QUALITY OF SANDCRETE HOLLOW BLOCKS IN KADUNA STATE

BY

DANUSO, OLAYINKA RASHEED
B.Sc (A.B.U.)

A THESIS SUBMITTED TO HIE POSTGRADUATE SCHOOL,
AHMADU BELLO UNIVERSITY, ZARIA
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF MASTER OF SCIENCE IN
(STRUCTURAL ENGINEERING)

DEPARTMENT OF CIVIL ENGINEERING
FACULTY OF ENGINEERING
AHMADU BELLO UNIVERSITY, ZARIA

JUNE, 1993

DECLARATION

I hereby declare that this thesis has been composed by myself and that it is a record of my own 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 references.



BANUSO, OLAYINKA RASHEED

CERTIFICATION

This thesis entitled "Quality of SANDCRETE HOLLOW BLOCKS PRODUCED IN KADUNA STATE by Banuso Olayinka Rasheed meets the regulations governing the award of the degree of master of Science (Structural Engineering) of Ahamdu Bello University, and is approved for its contribution to knowledge.

Date: 7/10/93

DR. S.P. EJEH

MAIN SUPERVISOR

Date: 27/9/93

ANTHONY J. AKPAN (MNSE)

SUPERVISOR

Date: 27/9/93

PROF O. ADEBISI

HEAD OF DEPARTMENT

Date: 29/3/94

Dean Postgraduate School

DEDICATION

This thesis is dedicated to Almighty God.

ACKNOWLEDGEMENTS

I would like to thank all those that contributed in one way or the other towards the execution of this research work.

In this respect, I wish to express my profound gratitude to the following persons:

My main supervisor, DR. S.P. Ejeh (B.ENG., M.Sc, PHD. A.M.I.C.E., M.NSE) for his various criticisms, suggestion and direction in all aspects of the project work.

My supervisor, ANTHONY J. AKPAN (B.Sc., M.Sc. M.NSE) for undertaking to read and also suggesting improvements in my scripts.

Messrs A.R.O. Bello, Ismaila Mohammed, Abdullahi Kabir and Emmanuel Ogwuche for their assistance in the laboratory part of this work.

Members of staff of Civil Engineering Department for their contributions during the course of my studies.

My beloved Mother, Brothers and Sisters for their untired and continued support of my education and for their understanding and encouragement.

Alhaji and Alhaja Bukoye for their moral and financial support during the course.

My cousin, Mr. B.A. Raji for his advice and encouragement.

My friend, Mr Moses Uba for his moral and financial support.

CONTENTS PAGE

Title Page i

Declaration ii

Certification iii

Dedication iv

Acknowledgement v

Table of Contents vi

List of Figures x

List of Plates xii

List of Tables xiii

Abstract xvii

1.0	CHAPTER ONE	
1.1	Introduction	1
1.2	Limitation	2
2.0	CHAPTER TWO	
2.1	Literature Review	4
3.0	CHAPTER THREE	
3.1	Experimentation	36
3.2	Sieve Analysis	37
3.3	Silt Content	41
3.4	Porosity of sand	42
3.5	Dry development strength	43
3.6	Wet Compressive Strength	47
3.7	Wet development strength	56

3.8	Ratio of wet to dry development strength	59
3.9	Density	60
3.10	Absorption of Water	61
3.11	Drying Shrinkage and Moisture Movement	62
4.0.	CHAPTER FOUR	
4.1	Analysis and Discussion of Results	63
4.2	Industry A	63
4.3	Industry B	70
4.4	Industry C	76
4.5	Industry D	81
4.6	Industry E	86

5.0	CHAPTER FIVE	
5.1	Conclusion and Recommendations	93
5.2	Conclusion	93
5.3	Recommendations	95
	REFERENCES	97
	APPENDIX	100

LIST OF FIGURES

Figure 1 11

Figure 2 63

Figure 3 65

Figure 4 66

Figure 5 69

Figure 6 70

Figure 7 72

Figure 8 73

Figure 9 75

Figure 10 76

Figure 11 78

Figure 12 78

Figure 13 80

Figure 14 82

Figure 15 83

Figure 16 84

Figure 17 86

Figure 18 87

Figure 19 88

Figure 20 89

Figure 21 90

Figure 22 91

Figure 23 91

LIST OF PLATES

PAGE

PLATE 1 47

PLATE 2 48

LIST OF TABLES

		PAGE
TABLE	1	5
TABLE	2	6
TABLE	3	7
TABLE	4	10
TABLE	5	14
TABLE	6	16
TABLE	7	17
TABLE	8	19
TABLE	9	23
TABLE	10	37
TABLE	11	38
TABLE	12	39

TABLE	26	49
TABLE	27	50
TABLE	28	51
TABLE	29	53
TABLE	30	54
TABLE	31	55
TABLE	32	56
TABLE	33	56
TABLE	34	57
TABLE	35	57
TABLE	36	58
TABLE	37	58
TABLE	38	59

TABLE	39	59
TABLE	40	66
TABLE	41	61
TABLE	42	61
TABLE	43	62

ABSTRACT

A study of the properties of sandcrete hollow block 1s important since they are widely used in the construction industry. An understanding of these properties is essential if blocks are to be used effectively., These properties have an important bearing on the appropriate application of the products and on the precautions to be taken to ensure their satisfactory behavior in service.

In this thesis, attempt have been made to present the current practices involved in the manufacture of sandcrete hollow blocks in Kaduna State. Various visits to various block industries were made and samples were taken from five industries that are fairly scattered in their location within the state.

Tests including dry development strength, wet compressive strength, wet development strength, drying shrinkage, moisture movement, density etc. were performed on the samples.

The work further points out the relationship between the wet development strengths at various soaking ages and the dry development strength at 28 days.

From the results, one observe that the 20 -- days development strength of industries A,B,C.D and E are 0.08N/mm2, 1.02N/mm2, 0.9N/mm2, 0.77N/mm2 and 0.91N/mm2 respectively. The block samples attained fairly steady strength from the 7th day of curing up till the 28th day.

Also the block samples attained a critical condition within 24 hours of immersion prior to testing for wet development strength. The average wet compressive strength of industries A,B,C,D and E are 0.47N/mm2, 0,584N/mm2, 0.550N/mm2, 0.501N/mm2 and 0.547N/mm2 respectively. While the average density of the block samples is 994Kg/mm3. These values however do not satisfy the relevant standards.

1.0 CHAPTER ONE

1.1 INTRODUCTION

A sandcrete hollow block can be described as a wall component with standard dimensions made from a mixture of portland cement, sand and water.

According to British Standard 2028/25/, a block is a walling Unit exceeding in length, width or height the dimension specified for a brick and the height of the block shall not exceed either it length or six times it thickness. The nominal sizes of sandcrete hollow blocks are given as 100mm x 230mm x 460mm, 150mm x 230 x 460mm and 230mm x 230mm x 460mm. The specified nominal mixes of sandcrete hollow blocks are between one part by volume of cement to six parts by volume of sand (1:6) and one part of cement to eight parts of sand (1:8). While the specified water/cement ratio is between 0.6 and 0.9.

Sandcrete blocks used for masonry structures are of significant importance that cannot be neglected. Sandcrete block is still one of the most popular form of walling unit for building and construction industries. This is due to the fact that it constitutes a high percentage of concrete work in building industry.

Sandcrete block is particularly used for both load bearing and non load bearing walls.

Initially several visits were made to most of the block industries in the state. This is to obtain general information in respect of materials, sizes, mode of production employed for the production of sandcrete hollow block in the state.

The second visit was to collect samples from selected industries. The state was divided into Five Zones, and a town is chosen from each zone. In each of the town, a well known block industry is chosen for sample collection. In each industry fifty (50) samples were collected. On the whole about 250 block samples were collected from the five industries for various standard tests in the laboratory.

The standard tests are dry development strength, wet development strength, wet compressive strength, density, moisture Movement, drying Shrinkage etc.

Generally the quality of sandcrete hollow blocks produced in Kaduna State is very poor and below the standard requirements.

1.2 LIMITATION

There is no doubt that in undertaking research work such as this nature there is bound to be problems in the course of the work Several visits were made to the various industries for collecting various information as earlier said. One however observe during the visits that the block unit price kept on changing giving rise to high cost of this project.

Moreso transportation problem was encountered, substantial number of blocks broke in the process of transporting from the industries to the laboratory. Some of the industries have not got good access road.

During the visits to the industries as mentioned above to collect information relating to the mode of production, sales etc. some of the management of the industries were suspicious and put forward unfriendly attitude.

These problems were partly solved by paying more for blocks and making several visits thereby making friends with them.

2.0 CHAPTER TWO

2.1 LITERATURE REVIEW

The properties of sandcrete blocks depend to a varying degree on the type and proportions of the constituent materials, the manufacturing process, and the mode and duration of curing employed, as well as on the form and size of the 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 etc. /9/.

Currently the standard specification for sandcrete blocks in Nigeria is under preparation by standard organization of Nigeria and may be out any moment from now. However, the British Standard specification/25/ has been the reference material used for quite sometimes now. Nevertheless, several studies have been carried out on sandcrete hollow blocks.

2.2 FORM AND SIZE

British standard 6073:1981 Part 1 defines a block as a masonry unit of a large size in all dimensions than specified for bricks but no dimension should exceed 650mm nor should the height exceed either its length or six times its thickness/18/.

In British standard 2028/25/, concrete blocks are divided into three types:

Type A — Dense aggregate concrete blocks

Type B — Lightweight aggregate concrete blocks

Type A and B are both suitable for load bearing walls and can be used for rendered external walls, all internal walls and partitions, panelling in

framed buildings.

Type C Lightweight aggregate concrete for non load bearing walls. Type C blocks are used for internal work only, for partitions and panelling to framed buildings.

There are three forms of sandcrete block; solid, cellular, and Hollow. Within each type, a variety of products are available thus providing many different uses to block work construction both in style and function. A solid block has no formed holes or cavities, while cellular and hollow blocks have one or more formed holes or cavities which in hollow blocks pass right through them/18/.

Concrete blocks are available in a wide range of sizes. Jackson /9/ gives the following work sizes as shown in Table 1.

TABLE 1: TYPICAL WORK SIZES OF CONCRETE BLOCKS

Face		
		Thickness, mm
Length, mm	Height, mm	
390	190	
440	140	
440	190	
440	215	
440	290	60,75,90,100
590	140	140,190,200,215
590	190	

* To obtain co-ordinating sizes, add 10 mm for mortar joint to the length and height dimensions but not to the thickness.

Also British Standard 2028 (table 1) /25/ specifies dimensions of blocks as shown in table 2

TABLE 2: DIMENSIONS OF HOLLOW SANDCRETE BLOCK

1	2	3	4
Block Type	Length x Height		Thickness (Work size)
	Co-ordinating size	Work size	
Type A	mm 400 x 100 400 x 200	mm 390 x 90 390 x 190	mm 75,90, 100 140, and 190
	450 x 225	440 x 215	75, 90, 100 140, 190 and 215
Type B	400 x 100 400 x 200	390 x 90 390 x 100	75, 90, 100 140 and 190
	450 x 200 450 x 225 450 x 300 600 x 200 600 x 225	440 x 190 440 x 215 440 x 290 590 x 190 590 x 215	75, 90, 100 140, 190 and 215
Type C	400 x 200 450 x 200 450 x 225 450 x 300 600 x 200 600 x 225	390 x 190 440 x 190 440 x 215 440 x 290 590 x 190 590 x 215	60 and 75

One of the characteristics of blocks is that their shape is one of their intrinsic properties.

2.3 COMPRESSIVE STRENGTH

The compressive strength of a sandcrete block depends on variables that affect it during production. These include the amount of cement, fine agrregate, water, degree of compaction, the curing conditions, age of the cement and the type of weather.

According to Florek/2/. who tested sandcrete hollow blocks in Bauchi, Kaduna, Mubi, Saminaka, and Zaria all in Northern Nigeria, the quality of these products are below expectation. The tests were carried out between 1978 and 1984. In his /2/ work, he came out with the average compressive strength for the following sizes of blocks as shown in table 3.

TABLE 3: AVERAGE COMPRESSIVE STRENGTH FOR VARIOUS SIZES OF BLOCKS

SIZES OF BLOCKS (MM)	AVERAGE STRENGTH (N/MM2)	STANDARD DEVIATION(N/MM2)	COEFFICIENT VARIATION (%)
100 x 230 x 460	1.64	0.399	24.3
150 x 230 x 460	3.88	2.471	49.3
230 x 230 x 460	2.43	1.872	77.1

Florek /2/ concluded that the quality of these products was very poor and below the standard requirements. He /2/ therefore recommended that the relevant standard taking into account Nigeria materials and equipment should be elaborated as soon as possible and quality tests of blocks are to be obligatory for all manufacturers. The tests should be carried out by authorized building materials testing laboratories.

However, it should be noted that the manufacturers brought the blocks to the Civil Engineering Laboratory for testing in order to obtain a test certificate. As such, there was every likelihood that the manufacturers must have prepared what is called special mixes. These special mixes are rich mixes produced by the manufacturer in order to obtain a good test certificate. To overcome the above shortfall, one has to buy the blocks as a customer who was going to use it for construction and taken necessary precaution as required by the standard.

Adepegba/1/observes that the strength of cement-stablished laterite and cement - stabilized sand increases with increasing cement content. At high cement content i.e. 9% cement content the granules of cement - stabilized sand behaves elastically whereas granules of cement stabilized laterite do not show elasticity/1/.

According to him /1/ the compressive as well as the tensile strength of latercrete are higher than those of sandcrete for cement content lower than 22% thereafter the strengths of sandcrete are higher.

He /1/ also observes that the most economic range of the use of these stabilized soil lies between 0 - 10 percent cement content. Above 21 percent cement content, latecrete lag behind sandcrete and at about 27 percent the strength of sandcrete doubles that of latecrete.

Also studies have been carried out into the strength of other walling units. Ejeh /6/ made studies on compressive strength of soilcrete hollow blocks. Some of his /6/ findings are stated below:

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

(b) The soilcrete hollow blocks have a ratio of average wet compressive strength to dry of 0.65.

(c) The soilcrete hollow blocks have a minimum wet compressive strength to dry compressive strength ratio of 0.42.

(d) 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.

(e) 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 gave higher compressive strength than the rest packing materials.

He /6/ also recommends that the compressive strength in relation to the compaction pressure should be investigated.

According to Graf/8/, the strength of concrete blocks if it is stored in water may be only 0.74 to 0.9 times the strength of air-dried blocks.

ANON/4/ observes that most concrete blocks are about 15 percent stronger when dry than when wet.

Nigerian Industrial Standard 74:1976/24/ specifies that the compressive strength of bricks of ordinary quality shall not be less than 2.5N/mm2.

Compressive strength is calculated as crushing load divided by the gross area/9/. The British Standard specification/25/ gives the average compressive strength of type A blocks as 3.5N/mm2 while the lowest individual block as 2.8N/mm2. which is about 80% of the average strength.

However, the Federal Ministry of Works during the Annual Conference in Kano (1979)/2/ 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 average compressive strength of 3 blocks should not be less than 2.1N/mm2 while lowest compressive strength of individual block is not less than 1.7N/mm2.

The Nigerian industrial standard (Draft) /26/ gives the following values as shown below in table 4.

TABLE 4 : COMPRESSIVE STRENGTH OF SANDCRETE BLOCKS

TYPES OF BLOCK	STRENGTH TEST ON AVERAGE OF 10 BLOCKS
A - Load bearing	3.45 N/mm2
B - Non load bearing	2.76n/mm2

The corresponding strength of the weakest individual block in the test sample must not be less than 80 percent of the average value.

The range of strengths specified in B.S. 6073: part 2/18/ is 2.8 to 3.5 N/mm2, while the most commonly used blocks fall within a strength band of 3.5 to 10N/mm2. This strength is specified as minimum average value of ten blocks of which no single value should fall below 80 percent of the permitted average value.

According to Frank /7/, of all the test the dry and wet development strength tests are the most important. To the architect and the eventual user of the house where the blocks are used, the other tests, though good for what they stand for in quality control aspects, are not as vital as the strength tests.

The strength of concrete at a given age and cured at a prescribed temperature is assumed to depend primarily on two factors: the water/cement ratio and the degree of compaction.

According to Duff Abrams in (1919), when concrete is fully compacted its strength is taken to be inversely proportional to the water/cement ratio/12/. Abrams found strength to be equal to $fc = K1/K2\ W/c$

Where W/c represents the water/cement ratio and K1 and K2 are empirical constants. Farel/12/ in 1896 formulated a general rule to calculate strength of concrete: $fc = K\ (\ c/(c+w+a)2$ where fc is the strength of concrete, c,w and a are the absolute volumes of cement, water and air respectively, and K is a constant.

The relation between strength and water/cement ratio of concrete is shown in figure 1.

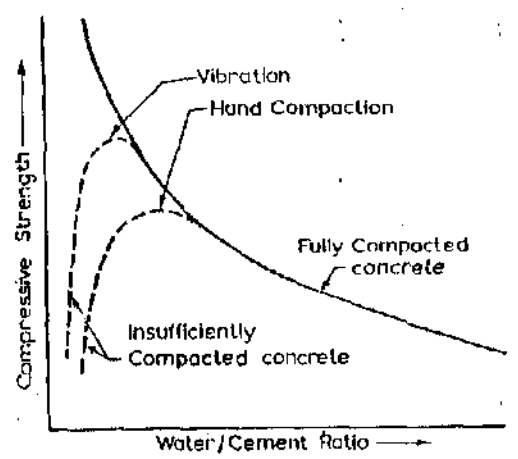


FIG 1: THE RELATION BETWEEN STRENGTH AND WATER/CEMENT RATIO OF CONCRETE

According to Neville /12/, strength of concrete and concrete Products is equally influenced by the volume of all voids in concrete.

Orchard /14/ asserts that the lower the density of lightweight concrete blocks the lower is the strength. Some lightweight concretes have a higher strength/weight ratio than others. The strength and density depend on the type of fine aggregate, the richness of the mix and the degree of compaction. A higher strength/density ratio is obtained with sandcrete blocks if they are cured by high pressure steam than if they are cured at atmospheric pressure.

The strength of a concrete blockwall can depend on:

(a) The vertical load it carries which imparts a compressive stress

which must be relieved before bending can cause any tensile forces.

(b) Flexural strength in a horizontal direction due to the interlocking bond and the ends of each panel being restrained.

A concrete blockwall may be loaded in direct compression or it may be subjected to bending imposed by wind loads if acting as a panel.

2.4 DENSITY

The object of the compaction of concrete and concrete products is to eradicate air holes and to achieve maximum density. In order to obtain maximum density it is necessary to use a mix which is of adequate workability to enable the operator to place it in position without difficulty with the equipment he has available/11/.

The density of sandcrete blocks is largely a function of the type of the fine aggregate, size and 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 typical range for dry density of sandcrete block is 500 to 2100 kg/m3/9/. The British Standard Specification/25/ states that the block density of type A blocks whether solid, hollow or cellular, shall be not less than 1500kg/m3. While Type B and C blocks shall be less than 1500kg/m3.

Florek and Ejeh /3/ obtained an average density of 1880kg/m3 for the soilcrete hollow blocks (400 x 150 x 150mm) produced by occidental Construction Company, Zaria.

Comparably the density of brick varies between about 1700kg/m3 and 2100kg/m3 depending on the composition of the brick and the manufacturer.

In accordance with Appendix B of the British Standard 2028/25/, density of concrete block is determined as follows:-

(a) The gross volume of each of the three blocks is calculated.

(b) The three blocks are weighed to the nearest 0.05kg.

(c) The block density of each block is calculated using the following formula.

$$\text{Block density in kg/m3} = \frac{\text{Weigh}}{\text{Gross volume}}$$

(d) The mean block density of the three blocks is reported to the nearest 10kg/M3.

2.5 DIMENSIONAL CHANGES

Sandcrete blocks will undergo some dimensional changes owing to variations in the ambient moisture and temperature conditions.

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

Lightweight concrete blocks are liable to high drying shrinkages and moisture movements but with suitable precautions these can be kept sufficiently small to prevent ill effects/14/.

The drying shrinkage and moisture movement depend on the cement and in particular its fineness, the richness of the mix, the water/cement ratio and the kind of curing in particular at early ages. The rate at which movement or shrinkage takes place also depends on the permeability of the concrete.

The British standard specification /25/ specifies that the average value of the drying shrinkage shall not exceed the values given below in Table 5.

TABLE 5: DRYING SHRINKAGE

BLOCK TYPE	DRYING SHRINKAGE (%)
A	0.04
B	0.06
C	0.08

Moreso, the average moisture movement shall not exceed 0.05 percent.

According to the United State Housing and Home Finance Agency, little trouble is likely to be experienced if the shrinkage is less than 0.06.

Building Research Station Digest observes that in the temperate Zone the amount of shrinkage that takes place when lightweight concrete dries is a major factor to consider/19/.

It is important not only that blocks should be well made, cured and adequately dried by the manufacturer, but also that they should be protected from moisture as much as possible from the time they leave the factory until the completion of the building; this implies that when necessary they must be covered during transit, whilst stacked on the site and during the progress of the building itself. Unless such precautions are taken the shrinkage will often result in cracking/19/.

In one of his work, Ejeh /3/ observed that differences in the height of soilcrete blocks tested was as a result of some variation in the volume of mixed materials poured into the dial box prior to compaction.

As additional precautions sandcrete blocks should be used in small areas, expansion joints should be provided at intervals and provision for movement should be made round the extremities when they are used to infill panels in framed structures /19/. If sandcrete blocks become wet after building into the wall they should be allowed to dry out thoroughly before plastering or rendering. The sandcrete blocks should not be wet excessively before the plaster or rendering is applied /19/.

Frank suggested that the storing of blocks before use should be encouraged since a large proportion of the block expansion from moisture absorption occur before being put into structure. This will lessen the degree of expansion in any finished blockwork /7/. He further stated that there is need then for manufacturers to test the moisture movement of their blocks and communicate same to buyers, to ensure the best use of their blocks. Some of the drying shrinkage is irreversible and if the blocks are kept under cover on the site before use and until built into the wall the moisture movement can be kept within harmless limits and shrinkage cracking is not likely to be serious /14/.

Because drying takes place at the surface of concrete, the magnitude of shrinkage varies considerably with the size and shape of the specimen.

One of the effects of shrinkage in structures is largely related to cracking. The pressure or absence of cracking depends not only on the potential contraction but also on the extensibility of concrete, its strength and its degree of restraint /10/.

The ratio of the increase in weight to the weight of the dry sample, expressed as a percentage, is termed absorption.

Nigerian industrial standard 74:1976 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 /24/. 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 /7/. Frank observed that for most ceramics the apparent porosity is approximately twice the figure obtained for water absorption /7/.

This statement was made as a result of the tests carried out and presented in tables 6 and 7 below.

TABLE 6: SAMPLE RESULTS OF APPARENT POROSITY, WATER ABSORPTION AND BULK DENSITY FROM PRODA DENSE REFRACTORY TEST SAMPLES

SAMPLE NO.	APPARENT POROSITY %	WATER ABSORPTION %	BULK DENSITY %
1.	35.37	20.26	2.70
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

TABLE 7: 24 - HOURS SOAKING TEST AND 5-HOURS BOILING TEST RESULTS FOR WATER ABSORPTION FROM THE SAME TEST SAMPLES

SAMPLE CODE NUMBER	% WATER ABSORPTION- 24 HRS SOAKING TEST	% WATER ABSORPTION 5 HOURS BOILING TEST
1	17.99	21.44
2	17.39	19.71
3	17.44	20.02
4	17.39	19.60
5	17.34	20.03
6	17.12	19.67
7	17.18	19.72
8	17.44	19.93
9	16.86	19.07
10	16.99	19.02

2.6 FIRE RESISTANCE AND THERMAL CONDUCTIVITY

Concrete blocks have good fire resistance properties. However, their actual fire endurance may be controlled by the type and grading of fine aggregate and the cement content int he mix, weight and thickness of the block. Concrete blocks of 100mm thickness can provide an adequate resistance of fire for up to 2 hours if loadbearing or up to 4 hours if non loadbearing. /9/. This is due to the fact that the load bearing blockwall is subjected to extra stress as a result of the imposed load. As such the fire resistance is lesser than the non loadbearing blockwall.

The thermal conductivity of a concrete block is largely dependent on its block density. Thus, in general, sandcrete blocks have relatively low thermal conductivity.

2.7 EFFLORESCENCE

Efflorescence of the type found in bricks is rarely occur with concrete blocks. Brickwork sometimes develops an efflorescence of white salts brought to the surface by water and deposited by evaporation. These salts may have an external origin (for example in soil water in contact with the brickwork) or may be derive from the mortar. However the salts frequently originate in the bricks themselves.

The efflorescence that occurs in concrete blocks is that which usually result into the formation of sodium, potassium or calcium carbonates. This is formed from the reaction that occurs between any of the Hydroxide and free carbondioxide. It occurrence can be further reduced by using a pozzolana in the mix, avoiding premature drying shrinkage and unsuitable curing of blocks. It also involve proper design, construction and maintenance of blockwork. In some cases, however, these salts may form sulphate which can cause deterioration of the block /9/.

Nigerian Industrial Standard 74: 1976/24/ states that the rate of efflorescence shall not be worse than "moderate" i.e. when the area covered by the salt deposit is greater than 10% and less than 50% of the area of the brick surface but unaccompanied by powdering or flaking of the surface.

2.8 SOUND INSULATION

Unrendered lightweight concrete blocks are often used for internal walls because they are believed to have good sound absorbing qualities.

Lightweight concrete blocks do not however reduce sound transmission and in general the heavier the block the greater is its ability to reduce the transmission of sound /14/.

2.9. CUTTING, NAILING AND RENDERING

All lightweight concrete blocks can be easily cut with normal bricklayer's tools. Chases for pipes runs e.t.c can also easily be formed and they will accept and hold nails quite readily. All lightweight concrete blocks provide a very good key for rendering and plastering /14/.

2.10 SAMPLING

Before tests are carried out proper sampling must be done so as to have a good representative of the entire blocks. The sampling can be classified either by random sampling or stratified sampling. The British Standard Specification/25/ gives the number of blocks necessary for each tests in table 8 shown below:

TABLE 8: NUMBER OF BLOCKS NECESSARY FOR EACH TEST

PURPOSE FOR WHICH REQUIRED	NO OF BLOCKS NECESSARY	
	TYPE A/B	TYPE C
(a) Checking and Measurement of dimension	10	10
(b) Determination of density	3	3
(c) Determination of strength	10	5

(d) Determination of drying shrinkage and/or moisture movement	4	4
(e) Spares	3	3
(f) Total required for full set of test	20	15

2.11 MATERIALS

There are specification governing the selection of constituent materials utilized to produce sandcrete blocks and manufacturers should strictly adhere to them if the strength of the sandcrete blocks is to be attained.

The binding agent (i.e. cement) shall comply with B.S. 12 or NIS 11:1974/23/. For ordinary portland cement.

They shall be delivered in the original sealed bags of the manufacturer and stored in a proper manner to avoid deterioration.

According to Nigerian Industrial Standard 11: 1979/23/, the ordinary portland cement shall have an average specific surface of not less than 2500 cm2/g/19/. The standard further specifies the initial setting time of the cement of not less than 45 minutes. While the final setting time should not be more than 10 hours. Ordinary Portland cement shall have an expansion of less than 10mm when tested for soundness.

Since at least three - quarter of the volume of sandcrete block is occupied by fine aggregate, it is not surprising that its quality is of considerable importance. Not only may the aggregate limit the strength of sandcrete block, as poor quality fine aggregate cannot produce strong sandcrete blocks. Also the properties of fine aggregate greatly affect the durability and structural performance of sandcrete block.

The fine aggregate (sand) shall be clean and free from deleterious matter and shall mainly pass through 4.76mm of B.S. test sieve. In the 1958 publication of the Building Research station Digest No. 22/201/, it was observed that sand should not contain very fine particles such as silt and clay, which will produce a concrete that requires a high water content, or chemical impurities which may affect the setting and hardening of the blocks.

When clay or silt exists as a coating to the sand particles it is likely to result in poor bond between the particles and the cement, and also in weaker and less durable concrete /20/. The British Standard 882: 1954/17/ specifies that the silt content int he sand for any concrete work should not be greater than 6 percent.

According to the 1961 Annual Report of the West African Building Research Institute /27/, it is recognized that West african Sands, particularly sea sand containing salt do not conform to the grading requirements. They lead to lower compressive strength of blocks.

Seashore sand containing chlorides may cause efflorescence and are liable to cause corrosion of reinforcement if the concrete is porous and becomes damp. But washing of the sea shore sand should largely overcome this difficulty /14/.

Fine aggregate exposed to rain collects a considerable amount of moisture on the surface of the particles.

Except at the surface of the stockpile the fine aggregate keeps this moisture over long periods. The moisture must be allowed for in the calculation of batch quantities /12/.

According to Neville /12/, the moisture content of fine aggregate changes with weather. This also changes from one part of a stockpile to another. As such the value of the moisture content has to be determined frequently. This is to enable users to determine the exact amount of water quantity to be added to the sandcrete block.

The presence of moisture in fine aggregate necessitates correction of the actual mix proportions: the weight of water added to the mix has to be decreased by the weight of the free moisture in the aggregates, and the weight of the aggregate must be increased by the same amount.

The water shall be clean, fit for drinking and fresh, and free from organic matter. The mixing water should conform with B.S. 3148: 1959.

Rosacometta /15/ specifies that the aggregate and cement mixture should have a consistency similar to the one of slightly moist earth. It /15/ further advised that the fundamental rule of using little water in the mix and a lot in the curing must be always kept in mind, because it is the most important secret for obtaining particularly resistant blocks.

Rosacometta /15/ gives the following proportion of cement and aggregates for sandcrete blocks as shown in table 9.

TABLE 9: PROPORTION OF CEMENT & AGGREGATES FOR SANDCRETE BLOCKS

			TYPES OF STRUCTURAL ELEMENTS	
			A	B
			For specially finished elements to be left in view and not plastered over	For floor blocks or partition blocks with anticipated plastering
Normal sand free from dusts, Lime or clay (0-2mm)		Litres	1200	200
Quarry or River Gravel) or dust free	)3-5mm	Litres	-	800
Crushed stone	)6-10"	Litres	-	200
Ordinary Portland cement		Litres	140-175	119-123
Water Free from impurities		Litres	80-100	60-70
Ratio of cement and sand			1:6-1:9	1:10

Water/cement Ratio	0.4-0.7	0.4-0.6

2.12 MODE OF PRODUCTION

The Production of sandcrete blocks may be carried out manually or mechanically. Rosacometta /15/ asserted that the nature of the mix considerably affects the vibration time required for a good filling of the mould and very fine aggregates require a rather long vibration time. The cement and aggregate used in the manufacture of the blocks shall be thoroughly blended during the mixing. The mix used for blocks shall not be richer than one part by volume of cement to six parts of combined fine and coarse aggregate, except that the proportions of cement to mixed aggregates may be increased to 1:4.5 where the thickness of the web of the block is 25mm or less /25/. Where normal strength is required, mixes ranging from one part by volume of cement to six-eight parts of sand (1:6-8) with a water/cement ratio ranging from 0.6 - 0.9 depending upon the workability and the strength required.

The manufacturing process of sandcrete block involves compaction of the newly mixed constituent materials (basically binder, water and fine aggregate) in a mould followed immediately by extrusion of the pressed block so that the mould can be used repeatedly. The blocks are then released directly onto pallets which are hand loaded. The finished blocks are required to be self supporting and able to withstand any movement and vibration from the moment they are extruded.

This account therefore for the reason why the mix is always drier than the normal concrete work /9/.

The curing of blocks as important as the use of a good mix. The blocks should be placed under a shed for the first 24 hours so as to protect blocks from the direct rays of sun, heavy rains and wind. The blocks should be under shed for the next 7 days. During this phase, rows of stacked up blocks should always be accurately sprinkled /15/. The method of stacking should allow reasonable circulation of air around the blocks.

The compression machine used for the compressive tests has a capacity of 250 Tons (250,000kg).

It was observed generally that the various industries visited use the same type of block making machine called VIBROBLOCK ROSACOMETTA which is made in Italy. The operation oft he machine is semi-automatic through unidirectional vibration and simultaneous compression.

According to Rosacometta /15/, all moving parts have to be cleaned daily so as to avoid the mixture of cement and sand from adhering on any part of the machine. This is to maintain the smooth running of the machine. It further states that tension and condition of the motor "V-belts" and the oil level in the vibrator box should be checked regularly. Also the springs of vibrating plate, moulding box and locking devices should be checked regularly to ensure efficiency. The various parts of the block making machine are described below:

1) VIBRATING MOULD BOX for forming the concrete blocks (inter-changeable)

2) VIBRATING PLATE bearing on four springs installed on the base

3) Partial hopper with smoothing device (removable)

4) PRESSING STRIPPER BEARING FRAME on inter-changeable slides

(with handle for hand operation)

5) PRESSING STRIPPER (Interchangeable)

6) DRIVING LEVER for compressing system (automatic return)

7) SLIDING GUIDES of the pressing stripper (with adjustable stops)

8) HAND LEVER for upward and downward motion of the mould box

9) BRACKETS on vibrating plate for centering and fixing the pallet

10) WOODEN BEARING PALLET of only one type for all production

11) VIBRATOR with counter rotating eccentrics (vertical unidirectional vibration)

12) PRESSING STRIPPER LOCKING DEVICES granting the exact height of the blocks and making the stripping operation easier

13) ELECTRIC MOTOR for vibration (2HP-2poles)

14) BEARING PLAT for same (working as belt-stretcher through tie rod and bolt)

15) TERMINAL BOX for connection to electric power net and to earth connection

16) CURRENT BREAKER for the unidirectional vibration

17) SPRING CUSHION

18) OIL LEVEL PLUG.

The detailed diagrams of the block making machine are shown in the Appendices 24, 25 and 26.

2.13 APPLICATION

Individual blocks when bonded together with mortar are referred to collectively as blockwork or alternatively block masonry. Masonry

construction today is used principally for non loadbearing and loadbearing walls, externally and internally. All blocks and bricks have broadly similar uses although their properties differ in some important respects depending on the raw materials used and the method of manufacture.

According to Building Research Station Digest 52:1953 /19/, advantages that results from the use of sandcrete blocks include an increased rate of building labour. In addition, sandcrete blocks have good insulating properties against transfer of heat.

2.14 SITE SURVEY

The survey covers the entire Kaduna State. The state is divided into five Zones and a town is randomly selected from each of the zone.

The towns are Birnin-Gwari in the west, zaria in the north, Kagoro in the south, Saminaka in the east and Kaduna in the center. A well known block making industry was chosen from each f the town.

Initially several visits were made to the various block making industries in the State. The preliminary visits was to collect information in respect of the mode of production, sizes, cost, materials, calibre of workers e.t.c. employed by the industries.

The final visits were made to the chosen industries in which block samples were collected for the various tests. The map of Kaduna State shown below indicates the selected towns.



INDUSTRY A - ZARIA

INDUSTRY B - KADUNA

INDUSTRY C - BIRNIN-GWARI

INDUSTRY D - SAMINAKA

INDUSTRY E - KAGORO

Fifty (50) block samples were randomly collected from each of the chosen industry. In the whole, Two hundred and fifty (250) block samples were collected from the five industries.

Block making industries have been in existence for quite some time now in Kaduna State. In the past, production of blocks had been carried out using the simplest formwork with hand batching and compaction. Nowadays majority of the block making industries use the semi-industrial methods. The operation of the machine is semi-automatic through unidirectional vibration and simultaneous compression.

There is no doubt that problems were encountered int he course of undertaking the site survey. Some of the block making industries were suspicious and uncooperative, however, others were friendly.

It was observed in all the industries visited that the manufacturers use two types of sand. These are soft sand and sharp sand mixed together in different proportions. From the discussion had with the manufacturers, the soft sand is said to provide extra bonding properties for the sandcrete blocks. Also the soft sand is said to be very smooth, plastic

and it is much easier to spread than he sharp sand.

Hence the justification for the use of soft sand in the production of sandcrete blocks int he state. From observation, the sand used by the various industries contained deleterious matters such as leaves, root of tree e.t.c It is equally important to note that crushed gravel is used as fine aggregate in some industries for the production of sandcrete blocks. The production is however on special demand.

From the various sites survey carried out within the state, it was noted that the industries used ordinary Portland cement for the production of sandcrete blocks. The common brand used are Sokoto, Ashaka and Elephant cements. These cements were sold at different prices.

While the Elephant brand were sold at N100 per 50kg. bag, the Ashaka brand were sold at N90. Whereas the Sokoto cement cost N85. The mode of storing cements in virtually all the industries visited was found wanting. This is because the cements were stored on bare floor in a store.

Generally it was observed in all the industries visited that water used in the production of sandcrete hollow blocks is direct from the tap. The water is however stored in an open tank which gets contaminated with time. Most of the industries have water tankers to collect water in event of water shortage.

As earlier stated the most common type of block making machine used in the state is called vibrobloc Rosacometta. This block making machine is made in Italy.

On survey it was observed that the 230mm x 230mm x 460mm type of block was found to be commonly used in the state. This is due to the fact that it is generally used in building including the use below the ground

level damp-proof course and are intended for load bearing walls up to two storeys without columns. Other types of blocks produced in the state are 150mm x 230mm x 460mm and 100mm x 230mm x 460mm.

The mode of batching employed by all the industries in the state is by volume measurement. The sand is measured out by using wheel barrow. The mixing of cement and sand is carried out manually.

It was observed that the blocks are placed in the open air immediately after production. These blocks are subjected to severe sunshine, heavy rainfall and wind.

It is the believe of the manufacturers that the blocks should be allowed to harden (dry) rapidly under the sun especially at the early stage of production. The blocks are then sprinkled with water once daily for a period of 2 to 3 days before being sold out.

The calibre of people working in the block making industries include the foreman, operator, mixer, driver, store man, security man and unskilled labour.

The chosen industries are designated as A,B,C,D and E. This does not however denote (represent) the order of quality of the blocks produced by the industries. It is purely for identification purpose.

INDUSTRY A

Industry A represents a block making industry located in Zaria town. The industry has been in existence since 12 years ago and it has been consistently producing sandcrete hollow blocks ever since.

The types of blocks produced are 150 x 230 x 460 (mm) and 23 x 230 x 460 (mm) which are commonly referred to as 6" and 9" respectively. The industry used ordinary portland cement and the brand commonly used are the

Sokoto, ashaka and Elephant cements. These cements are normally kept on a bare floor in a store.

The source of water supply is from the tap (pipe borne water) and stored in an open tank which gets contaminated with time. The method of batching used in the industry is by volume and the cement/sand ratio employed is a bag of 50kg of cement to five wheel barrow of sand. The proportion of the sand is two part of soft sand to three part of sharp san (2:3). The cement/sand ratio was measured and found to be one part of cement to ten part of sand (1:10) with a water/cement ratio of 0.8. The industry has no concrete mixer, as such constituent materials are normally mixed manually.

On the average, the industry produces 25 blocks (230 x 230 x 460mm type) from 50kg bag of cement. the production per day is about 1300 blocks, however, the production is subject to demand.

According to the manufacturer, the blocks are normally cured by sprinkling water on them once daily for two days after which they are stacked. The type of machine used for the production of the blocks is called Vibrobloc Rosacometta. The machine was bought five years ago.

It was gathered from the discussion had with the manufacturer that there are 15 workers in the services of the industry. The calibre of workers include one foreman, one operator, four mixers, 2 drivers, 1 security man and six unskilled labour.

The industry sells it block at the rate of N5 while the cost of transporting each block per kilometer is 4 kobo.

INDUSTRY B

Industry B denotes a block making industry located in Kaduna town. Kaduna is about 65km from Zaria and fifty block samples were randomly collected for various tests.

The blocks were sold at the rate of N5.20. While the industry charges 5 kobo for the cost of transporting a block per kilometer.

According to the manufacturer, the industry is ten years old. Three common types of blocks are produced by the industry, and these are 100 x 230 x 460(mm), 150 x 230 x 460(mm) and 230 x 230 x 460(mm). This particular industry uses the same brand of ordinary portland cement as in industry A.

It was observed that the industry uses a 50kg bag of cement to one wheel barrow of soft sand and four wheel barrow of sharp sand. The cement/sand ratio was measured and calculated to be one part of cement to ten part of san (1:10) while water/cement ratio is 0.857.

From one bag (50kg) of cement, the industry produces an average of 23 blocks and production per day is about One Thousand and Seven hundred (1,700) blocks. The method of curing employed by the industry is by spraying the blocks twice daily for three days. As in the case of Industry A, Vibrobloc Rosacometta type of block making machine is used and the machine has being in operation for 4 years.

There are eighteen (18) workers employed by the industry. The consist of one foreman, one operator, four mixers, one store man, two drivers, one security man, and eight unskilled labour.

INDUSTRY C

Industry C is located in Birni-Gwari in the west of Kaduna State and it is about 123km from Kaduna.

The two types of blocks produced by the industry are 150 x 230 x 460(mm) and 230 x 230 x 460(mm).

A survey carried out indicates that the brand of ordinary portland cement commonly used are Sokoto, Ashaka and Elephant. These cements are normally kept on a bare floor in a store.

It was observed that the industry uses a cement/sand ratio of one part of cement to ten part of sand (1:10) while the ratio of water/cement is 0.8.

The sand proportion is two part of soft sand to 3 part of sharp sand (2:3). The number of blocks produced from a bag (50kg) of cement is 24 and the average production per day is about 900 blocks.

It was gathered from discussion had with the manufacturer that the blocks are normally cured for two days by spraying once in a day mostly in the morning. The industry uses the same make of machine as in the other industries mentioned above.

The transportation cost of each block is 6 kobo per kilometer while the block is sold at the rate of N5.50.

INDUSTRY D

Industry D is based in Saminaka. Saminaka is situated in the eastern zone of Kaduna State and it is about 177km from Zaria.

The transportation cost per kilometer is 5 kobo for each block whereas each block cost N5.50.

The industry has been in operation since 1986 and one machine (Vibrobloc Rosacometta type) has being in use ever since. The machine is 6 years old.

A survey carried out showed that the industry uses SoKoto brand of ordinary portland cement.

It was observed that two types of blocks are commonly produced, and these are 150 x 230 x 460(mm) and 230 x 230 x 460(mm). The cement/sand ratio employed by the industry is one part of cement to ten part of sand (1:10), whereas the water/cement ratio is 0.8. The proportion of the sand is two part of soft sand to three part of sharp sand (2:3).

According to the manufacturer the industry produces an average of 700 blocks per day and from each bag (50kg) of cement, about 25 blocks are produced. After casting, the blocks are cured in the open air without any covering and water is sprayed once daily for a period of two days.

It was observed that there are 10 workers in the services of the industry. The calibre of workers include one foreman, one operator and two mixers.
Others are one driver, one security man and 4 unskilled labour.

INDUSTRY E

Industry E is located in Kagoro. Kagoro is situated in the southern zone of Kaduna State and it is about 250km from Kaduna. According tot he manufacturer, the industry is 7 years old and has 12 workers. The workers are one foreman, one operator, three mixers, two drivers, one security man and four unskilled labour.

It was observed that the type of blocks produced by the industry are 150 x 230 x 460(mm) and 230 x 230 x 460(mm). The brand of cement used are

Sokoto and ashaka. The source of water in the industry is pipe borne water and it is stored in an uncovered tank which becomes contaminated with time.

The cement/sand ratio employed by the industry was found to be one part of cement to ten part of sand (1:10) while the water/cement ratio is 0.686. Manual method of mixing constituent materials is employed in the industry.

The industry produces about 600 blocks daily with an average of 26 block from each bag (50kg) of cement. The mode of curing and the type of machine used in the industry are the same as in industries A, C, and D. The blocks are sold at the rate of N5.60 while the cost of transportation per kilometer is 4 kobo per block.

3.0 CHAPTER THREE

3.1 EXPERIMENTATION

In chapter two attempts have been made to collect information in respect of materials, cost and mode of production used by the various manufacturers in the state. The block samples as earlier stated in the chapter were collected from five locations within the state.

As earlier stated the locations are Zaria in the north, Kaduna in the centre, birnin Gwari in the west, Saminaka in the east and Kagoro which is at the south. The locations are designated as A,B,C,D and E respectively. This however does not represent the order of the quality of blocks produced by the various industries. In each of the location, a well known block industry is chosen and fifty (50) block samples were collected. About 250 block samples were brought to the laboratory for various tests.

In order to protect the block samples from extreme conditions of temperature and wind, the block samples were kept under cover in the laboratory before testing.

The tests include dry development strength, wet development strength, wet compressive strength, moisture movement, drying shrinkage e.t.c. The tests are carried out in accordance with the British and Nigerian Industrial standards.

In addition to the strength tests, sand samples were also obtained from the various industries. The sand samples were collected to determine their classification, silt content and porosity.

3.2 SIEVE ANALYSIS

Samples of sand were tested to determine whether or not their grading are suitable as fine aggregate. Comparison of the test results show that the sand fall partly within the limits of Zone 1 of the British Standard 882/17/.

The various test results are shown below in tables 10, 11, 12, 13 and 14.

TABLE 10: SIEVE ANALYSIS OF INDUSTRY A

WEIGHT OF SAND SAMPLE: 600g

B.S. SIEVE SIZE	WEIGHT RETAINED (g)	WEIGHT PASSED (g)	% RETAINED (%)	CUMULATIVE PERCENTAGE PASSING(%)	CUMULATIVE PERCENTAGE RETAINED(%)
10.00mm	0	6000	0	100	0
5.00mm	495	5535	7.75	92	8
2.36mm	994	4541	16.57	76	24
1.18mm	1747	2794	29.12	47	53
600Nm	1950	844	32.50	14	86
300Nm	612	232	10.20	4	96
150Nm	155	77	2.58	1	99
PAN	74	--	1.23	--	--
		TOTAL	=	366	
		FINENESS MODULUS	=	3.66	

TABLE 11: SIEVE ANALYSIS OF INDUSTRY B

WEIGHT OF SAND SAMPLE: 6000g

B.S. SIEVE SIZE	WEIGHT RETAINED (g)	WEIGHT PASSED (g)	% RETAINED (%)	CUMULATIVE PERCENTAGE PASSING %	CUMULATIVE PERCENTAGE RETAINED %
10.00mm	0	6000	0	100	0
5.00mm	530	5470	8.83	91	9
2.36mm	790	4680	13.17	78	22
1.18mm	1930	2750	32.17	46	54
600Nm	1998	752	33.30	13	87
300Nm	610	142	10.17	2	88
150Nm	120	22	2.00	1	99
PAN	20	--	0.33	--	--
		TOTAL =	369		
		FINENESS MODULUS =	3.69		

TABLE 12: SIEVE ANALYSIS OF INDUSTRY C

WEIGHT OF SAND SAMPLE: 600g

B.S. SIEVE SIZE	WEIGHT RETAINED (g)	WEIGHT PASSED (g)	% RETAINED (%)	CUMULATIVE PERCENTAGE PASSING %	CUMULATIVE PERCENTAGE RETAINED %
10.00mm	0	6000	0	100	0
5.00mm	925	5075	15.42	85	15
2.36mm	1220	3855	20.33	64	36
1.8mm	1615	2240	26.92	37	63
600Nm	1490	750	24.83	12	88
300Nm	565	185	9.42	3	97
150Nm	120	65	2.00	1	99
PAN	62	--	1.03	--	--
		TOTAL =	398		
		FINENESS MODULUS =	3.98		

TABLE 13: SIEVE ANALYSIS OF INDUSTRY D

WEIGHT OF SAND SAMPLE: 6000g

B.S. SIEVE SIZE	WEIGHT RETAINED (g)	WEIGHT PASSED (g)	% RETAINED %	CUMULATIVE PERCENTAGE PASSING %	CUMULATIVE PERCENTAGE RETAINED %
10.00mm	0	6000	0	100	0
5.00mm	717	5283	11.95	88	12
2.36mm	1005	4278	16.75	71	29
1.18mm	1760	2518	29.33	42	58
600Nm	1827	691	30.45	12	88
300mm	540	151	9.00	3	97
15Nm	109	42	1.82	1	99
PAN	38	--	0.63	--	--

TOTAL = 383

FINENESS MODULUS = 3.83

TABLE 14: SIEVE ANALYSIS OF INDUSTRY E

WEIGHT OF SAND SAMPLE: 6000g

B.S. SIEVE SIZE	WEIGHT RETAINED (g)	WEIGHT PASSED (g)	% RETAINED (%)	CUMULATIVE PERCENTAGE PASSING %	CUMULATIVE PERCENTAGE RETAINED %
10.00mm	0	6000	0	100	0
5.00mm	897	5103	14.95	85	15
2.36mm	895	4208	14.92	70	30
1.18mm	1685	2523	28.08	42	58
600Nm	1795	728	29.92	12	88
300Nm	542	186	9.03	3	97
150Nm	132	54	2.20	1	99
PAN	52	--	0.87	--	--
		TOTAL =	387		
	FINENESS MODULUS	=	3.87		

The various particles size distribution curves are shown in chapter four.

3.3 SILT CONTENT

The silt content of the sand samples as used by the various industries were also determined. Silt is a material between 0.002mm and 0.06mm. The test was carried out in accordance to the British standard 812: part 1:1975/16/.

Sand which contains silt in it is soft and smooth when compressed with hand. Thus the term soft sand. Similarly sand which is clean is coarse when compressed between hand, hence the term sharp. The results of the silt contents for sand Industries A,B,C,D and E are shown in table 15.

TABLE 15: RESULT OF SILT CONTENT

INDUSTRY	SHARP SAND	SOFT SAND	AVERAGE SILT
A	6.25	11.70	8.98
B	4.55	10.59	7.57
C	6.25	13.64	9.95
D	9.09	14.61	11.85
E	7.14	15.14	11.14

The various raw data results from which the above table was extracted is shown in Appendix 22. The standard however recommends 6 percent.

3.4 POROSITY OF SAND

This is the term describing the percentage of voids (pores) in the sand. The porosity of the sand samples were examined and the results are as shown in table 16.

The test was in accordance with the standards procedure /16/.

TABLE 16: POROSITY OF SAND %

INDUSTRY	POROSITY OF SAND
A	36
B	33
C	30
D	38
E	34

The various raw data results from which the above table was extracted is shown in Appendix 23.

3.5 DRY DEVELOPMENT STRENGTH

The aim of the dry development strength is to determine when the strength of the sandcrete block is fully developed. This is to ascertain when the block is fully ready for use.

The block samples having been brought to the laboratory were marked for identification. The strength indicated against each age is an average strength of three blocks for each industry. The ages of test are 3rd, 7th, 14th, 21st and 28th days. For even distribution, the loading is applied gradually until failure load is obtained. The test results are shown in tables 17, 18, 19, 20 and 21 below.

TABLE 17: DRY DEVELOPMENT STRENGTH OF INDUSTRY A

DATE OF CASTING: 04/02/92

TESTED BETWEEN CELOTEX

S/N	AGE DAYS	DATE TESTED	LENGTH MM	BREADTH MM	HEIGHT MM	LOAD KN	STRENGTH N/MM2
1	3	7/2/92	460	230	219	52.67	0.50
2	7	11/2/92	460	230	219	62.17	1.59
3	14	18/2/92	459	230	219	69.82	0.66
4	21	25/2/92	460	230	220	83.17	0.79
5	28	3/3/92	460	231	220	85.00	0.80

TABLE 18: DRY DEVELOPMENT STRENGTH OF INDUSTRY B

DATE OF CASTING: 04/02/92

TESTED BETWEEN CELOTEX

S/N	AGE DAYS	DATE TESTED	LENGTH MM	BREADTH MM	HEIGHT MM	LOAD KN	STRENGTH N/MM2
1	3	7/2/92	460	230	219	68.83	0.65
2	7	11/2/92	458	230	220	88.00	0.84
3	14	18/2/92	459	230	219	104.83	0.99
4	21	25/2/92	460	229	219	111.67	1.06
5	28	3/3/92	459	230	219	108.00	1.02

TABLE 19: DRY DEVELOPMENT STRENGTH OF INDUSTRY C

DATE OF CASTING: 04/02/92

TESTED BETWEEN CELOTEX

S/N	AGE DAYS	DATE TESTED	LENGTH MM	BREADTH MM	HEIGHT MM	LOAD KN	STRENGTH N/MM2
1	3	7/2/92	460	230	218	72.00	0.68
2	7	11/2/92	460	230	217	81.67	0.77
3	14	18/2/92	460	230	220	82.00	0.78
4	21	25/2/92	461	231	218	90.83	0.86
5	28	3/3/92	460	230	219	102.07	0.97

TABLE 20: DRY DEVELOPMENT STRENGTH OF INDUSTRY D

DATE OF CASTING: 04/03/92

TESTED BETWEEN CELOTEX

S/N	AGE DAYS	DATE TESTED	LENGTH MM	BREADTH MM	HEIGHT MM	LOAD KN	STRENGTH N/MM2
1	3	7/3/92	460	230	220	60.17	0.59
2	7	11/3/92	461	231	219	65.17	0.61
3	14	18/3/92	460	230	220	86.00	0.81
4	21	25/3/92	460	230	218	82.50	0.78
5	28	3/4/92	460	230	220	81.67	0.77

TABLE 21: DRY DEVELOPMENT STRENGTH OF INDUSTRY E

DATE OF CASTING: 04/03/92

TESTED BETWEEN CELOTEX

S/N	AGE DAYS	DATE TESTED	LENGTH MM	BREADTH MM	HEIGHT MM	LOAD KN	STRENGTH N.MM2
1	3	7/3/92	459	230	220	63.00	0.60
2	7	11/3/92	459	230	217	82.50	0.78
3	14	18/3/92	460	229	217	97.25	0.92
4	21	25/3/92	460	230	219	92.05	0.87
5	28	3/4/92	459	230	217	95.62	0.91

TABLE 22: COMBINED DRY DEVELOPMENT STRENGTH

AGE (DAYS)	INDUSTRY A	INDUSTRY B	INDUSTRY C	INDUSTRY D	INDUSTRY E
3	0.50	0.65	0.68	0.57	0.60
7	0.59	0.84	0.77	0.61	0.78
14	0.66	0.99	0.78	0.81	0.92
21	0.66	0.06	0.86	0.78	0.87
28	0.80	1.02	0.97	0.77	0.91

The raw data results from which the above tables were extracted are shown in Appendices 1,2,3,4 and 5.

From the results shown above the strength development as well as the strength are low when compared to the standard.

3.6 WET COMPRESSIVE STRENGTH

The wet compressive strength is to determine the worst condition the sandcrete block can be subjected to. The test is carried out after 28 days of age of the block samples.

The block samples previously measured were immersed in water and allowed to drain under damp sack materials before bedding on both faces with mortar. The mortar used was of one part by weight of cement to one part by weight of sand (1:1).

After bedding, the block samples were then immersed in water. Mortar cubes were also made out of the mortar mix used for bedding and were also immersed in water.

When the mortar has attained the required strength, the compressive strength of each block sample were determined. The block samples were soaked for four days prior to crushing. The strength indicated against each age is an average strength of three cubes for each industry.





PLATE II - BEDDED BLOCK SAMPLES BEING IMMERSED IN THE CURING TANK.

TABLE 23: MORTAR CUBES STRENGTH OF INDUSTRY A

DATE IMMERSED IN WATER - 05/03/92

AREA OF CUBE - (70 x 70)mm2

S/N	DATE TESTED	AGE OF CURING (DAYS)	FAILURE LOAD(KN)	AVERAGE STRENGTH N/mm2
1	6/3/92	1	117.67	24.01
2	7/3/92	2	126.33	25.78
3	8/3/92	3	136.00	27.76
4	9/3/92	4	140.67	28.71

TABLE 24: MORTAR CUBES STRENGTH OF INDUSTRY B

DATE IMMERSED IN WATER - 05/03/92

AREA OF CUBE - (70 X 70)mm2

S/N	DATE TESTED	AGE OF CURING (DAYS)	FAILURE LOAD (KN)	AVERAGE STRENGTH N/mm2
1	6/3/92	1	113.00	23.06
2	7/3/92	2	126.00	25.71
3	8/3/92	3	134.67	27.48
4	9/3/92	4	139.33	28.44

TABLE 25: MORTAR CUBES STRENGTH OF INDUSTRY C

DATE IMMERSED IN WATER - 05/03/92

AREA OF CUBE (70 x 70)mm2

S/N	DATE TESTED	AGE OF CURING (DAYS)	FAILURE LOAD (KN)	AVERAGE STRENGTH n/MM2
1	5/4/92	1	112.50	22.96
2	7/3/92	2	120.73	24.64
3	8/3/92	3	129.00	26.29
4	9/3/92	4	137.33	28.03

TABLE 26: MORTAR CUBES STRENGTH OF INDUSTRY D

DATE IMMERSED IN WATER - 04/04/92

AREA OF CUBE - (70 X 70)MM2

S/N	DATE TESTED	AGE OF CURING (DAYS)	FAILURE LOAD(KN)	AVERAGE STRENGTH N/mm2
1	5/4/92	1	114.33	23.33
2	6/4/92	2	122.98	25.10
3	7/4/92	3	134.17	27.38
4	8/4/92	4	142.00	28.98

TABLE 27: MORTAR CUBES STRENGTH OF INDUSTRY E

DATE IMMERSED IN WATER - 04/04/92

AREA OF CUBE - (70 X 70)mm2

S/N	DATE TESTED	AGE OF CURING (DAYS)	FAILURE LOAD (KN)	AVERAGE STRENGTH N/mm2
1	5/4/92	1	105.50	21.53
2	6/4/92	2	120.00	24.49
3	7/4/92	3	119.83	24.45
4	8/4/92	4	138.00	28.16

The raw data results from which the above tables were extracted are shown in Appendices 16,17,18, 19 and 20.

The wet compressive strength test results are shown in Tables 28,29,30,31 and 32.

TABLE 28: WET COMPRESSIVE STRENGTH OF INDUSTRY A

DATE IMMERSED IN WATER: 01/03/92

TESTED: 05/03/92

S/N	SAMPLE NO	AGE (DAYS)	DATE	LENGTH MM	BREADTH MM	HEIGHT MM	FAILURE LOAD(KN)	STRENGTH N/mm2
1	A1/05/03/ZR	4	5/3/92	461	232	230	50.6	0.473
2	A2/05/03/ZR	"	"	460	232	228	50.4	0.472
3	A3/05/03/ZR	"	"	461	230	231	50.0	0.472
4	A4/05/03/ZR	"	"	462	230	228	51.0	0.480
5	A5/05/03/ZR	"	"	460	231	228	53.0	0.499
6	A6/05/03/ZR	"	"	460	230	230	52.0	0.491
7	A7/05/03/ZR	"	"	460	230	230	49.0	0.463
8	A8/05/03/ZR	"	"	461	232	230	51.0	0.477
9	A9/05/03/ZR	"	"	462	231	228	49.0	0.459
10	A10/05/03/ZR"	"	"	462	232	228	44.0	0.411
11	A11/05/03/ZR"	"	"	460	231	230	46.0	0.433
12	A12/05/03/ZR "	"	"	461	231	230	55.0	0.516

AVERAGE STRENGTH = 0.471N/mm2

STANDARD DEVIATION = 0.027N/mm2

COEFFICIENT OF VARIATION = 5.732%

TABLE 29: WET COMPRESSIVE STRENGTH OF INDUSTRY B

DATE IMMERSED IN WATER: 01/03/92

TESTED: 05/03/92

S/N	SAMPLE NO	AGE (DAYS)	DATE	LENGTH MM	BREADTH MM	HEIGHT MM	FAILURE LOAD(KN)	STRENGTH N/mm2
1	B1/05/03/KD	4	5/3/92	460	232	233	64.0	0.600
2	B2/05/03/KD	"	"	461	232	232	64.0	0.598
3	B3/05/03/KD	"	"	461	231	232	65.0	0.610
4	B4/05/03/KD	"	"	462	230	231	55.5	0.522
5	B5/05/03/KD	"	"	461	231	232	66.5	0.624
6	B6/05/03/KD	"	"	461	231	232	56.5	0.531
7	B7/05/03/KD	"	"	460	231	231	60.0	0.565
8	B8/05/03/KD	"	"	460	230	232	52.0	0.490
9	B9/05/03/KD	"	"	461	232	231	59.0	0.552
10	B10/05/03/KD	"	"	463	232	230	68.0	0.633
11	B11/05/03/KD	"	"	460	230	232	65.0	0.614
12	B12/05/03/KD	"	"	462	231	232	70.0	0.656

AVERAGE STRENGTH = 0.583N/mm2

STANDARD DEVIATION = 0.047N/mm2

COEFFICIENT OF VARIATION = 8.062%

TABLE 30: WET COMPRESSIVE STRENGTH OF INDUSTRY C

DATE IMMERSED IN WATER: 01/03/92

TESTED: 05/03/92

S/N	SAMPLE NO.	AGE (DAYS)	DATE	LENGTH MM	BREADTH MM	HEIGHT MM	FAILURE LOAD(KN)	STRENGTH N/mm2
1	C1/05/03/BG	4	5/3/92	462	231	230	61.0	0.572
2	C2/05/03/BG	"	"	461	232	232	62.0	0.580
3	C3/05/03/BG	"	"	461	231	231	66.0	0.620
4	C4/05/03/BG	"	"	460	231	230	60.5	0.569
5	C5/05/03/BG	"	"	460	230	231	59.0	0.558
6	C6/05/03/BG	"	"	460	230	230	56.5	0.534
7	C7/05/03/BG	"	"	461	231	230	64.0	0.601
8	C8/05/03/BG	"	"	460	230	232	58.0	0.548
9	C9/05/03/BG	"	"	462	231	232	59.5	0.558
10	C10/05/03/BG	"	"	460	230	230	52.5	0.496
11	C11/05/03/BG	"	"	461	231	230	60.0	0.563
12	C12/05/03/BG	"	"	460	232	230	42.7	0.400

AVERAGE STRENGTH = 0.550N/mm2

STANDARD DEVIATION = 0.052N/mm2

COEFFICIENT OF VARIATION = 9.445%

TABLE 31: WET COMPRESSIVE STRENGTH OF INDUSTRY D

DATE IMMERSED IN WATER: 31/03/92

TESTED: 04/04/92

S/N	SAMPLE NO	AGE (DAYS)	DATE	LENGTH MM	BREADTH MM	HEIGHT MM	FAILURE LOAD(KN)	STRENGTH N/mm2
1	D1/05/03/SM	4	4/4/92	462	230	230	52.5	0.494
2	D2/05/03/SM	"	"	461	231	230	50.0	0.470
3	D3/05/03/SM	"	"	461	230	231	52.5	0.495
4	D4/05/03/SM	"	"	460	230	232	64.0	0.605
5	D5/05/03/SM	"	"	461	231	232	53.5	0.502
6	D6/05/03/SM	"	"	460	230	230	55.0	0.520
7	D7/05/03/SM	"	"	460	230	230	50.2	0.474
8	D8/05/03/SM	"	"	460	231	231	50.1	0.471
9	D9/05/03/SM	"	"	460	232	230	50.3	0.471
10	D10/05/03/SM	"	"	461	230	230	59.5	0.561
11	D11/05/03/SM	"	"	461	230	230	50.5	0.476
12	D12/05/03/SM	"	"	460	230	232	50.5	0.477

AVERAGE STRENGTH = 0.501N/mm2

STANDARD DEVIATION = 0.042N/mm2

COEFFICIENT OF VARIATION = 8.383%

TABLE 32: WET COMPRESSIVE STRENGTH OF INDUSTRY E

DATE IMMERSED IN WATER: 31/03/92

TESTED: 04/04/92

S/N	SAMPLE NO	AGE (DAYS)	DATE	LENGTH MM	BREADTH MM	HEIGHT MM	FAILURE LOAD(KN)	STRENGTH N/mm2
1	E1/05/03/KG	4	4/4/92	460	231	228	40.5	0.381
2	E2/05/03/KG	"	"	461	230	226	60.15	0.567
3	E3/05/03/KG	"	"	460	230	228	50.30	0.475
4	E4/05/03/KG	"	"	462	232	230	60.30	0.563
5	E5/05/03/KG	"	"	460	231	230	55.80	0.525
6	E6/05/03/KG	"	"	460	230	230	50.50	0.477
7	E7/05/03/KG	"	"	461	230	230	64.00	0.604
8	E8/05/03/KG	"	"	461	230	228	63.50	0.599
9	E9/05/03/KG	"	"	460	230	228	65.50	0.619
10	E10/05/03/KG	"	"	460	230	230	62.50	0.591
11	E11/05/03/KG	"	"	460	231	230	64.70	0.609
12	E12/05/03/KG	"	"	460	230	226	59.00	0.558

AVERAGE STRENGTH = 0.547N/mm2

STANDARD DEVIATION = 0.068N/mm2

COEFFICIENT OF VARIATION = 12.43%

TABLE 33: COMBINED WET COMPRESSIVE STRENGTH

INDUSTRY	A	B	C	D	E
AVERAGE STRENGTH N/mm2	0.471	0.583	0.550	0.501	0.547

3.7 WET DEVELOPMENT STRENGTH

The wet development strength was determined after 28 days of age.

The blocks were soaked in water and tested wet at various ages.

The strength value shown at each age is an average of three blocks tested for strength.

The test results are tabulated below in tables 34 to 38.

TABLE 34: WET DEVELOPMENT STRENGTH OF INDUSTRY A

DATE IMMERSED IN WATER: 4/3/92

WITHOUT BENDING BUT TESTED WITH CELOTEX

S/N	AGE (DAYS)	DATE	LENGTH MM	BREADTH MM	HEIGHT MM	LOAD KN	STRENGTH N/mm2
1	1	5/3/92	461	231	221	29.33	0.28
2	3	7/3/92	461	231	220	49.00	0.46
3	7	11/3/92	461	230	221	59.67	0.56
4	14	18/3/92	461	231	221	61.50	0.58
5	21	25/3/92	461	230	221	66.37	0.63
6	28	1/4/92	462	230	221	62.83	0.59

TABLE 35: WET DEVELOPMENT STRENGTH OF INDUSTRY B

DATE IMMERSED IN WATER 4/3/92

WITHOUT BENDING BUT TESTED WITH CELOTEX

S/N	AGE (DAYS)	DATE	LENGTH MM	BREADTH MM	HEIGHT MM	LOAD KN	STRENGTH N/mm2
1	1	5/3/92	461	230	221	37.33	0.35
2	3	7/3/92	461	231	221	76.66	0.72
3	7	11/3/92	461	230	220	82.57	0.78
4	14	18/3/92	462	232	220	84.00	0.79
5	21	25/3/92	461	231	220	67.67	0.64
6	28	1/4/92	461	231	221	77.17	0.78

TABLE 36: WET DEVELOPMENT STRENGTH OF INDUSTRY C

DATE IMMERSED IN WATER: 4/3/92

WITHOUT BENDING BUT TESTED WITH CELOTEX

S/N	AGE (DAYS)	DATE	LENGTH MM	BREADTH MM	HEIGHT MM	LOAD KN	STRENGTH N/mm2
1	1	5/3/92	461	230	220	35.33	0.33
2	3	7/3/92	461	231	220	69.67	0.65
3	7	11/3/92	461	230	221	70.00	0.66
4	14	18/3/92	461	230	220	69.67	0.66
5	21	25/3/92	461	231	221	63.33	0.60
6	28	1/4/92	462	231	221	72.50	0.68

TABLE 37: WET DEVELOPMENT STRENGTH OF INDUSTRY D

DATE IMMERSED IN WATER: 3/4/92

WITHOUT BENDING BUT TESTED WITH CELOTEX

S/N	AGE (DAYS)	DAYS	LENGTH MM	BREADTH MM	HEIGHT MM	LOAD KN	STRENGTH N/mm2
1	1	4/4/92	461	231	221	35.17	0.33
2	3	6/4/92	460	231	221	62.17	0.53
3	7	10/4/92	461	231	221	69.83	0.66
4	14	17/4/92	461	231	219	62.67	0.59
5	21	24/4/92	460	231	220	66.67	0.63
6	28	1/5/92	461	231	221	70.17	0.66

TABLE 38: WET DEVELOPMENT STRENGTH OF INDUSTRY E

DATE IMMERSED IN WATER: 3/4/92

WITHOUT BENDING BUT TESTED WITH CELOTEX

S/N	AGE (DAYS)	DATE	LENGTH MM	BREADTH MM	HEIGHT MM	LOAD KN	STRENGTH N/mm2
1	1	4/4/92	460	230	221	36.83	0.35
2	3	6/4/92	460	230	221	65.70	0.62
3	7	10/4/92	461	231	221	69.27	0.65
4	14	17/4/92	461	231	220	61.67	0.58
5	21	24/4/92	460	231	219	66.80	0.63
6	28	1/5/92	462	230	221	70.00	0.66

TABLE 39: COMBINED WET DEVELOPMENT (N/mm2)

AGE (DAYS)	INDUSTRY A	INDUSTRY B	INDUSTRY C	INDUSTRY D	INDUSTRY E
1	0.28	0.35	0.33	0.33	0.35
3	0.46	0.72	0.65	0.53	0.62
7	0.56	0.78	0.66	0.66	0.65
14	0.58	0.79	0.66	0.59	0.58
21	0.63	0.64	0.60	0.63	0.63
28	0.59	0.73	0.68	0.66	0.66

The raw data results from which the above tables were extracted are shown in Appendices 11,12,13,14 and 15.

3.8 RATIO OF WET TO DRY DEVELOPMENT STRENGTH

As earlier stated, the wet development strength were obtained by testing the blocks wet after 28 days at various soaking ages. The dry development strengths are the compressive strengths at various ages starting from 3-days and tested dry up to 28 days.

The ratio of the wet development strengths at various soaking ages to the dry development strength at 28 days are shown below in table 40.

TABLE 40: WET DEVELOPMENT STRENGTH TO DRY DEVELOPMENT STRENGTH RATIO IN PERCENTAGES

DAYS OF IMMERSION AFTER 28 DAYS	fWET/fDRY (28) (%)				
	INDUSTRY A	INDUSTRY B	INDUSTRY C	INDUSTRY D	INDUSTRY E
0	100	100	100	100	100
1	35	34	34	43	38
3	58	71	67	69	68
7	70	76	68	86	71
14	73	77	68	77	64
21	79	63	62	82	69
28	74	72	70	86	73

3.9 DETERMINATION OF DENSITY

The density was determined in accordance with the specification for precast concrete blocks (B.S. 2028: 1068)/25/.

The result are shown in table 41.

TABLE 41: DETERMINATION OF DENSITY

INDUSTRY	DENSITY (Kg/M3)
A	940
B	980
C	1050
D	1000
E	980
AVERAGE	994

TABLE 41: DETERMINATION OF DENSITY

INDUSTRY	DENSITY (Kg/M3)
A	940
B	980
C	1050
D	1020
E	980
AVERAGE	994

3.10 ABSORPTION OF WATER

The ratio of the increase in weight to the weight of the dry sample, expressed as a percentage, is termed absorption. The test was carried out in accordance with the British standard specification/25/.

TABLE 42: WATER ABSORPTION

INDUSTRY	WATER ABSORPTION (%)
A	10.11
B	10.05
C	6.48
D	8.77
E	13.37

The raw data results from which the above table was extracted are shown in Appendix 25.

3.11 DETERMINATION OF DRYING SHRINKAGE AND MOISTURE MOVEMENTS

The drying shrinkage and the moisture movement were determined in accordance with the Appendix E of the specification/25/ for precast concrete blocks (B.S. 2028). The results are shown in Table 43.

TABLE 43: DRYING SHRINKAGE AND MOISTURE MOVEMENT

SAMPLE	A	B	C	D	E	AVERAGE
DRYING SHRINKAGE %	0.025	0.038	0.031	0.033	0.021	0.030
MOISTURE MOVEMENT %	0.072	0.074	0.067	0.092	0.071	0.075

4.0 # CHAPTER FOUR

4.1 ANALYSIS AND DISCUSSION OF RESULTS

The detailed test results are as presented in chapter three. This chapter is mainly to analyze the data to ascertain the quality of Sandcrete hollow blocks produced in Kaduna State.

The test results carried out on the block samples are discussed as presented below.

4.2 INDUSTRY A

As can be seen from figure 2 and table 15 of chapter three, the Sandcrete blocks from industry A have generally very low dry development strength.

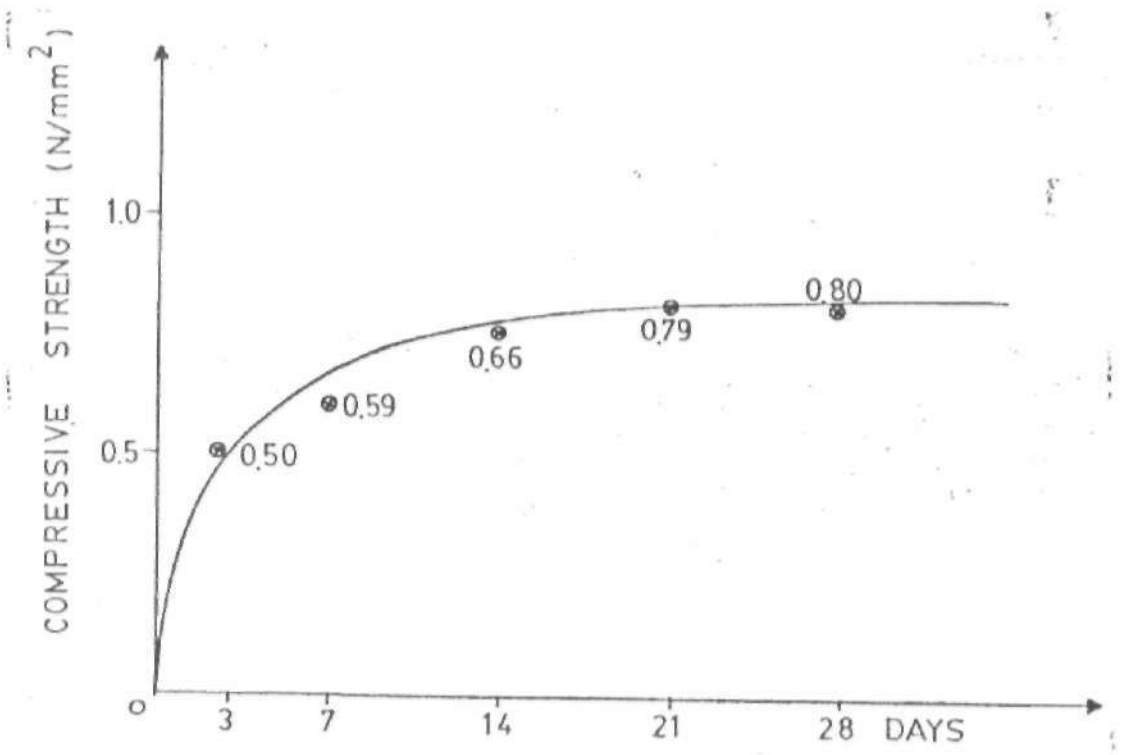


FIGURE 2: DRY DEVELOPMENT STRENGTH SAMPLE A

The value of the dry development strength at 28 days is 0.80N/mm2. Although most codes of practice do not specify the value of the dry development strength rather the values of the wet compressive strength is specified. However, it is expected that the dry development strength should be higher than the wet compressive strength. It can be seen that the dry development strength which is 0.8N/mm2 is however lower than the values specified by the codes for the wet compressive strength.

The Britain standard/25/ specified an average compressive strength of 3.5N/mm2.

It is observed that the block samples attained a steady strength as from the 7th day of curing, showing little strength difference from 7th to 28th days. This implies that the rate of hydration i.e. chemical reaction between cement and water is slower as from the 7th day. It should be emphasized however that hydration is a continuous process diminishing with age. Thus the continuous strength - increase.

The wet compressive strength is as shown in table 21. The average wet compressive strength is 0.471N/mm2. However, the British standard/25/specifies the average compressive strength as 3.5N/mm2 while the lowest individual block strength as 2.8N/mm2. Also the Federal Ministry of Works during the annual conference in Kano (1979/2/ recommended an average compressive strength of 2.1.N/mm2 while lowest compressive strength of individual block should not be less than 1.7N/mm2.

Furthermore, the Nigerian industrial standard under preparation specifies an average strength of 3.45N/mm2 for load bearing and 2.76N/nn2 for a non load bearing Sandcrete blocks. Most codes of practice specify 80% for the lowest percent of the individual strength to the average

compressive strength. It can be seen that the average wet compressive strength of 0.47N/mm2 for industry A is about 13.46 percent of the British Standard specification of 3.5N/mm2.

However, the coefficient of variation of the block samples satisfies the 20% limit specified for concrete structures/12/. The coefficient of variation for industry A is 5.73%. This implies that the manufacturing process in industry A is consistent. As such there is no much variance in the level of production.

The wet development strength can be seen from table 27 and presented in figure 3 shown below.

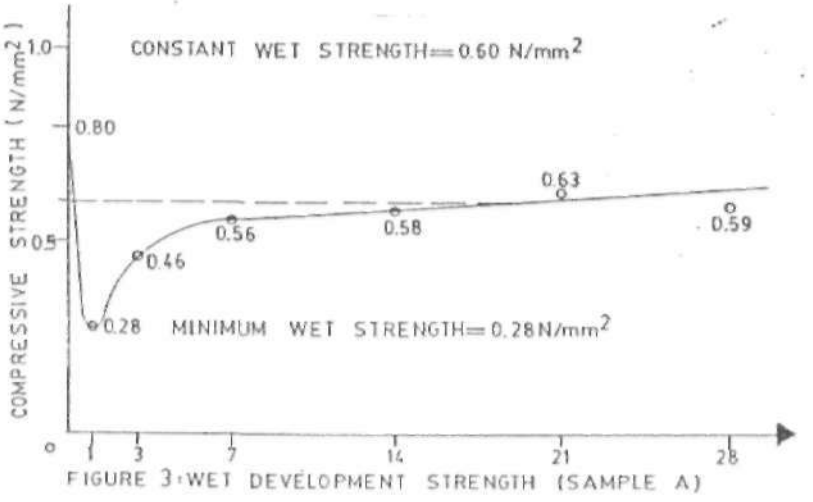


FIGURE 3:WET DEVELOPMENT STRENGTH (SAMPLE A)

One observe that as the samples are soaked in water, the 28 days dry development strength which is the highest strength on the graph dropped to the minimum strength of 0.28N/mm2 which is obtained when immersed for 28 hours prior to testing. This strength increases gradually up till the 7th to 14th day of immersion prior to testing when strength becomes stabilized or steady. However, the strength - increase do not reach the initial dry development strength value of 0.8N/mm2.

As the Sandcrete blocks are immersed in water, the y show an increase in volume and an increase in weight. This swelling is due to the absorption of water by the cement gel and the high silt content in the sand. The water molecules act against the cohesive forces and tend to force the gel particles further apart, with a resulting swelling pressure. In addition, the ingress of water decreases the surface tension of the gel, and a further small expansion takes place. This swell as a result of silt presence give rise to a sudden sharp drop in strength down to 35 percent. With time, the water particles get into cement gel and hydration reaction takes place leading to a gradual increase in strength. This increase in strength gradually comes to a steady increase but the actual strength is still lower than expected as a result of high silt content.

The ratio of the wet development strengths at various soaking ages to the dry development strength at 28 days is shown in table 33 and presented below in figure 4.

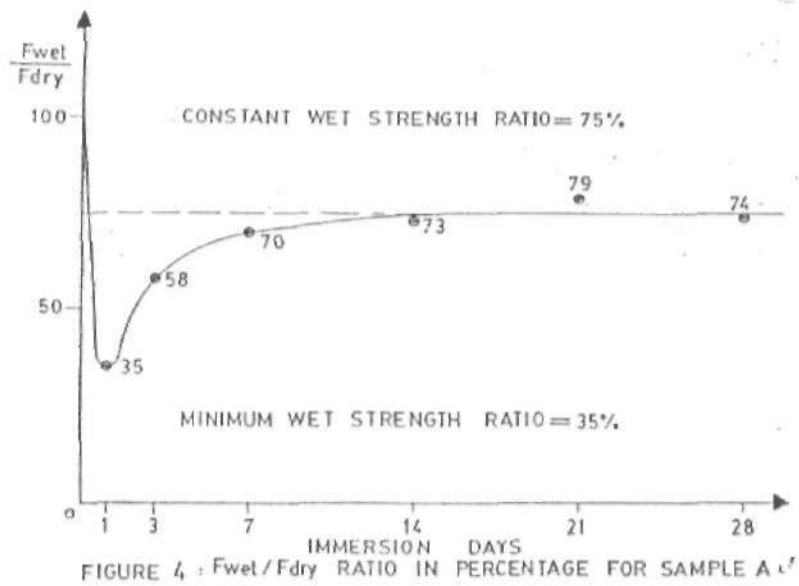


FIGURE 4 : Fwet / Fdry RATIO IN PERCENTAGE FOR SAMPLE A

It can be seen that the ratio of the wet to dry development strengths dropped to 35 percent within 24 hours of soaking prior to testing. This ratio increased to 74 percent at 28 days of soaking prior to testing. Thus the worst condition occurs within 24 hours of soaking.

One observed that the ratio is fairly steady as from the 7th day of immersion in water. While the constant wet strength ratio is 75%.

The British standard 2028/25/ specifies that the block density of TYPE A blocks shall be not less than 1500kg/m3. The average density for industry A is 940kg/m3 which is lower than the British standard specification. The test result is shown in table 34.

The test results of the drying shrinkage and the moisture movement is presented in table 36 of chapter three.

It can be seen that the drying shrinkage of industry A is 0.025% while the moisture movement in 0.072%. The average drying shrinkage of the block samples is within the limit specified by the standard whereas

the average moisture movement exceeds the specified limit. The British standard 2028/25/ specifies that the average value of the drying shrinkage shall not exceed 0.04% for type A block while the average moisture movement shall not exceed 0.05%.

As early stated both the dry development strength, wet development strength, and wet compressive strength do not satisfy any of the codes of practice. Furthermore, the block samples failed to satisfy the requirements of moisture movement. However, the average drying shrinkage satisfy the limit specified by the British standard/25/.

The low strength could be as a result of poor sand used by the industry. From the site survey carried out, it was observed that industry A uses two types of sand. These are soft sand and sharp sand. The proportioning of the sand is two part by volume of soft sand to three part by volume of sharp sand (2:3). The sand test indicates a high silt content. This is evident from table 10 which shows a silt contest of 6.25% for the sharp sand and 11.70% for the soft sand. While the average silt content is 8.98%. This value however exceeds the limit of 6% specified by the British standard 812: part 1: 1975/16.

From the literature review, the Building Research Station Digest No. 22/20/ observed that sand should not contain vary fine particles such as silt and clay, which will produce a concrete that requires a high water content. It further stated that when clay or silt exists as a coating to the sand particles it is likely to result in poor bond between the particles and the cement, and also in weaker and less durable concrete/20/.

It was observed also that the sand used by the industry contained deleterious matter such as leaves and root of tree. These materials have the tendency to decompose when brought in contact with moisture. This will result in the formation of pores in the Sandcrete blocks. This is evident from table 11 of chapter three where the porosity of the sand is 36%.

The low strength of blocks produced by industry A can also be attributed to inaccuracy in the proportioning of sand and cement. Industry A uses one part by volume of cement to ten part by volume of sand (1:10). It is important to emphasis that the proportioning of the cement/sand used by industry A is grossly lower than the British Standard specification of one part by volume of cement to six part by volume of sand (1:6).

From the sieve analysis result shown in table 10 and as presented in figure 5, one observe that the grading of the sand (fine aggregate) of industry A fell partially within the limits of Zone one.

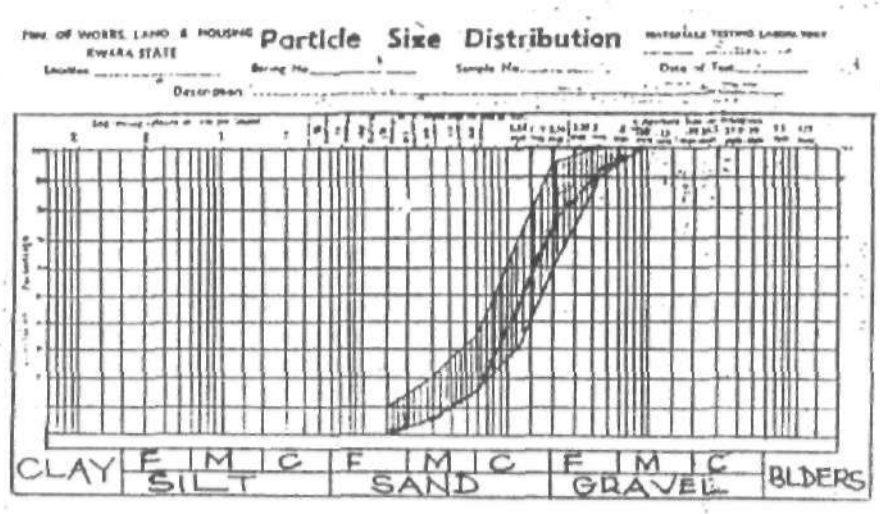


FIGURE 5: SIEVE ANALYSIS OF INDUSTRY A

From the figure shown above, one observe that the sand does not fall fully within the Zone, as such the sand cannot be considered to be fully suitable for the production of Sandcrete blocks. However, one can practically say that the sand is within Zone one.

One other important factor attributed to the low strength is the poor curing conditions as observed in industry A. Beside the fact that the blocks are not given sufficient water during curing, they are left in the open air without covering immediately after casting subjecting them to severe effect of temperature, wind and rain. Industry A cure its blocks by spraying them with water once daily in the morning for two days instead of spraying twice daily for a period of seven days.

Also the irregular servicing of block making machine could result into poor compaction. This invariably result to low density which is shown in table 34.

4.3 INDUSTRY B

As in the case of industry A, the sandcrete blocks produced by industry B have generally very low dry development strength. This can be seen in table 16 and presented in figure 6 shown below.

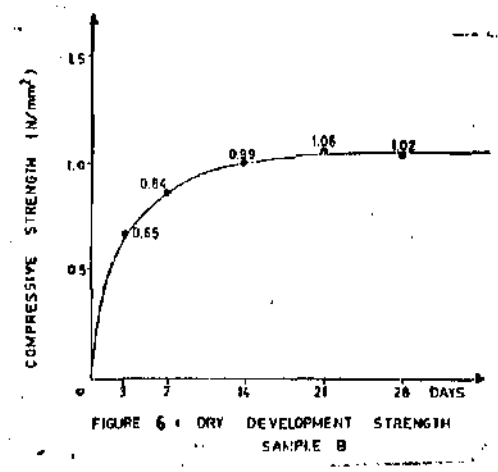


FIGURE 6 : DRY DEVELOPMENT STRENGTH SAMPLE B

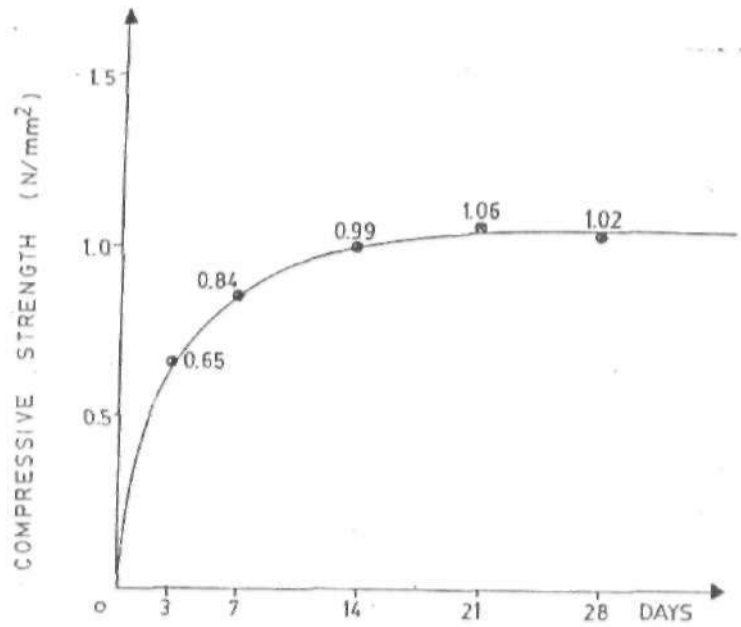


FIGURE 6 : DRY DEVELOPMENT STRENGTH SAMPLE B

The block samples attained an average dry development strength of 1.02N/mm2 at 28 days. This value is however lower than the values specified by both the British standard and the Nigerian industrial standards.

One observe that the dry development strength of 1.02N/mm is about 29.14 percent of the British Standard specification of 3.5N/mm2. Observing the figure it could be noted that the block samples attained fairly steady strength as from the 7th day to the 28th day as with the case of industry A.

As can be seen from table 22, the sandcrete blocks from industry B have a very low wet compressive strength when compared with the codes of practice. The average wet compressive strength is 0.583N/mm2. This strength value is however lower than both the British and Nigerian industrial standards and the Federal Ministry of Works specifications. As earlier stated, the British standard /25/ specifies an average compressive

strength of 3.5N/mm2. While the Federal Ministry of Work recommends an average compressive strength of 2.1N/mm2. One observe that this average compressive strength of 0.583N/mm2 is about 16.66 percent of the British standard specification of 3.5N/mm2. The value is about 27.76 percent of the Federal Ministry of Works specification of 2.1N/mm2.

The coefficient of variation of the blocks produced by industry B is 8.062 percent. This value is less than the 20% limit. As such the manufacturing process can be said to be consistent.

As can be seen from figure 7 and table 28, industry B equally has low wet development strengths.

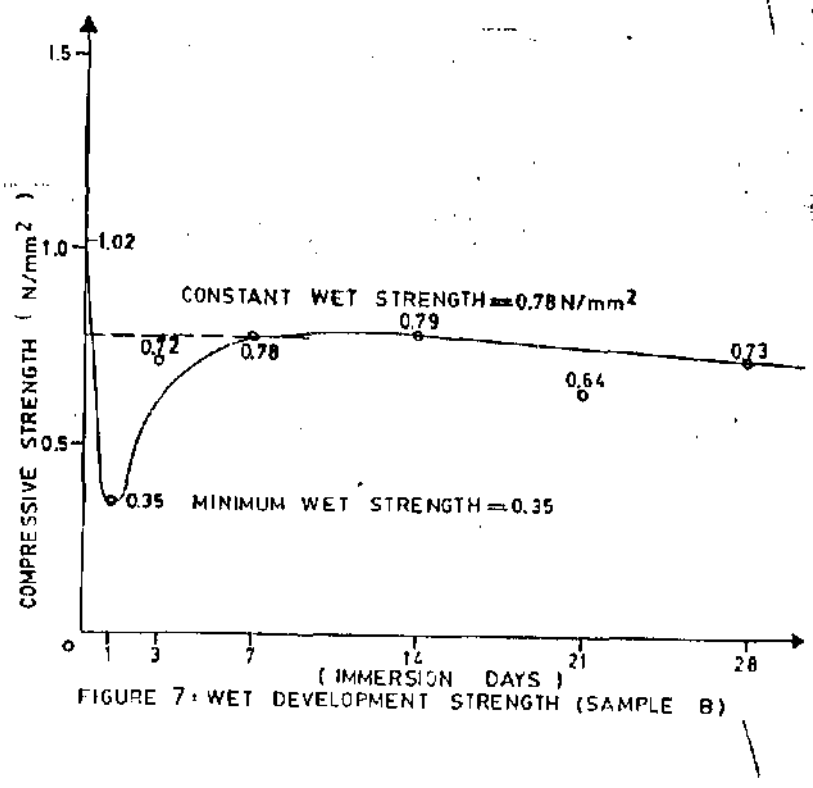


FIGURE 7: WET DEVELOPMENT STRENGTH (SAMPLE B)

One observe also that as the block samples are soaked in water, the 28 days dry development strength which is 1.02N/mm2 dropped to the minimum strength of 0.35N/mm2. This value is obtained when immersed for 24 hours prior to testing. As can be seen on the graph, this strength increases gradually up till the 7th day of immersion prior to testing. From the 7th day the strength increase becomes fairly stable, however this does not reach the highest dry development strength of 1.02N/mm2 shown on the graph.

As previously explained, the drop in values of the wet development strength is as a result of the presence of high silt content in the sand. The effect of silt on Sandcrete blocks is that it has the ability to absorb water. This resulted in reducing the strength of the blocks.

The ratio of the wet development strengths at various soaking ages to the dry development strength at 28 days was also determined for industry B. The test results are shown in table 33 and presented below in figure 8.

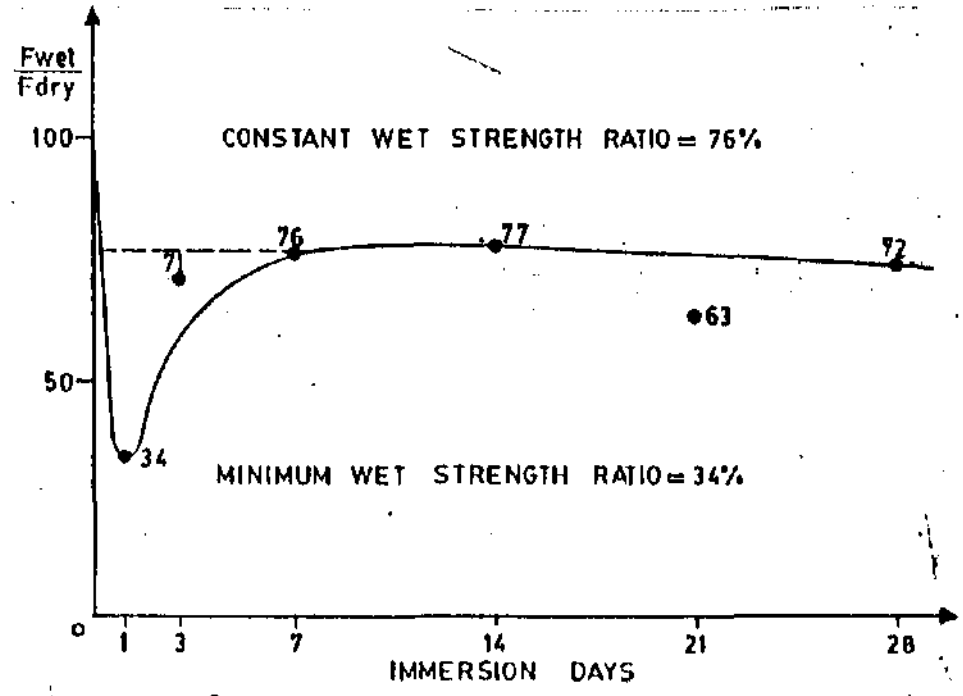


FIGURE 8 : Fwet/ Fdry RATIO IN PERCENTAGE FOR SAMPLE B

Observing the figure, it can be seen that highest dry development strength of 1.02N/mm2 (i.e. 100 percent) dropped down to 34 percent within 24 hours of soaking prior to testing. This shows a decrease of about 66 percent from the highest dry development strength. The 24-hours period of soaking could be said to be the worst condition. Thereafter the strength increases gradually to 72 percent after 28 days of soaking prior to testing. it can be seen that the minimum wet strength ratio is 34 percent while the constant wet strength ratio is 76 percent.

The average density of blocks produced by industry B is 980kg/m3. The test results are shown in table 34. The British standard 2028/25/ specifies that the density of type A blocks shall be not less than 1500kg/m3. This implies that the block samples produced from industry B do not satisfy the specification of the moisture movement. However, the blocks are within the limit specify for the drying shrinkage and the moisture movement are presented in table 36. Industry B has a drying shrinkage of 0.038 percent with a moisture movement of 0.074 percent.

As previously stated, blocks produced by industry B have low dry development strengths, wet development strengths and wet compressive strengths. The low strengths of blocks produced by industry B could be associated with poor sand. This is evident from the silt content presented in Table 10. The industry has a value of 4.55 percent for sharp sand and 10.59 percent for soft sand. While the average silt content is 7.57 percent. This value exceeds the 6 percent limit recommended by the British standard /25/. The proportioning of the sand used by industry B is one part by volume of soft sand to four part by volume of sharp sand (1:4).

It is observed that the proportioning of the sand and cement might have contributed to the low strength as experienced in industry B. The industry employs one part by volume of cement to ten part by volume of sand (1:10).

Observing the sieve analysis results shown in table 11 and presented in figure 9, it can be seen that the sand fell slightly out of the limits of Zone one. However, the sand can be assumed to be within Zone one.

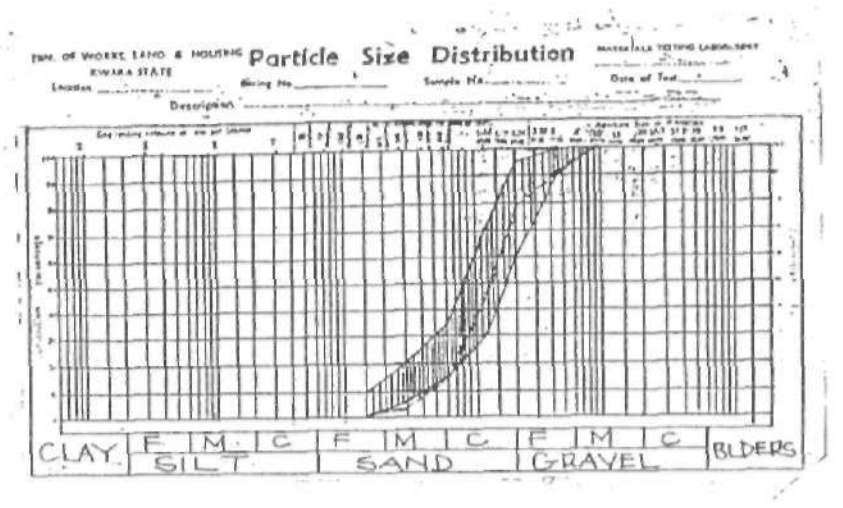


FIGURE 9: SIEVE ANALYSIS OF INDUSTRY B

The low strength of blocks produced by industry B can also be attributed to the condition of curing. The mode of curing employed by the industry is by laying the blocks in the open air without cover. In addition, the blocks are sprayed with water once daily for three days.

The consequence of laying the blocks without covering them especially at the early stage of casting could have a serious effect on the strength. This is due to the fact that the hydration process (i.e reaction between cement and water) will be shortened. Thus most of the water needed to enhance the strength of the blocks must have been evaporated.

4.4 INDUSTRY C

The average dry development strength of industry C at 28 days curing is 0.97N/mm2. This shows a relatively low strength value. The test results can be seen in table 17 and presented below in figure 10.

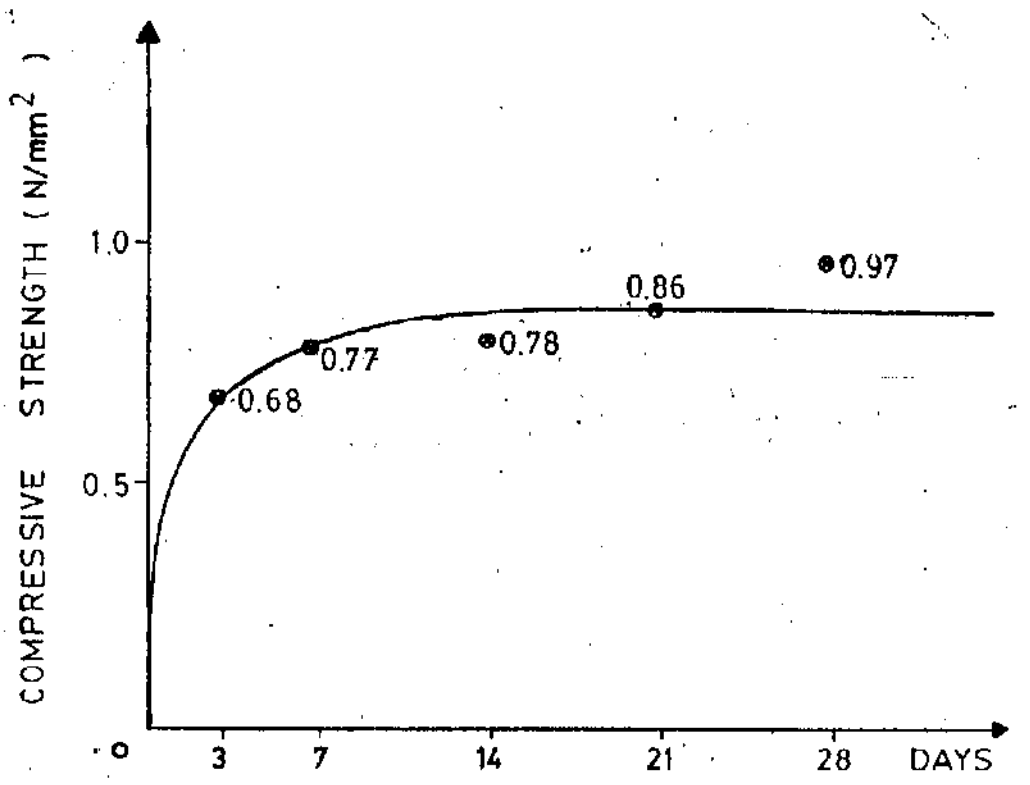


FIGURE 10 : DRY DEVELOPMENT STRENGTH
[SAMPLE C]

Observing figure 10, one can see that the industry attained an average dry development strength of 0.77N/mm2 on the 7th day of curing. While the strength increases steadily from the 7th - 28th day without much

difference in strength. This implies that the chemical reaction between the cement and water must have practically been completed diminishing with age.

The dry development strength of 0.97N/mm2 is about 27,71 percent of the 3.5N/mm2 specified by the British standard. This value is about 46.19 percent of the Federal Ministry of Work specification of 2.1N/mm2. This indicates a comparatively low strength value.

Industry C attained an average wet compressive strength of 0.55N/mm2. This value is generally lower than the average strengths specified by most codes of practice. This value of 0.55N/mm2 is approximately 15.71 percent of the British standard specification. It is also about 26.19 percent of the Federal Ministry of Works specification. The coefficient of variation of the block samples is 9.455 percent. This value is within the 20 percent limit.

The block samples of industry C have an average wet development strength of 0.33N/mm2 within 24 hours immersion prior to testing. This value is referred to as the minimum wet strength which is as a result of the drop in strength value of the 28 days dry development strength. This strength increases gradually up till the 7th day of immersion prior to testing. At this age, the strength becomes fairly stable up till the 28th day.

One observe however, that the strength-increase do not reach the 28-days dry development strength value of 0.97N/mm2.

The test results are shown in table 29 and presented in figure 11.

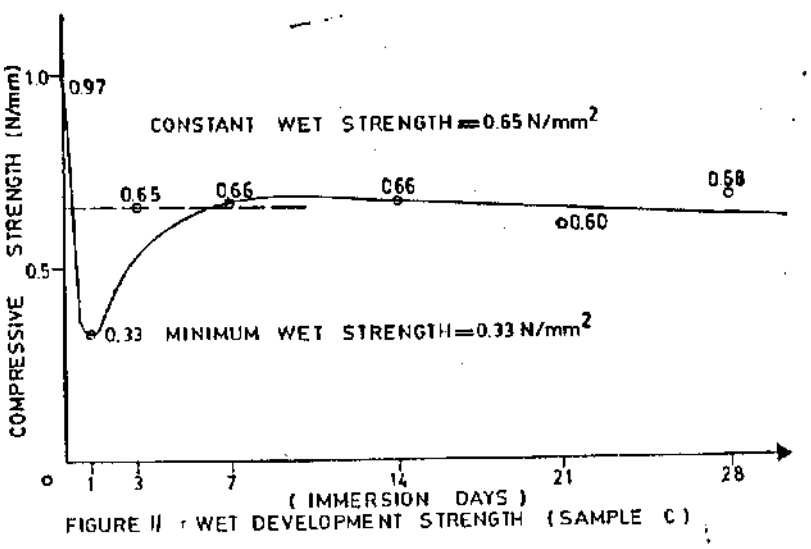


FIGURE II : WET DEVELOPMENT STRENGTH (SAMPLE C)

As earlier explained, the strength reduction in the wet development strength values is as a result of absorption of water by the silt content of the sand used for the production of the sandcrete blocks. The sand has an average silt content of 9.95 percent. While the soft sand has a silt content of 13.64 percent, the sharp sand has 6.25 percent.

The ratio of the wet development strengths at various soaking ages to the dry development strength at 28 days is shown in table 33 and presented below in figure 12.

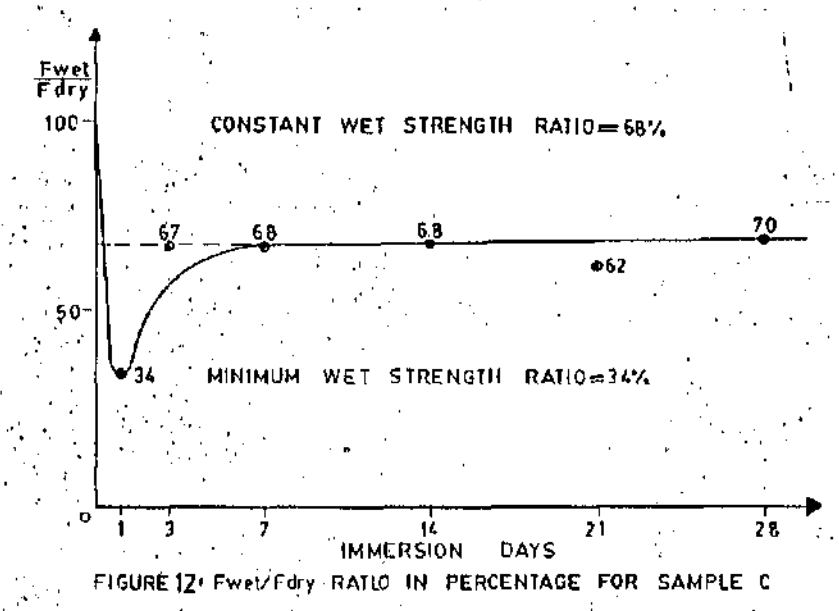


FIGURE 12: Fwet/Fdry RATIO IN PERCENTAGE FOR SAMPLE C

Observing the figure, it can be seen that the wet to dry development strength dropped to 34 percent within 24 hours of soaking prior to testing. This ratio increased to 70 percent at 28 days of soaking prior to testing. This indicates that the worst condition is observed within 24 hours of soaking prior to testing. It can be seen that the constant wet strength ratio is 68 percent.

Industry C has an average density of 1050kg/m3 which do not satisfy the specification of type A blocks. The result is presented in table 34 of chapter three.

The test results of the drying shrinkage and the moisture movement are 0.031 percent and 0.067 percent respectively. The drying shrinkage conforms with the limits of 0.04% specified by the British standard. While the moisture movement exceed the 0.05% specified by the British

standard. According to the United States Housing and Home Finance Agency, little trouble is likely to be experienced if the shrinkage is less than 0.06 percent, but a shrinkage of over 0.10 percent is definitely excessive /11/. The test results are presented in table 36 of chapter three.

The sieve analysis result of the sand used by industry C is presented below in figure 13 and shown in table 12 of chapter three.

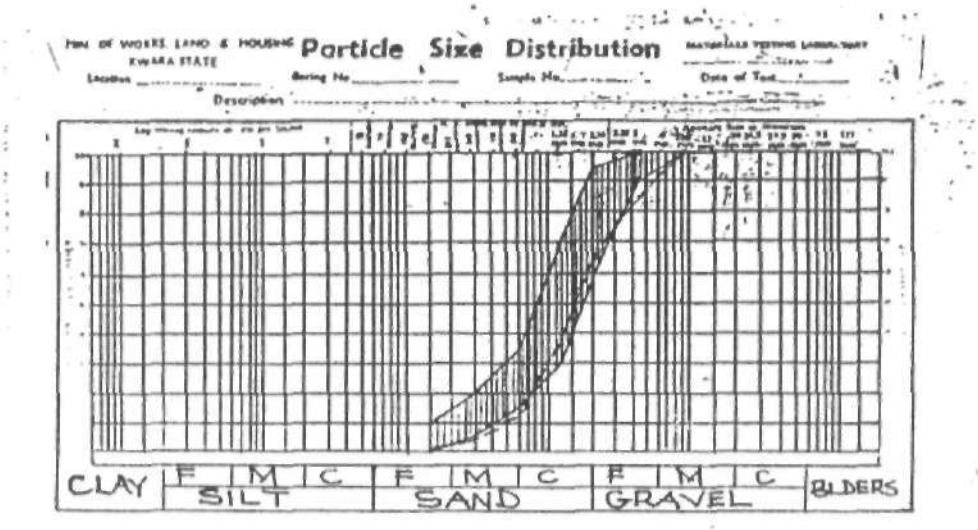


FIGURE 13: SIEVE ANALYSIS OF INDUSTRY C

It can be seen that the sand fall closely within the limits of Zone one.

As previously mentioned, the sandcrete blocks produced by industry C have generally low strength values. In addition the sandcrete blocks have high moisture movement.

These shortcomings can be attributed to among others the use of poor sand and in-appropriate curing conditions. The sand contained high silt content. This is evident from the percentage of silt content contained in both the soft sand and the sharp sand. The silt content of the soft sand is 13:64 percent while the sharp sand has 6.25 percent. The average silt

content is 9.95 percent.

The proportioning of sand employed by the industry is two part of volume of soft sand to three part by volume of sharp sand (2:3). The presence of the high silt content can be attributed mainly to the use of soft sand. The cement/sand ratio used by the industry is one part by volume of cement to ten part of volume of sand (1:10) as compared with the British standard specification of one part by volume of cement to six part by volume of sand (1:6).

The high percent of the moisture movement of the block samples can also be attributed to the presence of high silt content. silt has the tendency to absorb high water content. The test results of the moisture movement and the drying shrinkage are shown in table 36. The block samples have an average drying shrinkage of 0.031 percent and an average moisture movement of 0.067 percent.

It was observed also that the mode of curing employed by industry C is inadequate. The blocks are normally cured by spraying with water once daily for two days. From the literature review, Rosacometta/15/ asserted that blocks should be under shed for 7 days. It further stated that during this phase, rows of stacked up blocks should always be accurately sprinkled. Thus one of the reasons for the general low strength.

4.5 INDUSTRY D

As observed in the previously mentioned industries, sandcrete blocks produced by industry D have equally low strength values. As earlier stated, the low strength could be mainly due to sub-standard sand, poor curing conditions, poor proportioning of constituent materials, continuous use and irregular servicing of block making machine.

As can be seen from figure 14 shown below, block samples from industry D have an average dry development strength of 0.77N/mm2 at 28 days of curing.

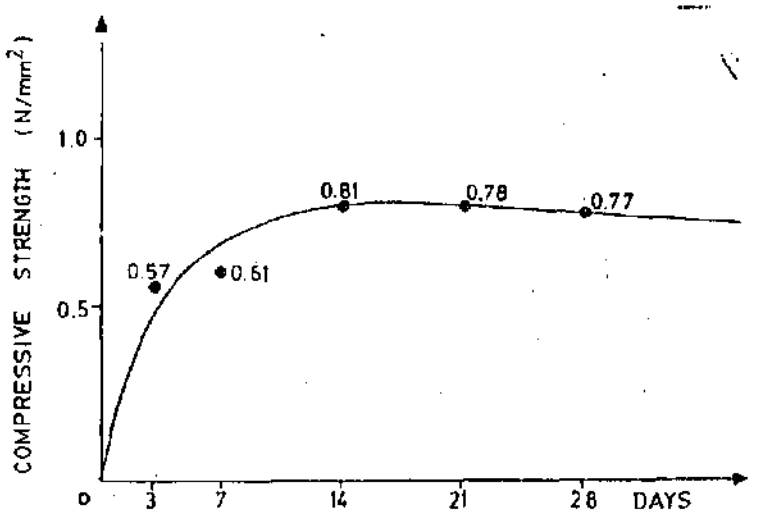


FIGURE 14 : DRY DEVELOPMENT STRENGTH [SAMPLE D]

This value of 0.77N/mm2 is however lower than the value specified by most codes of practice. The value of the dry development strength at 28 days curing is about 22 percent of both the British standard specification of 3.5N/mm2. Also the value is about 36.67 percent of the Federal Ministry of Works specification of 2.1N/mm2/2/.

This low strength could be attributed to poor curing condition as experienced at the early stage of casting the blocks. On survey, it was observed that blocks were cured by spraying with water once daily for two days. In addition, the blocks were left in the open air without cover subjecting them to severe effect of wind and temperature.

The wet compressive strength of industry D is as shown in table 25. The average wet compressive strength is 0.501N/mm2. This value represent

about 23.86 percent of the recommendation of the Federal Ministry of Works /2/ of 2.1N/mm2. It also represent 14.31 percent of the British standard specification of 3.5N/mm2. The coefficient of variation of the block samples is 8.383 percent. This however satisfies the 20 percent limits.

The test results of the wet development strength are shown in table 30 and presented below in figure 15.

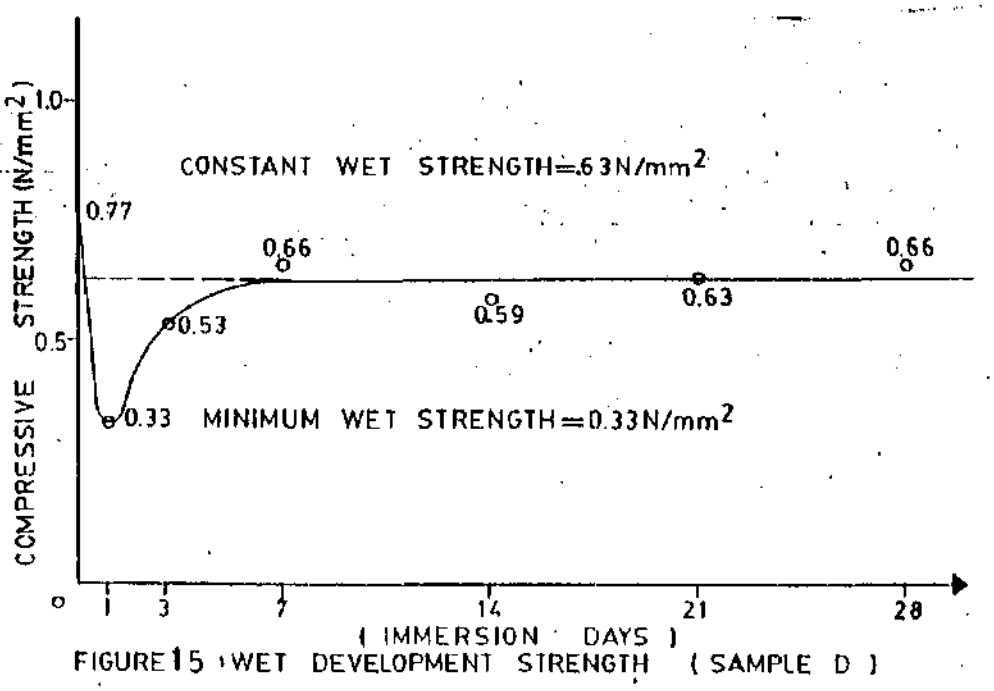


FIGURE 15 : WET DEVELOPMENT STRENGTH (SAMPLE D)

Observing figure 15, it can be seen that the 28 days dry development strength is 0.77N/mm2. This is the highest strength on the graph. The value of 0.77N/mm2 dropped down to 0.33N/mm2 when the block samples were soaked in water for 24 hours prior to testing. Therefore, the strength

increases gradually until the 7th day when the strength-increase becomes stabilized.

The strength-increase becomes steady from the 7th-28th days of soaking prior to testing. However, the strength-increase do not reach the 28 days dry development strength. The figure shows a minimum wet strength of 0.33N/mm2 and a constant wet strength of 0.63N/mm2.

As previously explained, the sudden drop in strength after the samples have been soaked for 24 hours prior to testing was as a result of absorption of water by the blocks. As the blocks absorb water, the water molecules act against the cohesive forces. As water gets into the cement gel, hydration reaction takes place leading to a gradual increase in strength.

One observed that the ratio of the wet to dry development strength dropped down to 43 percent within 24 hours of soaking prior to testing. The 43 percent indicates the minimum wet strength ratio. At the 28-days of soaking prior to testing, the ratio increased to 86 percent. While the constant wet strength ratio is 84 percent. The ratio of the wet development strengths at various soaking ages to the dry development strength at 28 days is shown in table 33 and presented in figure 16.

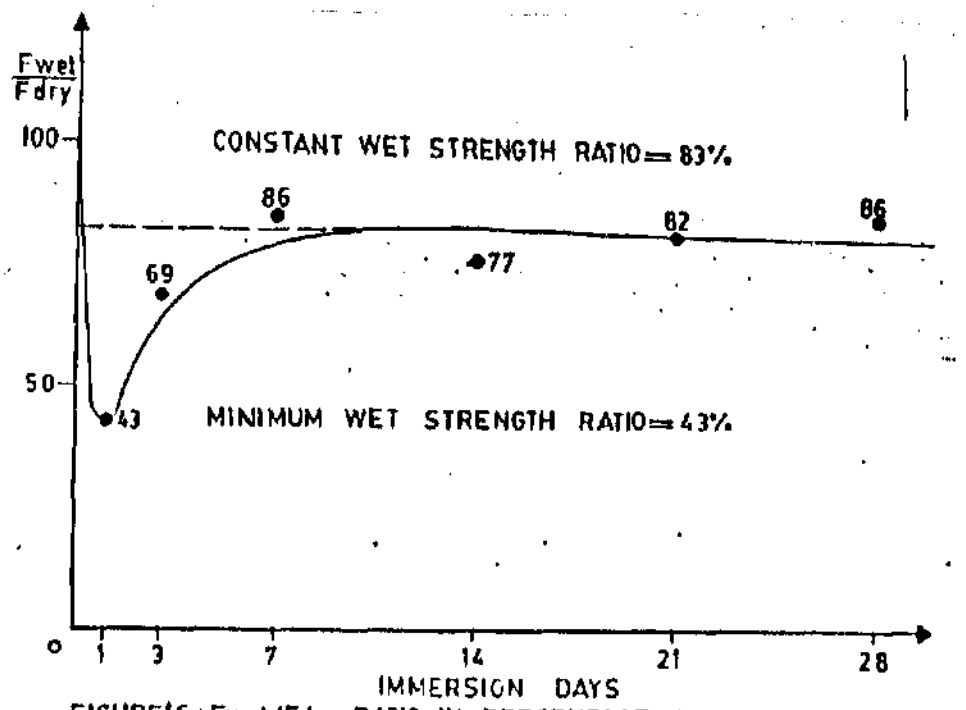


FIGURE16 :Fwet/Fdry RATIO IN PERCENTAGE FOR SAMPLE D

The average density of blocks produced by industry D is 1020kg/m3. This value of 1020kg/m3 do not conform with the limit of type A blocks in accordance with the British standard specification/25/. The test results are shown in table 34.

Block samples produced by industry D has appreciably high moisture movement of 0.092 percent. While the drying shrinkage is 0.033 percent. The average drying shrinkage is within the limit of 0.04 percent specified by the standard. However, the average moisture movement exceeds the specified limit of 0.05 percent.

On survey, it was observed that the industry uses sub-standard sand, revealing high silt content. The sand used by the industry indicates a silt content of 9.09 percent for the sharp sand and 14.61 percent for the soft sand. The average silt content is 11.85 percent which is higher than the 6 percent specified by the British standard 812 1975/16. The test results are presented in table 10.

From the site survey carried out, it was also noted that the proportioning of the sand is two part by volume of soft sand to three part by volume of sharp sand (2:3). While the cement/sand ratio employed by the industry is one part by volume of cement to ten part by volume of sand (1:10). The effect of the high silt content and inappropriate proportioning of materials resulted to low strength as experienced by the industry.

Considering the sieve analysis result as presented in figure 17 and shown in table 13, the sand can practically be said to fall within Zone one.

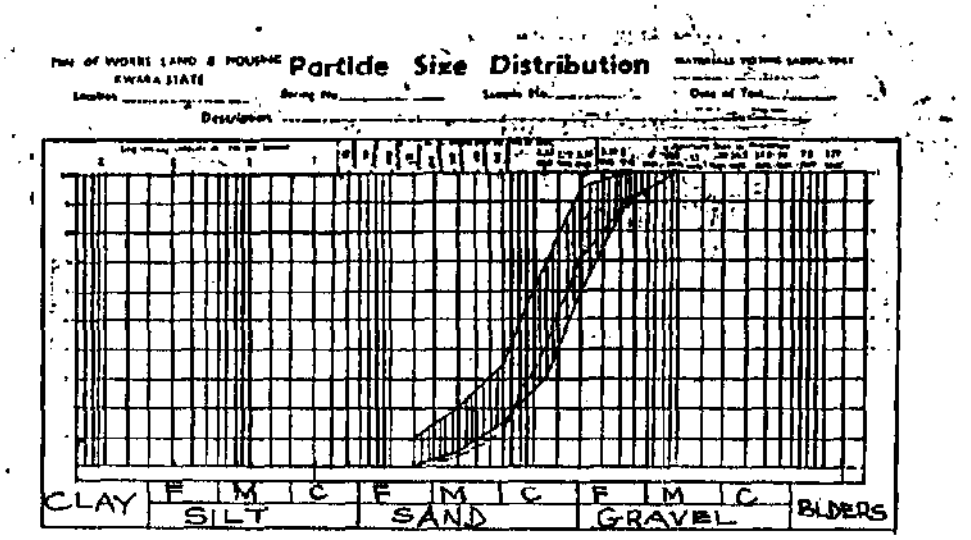


FIGURE 17: SIEVE ANALYSIS OF INDUSTRY D.

4.6 INDUSTRY E

Considering table 19 of chapter three and figure 18 shown below, the dry development strength of the block samples at 28 days curing is 0.91N/mm2.

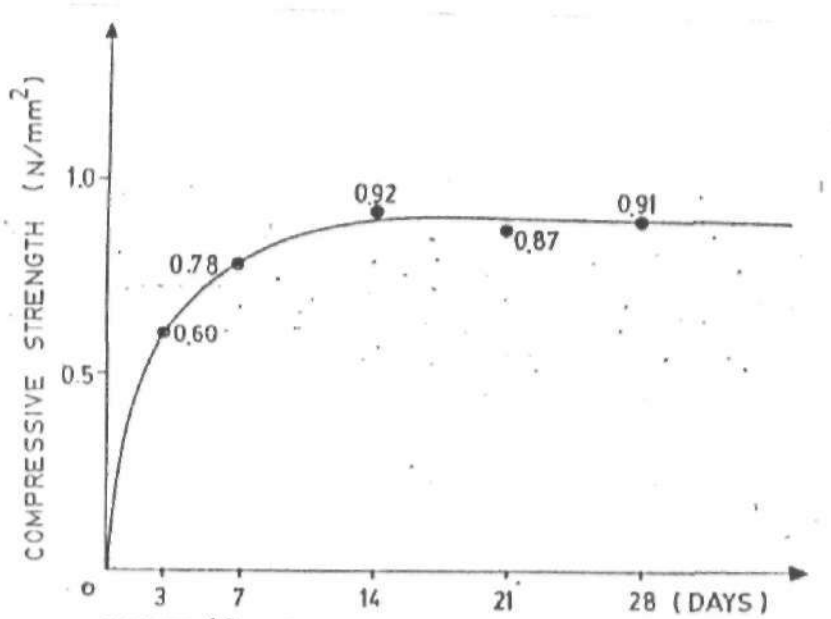


FIGURE 18: DRY DEVELOPMENT STRENGTH
[SAMPLE E]

It can be seen that the strength increases gradually exhibiting a parabolic curve which is true for all materials testing. The strength increases gradually up till the 14th day of curing when the strength becomes fairly stabilized. Between the 14th to 28th days of curing, the test results show little strength difference.

One observe however that the strength values are comparatively low. The value of 0.91N/mm2 is about 26 percent of the British standard specification of 3.5N/mm2.

The average wet compressive strength of industry E is 0.547N/mm2 while the coefficient of variation is 12.43 percent.

The test results are presented in table 25 of chapter three. The Federal Ministry of Works/2/ recommended an average wet compressive strength of 2.1N/mm2 while the British standard specified 3.5N/mm2. The average wet compressive strength of 0.547N/mm2 is lower than both the specifications of the Federal Ministry of Works and the british standard. This strength is about 26.05 percent of the Federal Ministry of Works recommendation nd about 15.63 percent of the British standard

specifications.

The wet development strength can be seen from table 31 and presented in figure 19 shown below.

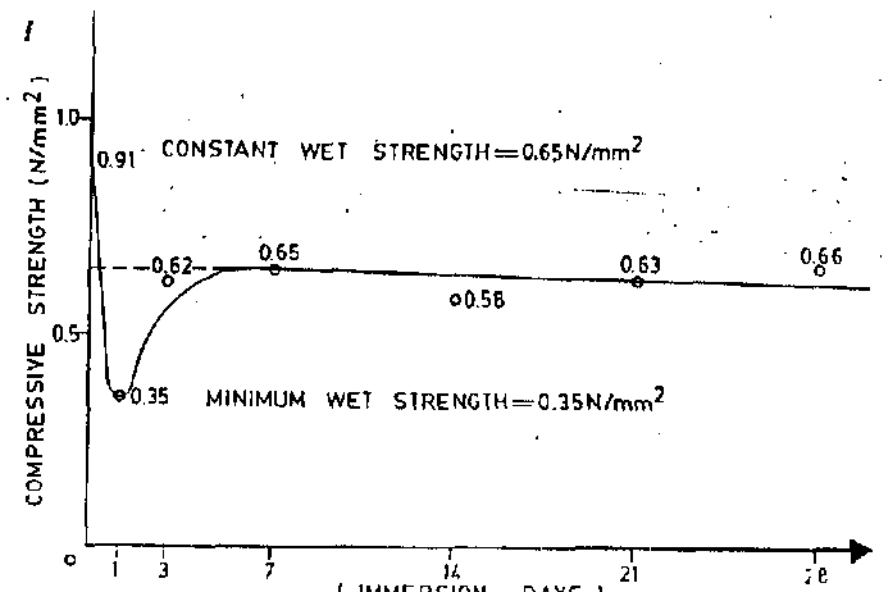


FIGURE 19: WET DEVELOPMENT STRENGTH (SAMPLE E)

Observing figure 19, the 28 days dry development strength is 0.91N/mm2. This is the highest strength attained at 28-days before immersion in water. This value of 0.91N/mm2 dropped down to 0.35N/mm2 when the block samples were soaked 24 hours prior to testing. The value of 0.35N/mm2 is the minimum wet strength.

As earlier explained, the sudden drop in strength is as a result of absorption of moisture by the presence of silt. At this phase, the water molecules tend to act against the cohesive forces. This strength increases gradually up till the 7th day of immersion prior to testing when the strength becomes 0.65N/mm2. The strength become steady from 7th to 28th days with little strength variation. However, the strength do not reach the 28-days dry development strength value of 0.91N/mm2. it can be

seen from figure 19 that the constant wet strength is 0.65N/mm2.

The ratio of the wet development strengths at various soaking ages to the dry development strength at 28 days is shown in table 33 and presented below in figure 20.

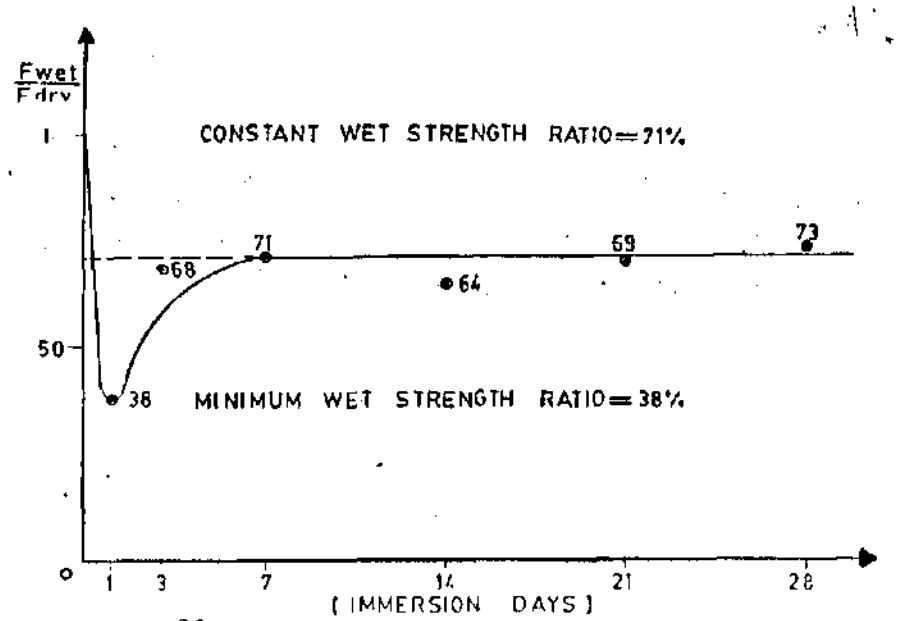


FIGURE 20: Fwet/Fdry RATIO IN PERCENTAGE FOR SAMPLE E

Considering figure 20 above, one observe that the 28 days dry development strength (i.e. 100%) dropped down to 38 percent when soaked within 24 hours prior to testing. This indicating the minimum wet strength ratio. As observed in the other industries, the strength increases gradually until it gets to 73 percent at the 28 days of soaking prior to testing. It can be seen that the constant wet strength ratio is 71 percent.

The average density of blocks produced by industry E is 980kg/m3. This value is lower than the specification of type A blocks. The british standard /25/ recommends that the average density of type A block should be not less than 1500kg/m3. The test result is shown in table 34 of

chapter three.

The average drying shrinkage of industry E is 0.021 percent while the average moisture movement is 0.071 percent. The test results can be seen in table 36. The average moisture movement exceeds the limits of 0.05 percent while the drying shrinkage is within the limits of 0.04 percent specified by the British standard.

The sieve analysis of the fine aggregate (sand) used by industry E is shown in table 14 and presented below in figure 21.

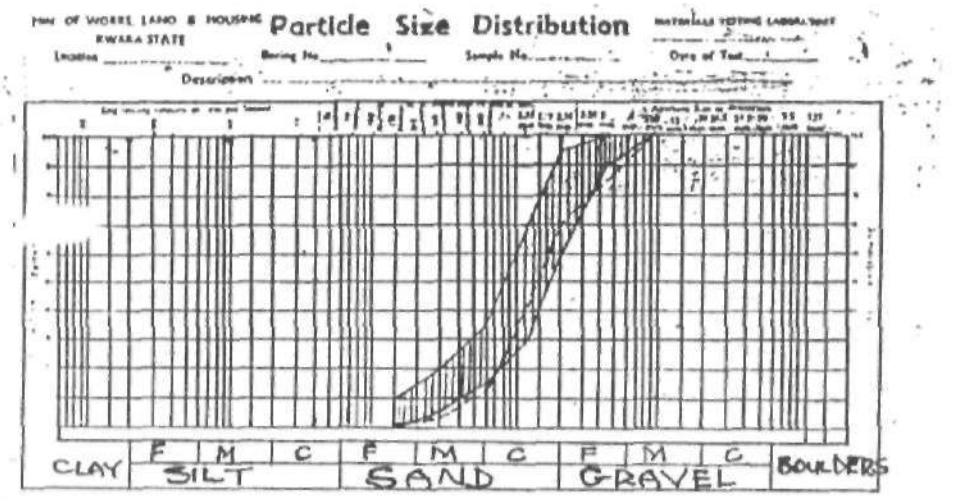


FIGURE 21: SIEVE ANALYSIS OF INDUSTRY E

Observing figure 21, it revealed that the sand falls within Zone one.

The proportioning of the constituents materials and the mode of curing employed by industry E are similar to industries A, C and D.

It was observed generally that information collected in respect of the mode of production, sizes, materials and test results are similar in all the various industries.

Although the various test results showed that the blocks produced from all the industries fall short of the standards. However, industry B appears to have a relatively better strength results than industries A, C,

D and E.

The comparison of strength results are presented in figures 22 and 23.

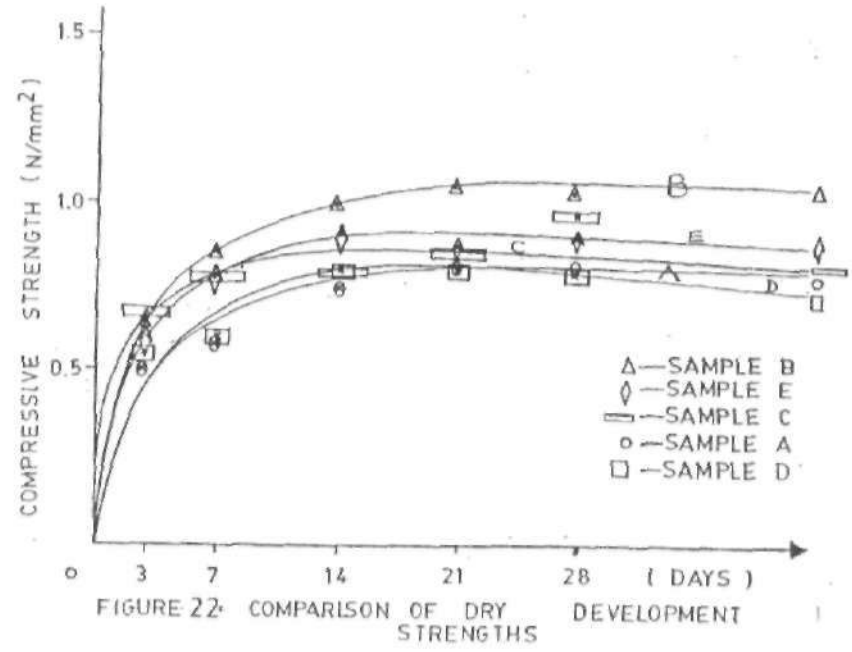


FIGURE 22 COMPARISON OF DRY STRENGTHS DEVELOPMENT

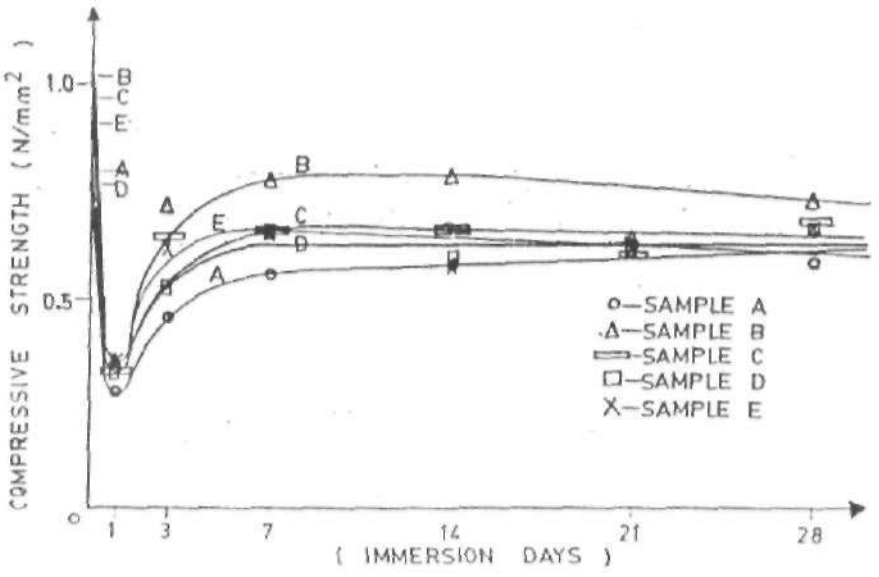


FIGURE 23 COMPARISON OF WET DEVELOPMENT STRENGTHS

It can be seen from figures 22 and 23 shown above that industry B has the best values for both the dry development strength and the wet development strength.

The 28 - days dry development strengths are 0.80N/mm2, 1.02N/mm2, 0.97N/mm2. 0.77N/mm2 and 0.91N/mm2 for industries A, B, C, D and E respectively. Also the wet development strength at 28 days of soaking prior to testing are 0.59N/mm2, 0.73N/mm2, 0.68N/mm2, 0.66N/mm2 and 0.66N/mm2 for industries A, B, C, D and E respectively. Considering table 26, it can be seen that the wet compressive strengths are 0.47N/mm2, o.583N/mm2, 0.550N/mm2, 0.50N/mm2 and 0.547N/mm2 for industries A, B, C, D and E respectively.

The relatively high strength values of industry B could fairly be attributed to the curing conditions of the industry. From the discussion had with the manufacturers, blocks produced by industry B are cured by spraying with water once daily for three days. While blocks from industries A, C, D and E are cured once daily for two days.

Furthermore, the sand tests show that the sand from industry B has the best silt content. This is evident from the types of sand employed by the industry. While industry B uses one part by volume of soft sand to four part by volume of sharp sand (1:4), industries A, C, D and E use two part by volume of soft sand to three part by volume of sharp sand (2:3) with a 50kg bag of cement for a batch.

The average silt content are 8.98%, 7.57%, 9.95%, 11.85% and 11.14% for industries A, B, C, D and E respectively. These values however exceed the limit of 6 percent specified by the standard.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

The thesis considered the materials and conditions of production of sandcrete hollow blocks. The various test and analysis carried out are aimed toward determining the quality of sandcrete hollow blocks produced in Kaduna State.

Generally the qualities of the blocks produced by the various industries do not comply with both the British standard and the Nigerian industrial standard.

1. For the dry development strength, all the block samples attained fairly steady strength from the 7th day up till the 28th day. However, these strengths are significantly low.

2. The block samples attained a critical condition within 24 hours of immersion prior to testing for wet development strength. This immersion period gives the minimum wet development strength value. The minimum wet development strengths are 0.20/N/mm2, 0.35N/mm2, 0.33N/mm2, 0.33N/mm2 and 0.35N/mm2 for industries A, B, C, D and E respectively.

3. The average wet development strengths at 28 - days of immersion prior to testing are 0.59N/mm2, 0.73N/mm2, 0.68N/mm2, 0.66N/mm2 and 0.66N/mm2 for industries A,B,C,D and E respectively.

It is important to emphasis that the wet strength increase as observed in all the industries do not reach the initial 28 - days dry development strength.

4. The ratio of the wet development strengths at various soaking

ages to the dry development strength at 28 days showed a sharp drop in strength for all the industries.

The constant wet strength ratio are 75%, 76%, 68%, 83% and 71% for industries A, B, C, D, and E respectively.

5. The block samples attained an average wet compressive strengths of 0.47N/mm2, 0.583N/mm2, 0.550N/mm2, 0.50/N/mm2 and 0.547N/mm2 for industries A, B, C, D and E respectively. These values are however lower than the British standard specification of 3.5N/mm2.

6. One observe in all the industries visited that the mode of curing is by laying the blocks in the open air without cover. The blocks are then sprayed with water once daily for two or three days.

This method of curing especially at the early stage of casting could have a serious negative effect on the strength. This is due to the fact that most of the water required for the hydration process must have been evaporated.

7. The ratio of the increase in weight to the weight of the dry sample express as a percentage, is termed water absorption. The average water absorption of the block samples is 9.76 percent.

8. The average density of the sandcrete hollow blocks produced in Kaduna State is 994kg/m3. This is however lower than 1500kg/m3 recommended by the British standard for type A block.

9. The moisture movement of the blocks produced from all the industries exceeded the 0.05% specified by the British standard 2028/25/. The average moisture movement for the five industries is 0.075%.

10. However, the blocks have an average drying shrinkage of 0.03 percent which conforms with the 0.04% limit specified by most codes of practice.

5.2 RECOMMENDATIONS

From the various test results presented, it shows that the quality of the sandcrete hollow blocks fall short of the specifications. As such there is an urgent need for strong recommendations for the mode of production and use of sandcrete hollow blocks in Kaduna State.

1. First and foremost manufacturers' 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 certificate attached to their products.

2. 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.

3. Users of cement should be educated on the danger of prolonged storage of cement. Cement should not be stored longer than six months and should be used as soon as practicable.

4. Also the practice of storing cement on bare floor as observed virtually in all the industries should be discouraged.

5. For standard curing, the blocks should be left under cover and kept wet by watering twice daily for at least seven days. At this age, hydration must have been practically completed. Although hydration is a continuous process diminishing with age.

6. The use of "soft" sand should be discouraged. As indicated in the test results, "soft" sand contains high percentage of silt content which has a serious effect on the strength of sandcrete blocks. Thus the manufacturers should insist on the use of good quality sand.

7. Block making machine should be used in accordance with the

manufacturers specifications, checked and serviced regularly so that blocks of uniform strength are produced.

8. The sizes of blocks in relation to the compaction pressure should be investigated. One observe that the sizes vary due to the fact that compaction pressure was not constant.

REFERENCE

1. ADEPEGBA, D. - "The Structural Properties of latecrete and sandcrete." Journal of testing and Evaluation, JTEVA, volume 3, No. 6, November, 1975.

2. ANDRZEJ, F. - Quality of sandcrete blocks manufactured in Northern part of Nigeria. Proceedings of Federal Ministry of Works and Housing, 17th Annual Conference February, 1985.

3. ANDRZEJ, F & EJEH, S. P. - Soilcrete Hollow block as a building unit - Proceedings of the seminar on the use of clay bricks/blocks, Zaria. October, 1985.

4. ANON, J. - An introduction to lightweight concrete. Brochure No. B6 14 issued by the cement and concrete Association. Revised October, 1960.

5. EJEH, S. P. - Effect of soaking period and packing materials on compressive strength of soilcrete hollow blocks. A paper presented at inter-departmental seminar. Department of Civil Engineering, Ahmadu Bello University, Zaria, March, 1983.

6. EJEH, S. P. - Compressive strength of soilcrete hollow blocks. A thesis submitted to the post graduate school, Ahmadu bello University, in "partial" fulfillment of the requirements for the degree of master of Engineering in (Civil Engineering) October, 1982.

7. FRANK, I. I. - The properties of fired Building Bricks viewed against that of sandcretes. Proceedings of the seminar on the clay Bricks and blocks, Zaria. October, 1985.

8. GRAF G. - Gas Concrete, foamed concrete, lightweight concrete blocks. Cement and concrete Association Library Translation No. 47. Verlag Konrad Wittwer publication 1949.

9. JACKSON, N. - Civil Engineering Materials. The Macmillan Press Limited. Third Edition, 1983.

10. KELLY, J. W. - Cracks in Concrete - the causes and cures. Heinemann Education Books Limited April, 1964.

11. MURDOCK, L. J. - Concrete Materials and Practice. London Edward Arnold (Publishers) Limited. 1968.

12. NEVILLE, A. M. - Properties of concrete. Pitman Publishing Limited. Third Edition 1981.

13. NOVGORODSKY, M. - Testing of Building Materials and Structures. M/R Publishers Moscow. 1973.

14. ORCHARD, D. F. - Concrete Technology. Contractors Record Limited, 1962.

15. ROSACOMETTA - Instructions and specifications for operation and maintenance of the Vibrobloc Model "V.5 - P" 1975.

16. British standard 812: 1975 - Sampling and testing of mineral Aggregates, Sand and Filler.

17. British standards 882, 120/1:1954 UDC 69.322:692.2. Concrete aggregate from natural sources.

18. British standard 6073: 1981 Precast concrete masonry units. part 1: specification for precast concrete masonry units; part 2: Method for specifying precast concrete masonry units.

19. Building Research station Digest No. 52, March 1953. Lightweight concrete blocks for Housing.

20. Building Research station Digest No. 22, March 1958. Sand for Concrete.

21. CP. 111: 1948 Structural Recommendations for load bearing walls.

22. CP 121: 1973 walling, part 1: Brick and block masonry.

23. Nigerian industrial standard 11: 1974 UDC 666:64 Specification for ordinary Portland Cement.

24. Nigerian industrial standard 74:1976 UDC 624. 012.8 Specification for Burnt clay Building Units. Timmy Press.

25. Specification for precast concrete blocks British standard: 1364: 1968 Gaylard and Sons Limited.

26. Specification for sandcrete blocks in Nigeria: Nigerian Industrial standard (Draft).

27. West Africa Building research institute Annual Report, 1961. West African Building research institute Accra, Ghana.

APPENDIX I

INDUSTRY A:

DATE OF CASTING: 1/02/92
TEST: DRY DEVELOPMENT STRENGTH

S/NO	DATE TESTED	SAMPLE NUMBER	LENGTH mm	BREADTH mm	HEIGHT mm	HOLLOW SIZE mm x mm	GROSS AREA m2	VOLUME m3	WEIGHT KG	FAILURE LOAD KN	DENSITY KG/m3	STRENGTH N/mm2	AVERAGE STRENGTH N/mm2
1.		A1/07/02/ZR	460	230	220	168 x 140	0.1058	0.0233	21.70	52.50	932.3	0.496	
2.	7/2/92	A2/07/02/ZR	460	230	218	166 x 140	0.1058	0.0231	21.75	61.50	943.0	0.487	0.50
3.		A3/07/02/ZR	460	229	218	168 x 140	0.1056	0.0230	21.80	64.00	949.3	0.513	
4.		A4/11/02/ZR	460	230	219	168 x 140	0.1058	0.0232	21.00	63.00	906.3	0.595	
	11/2/92	A5/11/02/ZR	459	230	220	166 x 140	0.1056	0.0232	22.00	54.50	947.2	0.516	0.59
6.		A6/11/02/ZR	460	230	218	167 x 140	0.1058	0.0231	22.00	69.00	953.9	0.652	
7.		A7/18/02/ZR	460	231	218	166 x 138	0.1063	0.0232	21.75	66.00	938.9	0.621	
8.	18/2/92	A8/18/02/ZR	459	230	218	166 x 140	0.1056	0.0230	21.05	70.50	914.7	0.668	0.66
9.		A9/18/02/ZR	459	230	220	168 x 140	0.1056	0.0232	22.15	72.95	953.7	0.691	
10.		A10/25/02/Z	460	230	220	168 x 140	0.1058	0.0233	21.65	80.50	930.1	0.761	
11.	25/2/92	A11/25/02/Z	460	230	219	168 x 138	0.1058	0.0232	22.15	86.00	956.0	0.813	0.79
12.		A12/25/02/Z	460	230	220	166 x 140	0.1058	0.0233	21.70	83.00	932.3	0.784	
13.		A13/03/02/Z	460	230	220	168 x 140	0.1058	0.0233	21.95	82.50	943.0	0.780	
14.	3/3/92	A14/02/03/Z	460	231	220	167 x 140	0.1063	0.0234	21.85	88.00	934.7	0.828	0.80
15.		A15/03/03/Z	460	231	220	168 x 140	0.1063	0.0234	21.25	84.50	909.0	0.795	

APPENDIX 2

INDUSTRY B:

DATE OF CASTING: 4/02/92
TEST: DRY DEVELOPMENT STRENGTH

S/NO	DATE TESTED	SAMPLE NUMBER	LENGTH mm	BREADTH mm	HEIGHT mm	HOLLOW SIZE mm x mm	GROSS AREA m2	VOLUME m3	WEIGHT KG	FAILURE LOAD KN	DENSITY KG/m3	STRENGTH N/mm2	AVERAGE STRENGTH N/mm2
1.		B1/07/02/KD	460	230	220	166 x 140	0.1058	0.0233	22.85	74.00	981.7	0.699	
2.	7/2/92	B2/07/02/KD	460	230	218	168 x 138	0.1058	0.0231	22.55	73.50	977.7	0.695	0.65
3.		B3/07/02/KD	460	231	218	166 x 140	0.1063	0.0232	22.35	59.00	964.9	0.555	
4.		B4/10/02/KD	460	230	220	168 x 138	0.1058	0.0233	22.75	82.5	977.4	0.780	
5.	11/2/92	B5/11/02/KD	457	230	220	168 x 140	0.1051	0.0231	22.35	90.0	966.5	0.856	0.84
6.		B6/11/02/KD	458	230	220	166 x 138	0.1053	0.0232	22.20	91.5	957.9	0.869	
7.		B7/18/02/KD	458	229	218	166 x 140	0.1049	0.0229	22.60	98.0	988.6	0.934	
8.	18/2/92	B8/11/02/KD	460	230	220	166 x 138	0.1058	0.0233	22.55	91.5	968.8	0.865	0.99
9.		B9/18/02/KD	460	230	220	166 x 140	0.1058	0.0233	22.70	125.0	975.3	1.181	
10.		B10/25/02/K	460	228	218	166 x 140	0.1049	0.0229	21.60	113.5	944.7	1.082	
11.	25/2/92	B11/25/02/K	460	230	218	166 x 140	0.1058	0.0231	22.75	125.0	986.4	1.181	1.06
12.		B12/25/02/K	460	230	220	166 x 140	0.1058	0.0233	22.10	96.5	949.5	0.912	
13.		B13/03/03/K	458	230	218	168 x 140	0.1051	0.0230	22.20	95.5	966.7	0.897	
14.		B14/03/03/K	460	230	220	168 x 140	0.1058	0.0233	21.80	122.5	936.6	1.158	1.02
15.	3/3/92	B15/03/03/K	460	230	220	168 x 140	0.1058	0.0233	22.35	106.0	960.2	1.002	

456043

APPENDIX 3

INDUSTRY C:

DATE OF CASTING: 4/02/92
TEST: DRY DEVELOPMENT STRENGTH

S/NO	DATE TESTED	SAMPLE NUMBER	LENGTH mm	BREADTH mm	HEIGHT mm	HOLLOW SIZE mm x mm	GROSS AREA m2	VOLUME m3	WEIGHT KG	FAILURE LOAD KN	DENSITY KG/m3	STRENGTH N/mm2	AVERAGE STRENGTH N/mm2
1.		C1/07/02/BG	460	230	218	170 x 140	0.1058	0.0231	24.05	58.5	1042.7	0.647	
2.	7/2/92	C2/07/02/BG	461	231	216	170 x 140	0.1065	0.0230	24.85	79.5	1080.3	0.747	0.68
3.		C3/07/02/BG	459	230	219	168 x 140	0.1056	0.0231	23.80	68.0	1029.4	0.644	
4.		C4/11/02/BG	460	230	217	168 x 141	0.1058	0.0230	23.50	89.0	1023.5	0.841	
5.	11/2/92	C5/11/02/BG	459	229	217	166 x 140	0.1053	0.0229	23.30	75.0	1045.6	0.712	0.77
6.		C6/11/02/BG	460	230	218	168 x 140	0.1060	0.0231	24.30	81.0	1051.3	0.764	
7.		C7/18/02/BG	459	230	220	168 x 140	0.1056	0.0231	23.5	85.5	1011.8	0.810	
8	18/2/92	C8/18/02/BG	460	230	220	168 x 140	0.1058	0.0233	23.6	82.0	1013.9	0.775	0.78
9.		C9/18/02/BG	460	230	220	170 x 140	0.1058	0.0233	24.0	78.5	1031.1	0.742	
10.		C10/25/02/BG	461	231	218	168 x 138	0.1065	0.0232	23.5	91.0	1012.3	0.855	
11.	25/2/92	C11/25/02/BG	461	231	218	167 x 140	0.1065	0.0232	22.6	88.0	973.5	0.826	0.86
12.		C12/25/02/BG	460	231	218	168 x 140	0.1058	0.0231	23.9	93.5	1036.2	0.884	
13.		C13/03/03/BG	460	230	220	170 x 140	0.1058	0.0233	23.8	102.5	1022.5	0.969	
14.	3/3/92	C14/03/03/BG	460	230	218	168 x 138	0.1058	0.0231	24.5	105.3	1062.3	0.995	0.97
15.		C15/03/03/BG	460	230	218	167 x 140	0.1058	0.0231	24.0	98.6	1040.6	0.930	

APPENDIX 4

INDUSTRY D

DATE OF CASTING: 4/02/92
TEST: DRY DEVELOPMENT STRENGTH

S/NO	DATE TESTED	SAMPLE NUMBER	LENGTH mm	BREADTH mm	HEIGHT mm	HOLLOW SIZE mm x mm	GROSS AREA m2	VOLUME m3	WEIGHT KG	FAILURE LOAD KN	DENSITY KG/m3	STRENGTH N/mm2	AVERAGE STRENGTH N/mm2
1.		D1/07/03/SM	460	230	220	168 x 138	0.1058	0.0233	24.35	58.0	1046.1	0.548	
2.	7/3/92	D2/07/03/SM	460	230	219	168 x 140	0.1058	0.0232	23.60	66.0	1018.5	0.624	0.57
3.		D3/07/03/SM	461	230	220	166 x 140	0.1060	0.0233	23.20	56.5	994.6	0.533	
4.		D4/11/03/SM	460	230	218	168 x 139	0.1058	0.0231	23.80	61.5	1031.3	0.581	
5.	11/3/92	D5/11/03/SM	461	231	220	168 x 140	0.1065	0.0234	23.70	73.0	1011.6	0.686	0.61
6.		D6/11/03/SM	461	231	219	168 x 140	0.1065	0.0233	23.80	61.0	1020.5	0.573	
7.		D7/18/03/SM	460	230	220	170 x 140	0.1058	0.0233	24.0	83.5	1031.1	0.789	
8.	18/3/92	D8/18/03/SM	460	230	220	166 x 135	0.1058	0.0233	24.2	92.5	1033.7	0.874	0.81
9.		D9/18/03/SM	460	230	220	168 x 140	0.1058	0.0233	23.3	82.0	1001.0	0.775	
10.		D10/25/03/SM	460	230	220	167 x 138	0.1058	0.0233	23.5	74.5	1009.6	0.704	
11.	25/3/92	D11/25/03/SM	460	231	218	168 x 140	0.1063	0.0232	23.45	85.0	1012.3	0.800	0.78
12.		D12/25/03/SM	460	230	217	170 x 140	0.1058	0.0233	23.65	88.0	1030.1	0.832	
13.		D13/01/04/SM	459	230	220	168 x 138	0.1056	0.0232	23.0	91.5	990.3	0.867	
14.	1/4/92	D14/01/04/SM	460	230	219	168 x 140	0.1058	0.0232	23.0	77.5	992.7	0.735	0.77
15.		D15/01/04/SM	460	230	220	170 x 140	0.1058	0.0233	22.8	76.0	979.5	0.718	

APPENDIX 5

INDUSTRY E:

DATE OF CASTING: 4/03/92
TEST: DRY DEVELOPMENT STRENGTH

S/NO	DATE TESTED	SAMPLE NUMBER	LENGTH mm	BREADTH mm	HEIGHT mm	HOLLOW SIZE mm x mm	GROSS AREA m2	VOLUME m3	WEIGHT KG	FAILURE LOAD KN	DENSITY KG/m3	STRENGTH N/mm2	AVERAGE STRENGTH N/mm2
1.		E1/07/03/KG	460	229	220	170 x 140	0.1053	0.0232	22.55	64.5	973.0	0.612	
2.	7/3/92	E2/07/03/KG	458	230	219	165 x 140	0.1053	0.0231	22.35	58.5	968.8	0.555	0.60
3.		E3/07/03/KG	460	231	220	167 x 140	0.1063	0.0234	23.10	66.0	988.1	0.621	
4.		E4/11/03/KG	458	230	216	168 x 140	0.1053	0.0228	22.85	79.75	1004.2	0.757	
5.	11/3/92	E5/11/03/KG	458	230	218	168 x 138	0.1053	0.0230	23.00	83.30	1001.6	0.796	0.78
6.		E6/11/03/KG	460	230	218	168 x 138	0.1053	0.0230	23.10	83.85	1005.9	0.796	
		E7/18/03/KG	460	229	216	168 x 138	0.1053	0.0228	23.00	91.50	1010.8	0.869	
.	18/3/92	E8/18/03/KG	460	228	218	166 x 140	0.1049	0.0229	22.85	94.90	999.4	0.905	0.92
.		E9/18/03/KG	460	230	218	165 x 140	0.1058	0.0231	23.05	105.35	993.4	0.996	
10.		E10/25/03/KG	460	230	218	168 x 140	0.1058	0.0231	22.55	89.25	977.7	0.844	
11.	25/3/92	E11/25/03/KG	460	230	220	168 x 138	0.1058	0.0233	22.75	97.75	977.4	0.924	0.87
12.		E12/25/03/KG	461	230	220	168 x 140	0.1061	0.0233	22.85	89.15	979.6	0.841	
13.		E13/01/04/KG	458	230	218	168 x 140	0.1053	0.0230	22.75	93.65	990.7	0.889	
14.	1/4/92	E14/01/04/KG	460	229	216	170 x 138	0.1053	0.0228	22.80	99.95	1002.0	0.949	0.91
15.		E15/01/04/KG	460	230	218	168 x 140	0.1058	0.0231	22.80	93.25	979.9	0.881	

APPENDIX 6

INDUSTRY A:

TEST: WET COMPRESSIVE STRENGTH (TESTED BETWEEN MORTAR CAPANE)
DATE IMMESED IN WATER: 5/3/92
DATE TESTED: 9/3/92
DATE MORTAR CUBES ATTAINED LEAST STRENGTH: 9/3/92

S/NO	SAMPLE NUMBER	LENGTH mm	BREADTH mm	HEIGHT mm	HOLLOW SIZE BEFORE CAPPING mm x mm	GROSS AREA m2	VOLUME m3	WEIGHT KG	FAILURE LOAD KN	DENSITY KG/m3	STRENGTH N/mm2
1.	A1/09/03/ZR	461	232	230	168 x 138	0.1070	0.0246	30.3	50.6	1231.8	0.4730
2.	A2/09/03/ZR	460	232	228	170 x 138	0.1067	0.0243	31.1	50.4	1278.1	0.472
3.	A3/09/03/ZR	461	230	231	168 x 140	0.1060	0.0245	30.4	50.0	1241.2	0.472
4.	A4/09/03/ZR	462	230	228	168 x 140	0.1063	0.0242	31.1	51.0	1283.7	0.480
5.	A5/09/03/ZR	460	231	228	165 x 140	0.1063	0.0242	31.0	53.0	1279.5	0.499
6.	A6/09/03/ZR	460	230	230	170 x 140	0.1058	0.0243	30.5	52.0	1253.4	0.491
7.	A7/09/03/ZR	460	230	230	168 x 140	0.1058	0.0243	31.9	49.0	1310.3	0.463
8.	A8/09/03/ZR	461	232	230	168 x 138	0.1070	0.0246	32.0	51.0	1300.9	0.477
9.	A9/09/03/ZR	462	231	228	170 x 140	0.1067	0.0243	30.7	49.0	1261.7	0.459
10.	A10/09/03/ZR	462	232	228	170 x 140	0.1072	0.0244	31.5	44.0	1289.8	0.411
11.	A11/09/03/ZR	460	231	230	168 x 140	0.1063	0.0244	32.2	46.0	1317.5	0.433
12.	A12/09/03/ZR	461	231	230	168 x 138	0.1065	0.0245	31.5	55.0	1286.1	0.516

AVERAGE STRENGTH = 0.471 N/mm2
STANDARD DEVIATION = 0.027 N/mm2
Coefficient and Variation = 5.732 %

APPENDIX 7

INDUSTRY B:

TEST: WET COMPRESSIVE STRENGTH (TESTED BETWEEN MORTAR CAPPING)
DATE IMMERSED IN WATER: 5/3/92
DATE TESTED: 9/3/92
DATE MORTAR CURES ATTAINED LEAST STRENGTH: 9/3/92

S/NO	SAMPLE NUMBER	LENGTH mm	BREADTH mm	HEIGHT mm	HOLLOW SIZE BEFORE CAPPING mm x mm	GROSS AREA m2	VOLUME m3	WEIGHT KG	FAILURE LOAD KN	DENSITY KG/m3	STRENGTH N/mm2
1.	B1/09/03/KD	460	232	233	168 x 140	0.1067	0.0249	31.3	64.0	1258.8	0.600
2.	B2/09/03/KD	461	232	232	166 x 140	0.1070	0.0248	31.3	64.0	1261.4	0.598
3.	B3/09/03/KD	461	231	232	166 x 140	0.1065	0.0247	31.6	65.0	1275.0	0.610
4.	B4/09/03/KD	462	230	231	170 x 137	0.1063	0.0245	29.5	56.0	1201.8	0.522
5.	B5/09/03/KD	461	231	232	170 x 138	0.1065	0.0247	31.7	66.5	1283.1	0.624
6.	B6/09/03/KD	461	231	232	168 x 138	0.1065	0.0247	31.3	56.5	1260.9	0.531
7.	B7/09/03/KD	460	231	231	166 x 139	0.1063	0.0245	31.5	60.0	1283.3	0.565
8.	B8/09/03/KD	461	230	232	166 x 138	0.1060	0.0246	31.2	62.0	1268.3	0.490
9.	B9/09/03/KD	461	232	231	166 x 140	0.1070	0.0247	31.7	59.0	1283.1	0.552
10.	B10/09/03/KD	460	232	230	168 x 137	0.1074	0.0247	31.4	68.0	1271.0	0.633
11.	B11/09/03/KD	460	230	232	170 x 140	0.1058	0.0245	31.8	65.0	1295.5	0.614
12.	B12/09/03/KD	462	231	232	168 x 140	0.1067	0.0248	32.0	70.0	1292.4	0.656

AVERAGE STRENGTH = 0.593 N/m2
STANDARD DEVIATION = 0.047 N/mm2
Coefficient of Variation = 8.062 %

APPENDIX 8

INDUSTRY C:

TEST: WET COMPRESSIVE STRENGTH (TESTED BETWEEN MORTAR) CAPPING
DATE INMERSED IN WATER: 5/3/92
DATE TESTED: 9/3/92
DATE MORTAR CUBES ATTAINED LEAST STRENGTH = 9/3/92

S/NO	SAMPLE NUMBER	LENGTH mm	BREADTH mm	HEIGHT mm	HOLLOW SIZE BEFORE CAPPING mm x mm	GROSS AREA m2	VOLUME m3	WEIGHT KG	FAILURE LOAD KN	DENSITY KG/m3	STRENGTH N/mm2
1.	C1/09/03/BG	462	231	230	165 x 135	0.1067	0.0245	32.10	61.0	1307.7	0.572
2.	C2/09/03/BG	461	232	232	170 x 135	0.1070	0.0248	32.15	62.0	1295.7	0.580
3.	C3/09/03/BG	461	231	231	165 x 140	0.1065	0.0246	33.50	66.0	1361.8	0.620
4.	C4/09/03/BG	460	231	230	165 x 140	0.1063	0.0244	31.00	60.5	1268.4	0.569
5.	C5/09/03/BG	460	230	231	165 x 140	0.1058	0.0244	31.55	59.0	1290.9	0.558
6.	C6/09/03/BG	460	230	230	165 x 138	0.1058	0.0243	32.10	56.5	1319.3	0.534
7.	C7/09/03/BG	461	231	230	166 x 140	0.1065	0.0245	33.00	64.0	1347.3	0.601
8.	C8/09/03/BG	460	230	232	168 x 140	0.1058	0.0245	32.20	58.0	1311.8	0.548
9.	C9/09/03/BG	462	231	232	168 x 140	0.1067	0.0248	33.0	59.5	1332.8	0.558
10.	C10/09/03/BG	460	239	230	170 x 140	0.1058	0.0243	30.5	52.5	1253.4	0.496
11.	C11/09/03/BG	461	231	230	168 x 138	0.1065	0.0245	31.90	60.0	1302.4	0.563
12.	C12/09/03/BG	460	232	230	168 x 138	0.1067	0.0245	30.05	42.7	1224.3	0.400

AVERAGE STRENGTH = 0.55N/mm2
STANDARD DEVIATION = 0.052N/mm2
Coefficient of variation = 9.455 %

APPENDIX 9

INDUSTRY D:

TEST: WET COMPRESSIVE STRENGTH (TESTED BETWEEN MORTAR CAPPING)
DATE IMERSED IN WATER: 4/4/92
DATE TESTED: 8/4/92
DATE MORTAR CUBES ATTAINED LEAST STRENGTH: 8/4/92

S/NO	DATE TESTED	LENGTH mm	BREADTH mm	HEIGHT mm	HOLLOW SIZE BEFORE CAPPING mm x mm	GROSS AREA m2	VOLUME m3	WEIGHT KG	FAILURE LOAD KN	DENSITY KG/m3	STRENGTH N/mm2
1.	D1/08/04/SM	462	230	230	165 x 140	0.1063	0.0244	32.25	52.5	1319.6	0.494
2.	D2/08/04/SM	461	230	230	168 x 138	0.1065	0.0245	31.50	50.0	1286.1	0.470
3.	D3/08/04/SM	461	231	231	166 x 140	0.1060	0.0245	32.70	52.5	1335.1	0.495
4.	D4/08/04/SM	460	232	232	165 x 140	0.1058	0.0245	33.55	64.0	1366.8	0.605
5.	D5/08/04/SM	461	232	232	168 x 140	0.1065	0.0247	33.50	53.5	1356.9	0.502
6.	D6/08/04/SM	460	230	230	168 x 138	0.1058	0.0243	32.75	55.0	1345.9	0.520
7.	D7/08/04/SM	460	230	230	165 x 140	0.1058	0.0243	33.40	50.2	1372.6	0.474
8.	D8/08/04/SM	460	231	231	168 x 135	0.1063	0.0245	32.70	50.1	1332.2	0.471
9.	D9/08/04/SM	460	232	230	166 x 138	0.1067	0.0245	32.80	50.3	1336.3	0.471
10.	D10/08/04/SM	461	230	230	168 x 140	0.1060	0.0244	33.60	59.5	1373.7	0.561
11.	D11/08/04/SM	461	230	230	168 x 138	0.1060	0.0244	33.05	50.5	1355.2	0.476
12.	D12/08/04/SM	460	230	232	165 x 135	0.1058	0.0245	32.50	50.5	1324.1	0.477

AVERAGE STRENGTH = 0.501N/mm2
STANDARD DEVIATION = 0.042N/mm2
Coefficient of variation = 8.383 %

APPENDIX 10

INDUSTRY E:

TEST: WET COMPRESSIVE STRENGHT (TESTED BETWEEN MORTAR CAPPING)
DATE INMERSED IN WATER: 4/4/92
DATE TESTED: 8/4/92
DATE MORTAR CUBES ATTAINED LEAST STRENGTH: 8/9/92

S/NO	SAMPLE	LENGTH mm	BREADTH mm	HEIGHT mm	HOLLOW SIZE BEFORE CAPPING mm x mm	GROSS AREA m2	VOLUME m3	WEIGHT KG	FAILURE LOAD KN	DENSITY KG/m3	STRENGTH N/mm2
1.	E1/08/04/KG	460	231	228	165 x 140	0.1063	0.0242	31.05	40.50	1281.6	0.381
2.	E2/08/04/KG	461	230	226	165 x 140	0.1060	0.0240	32.30	60.15	1373.0	0.567
3.	E3/08/04/KG	460	230	226	170 x 135	0.1058	0.0241	33.10	50.30	1372.2	0.475
4.	E4/08/04/KG	462	232	230	168 x 140	0.1072	0.0247	32.40	60.30	1314.3	0.563
5.	E5/08/04/KG	460	231	230	168 x 135	0.1063	0.0244	32.00	55.80	1309.3	0.525
6.	E6/08/04/KG	460	230	230	168 x 135	0.1058	0.0243	32.30	50.50	1327.4	0.477
7.	E7/08/04/KG	461	230	230	170 x 135	0.1060	0.0244	33.20	64.00	1361.4	0.604
8.	E8/08/04/KG	461	230	228	170 x 136	0.1060	0.0242	31.80	63.50	1315.4	0.599
9.	E9/08/04/KG	460	230	228	168 x 140	0.1058	0.0241	33.4	65.50	1384.6	0.619
10.	E10/08/04/KG	460	230	230	166 x 140	0.1058	0.0243	33.4	62.50	1372.6	0.591
11.	E11/08/04/KG	460	231	230	168 x 140	0.1063	0.0244	33.8	64.70	1383.0	0.609
12.	E12/08/04/KG	460	230	226	170 x 140	0.1058	0.0239	33.65	59.00	1407.3	0.558

AVERAGE STRENGHT = 0.547 N/mm2
STANDARD DEVIATION = 0.068 N/mm2
Coefficient of variation = 12.43%

APPENDIX II

INDUSTRY A:

TEST: WET DEVELOPMENT STRENGTH
DATE IMMERSED IN WATER: 4/3/92

S/NO	DATE TESTED	SAMPLE NUMBER	LENGTH mm	BREADTH mm	HEIGHT mm	HOLLOW SIZE mm x mm	GROSS AREA m2	VOLUME m3	WEIGHT KG	FAILURE LOAD KN	DENSITY KG/m3	STRENGTH N/mm2	AVERAGE STRENGTH N/mm2
1.		A1/05/03/ZR	461	230	220	165 x 140	0.1060	0.0233	24.85	31.50	1065.3	0.297	
2.	5/3/92	A2/05/03/ZR	461	231	221	168 x 140	0.1065	0.0235	23.90	27.00	1015.5	0.254	0.28
3.		A3/05/03/ZR	460	231	22	170 x 135	0.1063	0.0236	23.65	29.50	1002.6	0.278	
4.		A4/07/03/ZR	460	230	220	164 x 136	0.1058	0.0233	24.15	48.00	1037.3	0.454	
5.	7/3/92	A5/07/03/ZR	462	230	221	166 x 138	0.1063	0.0235	24.50	51.50	1043.3	0.485	0.46
6.		A6/07/03/ZR	460	232	220	166 x 140	0.1067	0.0248	23.20	47.50	979.2	0.445	
7.		A7/11/03/ZR	462	230	221	170 x 135	0.1063	0.0235	23.50	64.50	1000.7	0.607	
8.	11/3/92	A8/11/03/ZR	460	230	220	168 x 135	0.1058	0.0233	23.70	55.00	1018.2	0.520	0.56
9.		A9/11/03/ZR	460	231	222	166 x 134	0.1063	0.0236	24.50	59.50	1038.6	0.560	
10.		A10/18/03/ZR	461	231	222	168 x 138	0.1065	0.0236	23.65	58.50	1000.4	0.549	
11.	18/3/92	A11/18/03/ZR	460	232	221	166 x 140	0.1067	0.0236	24.15	56.00	1024.0	0.525	0.58
12.		A12/18/03/ZR	461	231	221	170 x 138	0.1065	0.0235	25.75	70.00	1094.1	0.657	
13.		A13/25/03/ZR	462	230	220	165 x 140	0.1063	0.0234	23.55	46.50	1007.4	0.438	
14.	25/3/92	A14/25/03/ZR	460	231	222	168 x 136	0.1063	0.0236	26.05	89.50	1104.3	0.842	0.63
15.		A15/25/03/ZR	461	230	221	170 x 138	0.1060	0.0234	25.25	63.00	1077.6	0.594	
16.		A16/01/04/ZR	462	231	222	165 x 140	0.1067	0.0237	24.85	52.00	1049.9	0.492	
17.	1/4/92	A17/01/04/ZR	461	230	221	168 x 138	0.1063	0.0235	23.80	75.00	1013.5	0.706	0.59
18.		A18/01/04/ZR	461	230	221	166 x 140	0.1060	0.0234	25.95	61.00	1107.4	0.575	

APPENDIX I2

INDUSTRY B:

TEST: WET DEVELOPMENT STRENGTH
DATE IMMERSED IN WATER: 4/3/92

WITHOUT BEDDING BUT TESTED WITH CELOTEX

S/NO	DATE TESTED	SAMPLE NUMBER	LENGTH mm	BREADTH mm	HEIGHT mm	HOLLOW SIZE mm x mm	GROSS AREA m2	VOLUME m3	WEIGHT KG	FAILURE LOAD KN	DENSITY KG/m3	STRENGTH N/mm2	AVERAGE STRENGTH N/mm2
1.		B1/05/03/KD	460	231	221	166 x 140	0.1063	0.0235	23.4	57.5	996.4	0.541	
2.	5/3/92	B2/04/03/KD	463	230	221	170 x 138	0.1065	0.0235	25.6	22.0	1087.8	0.207	0.35
3.		B3/15/03/KD	460	230	222	166 x 140	0.1058	0.0235	24.4	32.5	1038.9	0.307	
4.	7/3/92	B4/07/03/KD	460	232	222	165 x 135	0.1067	0.0237	26.4	99.0	1122.7	0.928	
5.		B5/07/03/KD	460	231	221	166 x 135	0.1065	0.0235	26.2	72.5	1113.3	0.681	0.72
6.		B6/07/03/KD	461	231	221	168 x 138	0.1067	0.0236	25.5	58.5	1081.2	0.548	
7.		B7/11/03/KD	462	230	221	168 x 138	0.1063	0.0235	22.75	64.0	968.8	0.602	
8.	11/3/92	B8/11/03/KD	462	231	221	166 x 140	0.1063	0.0234	25.30	88.5	1082.3	0.833	0.78
9.		B9/11/03/KD	460	230	220	166 x 135	0.1058	0.0233	26.50	95.2	1138.5	0.900	
10.		B10/18/03/KD	460	231	221	170 x 138	0.1065	0.0235	25.50	95.5	1085.5	0.897	
11.	18/3/92	B11/18/03/KD	461	232	220	168 x 140	0.1070	0.0235	25.60	72.0	1088.0	0.673	0.79
12.		B12/18/03/KD	463	232	219	170 x 135	0.1074	0.0235	26.50	84.5	1126.5	0.787	
13.		B13/25/03/KD	461	232	220	166 x 135	0.1070	0.0235	26.65	73.5	1132.6	0.687	
14.	25/3/92	B16/25/03/KD	460	230	219	165 x 140	0.1058	0.0232	26.85	69.5	1158.8	0.657	0.64
15.		B15/25/03/KD	462	231	220	166 x 135	0.1057	0.0235	25.75	60.0	1096.7	0.562	
16.		B16/01/04/KD	463	231	220	170 x 140	0.1070	0.0235	27.05	87.5	1149.6	0.818	
17.	1/4/92	B17/01/04/KD	460	231	221	168 x 138	0.1063	0.0235	24.20	69.0	1040.5	0.649	0.73
18.		B18/01/04/KD	460	230	221	168 x 136	0.1058	0.0234	24.65	75.0	1054.2	0.709	

APPENDIX 13

INDUSTRY C:

TEST: WET DEVELOPMENT STRENGTH
DATE IMMERSED IN WATER: 4/03/92

WITHOUR BEDDING BUT TESTED WITH CELOTEX

S/NO	DATE TESTED	SAMPLE NUMBER	LENGTH mm	BREADTH mm	HEIGHT mm	HOLLOW SIZE mm x mm	GROSS AREA m2	VOLUME m3	WEIGHT KG	FAILURE LOAD KN	DENSITY KG/m3	STRENGTH N/mm2	AVERAGE STRENGTH N/mm2
1.		C1/05/03/BG	463	230	220	170 x 134	0.1065	0.0234	26.45	47.5	1129.0	0.446	
2.	5/3/92	C2/05/03/BG	460	231	218	170 x 138	0.1063	0.0232	23.95	20.0	1033.9	0.188	0.33
3.		C3/05/03/BG	460	230	221	165 x 135	0.1058	0.0234	24.65	38.5	1054.2	0.364	
4.		C4/07/03/BG	461	232	220	168 x 136	0.1070	0.0235	25.75	52.0	1094.4	0.486	
5.	7/3/92	C5/07/03/BG	460	231	218	165 x 135	0.1063	0.0232	25.70	45.0	1109.4	0.423	0.65
6.		C6/07/03/BG	463	231	222	166 x 136	0.1070	0.0237	25.95	112.0	1092.9	1.047	
7.		C7/11/03/BG	460	230	220	165 x 140	0.1058	0.0233	26.15	65.15	1123.5	0.619	
8.	11/3/92	C8/11/03/BG	462	230	221	166 x 136	0.1063	0.0235	25.45	45.0	1093.7	0.423	0.66
9.		C9/11/03/BG	460	230	222	168 x 134	0.1058	0.0235	23.60	99.0	1004.8	0.940	
10.		C10/18/03/BG	462	230	220	170 x 138	0.1063	0.0234	25.30	57.5	1082.3	0.541	
11.	18/3/92	C11/18/03/BG	460	231	220	168 x 140	0.1063	0.0234	22.75	63.0	973.2	0.593	0.66
12.		C12/18/03/BG	460	230	220	168 x 138	0.1058	0.0233	26.90	88.5	1155.7	0.836	
13.		C13/25/03/BG	460	230	222	165 x 136	0.1058	0.0235	27.25	73.5	1160.2	0.695	
14.	25/3/92	C14/25/03/BG	462	231	221	168 x 136	0.1067	0.0236	24.55	62.0	1040.9	0.581	0.60
15.		C15/25/03/BG	460	231	221	168 x 135	0.1063	0.0235	25.30	54.5	1077.4	0.513	
16.		C16/01/04/BG	461	231	220	167 x 140	0.1065	0.0234	25.35	66.5	1082.0	0.624	
17.	1/4/92	C17/01/04/BG	463	230	220	170 x 135	0.1065	0.0234	26.60	72.0	1135.4	0.676	0.68
18.		C18/01/04/BG	462	231	223	168 x 136	0.1067	0.0238	25.40	79.0	1067.3	0.740	

APPENDIX 14

INDUSTRY D:

TEST: WET DEVELOPMENT STRENGTH
DATE IMMERSED IN WATER: 3/4/92

WITHOUT BEDDING BUT TESTED WITH CELOTEX													
S/NO	DATE TESTED	SAMPLE NUMBER	LENGTH mm	BREADTH mm	HEIGHT mm	HOLLOW SIZE mm x mm	GROSS AREA m2	VOLUME m3	WEIGHT KG	FAILURE LOAD KN	DENSITY KG/m3	STRENGTH N/mm2	AVERAGE STRENGTH N/mm2
1.		D1/04/04/SM	461	231	222	166 x 135	0.1065	0.0236	25.7	22.5	1087.1	0.211	
2.	8/4/92	D2/04/04/SM	460	230	221	166 x 138	0.1058	0.0234	25.4	42.5	1129.1	0.402	0.33
3.		D3/04/04/SM	462	231	220	165 x 136	0.1067	0.0235	26.6	40.5	1107.4	0.379	
4.		D5/05/04/SM	460	230	220	166 x 134	0.1058	0.0233	25.2	86.0	1082.7	0.813	
5.	6/4/92	D5/06/04/SM	460	232	221	168 x 134	0.1067	0.0236	26.5	36.5	1081.2	0.370	0.53
6.		D6/06/04/SM	461	231	223	168 x 136	0.1065	0.0237	26.6	61.0	1120.1	0.400	
7.		D7/10/04/SM	462	230	221	168 x 138	0.1063	0.0235	25.5	108.0	1085.9	1.016	
8.	10/4/92	D8/10/04/SM	461	230	220	164 x 135	0.1060	0.0233	25.5	55.0	1093.2	0.519	0.66
9.		D9/10/04/SM	460	232	221	168 x 134	0.1067	0.0236	26.5	46.5	1123.6	0.436	
10.		D10/17/04/SM	460	231	219	166 x 135	0.1063	0.0233	26.85	61.5	1153.8	0.579	
11.	17/4/92	D11/17/04/SM	460	231	219	166 x 138	0.1063	0.0233	25.50	63.0	1095.8	0.593	0.59
12.		D12/17/04/SM	462	230	220	166 x 136	0.1063	0.0234	26.60	63.5	1137.9	0.598	
13.		D13/24/04/SM	460	231	219	166 x 136	0.1063	0.0233	24.50	57.5	1052.8	0.541	
14.	24/4/92	D14/24/04/SM	459	233	220	166 x 138	0.1069	0.0235	22.60	81.0	960.5	0.757	0.63
15.		D15/24/04/SM	461	230	221	168 x 140	0.1060	0.0234	25.30	61.5	1079.7	0.598	
16.		D16/01/05/SM	460	231	222	170 x 138	0.1063	0.0236	25.3	61.0	1072.5	0.574	
17.	1/5/92	D17/01/05/SM	461	230	221	168 x 138	0.1060	0.0234	26.4	56.5	1126.6	0.533	0.66
18.		D18/01/05/SM	462	232	221	166 x 140	0.1072	0.0237	26.5	93.0	1118.7	0.868	

APPENDIX 15

INDUSTRY E:

TEST: WET DEVELOPMENT STRENGTH
DATE IMMERSED INWATER: 3/4/92

WITHOUT BEDDING BUT TESTED WITH CELOTEX

S/NO	DATE TESTED	SAMPLE NUMBER	LENGTH mm	BREADTH mm	HEIGHT mm	HOLLOW SIZE mm x mm	GROSS AREA m2	VOLUME m3	WEIGHT KG	FAILURE LOAD KN	DENSITY KG/m3	STRENGTH N/mm2	AVERAGE STRENGTH N/mm2
1.		B1/04/04/KG	460	230	222	167 x 138	0.1058	0.0235	25.70	29.5	1094.2	0.279	
2.	4/4/92	B2/04/04/KG	460	231	220	166 x 140	0.1063	0.0234	23.45	50.55	1003.1	0.476	0.35
3.		B3/04/04/KG	460	230	220	165 x 135	0.1058	0.0233	24.50	30.45	1052.6	0.288	
4.		B4/06/04/KG	460	230	221	168 x 136	0.1058	0.0234	26.60	56.70	1133.4	0.536	
5.	6/4/92	B5/06/04/KG	460	230	222	170 x 135	0.1058	0.0235	26.05	59.80	1109.5	0.565	0.62
6.		B6/06/04/KG	460	230	220	166 x 136	0.1058	0.0233	24.55	80.60	1054.7	0.762	
7.		B7/10/04/KG	460	231	220	168 x 136	0.1063	0.0234	26.50	56.80	1133.6	0.535	
8.	10/4/92	B8/10/04/KG	462	231	221	166 x 138	0.1067	0.0236	90.50	24.95	1057.9	0.848	0.65
9.		B9/10/04/KG	461	230	221	168 x 140	0.1060	0.0234	25.05	60.50	1069.0	0.569	
10.		B10/17/04/KG	462	230	220	166 x 135	0.1063	0.0234	25.55	72.5	1092.9	0.682	
11.	17/4/92	B11/17/04/KG	461	231	221	168 x 136	0.1065	0.0235	25.95	60.8	1102.6	0.563	0.58
12.		B12/17/04/KG	461	231	220	170 x 135	0.1065	0.0234	26.85	52.5	1146.1	0.493	
13.		B13/24/04/KG	460	230	218	166 x 136	0.1058	0.0231	26.55	73.50	1151.1	0.695	
14.	24/4/92	B14/24/04/KG	460	231	220	165 x 135	0.1063	0.0234	26.20	64.50	1120.8	0.607	0.63
15.		B15/24/04/KG	461	231	220	166 x 138	0.1065	0.0234	23.45	62.40	1000.9	0.586	
16.		B16/01/05/KG	462	231	220	166 x 148	0.1067	0.0235	25.65	85.90	1092.5	0.805	
17.	1/5/92	B17/01/05/KG	463	230	220	165 x 135	1.1063	0.0234	26.30	53.30	2150.7	0.559	0.66
18.		B18/01/05/KG	461	230	222	168 x 136	0.1060	0.0235	24.15	64.80	1026.0	0.611	

APPENDIX 16

INDUSTRY A

TEST: MORTAR CUBES STRENGTH

DATE IMMERSED IN WATER: 5/03/92

S/N	DATE TESTED	SAMPLE NUMBER	AGE OF CURING (DAYS)	FAILURE LOAD KN	STRENGTH N/MM2	AVERAGE STRENGTH N/MM2
1		A1/06/03/ZR	1	114	23.27	
2	6/3/92	A2/06/03/ZR	1	121	24.69	24.01
3		A3/06/03/ZR	1	118	24.08	
4		A4/07/03/ZR	2	126	25.71	
5	7/3/92	A5/07/03/ZR	2	125	25.51	25.78
6		A6/07/03/ZR	2	128	26.12	
7		A7/08/03/ZR	3	136	27.76	
8	8/3/92	A8/08/03/ZR	3	135	27.55	27.76
9		A9/08/03/ZR	3	137	27.96	
10		A10/09/03/ZR	4	141	28.78	
11	9/3/92	A11/09/03/ZR	4	138	28.16	28.71
12		A12/09/03/ZR	4	143	29.18	

APPENDIX 17

INDUSTRY B

TEST: MORTAR CUBES STRENGTH

DATE IMMERSED IN WATER: 5/03/92

S/NO	DATE TESTED	SAMPLE NUMBER	AGE OF CURING (DAYS)	FAILURE LOAD KN	STRENGTH N/MM2	AVERAGE STRENGTH N/MM2
1		B1/06/03/KD	1	107	21.84	
2	6/3/92	B2/06/03/KD	1	121	24.69	23.06
3		B3/06/03/KD	1	111	22.65	
4		B4/07/03/KD	2	130	26.53	
5	7/3/92	B5/07/03/KD	2	125	25.51	25.71
6		B6/07/03/KD	2	123	25.10	
7		B7/08/03/KD	3	132	26.94	
8	8/3/92	B8/08/03/KD	3	137	27.96	27.48
9		B9/08/03/KD	3	135	27.55	
10		B10/09/03/KD	4	140	28.57	
11	9/3/92	B11/09/03/KD	4	141	28.78	28.44
12		B12/09/03/KD	4	137	29.96	

APPENDIX 18

INDUSTRY C

TEST: MORTAR CUBES STRENGTH

DATE IMMERSED IN WATER: 5/03/92

AREA OF CUBE - (70 X 70)MM2

S/NO	DATE TESTED	SAMPLE NUMBER	AGE OF CURING (DAYS)	LOAD KN	FAILURE STRENGTH N/MM2	AVERAGE STRENGTH N/MM2
1		C1/06/03/BG	1	117.0	23.68	
2	6/3/92	C2/06/03/BG	1	108.0	22.96	24.01
3		C3/06/03/BG	1	112.5	22.96	
4		C4/07/03/BG	2	121.6	24.82	
5	7/3/92	C5/07/03/BG	2	125.7	25.65	24.64
6		C6/07/03/BG	2	114.9	23.45	
7		C7/08/03/BG	3	131.0	26.73	
8	8/3/92	C8/08/03/BG	3	123.5	25.10	26.29
9		C9/08/03/BG	3	132.5	27.04	
10		C10/09/03/BG	4	136.0	27.76	
11	9/3/92	C11/09/03/BG	4	142.0	28.98	28.03
12		C12/09/03/BG	4	134.0	27.35	

APPENDIX 19

INDUSTRY D

TEST: MORTAR CUBES STRENGTH

DATE IMMERSED IN WATER: 4/04/92

AREA OF CUBE - (70 X 70)MM2

S/NO	DATE TESTED	SAMPLE NUMBER	AGE OF CURING (DAYS)	FAILURE LOAD KN	STRENGTH N/MM2	AVERAGE STRENGTH N/MM2
1		D1/05/04/SM	1	117.00	23.88	
2	5/4/92	D2/05/04/SM	1	106.00	21.63	23.33
3		D3/05/04/SM	1	120.00	24.49	
4		D4/06/04/SM	2	131.05	26.75	
5	6/4/92	D5/06/04/SM	2	118.8	24.25	25.10
6		D6/06/04/SM	2	119.1	24.30	
7		D7/07/04/SM	3	132.5	27.04	
8	7/4/92	D8/07/04/SM	3	134.0	27.35	27.38
9		D9/07/04/SM	3	136.0	27.76	
10		D10/07/04/SM	4	137.0	27.96	
11	8/4/92	D11/08/04/SM	4	145.0	29.59	28.98
12		D12/08/04/SM	4	144.0	29.39	

APPENDIX 20

INDUSTRY E

TEST: MORTAR CUBES STRENGTH

DATE IMMERSED IN WATER: 4/04/92

AREA OF CUBE - (70 X 70)MM2

S/NO	DATE TESTED	SAMPLE NUMBER	AGE OF CURING (DAYS)	FAILURE LOAD KN	STRENGTH N/MM2	AVERAGE STRENGTH N/MM2
1		E1/05/04/KG	1	102.50	20.92	
2	5/4/92	E2/05/04/KG	1	110.00	22.45	21.53
3		E3/05/04/KG	1	104.00	21.22	
4		E4/06/04/KG	2	122.00	24.90	
5	6/4/92	E5/06/04/KG	2	121.00	24.69	24.49
6		E6/06/04/KG	2	117.00	23.88	
7		E7/07/04/KG	3	120.50	24.59	
8	7/4/92	E8/07/04/KG	3	121.00	24.69	24.45
9		E9/07/04/KG	3	118.00	24.08	
10		E10/08/04/KG	4	140.00	28.57	
11	8/4/92	E11/08/04/KG	4	136.00	27.76	28.16
12		E12/08/04/KG	4	138.00	28.16	

APPENDIX 21

CALCULATION OF ABSORPTION OF WATER

INDUSTRY A

Average Weight of 3 blocks air dry = 21.75kg

Average Weight of 3 blocks immersed in water for 48 hours = 23.95kg

∴

$$\text{Water Absorption} = \frac{23.95 - 21.75}{21.75} \times 100$$

$$= 10.11\%$$

INDUSTRY B

Average Weight of 3 blocks air dry = 22.58kg

Average Weight of 3 blocks immersed in water for 48 hours = 24.85kg

∴

$$\text{Water Absorption} = \frac{24.85 - 22.58}{22.58} \times 100$$

$$= 10.05\%$$

INDUSTRY C

Average Weight of 3 blocks air dry = 24.23kg

Average Weight of 3 blocks immersed in water for 48 hours = 25.80kg

∴

$$\text{Water Absorption} = \frac{25.80 - 24.23}{24.23} \times 100$$

$$= 6.48\%$$

INDUSTRY D

Average Weight of 3 blocks air dry = 23.72kg

Average Weight of 3 blocks immersed in water for 48 hours = 25.80kg

∴

Water Absorption = $\frac{25.80 - 23.72}{23.72} \times 100$

= 8.77%

INDUSTRY E

Average Weight of 3 blocks air dry = 22.67kg

Average Weight of 3 blocks immersed in water for 48 hours = 25.70kg

∴

Water Absorption = $\frac{25.70 - 22.67}{22.67} \times 100$

= 13.37%

APPENDIX 22

DETERMINATION OF SILT CONTENT

INDUSTRY A

A. "SHARP" SAND

Height of sand = 75ml

Height of sand + silt = 80ml

:. Height of silt = 5ml

% of silt = 5/80 x 100 = 6.25%

B. "SOFT" SAND

Height of sand = 83ml

Height of sand + silt = 94ml

:. Height of silt = 11ml

% of silt = 11/94 x 100 = 11.70%

INDUSTRY B

A. "SHARP" SAND

Height of sand = 84ml

Height of sand + silt = 88ml

:. Height of silt = 4ml

% of silt = 4/88 x 100 = 4.55%

B. "SOFT" SAND

Height of sand = 76ml

Height of sand + silt = 85ml

:. Height of silt = 9ml

% of silt = 9/85 x 100 = 10.59%

INDUSTRY C

A. "SHARP" SAND

Height of sand = 75ml

Height of sand + silt = 80ml

:. Height of silt = 5ml

% of silt = 5/80 x 100 = 6.25%

B. "SOFT" SAND

Height of sand = 76ml

Height of sand + silt = 88ml

:. Height of silt = 12ml

% of silt = 12/88 x 100 = 13.64%

INDUSTRY D

A. "SHARP" SAND

Height of sand = 80ml

Height of sand + silt = 88ml

:. Height of silt = 8ml

% of silt = 8/88 x 100 = 9.09%

B. "SOFT" SAND

Height of sand = 76ml

Height of sand + silt = 89ml

:. Height of silt = 13ml

% of silt = 13/89 x 100 = 14.61%

INDUSTRY E

A. "SHARP" SAND

Height of sand = 78ml

Height of sand + silt = 84ml

:. Height of silt = 6ml

% of silt = 6/84 x 100 = 7.14%

B. "SOFT" SAND

Height of sand = 78ml

Height of sand + silt = 92.5ml

:. Height of silt = 14ml

% of silt = 14/92.5 x 100 = 15.14%

APPENDIX 23

DETERMINATION OF POROSITY OF SAND

INDUSTRY A

Volume of sand = 1000ml

Volume of water = 1000ml

Volume of mixture = 164nl

:. Voids in sand = 1000 - 640 = 360ml

% porosity = $\frac{360}{1000} \times 100 = 36\%$

INDUSTRY B

Volume of sand = 1000ml

Volume of water = 1000ml

Volume of mixture = 1670ml

:. Voids in sand = 1000 - 670 = 330

% porosity = $\frac{330}{1000} \times 100 = 33\%$

INDUSTRY C

Volume of sand = 1000ml

Volume of water = 1000ml

Volume of mixture = 1700ML

:. Voids in Sand = 1000 - 700 = 300

% porosity = $\frac{300}{1000} \times 100 = \underline{30\%}$

INDUSTRY D

Volume of sand = 1000ml

Volume of water = 1000ml

Volume of mixture = 1620ml

:. Voids in Sand = 100 - 620 = 380ml

% porosity = $\frac{380}{1000} \times 100 = 38\%$

INDUSTRY E

Volume of sand = 1000ml

Volume of water = 1000ml

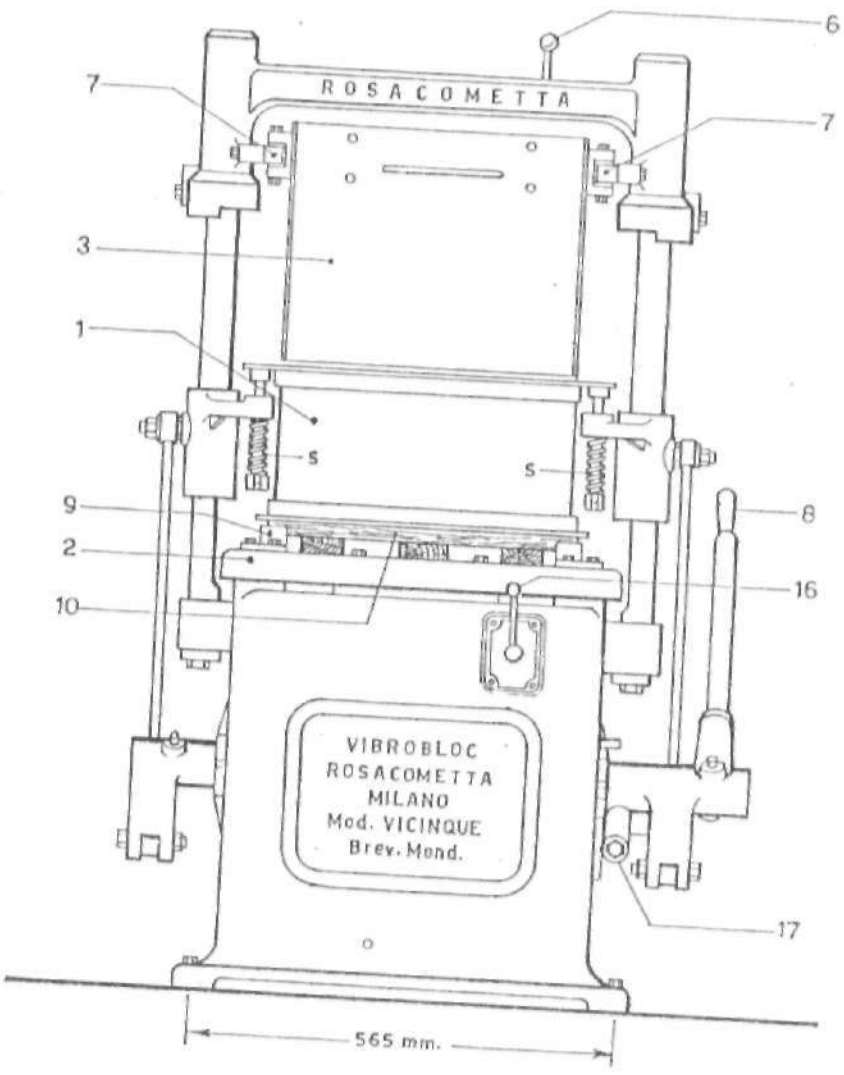
Volume of mixture = 1660ml

:. Voids of Sand = 1000 - 660 = 340

% porosity = $\frac{340}{1000} \times 100 = 34\%$

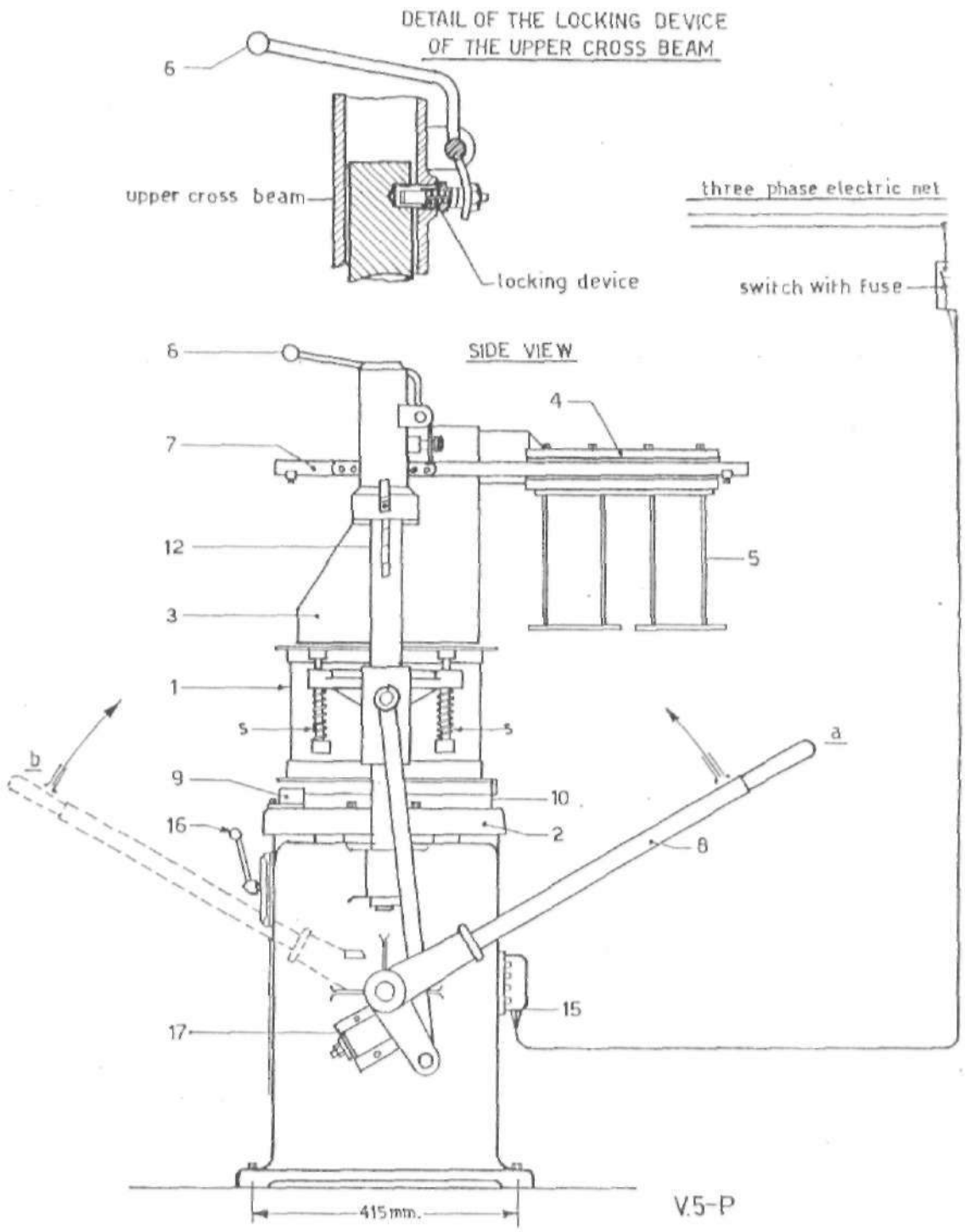
APPENDIX 24: BLOCK MAKING MACHINE

FRONT VIEW



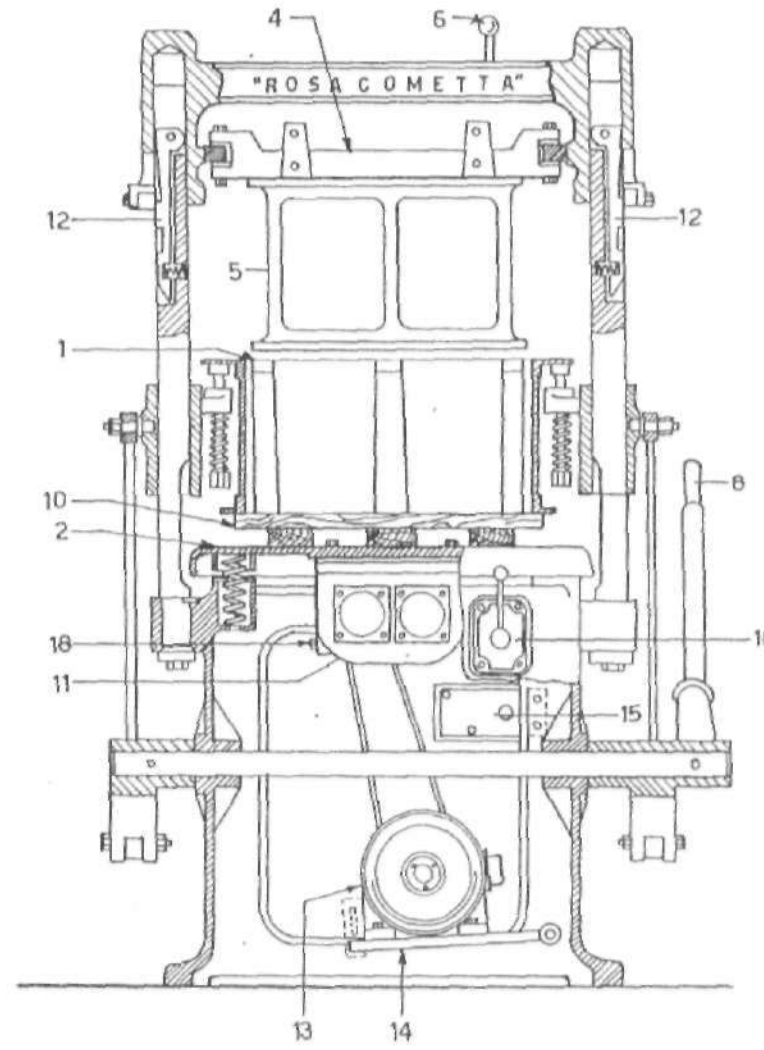
V.5–P

APPENDIX 25: BLOCK MAKING MACHINE

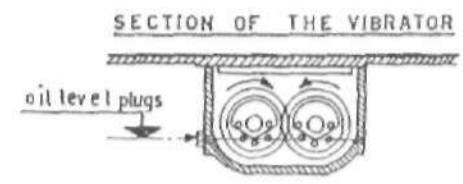


APPENDIX 26: BLOCK MAKING MACHINE

CROSS SECTION
WITH PRESSING STRIPPER UPWARD



SECTION OF THE VIBRATOR



V.5 P