THE QUALITY OF SANDCRETE HOLLOW BLOCKS MANUFACTURED IN ILORIN AND ITS ENVIRONS

BY

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DECLARATION

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

All sources of information are specifically acknowledged by means of references.

ADESHOLA F. AYINMODE

NOVEMBER, 1992.

CERTIFICATION

This thesis entitled "The Quality of Sandcrete Hollow Blocks Manufactured in Kwara State" by ADESHOLA FOLASHADE AYINMODE meets the regulations governing the award of the degree of Masters of Science in Structural Engineering, and is approved for its contribution to the knowledge and its literacy presentation.

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DEDICATION

This thesis is dedicated to:

- the Almighty Father who is ever faithful and Kind.

- My ever loving Fiance, Olukunle and my dear Brother, Adekunle whose presence and prayers have been my sources of inspiration during this course.

- My wonderful brother, Tunde who is ever caring

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"Quality control should be aimed at the output of high - quality products to meet increased requirements for structural strength and other physical and mechanical properties".

"Inspection of quality of incoming materials and the procedure inspection should ensure the output of high quality products and the exclusion of any neglects in case of high grade raw materials".

- Novgardsky (1973)

ABSTRACT

The quality of a building material or structural unit in any country cannot be over-emphasized, if such country or Nation wants a safe and durable structures.

Sandcrete blocks have been widely used all over Nigeria as building structural units. Block industries are scattered all over the places all in an attempt to satisfy the demand within the country.

In this research, Kwara State was the focus. Visits were made to almost all the block industries within the State and mode of production, method of curing, market survey and type of materials used in production were studied. Later on five industries - labelled A, B, C, D and E - were chosen and samples were collected for quality test. Tests like dry compressive strength development, wet compressive strength development, wet - compressive strength (with bed faces bedded in mortar), water absorption, Density, shrinkage and efflorescence were carried out and reflected graphically as due necessary. Also sand samples were collected from these industries to determine the silt content and grading analysis.

The result of this tests reflected that the compressive strength of the sanderete hollow blocks tested in Kwara State are very low in comparison with the standard requirements. The highest compressive strength is 1.14N/mm^2 against the 2.76N/mm^2 recommended by the Nigerian industrial standard organisation. It was observed that most of these blocks were badly cured and produced with sand of high silt content which might have been the reason for the low strength. However, the aggregate possess good grading and the blocks have good Shrinkage, Efflorescence, Density

and water absorption qualities.

Hence, it is recommended that Manufacturers should ensure that stern and proper control and supervision are exercised during the production of these sandcrete blocks. Likewise routine quality tests of sandcrete blocks should be seen as crucial matter.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

The Nigerian Construction Industry has come a long way in its intensified effort to increase the varieties of construction materials available for use as would be found in other parts of the world. As more and more construction products are being introduced to augment for or add to the few existing ones, little effort has been geared towards upgrading the former products to meet the set standard code for the materials.

In recent times emphasis has been placed on the use of stabilized or unstabilized soilcrete blocks and de-emphasized the continuous use of sandcrete blocks. It is glaring that sandcrete blocks are the most popularly used walling units in Nigeria and their importance as part of the building materials cannot be over emphasized in the building industry. The display of neglect by not using the standard code as a guide caused the masonry units to be currently produced with a great mark of deterioration in quality. Likewise, the manufacturers are unconscious of uplifting their products to the specified standard for a better quality work.

However, the question that should come to a sound mind is whether popular masonry units such as sandcrete blocks should suffer neglect of quality control. People have often agreed that inspite of the Government efforts to give the use of brick a face value, the brick industries had had little impact on the populace and therefore had not reduced the over-dependence on cement. It was opined that (5) local builders use sandcrete block and other cement products in preference to competing clay products. The reason was said to lie partly in the general availability of sandcrete blocks and consequently, masons' capability of handling them in addition to their relatively lower cost (5). Much could also be said of the conservative tendency of the public, most of whom still prefer sandcrete blocks to bricks. Besides, masonry artisans have not acquired the technical skill in laying the former very well.

Moreover, it has not yet been established that soilcrete blocks are relatively cheaper than sandcrete blocks. According to some notable educationists (22), clay product is costlier than sandcrete blocks when the price index is greater than 1.0 and conversely it is cheaper when the price index is less than 1.0. They also observed that price of clay bricks in some factories are just comparable to sandcrete blocks.

The production of poor quality sandcrete blocks will, in no doubt, result to erection of a bad and less durable masonry, liable to cracking. Set back from the required

standard is brought about by the variations in the quantity and composition of raw materials used, the moulding procedures such as mode of mixing, method of curing, degree of compaction and the type of machines used.

The deviation which exist between the attained existing standard and the required standard therefore calls for more investigations into the production of sandcrete blocks and if need be, the routine test of the quality of the finished products. Paying good attention to these aspects i.e. the aforementioned characteristics would enhance the manufacturing of qualitative and improved walling units to suit local building requirement.

1.2 AIM AND OBJECTIVES

In recognition of the wide application of sandcrete blocks and the need to upgrade it to a reputable standard, every endeavour in this study will be geared towards finding the quality of sandcrete hollow blocks produced in Kwara State through:

(i) Collecting information on the source and quality of raw materials used by some manufacturers of these sandcrete blocks in other to ascertain whether they meet the required standards.

(ii) Identifying the varying ways of production in terms of mixing, mix proportions, compaction, curing, etc. and how they affect the quality of products.

(iii) Determining some of the physical properties, most especially the compressive strength of sampled blocks.

(iv) Studying the development of dry and wet strength of sampled blocks.

(v) Establishing the relative difference between the sampled blocks and the required standards.

(vi) Giving useful suggestions as to how the quality of blocks can be improved.

1.3 METHODOLOGY

The study was purposed to determine the quality of sandcrete blocks in Kwara State as such it involves, basically, the laboratory verification of properties of these units, extraction of information from previous relevant research work and also collection of information existing within the State about the building units.

In a bid to achieve this goal, sandcrete blocks were sampled from reputable manufacturers based in five chosen locations within Kwara State.

It has been recommended that sampling of blocks for testing could be by random sampling or stratified sampling (15). However, random sampling was the method used in each location to collect samples of block used for the physical tests. The collected samples were subsequently tested for dry compressive strength and wet compressive strength development. This wet compressive strength test involves soaking the blocks after 28 days air-curing and subjecting them to test at different ages, i.e 3, 7, 14, 21 and 28 days respectively. Some samples of blocks were also bedded in mortar (mix ratio of 1 part of cement to 1 part of sand) for determining the individual compressive strength (2).

Other properties such as the drying shrinkage, water absorption and efflorescence were equally tested to ascertain their various qualities. All the physical tests were however carried out in accordance with the specifications laid down by the British standard specification (2).

For more detailed information, the research in - corporates field studies through conducting oral interview in the chosen Block Factories and many others. Questions asked reflected the same objectives. Also, literature constituted another source for the study.

1.4 THE SCOPE OF THE STUDY

Five sandcrete hollow block Industries located in selected areas of Kwara State were chosen for the purpose of this study. These Industries are designated

as A, B, C, D and E and are situated in the following locations respectively:-

A. Located in Kulende, Ilorin - East Local Government Areas.

B. Situated in Odo-ota, Asa Local Government Area.

C. Located in Adinimole, Ilorin - West, Local Government Area.

D. Situated in Bode - Saadu, Moro Local Government Area.

E. Located in Agbo-Oba, Ilorin - West Local Government Area.

The location of each Industry is shown in the map below:



FIG. 1

In view of the huge cost that might be incurred in transporting the blocks to Zaria and the consequent damage that may be inflicted on the units, the laboratory tests were executed in a standard laboratory situated in Bode - Saadu, Moro Local Government of Kwara State. The laboratory is located at about 60km away from the capital city of Kwara State and it is owned by Aprofim Nigeria Ltd. - the main contractor handling the Bode - Saadu/Kama Road project - under the surveillance of Kwara State Ministry of Works, Ilorin.

Initially, work was to be concentrated on the commonest size of sandcrete blocks used in construction (i.e. the 230 x 230 x 450mm blocks) but the type of crushing machine available could not permit their use instead the 150 x 225 x 450mm blocks were employed. These blocks were subjected to various tests as mentioned earlier. It is important to mention that samples of hand-moulded blocks were never included in the investigation.

It was observed from the test results that sandcrete hollow blocks produced in Kwara State are yet to meet the required standards.

1.5 LIMITATION AND PROBLEMS

The limitation to this study and the problems encountered include:

(i) The inavailability of a standard crushing machine for full size sandcrete hollow blocks in Ilorin, the capital city of Kwara State. The search for such a machine took a period of 2 months which therefore caused delay in the commencement of the project work. Besides, the cost of transporation of carrying the investigation in the available laboratory situated at Bode - Saadu was considerably high.

(ii) The number of samples collected for the purpose of the investigation was limited to the number stipulated in British standard specification for precast concrete blocks. The Nigerian Standard for sandcrete hollow blocks under preparation was also used to determine the number to be tested.

CHAPTER TWO

LITERATURE REVIEW

2.1 PREAMBLE

Blocks are smooth and rectangular precast units manufactured in variety of sizes. They may be made from varying materials such as concrete, clay, etc. The bonding together of individual block unit with mortar (binding agent) results to a wall formation. Wall, without doubt, plays a vital role in a building structure since it is meant to enclose the entire area of such building and resist to an extent laterally applied forces. For effective performance of these tasks a wall has to satisfy functional requirements such as strength, exclusion of moisture, sound insulation, thermal insulation, fire resistance and durability.

However, it is apparent that these functions are not that of the wall element but the materials of which the element is made. A block work notably exhibits the characteristics of its materials and as such the latter should possess inherently good properties. For example, estimation of the strength of a wall is obtained by making inference from the crushing strength of the individual units. It has been written that the strength of walls increases, but not in direct proportion to unit strength (10).

The compressive strength of block work are said to vary from about 1/4 to 1/3 of the crushing strength of the blocks themselves (31). Other authors who work in these area include:

1. Neild (29) who mentioned that the strength of a wall is chiefly a matter of the material to resist direct compression when built up in the manner in which it is to be used.

2. Code of practice for blockwall (6) explained that the durability of blockwork will vary according to the nature of the units.

Furthermore, cracks in walls are as a consequence of the use of low quality blocks and may subsequently lower the value of the strength, durability, exclusion of rain and thermal insulation of the walls. The West African Building Research Institute (37) recognises the danger of cracks in wall when it said that the cracking of buildings in many areas in West Africa prompted an investigation into the part which sand - cement blocks play in such failures. An opinion was also expressed that good quality blocks should improve hygiene, since there will be no cracks on the surface for insects to lodge in, reduce housing maintenance and repair costs and in general increase the life span of a building (35). It is a fact that good quality blocks will increase the public confidence in promoting their wide range of applications.

2.2 SANDCRETE BLOCKS - AS WALLING UNITS

Sandcrete block is synonymous to precast concrete block in the Nigerian Context. It is generally hollow in nature and have gained wide and broad application all through the years as a wall component. Sandcrete block is a type of block made from a semi-wet mix of fine aggregate and cement. Ronald Smith (32) defines concrete block as a name given to a type of Masonry Unit made from a mix of fine aggregate and cement with or without colour. The British Standard (2) specifies a mix of cement and combined aggregates of fine and coarse aggregate for precast concrete blocks. Two notable authors (14) clarified that type B units essentially comprise solid blocks of autoclaved aerated concrete, which can be hollow or solid. Some are made of lightweight or chemically stabilized graded wood particles or similar produced units.

There exist variations in the manufacturing of these blocks. It has been established that the constituent materials are mixed in various proportions to produce blocks of varying strength for various purposes. Where normal strength is required, mixes are of the range of 1 part of cement to 6 parts of fine aggregate; to a minimum of 1 part of cement to 8 parts of fine aggregate. The range of water/cement ratio often recommended is between 0.4 - 0.7 and the cement/sand

ratio has between 1:6 to 1:13 (15). The British Standard (2) stipulated that a cement - sand ratio of 1 part of cement to 6 parts of combined fine and coarse aggregate should be used for blocks except that the proportion may be increased to 1 part of cement to 4½ parts of aggregates where the thickness of the web of the block is 25mm or less. Mixing of the constituents are pre-requisite to good quality units. Mixing of the materials could be manual or plant-mixed depending on the production capacity of the manufacturer. Whichever method is adopted, the British Standard (2) said that the cement and aggregate used in the manufacture of the blocks shall be thoroughly blended during the mixing of concrete. Also NIS specification for sandcrete - yet to be published (28) recommends that where hand mixing is carried out,the materials should be turned over until an even colour and consistency throughout is attained.

Sandcrete blocks are notably used for both load bearing and Non-load bearing walls. Concrete blocks are grouped into classes based on their functions and nature. They may be termed as solid - without Cavities or Hollow - with large holes or cavities which pass through the block. They can also be cellular with large holes or cavities with one bed face closed (usually laid uppermost). A recommendation was made that hollow blocks should have cavities whose minimum dimensions are 75mm x 50mm (14).

The hollow nature of a block is supposed to make it handy and lessen its weight. T. M. Stoll (3) recommended that the blocks exceeding 4" (102mm) in thickness should often be cast hollow to save materials, reduce weight and improve thermal insulation. He however, mentioned that their impact strength is low and great care should be exercised in handling them. The following views on the percentage of voids expected in the sandcrete blocks as expressed by Alan (9) are given below:

TABLE 1: ALLOWABLE PERCENTAGE OF VOID WITH RESPECT TO TOTAL VOLUME

Type of blocks	Allowable Void Percentage
Solid blocks	25% or less
Hollow blocks	Greater than 25%
Cellular blocks	Not more than 50%

In expressing his own opinion, Jackson (16) gave no specific limits of formed void in relation to overall block volume but felt that the external shell wall thickness should not be less than 15mm or 1.75 times the normal size of the aggregate whichever is greater.

Type B - Lightweight/Dense aggregate concrete block for general use in building including the use below the ground level damp proof course. Density is less than 1500kg/m^3.

Type C - Lightweight aggregate concrete block for internal non-load bearing walls. The density is less than 1500kg/m^3.

3. In general, total width of cavity in any block must not exceed 65% of its thickness and the volume of cavity in the block shall not be more than 50% of its gross volume.

For optimum standard, the dimensions of concrete blocks are regularised given certain amount of tolerances. In terms of its dimension, a block is defined as having length, width or height greater than that specified for a brick. The height of a block should not exceed either its length or six times its thickness to avoid confusion with slab and panels (9). However, Jackson (16) see a block as a unit not exceeding 650mm in length and gave certain work sizes of concrete blocks as shown in table 2 below:

TABLE 2: WORK SIZES OF CONCRETE BLOCKS AS GIVEN BY JACKSON (16)

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

While the British Standard (2) gave recommended sizes of type A and B as below:

TABLE 3: DIMENSIONS OF BLOCKS RECOMMENDED BY BS 2028

Type	Dimension	Work Size (mm)	Co-ordinated Size (mm)	
A	Length	448	397 or 499	±3
	Height	143 or 219	92 or 194	±3
	Thickness	51, 64, 76, 102	76, 92, 102.	±1.5
		152 or 219	143, 178 or 194	
B	Length	448	397, 499 or 600	±3
	Height	219	194 or 225	±3
	Thickness	76, 89, 102, 152	76, 92, 102,	±1.5
		203 or 219	143, 113 or 194	

No dimensions of any block should fall outside the stipulated limit or tolerance.Some researchers (23) emphasized that it should be remembered that concrete block is always 3/8" (9.4mm) smaller in dimension than its designated or nominal size. Neild (29) allowed tolerance of ± 1/8" (3mm) in width and length and ± 1/16" (1.6mm) in thickness. In his own opinion, blocks are true to the shapes in which they are cast and no provision is needed against warping. In its own specification,NIS (28) mentioned that sandcrete blocks should be of varying sizes of 450 x 225 x 113mm; 450 x 225 x 150mm and 450 x 225 x 225mm with web thickness of 25mm, 37.5 and 50mm respectively. But in a paper delivered by Florek (13), he described the nominal sizes of sandcrete blocks as

230 x 230 x 460mm; 150 x 230 x 460mm and
100 x 230 x 460mm.

He also observed that there has been no Nigerian Standard concerning these blocks. In a paper written by Iloghalu (15), the sandcrete blocks dimensions are given as:

228 x 228 x 457mm solid and hollow types approximating to 9" x 9" x 18";
228 x 152 x 457mm solid and hollow types approximating to 9" x 6" x 18" and
228 x 127 x 457mm solid type approximating to 9" x 5" x 18"

Nigerian sandcrete blocks, though hollow in nature, can be designated as type A or B blocks which have gained wide use as Load bearing and Non-load bearing walling units

for both low-rise and high-rise buildings. Nigerian Block Manufacturers have never taken cognisance of producing special blocks such as half length block, quoin blocks. In effect, bricklayers are fond of cutting blocks thereby slowing down construction work and resulting into escalation of construction cost. Gage and Kirkbride (14) advised that manufacturers should be able to supply as standard items and not as specials, half-length blocks, full length quoin blocks, etc. Sandcrete blocks have major advantages including the lightness in weight leading to consequent reduction of dead load and the high thermal insulation due to their hollow nature.

2.2.1 MATERIALS

So far, there is no published standard specification for sandcrete blocks. Thus, there is no standard specification to suit the local materials use for these blocks. Therefore, blocks currently manufactured are produced to meet up with the British Standard specification. By implication, constituent materials utilized to make these sandcrete blocks should conform to the already laid down specifications in the British Code.

The ordinary portland cement is the most widely used matrix for block production and it is locally obtained from a wide variety of sources. It was specified (27) that the cement used in production of

blocks should comply with the B.S 12: portland cement (ordinary and rapid hardening) or B.S 146: where portland blast furnace cement is the choice of matrix. Nevertheless, NIS (27) made the following recommendations on the properties of cement:

1. Fineness shall give an average specific surface area of not less than 2500cm^2/g.
2. The initial and final setting time must not be less than 45mins and more than 10 hours respectively.
3. The cement powder shall possess an expansion of not greater than 10mm.
4. The average compressive strength of 3 mortar cubes prepared and tested for 3 days (72 ± 1hr) and 7 days (168 ± 2hrs) strength shall not be less than 15MN/m^2 and 24MN/m^2 respectively.

To maintain the quality of cement brought to the site of production proper storage is urgent and of vital importance. Cement needs to be well stacked in a dried place free from moisture. It is also imperative that each consignment of cement should be stored in such a manner as to permit the use in order in which it is delivered.

Traditionally, local and relatively cheap river sand is used in the manufacturing of sandcrete blocks. This complies with the specification that natural aggregates should

be used in forming them (3). Ejeh and Abatan (38) recognised the fact that some sand used for concrete are lateritic, thus giving rise to low strengths. Aggregates for blocks should be hard, durable, clean and free from deleterious matter e.g. clay, silt, etc. The maximum quantities of clay, silt and fine dust determined should not exceed 6% by weight depending on the method of test stipulated in BS 812 (4). If the field settling test method is adopted, it shall not be more than 6% by volume.

In the 1961 annual report published by West African Building Research Institute (37), it is recognised that West African sands, particularly sea sands which are often single sized or too fine, do not conform to the grading requirement and blocks of lower compressive strength are obtained. This is a recognised fact since manufacturers of these blocks do not determine the grading of their aggregates before they are utilized. The object of grading aggregates is to produce concrete with satisfactory plastic properties (workability, cohesion and resistance to bleeding) as well as satisfactory hardened properties (strength, durability, void contents and surface finish) using a little cement as possible. Thus, the grading of aggregate is a vital issue because it has great influence on the shrinkage cracking of a block. The BS 882: 1973 (3) considered that any fine aggregate whose grading falls within the limits of zones 1, 2, 3 and 4 is suitable for concrete.

Zone 1 is the coarsest grading and can be used for mixes with a low water/cement ratio (25). Zone 4, on the other hand, represents the finenest grading. This zone is cohesive and has high specific surface thus requiring more cement than when the coarser grading is used. The NIS specification for sandcrete blocks (28) recommended a suitable sand falling within zones 1 and 2 of the B.S test sieve. The specified percentage passing certain number of sieves for zones 1 and 2 as given by Jackson (16) are shown in table 4 below:

TABLE 4: THE SPECIFIED PERCENTAGE PASSING CERTAIN SIEVES FOR ZONE 1 AND 2

B.S. Sieve No.	Zone 1 (%)	Zone 2 (%)
4.7mm	100	100
2.36mm	90 - 100	75 - 100
1.18mm	60 - 95	55 - 90
600 Microns	15 - 34	35 - 50
300 Microns	5 - 20	8 - 30
150 Microns	0 - 10	0 - 10

It is also expected that the sand should mainly pass through a 4.69mm (3/16) B.S test sieve. Jackson (16) expressed the view that the maximum size of aggregate used in production of concrete blocks should not exceed 10mm. In his paper on the "quality of sandcrete hollow blocks", Florek (13) mentioned that the maximum size of natural aggregate to be used is between 5mm and 10mm.

The use of good water is important to block production. For good quality blocks, it is recommended that water employed should be clean, fit for drinking and free from organic matter and salt. In most block Industries in Nigeria, except in local areas, water used in making blocks are found to conform to the specified standards since the source of water supply is directly from the service pipes fed by the water works. However, the manufacturers are deficient in accurate proportioning of water to obtain the required mix consistency. In reality, there is no rule of thumb as to the water content requirement of a block. Neild (29) explained that blocks designed to be rendered are made from semi-dry mix while facing blocks are made from a wet one. The former results in a block of porous open texture. NIS (28) specified that water should be added through a fire hose in just sufficient quantity.

Likewise, the result of various tests carried out have confirmed that the strength of sandcrete blocks as other cement products, increases as water - cement ratio decreases up to certain limit (15). Iloghalu (15) however, gave the range of water/cement ratio to be between 0.4 - 0.7.

It is apparent that standards of raw materials utilized is crucial to a good and durable block production. Where manufacturers fail to comply with the known specifications for raw materials, low quality products result. Further, the West African Building Research Institute, 1961 annual report asserted that such blocks have nevertheless proved satisfactory in building construction and consequently, it hoped that by further tests on full sized blocks standards will be established for the manufacture of sand - cement blocks for use in West Africa.

2.2.2 MANUFACTURING PROCESSES

The method adopted in the manufacturing process of a block also affects its eventual properties. The manufacturing processes include:

Batching, Mixing, Compacting, Curing and Storage. The production of sandcrete blocks are carried out manually _ termed as hand-moulding or mechanically.

Generally, the most common way of batching is batching by volume inspite of the fact that it is not a very reliable method in comparison to batching by weight. It may be deduced that manufacturers avoid batching by weight because of the time and the diligence it demands in arriving at accurate measurement. It was observed that when sand is batched by volume, the water content of the sand greatly influences the resulting quality of concrete. Hence, if batching is done by weight, the water content of the sand would still be troublesome but not to as great extent as by volume (8). Evans and Wilby (8) also added that it should be realised that batching by weight, in preference to volume, saves cement and gives a more consistent mix.

Blocks can be formed by using varying types of machines. They could be the egg-laying type (which is mobile and produces blocks directly onto a horizontal surface as it moves along)or the pallet machine (which is stationary and casts onto movable pallets). Most block -making machines employ pressure or vibration or

a combination of the two. The manufacturing process involves compaction of the newly mixed constituent materials in a mould box followed immediately by demoulding on their pallets so that the mould box can be used repeatedly. The use of a sufficiently dry mixes ensures that the blocks can be removed immediately after vibration. Some Researchers (8) observed that segregation can even occur with very dry mixes if the vibration employed is excessive. Thus vibration used with an apparently dry mix should be just sufficient to make the concrete flow into sharp corners of the mould. In one journal released by United Nations Development Organisation (35), two basic methods of forming a block were given. These include:

(i) Blocks formed at constant pressure

(ii) Blocks formed at constant volume.

Constant Pressure Method

If the constant pressure method is used to form or compact a mix in mould, the mix is subjected to uniform pressure which reduces the air voids in the materials. The particles move together until a time is reached when the external pressure equals the internal pressure.

At such a time, no further compaction movement takes place. The fixed pressure, the moisture content of the mix and the initial quantity of the material deposited into the mould determine the thickness of a block. Thus, the production of uniform blocks therefore requires that both the quantity and the moisture content of the mix remain constant at all times (35).

Constant Volume Method

When using the constant volume method, the external compacting pressure varies so that blocks of uniform thickness are produced even though the quantity of mix may vary. Variation in the quantity of mix results in a variation in density of blocks produced (35).

It was explained further (35) that in both the constant pressure or constant volume methods, the weight or volume of a mix fed into a mould, as well as the moisture content of the mix, at each pressing should be kept uniform. Frequent checks should be made to ensure the production of blocks of uniform sizes and density. A device that operates both at constant pressure and at constant volume is said to produce more uniform blocks.

For effectiveness, few experimental pressings are advised to be conducted before the correct amount of mixture is determined. In one research carried out by Ejeh and Florek (11), the observation made was that if the compaction pressure is kept constant and the volume of material poured into the mould is varied, larger volume of materials will result into greater height and weight of blocks. Also if the volume is kept constant and the compaction varied, a high compactive force results into a block of smaller height and vice-versa. They also deduced that the varying height is as a result of varying volume of mixed materials poured into the mould prior to compaction.

Method of curing is one of the factors in the manufacture of concrete masonry units which influence shrinkage cracking (17). Adequate curing of blocks is essential to ensure that the cement hydrates sufficiently for the blocks to be handled without being damaged, most especially on the transit. The method of curing adopted in sandcrete blocks production is air-curing. After extrusion from the machine, blocks are spaced out and cured with intermittent spraying of water for a particular period of time which varies from Industry to Industry. In a laid down standard (28), after blocks are removed from the

machine, they should be left on pallets (in separate rows with spaces in-between) for at least 24 hours and kept wet by spraying. In addition, when the blocks are removed from the pallets, they should be cured (kept wet) for at least 3 days. It was recommended that the blocks should be stored for at least 3 days prior to use, after the previous period of curing. From the NIS specification (28), it is not quite known whether curing should be by immersion or by intermittent spraying. G.D. Taylor (34) opined that curing as a process is in no way dependent on air, so that once setting is complete, ideal curing conditions are those in which the concrete is completely saturated.

T. M. Stoll and Evstratov (33) shared the view that blocks should be cured either by keeping them moist in a sheltered place for five days and then allowing them to dry out slowly (the whole process taken at least 4 weeks). They also mentioned that it is essential for the initial shrinkage, which takes place during drying to cease before the blocks are used, if not, there is a serious risk of joints opening and cracks occuring in the finished wall. Jackson (16) describes one method of curing of concrete blocks as steam curing at atmospheric pressure. He said that immediately blocks are released on pallets, they should

be transfered to curing chambers (where the blocks are subjected to steam curing) for about 12 hours and then stacked outside for final curing up to the age of 7 days. In his own observation too, the longer the period during which concrete is kept in water, the greater is its final strength. Below is his pictorial representation of the development of concrete strength under various curing conditions. These results as obtained by Jackson is based on Gilkey (16).

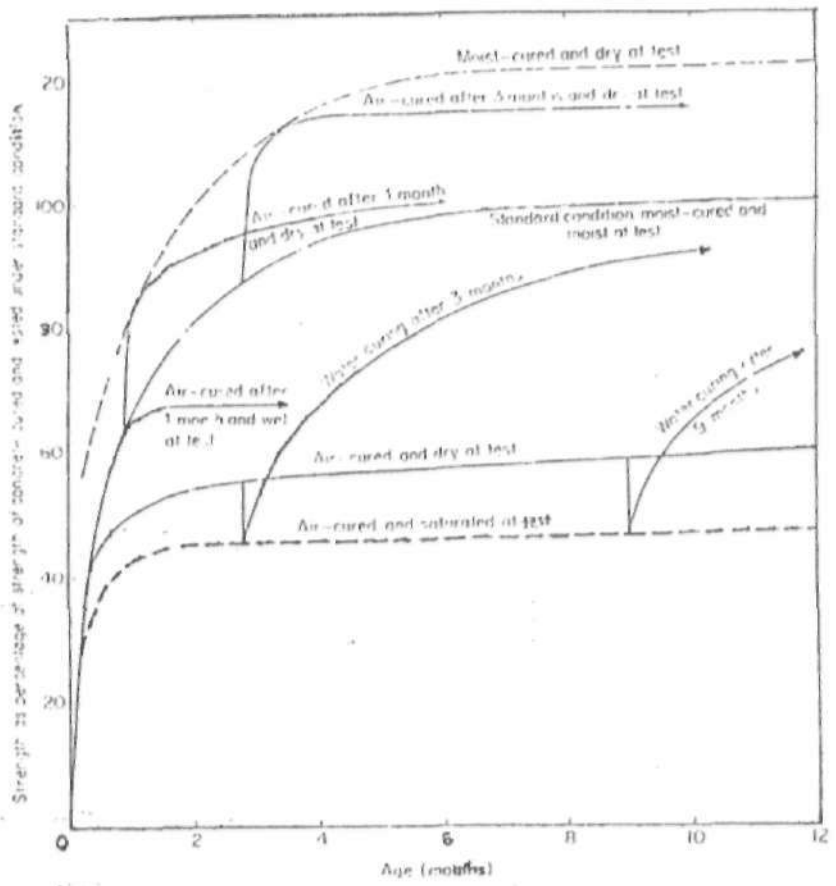


Fig. 1a Effect of curing and conditions of concrete when tested on concrete strength

From the curve it is apparent that concrete left in air achieves the lowest strength values at all ages owing to the evaporation of the free mixing water from the concrete.

CP 121, Part 1: 1973 (6) emphasized that concrete blocks which have not been autoclaved (blocks cured by steam at high pressures) should have been stored before use, exposed to the wind but protected from rain, for at least 4 weeks at normal temperature and longer in colder weather. In the "design in Blockwork" (14), the three major method of curing are described as: Normal air curing, Steam curing and Autoclaving.

Normal Air Curing:

Under this condition, blocks must be kept moist and protected from wind and sun for about 3 - 7 days depending upon atmospheric condition. After this initial curing period the blocks should be protected from rain so that they are as dry as possible before delivery. This process is found to be slow and blocks will not cure at temperatures below freezing point. Because of the slow speed and difficulty of controlling conditions, it may not be the best method for larger plants (14).

Steam Curing:

Involves the application of heat at high humidity. This method can give high early strength and maturing, but ultimate strength of blocks is rather less than if they were air - cured. There is no appreciable difference in the shrinkage characteristics of such blocks, unless the blocks are cooled so that they dry quickly and are kept dry (14).

Autoclaving:

This method enables dry blocks to be delivered at 24 hours of its production thus, reducing storage and inventory control. It can also help to reduce irreversible moisture movements and the cement content without reducing the strength. The latter occurs when silica combines with lime in the cement at autoclaving temperature. Autoclaved blocks are found to be more uniform in colour. This method requires special equipment which is therefore expensive to install and operate (14).

Neild (29) said that curing of concrete masonry units should be done under warm and moist condition since water is necessary if the cement is to develop its full strength. To him, under normal conditions the time for curing is about 4 weeks, but the completion test is not one of time.

It is rather of the standards of strength, moisture movement and shrinkage which the concrete reach.

However, curing is a function of strength. An increase in compressive strength of blocks can be obtained if the curing period is extended. Curing should continue until the units have sufficient strength to resist shrinkage cracking. To substantiate the above statement, an author (29) exaplained that concrete blocks should have undergone the initial irreversible shrinkage, that is, they should have been thoroughly cured before being sold. He also added that a purchaser should ensure that the profit made from quick sales has not led the manufacturer to under estimate the time needed for maturing.

Storage and handling is a crucial factor to be considered in the manufacturing process of concrete masonry units. During all stages in packing, transporting, handling and storing, edges should be protected from damage to prevent alteration in dimension and avoid undue breakage. On work site or production site, blocks should be stacked on their bedding faces on a strong level surface. It is likewise important to keep blocks in a dry condition prior to use. Raymond Moxley (24) ascribed importance to keeping concrete dried before use when he said that they should be covered in such a way that air can circulate freely around them.

He observed that if they are built into the wall wet, they will shrink slightly as they dry and cracks may occur. Ragsdale and Raynhan (20) in their own views also see this step as a safeguard against subsequent excessive drying shrinkage. They said that blocks should be protected from rain during transit from the manufacturers to the site and also during construction. A notable code of practice (6) specified that blocks should be unloaded onto a reasonably dry and level ground on site. It should be protected from rain; handled with care and should be free from circulation of air around the stack. It also emphasized the avoidance of stacking on newly cast slab except it is matured.

Concrete blocks must be kept under good storage conditions. Adequate drying is expected before use otherwise drying will continue after the wall is built and shrinkage cracks may occur.

2.3 PROPERTIES OF CONCRETE BLOCKS

The determination of good quality blocks is relatively the judgement that can be drawn from its properties. These properties include: The Compressive Strength, Drying Shrinkage, Moisture Movement, Density, Efflorescence, Appearance, Fire Resistance,

Sound Insulation and Thermal properties. The above properties affect the structural elements where blocks are used.

2.3.1 Compressive Strength

Compressive strength is the maximum load a single unit can withstand when subjected to compression. The variables that can easily affect the strength of a block are many, namely: Quantity and proportioning of the raw materials, degree of compaction and mode and duration of curing. In general, for a given set of materials, the strength of a concrete block will increase with its density.

The compressive strength of concrete blocks could either be the average strength of 10 blocks or the lowest compressive strength of any individual block tested (2). The BS specification (2) tabulated the permitted values of compressive strength of Type A and B blocks as shown below in table 5.

TABLE 5: RECOMMENDED VALUES OF COMPRESSIVE STRENGTH OF TYPE A AND B BLOCKS

Block type and designation	Minimum Compressive Strength	
	Average of 10 blocks (N/mm^2)	Lowest individual blocks (N/mm^2)
A (3.5)	3.5	2.8
A (7)	7.0	5.6
A (10.5)	10.5	8.4
A (14)	14.0	12
A (21)	21.0	16.8
A (28)	28.0	22.4
A (35)	35.0	28.0
B (2.8)	2.8	2.25
B (7)	7.0	5.6

This code made provision for other strength to be agreed between the purchaser and the manufacturer. In the book written by Gage and Kirkbride (14), strength is known to be the average compressive strength of a test sample of 10 blocks. They stipulated that the compressive strength of the weakest individual block in the test sample must not be less than 80%

of the average value so as to exercise control on the quality of the blocks in the consignment as a whole. Jackson (16) gave the range of strength values specified by BS 6075, part II as 2.8 - 35N/mm^2. But in his own view, giving considerations to cost the more normal practical upper limit will be about 20N/mm^2 and the most commonly used blocks will fall within 10N/mm^2. He also mentioned that for any given strength, the form of block (solid, cellular, or hollow) will not affect its load carying capacity. Some group of authors (14) attested to this fact by explaining that solid, hollow and cellular load-bearing blocks are tested for compressive strength in the same manner (compressive strength is obtained by dividing crushing load by overall cross-sectional area of the block). Thus, there is no difference in the load-carrying capacity of these types of block of equal compressive strength.

Also, NIS (28) considered the compressive strength as the average compressive strength of a test sample of 10 blocks. It specifies an average strength of 3.45N/mm^2 and 2.76N/mm^2 for load bearing and Non-load bearing blockwork respectively. However, the compressive strength of the weakest individual block in the test sample must not be less than 80% of the average value. Ejeh and Florek, in one of their papers (12), wrote that the Federal Ministry of Works specified the average compressive strength of 3 sandcrete blocks to be not less than 2.1N/mm^2 and the lowest individual strength to be not less than 1.7N/mm^2 (which is about 80% of the average strength) when tested in a dry state. Florek (13) reviewed that compressive strength of types A blocks, based on gross loaded areas (i.e. 230 x 460mm; 150 x 460mm and 100 x 460mm), should not be less than; (i) average compressive strength of 12 blocks which is 3.45Nmm^2; (ii) lowest compressive strength of individual block which is 2.59N/mm^2.

He emphasized the fact that relatively high strength of block is required because of load imposed on the wall and durability in severe climatic conditions (heavy rains, low external ambient temperature, soaking and drying walls etc.). He added that these conditions are not of harmful effects in Nigeria. Between 1978 and 1984, Florek (13) carried out tests on sampled sandcrete hollow block produced in some towns in Northern State (Bauchi, Ikara, Kaduna, Mubi, Saminaka and Zaria). These blocks were delivered in batches to the Civil Engineering Department of Ahmadu Bello University. The test result (Test carried out according to BS 2028) revealed the following:

(i) Compressive strength of 29 sandcrete hollow blocks (100 x 230 x 460mm) as ranging from 0.85 - 2.5N/m^2 with an average strength of 1.64N/mm^2.

(ii) For 54 samples of sandcrete hollow blocks (150 x 230 x 469mm). Compressive strength ranged from 0.97 to 8.81 N/Mm^2 with an average strength of 3.88N/mm^2,

(iii) Compressive strength of 223 sandcrete hollow blocks (230 x 230 x 460mm) ranges from 0.50 - 8.68N/mm^2 with an average strength of 2.43N/mm^2.

Nonetheless, these test results on the sandcrete hollow blocks indicated that of a special mix rather than the ones actually produced for Masonry Construction on the site. In spite of this fact, Florek confirmed

that the quality of the products is very poor and below the standard requirements.

2.32 Density:

The effectiveness of other properties mainly depends on the density, in the fact that a more dense block will not allow the ingress of heat, sound and moisture. For an ultimate density, the compacting pressure and the moisture content must be given due consideration during manufacturing process. In one of the United Nations industrial development organisation journals (53), dry density of a block is said to have direct relationship with the compacting or moulding pressure, the moisture content of a mix and the strength or durability of that block. Any wall constructed with blocks of variable density will, in time, suffer from uneven erosion.

The BS 2028 (2) recommended that block density of type A blocks (in any form) should not be less than 1500kg/m^3 and similarly that of types B and C blocks should not be greater than 1500kg/m^3. Jackson (16) however gave the range of dry density of concrete blocks to be 500 - 2100kg/m^3. He said that lightweight and dense aggregate concrete blocks of cellular and hollow forms fall in the middle of the range.

Likewise, Gage and Kirkbride (14) observed that density of concrete blocks made of natural aggregates is normally about 1920 to 2080kg/m^3.

2.33 Dimensional Changes:

All masonry units undergo changes of dimension with wetting and drying and with temperature changes. These changes are small, but they can cause cracking of walls or damages to other parts of the structure unless adequate precautions are taken. In one of the researches by Kalousek et al (18), they explained that a characteristic of all portland cement concrete, including masonry units, is the tendency to decrease in volume with either a decrease in moisture contents or temperature. This decrease in volume may result into shrinkage cracks when concrete masonry is restrained from shrinking.

. Concrete products, in addition to the causes mentioned above, exhibit shrinkage which do not occur as a result of chemical changes within their composition. This chemical process is associated with carbonation, hydration and curing. CP 121 (6) attested to this fact by mentioning that concrete units shrink after manufacture, due to drying and carbonation shrinkage in concrete products is affected by changes in moisture content, when the

cement gel within the concrete loses or absorb moisture by evaporation. Internal stresses are created as water recedes or increases in the capillary pores. This action leads to consequent contraction or expansion and any restrain exerted will cause cracking to occur in the units. Shrinkage may be classified into two types: Irreversible shrinkage on first drying (termed as initial shrinkage or drying shrinkage) and consequent reversible shrinkage (termed as moisture movement). Jackson (16) however, classified shrinkage as plastic - that caused by the settlement of solids and loss of free water from the plastic concrete; autogenous - that caused by the chemical combination of cement and water; and drying shrinkage - that due to drying of concrete.

Drying shrinkage is seen as a key factor in the use of concrete blocks. Alan (9) said that it is more troublesome and thus precautions should be taken to prevent cracking of blockwork. Neild (29) explained that the most persistent reason for cracks in the joints is the drawing away of the units themselves either in the considerable drying shrinkage which attends rich mixes, or even in the initial reversible shrinkage of blocks placed when still green. Jackson (16) too considered drying shrinkage as the most important in normal application of a masonry. He defined Drying Shrinkage as the movement that occurs in a concrete unit when water is drawn out of its cement gel.

Lea (21) clarified the fact that shrinkage does not commence until free water disappears in the material.

After an initial high rate of drying shrinkage, concrete is said to shrink continously for a long period of time but at a continously decreasing rate with 50% of total shrinkage occuring in the first year (16). Kalousek (17) carried out a research and concluded that concrete blocks undergo shrinkage at high relative humidity which may be caused largely by the capillary - tension stress. He further explained that since elastic strain is released, concrete should re-expand at some lower humidity. He felt that dried concrete block would not expand very much at high humidities probably because the capillary tension stress is developed to a marked degree. He specified a drying shrinkage value of 0.06 - 0.09%. BS 2028 (2) recommended that the average shrinkage value of any sample should not exceed the values tabulated below in table 6.

TABLE 6: THE RECOMMENDED AVERAGE SHRINKAGE VALUES BY BS 2028

Block type	Average Compressive Strength (N/mm^2)	Block density Kg/m^3	Maximum drying shrinkage (%)
A	less than 10.5	All	0.03
	10.5 and above	All	0.06
B	7.00 and above	All	0.08
		over 625	0.07
		625 and less	0.09
C	All blocks	over 625	0.08
		625 and less	0.09

Jackson (16) also gave the permissible values of drying shrinkage to be 0.06 - 0.09%. CP 121 (6) stipulated permissible values of 0.02 - 0.06% for type A concrete blocks and 0.04 - 0.09% for lightweight concrete blocks.

It is apparent that the concrete units most susceptible to shrinkage are those with high cement contents, high water/cement ratios. Some researchers (8) described that the co-efficient of shrinkage is less for a lean mix than for a rich mix (i.e. rich in cement content): less for low water to cement ratio than a high one; very sensitive to method of curing; and is influenced by all other possible variables to a less influential extent. In one of the

Journals of American Concrete the research paper by Kalousek et al (18), major factors in the manufacture that influences shrinkage cracking are enumerated as:

(1) Gradation of aggregate

(2) Chemical and physical properties of cement and aggregate

(3) Mix proportions (both of aggregate and cement)

(4) Mix consistency

(5) Method of curing

(6) Design of the unit.

Generally, drying shrinkage of concrete blocks can be reduced significantly by ensuring that the units are properly matured and by preventing them from becoming excessively wet on site prior to their use. Ragsdale and Rayhan (20) stated that most blocks are made under carefully controlled conditions, and many are autoclaved to accelerate hardening and curing and to reduce drying shrinkage. The Code (6) pointed out that non-autoclaved units are subjected to a slow non-reversible carbonation shrinkage caused by chemical reaction of carbon-dioxide from the atmosphere with some of the production of hydration of this cement.

On the other hand, Moisture Movement (wetting expansion) is the swelling which occurs when a dried concrete masonry unit is subjected to a moist environment. This kind of shrinkage is reversible, though the magnitude of its expansion is not sufficient to recover all the initial

shrinkage even after prolonged immersion in water. Gage and Kirbride (14) described moisture movement as slightly less than the value of drying shrinkage. Likewise the Code (6) confirmed that the wetting expansion rarely causes difficulty because it is less than the initial drying shrinkage.

Shrinkage in concrete blocks due to temperature change are not of paramount importance. The dimensional changes in concrete blocks associated with a given change in temperature cannot be varied greatly by choice of materials or manufacturing techniques. But if ambient temperature would vary widely, their effects must be duly considered in design. CP 121 (6) added that movement due to normal changes in temperature of internal walls are likely to be small and are not an important cause of cracking - no special consideration need to be given to them in design. Except that provision should be made to accommodate movement where temperature variations are likely to be large.

2.34 Efflorescence:

Efflorescence is a chemical property of blocks. It is a light, whitish crystallization deposited on the surface of masonry units. It is the result of evaporation of water carrying soluble salts to the wall surface. Such efflorescence as occurs in concrete blocks normally consist of sodium, potassium

and carbonates formed as a result of a reaction between the corresponding free hydroxides brought to the surface and atmospheric carbon dioxide (16). However, situations exist where these salts may form sulphates which can cause deterioration of the blocks. Neild (29) agrees that though efflorescence is disfiguring,, it has no very serious effect in durability of the material itself. Fitzmaurice (10) expressed an opinion that crystallization in skin formation is the most important factor in causing deterioration of walling materials. He described that where the salts crystallize in the pores of the surface layer of the material (not on surface), there is a tendency for a hard surface skin to be formed with properties different from main body of the wall. In case of materials of poor resistance to such effects this surface skin may flake off in time. Certain authors (14) expressed the view that open textured blocks weather well because the rain tends to find its way behind the visible surface and efflorescence (when it occurs) is distributed and not concentrated on the face as happens with blocks of smoother texture. However, Neild felt that the surface of a good quality block is not affected by soluble salts, except very slightly, by gases in a polluted environment. Efflorescence is classified as Nil, slight, moderate, heavy or serious (15). But Alan (9) recommended that efflorescence must not exceed 50% of the area of face.

Generally, efflorescence could be reduced by avoiding unsuitable curing of blocks and the premature drying shrinkage.

2.35 Durability:

Durability of a walling unit in service depends solely upon its chemical composition, pore structure, condition of exposure, and to some extent on its mechanical strength. It is a very elusive property to attempt to measure in definite qualitative terms. Ragsdale and Raynhan (20) defined durability in concrete blockwork as the ability of the blockwork to withstand the effects of the environments both chemically by aggressive ground water, polluted air in industrial areas, and mechanically by abrasion, impacts and excessive loading. They opined that since concrete is an inherently durable material so too is concrete blockwork. Dense concrete blocks have high durability while open-textured blocks are more vulnerable to chemical attack but, provided they are made of adequate strength, they will be resistant to normal atmospheric pollution (14).

2.36 Other Properties:

These properties are the fire resistance, thermal insulation and sound insulation. And they are directly dependent on the density of the blocks.

Concrete blocks have good fire resistance properties as it could be inferred from the behaviour of concrete. Jackson (16) suggested that actual fire resistance endurance could be controlled by the type of aggregate; cement content in a mix, the form, weight and thickness of the blocks and its moisture content. He added that most concrete blocks of 100mm thick can provide an adequate fire resistance for up to 2 hrs. if load-bearing or up to 4 hrs for non-loadbearing. In the "design of blockwork" (14), it was mentioned that CPIII and Building regulations call for an unplastered thickness of only 100mm for 2 hrs fire resistance with a wide range of materials including concrete blocks. The authors confessed that the Building regulation lack any officially proven fire resistance for most hollow or cellular dense concrete blockwork.

Furthermore, it is imperative to have access to information on the thermal insulation properties of masonry materials because of the rising flair for heating and air conditioning and to provide for acceptable conditions in buildings. The thermal conductivity of blocks vary with their density. The more dense they are, the less the transmission of heat. In the review of Arnold (1969) reports, Jackson (16) mentioned that autoclaved aerated concrete blocks, lightweight concrete blocks, and hollow and cellular concrete blocks, because of their lower net density, have lower thermal conductivities

than their solid counterparts. Another author (1) said that where a building is continously heated, advantage should be taken of the thermal capacity of a dense material since they possess better thermal storage capacity than lightweight materials. In their own views, Gage et al (14) believe that lighter blocks possess better insulating values, but their strength may be lower. They also added that hollow and cellular blocks have better thermal insulation properties than solid blocks of the same material and thickness due to their lower net density. Thermal conductivity also varies with the moisture content in direct proportion.

Moreso, sound insulation is one of the qualities a building unit should have when applied in a wall. Blocks provide insulation against airborne sound in ratio to its density and thickness. The Code (6), described the opening in texture of the units (i.e. giving free air paths) as the reason for considerable reduction in sound insulation. Contrarily, Gage and Kirkbride (14) stated that open-textured blocks have the advantage of helping to reduce the noise level in a room by the absorption of sound. They observed that lightweight aggregate blocks have moderately high sound absorption qualities, but dense concrete blocks generally have a lower capacity for sound absorption because their surface tends to be more solid, and reflect the sound.

Generally, there has not been any clauses in known standard specifications for precast concrete blocks which have taken care of the thermal insulation, fire resistance and sound insulation properties of concrete masonry blocks.

2.4 Current Trends in Block Industries Located in Kwara State:

For more comprehensive research work, field studies of some of the sandcrete block industries were conducted. These studies cover the five block manufacturing industries and some others in addition to the five chosen industries. It was apparent that more block industries are located within Ilorin, the State capital and the nearby Local Government areas. These areas are known to have more patronage as a result of more construction activities in town than the villages. From the survey of the block industries, the five industries chosen are the well established block industries. Some of the Local Government areas, even though have block industries, do not have the proper means of moulding, curing and in some cases accessibility by road are often impossible.

Industry A:

Industry A is located in Kulende area of Ilorin - East Local Government in Kwara State. The Industry started production of blocks 15 years ago. She has

on her roll of employment an average number of 50 staff. She has an administrative manager, a technical manager, 2 foremen, drivers, operators and labourers.

This block industry produces varying sizes or types of blocks. She moulds 230 x 230 x 450mm (known as 9" block); 150 x 230 x 450mm (known as 6" block); 100 x 230 x 450mm (known as 4" block) blocks and decorative blocks termed as fancy blocks. The manufacturer, though produce the 4" blocks sparingly, felt that the industry stands the risk of poor patronage since they are not in great demand. Its daily production is estimated at about 1,000 blocks. The industry installed two rosacometta pallet type of machines in the yard of production for moulding of the blocks. Its sandcrete blocks are also composed of cement, aggregates and water. This Industry utilizes a cement product from the West African Portland Cement Company in Ogun State tagged as "Elephant Cement" and she uses burhen cement product. This burham cement is imported from abroad and bagged in Nigeria. Usually, she receives consignment of cement in bags or in bulk. The bulk cement is stored in silos erected in the same yard of production. When necessary the cement is bagged by the Industry herself. However, one was not aware of any available bagging equipment. The manufacturer uses different kinds of fine aggregates namely: sharp sand, light brown soft sand and the granite dust. He claimed to use a mix ratio of 1 part of cement to 6½ parts of fine

aggregate by volume. Where soft and sharp sand are the choice of fine aggregates, the mix proportion is 1:1. Also if granite dust and sharp sand are the choice, the mix proportion is also 1:1. The aggregates are left in stock piles in the production yard. The industry has an already sunk borehole as a source of water supply for block production to avoid interruption in production.

Batching of constituents is by volume. The Industry uses wheel barrow to batch her aggregates. She uses 2 bags of cement per 6½ wheel barrows of fine aggregates (estimated at mix ratio.. of 1 part of cement to 6½ parts of sand). Usually, 21 blocks of 9" block are formed out of 1 bag of cement. While 42 blocks of 6" block are moulded from the same quantity of cement (1 bag). It was confirmed that the mix water is never proprotioned. Water is added until a satisfactory consistency is achieved. Mixing of the constituents is carried out on an elevated cement platform located close to the machines. The method of curing of the blocks produced by the industry is by intermittent wetting (using water hose) for not more than 3 days. During this period, wetting is done in the morning and evening alternatively. The manufacturer emphasized that during rainy season curing is executed only once.

The Industry have some stores erected in the yard of production for storage purposes. The end products are placed in rows in an open air. The blocks are not shielded from direct ray of the sun. However, this industry is a very large plant and has been rated as one of the best block manufacturers in Kwara State.

Industry B:

It is located in Odo-ota in Asa Local Government area of Kwara State. The block Industry was established 12 years ago and consist of about workers which includes a managing director, a foreman, operators, drivers and labourers.

The industry produces the most common sizes of blocks, i.e. 230 x 230 x 450mm and 150 x 230 x 450mm blocks. The daily production is estimated at 450 blocks. This Industry has only one pallet machine (rosacometta) which is used in block production. It mainly uses the "Elephant Cement" and the type of sand is the sharp sand and soft sand which are mixed up in equal proportion (1½ wheel barrows of sharp sand to 1½ of soft sand). The mix proportion of the constituents is normally in the ratio 1 part of cement to 6 parts of sand given as 3 wheel barrows of aggregates to 1 bag of cement. The manufacturer claimed that 20 - 25 blocks of 9" block are moulded from 1 bag of cement. As a source of water supply, a reservoir is constructed close to the point of production. The mode of mixing is also manual and it is carried out on

an elevated cement platform located near the machine. The Industry only cures her blocks for 2 days i.e. in the evening of the first day and second day respectively. No shed has been provided to shield the cured blocks. They are left in open spaces as practised in some other Industries.

A small structure was erected to house the centre of production and the stored materials. Blocks are stock piled in 5 layers after they have matured. Aggregates too are stockpiled in the immediate environment of the Industry.

Industry C:

She is situated in Adenimole of Ilorin - West Local Government area. She commenced her production 3 years ago. Her staff strength is estimated at 10. The Industry is composed of the Managing Director, a foreman, a director, two operators and some labourers.

The Manufacturer confirmed the production of the three common blocks: 230 x 230 x 450mm, 150 x 230 x 450mm and 100 x 230 x 450mm blocks. A total of about 300 blocks are produced daily. She also utilizes a rosacometta pallet type of machine for the production. Also this Industry uses the West African Portland Cement (Elephant Cement) and makes use of both the soft sand and sharp sand in equal proporti

(2 wheel barrows of soft sand to 2 wheel barrows of sharp sand). These aggregates are also left in stockpiles in the production.

This Industry carries out batching by volume using a wheel barrow. It batches 4 or 5 wheel barrows of aggregates per 1 bag of cement (estimated to mix ratio of 1 part of cement to 8 parts of sand respectively.) Usually 18 - 22 blocks are moulded from 1 bag of cement. Close to the range of production is situated a concrete reservoir to offset any interruption in water supply. Water used for mixing is never proportioned. Water is only added until a satisfactory consistency is achieved. Manual mixing is adopted in mixing the constituent materials. This Industry cured her blocks for a period of two days in an open space devoid of shed. Curing method is just by intermittent spraying of water. Sheds are erected to house the production centre and the stored materials. Aggregates are stockpiled close to the range of production. Usually, the blocks produced are stockpiled in 5 layers ready for transportation.

Industry D:

This industry was just established a year ago. The manufacturer already had a branch in Bacita which he started 11 years ago. She is situated in Bode - Saadu, Moro Local Government of Kwara State. At present, she has

about 6 workers which include the Managing Director, a foreman and labourers.

Only the 9" (230 x 230 x 450mm) and 6" (150 x 230 x 450mm) blocks are manufactured. She produces about 200 blocks per day. At the time of investigation, only one rosacometta pallet type of machine was installed for production. The Manufacturer also confirmed the use of the "Elephant Cement" since it is the most available brand of cement. Soft sand are often used in combination with sharp sand, though the ratio in which they are mixed was not stated. At the time of visit, only stockpiles of sharp sand were seen.

The Industry carries out batching by volume using a wheel barrow. The constituents are mixed in the ratio of 1 part of cement to 8 parts of sand - an equivalent of 1 bag of cement to 4 wheel barrows of fine aggregate. Usually, 22 - 24 blocks of 9" blocks and 42 blocks of 6" blocks are produced from a mix of 1 bag of cement respectively. Likewise, the mix water is not always proportioned. Some drums are placed on the site of production to store water. Clean water is normally brought to this Industry from Jebba, a nearby town. The normal curing period adopted for the blocks is 3 days. These blocks are not protected from weather influences. At the time of investigation, no structure was erected on the production site. The manufacturer hoped that before the year runs out shed would be erected to store necessary materials.

Visually, the blocks produced are of good texture and colour. The time of visit was in November, 1991 to January, 1992.

Industry E:

Industry E is situated in Ilorin - West Local Government area of the State. The Industry was established about 2 years ago. She has on her roll of employment an average of 8 workers. These include two Directors, a Foreman, a driver and labourers.

She manufactures 230 x 230 x 450mm, 150 x 230 x 450mm and 100 x 230 x 450mm blocks. The manufacturer confessed that the latter (4" block) is not marketable. The factory produces about 300 blocks daily. Only one rosacometta type of pallet machine is used for production of the blocks. The type of cement utilized is the same as the others. Though she uses two types of sand (the sharp sand and soft sand), the purported sharp sand is more of a lateritic soil. The type of sand used give rises to a brownish grey colour on the blocks. The mix proportion of the constituents is normally 1 part of cement to 8 parts of sand (i.e. 1 bag of cement per 4 wheel barrows of sand). For ample supply of water for production, the factory has a storage water tank which is fed by a pipe-borne water. As confirmed, no proportioning of the mix water is carried out but it depends on the consistency of mix required.

Batching of mix is by volume just as reported from other industries. The mixing of constituent materials is carried out manually on an elevated cement platform close to the machine. The factory only adopts a day curing for its blocks. Spraying of blocks with water takes place a day after moulding. Nonetheless, the factory has no shed to protect the blocks neither are the blocks covered with a water-proof material. Adjacent to the place of production is erected a store room where tools and materials are kept. Cured blocks are stockpiled in 5 layers ready for sale.

General Review :

The research work also prompted the visits to some other block industries within Kwara State. Some of the industries are located in Ifelodun, Irepodun and Offa Local Government areas of Kwara State.

From investigation, there is no much variance in the mode of manufacture in these Industries. Some of these industries not only produce blocks but manufacture precast units such as concrete rings. In very remote parts of the State where blocks are not in high demand, production is not very frequent as in those areas where they are marketable.

Generally, block Industries produce three major types of sandcrete hollow blocks - the 9" (230 x 230 x 450mm); the 6" (150 x 230 x 450mm) and the 4" (100 x 230 x 450mm) sandcrete blocks. Many Industries preferably produce only 9" and 6" blocks because the 4" blocks are not in high demand.

Very few industries produce the decorative kind of blocks. Some manufacturers who produce the 4" blocks sparingly, felt that they stand the risk of poor patronage since they are not in great demand. Large plants produce an average of 500 blocks per day while small plants produce an average of 300 blocks per day. Where production is not frequent, Industries are known to produce once in one or two weeks depending on the location. Some Industries produce the different types of blocks on different days. Majority of the Industries use the "elephant" cement manufactured by the West African Portland Cement Company. This cement is the readily available brand in that part of the country and it is the closest source of supply as confirmed by the Manufacturers. Aggregates used in production include river sand (sharp sand), soft sand and crushed granite sand. Very few Industries took advantage of this granite crushed sand because of its relatively high cost. Report showed that good river sand are found in Asa Local Government and Moro Local Government areas.

Mix constituents are batched by volume rather than by weight. Various manufacturing Industries use wheel barrows to batch their aggregates. Manufacturers claimed that they use mix proportion of 1 bag of cement per 3 - 5 wheel barrows of fine aggregate (i.e. the mix ratio of 1 part of cement to 6 - 10 parts of sand). The mix water are generally clean. The manufacturers do not proportion it, thus, the mixes vary in consistency. This may not be too

far from the fact that no standard specifications have been laid down for proportioning water used for forming blocks. Majority of the industries, either large or small, adopt manual mix except one of the industries visited which uses a mixer. The popularly used machine for moulding block is called rosacometta though some industries purchased the locally - made type. It is a pallet machine stationed at a particular point and power-driven by diesel (lister or hazt) or electricity. Report shown that not more than 2 industries possess the locally made egg - laying type of moulding machine. Usually, the pallet machine produces one 9" blocks at a time and two 6" blocks at a time. Compaction by these machines are both by pressure and vibration. It was observed that the degree of compaction may vary from one block to the other since there is no specified time for vibration. Time for vibration is left at the operator's discretion.

Their method of curing is by intermittent wetting using a water hose or buckets where such is not available. The period of curing adopted for the sandcrete blocks is between 1 and 3 days. It was also noticed that sheds are not provided to protect the blocks from influence of weather or speedy evaporation of mix water. Blocks are arranged in open spaces. The general belief is that blocks can be used for erection after 3 days of production. Hence, moulded blocks are sold out after 3 days except in the situation where there is no market for them. In most of

the production sites visited,stores were erected for the purpose of storing materials and tools just as seen in the other five industries. Stockpiling of the products are made in not more than 3 - 5 layers depending on the sizes of blocks. Where there are constant sales, the blocks are left in rows of just a layer. Prices of blocks vary from one industry to the other and they depend on the prevailing economic situation. During the time this research was carried out prices of blocks were not steady. At the time of the interview, the prices of 9" blocks were between ₦5 and ₦6.50 while 6" blocks sold at between ₦4.50 - ₦5.60. It was observed that those who produced at lower limit of the price range manufacture seemingly poorer quality of blocks and vice-versa.

From the oral interview conducted, it was learnt that no manufacturer has ever carried out any kind of test whether on the raw materials which he uses or the end products since the inception of his industry. Some only observed that fineness or coarseness of the sand utilized would produce lighter blocks which may lead to eventual breakages. It was also stated that too much of soft sand in the mix may give the same result and in addition such blocks take longer period of drying. The general observation is that the blocks produced have varying heights probably because of the variation in compacting pressure or the quality of mix fed into a mould. Also cracks are often formed on some blocks immediately or few hours after production. This was attributed to unequal lifting of the pallets on both sides after the extrusion of

the blocks from the machine. The plates (I - V) below show the different operations at different industries recorded during the visit.



Plate I - SHOWING THE ROSACOMETTA TYPE OF PALLET MACHINE INSTALLED BY INDUSTRY AND IN THE BACKGROUND IS A SEMI-WET MIX OF CEMENT AND AGGREGATE.



Plate II - SHOWING BLOCKS LEFT ON PALLETS IN OPEN AIR AFTER REMOVAL FROM THE MACHINE.



Plate III - SHOWING THE METHOD OF STACKING OF END PRODUCTS AFTER CURING.



Plate IV - SHOWING AN OPERATOR AND A LABOURER AT WORK IN INDUSTRY C. ALSO IN THE BACKGROUND IS SHOWN THE CONSISTENCY OF MIX USED BY THIS INDUSTRY.



Plate V - SHOWING THE METAL MOULDS USED FOR MANUFACTURING 9", 6" and 4" BLOCKS.

CHAPTER THREE

EXPERIMENTAL TESTS AND RESULTS

3.1 Sample Collection:

As earlier stated, many block Industries were visisted within Kwara State. Most of the information obtained during the visit were given in chapter Out of the many visited, five block Industries w chosen for sample collection. Two of the Indus s are within Ilorin - West Local Government area one from Ilorin - East Local Government area and the remaining two Industries are located in Moro Local Government and Asa Local Goverment areas.

From the survey of the block Industries, the five industries chosen are the well established block Industries. Secondly, some of the Local Government areas, even though have block industries, do not have the proper means of moulding, curing and in some cases accessibility by road are often impossible. It was also observed that in the selected Industries, a lot of customers patronise them. One of the major customers are often the State and Local Governments where the blocks are used to erect Government infrastructures. On the whole, more block Industries are located within Ilorin and the nearby Local Government areas. These could be due to the fact that these areas are close to Ilorin and have more patronage as a result of more construction activities in towns than the villages.

Moro Local Government Headquarters is about 60 kilometres from Ilorin while Asa Local Government Headquarters is about 25 kilometres from Ilorin.

These five Industries are labelled A, B, C, D and E and with indentification marks Kw/K representing Kulende; Kw/O representing Odo-Ota; Kw/A representing Adinimole; Kw/B representing Bode Saadu and Kw/G representing Agbo-Oba respectively. The label A does not imply that Industry A is better than B nor B better than C. It is only to distinguish one Industry from the other. The labelling has no relation to the quality of the blocks. Fifty samples of block were randomly chosen from each of the Industries and thus a total of 250 blocks were collected for the execution of this research. Since one went there both as a researcher and at the same time as a buyer, the blocks were sold out at an average of ₦5.00 per block with an extra charge of ₦1.00 per block as cost of transportation.

Since the quality of the sand used in moulding a block is also crucial in the determination of the quality of such block, one has thought it wise to collect various samples of sand utilized by those Industries for the purpose of identification, classification and the cement used by these Industries indicated that the cement were good. Most of the cement used were the West African Portland Cement tagged "elephant" cement which most of them claimed is best.

3.2 Experimental Tests:

The research covered both the laboratory tests on the finished products (blocks) and the aggregates used in their production. 250 blocks were collected on the whole thus making a total number of 50 blocks per location. For each test carried out (e.g. Wet Compressive Strength Development), three samples were used.

3.21 Field identification and classification test for sand samples.

3.21.1 Visual Tests

The sand sample taken from each Industry was observed as to colour and texture. The observations are given as follows:

Industry A: The Industry uses 3 different kinds of sand namely: Granite dust; Sharp sand and soft sand. The granite dust is greyish in colour containing sizes not greater than 5mm. The sharp sand is a washed light brown sand with little coarse particles. while the soft sand is also light brown but very fine in nature.

Industry B: The sample of sand is light brown in colour and consists of both fine and coarse particles.

Industry C: The samples are of two types: river sand and soft sand. The river sand is a light brown fine - grey sand with little coarse particles. The latter is a greyish silty sand of fine nature.

Industry D: The sand sample is a river washed sand. It is light brown in colour and consists of little coarse particles.

Industry E: The Industry utilizes two different types of sand. One is dark brown lateritic soil without coarse particles while the other (soft sand) is a greyish fine sand with absence of odour.

3.21.2 Particle Size Distribution

300 gms of oven dried sample was passed through a batch of British standard sieves by using the mechanical shaker for 10 minutes. The test was repeated for the remaining four samples and the test results for Industries A, B, C, D and E are given as below. The test is carried out in accordance with BS 812:part II.

TABLE 7: SIEVE ANALYSIS RESULT DATA FOR INDUSTRY A

Sieve size (mm)	Total Percentage Passing (%)			
	Sample 1	*Sample 2*	*Sample 3*	*Average*
2.8	99.7	91.7	73.3	88.2
2.36	99.4	88.7	68.4	85.5
2.0	99.0	85	63.7	82.5
1.7	98.0	80	59.0	79
1.18	95.3	63	51,3	69.9
.850	87	45	43.0	58.3
.710	81.3	18.2	38.7	46.1
.300	39	6.8	21.4	22.4
.212	18	1.9	14.5	11.5
.180	14.3	1.3	11.0	8.9
.150	9.3	0.7	6.0	5.3
.125	3	0.3	2.2	1.8

The raw data results from which table 7 was extracted is as shown in Appendix A - 1

TABLE 8: SIEVE ANALYSIS RESULT DATA FOR INDUSTRY B

Sieve size (mm)	Total Percentage Passing (%)
2.8	78.7
2.36	76.3
2.0	74.3
1.7	72
1.18	65.3
.850	56.3
.710	48.7
.300	15
.212	5
.180	3.7
.150	2
.125	1.3

The raw data from which table 8 was extracted is as shown in Appendix A - 2

TABLE 9: SIEVE ANALYSIS RESULT DATA FOR INDUSTRY C

Sieve size (mm)	Total Percentage Passing (%)		
	Sample 1	Sample 2	Average
2.8	84.7	90.3	87.5
2.36	83	89.2	86.1
2.0	81.3	87.8	84.6
1.7	79.3	86.8	83.1
1.18	73	83.2	78.1
.850	63.3	75.2	69.3
.710	56.7	68.8	62.8
.300	21	23.5	22.3
.212	8.3	9.7	9
.180	5	8	6.5
.150	3	4	3.5
.125	1	1.7	1.4

The raw data results from which table 9 was extracted is shown in Appendix A - 3.

TABLE 10: SIEVE ANALYSIS RESULT DATA FOR INDUSTRY D

Sieve size (mm)	Total Percentage Passing (%)
2.8	75.8
2.36	72.5
2.0	69.3
1.7	66.3
1.18	54.7
.850	38.7
.710	28.3
.300	4.3
.212	0.7
.180	0.3
.150	0.1
.125	-

The raw data results from which table 10 was extracted is shown in Appendix A - 4.

TABLE 11: SIEVE ANALYSIS RESULT DATA FOR INDUSTRY E

Sieve size (mm)	Total Percentage Passing (%)		
	Sample 1	Sample 2	Average
2.8	99.8	94.3	97.1
2.36	99.5	92.8	96.2
2.0	98.8	90.5	94.7
1.7	97.8	87.2	92.5
1.18	91.5	79.2	85.4
.850	79.8	62	70.9
.710	70.7	54.2	62.5
.300	18	14.5	16.3
.212	6	6	6
.180	4.5	4.3	4.4
.150	3.5	3	3.3
.125	2	1.7	2.9

The raw data results from which table 11 was extracted is as shown in Appendix A - 5.

3.22 THE FIELD SETTLING TEST:

This test was carried out to determine the percentage of silt content or crusher dust in the sand samples collected from various Industries. It was performed in accordance with clause 14, BS 812. The code stipulated that the percentage of silt content by volume must not exceed 6%.

TABLE 12: THE FIELD SETTLING TEST RESULTS FOR INDUSTRIES A, B, C, D AND E

Industry	Sample	Percentage of Silt (%)	Average (%)
	Soft sand	12.4	-
A	Granite dust	7.4	7.2
	Sharp sand	1.7	-
B	Sharp sand	4.4	4.4
C	Sharp sand	8.2	8.3
	Soft sand	8.3	-
D	Sharp sand	1.9	1.9
E	Sharp sand	21.1	19.4
	Soft sand	17.7	-

The raw test from which table 12 was extracted is as shown in Appendiex A - 6.

3.23 DRY COMPRESSIVE STRENGTH DEVELOPMENT TEST:

This entails the determination of dry development strength of blocks at the ages of 3, 7, 14, 21 and 28 days respectively. After the blocks are set, curing starts given rise to strength increase with age. This test is aimed at determining the age at which the hardening process is fairly stable. For the purpose of the test, it was ensured that the required number of blocks were manufactured on a particular day in various locations. In each of these Industries, the required blocks were randomly sampled, purchased, given identification marks and left to undergo the normal curing conditions. On the third day, 3 blocks were collected from each location for the purpose of testing the 3 days compressive strength. The same procedure of collection was repeated at ages of 7, 14, 21 and 28 days respectively.

The measurement of the compressive strength of the sandcrete hollow blocks was executed in accordance with appendix C.4 of BS 2028. The test results for Industries A, B, C, D and E are presented in tables 13 to 17.

TABLE 13: DEVELOPMENT OF DRY COMPRESSIVE STRENGTH OF SANDCRETE BLOCKS FOR INDUSTRY A

S/No	Length (mm)	Breadth (mm)	Height (mm)	Age (dys)	Failure Load (KN)	Strength (N/mm^2)
1.	449	152	219	3	30	0.44
2.	456	152	218	7	28	0.40
3.	456	152	219	14	38.3	0.50
4.	454	152	219	21	36.3	0.53
5.	457	151	217	28	46.7	0.68

The raw data results from which an average of three was taken is shown in Appendix A - 7.

TABLE 14: DEVELOPMENT OF DRY COMPRESSIVE STRENGTH OF SANDCRETE BLOCKS FOR INDUSTRY B

S/No	Length (mm)	Breadth (mm)	Height (mm)	Age (dys)	Failure Load (KN)	Strength (N/mm^2)
1.	456	152	217	3	12	0.17
2.	455	152	225	7	22.3	0.32
3.	455	152	221	14	33.3	0.48
4.	454	152	219	21	32.7	0.47
5.	455	152	220	28	24.3	0.35

The raw data results from which an average of three was taken is shown in Appendix A - 8.

TABLE 15: DEVELOPMENT OF DRY COMPRESSIVE STRENGTH OF SANDCRETE BLOCKS FOR INDUSTRY C

S/No	Length (mm)	Breadth (mm)	Height (mm)	Age (dys)	Failure Load (KN)	Strength (N/mm^2)
1.	456	150	220	3	16	0.23
2.	449	152	220	7	35.7	0.52
3.	451	151	222	14	28.3	0.42
4.	451	150	221	21	29.3	0.43
5.	451	153	222	28	21.7	0.32

The raw data results from which an average of three was taken is as shown in Appendix A - 9.

TABLE 16: DEVELOPMENT OF DRY COMPRESSIVE STRENGTH OF SANDCRETE BLOCKS FOR INDUSTRY D

S/No	Length (mm)	Breadth (mm)	Height (mm)	Age (dys)	Failure Load (KN)	Strength (N/mm^2)
1.	456	152	218	3	22	0.32
2.	454	152	218	7	31.7	0.46
3.	457	151	221	14	36	0.52
4.	455	152	218	21	32.6	0.47
5.	456	152	223	28	28.3	0.41

The raw data results from which an average of three was taken is as shown in Appendix A - 10.

TABLE 17: DEVELOPMENT OF DRY COMPRESSIVE STRENGTH OF SANDCRETE BLOCKS FOR INDUSTRY E

S/No	Length (mm)	Breadth (mm)	Height (mm)	Age (dys)	Failure Load (KN)	Strength (N/mm^2)
1.	446	152	219	3	10	0.15
2.	447	151	217	7	6.7	0.10
3.	449	150	220	14	14	0.21
4.	444	150	219	21	14.3	0.22
5.	449	151	221	28	10	0.15

The raw data results from which an average of three was taken is as shown in Appendix A - 11.

3.24 WET COMPRESSIVE STRENGTH DEVELOPMENT TEST

The test was carried out after the blocks have attained the age of 28 days. The sampled blocks were immersed in water and crushed on different immersion days of 3, 7, 14, 21 and 28. The wet compressive strength is therefore the strength of blocks immersed after 28 days of curing.

The need for the wet compressive test stemmed from the fact that the masonry units show a marked reduction in strength when tested in wet condition (10). Jackson explained that in the case of compression tests, air-dry concrete units have significantly higher strength than those tested in a saturated condition. He attributed

lower strength of wet concrete units to the development of internal pore pressure as the external load is applied. Tables 18 to 22 show the test results from the various industries for wet compressive strength development.

TABLE 18: DEVELOPMENT OF WET COMPRESSIVE STRENGTH OF SANDCRETE BLOCKS FOR INDUSTRY A

S/No	Length (mm)	Breadth (mm)	Height (mm)	Age (dys)	Failure Load (KN)	Strength (N/mm^2)
1.	465	157	224	3	35	0.48
2.	464	157	225	7	37.5	0.52
3.	466	158	220	14	45.7	0.62
4.	464	157	225	21	38.3	0.53
5.	465	157	220	28	45	0.62

The raw data results from which an average of three was taken is shown in Appendix A - 12

TABLE 19: DEVELOPMENT OF WET COMPRESSIVE STRENGTH OF SANDCRETE BLOCKS FOR INDUSTRY B

S/No	Length (mm)	Breadth (mm)	Height (mm)	Age (dys)	Failure Load (KN)	Strength (N/mm^2)
1.	463	157	226	3	12.7	0.18
2.	463	157	225	7	17.5	0.24
3.	460	158	223	14	28.3	0.39
4.	462	158	227	21	25	0.34
5.	462	158	225	28	31.7	0.43

The raw data results from which an average of three was taken is shown in Appendix A - 13.

TABLE 20: DEVELOPMENT OF WET COMPRESSIVE STRENGTH OF SANDCRETE BLOCKS FOR INDUSTRY C

S/No	Length (mm)	Breadth (mm)	Height (mm)	Age of immersion (dys)	Failure Load (KN)	Strength (N/mm^2)
1.	461	156	223	3	20	0.28
2.	460	157	225	7	23.3	0.32
3.	461	157	226	14	25	0.35
4.	461	157	225	21	35	0.48
5.	459	156	225	28	35	0.49

The raw data results from which an average of three was taken is shown in Appendix A - 14.

TABLE 21: DEVELOPMENT OF WET COMPRESSIVE STRENGTH OF SANDCRETE BLOCKS FOR INDUSTRY D

S/No	Length (mm)	Breadth (mm)	Height (mm)	Age of immersion (dys)	Failure Load (KN)	Strength N/mm^2)
1.	465	158	226	3	35	0.48
2.	465	158	225	7	43.3	0.59
3.	460	158	228	14	30	0.41
4.	462	157	228	21	16.7	0.23
5.	465	157	228	28	55	0.75

The raw data results from which an average of three was taken is shown in Appendix A - 15.

TABLE 22: DEVELOPMENT OF WET COMPRESSIVE STRENGTH OF SANDCRETE BLOCKS FOR INDUSTRY E

S/No	Length (mm)	Breadth (mm)	Height (mm)	Age of immersion (dys)	Failure Load (KN)	Strength (N/mm^2)
1.	455	157	218	3	6.3	0.09
2.	456	158	222	7	13.3	0.19
3.	456	157	222	14	20	0.28
4.	453	156	223	21	18.3	0.26
5.	456	156	223	28	16.7	0.24

The raw data results from which an average of three was taken is as shown in Appendix A - 16.

3.25 WET COMPRESSIVE STRENGTH OF BLOCKS BEDDED WITH CEMENT - SAND MORTAR IN ACCORDANCE WITH BS 2028

The test is mainly to determine the compressive strength of the blocks as directed in the standard. The essence of this test is to ensure a more accurate value of compressive strength of blocks. The bedded faces give a smooth surface and enable the load to be distributed uniformly over the area of the blocks. The test was performed in accordance with Appendix C, BS 2028. The test results are given in tables 24 to 28 for the various Industries.

For the purpose of control, mortar cubes were cast from the mortar used for bedding the surface of the blocks. These cubes were tested after 19 days of immersion and

the results are given in table 23 below.

TABLE 23: COMPRESSIVE STRENGTH OF CEMENT MORTAR CUBES FOR ALL BLOCKS

S/No	Length (mm)	Breadth (mm)	Height (mm)	Weight (kg)	Density (kg/m^3)	Failure Load (KN)	Age (dys)	Strength (N/mm^2)
1.	75	74.5	75	0.77	1837	75	5	13.42
2.	75	75	75	0.773	1832	125	14	22.22
3.	75	75	75	0.77	1825	155	19	27.56

TABLE 24: WET COMPRESSIVE STRENGTH OF SANDCRETE BLOCKS OF INDUSTRY A BEDDED WITH MORTAR

Identification Number	Length (mm)	Breath (mm)	Height (mm)	Failure Load (KN)	Strength (N/mm^2)
Kw/K/31	467	157	230	86	1.17
Kw/K/32	465	157	230	86	1.18
Kw/K/33	465	157	230	83.7	1.15
Kw/K/34	464	156	230	85	1.17
Kw/K/35	467	157	229	84.5	1.15
Kw/K/36	467	156	230	83	1.14
Kw/K/37	467	157	230	83	1.14
Kw/K/38	460	158	229	80	1.08
Kw/K/39	465	158	230	82	1.12
Kw/K/40	467	157	230	82.5	1.13

Average compressive strength is $1.14N/mm^2$.

TABLE 25: WET COMPRESSIVE STRENGTH OF SANDCRETE BLOCKS OF INDUSTRY B BEDDED WITH MORTAR

Identification Number	Length (mm)	Breadth (mm)	Height (mm)	Failure Load (KN)	Strength (N/mm^2)
Kw/0/31	462	158	225	45	0.62
Kw/0/32	463	157	227	48	0.66
Kw/0/33	462	158	230	55	0.75
Kw/0/34	462	158	230	50	0.69
Kw/0/35	458	157	230	52	0.72
Kw/0/36	463	157	227	49	0.67
Kw/0/37	462	157	227	51	0.70
Kw/0/38	462	157	230	50	0.69
Kw/0/39	462	157	230	53	0.73
Kw/0/40	463	157	230	55	0.76

Average compressive strength is $0.70N/mm^2$

TABLE 26: WET COMPRESSIVE STRENGTH OF SANDCRETE BLOCKS OF INDUSTRY C BEDDED WITH MORTAR

Identification Number	Length (mm)	Breadth (mm)	Height (mm)	Failure Load (KN)	Strength (N/mm^2)
Kw/A/31	460	157	225	60	0.83
Kw/A/32	460	155	230	60	0.84
Kw/A/33	460	157	227	60	0.83
Kw/A/34	462	157	227	65	0.90
Kw/A/35	460	158	230	55	0.76
Kw/A/36	420	155	228	64	0.89
Kw/A/37	420	155	227	58	0.81
Kw/A/38	420	157	230	65	0.90
Kw/A/39	460	158	230	53	0.73
Kw/A/40	460	157	227	55	0.76

Average compressive strength is $0.83N/mm^2$.

TABLE 27: WET COMPRESSIVE STRENGTH OF SANDCRETE BLOCKS OF INDUSTRY D BEDDED WITH MORTAR

Identification Number	Length (mm)	Breadth (mm)	Height (mm)	Failure Load (KN)	Strength (N/mm^2)
Kw/B/31	462	158	234	65	0.89
Kw/B/32	462	158	228	60	0.82
Kw/B/33	464	157	230	60	0.82
Kw/B/34	465	157	230	58	0.82
Kw/B/35	462	159	227	60	0.89
Kw/B/36	465	158	228	65	0.96
Kw/B/37	465	157	230	70	0.96
Kw/B/38	465	157	230	60	0.86
Kw/B/39	465	157	230	70	0.96
Kw/B/40	465	157	228	67	0.92

Average compressive strength = $0.87N/mm^2$.

TABLE 28: WET COMPRESSIVE STRENGTH SANDCRETE BLOCKS OF INDUSTRY E BEDDED WITH MORTAR

Identification Number	Length (mm)	Breadth (mm)	Height (mm)	Failure Load (KN)	Strength (N/mm^2)
Kw/G/31	457	157	227	42	0.59
Kw/G/32	455	157	230	45	0.63
Kw/G/33	452	157	225	40	0.56
Kw/G/34	455	155	227	42	0.60
Kw/G/35	457	157	230	42	0.60
Kw/G/36	457	158	230	40	0.55
Kw/G/37	453	155	227	33	0.32
Kw/G/38	455	157	230	37	0.52
Kw/G/39	457	157	227	40	0.39
Kw/G/40	457	157	230	42	0.59

Average compressive strength is $0.54N/mm^2$.

3.26: DENSITY TEST:

This test is aimed at determining the unit weight of varying blocks. Density of blocks at varying ages were measured. The test was carried out in accordance with Appendix B of BS 2028 and the test results for Industries A, B, C, D and E are shown in tables 29 to 33.

TABLE 29: DRY DENSITY OF SANDCRETE BLOCKS OF INDUSTRY A AT VARYING AGES

S/No	Area (mm^2)	Volume (m^3)	Weight (kg)	Age (dys)	Density (kg/m^3)
1.	68300	0.015	16.78	3	1119
2.	69400	0.015	16.45	7	1097
3.	69000	0.015	16.47	14	1098
4.	69100	0.015	16.11	21	1074
5.	69200	0.015	16.26	28	1084

Average dry density is $1094kg/m^3$

The raw data results from which an average was taken is as shown in Appendix A - 7.

TABLE 30: DRY DENSITY OF SANDCRETE BLOCKS OF INDUSTRY B AT VARYING AGES

S/No	Area (mm^2)	Volume (m^3)	Weight (Kg)	Age (dys)	Density (Kg/m^3)
1.	69300	0.015	17.64	3	1176
2.	68700	0.016	17.18	7	1074
3.	69000	0.015	17.07	14	1138
4.	68000	0.015	17.15	21	1143
5.	69000	0.015	17.37	28	1158

Average dry density is $1138kg/m^3$.

The raw data results from which an average was taken is shown in Appendix A - 8.

TABLE 31: DRY DENSITY OF SANDCRETE BLOCKS OF INDUSTRY C AT VARYING AGES

S/No	Area (mm^2)	Volume (m^3)	Weight (Kg)	Age (dys)	Density (Kg/m^3)
1.	68500	0.015	16.33	3	1089
2.	68300	0.015	16.08	7	1072
3.	68200	0.015	15.92	14	1061
4.	67600	0.015	15.94	21	1063
5.	68900	0.015	15.87	28	1058

Average dry density is $1069kg/m^3$

The raw data results from which an average was taken is shown in Appendix A - 9.

TABLE 32: DRY DENSITY OF SANDCRETE BLOCKS OF INDUSTRY D AT VARYING AGES

S/No	Area (mm^2)	Volume (m^3)	Weight (Kg)	Age (dys)	Density (Kg/m^3)
1.	69400	0.015	16.69	3	1113
2.	69000	0.015	16.81	7	1121
3.	69100	0.015	16.50	14	1100
4.	69100	0.015	16.18	21	1079
5.	69300	0.016	16.42	28	1026

Average dry density is $1088kg/m^3$

The raw data results from which an average was taken is shown in Appendix A - 10.

TABLE 33: DRY DENSITY OF SANDCRETE BLOCKS OF INDUSTRY E AT VARYING AGES

S/No	Area (mm^2)	Volume (m^3)	Weight (Kg)	Age (dys)	Density (Kg/m^3)
1.	67600	0.015	17.33	3	1155
2.	67600	0.015	16.45	7	1097
3.	67400	0.015	16.38	14	1092
4.	66700	0.015	16.74	21	1116
5.	67900	0.015	16.75	28	1117

Average dry density is $1115kg/m^3$

The raw data results from which an average was taken is shown in Appendix A - 11.

3.27 WATER ABSORPTION TEST

Water absorption is the difference between the dry weight and final wet weight expressed as a percentage of dry weight. Water absorption tests are good indications of the apparent porosity of blocks. The test is carried out in accordance with Appendix B.1, N15 74. This code limits the water absorption of burnt clay building units to 25% by weight after immersion in water for 24 hours. The water absorption test results of Industries A. B. C. D and E are set out in tables 34 to 38.

TABLE 34: WATER ABSORPTION TEST RESULTS FOR INDUSTRY A

Sample Number	Kw/K/41	Kw/K/42	Kw/K/43
Dry Weight (kg)	16.20	16.40	16.80
Wet Weight (kg)	18.52	18.29	19.32
Water absorption(%)	14.30	11.50	15.00

Average water absorption = 13.6%.

TABLE 35: WATER ABSORPTION TEST RESULTS FOR INDUSTRY B

Sample Number	Kw/0/41	Kw/0/42	Kw/0/43
Dry weight (kg)	17.80	17.40	16.60
Wet weight (kg)	19.62	19.18	18.21
Water absorption (%)	10.20	10.20	9.70

Average water absorption = 10.0%

TABLE 36: WATER ABSORPTION TEST RESULTS FOR INDUSTRY C

Sample Number	Kw/A/41	Kw/A/42	Kw/A/43
Dry weight (kg)	15.90	16.00	16.40
Wet weight (kg)	18.09	17.84	18.52
Water absorption (%)	13.70	11,50	13.60

Average water absorption = 12.9%.

TABLE 37: WATER ABSORPTION TEST RESULTS FOR INDUSTRY D

Sample Number	Kw/B/41	Kw/B/42	Kw/B/43
Dry weight (kg)	16.80	16.40	15.80
Wet weight (kg)	19.76	18.06	18.03
Water absorption (%)	17.60	10.10	14.10

Average water absorption = 13.9%

TABLE 38: WATER ABSORPTION TEST RESULTS FOR INDUSTRY E

Sample Number	Kw/G/41	Kw/G/42	Kw/G/43
Dry weight (kg)	17.70	16.50	16.30
Wet weight (kg)	20.18	19.21	18.37
Water absorption (%)	14.00	16.4	12.7

Average water absorption = 14.4%.

3.28 EFFLORESCENCE TEST

Efflorescence is a crystallization deposited on the surface of masonry units. Such efflorescence as occurs in concrete blocks are found to consist of sodium, potassium, calcium carbonates and sulphates which can

cause deterioration of the blocks as earlier stated (16). The test was carried out in accordance with Appendix C, NIS 74. It also recommended that the rating of efflorescence should not be worse than "moderate". Usually efflorescence is reported as Nil, Slight, Moderate, Heavy and serious. The efflorescence test results for Industries A, B, C, D and E are set out in table 39.

TABLE 39: EFFLORESCENCE TEST RESULTS FOR INDUSTRIES A, B, C, D AND E

Sample Number	Classification
A	Nil: Very little presence of efflorescence in the hollow
B	Nil
C	Nil
D	Nil
E	Nil: Very little presense of efflorescence in the hollow

3.29 DRYING SHRINKAGE AND MOISTURE MOVEMENT TEST

The drying shrinkage and the moisture movement of the sandcrete hollow blocks were measured according to BS 2028. Bs 2028:1968 limits the drying shrinkage and moisture movement of a type B block to 0.07% if the average compressive strength and density are less than

7.0N/mm^2 and over 625kg/m^3 respectively. The results of the test are shown in tables 40 and 41.

TABLE 40: DRYING SHRINKAGE TEST RESULTS

Sample Number	Drying Shrinkage (%)	Average Drying Shrinkage (%)
Kw/K/44	0.03	
Kw/K/45	0.02	0.02
Kw/K/46	0.04	
Kw/O/44	0.05	
Kw/O/45	0.01	0.02
Kw/O/46	0.002	
Kw/A/44	0.003	
Kw/A/45	0.02	0.008
Kw/A/46	0.002	
Kw/B/44	0.01	
Kw/B/45	0.06	0.02
Kw/B/46	0.002	
Kw/G/44	0.001	
Kw/G/45	0.001	0.001
Kw/G/46	0.001	

TABLE 41: MOISTURE MOVEMENT TEST RESULTS

Sample Number	Moisture Movement (%)	Average Moisture Movement (%)
Kw/K/44	0.001	
Kw/K/45	0.01	0.02
Kw/K/46	0.008	
Kw/O/44	0.02	
Kw/O/45	0.01	0.01
Kw/O/46	0.003	
Kw/A/44	0.003	
Kw/A/45	0.004	0.007
Kw/A/46	-	
Kw/B/44	0.02	
Kw/B/45	0.01	0.01
Kw/B/46	0.006	
Kw/G/44	0.001	
Kw/G/45	0.001	0.001
Kw/G/46	0.001	

3.3 COMPRESSIVE STRENGTH OF CEMENT - MORTAR CUBES CAST FROM CEMENT - SAND MIX RATIO OF 1:8

After the investigation, it became apparent that the most common mix ratio for sandcrete blocks is the mix ratio of 1 part of cement to 8 parts of sand. For the purpose of verification of the possible ultimate

compressive strength which a block made of cement - sand mix of ratio 1:8 can possess,some number of cement mortar cubes were cast. This would act as basis of comparison of the test results of the sample blocks. The resulting compressive strength are tabulated as below:

TABLE 42: COMPRESSIVE STRENGTH OF CEMENT MORTAR CUBES (RATIO 1:8)

Sample Number	Length (mm)	Breadth (mm)	Height (mm)	Weight (kg)	Load (KN)	Age (dys)	Strength (N/mm^2)
1.	150	150	150	6.57	150	28	6.67
2.	150	150	150	6.58	148	28	6.58
3.	150	150	150	6.53	149	28	6.62
4.	150	150	150	6.64	158	28	7.02
5.	150	150	150	6.64	153	28	6.8
6.	150	150	150	6.58	148	28	6.57
7.	150	150	150	6.56	145	28	6.44
8.	150	150	150	6.64	150	28	6.67

Average strength is $6.67N/mm^2$

CHAPTER FOUR

ANALYSIS AND DISCUSSION OF RESULTS

The detailed tests presented in the previous section has been carried out to ensure a thorough analysis of the data. It was analysed according to the various tests as set out below:

4.1 SAND SAMPLE

A. Grading

Figure 2 below shows the grading curve of Industry A sand sample. This sample falls within zone 2 grading. Grading curve of Industry B as seen in figure 3 also lies within zone 2. Both samples A and B curve lie close to the lower limit of the zone 2.

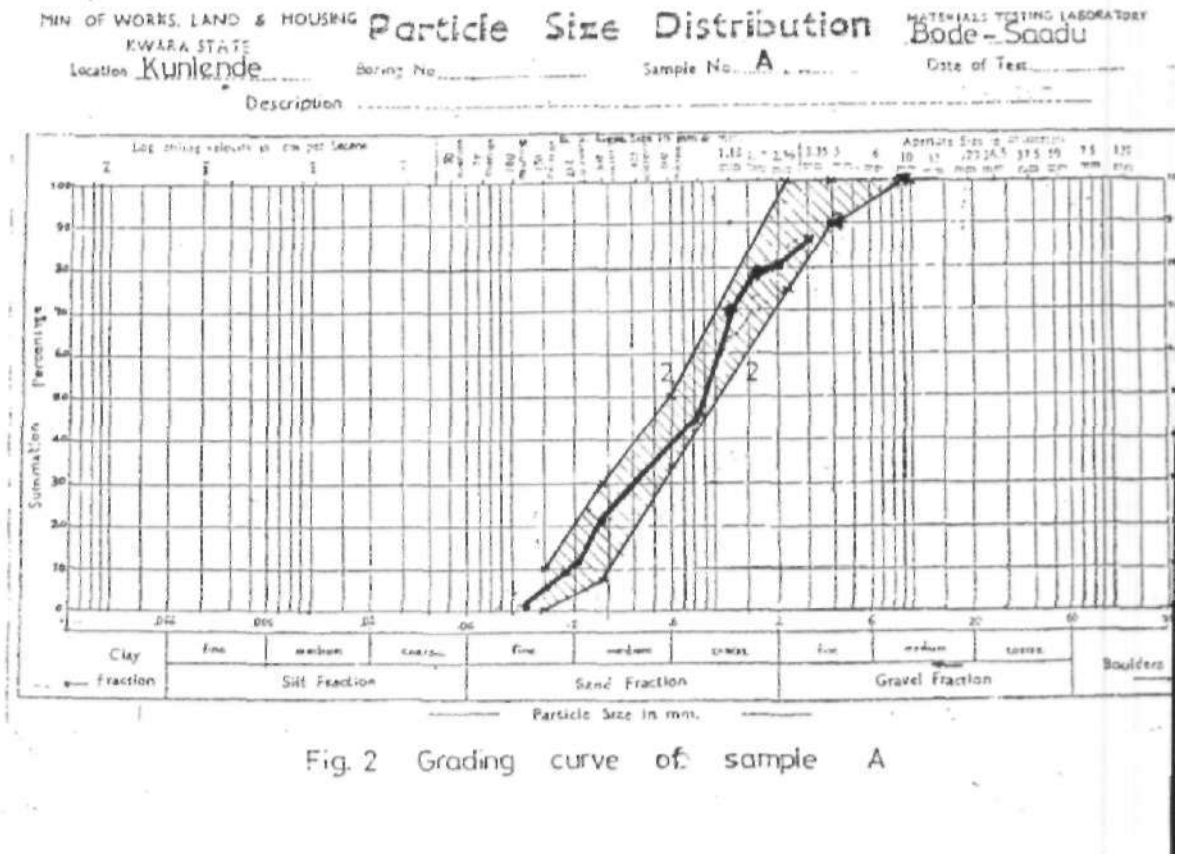


Fig. 2 Grading curve of sample A

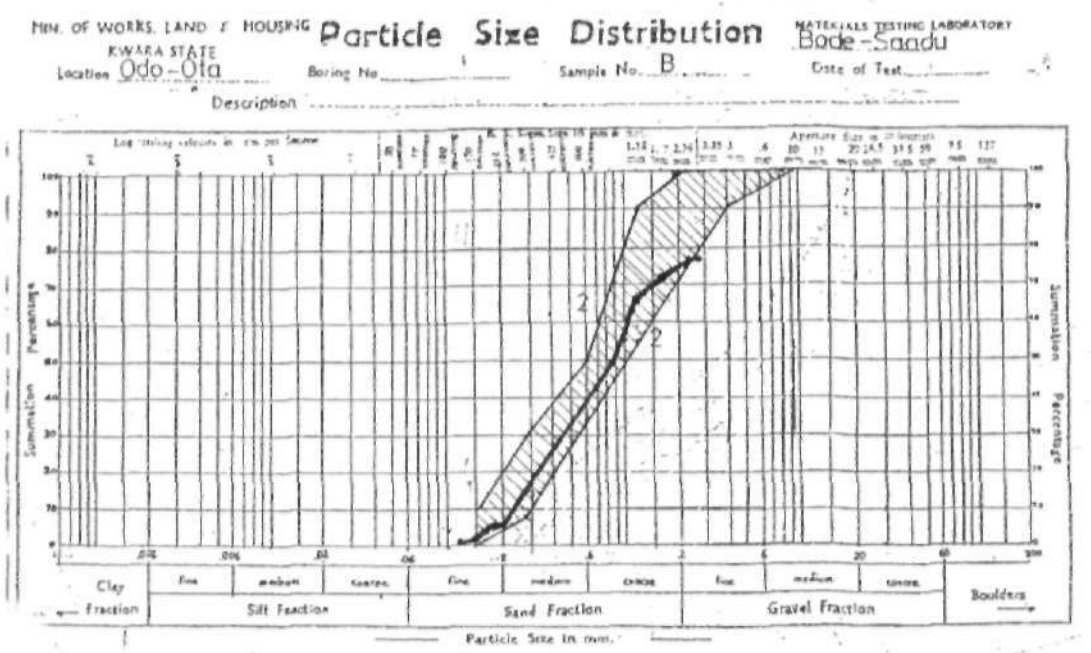


Fig. 3 Grading curve of sample B

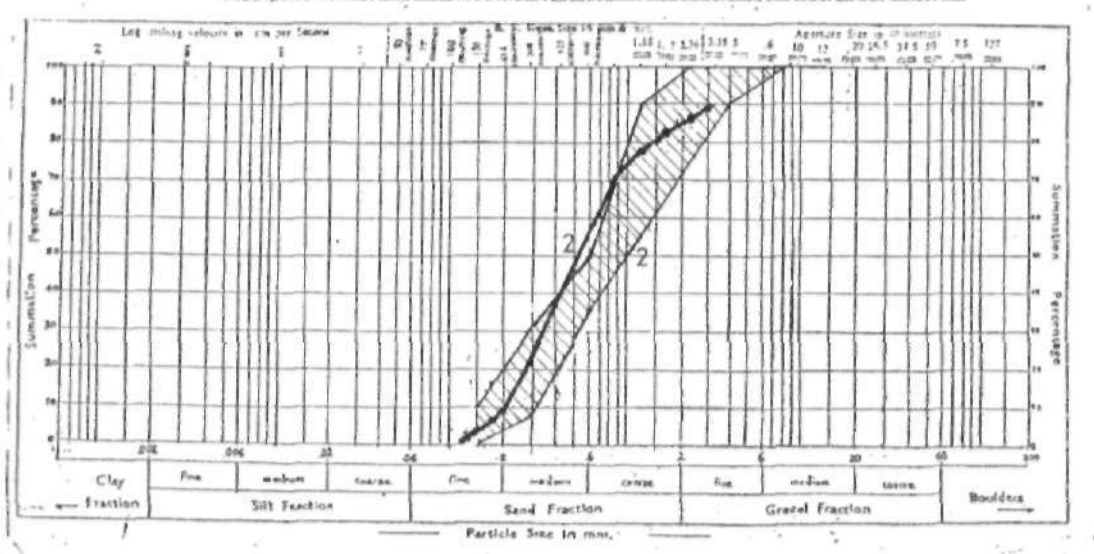


Fig. 4 Grading curve of sample C

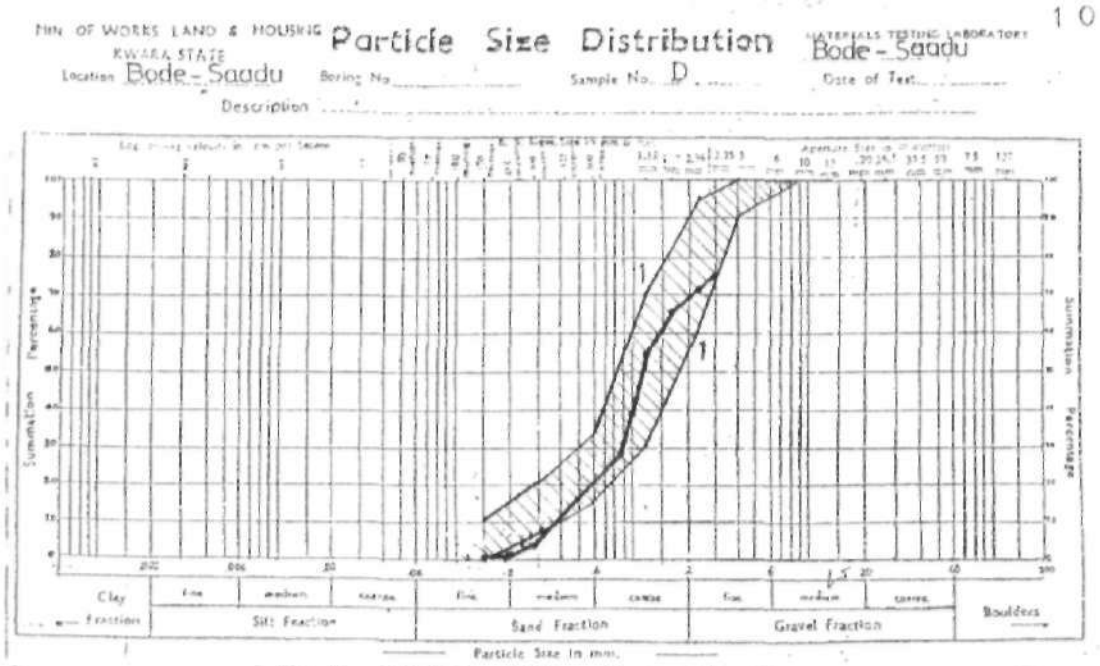


Fig. 5 Grading curve of sample D

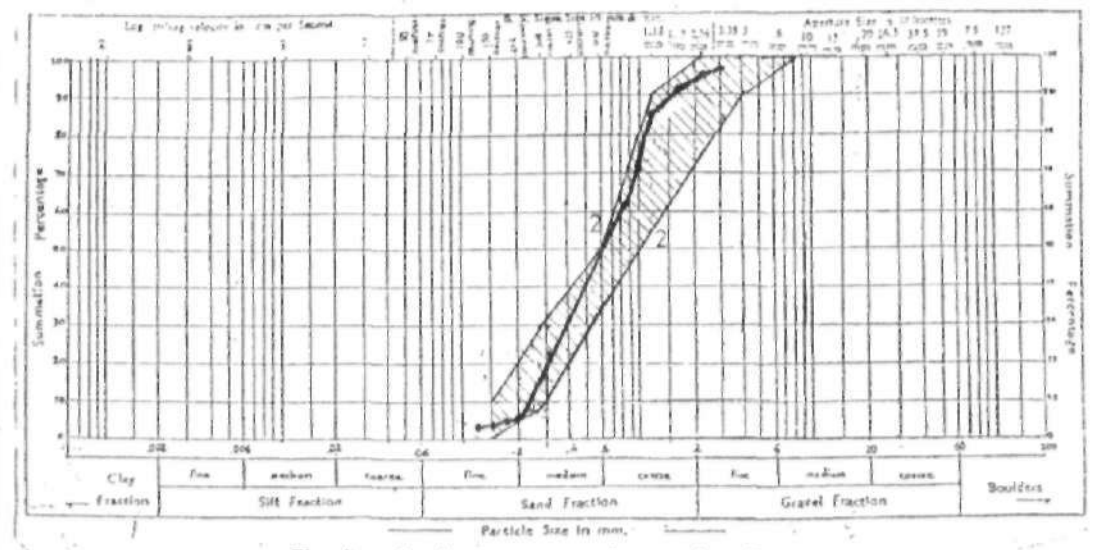


Fig. 6 Grading curve of sample E

Likewise, Figures 4 and 6 (as seen above) showing grading curves of industries C and E sand samples respectively fall within the zone 2 grading. Sample C lies close to the upper limit of the standard grading curve 2. Thus, this sample can be said to be finer than the other samples. However, sample D, as shown in figure 5 above, falls within zone 1 grading. From the zoning as well as usual inspection, sample D is coarser than the other samples.

Generally, the sand collected from all the Industries (A, B, C, D and E) met the stipulated grading requirements since they fall within zones 1 and 2 (28). This indicates that these samples are workable and suitable for the production of sandcrete blocks given consideration that they are made of semi-wet mix.

B. The Field Settling Test

Clause 14, Bs 812 recommended that the silt content or crusher dust in a sand sample must not exceed 6% by volume. Presence of such impurities is known to interfere with the process of hydration of the cement and it prevents the development of good bond between aggregate and cement paste. The average percentages of silt and crusher dust of Industries A, C, E are 7.2, 8.3 and 19.4 percent respectively as shown in chapter three. Their values exceeded the recommended values specified in the code. The high values of silt content or crusher dust indicated that bonds between

the aggregate and the cement coatings of the blocks would be affected since some silt or fine dust may be present in form of loose particles. This leads also to poor hydration. It may be responsible for the low value of compressive strength of these blocks for the fact that the process of hydration is interrupted and subsequently weak bond is formed. As seen in table 10 of chapter three, percentage of silt of sand samples collected from Industries B and D which are 4.4 and 1.9 percent respectively met up with the specification of clause 14, Bs 812. The sand samples of these Industries are quite good or suitable to produce blocks of considerable compressive strength if other conditions remain favourable.

4.2 DIMENSIONS OF VARIOUS BLOCKS

TABLE 43 TABLE SHOWING THE AVERAGE DIMENSIONS OF THE BLOCKS OF INDUSTRIES A, B, C, D AND E

Industry		A	B	C	D	E
Length (mm)	±3	454	455	452	456	447
Breadth (mm)	±1.5	152	152	151	151	151
Height (mm)	±3	218	220	221	220	220
Percentage of void in blocks (%)		46.8	41.2	48.7	48.3	42.8
Percentage of solid materials (%)		53.2	58.8	51.3	51.8	57.2

As specified by Nigerian Industrial Standard Organisation (28), the normal size of a 6" sandcrete block should be 450 x 225 x 150mm. While the Bs 2028 specified a work size of 448 x 219 x 152mm for a type B block with a tolerance of ±3m for length and height; and ±1.5mm tolerance in thickness. From table 43, only the length of blocks of Industries C and E fall within the permissible deviations specified by the Bs 2028 while those of Indudstries A, B and D do not meet up with the requirement. Using the tolerance specified by Bs 2028 for NIS (28), it was observed that the same C and E met the requirement of the length while the rest could not meet the tolerance of ±3mm.Furthermore, all the Industries have their block height ranging from 218 - 221mm as shown in table 43. These dimensions are within the stipulated tolerance of ±3mm of 219mm specified by Bs 2028. Using the tolerances stipulated Bs 2028 (2) for NIS (28), it can be observed that all the Industries failed to meet the required tolerances. Also the thickness or width of the blocks of Industries A and B, as seen in table 43, are the same as that specified by Bs 2028 (2). Those of Industries C, D and E, though are not the same, are within the tolerance of ± 1.5mm. They also met that of NIS (28) when a tolerance of ± 1.5mm is imposed on them. From this research, it is glaring that the quoted standard dimensions for all sizes of sandcrete hollow blocks (9", 6" and 4") may not be the most appropriate dimensions after all. One may then declare that the dimensions stated by Iloghalu (15) are the true representation or the correct approximation of dimensions

of blocks available in the market today. He (15) quoted the main dimensions of blocks as:

228 x 228 x 457mm (approx. 9" x 9" x 18")

228 x 152 x 457mm (approx. 9" x 6" x 18")

228 x 127 x 457mm (approx. 9" x 5" x 18")

Moreso, clause 2 of Bs 2028 defines a concrete hollow block as a block which the solid material is between 50% and 70% of the total volume of the block. Referring to table 43, blocks of Industries A, B, C, D and E have solid materials of 53.2, 58.8, 51.8 and 57.2 percent of the total volume respectively. From this result it is glaring that the various blocks produced by these Industries fulfil the stipulated requirement of not less than 50% solid materials by volume. Thus, these blocks are deemed to be recognised as hollow blocks.

4.3 DEVELOPMENT OF DRY COMPRESSIVE STRENGTH

The test results of dry compressive strength development of Industries A, B, C, D and E sandcrete blocks are presented in tables 13 to 17 in chapter three. And they are shown in figures 7 to 11 respectively.

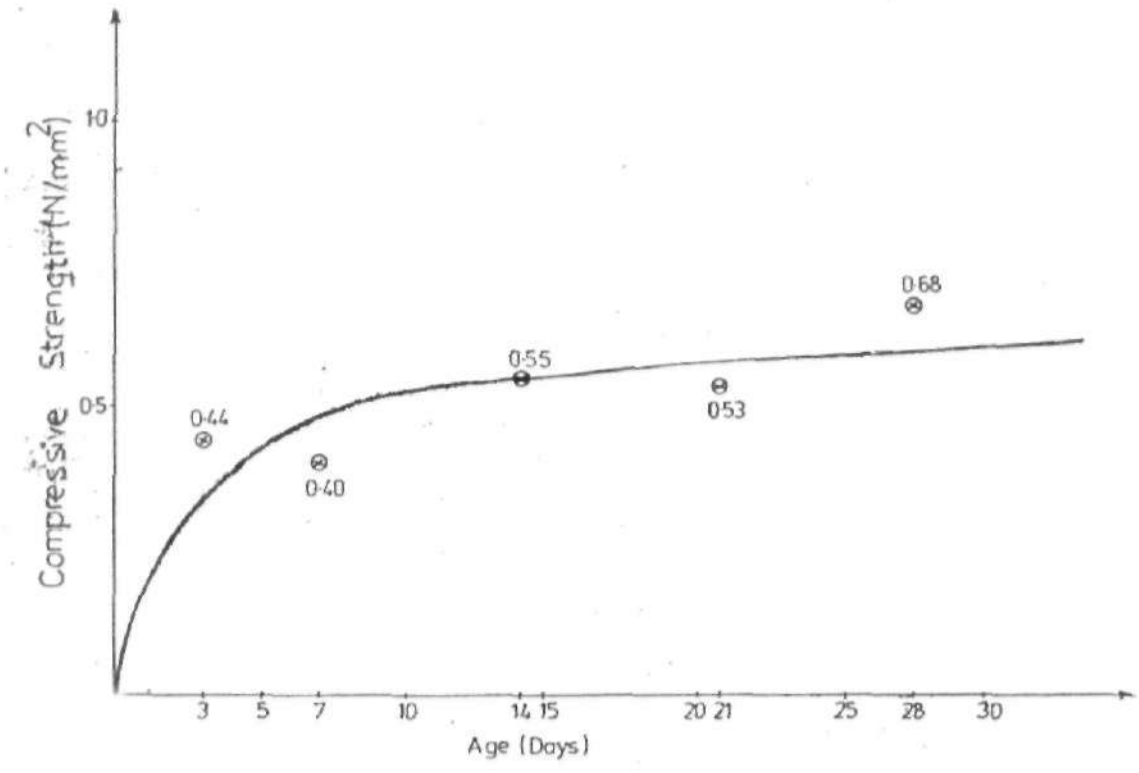
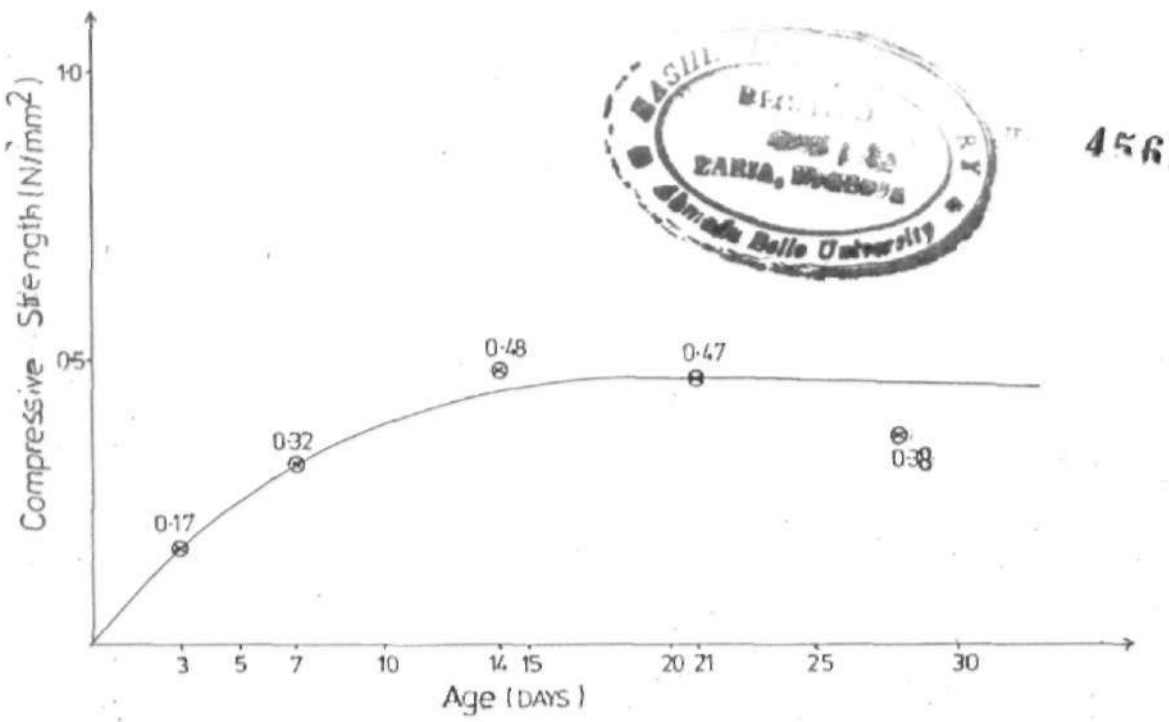


Fig. 7 Development of dry strength of industry A Blocks



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Fig. 8 Development of dry strength of industry B Blocks

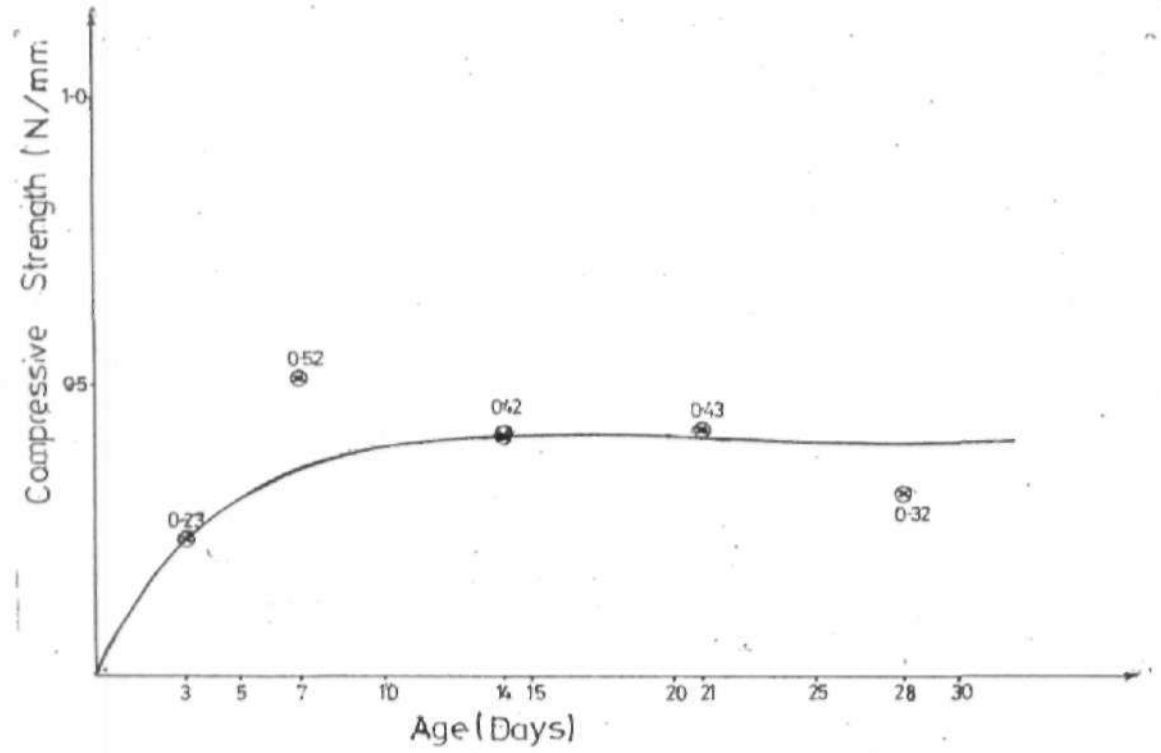


Fig. 9 Development of dry strength of industry C Blocks

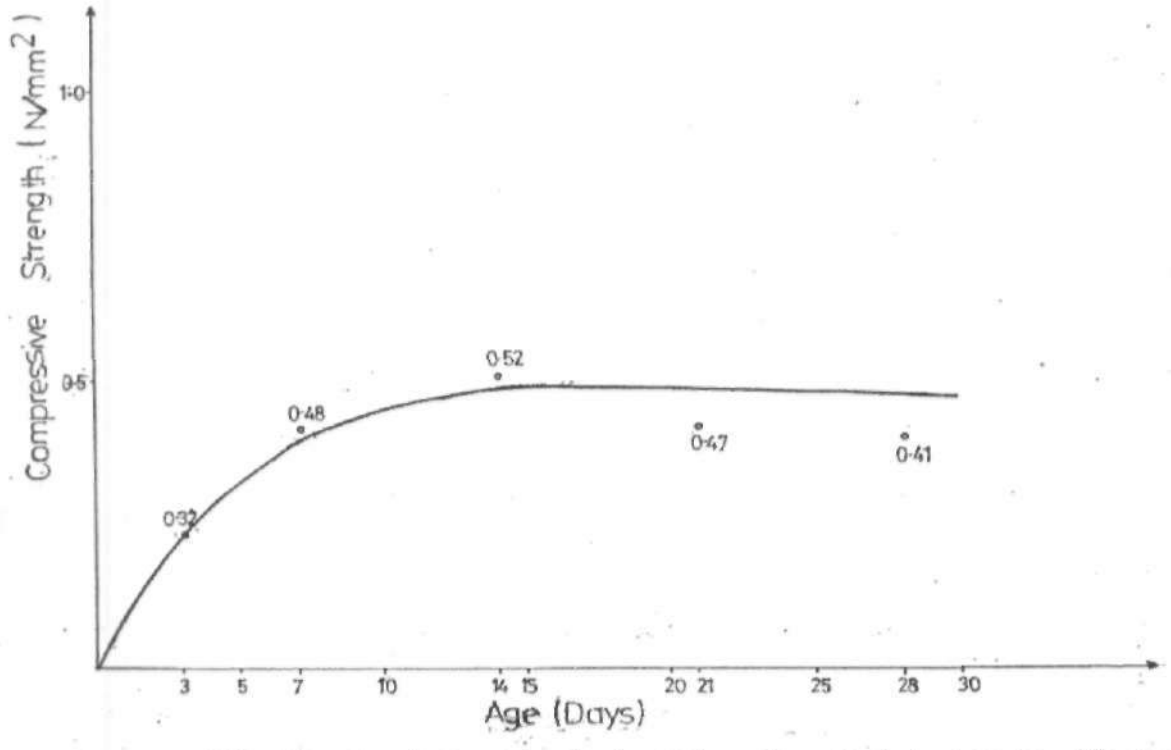


Fig 10 Development of dry strength of industry D Blocks

Generally, as can be seen from figures 7 to 11, most of the blocks from the various Industries will develop their strength at about 7 days of curing. From chapter two and ones visit to the Industries, most of them, if not all, cure their produced samples for only 1 to 3 days. It is imperative to cure (using recommended method) the blocks for at least, one week before they are utilised (34). Gage and Kirkbride (14) recommended 3 to 7 days for a normal air-curing.

It was also observed that there were no water-proof or sheds to cover the blocks and protect them in any of the Industries. One believes that Gage and Kirkbride (14) recommended as from 3 days curing when the blocks are under shade. Since this is the popular method used by Nigerian Block Manufacturers, there is a need to ensure that their blocks are properly cured for at least 7 days under shade to realise the full strength development.

Most of the samples give the parabolic nature of the curve which was also observed in concrete materials. The results of the dry compressive strength development of Industries A, B, C, D and E when plotted on the same axes are as shown in Figure 12 below:

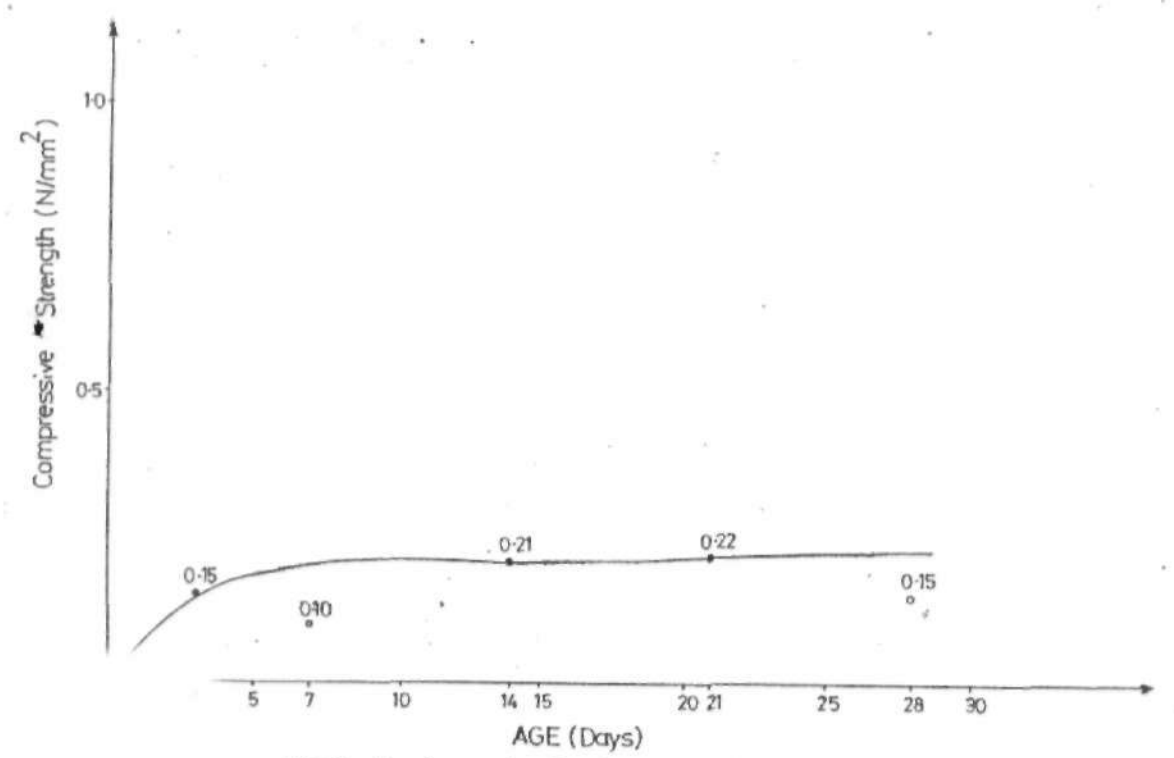


Fig.11 : Development of dry strength of industry E Sandcrete Blocks

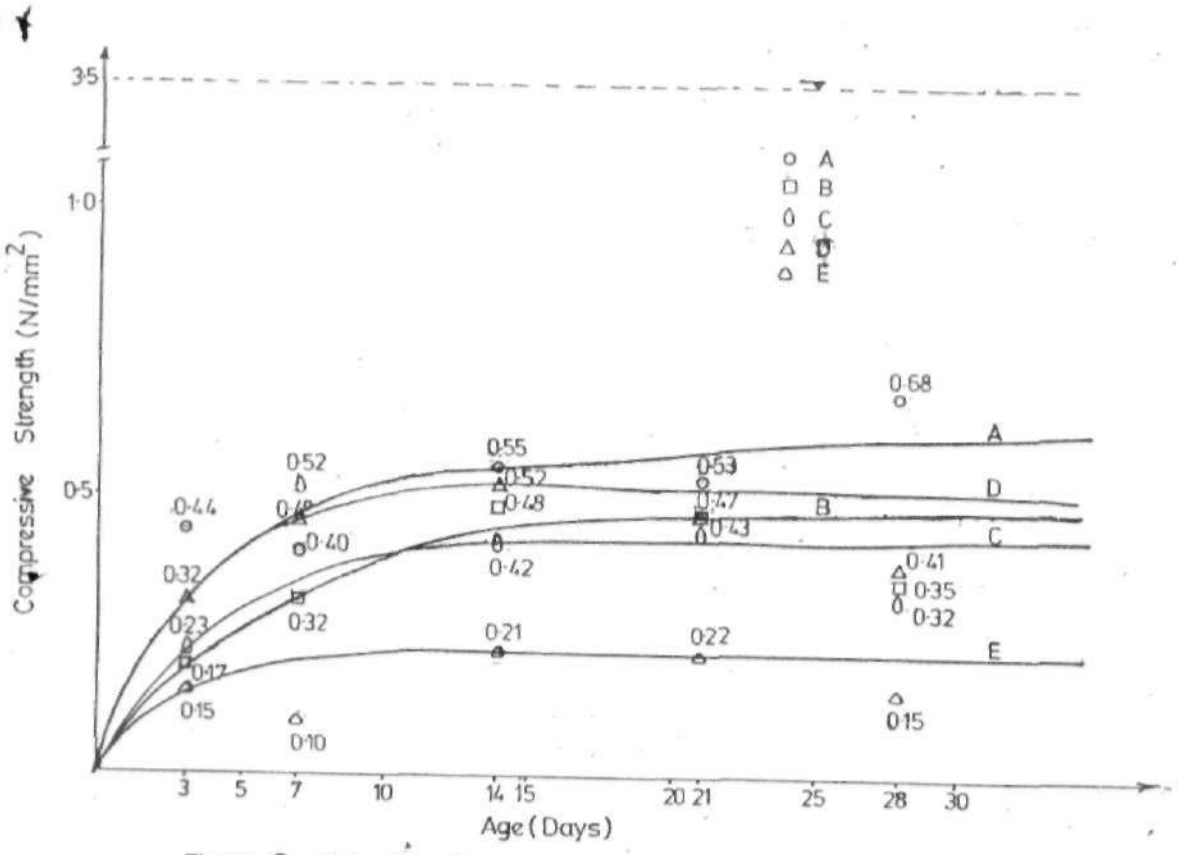


Fig. 12: Combined dry strength development

The figure shows that Industry A sandcrete blocks attained higher strength development than others. This is followed by Industries B, C, D and E respectively. Industries A and D blocks attained higher strength than B, C and E because they are cured for 3 days rather than one or two days curing which the latter ones (B, C and E) under-went. Though, Industries A and D cure their blocks for the same number of days, the difference in the strength may be attributed to the variation in mix ratio. Industry A uses a mix ratio of 1 part of cement to 6½ parts of sand while Industry D uses 1 part of cement to 8 parts of sand. The mix of the former (A) is richer (i.e. contains higher cement content) than the latter (B).

Industries B and C cure their blocks for two days while that of E cures for only one day. However, Industry B has a higher strength than Industry C as shown in figure 12. This may again be due to the fact that Industry B blocks have a richer mix than those of Industry C. Industry B uses a mix of 1 part of cement to 6 parts of sand while C uses 1 part of cement to 8 parts of sand. On the whole, Industry E blocks has the lowest strength development as shown in figure 12. The reason for the reduced strength cannot be far-fetched. Industry E sandcrete blocks under-went only 1 day curing which is not sufficient to make the blocks to attain maximum strength development. Moreso, table 12 of chapter 3 shows that the sand sample of Industry E has a very high silt content of 19.4% instead of the maximum (6%) stipulated by the Bs 812 (4).

Even though all the blocks of these Industries showed some development of dry compressive strength, parabolic nature of the curve, none of them satisfied the dry compressive strength of blocks at 28 days age. Bs 2028 (2) specified a minimum compressive strength of 2.8N/mm^2 (for a type B block) for an average of 10 blocks with the lowest individual strength being 2.25N/mm^2. NIS (28), however, specified compressive strength of Load Bearing and Non-Load Bearing blocks as 3.45N/mm^2 and 2.76N/mm^2 respectively for an average of 10 blocks. It also recommended the compressive strength of the weakest individual blocks to be 2.76 and 2.21N/mm^2 respectively. From the graph (Fig. 12), the highest strength is 0.68N/mm^2. Thus, it neither satisfied the lowest individual strength nor the average strength. The value of strength indicated in the graph is an average of 3 samples for each strength.

4.4 DEVELOPMENT OF WET COMPRESSIVE STRENGTH

Development of wet compressive strength of the blocks from the various Industries were carried out as shown in tables 18, 19, 20, 21 and 22 of chapter three. The test results when plotted on the graph are as shown in figures 13, 14, 15, 16 and 17 below for Industries A, B, C, D and E respectively.

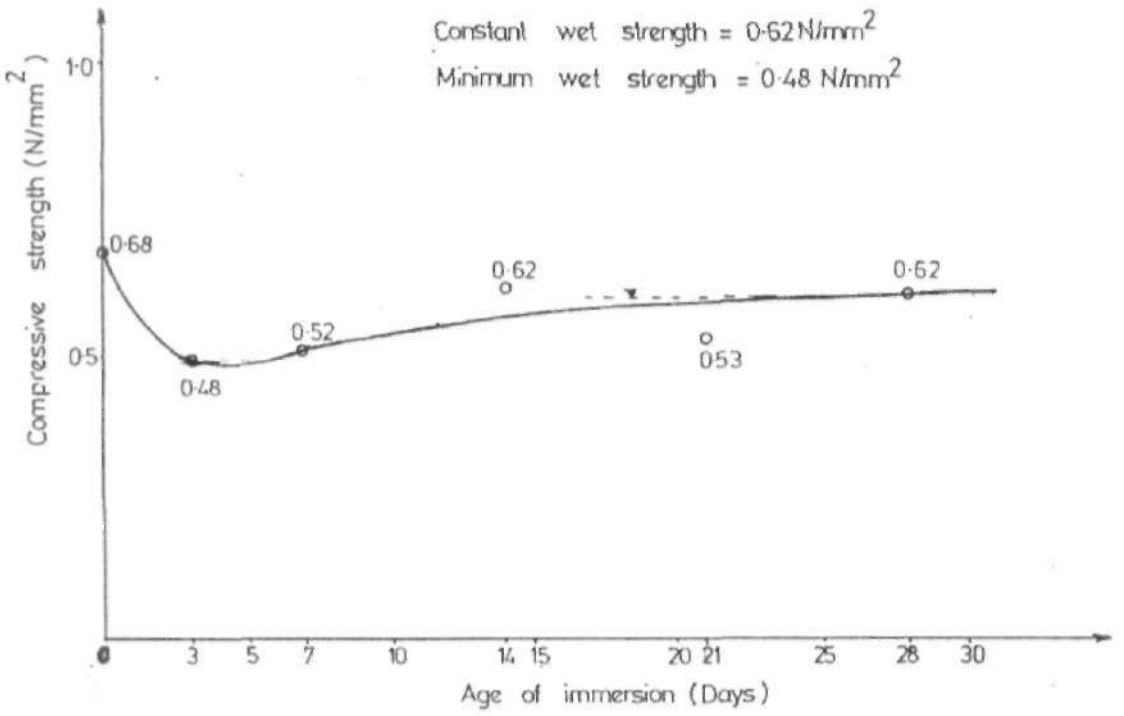


Fig.13: Development of wet compressive strength of industry A

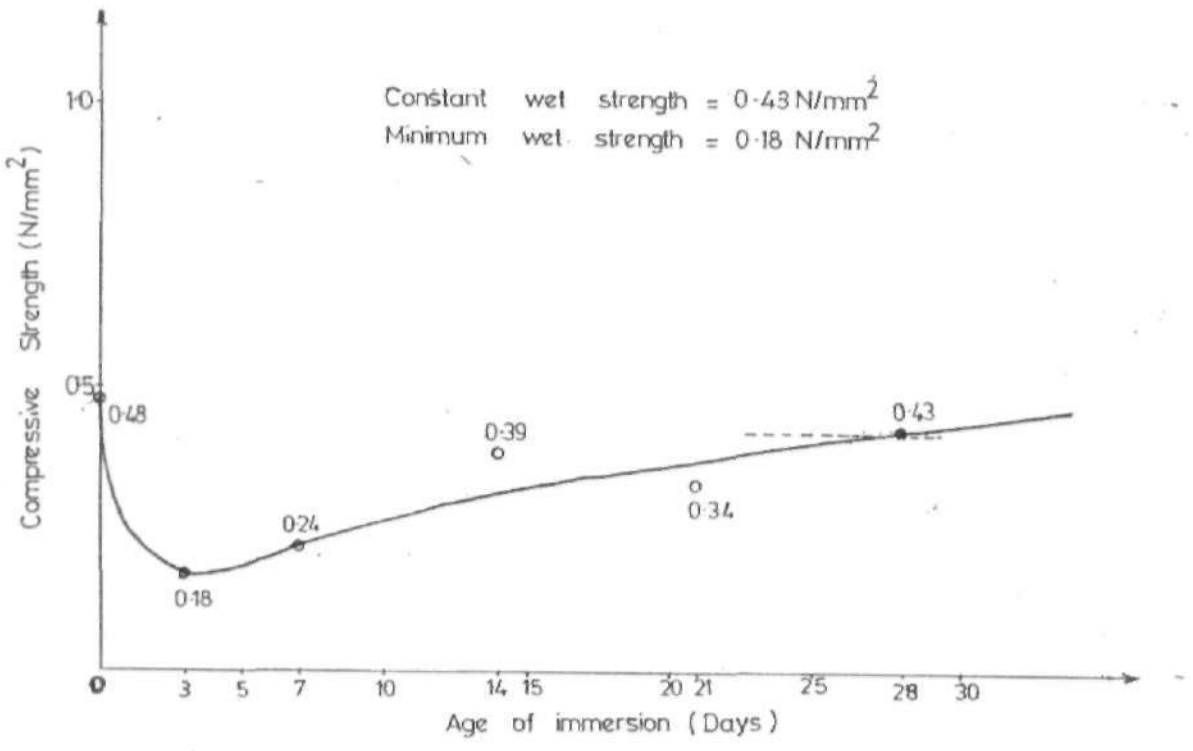


Fig. 14: Development of wet compressive strength of industry B

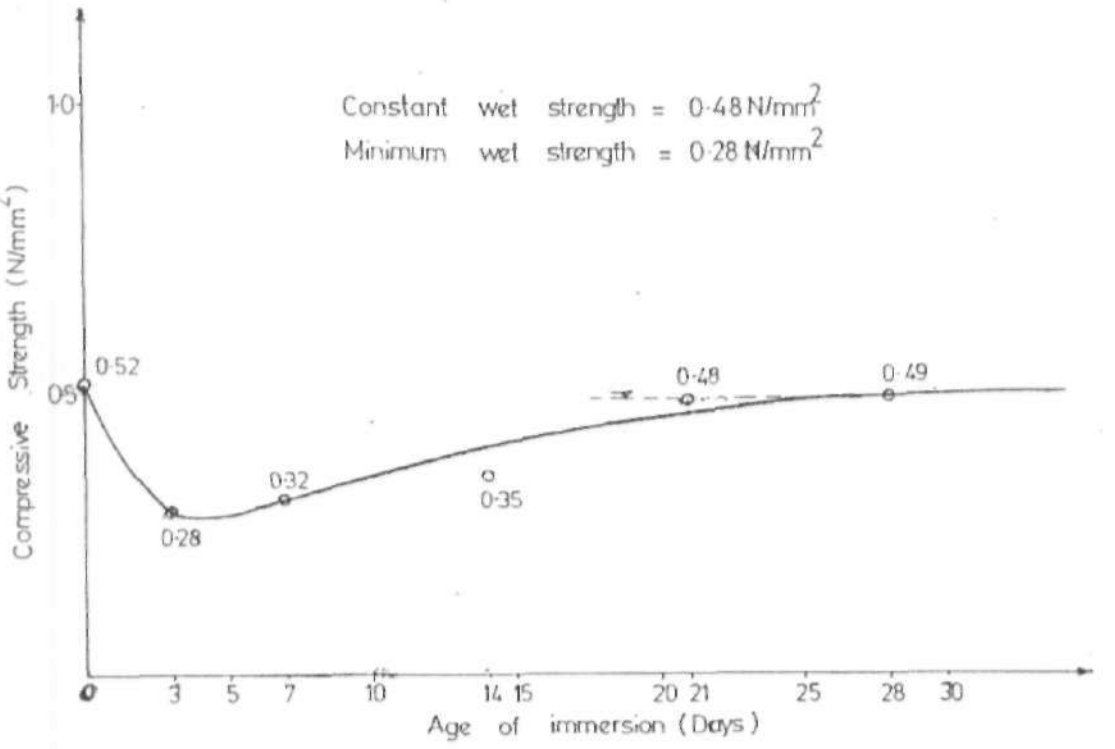


Fig. 15: Development of wet compressive strength of industry G

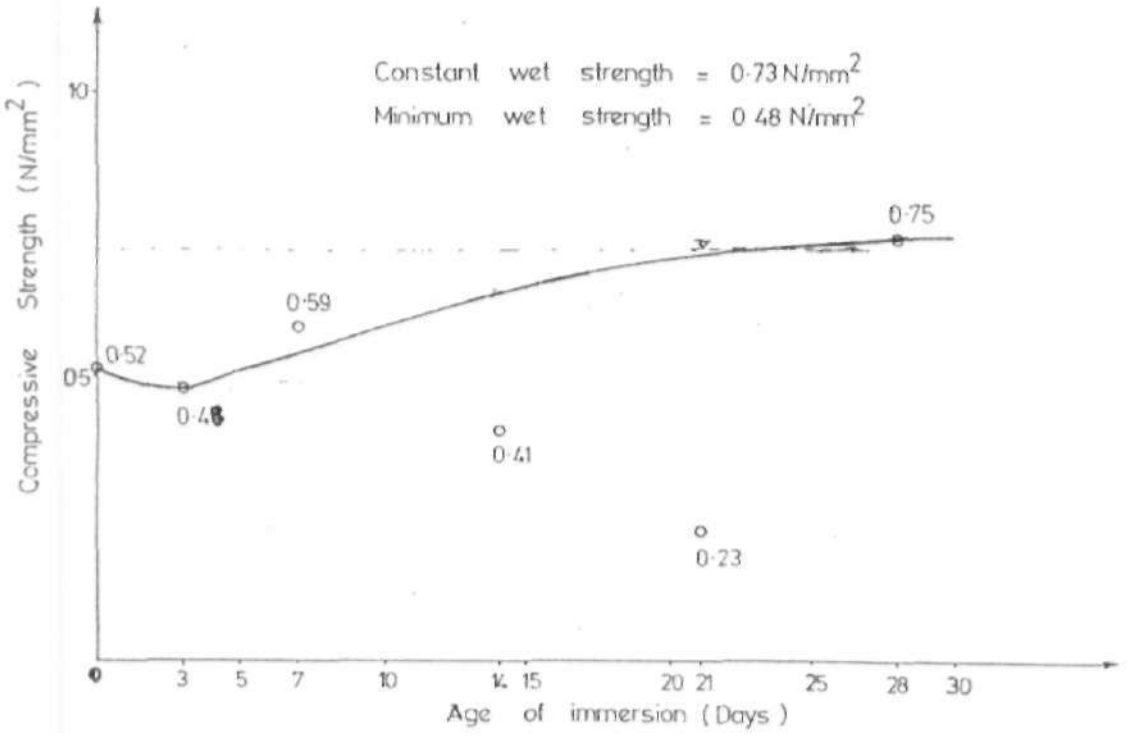


Fig. 16: Development of wet compressive strength of industry D

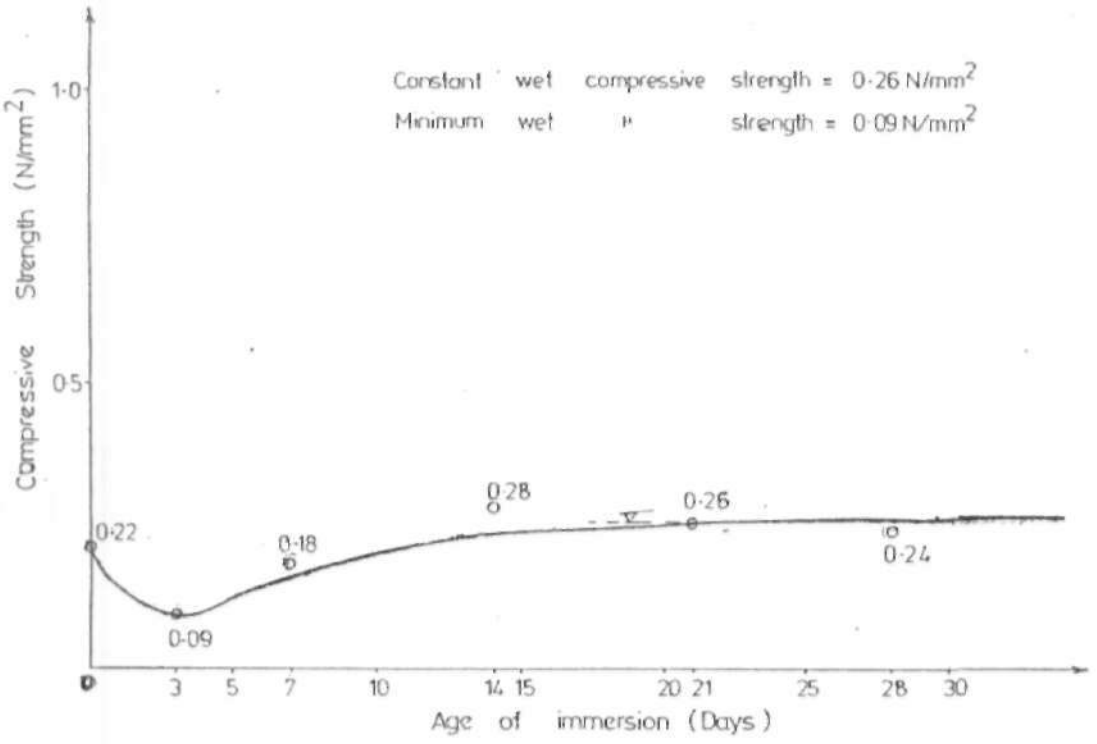


Fig. 17 : Development of wet compressive strength of industry E

These blocks were tested for wet compressive strength after 28 days of age. Before this test was carried out, the blocks were soaked in water ready to be tested for various wet ages.

Assuming the dry strength at 28 days to be the strength at zero immersion, then the graph of figure 17 for example will have $0.68N/mm^2$ at zero immersion. This dry strength at 28 days of age was inserted to see the effect of immersion in water on the strength of the blocks. On immersion in water, the wet compressive strength drops sharply when compared to the dry compressive strength. As from three days of immersion, the wet compressive strength starts to develop and there is a gradual increase in the wet compressive strength. This leads to the curve rising gradually and pointing upwards at an inclined angle. The increase in wet compressive strength as a result of immersion decrease with time of immersion. This indicates the hydration of the cement when in contact with water. At 3 days of immersion period, the curves shown sharp drop in values. These values are given as the minimum wet compressive strength in this thesis. The sudden reduction in compressive strength may be due to diffusion and retention of water into the capillaries or pores of the blocks. And the consequent increase in strength with time may be ascribed to the formation of hydrated products as the water reacts with the cement gel.

Furthermore, after 7 days, the curves (as seen in figures 13 to 17) are observed to attain practically steady state level. This gradual steady state is referred to as constant wet compressive strength in this thesis. There is generally low wet compressive strength value of the blocks when compared to the dry compressive strength. The concrete tested in a saturated condition are known to possess lower strength.

As seen in figures 13, 14, 15, 16 and 17, the dry compressive strength of Industry A, B, C, D and E samples are 0.68, 0.48, 0.52, 0.52 and 0.22N/mm^2 respectively. These graphs also showed that the minimum wet compressive strength are 0.48, 0.18, 0.23, 0.48 and 0.09N/mm^2 respectively. It therefore, follows that for Industries A, B, C, D and E samples, the constant wet compressive strength are 0.62, 0.43, 0.48, 0.73 and 0.26N/mm^2 respectively from the graph. From the results, the ratio of percentages of wet to dry compressive strength could be obtained. Thus, there are two types of wet strength to dry strength ratios to be considered. The constant wet strength ratio and the minimum wet strength. The minimum wet strength to dry strength of Industries A, B, C, D and E are 70, 40, 55, 92 and 40 percent respectively. For these Industries, the percentage of constant wet strength are 90, 90, 92, 140 and 120 percent respectively. The very high percentages of wet strength to dry strength (i.e. 140 and 120) showed that the blocks were badly cured initially.

Figure 18 (below) shows the wet compressive strength development of Industries A, B, C, D and E when plotted on the same axes. In the figure, Industries A, B, C, D and E blocks possess lower wet strength than their corresponding dry strength. Only sandcrete blocks of Industry D has higher wet strength (0.75N/mm^2) than the initial dry strength of (0.52N/mm^2). This increase in wet strength indicates that these blocks were not properly cured at the time of production. Generally, these constant wet compressive strength did not meet the lowest individual block strength (which is 80% of the average value of 10 blocks) specified by the relevant standard codes.

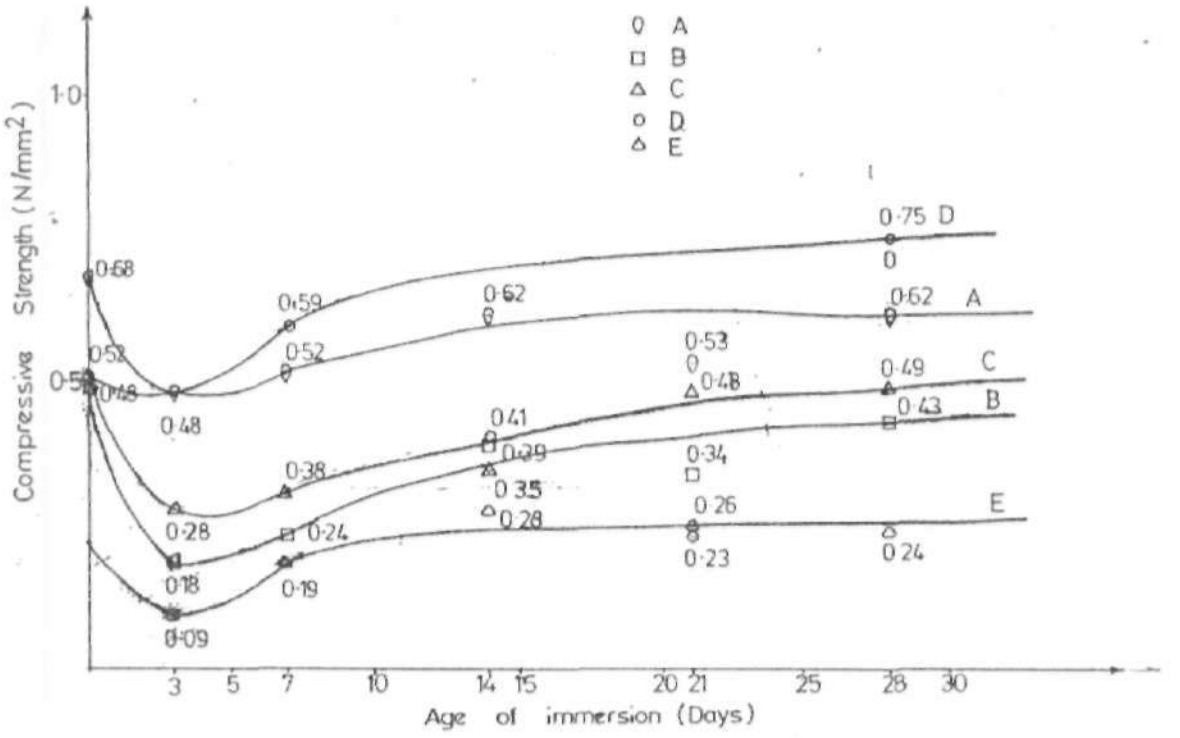


Fig. 18: combined wet strength development.

4.5 WET COMPRESSIVE STRENGTH

The test was executed to determine the wet compressive strength of 10 blocks such that the bed faces were bedded with cement-sand mortar. The blocks were tested after 28 days of age. The Bs 2028 recommended that the average strength of these blocks should be given as the minimum compressive strength.

The minimum compressive strength as specified by the code stated above is 2.8N/mm^2 while the strength of the lowest individual block must not be less than 2.25N/mm^2. NIS (28) recommended a minimum strength of 3.45N/mm^2 for type A block and 2.76N/mm^2 for a type B block. Where types A and B are Load-bearing and Non-load bearing respectively. However, the Federal Ministry of Works during the Annual Conference in Kano,1979, specified the average compressive strength of 3 sandcrete blocks to be at least 2.1N/mm^2 and the lowest individual strength not to be less than 1.7N/mm^2 (13).

The results of the wet compressive strength test of Industries A, B, C, D and E are presented in tables 24, 25, 26, 27 and 28 respectively. Below is a table showing the average compressive strength, the standard deviation and the co-efficient of variation of the various Industries.

TABLE 44 TABLE SHOWING THE AVERAGE WET COMPRESSIVE STRENGTH, STANDARD DEVIATION AND CO-EFFICIENT OF VARIATION OF INDUSTRIES A,B,C,D AND E

Industry	Average Compressive Strength (N/mm^2)	Standard Deviation (N/mm^2)	Co-efficient of Variation (%)
A	1.14	0.03	2.6
B	0.70	0.05	7.1
C	0.83	0.06	7.2
D	0.87	0.06	6.9
E	0.54	0.1	18.5

The overall Average strength = $0.82N/mm^2$

The overall Standard deviation = $0.05N/mm^2$

The overall Co-efficient of variation = 6.1%

From the table above, the average compressive strength of Industries A, B, C, D and E are 1.14, 0.70, 0.83, 0.87 and $0.54N/mm^2$ respectively. In comparison to the standard specifications mentioned above, the resulting strength of blocks tested in this state are considerably very low. Since the wet compressive strength is the most crucial property that determines the quality of a concrete product, the quality of these sandcrete blocks could be classified as very poor and below standard requirements. Industry A showed the highest strength value than the others while the order of magnitude of strength of other Industries are B, C, D and E. Industry A and D blocks were cured for 3 days, C and B blocks were cured for 2 days,

while E blocks were only cured for 1 day. Difference in the strength of A and D blocks inspite of undergoing the same curing period, is because Industry A claimed to use a richer mix (1 part of cement to 6½ parts of sand) than Industry D (1 part of cement to 8 parts of sand). Industry A also utilizes crushed granite sand as a fine aggregate in moulding her blocks. Granite is known to possess higher strength than ordinary sand.

Generally, these block manufacturing Industries are deficient in adopting the normal curing period of not less than 7 days. From the test results, it is observed that the more the curing period, the higher the strength of these blocks. Thus, the reduced strength generally is as a result of manufacturing not complying with the required standard of curing. Another contributing factor is the high silt content. Referring to table 12, sand samples of Industries A, B and E contain 7.2, 8.3, 19.4% silt respectively. These values are higher than the maximum value of 6% recommended by standard code. Industry E sand sample, which is brown in colour contain the highest value of silt (i.e. 19.4%). Consequently, her blocks gave the lowest value of compressive strength.

Furthermore, it was observed that the value of the wet compressive strength of the bedded blocks are considerably higher than the dry compressive strength. The blocks used for the wet compressive strength were immersed in water for at least 7 days before testing. The water immersion must have led to the increase in strength since suitable curing was applied. The strength

at any particular age can be further increased as a result of hydration. This may be as a result of previously unwetted particles of cement which might have been hydrated as the blocks were immersed in water. It is also an indication that sufficient water might not have been used at the time of curing to allow all the cement particles to participate in the hydration process.

Moreover, the mix proportions of these Industries (except A and B) did not meet the standard requirement of minimum mix proportion (1 part of cement to 6 parts of sand) recommended by the Bs 2028. Though it is stipulated that the mix must be of mixed aggregates of coarse and fine aggregates. It was observed that all these Industries use soft sand in combination with the so called sharp sand. This has not been recommended by the code. This soft sand has high specific surface because of its fineness (classified as zone 4 sand) and have high silt content thus, could contribute to the reduction in strength of these blocks.

Nonetheless, table 43 showed that the co-efficient of variation of Industries A, B, C, D and E are 2.6, 7.1, 7.2, 6.9 and 18.5% respectively and the overall co-efficient of variation is 6.1%. For testing concrete products, co-efficient of variation should not be more than 20%. Above this value, the production is regarded as unsatisfactory and not uniform. All the values of co-efficient of variation of these Industries and the overall value fall within the stipulated percentages.

These therefore, indicate that their production is satisfactory and consistent but of very low wet and dry compressive strength as a result of bad curing.

4.6 DENSITY TEST

The test results of the dry density at varying ages of Industries A, B, C, D and E are presented in tables 29, 30, 31, 32 and 33 respectively. The plotted graphs are as shown below in figures 19, 20, 21, 22 and 23 respectively for Industries A, B, C, D and E.

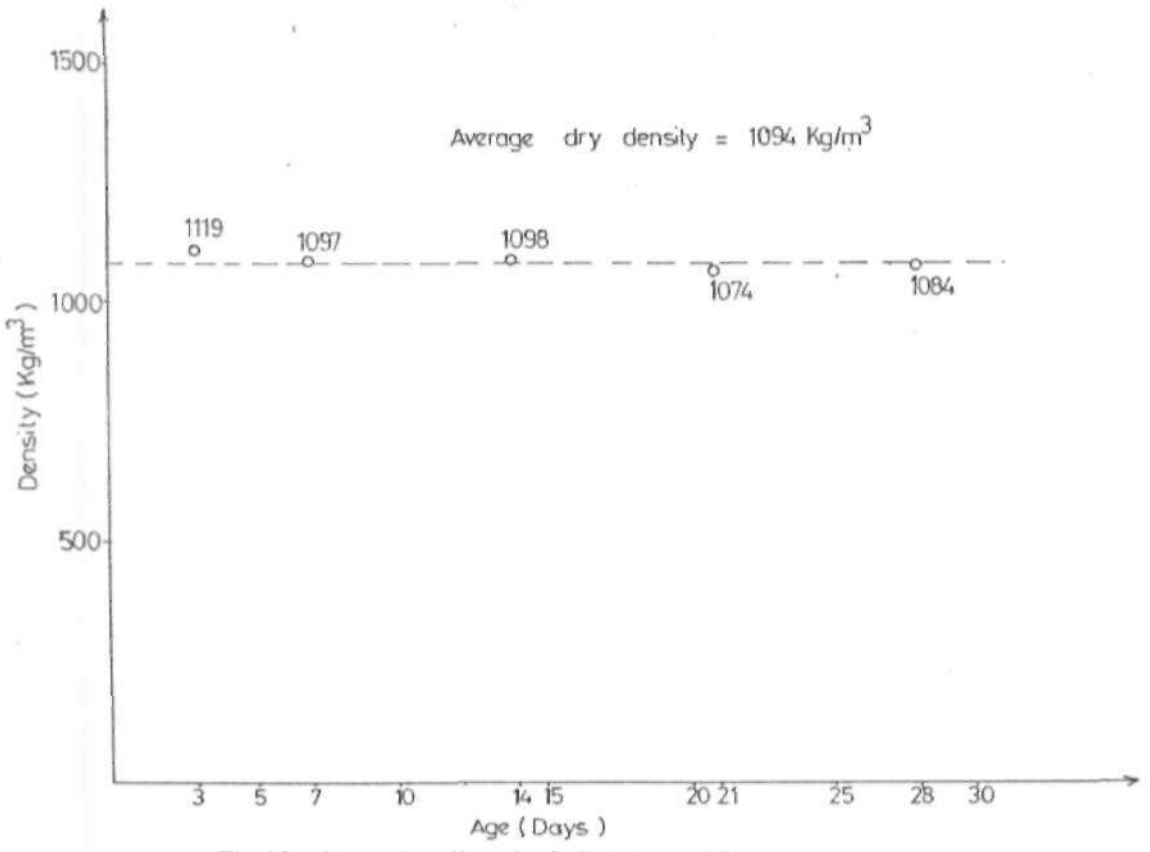


Fig. 19 Dry density of industry A Blocks

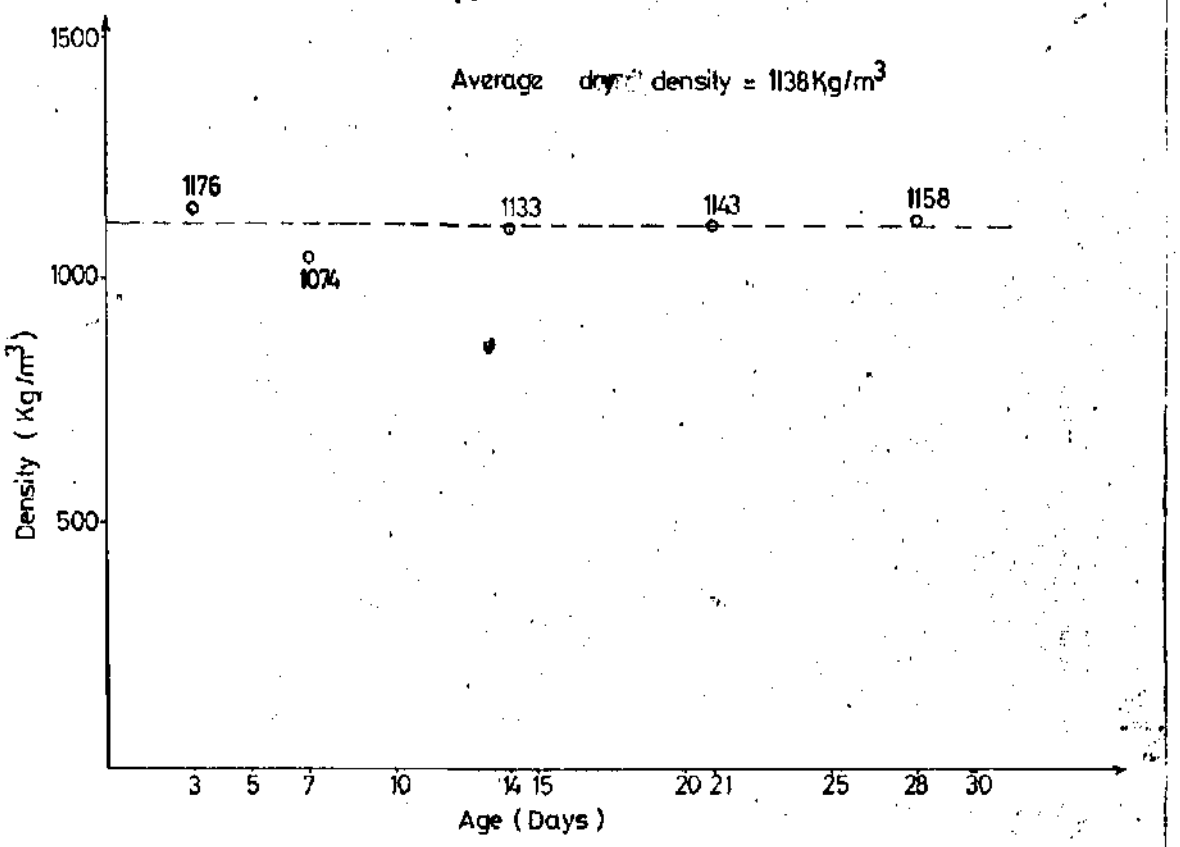


Fig. 20 Dry density of industry B Blocks

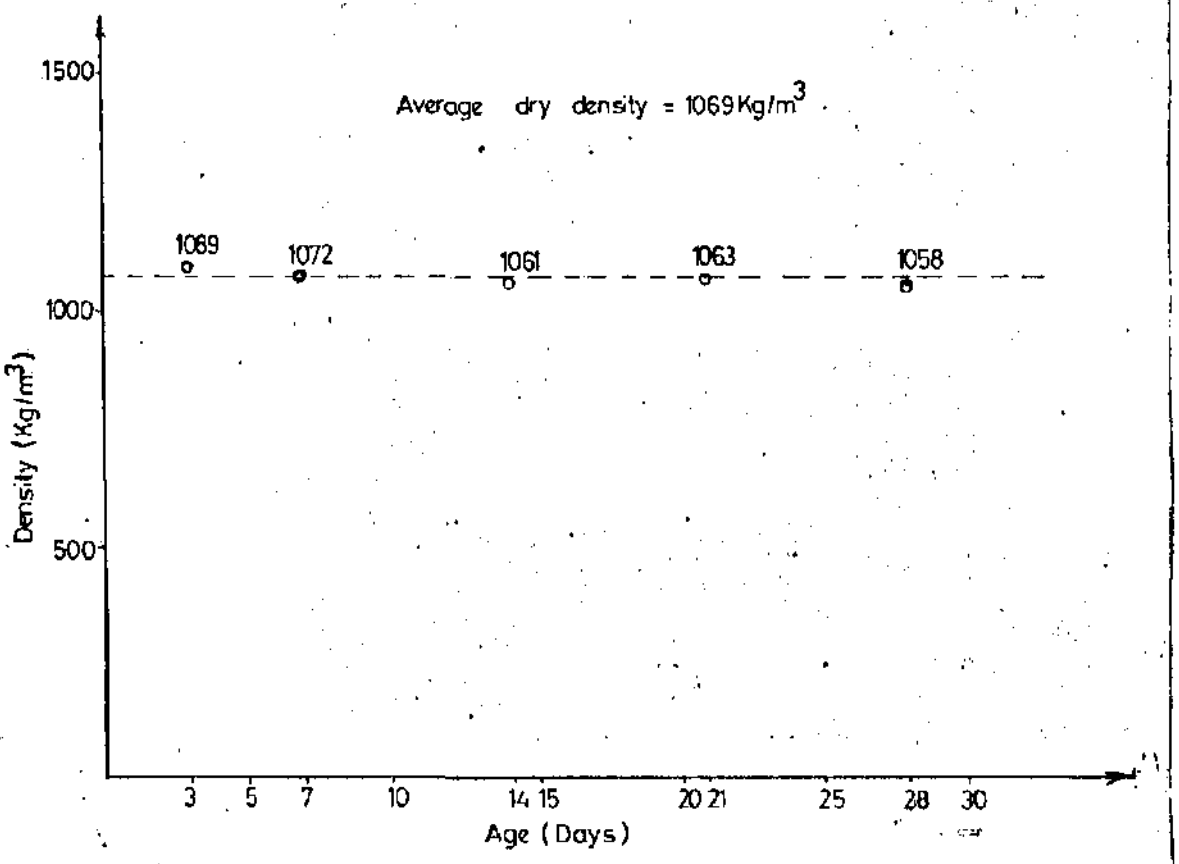


Fig. 21 Dry density of industry C Blocks

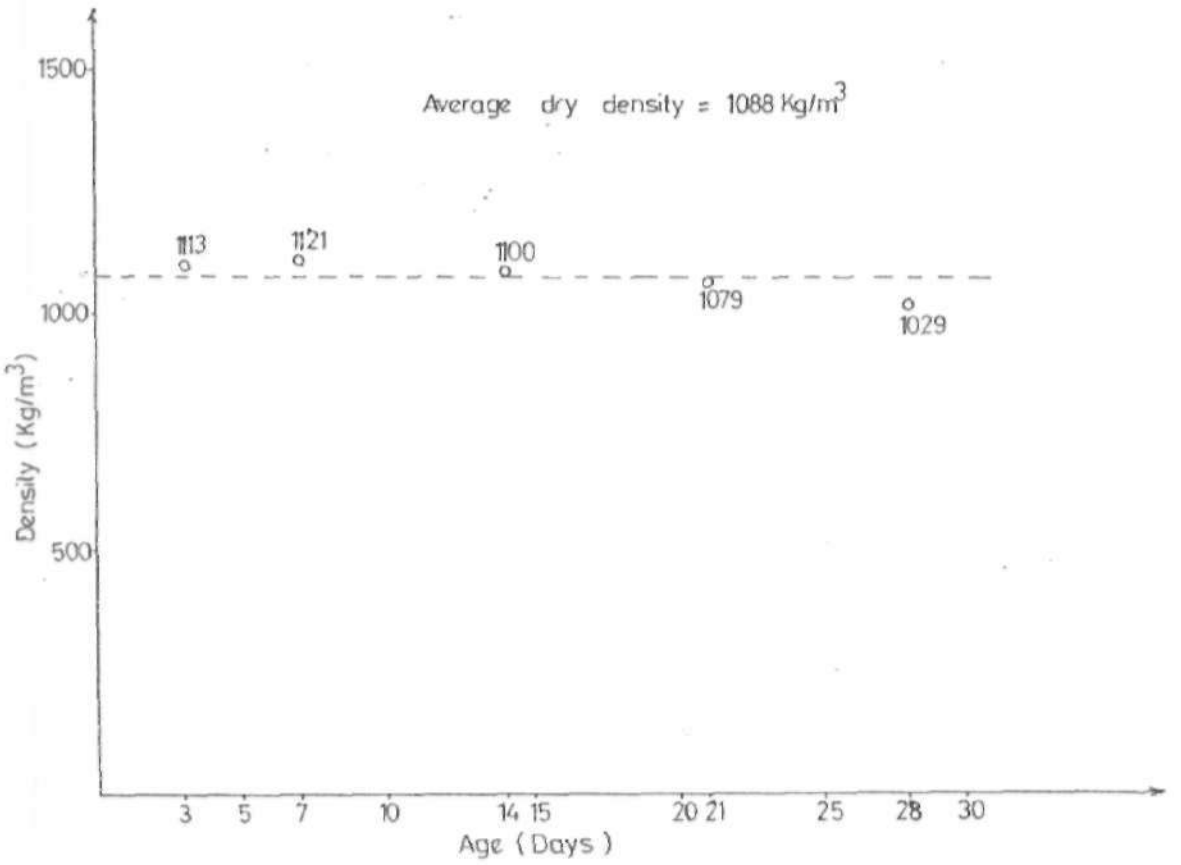


Fig. 22: Dry density of industry D Blocks.

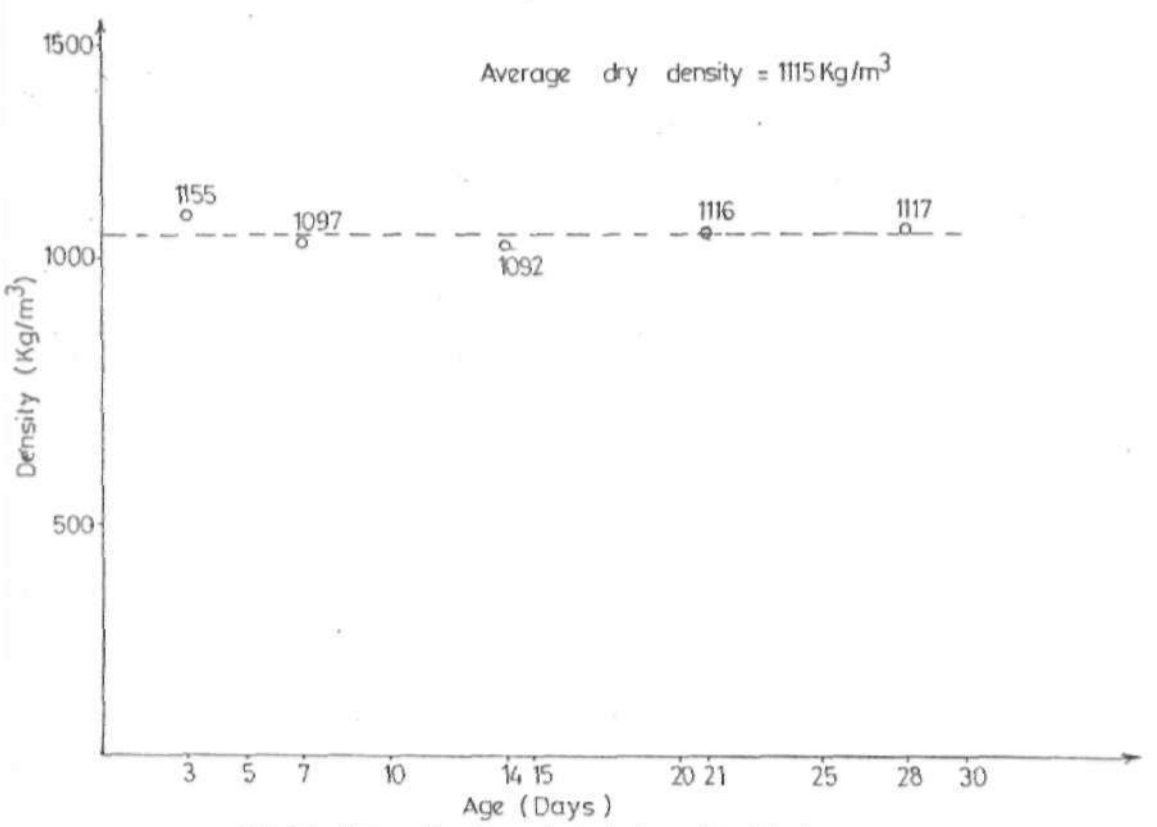


Fig. 23: Dry density of industry E Blocks

As seen in the figures above, the average densities of Industries A, B, C, D and E are 1094, 1138, 1069, 1088 and 1115kg/m^3 respectively. The dry density values satisfy the recommended values of not greater than 1500kg/m^3 specified by Bs 2028 for type B blocks. The effectiveness of other properties mainly depends on the density. Dry density of a block has direct relationship with the strength and other properties such as the thermal insulation, water absorption and sound insulation. From the test results, it could be deduced that if other conditions are satisfied, these blocks should possess strong and durable qualities. This is also an indication that these blocks have less weight and hence make them easy to handle.

Figure 24 shows the graph of the densities of Industries A, B, C, D and E when plotted on the same axes. From the figure, the average density value of blocks produced in Kwara State is given as 1101kg/m^3. This is also a value well below the recommended standard.

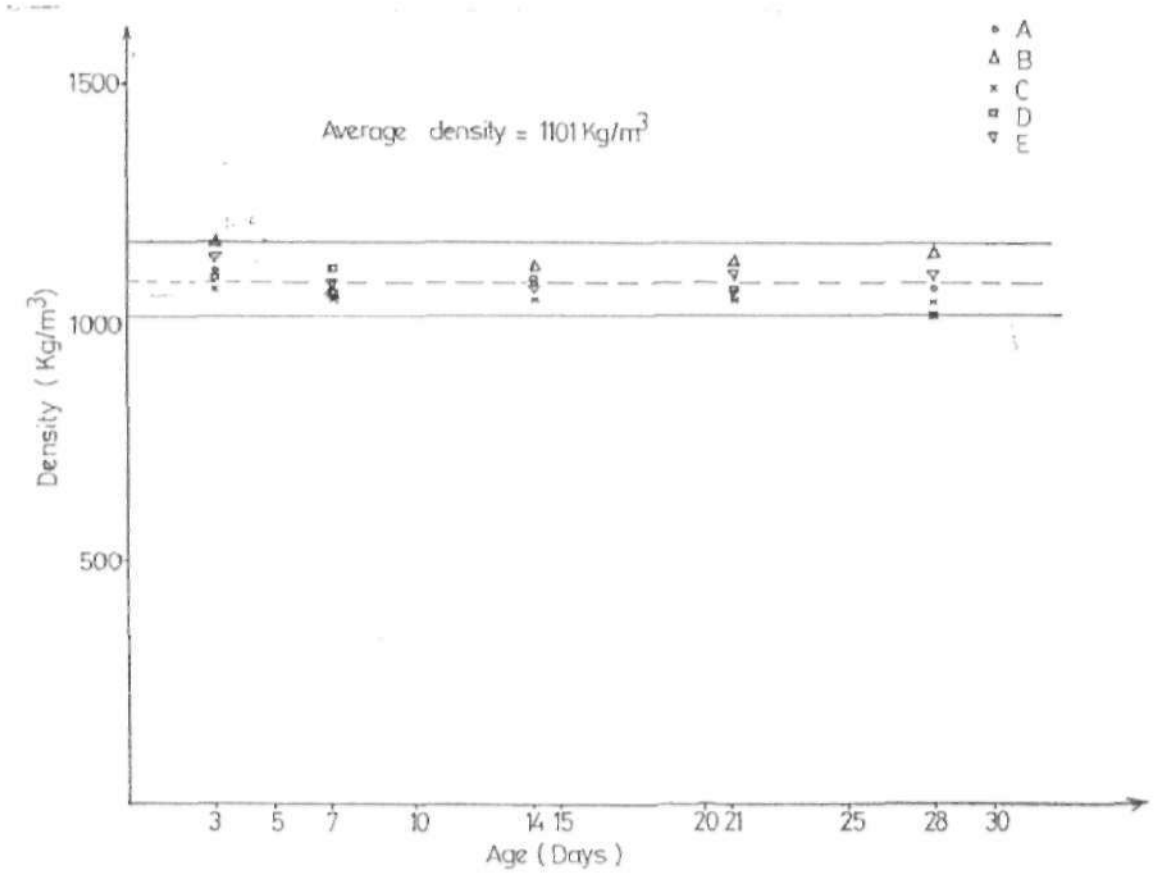


Fig 24: Dry density of industries A, B, C, D and E

4.7 WATER ABSORPTION TEST

The test results of the water absorption of Industries A, B, C, D and E blocks are as given in chapter three. Their average water absorption were 13.6, 10, 12.9, 13.9 and 14.4 percent respectively. NIS 74 (26) specified 25% for burnt clay blocks. The values of water absorption of all these blocks also satisfied the standard requirement for a block. Water absorption tests are good indication of apparent porosity of blocks. Porous blocks are more subjected to chemical attacks and possess less density which will in turn affect other qualities.

4.8 EFFLORESCENCE

The test results of efflorescence of Industries A, B, C, D and E are presented in table 39.

The blocks of all the Industries which were tested for efflorescence are classified as NIL. Since there is no perceptible presense of efflorescence. Though, the blocks of Industries A, D and E showed very little presence of efflorescence in the hollows. The very little efflorescence noticed is not sufficient to classify the efflorescence as SLIGHT. Generally, efflorescence is known to be a rare problem with concrete blocks except in very porous ones.

4.9 DRYING SHRINKAGE AND MOISTURE MOVEMENT TEST

The test results of the drying shrinkage and moisture movement were presented in tables 40 and 41 of chapter three. The average drying shrinkage of Industries A, B. C. D and E are 0.02, 0.02, 0.008, 0.02 and 0.001% respectively. Also the wetting expansion values are 0.02, 0.01, 0.007, 0.01 and 0.001% respectively. The Bs 2028 specified that the drying shrinkage of type B blocks shall not be more than 0.08% while the moisture movement must not be more than 0.05%. The values of both drying shrinkage and moisture movement of these blocks, however, satisfied the standard requirement. These concrete units do not have

high values of shrinkage because of their mix proportion.

Concrete units most susceptible to shrinkage are those with high cement contents and high water/cement ratio (8). Shrinkage is more troublesome in the use of blocks since it could cause cracking of these units in walls as alternate movement are experienced. Since these blocks possess satisfactory values of shrinkage, it is an indication that they may not exhibit cracks where walls of which they are made are subjected to alternate contraction or expansion.

However, the compressive strength qualities is more vital as this also can easily lead to failure when the units are used for structural elements.

4,10 COMPRESSIVE STRENGTH OF CEMENT MORTAR CUBES (1:8)

Referring to table 42, the compressive strength of 8 cement mortar cubes of concrete cube size made out of a mix ratio of 1 part of cement to 8 parts of sand are given as 6.67, 6.53, 6.62, 7.02, 6.8, 6.57, 6.44 and 6.67N/mm^2. The average compressive strength is 6.67N/mm^2.

From investigation, the common mix ratio was 1 part of cement to 8 parts of sand. The cubes were cast to allow for a basis of comparison. The strength measured in a carefully prepared test specimen would differ from the strength required in the actual product, thus, the expected strength is given as below:

Standard deviation (σ) = 0.16N/mm^2

Mean strength ($\bar{x}$) = 6.67N/mm^2

Characteristic strength (fcu) = $\bar{x} - 1.64\sigma$

fcu = 6.67 - 1.64 x 0.16

= 6.67 - 0.26 = 6.41N/mm^2

The characteristic strength = 6.41N/mm^2

The expected strength in the wall or say actual block = 0.4 fcu

= 0.4 x 6.41

= 2.56N/mm^2

It is obvious that if sandcrete blocks are processed and moulded under good condition and proper control, the expected strength of such blocks made of a mix ratio of 1 part of cement to 8 parts of sand should have a compressive strength of 2.56N/mm^2. This strength nearly agrees with the stipulated compressive strength of at least 2.76N/mm^2 recommended by the Bs 2028 for type B blocks. The tested cubes were immersed in water for 28 days in other to attain these strength. From all indications, the ideal curing conditions for these blocks are those in which the concrete units are completely saturated.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS:

The tests and analysis presented in the previous chapters had been carried out to enable basic conclusions to be drawn. These would also serve as a useful information on future research on the sandcrete blocks production and their physical properties. The conclusions arrived at include the following:

1. Generally, the compressive strength of the sandcrete blocks tested in Kwara State are very low in comparison with the standard requirements. The highest compressive strength obtained from the test is 1.14N/mm^2.

2. Block Manufacturing Industries adopt the curing period of between 1 - 3 days.

3. The blocks are not cured under shed, to protect them from direct influence of weather neither do they cover them with water-proof material.

4. The majority of the Industries use the mix proportion of 1 part of cement to 8 parts of sand while very few use 1 part of cement to 6 parts of sand.

5. The sandcrete hollow blocks will practically develop its dry compressive strength after 7 days.

6. The average wet compressive strength of the sandcrete blocks produced in Kwara State is 0.82N/mm^2. This is below standard requirement.

7. The average minimum wet compressive strength and percentage minimum wet to dry strength are 0.30N/mm^2 and 59% respectively.

8. The average constant wet compressive strength and percentage constant wet to dry strength are 0.50N/mm^2 and 106% respectively.

9. The overall standard deviation and co-efficient of variation of the sandcrete blocks are 0.05N/mm^2 and 6.1% respectively. These depict satisfactory and consistent production.

10. The average cube strength of mortar cast from a mix ratio of 1 part of cement to 8 parts of sand is 6.67N/mm^2. The expected strength of sandcrete block moulded out of this mix is given as 2.56N/mm^2.

11. The fine aggregates used by the Industries located in Kwara State are well-graded sand suitable for block-making in terms of grading.

12. Majority of the fine aggregates (sand) used contain high silt content and they are therefore bad.

13. The dimensions of blocks (most especially the length and the thickness) did not meet up with the given tolerances. Within a particular Industry, blocks are found to vary highly in dimension. The average dimension of the 6" sandcrete blocks produced in Kwara State is 151 x 220 x 453mm.

14. Blocks exhibited little shrinkage which falls within the specified limit.

15. Efflorescence is not perceptible in sandcrete hollow blocks produced in Kwara State.

16. The blocks passed the water absorption test requirement. The average water absorption rate being 13.0%.

17. The average density of blocks produced in Kwara State is 1100kg/m^3.

18. The test results proved that the use of crushed granite sand as a fine aggregate in producing blocks will be an added advantage in improving the strength. Though, it is imperative that the dust present in such sand be washed prior to use.

5.2 RECOMMENDATIONS

1. The routine quality tests of sandcrete blocks should be seen as a crucial matter instead of treating it with a wave of hand. This will in no doubt upgrade the present production standard since these blocks are still recognised as the most popular walling units in Nigeria.

2. Manufacturers should ensure that stern and proper control and supervision are exercised during the production of these sandcrete blocks.

3. There is also the need for the Nigerian Standard Organisation to publish detailed specification for sandcrete hollow blocks production. In addition, this organisation should closely monitor the production processes of the block manufacturers.

4. The manufacturers should be educated on the importance of curing their products under shed or the use of water-proofing materials as an alternative to help improve the quality of blocks.

5. It is advisable that the appropriate University authorities should provide training facilities for the Block Manufacturers. This will, in no doubt help to boost their knowledge in the production of good quality blocks.

6. Moreso, manufacturers should not fail to exercise good supervision to ensure that the machines operate on constant pressure and constant volume at all times. This will help to eliminate the variation in dimensions of produced blocks.

7. It is also recommended that further research should be carried out to investigate into the standard compaction pressure of sandcrete block moulding machines and the normal vibrating period. The effect of the compaction pressure on the variation of dimensions of blocks should also be studied.

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APPENDIX A - I

SIEVE ANALYSIS RESULTS FOR INDUSTRY A

Sample 1: Light brown soft sand

Sieve size (mm)	Weight retained (gm)	Total weight passing (gm)	Total Percentage passing %
2.8	1	299	99.7
2.36	0.9	298.1	99.4
2.0	1.1	397	99
1.7	3	294	98
1.18	8	286	95.3
.850	25	261	87
.710	17	244	81.3
.300	127	117	39
.212	63	54	18
.180	11	43	14.3
.150	15	28	9.3
.125	19	9	3
Pan	9	-	-

Sample 2: Sharp Sand

Sieve size (mm)	Weight retained (gm)	Total weight passing (gm)	Total Percentage passing %
2.8	25	275	91.7
2.36	9	266	88.7
2.0	11	255	85
1.7	15	240	80
1.18	51	189	63
.850	54	135	45
.710	80.5	54.5	18.2
.300	34.2	20.3	6.8
.212	14.5	5. 8	1.9
.180	1.8	4	1.3
.150	2.0	2	0.7
.25	1.0	1.0	0.3
Pan	1.0	-	-

Sample 3: Crushed Granite Sand

Sieve size (mm)	Weight retained (gm)	Total weight passting (gm)	Total Percentage passing (%)
2.8	80	220	73.3
2.36	14.9	205.1	68.4
2.0	14	191.1	63.7
1.7	14	171.1	59.0
1.18	23.1	154	51.3
.850	24.9	129.1	43.0
.710	13	116.1	38.7
.300	52	64.1	21.4
.212	20.5	43.6	14.5
.180	10.5	33.1	11.0
.150	15	18.1	6.0
.25	11.5	6.6	2.2
Pan	6.6	-	-

APPENDIX A - 2

SIEVE ANALYSIS RESULTS FOR INDUSTRY B

Sieve size (mm)	Weight retained (gm)	Total weight passing (gm)	Total Percentage passing (%)
2.8	64	236	78.7
2.36	7	229	76.3
2.0	6	223	74.3
1.7	7	216	72
1.18	20	196	65.3
.850	27	169	56.3
.710	23	146	48.7
.300	101	45	15
.212	30	15	5
.180	4	11	3.7
.150	5	6	2
.125	2	4	1.3
Pan	4	-	-

APPENDIX A - 3

SIEVE ANALYSIS TEST RESULTS FOR INDUSTRY C

Sample 1:

Sieve size (mm)	Weight retained (gm)	Total weight passing (gm)	Total Percentage passing (%)
2.8	46	254	84.7
2.36	5	249	83
2.0	5	244	81.3
1.7	6	238	79.3
1.18	19	219	73
.850	29	190	63.3
.710	20	170	56.7
.300	107	63	21
.212	38	25	8.3
.180	10	15	5
.150	6	9	3
.125	6	3	1
Pan	3	-	-

Sample 2: Greyish Soft Sand

Sieve size (mm)	Weight retained (gm)	Total weight passing (gm)	Total Percentage passing (%)
2.8	29	271	90.3
2.36	3.5	267.5	89.2
2.0	4	263.5	87.8
1.7	3	260.5	86.8
1.18	11	249.5	83.2
.850	24	225.5	75.2
.710	19	206.5	68.8
.300	136	70.5	23.5
.212	41.5	29	9.7
.180	5	24	8
.150	12	12	4
.125	7	5	1.7
Pan	5	-	-

APPENDIX A - 4

SIEVE ANALYSIS TEST RESULTS FOR INDUSTRY D

Sieve size (mm)	Weight retained (gm)	Total weight passing (gm)	Total Percentage passing (%)
2.8	72.5	227.5	75.8
2.36	10	217.5	72.5
2.0	9.5	208	69.3
1.7	9	199	66.3
1.18	35	164	54.7
.850	48	116	38.7
.710	31	85	28.3
.300	72	13	4.3
.212	11	2	0.7
.180	1	1	0.3
.150	0.8	0.2	0.1
.125	0.2	-	-
Pan	-	-	-

APPENDIX A - 5

SIEVE ANALYSIS TEST RESULTS FOR INDUSTRY E

Sample 1:

Sieve size (mm)	Weight retained (gm)	Total weight passing (gm)	Total Percentage passing (%)
2.8	0.5	299.5	99.8
2.36	1	298.5	99.5
2.0	2	296.5	98.8
1.7	3	293.5	97.8
1.18	19	274.5	91.5
.850	35	239.5	79.8
.710	27.5	212	70.7
.300	158	54	18
.212	36	18	6
.180	4.5	13.5	4.5
.150	3	10.5	3.5
.125	3.5	7	2
Pan	7	-	-

Sample 2:

Sieve size (mm)	Weight retained (gm)	Total Weight passing (gm)	Total Percentage passing (%)
2.8	17	283	94.3
2.36	4.5	278.5	92.8
2.0	7	271.5	90.5
1.7	10	261.5	87.2
1.18	24	237.5	79.2
.850	51	186.5	62
.710	24	162.3	54.2
.300	119	43.5	14.5
.212	25.5	18	6
.180	5	13	4.3
.150	4	9	3
.125	4	5	1.7
Pan	5	-	-

APPENDIX A - 6

THE FIELD SETTLING TEST RESULTS

Industry	Sample Number	Weight of sample (cm^3)	Height of sand (cm^3)	Difference in level (cm^3)	Silt content (%)
A	1	100	87.6	12.4	12.4
	2	100	92.6	7.4	7.4
	3	100	98.3	1.7	1.7
B		10 4	99.4	4.6	4.4
C	1	100	91.8	8.2	8.2
	2	99.8	91.5	8.3	8.3
D		101	99	2.0	1.98
E	1	98.6	77.8	20.8	21.1
	2	100	82.4	17.6	17.6

APPENDIX A - 7

DRY COMPRESSIVE STRENGTH DEVELOPMENT TEST RESULT

FOR INDUSTRY A BLOCKS

Identification No	Length (mm)	Breadth (mm)	Height (mm)	Weight (kg)	Age (dys)	Density kg/m³	Failure Load KN	Crushing strength (N/mm²)
Kw/K/1	450	152	220	16.52	3	1101	20	0.29
Kw/K/2	448	152	218	16.46	3	1097	35	0.51
Kw/K/3	450	152	218	17.35	3	1157	35	0.51
Kw/K/4	457	152	217	16.68	7	1112	35	0.50
Kw/K/5	457	152	220	16.21	7	1081	30	0.48
Kw/K/6	455	152	218	16.44	7	1096	19	0.28
Kw/K/7	457	150	218	15.77	14	1051	28	0.41
Kw/K/8	454	152	218	17.08	14	1139	40	0.56
Kw/K/9	457	152	220	16.57	14	1106	47	0.68
Kw/K/10	457	152	218	15.81	21	1054	38	0.55
Kw/K/11	449	152	220	16.78	21	1119	35	0.51
Kw/K/12	458	152	218	15.73	21	1049	36	0.52
Kw/K/13	457	150	215	16.19	28	1079	45	0.66
Kw/K/14	457	152	218	16.22	28	1081	45	0.65
Kw/K/15	457	152	217	16.36	28	1091	50	0.72

APPENDIX A - 8

DRY COMPRESSIVE STRENGTH DEVELOPMENT TEST RESULTS

FOR INDUSTRY B BLOCKS

Identification No	Length (mm)	Breadth (mm)	Height (mm)	Weight (kg)	Age (dys)	Failure Load (KN)	Density (Kg/m^3)	Crushing strength (N/mm^2)
Kw/0/1	455	152	218	17.76	3	15	1184	0.22
Kw/0/2	457	152	218	17.55	3	10	1170	0.14
Kw/0/3	455	152	215	17.62	3	10	1175	0.15
Kw/0/4	457	153	225	16.64	7	20	1040	0.29
Kw/0/5	450	150	225	17.26	7	20	1152	0.30
Kw/0/6	453	152	225	17.61	7	27	1101	0.39
Kw/0/7	450	152	218	17.37	14	45	1158	0.66
Kw/0/8	457	152	220	16.45	14	28	1097	0.41
Kw/0/9	457	152	225	17.40	14	27	1088	0.39
Kw/0/10	442	152	215	16.58	21	30	1105	0.45
Kw/0/11	460	152	222	18.04	21	28	1203	0.40
Kw/0/12	460	152	220	16.83	21	40	1122	0.57
Kw/0/13	450	153	212	17.06	28	20	1137	0.29
Kw/0/14	457	152	225	17.35	28	25	1084	0.36
Kw/0/15	457	152	222	17.0	28	28	1180	0.40

APPENDIX A - 9

DRY COMPRESSIVE STRENGTH DEVELOPMENT TEST RESULTS FOR INDUSTRY C BLOCKS

Identification No	Age (dys)	Length (mm)	Breadth (mm)	Height (mm)	Weight (Kg)	Failure Load (KN)	Density (Kg/m^3)	Crushing strength (N/mm^2)
Kw/A/1	3	455	150	221	16.17	18	1078	0.26
Kw/A/2	3	457	150	220	16.78	20	1118	0.29
Kw/A/3	3	457	150	220	16.04	10	1069	0.15
Kw/A/4	7	450	152	218	16.40	35	1093	0.51
Kw/A/5	7	449	152	220	15.45	30	1030	0.44
Kw/A/6	7	448	152	222	16.40	42	1093	0.62
Kw/A/7	14	450	152	221	15.82	25	1055	0.37
Kw/A/8	14	457	150	222	15.90	35	1060	0.51
Kw/A/9	14	445	152	223	16.03	25	1068	0.37
Kw/A/10	21	445	150	220	15.99	26	1066	0.39
Kw/A/11	21	450	150	223	16.10	32	1073	0.47
Kw/A/12	21	457	150	220	15.73	30	1048	0.44
Kw/A/13	28	448	152	222	15.95	20	1063	0.29
Kw/A/14	28	450	152	225	15.91	25	1061	0.37
Kw/A/15	28	455	154	218	15.75	20	1051	0.29

APPENDIX A - 10

DRY COMPRESSIVE STRENGTH DEVELOPMENT TEST

RESULTS FOR INDUSTRY D BLOCKS

Identification No	Age (dys)	Length (mm)	Breadth (mm)	Height (mm)	Weight (Kg)	Density (Kg/m^3)	Failure Load (KN)	Crushing strength (N/mm2)
Kw/B/1	3	457	152	218	16.79	1119	11	0.16
Kw/B/2	3	455	152	218	17.75	1183	30	0.43
Kw/B/3	3	457	152	218	15.53	1035	25	0.36
Kw/B/4	7	455	152	218	17.91	1194	30	0.43
Kw/B/5	7	450	152	218	16.14	1076	30	0.44
Kw/B/6	7	457	152	218	16.39	1087	35	0.50
Kw/B/7	14	455	151	230	16.55	1034	43	0.63
Kw/B/8	14	457	151	215	16.71	1114	20	0.29
Kw/B/9	14	457	152	218	16.25	1083	45	0.65
Kw/B/10	21	457	152	218	16.52	1102	30	0.43
Kw/B/11	21	457	152	218	16.21	1081	42	0.60
Kw/B/12	21	450	152	218	15.81	1054	25	0.37
Kw/B/13	28	457	152	225	16.56	1035	25	0.36
Kw/B/14	28	454	152	220	16.37	1091	30	0.43
Kw/B/15	28	457	152	225	16.32	1020	30	0.43

APPENDIX A - 11

DRY COMPRESSIVE STRENGTH DEVELOPMENT TEST RESULTS

FOR INDUSTRY E BLOCKS

Identification No	Age (dys)	Length (mm)	Breadth (mm)	Height (mm)	Weight (Kg)	Density Kg/m^3	Failure Load (KN)	Crushing strength (N/mm^2)
Kw/G/1	3	450	150	220	17.03	1135	10	0.15
Kw/G/2	3	447	152	218	17.66	1177	10	0.15
Kw/G/3	3	440	153	220	17.31	1154	10	0.15
Kw/G/4	7	446	152	216	16.50	1100	5	0.07
Kw/G/5	7	450	150	215	16.27	1085	10	0.15
Kw/G/6	7	445	152	220	16.60	1107	5	0.07
Kw/G/7	14	450	150	221	15.81	1054	15	0.22
Kw/G/8	14	448	150	220	16.79	1119	17	0.25
Kw.G/9	14	450	150	218	16.54	1103	10	0.15
Kw/G/10	21	450	150	215	16.34	1089	20	0.30
Kw/G/11	21	440	150	220	16.46	1097	10	0.15
Kw/G/12	21	441	151	223	17.43	1162	13	0.20
Kw/G/13	28	448	150	225	16.05	1070	10	0.15
Kw/G/14	28	450	150	220	17.19	1153	10	0.15
Kw/G/15	28	450	153	218	17.01	1134	10	0.15

APPENDIX A - 12

WET COMPRESSIVE STRENGTH DEVELOPMENT TEST RESULTS FOR

INDUSTRY A BLOCKS

Identification No	Age (dys)	Length (mm)	Breadth (mm)	Height (mm)	Weight (Kg)	Density Kg/m³	Failure Load (KN)	Crushing strength (N/mm²)
Kw/K/16	3	465	157	222	17.80	1113	30	0.41
Kw/K/17	3	465	157	225	18.55	1160	45	0.62
Kw/K/18	3	465	158	225	18.39	1082	30	0.41
Kw/K/19	7	465	158	225	17.08	1004	30	0.41
Kw/K/20	7	462	157	225	17.87	1117	35	0.48
Kw/K/21	7	465	157	Broken	on	site		
Kw/K/22	14	465	157	220	17.09	1068	30	0.41
Kw/K/23	14	466	158	220	18.24	1140	65	0.88
Kw/K/24	14	467	158	220	18.13	1133	42	0.57
Kw/K/25	21	463	157	225	17.89	1118	50	0.69
Kw/K/26	21	465	157	225	17.89	1052	30	0.41
Kw/K/27	21	463	158	225	17.45	1091	35	0.48
Kw/K/28	28	465	157	225	17.99	1124	45	0.61
Kw/K/29	28	465	157	215	17.60	1100	40	0.54
Kw/K/30	28	465	157	220	18.07	1129	50	0.68

APPENDIX A - 13

WET COMPRESSIVE STRENGTH DEVELOPMENT TEST RESULTS

FOR INDUSTRY B BLOCKS

Identification No	Age (dys)	Length (mm)	Breadth (mm)	Height (mm)	Weight (Kg)	Density Kg/m³	Failure Load (KN)	Crushing strength (N/mm²)
Kw/0/16	3	463	157	227	18.72	1101	15	0.21
Kw/0/17	3	462	158	227	19.17	1128	10	0.14
Kw/0/18	3	463	157	223	18.13	1067	13	0.19
Kw/0/19	7	462	157	225	18.39	1149	25	0.35
Kw/0/20	7	463	157	225	18.92	1183	10	0.14
Kw/0/21	7	B R O K E N						
Kw/0/22	14	458	158	225	18.97	1186	30	0.41
Kw/0/23	14	462	158	220	18.74	1171	25	0.34
Kw/0/24	14	461	157	225	18.53	1158	30	0.41
Kw/0/25	21	463	157	227	18.82	1107	20	0.28
Kw/0/26	21	462	159	226	18.68	1099	30	0.41
Kw/0/27	21	462	157	227	18.41	1083	25	0.35
Kw/0/28	28	463	160	225	19.10	1124	40	0.55
Kw/0/29	28	462	157	225	18.89	1181	35	0.48
Kw/0/30	28	462	158	226	18.68	1099	20	0.27

APPENDIX A - 14

WET COMPRESSIVE STRENGTH DEVELOPMENT TEST

RESULTS FOR INDUSTRY C BLOCKS

Identification No	Age (dys)	Length (mm)	Breadth (mm)	Height (mm)	Weight (kg)	Density Kg/m^3	Failure Load (KN)	Crushing strength (N/mm^2)
Kw/A/16	3	460	155	220	17.79	1112	15	0.21
Kw/A/17	3	460	154	225	18.04	1128	25	0.35
Kw/A/18	3	462	159	225	18.09	1064	20	0.27
Kw/A/19	7	460	157	225	17.62	1101	25	0.35
Kw/A/20	7	460	157	225	17.61	1100	25	0.35
Kw/A/21	7	460	158	225	17.67	1104	20	0.28
Kw/A/22	14	462	157	225	17.64	1103	30	0.41
Kw/A/23	14	460	158	225	17.20	1075	15	0.21
Kw/A/24	14	462	157	227	18.20	1138	30	0.41
Kw/A/25	21	460	157	225	27.55	1097	40	0.55
Kw/A/26	21	462	157	225	17.41	1088	25	0.35
Kw/A/27	21	460	157	225	17.91	1119	40	0.55
Kw/A/28	28	463	155	225	18.17	1136	40	0.56
Kw/A/29	28	457	157	225	17.82	1114	30	0.42
Kw/A/30	28	457	156	225	18.05	1128	35	0.49

APPENDIX A - 15

WET COMPRESSIVE STRENGTH DEVELOPMENT TEST

RESULTS FOR INDUSTRY D BLOCKS

Identification No	Age (dys)	Length (mm)	Breadth (mm)	Height (mm)	Weight (kg)	Density Kg/m^3	Failure Load (KN)	Crushing strength (N/mm^2)
Kw/B/16	3	462	158	222	18.10	1131	30	0.41
Kw/B/17	3	467	160	225	18.02	1060	40	0.58
Kw/B/18	3	465	157	232	18.45	1085	35	0.48
Kw/B/19	7	465	159	225	17.86	1051	50	0.68
Kw/B/20	7	465	159	230	17.54	1096	40	0.54
Kw/B/21	7	465	157	230	17.43	1025	40	0.55
Kw/B/22	14	464	158	230	17.06	1067	25	0.34
Kw/B/23	14	462	158	225	16.99	1062	35	0.48
Kw/B/24	14	455	157	230	17.83	1114	30	0.42
Kw/B/25	21	462	157	225	18.02	1126	20	0.28
Kw/B/26	21	463	158	235	17.10	1006	15	0.21
Kw/B/27	21	462	157	225	17.98	1124	15	0.21
Kw/B/28	28	465	158	230	18.15	1068	55	0.75
Kw/B/29	28	465	158	225	17.84	1049	55	0.75
Kw/B/30	28	465	156	230	18.35	1079	55	0.76

APPENDIX A - 16

WET COMPRESSIVE STRENGTH DEVELOPMENT TEST

RESULTS FOR INDUSTRY E BLOCKS

Identification No	Age (dys)	Length (mm)	Breadth (mm)	Height (mm)	Weight (kg)	Density Kg/m^3	Failure Load (KN)	Crushing strength (N/mm^2)
Kw/G/16	3	457	157	215	18.27	1218	7	0.10
Kw/G/17	3	453	157	218	19.61	1226	7	0.10
Kw/G/18	3	455	157	222	18.14	1134	5	0.07
Kw/G/19	7	455	157	225	18.26	1141	10	0.14
Kw/G/20	7	457	157	222	18.61	1163	20	0.28
Kw/G/21	7	455	160	220	17.01	1063	10	0.14
Kw/G/22	14	457	158	225	19.23	1202	30	0.42
Kw/G/23	14	457	157	222	17.98	1124	15	0.21
Kw/G/24	14	455	155	218	17.06	1066	15	0.21
Kw/G/25	21	452	157	222	17.67	1104	20	0.28
Kw/G/26	21	453	157	222	18.92	1183	20	0.28
Kw/G/27	21	455	155	225	17.52	1095	15	0.21
Kw/G/28	28	458	156	223	17.89	1118	25	0.35
Kw/G/29	28	455	157	225	18.85	1178	10	0.14
Kw/G/30	28	455	155	222	16.70	1044	15	0.21