67% of the 28 - day strength. These values are below the recommended values by Nigerian Industrial Standard 1974 /11/ and the FMW/12/values which are 3.45 and $2.1N/mm^2$, respectively. When compared to similar works, the values fall within the range obtained in Kano, Kogi and Kaduna States. For instance, MUSA (1994)/9/ obtained an overall average dry development strength of $0.5N/mm^2$ after 28 days and the maximum and minimum are 0.92 and $0.46N/mm^2$, respectively.

(i) Wet development strength

Figures 12- 17 are translations of Tables 12 - 16. In all the industries the shape of the graph of strength against age is similar to those obtained by STEPHEN/8/ in 1982 and MUSA/9/ in 1994. Figures 12 - 16 show the graphs for A,B,C,D and E, respectively. Figure 17 is the graph for the collective curves of all the industries.

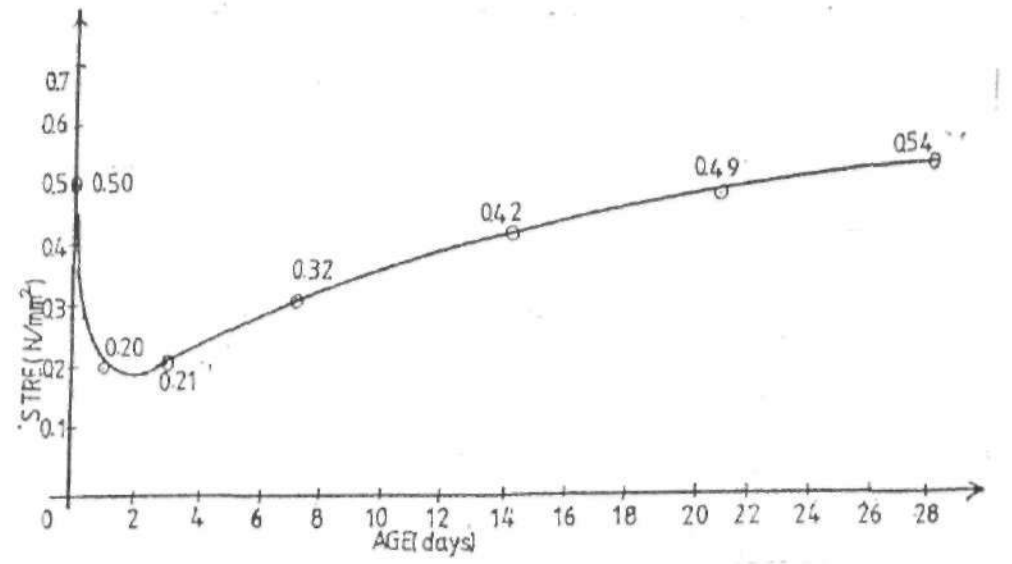

FIGURE 12- WET DEVELOPMENT STRENGTH FOR INDUSTRY A

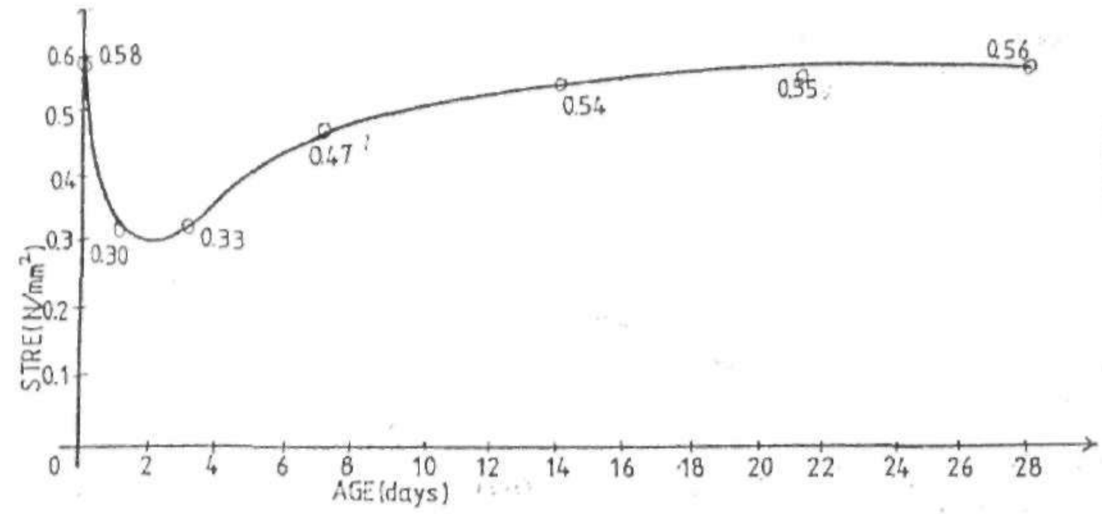

FIGURE 13- WET DEVELOPMENT STRENGTH FOR INDUSTRY B

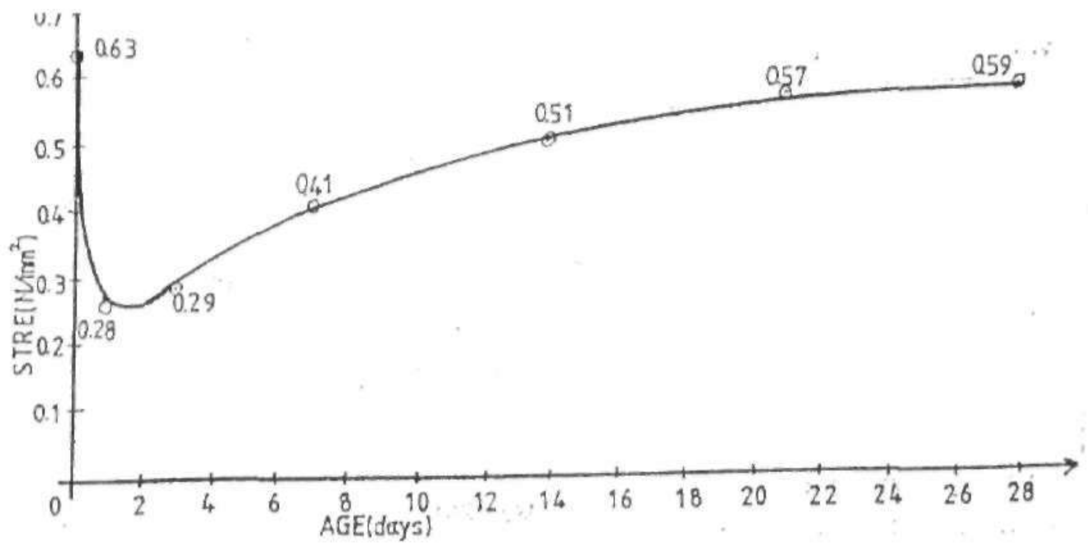

FIGURE 14 - WET DEVELOPMENT STRENGTH FOR INDUSTRY C

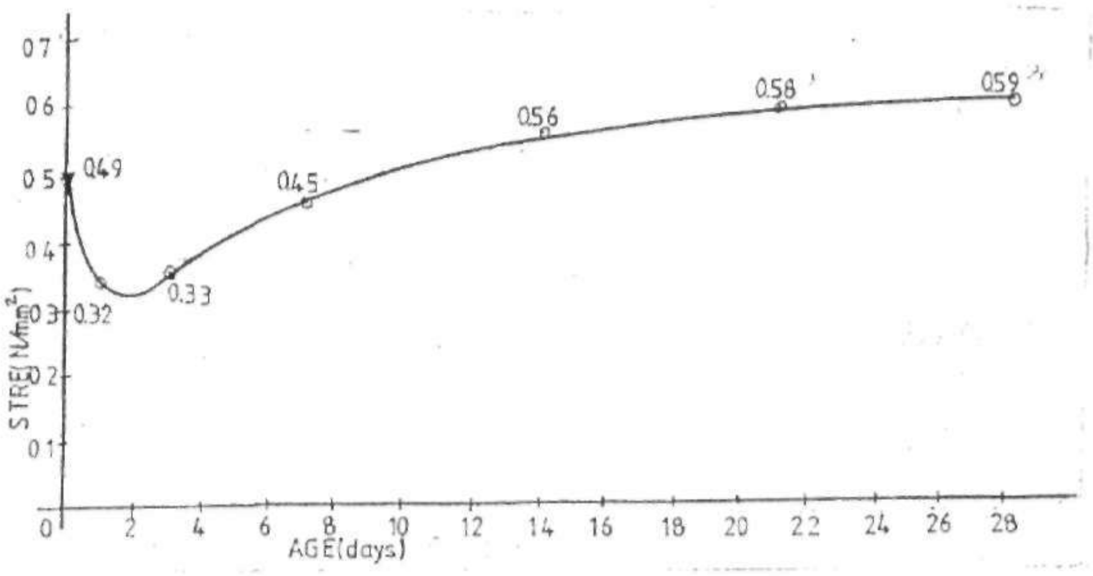

FIGURE 15 - WET DEVELOPMENT STRENGTH FOR INDUSTRY D

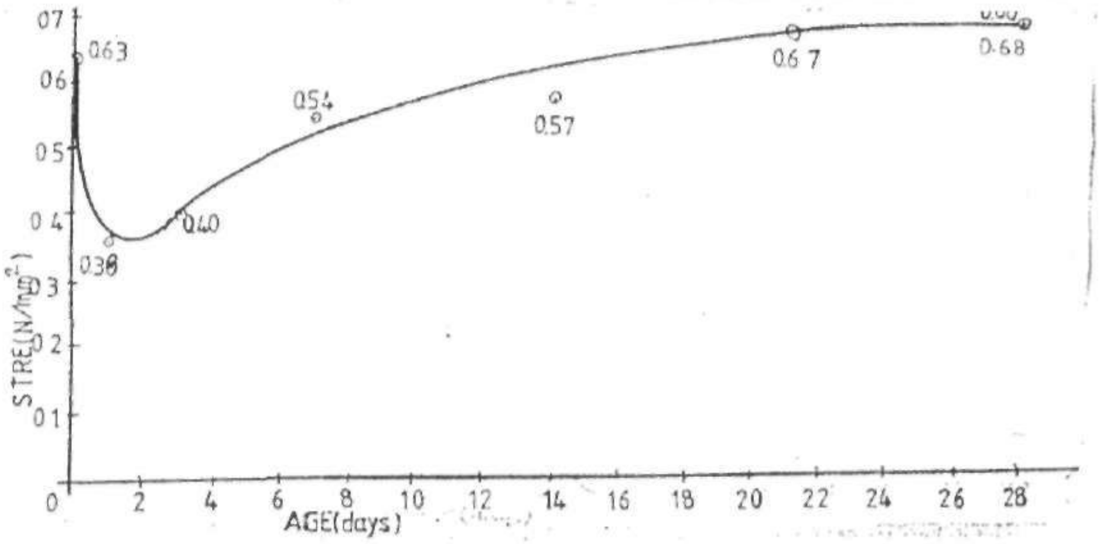

FIGURE 16 - WET DEVELOPMENT STRENGTH FOR IDUSTRY E

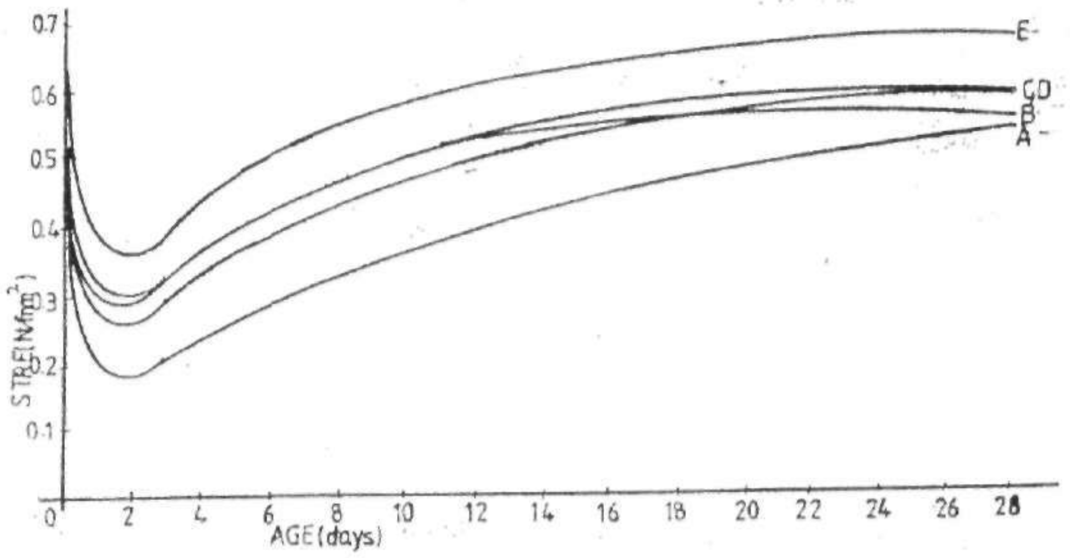

FIGURE 17 - WET DEVELOPMENT STRENGTH COMPARED

It is apparent from the graphs that the strength of the blocks start to drop rapidly after one day of soaking in water. The loss in strength is over fifty percent of the dry strength before soaking. As from three days the blocks start to gain strength again. The rate of gain is not as rapid as the rate of loss, but progressively slower. Two considerable observations are obvious from the figures 7;

a) The sharp drop in wet strength before gain in strength. On soaking, the blocks absorb water and this occupies the cavities or voids within the sandcrete. At this time, testing for strength will result in low strength as shown in blocks soaked for 1-3 days. After the absorption of water into dry and inadequately cured medium, hydration starts again as a result of the presence of moisture giving rise to increased strength with time.

b) The wet strength is higher than the dry strength, which should not be. The wet strength increased slowly from the 3rd day of soaking and is higher than the dry strength on the 28th day. It is not normal for the wet strength to be higher than the dry strength. This abnormal behaviour is as a result of indequate curing of the blocks from the industry. The water content was insufficient for hydration. Thus, by soaking the blocks in water, enough water is provided for hydration. Hence, the blocks are provided with sufficient water and naturally curing is expected to increase strength.

   The 28 - days average wet development strength of $0.54N/mm^2$ is below the Nigerian Industrial Standard (1974) and Federal Ministry of Works (1985). However, it falls within values obtained in Kano State, that is $0.39N/mm^2$ on average.

(iii) Wet Compressive (Bedded) Strength

The wet compressive (bedded) strength values for industries A, B, C, D and E being 0.42, 0.45, 0.40, 0.40 and $0.41N/mm^2$ are rather too low when compared to the requirements of the Nigerian Industrial Standard (1974) and Federal Ministry of Works (1985). The strength values, the standard deviation of $0.02N/mm^2$ and coefficient of variation of 2.4% indicate that the blocks production is consistent. Generally, the strength of the blocks produced in the State is low. Various factors are responsible for this low strength. These factors are the presence of silt in the sand used, inadequate curing, lean mix, inadequate compaction and lack of shade during drying process. The silt can form coatings on the coarse sand particles, thus weakening the bond with the cement paste. This results in low strength. The blocks are cured by spraying water once a day for three days. Meanwhile, in order to meet demands for good quality, sandcrete blocks should be cured for at least seven days. The main aim of curing is to keep the blocks saturated until the original water-filled space in the fresh cement paste has been filled by the products of hydration. The chemical process of hydration continues at a diminishing rate for an inadequate period, as long as moisture is present and temperature is favourable. Hence, ineffective curing is causing inadequate and non-uniform development of the cementitious matrix. This has not only decreased the strength, but decreased the durability, increased permeability, decreased abrasion - resistance and general dimensional stability of the blocks.

The mix ratio used is 1:12 by volume, whereas the Nigerian Industrial Standard II: 1974 recommends the richest mix of 1:6 and up to 1:8 by volume of cement to sand. For a mix, there is an upper limit for the sand content beyond which there will be insufficient cement paste or coat all the particles. As sand content increases beyond this limit, the strength of the final product usually decreases.

The addition of water to restore workability as a result of its fall due to loss of moisture during delay in moulding, termed re-tempering, is also responsible for the low strength. The probable reason for this effect is that the added water forms part of the effective water which governs the strength. Variation in volume and non-uniform compaction pressure may result in air voids, which are in excess of those due to water which is needed for hydration thus lowering the strength of the blocks.

Finally, proper shading is not provided, and this affects the strength of the blocks adversely. The constituent materials are rarely stored in a cool place. Excessive mixing is done as a result of delay in moulding. All these results in high evaporation losses of mixing and curing water and early - stiffening, which are accompanied by increased surface shrinkage, possibility of cracking and a loss in 28 day strength.

(iv) Density

The results shown on Tables 23 - 27 are plotted to obtain figures 18 - 22 which show that the density of the blocks increase linearly with age.

Fhe Figures show the graph of density against age as straight lines.

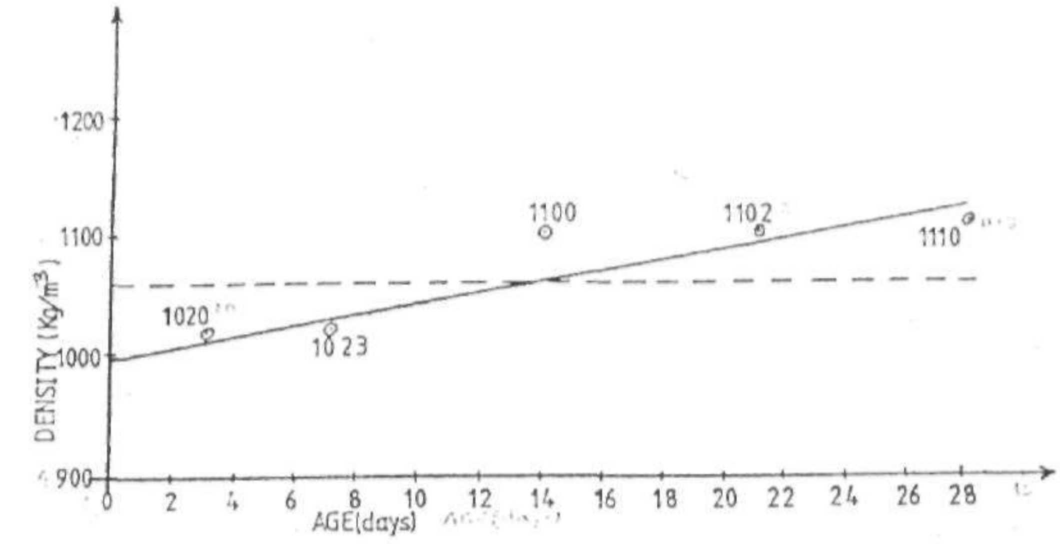

FIGURE 18 - DENSITY FOR INDUSTRY A

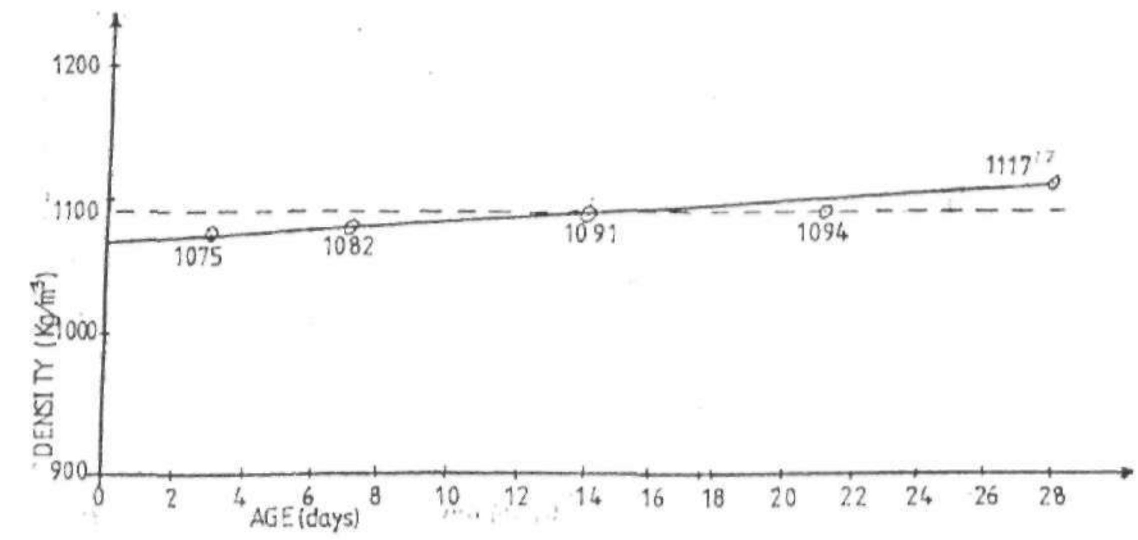

FIGURE 19 - DENSITY FOR INDUSTRY B

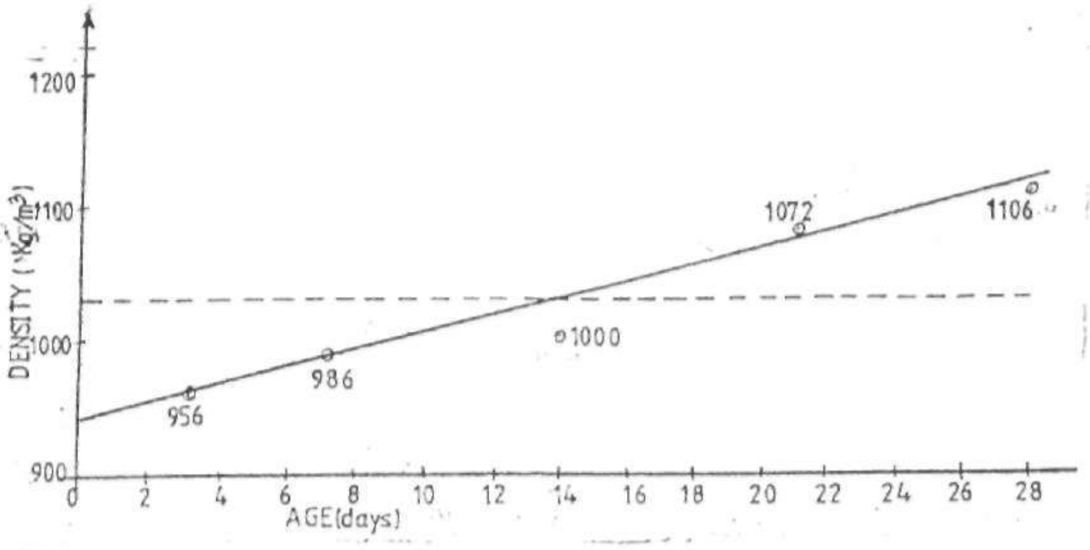

FIGURE 20 - DENSITY FOR INDUSTRY C.

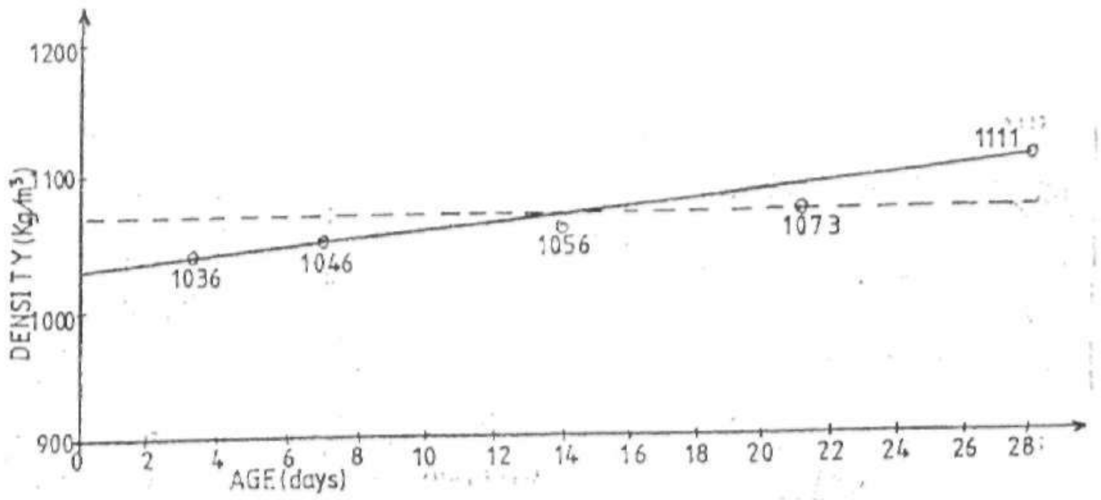

FIGURE 21 - DENSITY FOR INDUSTRY D.

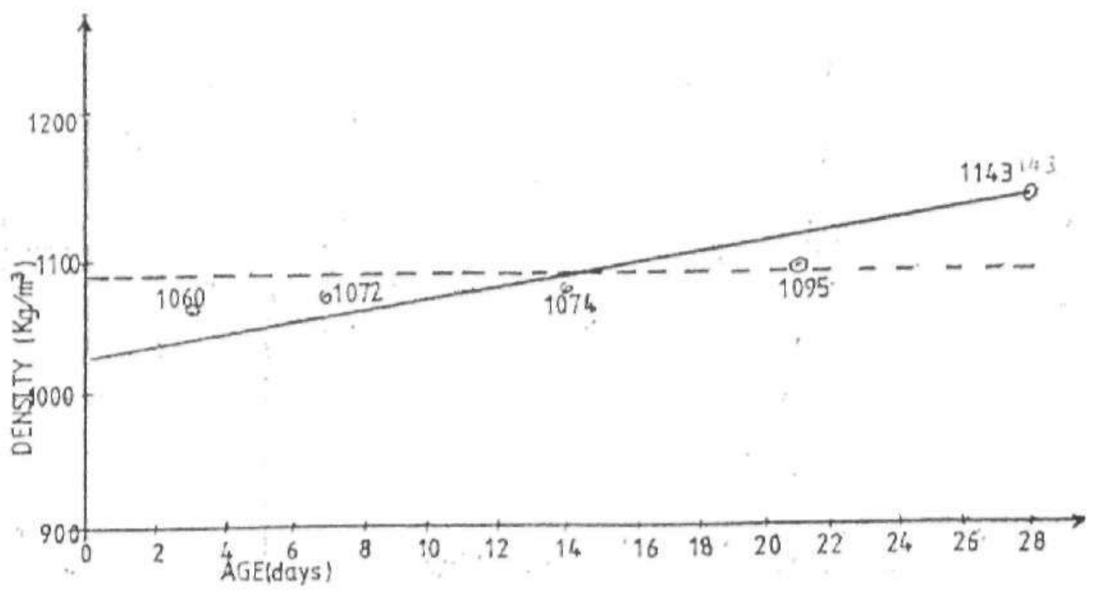

FIGURE 22- DENSITY FOR INDUSTRY E.

There is a sudden jump in the value of the density at three days and fourteen days. As from fourteen days the increase is smaller. As a result of bad curing, the strength is low, thus low density. As from 14 days there is a substantial increase in strength resulting in high density. At early age, this effect is more pronounced as observed from the figure 8 for the first seven days. At later age, when curing is improved, as a result of soaking in water, the rate of increase in density is smaller.

The density is generally over 1000kg/m³ which is below the recommended value of 1500kg/m³/10/. The density of sandcrete blocks is determined by the materials used as well as by the void content.
As for the materials, the sand used in most industry is fair.

(v) Dimensional Deviation

The dimensional measurements show that most of the blocks fall within dimensional tolerance. Yet, a considerable proportion (about 20%) fall outside it. See Tables 11- 15 in the appendix.

(vi) Drying Shrinkage and Wetting Expansion

Tables 28 - 32 and Tables 33 - 37 show that the drying shrinkage and wetting expansion are satisfactory.

(vii) In order to check the quality of blocks made to Nigerian Industrial Standard (1974) specifications the three blocks made attained 2.33N/mm² after 28 days. Table 37A in the appendix shows the results obtained. The result obtained here indicates the following facts;

a) the materials used for producing blocks in Benue State by the commercial block makers are good materials, but because of lack of control, the producers are careless about the state and proportions of these materials in their production.

b) If the specifications in the standard codes are strictly followed in the production of sandcrete blocks, the required strengths can be attained by local block makers.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

(a) The sand used in producing the blocks is not good enough because it contains a considerrable amount of impurities, and the manufacturers mix it with plaster sand. Even though the silt content is acceptable, the sand is not clean.

(b) The mix ratio of 1:12 of cement to sand by volume is poor because the sand content is too much for the cement content. The recommended mix ratio is 1:6 of cement to sand by volume, hence the mix ratio is not satisfactory.

(c) The condition under which the blocks are produced is not conducive for good quality production. Because of high temperatures and lack of proper shade, the water for hydration evaporates during mixing thus resulting in re-tempering. Re-tempering is not usually allowed because it reduces strength.

(d) The blocks are generally cured for a maximum of three days instead of seven days, thus curing is inadequate.

(e) During storage the blocks are generally stacked over five blocks high instead of the maximum five blocks high.

(f) The producers of the blocks are ignorant of the standards required of their products, and they do not employ the services of skilled labour such as Engineers or Architects.

(g) The strength of the blocks are too low when compared with local and international standards.

(h) The density, dimensional tolerance, drying shrinkage and wetting expansion are all within satisfactory region.

(i) Finally, it can be said that the quality of the sandcrete hollow blocks produced in Benue state is not satisfactory when compared to both local and international standards.

5.2 RECOMMENDATIONS

The standard Organisation of Nigeria and the Nigerian Society of Engineers are to moderate the activities of block manufacturers. This can be achieved as follows:

a) Enlighten the manufacturers about the required standards of the blocks produced. This enlightenment can be done through the electronic and print media as well as seminars.

b) Establish a taskforce to enforce the standard specifications and to penalize defaulters.

c) Ensure that at least one qualified Engineer or Architect is on the board of every block manufacturing industry. This person can be a full-time employee or a part-time one.

d) Professionals are to be encouraged to establish block industries.

e) The related Engineering Departments of the tertiary instutitions are to be encouraged to establish block industries.

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APPENDIX

Tables of Raw Data

TABLE 38 - DRY DEVELOPMENT STRENGTH FOR INDUSTRY A

S/NO	LENGTH (mm)	BREATH (mm)	AGE (DAYS)	FAILURE LOAD(KN)	DRY STRENGTH N/mm²	AVERAGE STRENGTH (N/mm²)	STD.DEV (N/mm²)	COEF OF VAR (%)
1 2 3	458 459 457	229 230 229	3	23 24 22	0.22 0.23 0.21	0.22	0.01	4.5
4 5 6	458 460 455	230 230 225	7	24 28 30	0.23 0.26 0.29	0.26	0.03	11.5
7 8 9	457 456 458	225 230 230	14	42 46 44	0.41 0.44 0.42	0.42	0.02	4.8
10 11 12	460 455 456	225 225 230	21	50 46 48	0.48 0.45 0.46	0.46	0.02	4.3
13 14 15	458 460 455	230 225 225	28	70 36 50	0.66 0.35 0.49	0.50	0.16	32.0

TABLE 39 - DRY DEVELOPMENT STRENGTH FOR INDUSTRY B

S/NO	LENGTH (MN)	BREATH (MN)	AGE (DAYS)	FAILURE LOAD(KN)	DRY STREN. GTH N/mm²)	AVERAGE STRENGTH (N/mm²)	STD.DEV (N/mm²)	COEF OF VAR (%)
1 2 3	457 458 456	228 225 230	3	33 34 36	0.32 0.33 0.34	0.33	0.01	3.0
4 5 6	458 457 460	225 228 230	7	44 48 49	0.54 0.58 0.55	0.45	0.02	4.4
7 8 9	457 456 455	230 225 228	14	46 52 48	0.44 0.51 0.46	0.47	0.04	8.5
10 11 12	456 457 458	230 228 225	21	66 50 56	0.63 0.48 0.54	0.55	0.08	14.5
13 14 15	460 460 458	225 228 230	28	56 66 60	0.54 0.63 0.57	0.58	0.05	8.6

TABLE 40 - DRY DEVELOPMENT STRENGTH FOR INDUSTRY C

S/NO	LENGTH (mm)	BREATH (mm)	AGE (DAYS)	FAILURE LOAD(KN)	DRY STRENGTH N/mm²	AVERAGE STRENGTH (N/mm²)	STD.DEV (N/mm²)	COEF OF VAR (%)
1	458	230		33	0.31			
2	460	230	3	36	0.34			
3	455	225		35	0.34	0.33	0.02	6.1
4	460	225		52	0.50			
5	455	225	7	56	0.55			
6	456	230		50	0.48	0.51	0.04	7.8
7	458	230		56	0.54			
8	460	225	14	56	0.55			
9	455	225		60	0.59	0.55	0.03	8.3
10	458	230		68	0.65			
11	460	230	21	62	0.59			
12	455	225		64	0.63	0.62	0.03	4.8
13	457	225		68	0.66			
14	456	230	28	62	0.59			
15	458	230		66	0.63	0.63	0.04	6.3

TABLE 41 - DRY DEVELOPMENT STRENGTH FOR INDUSTRY D.

S/NO	LENGTH (mm)	BREATH (mm)	AGE (DAYS)	FAILURE LOAD(KN)	DRY STRENGTH N/mm²	AVERAGE STRENGTH (N/mm²)	STD.DEV (N/mm²)	COEF OF VAR (%)
1	457	228		24	0.23			
2	460	230	3	20	0.19			
3	458	225		19	0.18	0.20	0.03	15.0
4	457	230		32	0.30			
5	456	228	3	32	0.19			
6	455	225		34	0.33	0.31	0.02	6.5
7	456	225		46	0.44			
8	457	228	14	40	0.38			
9	458	230		44	0.42	0.41	0.03	7.3
10	460	225		44	0.43			
11	460	228	21	52	0.50			
12	458	230		50	0.47	0.47	0.04	8.5
13	458	230		56	0.53			
14	457	225	28	50	0.49			
15	460	228		46	0.44	0.49	0.05	10.2

TABLE 42 DRY DEVELOPMENT STRENGTH FOR INDUSTRY E

S/NO	LENGTH (mm)	BREATH (mm)	AGE (DAYS)	FAILURE LOAD(KN)	DRY STRENGTH (N/mm^2)	AVERAGE STRENGTH (N/mm^2)	STD.DEV (N/mm^2)	COEF OF VAR (%)
1	455	230		29	0.28			
2	458	225	3	33	0.32			
3	460	230		29	0.27	0.29	0.03	10.3
4	457	225		40	0.39			
5	456	225	7	36	0.35			
6	458	230		42	0.40	0.38	0.03	7.9
7	455	230		54	0.52			
8	460	225	14	52	0.50			
9	458	225		56	0.54	0.52	0.02	3.8
10	455	230		58	0.56			
11	460	230	21	64	0.60			
12	458	225		60	0.58	0.58	0.02	5.2
13	456	225		68	0.66			
14	455	230	28	68	0.65			
15	460	230		60	0.57	0.63	0.05	7.9

TABLE 43 - WET DEVELOPMENT STRENGTH FOR INDUSTRY A

S/NO	LENGTH (mm)	BREATH (mm)	AGE (DAYS)	FAILURE LOAD(KN)	DRY STRENGTH (N/mm^2)	AVERAGE STRENGTH (N/mm^2)	STD.DEV (N/mm^2)	COEF OF VAR (%)
1	458	230		22	0.21			
2	460	229	1	20	0.19			
3	461	230		21	0.20	0.20	0.01	5.0
4	460	231		23	0.22			
5	459	229	3	18	0.17			
6	460	230		25	0.24	0.21	0.04	19.0
7	460	230		36	0.34			
8	459	230	7	32	0.30			
9	460	229		34	0.32	0.32	0.02	6.3
10	461	228		46	6.44			
11	460	230	14	36	0.34			
12	458	230		44	0.42	0.40	0.05	12.5
13	458	231		40	0.38			
14	459	230	21	60	0.57			
15	460	229		56	0.53	0.49	0.10	20.4
16	460	228		36	0.34			
17	461	230	28	72	0.68			
18	460	230		62	0.59	0.54	0.18	33.3

TABLE 44 - WET DEVELOPMENT STRENGTH FOR INDUSTRY B

S/NO	LENGTH (mm)	BREATH (mm)	AGE (DAYS)	FAILURE LOAD(KN)	DRY STREN. GTH N/mm²	AVERAGE STRENGTH (N/mm²)	STD.DEV (N/mm²)	COEF OF VAR (%)
1	459	230		32	0.30			
2	460	229	1	35	0.33			
3	458	228		28	0.27	0.30	0.03	10.0
4	459	228		33	0.32			
5	460	230	3	37	0.35			
6	460	229		34	0.32	0.33	0.02	6.1
7	458	228		48	0.46			
8	459	230	7	50	0.47			
9	460	230		52	0.49	0.47	0.02	4.3
10	460	230		58	0.55			
11	461	230	14	54	0.51			
12	460	229		60	0.57	0.54	0.03	5.6
13	460	228		56	0.55			
14	459	230	21	56	0.47			
15	460	230		62	0.59	0.55	0.06	11.3
16	461	231		50	0.47			
17	460	230	28	60	0.57			
18	458	229		66	0.63	0.56	0.08	14.3

TABLE 45 - WET DEVELOPMENT STRENGTH FOR INDUSTRY C

S/NO	LENGTH (mm)	BREATH (mm)	AGE (DAYS)	FAILURE LOAD(KN)	DRY STREN. GTH (N/mm²)	AVERAGE STRENGTH (N/mm²)	STD.DEV (N/mm²)	COEF OF VAR (%)
1	461	230		32	0.30			
2	460	230	1	35	0.33			
3	459	229		22	0.21	0.28	0.06	21.4
4	458	229		31	0.30			
5	460	228	3	33	0.31			
6	459	230		27	0.26	0.29	0.03	10.3
7	461	231		44	0.41			
8	460	230	7	44	0.42			
9	458	229		42	0.40	0.41	0.01	2.4
10	458	228		56	0.54			
11	459	230	14	50	0.47			
12	460	230		54	0.51	0.51	0.04	7.8
13	460	230		64	0.60			
14	461	230	21	56	0.53			
15	460	229		62	0.59	0.57	0.04	7.0
16	460	228		64	0.61			
17	459	230	28	54	0.51			
18	460	230		68	0.64	0.59	0.07	11.9

TABLE 46 WET DEVELOPMENT STRENGTH FOR INDUSTRY D

S/NO	LENGTH (mm)	BREATH (mm)	AGE (DAYS)	FAILURE LOAD(KN)	DRY STRENGTH (N/mm^2)	AVERAGE STRENGTH (N/mm^2)	STD.DEV (N/mm^2)	COEF OF VAR (%)
1	459	230		33	0.31			
2	558	230	1	33	0.31			
3	460	230		36	0.34	0.32	0.02	6.25
4	460	230		34	0.32			
5	461	230	3	36	0.34			
6	460	230		35	0.33	0.33	0.01	3.03
7	460	230		48	0.45			
8	461	230	7	50	0.47			
9	460	228		46	0.44	0.45	0.02	4.4
10	460	229		60	0.57			
11	459	230	14	60	0.57			
12	460	231		56	0.53	0.56	0.02	3.6
13	461	230		60	0.57			
14	460	230	21	62	0.59			
15	458	228		60	0.57	0.58	0.01	1.7
16	458	229		68	0.65			
17	459	230	28	54	0.51			
18	460	230		64	0.60	0.59	0.07	11.9

TABLE 47 - WET DEVELOPMENT STRENGTH FOR INDUSTRY E

S/NO	LENGTH (mm)	BREATH (mm)	AGE (DAYS)	FAILURE LOAD(KN)	DRY STRENGTH (N/mm^2)	AVERAGE STRENGTH (N/mm^2)	STD.DEV (N/mm^2)	COEF OF VAR (%)
1	459	230		39	0.37			
2	458	231	1	41	0.39			
3	460	229		40	0.38	0.38	0.01	2.6
4	461	228		43	0.41			
5	460	229	3	41	0.39			
6	459	230		42	0.40	0.40	0.01	2.5
7	460	229		56	0.53			
8	461	230	7	60	0.57			
9	460	230		54	0.51	0.54	0.03	5.6
10	461	230		56	0.53			
11	460	230	14	64	0.60			
12	458	228		62	0.59	0.57	0.04	7.0
13	460	229		66	0.63			
14	459	230	21	74	0.70			
15	460	230		72	0.68	0.67	0.04	6.0
16	458	230		76	0.72			
17	459	230	28	62	0.59			
18	460	228		76	0.72	0.68	0.08	11.8

TABLE 52 - DRY DENSITY FOR INDUSTRY E

S/NO	LENGTH (mm)	BREATH (mm)	HEIGHT (mm)	AGE (days)	WEIGHT (kg)	DRY DENSITY (Kg/m^3)	AVERAGE DENSITY (Kg/m^3)	STD.DEV. (Kg/m^3)	COEF. VAR(%)
1	458	229	220		24.23	1050			
2	460	228	217	3	23.78	1045			
3	455	230	218		24.75	1085	1060	21.79	2.1
4	455	229	215		24.60	1098			
5	459	230	216	7	25.00	1096			
6	458	228	220		23.50	1022	1072	43.31	4.0
7	460	230	218		24.65	1067			
8	458	228	220	14	25.55	1111			
9	457	229	220		24.00	1043	1074	34.50	3.2
10	455	228	218		24.55	1086			
11	458	229	215	21	25.50	1133			
12	457	230	220		24.60	1065	1095	34.82	3.2
13	455	229	215		25.60	1143			
14	458	230	218	28	25.75	1120			
15	459	228	217		26.60	1167	1143	23.51	2.1