THE SUITABILITY OF HUSKSCRETE BLOCKS AS CONSTRUCTION UNITS

BY

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DECLARATION

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

All sources of information are specifically acknowledged by means of references at the end of the thesis.



MUHAMMAD, Sulaiman Mahmud

December, 1992

D a t e

CERTIFICATION

AHMADU BELLO UNIVERSITY, ZARIA
DEPARTMENT OF BUILDING

This thesis entitled "THE SUITABILITY OF HUSKSCRETE BLOCKS AS CONSTRUCTION UNITS" by MUHAMMAD, Sulaiman Mahmud meets the regulations governing the award of Master of Science (in Construction Technology) of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This work is fondly dedicated to my brother, Alhaji Mahmud Turi Muhammadu for his kindness and brotherly encouragements.

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ABSTRACT

With the aim of developing construction units from the waste materials from agriculture, a study was made on how suitable Rice husks could be as an aggregate in Building blocks making.

As far as possible the properties of Rice husks as an aggregate were found. It has specific gravity of 1.27, water absorption 162 percent by weight and needs W/C of 0.65 to 0.95 to form a semi-dry mortar for block making.

Huskscrete blocks got from mixes such as 1:4 cement/Rice husks, 1:1.25 : 3.75 cement/sand/Rice husks were tested for crushing strength, average dry weight, density and water absorption. Their economics was high lighted in the cost analysis of $1M^3$ of mortar for different mixes of sandcrete and huskscrete blocks.

Blocks incorporating Rice husks attained average compressive strength of $1.8N/mm^2$ to $5.2N/mm^2$ at 28 days which is comparable to BS.6073 requirement.

To make Huskscrete blocks, more effective as construction units, certain measures were suggested. And the blocks are recommended for use in constructing load and non-loadbearing walls in Nigeria especially in areas having Rice husks in abundance.

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CHAPTER - ONE

I N T R O D U C T I O N

1.2 BACKGROUND

It must be recognised that housing is an essential human need; next to food in importance, and in unit cost basis, perhaps even more expensive than food.

In recent time, building a house has become too costly, and personal house ownership is almost beyond the average Nigerians. The most glaring reason is the expensive nature of building materials

Prices of building materials such as cement, reinforcing rods, roofing sheets, paints, timber, nails etc. as well as labour have risen considerably. Table 1.1 below shows the price comparison of 1986 and 1990.

TABLE - 1.1: Market Survey of Prices in 1986 and 1991 in Bida, Niger State

Material	Quantity	Prices in 1986	Naira (₦) 1991
Cement	50kg	13.00	53.00
Sand	$0.4m^3$	20.00	60.00
Nails	1 bag	35.00	280.00

That apart the ownership of a house has become difficult because of the existing trend in Nigeria as regard the new tastes in the production of buildings.

In most Nigerian cities traditional building is fast becoming a thing of the past, as new materials and technology are being imported into the country's building industry. New building materials, such as fibre glass, synthetic rubber / Asbestos roof sheets, wall tiling and mosaics as well as industrialised method of building fabrics formation are taken as modernity by Nigerians and even the policy makers. Hence local building materials and technology are relegated and are being abhorred.

The modern elites are the chief propagators of this new trend which is becoming the model for Nigerian populace.

This situation has made the country to be over dependent on imported materials, or on locally produced materials with high foreign input and thus high prices. The trend has brought along with it the gradual disappearance of traditional skills in building methods and making the problem to be more compounded.

With this development it is becoming almost impossible for average Nigerians to afford the most minimal low-cost housing constructed to acceptable standards with standard building materials.

To reverse the trend and to meet the massive needs for housing in Nigeria, building should no longer be limited to a number of standarised techniques based on the use of imported building materials. It should involve an understanding of the properties and characteristic of an increasing number of by-products from Agriculture, mining and industries which are in abundance and being wasted away. They could then be usec if appropriately proportioned with cementitious material, seasoned and strengthened or even burnt as the case may be, for construction of houses at a reduced cost.

Beside that there is also the need for the country to lay emphasis on adaptive research so that existing building techniques may be used more efficiently and new forms of construction may be developed to suit our own environment.

Therefore this research hopes to stop the burning of heaps of Rice husks as a means of disposable in Rice growing areas of the country. They will be of economic benefit if Building blocks can be produced from their use and an efficient means of disposal will be got.

1.2 OBJECTIVES OF THE RESEARCH

The housing problems in the country could be solved by methods which do not require heavy capital investment provided a spirit of communal service can be generated. Hence, if waste products from the economy can be harnessed to produce building materials by means of simple hand tools, the problems of shelter can be reduced to a great extend in Nigeria.

It is in the light of above, this research hopes to find out if Rice husks will be ingredient in the block making. Hopefully the research could further provoke more works on Rice husks utilisation for other building materials.

Specifically, the project is aimed at finding -

(a) The possibility of using Rice husks for the production of huskscrete block.

(b) a suitable sand/husks proportion for the production of building blocks.

(c) the cost effectiveness of blocks so produced.

1.3 SCOPE AND LIMITATIONS

The greatest limitations in research works in Nigeria are lack of sufficient equipment and the back-up infrastructure. The lack of competent technicians to work with the researcher is a major limitation. All these are apart from lack of enough funds.

These problems are the limitations in this research.

Another equally important limitation is the paucity of current and upto date technical journals, research works, latest standards, etc which the researcher requires for the research programme.

In the light of above, tests such as grading - sieve analysis, specific gravity and water absorption and bulk density were the ones carried out on Rice husks.

In the case of a Huskscrete blocks, the compressive strength, drying shrinkage, water absorption, dry weight, densities, thermal insulation and sound insulation were carried out.

1.4 METHODOLOGY

The behaviour of an aggregate depends on its properties. In the case of Rice husks the properties determined were specific gravity, water absorption, bulk density and grading by sieve analysis.

Nominal mixes of sandcrete cubes were first tried to determine the average compressive strength of each ratio. Thus 1:2, 1:3, 1:4, 1:5, 1:6 and 1:7 cement sand ratios was used.

Trial tests were also carried out on Rice huskscrete cubes and mix ratios of 1:2, 1:3, 1:4, 1:5, and 1:6 cement Rice husks ratios were used.

Based upon the trial tests further laboratory tests were carried out using the following mixes:

(a) Sandcrete blocks

The mix 1:5 cement: sand was used and all other works were based on this ratio.

(b) Rice huskscrete blocks

Using Rice husks exclusively as the aggregate the mixes of 1:3, and 1:4 cement : Rice husks was tested.

Varying the quantities of sand and Rice husks the following ratios were also used.

i) 1: 2½ : 2½ cement : sand : Rice husks.

This is equivalent to 50 percent sand and 50 percent Rice husks in the mix.

ii) 1: 1.25: 3.75 cement : sand : Rice husk. This is equivalent to 25 percent sand and 75 percent Rice husks.

iiii 1: 3.75 : 1.25 cement : sand : Rice husks which is equivalent to 75 percent sand and 25 percent Rice husks.

Steel mould of 460mm length x 150mm width x 230mm height was used for further laboratory test and manual block moulding method used.

A total of 40 blocks were produced for each mix, cured and crushed at the ages of 14 days and 28 days respectively taking 20 blocks at each age to determine the compressive strength.

It should be noted that the mixing of ingredients was done by tilting drum concrete mixer.

The results obtained from the block crushing strength tests were analysed to ascertain the average compressive strength, average dry weight.

Economics of blocks from Rice husks was shown by cost analysis of $1m^3$ of materials for sandcrete and Huskscrete blocks.

CHAPTER - TWO

LITERATURE REVIEW

2.1 FUNDAMENTALS OF SANDCRETE OR CONCRETE

The term building block normally refers to a walling unit larger in size than that of brick but small enough to be handled by the blocklayer with one or both hands. Concrete blocks, also termed concrete masonry unit (CMU), is made of a relatively dry mixture of cement, aggregate, water and often admixture. The cement is usually standard portland cement. The aggregate could be normal weight, light weight or heavy depending on the use.

(Punmia 1987) observed that "the face thickness of the hollow blocks should at least be 55 to 60 percent of the gross area". The cores in the blocks are at least two in number and should preferably be oval shaped.

(Eldridge 1974) gave the following possible compressive strength in (MN/mm^2) that can be attained by concrete blocks using the various aggregate as below.

Gravel : 13.5 - 42

Limestone : 13.5 - 42

Clinker : 2.0 - 7.0

Pulverised fuel ash : 2.75 - 55.0

Expanded clay : 2.0 - 62.0

Foamed slag : 2.0 - 24.0

Aerated;

air-cured : 0.5 - 5.5

autoclaved : 2.0 - 5.0

B.S 6073 requires the minimum compressive strength for concrete blocks to be 2.8N/mm^2.

The nominal dimensions of CMUS are composed of nearly any combination of the following, widths are 100, 150, 200, 250 and 305mm and lengths come in 200, 250, 305, 405 and 610mm. Generally a full block would be 405mm long and a half block 200mm long.

Concrete masonry blocks are manufactured in the following surface finishes;-

(a) Common finished surface

(b) Glazed finish

(c) Slumped finish

(d) Specially faced finish

(e) Coloured finish

Common finish surface has fine to coarse texture which can be obtained by varying the mix proportions and by using appropriate aggregates. If the exposure of the aggregates is required, it can be obtained either by treating the surface by dilute acid solution or by scrubbing it while concrete has not fully set.

Glazed finish is used for decorative work. It can be obtained in a manner similar to glazing of tiles. Glazed finish concrete blocks are water resistant. Slumped finish is the rough finish, which is obtained using the concrete of desired slump. When the forms are open, the blocks settle slightly, causing rough surface. In specially faced finish, finishing materials such as marble etc. is incorporated on the facing side of the block. Coloured finish can be obtained by mixing various pigments to the concrete mix.

However, in Nigeria most blocks are slumped finish.

2.2 BLOCK CLASSIFICATION

Sandcrete masonry units fall into four general classifications.

(a) Hollow loadbearing

(b) Solid loadbearing

(c) Non-loadbearing solid

(d) Non-loadbearing hollow.

The distinction between solid CMUS and hollow CMUS is that solid units must be 75 percent solid materials in any general cross section leaving a maximum of 25 percent of the gross area in cells or cores.

Solid blocks have no formed holes or cavities, other than slots for cutting. Cellular blocks have one or more cavities which do pass through and hollow blocks have one or more holes which do pass through. The external wall thickness must be at least 15mm or 1.75 x nominal minimum size of aggregate, whichever is the greater.

Concrete blocks are designed and made use of in all kinds of masonry construction, formed in a wide variety of shapes and sizes. Some of the uses are exterior and interior loadbearing walls, fire walls, party walls, curtain walls, panel walls partitions, backing for other masonry facing materials, fire proofing over structural - steel members, piers pilasters, columns, retaining walls, chimneys and fire places, concrete floor units, filters for ribbed concrete floors and patio paving unit.

2.3 MANUFACTURE OF SANDCRETE OR CONCRETE BLOCKS

Blocks are formed in machines with steel moulds; the mix in semi-dry form is consolidated by vibration and compaction. This permits accurately formed block and allows the moist mixture. Thus the moulds can be removed immediately after impact.

Commercial production is by a power driven automated machine with gang moulds that produce thousands of units each day.

The blocksare cured and dried. The tendency of the block to crumble, shrink and crack is deterred by curing. During the curing operation the blocks are kept moist so that setting and hardening is gradual. During the drying operation the moisture content is reduced to average air humidity, preventing the moisture of the block from being reduced by the surrounding air at the time of laying.

Curing and drying are accomplished in the open air. Most manufacturers in Nigeria use water to cure concrete blocks. The procedure consists of:-

(a) Laying the moulded blocks in an open space and

(b) Sprinkling or spraying water on the moulded blocks using water roses or hoses.

Where neither hoses nor roses are available water can be drawn in buckets and splashed on the blocks using the hands. Curing periods for blocks may vary from 7 to 28 days. This period may be shortened if rapid hardening portland cement is used.

The open-air procedure requires from two to four weeks.

The water must be clean and free from deleterious substance, acids or sugar.

According to (Punmia 1987), the following points should be kept in mind while manufacturing the concrete masonry blocks.

(a) The cement - aggregate ratio should not be leaner than 1:6.

(b) The aggregate should have a mixture of fine aggregate 60 percent and coarse aggregate (6 to 12mm size) 40 percent. The fineness modulus as the fixed aggregate should be between 2.9 to 3.6.

(c) Concrete should not have very lean consistency.

(d) Machine casting is preferable to hand casting, to obtain better finish.

(e) After taking the block out of mould, they should be kept under shade for at least 24 hours, and proper curing undertaken and the blocks may be stacked with cells horizontal.

(f) Blocks should be used only after about 3 to 4 weeks after curing.

(g) The compressive strength of blocks should not be less than 2.8N/mm^2 after 28 days curing.

(h) The blocks used for external walls should have absorption less than 10 percent. For internal walls, the absorption should be less than 15 percent.

2.4 SIZES OF SANDCRETE BLOCKS MANUFACTURED IN NIGERIA

The sizes of sandcrete blocks manufactured in Nigeria depend on the design requirements of the building. However, most local people mould concrete blocks without any regard to the load-bearing capacity of the walls. In this case, people base the size on trial and error previous experience and economy. Most of these locally made blocks are now hollow. (Ezeji 1984) observed that the sizes included such as:-

450mm x 100mm x 225mm

450mm x 125mm x 225mm

450mm x 150mm x 225mm

Commercially made blocks are available in sizes:

450mm x 225mm x 225mm (hollow or cavity)

450mm x 150mm x 225mm (hollow or cavity)

450mm x 113mm x 225mm (Solid and hollow).

TABLE 2.1: Sizes and Uses of Blocks Manufactured in Nigeria

Size	Description	Use(s)
450mm x 100mm x 225mm	Solid	Partition in storeyed buildings external wall in bungalows.
450mm x 113mm x 225mm	Solid	External walls in bungalows partitions in storeyed buildings. General walling purposes.
450mm x 150mm x 225mm	Hollow	For general purpose as external and partition walls in bungalows and storeyed buildings.
450mm x 225mm x 225mm	Hollow	For foundation walls in bungalows and storeyed buildings. For external walls in storeyed buildings.

Source: (Ezeji 1984).

2.5 MIXES OF MATERIALS FOR SANDCRETE BLOCKS

As is the case with their sizes, locally (individually) made blocks differ in their mixes and consequently in their strength, from commercially made blocks. Most local people use headpans and wheel barrows for measuring sand. Usually the strength of the mix is determined by the number of blocks desired from a mixture of some quantity of sand and one bag of cement. Consequently, some private block moulders often mould 30 to 32 blocks out of a mixture of sand and one bag of cement, whereas other people may mould as many as 48 or 50 blocks of the same size from the same quantity of cement. Cement used by individual block moulders is usually normal portland cement.

Commercial block moulding industries, however use procedures which are some what different from the local practice. For example, as observed by (Ezeji 1984) most concrete block industries use a mixture of 16 headpans or four wheel barrows of sand to one bag of cement. Others use a mixture of 12 headpans of sand to one bag of cement. One bag of cement is considered equal to two headpan measures.

It should be noted here that, while it is good practice to mix a certain quantity of cement,

by weight, with an appropriate quantity of sand, also by weight, most block moulding industries in Nigeria prefer to mix these materials by volume. Another important point to note is that most concrete block moulding industries in the country use the same mixture of sand and cement to produce different sizes of blocks.

2.6 MATERIALS USED IN THE MANUFACTURE OF SANDCRETE OF CONCRETE BLOCKS

The must common materials used in manufacturing concrete blocks in Nigeria are:-

Sand

Cement

Water.

Sand. River sand is used is used extensively in preference to other sources of sand, particularly the type of sand that is obtained on the ground surface along road sides or from drains. The reason for this is that sand obtained from river is already washed and, therefore, contains less silt and other impurities than sand collected from drains, which may need washing before use.

It should be noted that sand from quarry as well as from inland deposits serves also for making concrete blocks.

Cement. Normal portland cement is the commonly used by most private concrete block moulder and some sandcrete block manufacturers. However bigger block manufacturer and larger contracting companies usually uses rapid hardening cement because the shorter curing time helps them to meet the demands of their customers. Besides, limited space often dictates that faster setting cement be used for manufacture of concrete blocks.

Water. A major requirement of water used in manufacture of concrete blocks is that it should be free from salts and other impurities. To meet this requirement, concrete block manufacturers usually have pipe-borne water connected to their factory sites. In areas where pipe-borne water is not available, block manufacturers usually buy water tankers to collect water from rivers or from nearby taps. In other cases, block manufacturers buy large water containers which are filled for a fee by water tanker drivers. During the rainy season and particularly if river sand is used in block moulding, less water is needed for concrete block manufacture. In the time of rainy season the quantity of water used in mixing cement and sand ratio is reduced by about 50 percent. The same goes when curing the blocks (Ezeji 1984)

2.7 EQUIPMENT AND MACHINES USED IN THE MANUFACTURE OF SANDCRETE OR CONCRETE BLOCKS

Most concrete block manufacturing industries need all or some of the following tools, machines and equipment for their operations:

(a) Single and/or multiblock machines

(b) Mixers

(c) Wheelbarrows

(d) Shovels

(e) Headpans

(f) Plates (locally called "pilate" or pellet)

(g) Water tanks

(h) Water tankers

(i) Delivery vehicles

(j) Small barrels, tins and roses.

(k) Water hoses

(l) Trowels.

Machines: These are available in various makes and sizes. Some of these machines are manually operated. Others are either electrically or diesel operated. In addition, some of the block moulding machines only mould one block at a time, whereas others mould two or more blocks at a time.

Mixers: Mobile (portable) and heavy - duty, rotary drum mixers are available in the market.

However, a good number of block moulding factories use the portable mixers and some use no mixer at all. The parts of a mixer consist of a tilting drum; a tilt hand lever; a feed chute; and a hauling pole.

The use of mixers in mixing sand, cement and water ensures proper consistency of these materials.

Wheel barrows: Wheelbarrows are important to the concrete block industry for two reasons. Firstly, the wheelbarrows are used in transporting sand from its dump to the mixers or mixing platforms, secondly wheelbarrows are used by most concrete block manufactures for measuring the quantity of sand to be mixed with a given quantity of cement.

Shovels: Shovels are used in the concrete block industry to transfer sand from its dump into mixing drums or into wheelbarrows, and for turning (mixing) sand, cement and water, where mixers are not available.

Headpans: They are used in measuring sand, for transportation of water from water tanks or drums, and as water containers for washing the plates.

Plates: are wooden boards used in supporting the hollow blocks from the machines after moulding. Plates also assist in transportation of newly moulded blocks to curing locations. Usually plates are not removed until the blocks were cured.

Water tanks: Water tanks are available in a variety of shapes and sizes, and are used for storing water to be used in mixing block ingredients. Available sizes include tanks of 2330 litres or over, while the shape of the tanks are rectangular, square or circular in plan.

Water tankers: These are vehicles similar to these used in transporting petroleum, water tankers are used to collect water from the river or nearby taps. Water for block moulding can be purchased by manufacturers from tanker drivers and stored in water tanks or containers. Depending on proximity of the water source, tanker drivers sometimes charge as mush as ₦60.00 for every 2,300 litres measure of water.

Delivery vehicles: These are mainly large trucks or lorries with open bodies and no slats insides. Delivery vehicles are used for transporting moulded blocks to customers. Usually the responsibility for replacing blocks that got broken during transportation rests on the manufacturer.

Silos: These are airtight compartments used to preserve cement. Cement stored in silos remain for a longtime without deterioration. They can be ordered from cement manufacturers. Barrels and roses: In places where water tanks are not available, barrels or drums as well as tins are used for storing water. Roses consist of metallic containers that have long spouts the end of which are usually covered with a gauze-like piece of metal, through which water spread out. Roses are used where care has to be exercised in adding water, as during mixing, or when water should not be poured onto blocks with great force, for example, during curing.

Water hoses: Water hoses are used in transfering water from the water tanks into smaller containers like drums, tins or roses. Water hoses with nozzles are also available, and are used for sprinkling water on blocks during curing.

Trowels: Trowels are used by block manufacturers for scrapping off mixed cement and sand that may have adhered to the plates during the moulding or curing of concrete blocks.



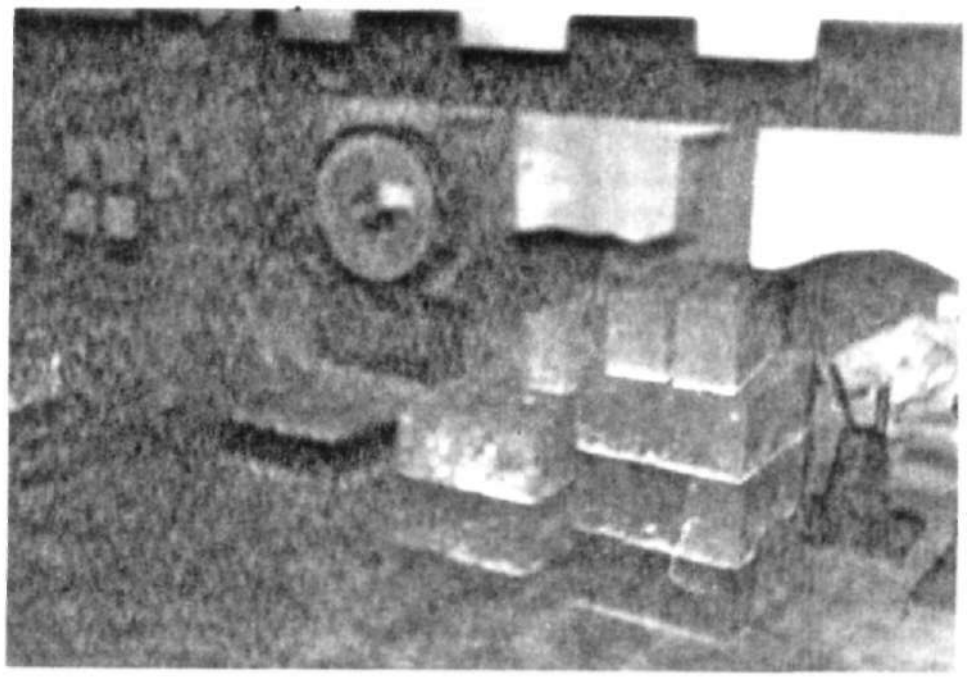


PLATE I: Equipment and Manufactured Blocks

2.8 PROPERTIES OF SANDCRETE OR CONCRETE BLOCKS

B.S 6073: Precast concrete masonry units, used in their usual aspect, exceed the length, width or height specified for bricks, have height not exceeding six times their thickness and do not exceed 650mm in any size direction.

Block heights of 215 and 290mm relate to three and four brick courses and a block 440mm long relates to two brick stretchers, all with 10mm joints.

Blocks can be laid more quickly than bricks. Generally, blocks are intended to be plastered or rendered, but many products, more particularly concrete blocks, are sufficiently regular in shape and size and otherwise of good appearance without plaster for walling.

Concrete blocks are generally termed either dense or lightweight.

2.8.1 Density

TABLE 2.2: Approximate Density Ranges are as given by (Everet 1984):

	kg/m^3
Gravel and limestone aggregates	2,000-2,400
Lightweight aggregates	720-2,000
Aerated	400- 800

B.S. 2028, 1364 (with drawn) related 625kgm^3 to strengths up to 7N/mm^2 and 1500kg/m^3 to strengths up to 35N/mm^2. However, density being no gurantee of strength.

2.8.2 Strength

B.S. 6073 requires average crushing strength for ten blocks not less than 75mm thick, to be not less than 2.8N/mm^2 and the strength for any individual block to be not less than 80 percent of the average. The average transverse strength of five blocks less than 75mm thick, which are deemed to be non-load-bearing, must be not less than 0.65N/mm^2. (Everete 1984) gives the minimum crushing strength for typical products.

TABLE 2.3: Minimum Crushing Strength Requirement as Per B.S. 6073 Part 1: 1981

	Concrete density (excluding voids) kg/m^3	Strength N/mm^2
Dense aggregate	1500 - 2,100	2.8 - 35
Light weight aggregate	700 - 1,500	2.8 - 10.5
Autoclaved aerated	400 - 900	2.8 - 7.0

Very low density blocks may require loads from joist hangers and similar point loads to be distributed.

Preliminary design block strengths for CP111 are: 2.8N/mm^2 for one and two storey houses; 3.5N/mm^2 for three storey houses flats and maisonettes and 5.0 - 7.0N/mm^2 for four storey flast and maisonettes. The higher strengths are proposed where opening sizes are larger than nromal. (Fisher 1974) observed that most lightweight concrete blocks have a crushing strength between 2.1N/mm^2, hollow blocks at the lower and solid blocks at the higher end of scale.

2.8.3 Drying Shrinkage

BS 6073 part 1: 1981 limits drying shrinkage to 0.06 percent generally, and to 0.09 percent for autoclaved aerated concrete blocks.

Shrinkage cracks in walls should be avoided by the use of block with low drying shrinkage; other measures of precaution as suggested by (Everett 1984); are:-

(a) Keep the blocks as dry as possible before and during construction and until construction is complete. If wetting is essential in very hot weather as little water as possible should be used.

(b) Use a mortar which contains no more portland cement than is required to resist possible freezing during block laying,

to suit loading or the exposure to be expected in service. A relatively weak mortar is able to accommodate the moisture movement of the blocks so that any hair cracks tend to form around individual blocks, and cracks through both joints and blocks are unlikely to occur.

(a) Avoid restraint, where possible, and provide movement joints at susceptible places such as between the heads and sills of superimposed windows, at charges in thickness or height and at intervals of not more than 8m in long walls. Movement joints are also required between concrete blocks and clay brickwork to allow for differential and possibly opposed movements of the different materials.

Joints may be filled with a resilient materials to within 13mm of the outside face and either sealed with mastics as the work proceeds, or left open until construction water has evaporated from the brickwork before pointed with mortar. Rigid fixings and renderings must not be carried over such contraction joints.

Shrinkage of interior walls can usually be accommodated by joints including polythene, building paper or similar seperators.

2.8.4 Thermal Movement

Thermal movement which is greater in gravel aggregate blocks than in lightweight aggregate and aerated blocks is not normally critical, except in conditions such as partitions below poorly insulated flat roofs. However, concrete blocks have the following thermal movements.

TABLE 2.4: Thermal Movement of Concrete Block as Given by (Everette 1984).

Materials	Coefficient of Thermal expansion x 10^{-6} per degc.
Concrete blocks of various aggregates	10 - 14
Aerated concrete blocks	8

The thermal conductivity of blocks varies mainly with density. Thus, K values (W/m degc.) are 1.10 - 1.75 for dense aggregate blocks 0.21 - 0.60 for lightweight aggregate blocks and 0.15 - 0.27 for autoclaved aerated concrete blocks (Everette 1984).

The second amendment to part F of the Building Regulations issued in 1982 requires a maximum U value of walls of dwellings of 0.6W/m^2 degc.

This standard can be met, even where one leaf of brickwork is employed, by using thicker and lighter blocks and by supplementary insulation outside, in the cavity and/or internally.

Expanded polystyrene filling in voids in blocks assists insulation.

2.8.6 Fire Resistance

Fire resistance is a property of an element; e.g walls, columns, floors, beams glazing and doors, and not of individual materials. It is expressed as the period of time in hours and minutes during which an element survives the tests laid down in BS 476: Part 8: 1972 while continuing to perform its normal structural or separating function. An element under test is deemed to have failed in the event of:

(a) Collapse

(b) The formation of holes or orifices in a separating element through which flames can pass.

(c) Excessive heat transmission through a separating structure likely to lead to the ignition of combastible materials in contact with the outer face. The mean temperature of the unexposed durface must not rise more than 140^{o}C,

or the temperature at any point more than 180°C above the initial temperature. (In the case of doors and glazing it is sometimes assumed that combustible materials will not be placed against them and this requirement is waived).

Elements are graded in standard periods of ½, 1,2,3,4 and 6 hours and a further grading of 1½ hours is recognised under the Building Regulations.

Fire resistance is good. Blocks with class 1 aggregates provide 2 hours fire resistance in unplastered 100mm walls.

Lightweight aggregate concrete blocks made with pumice, foamed blast-furnace slag, sintered pulverised fuel ash, expanded clay, well burned cinder and similar non-combustible aggregates have lower thermal movement than dense concrete blocks and retain a higher proportion of their initial strengths in fires (Foster 1979).

All crushed natural stones other than limestone including granite and gravel, consisting of flint and crushed quartzites, tend to break up and spall voilently and are the least reliable aggregates in common use.

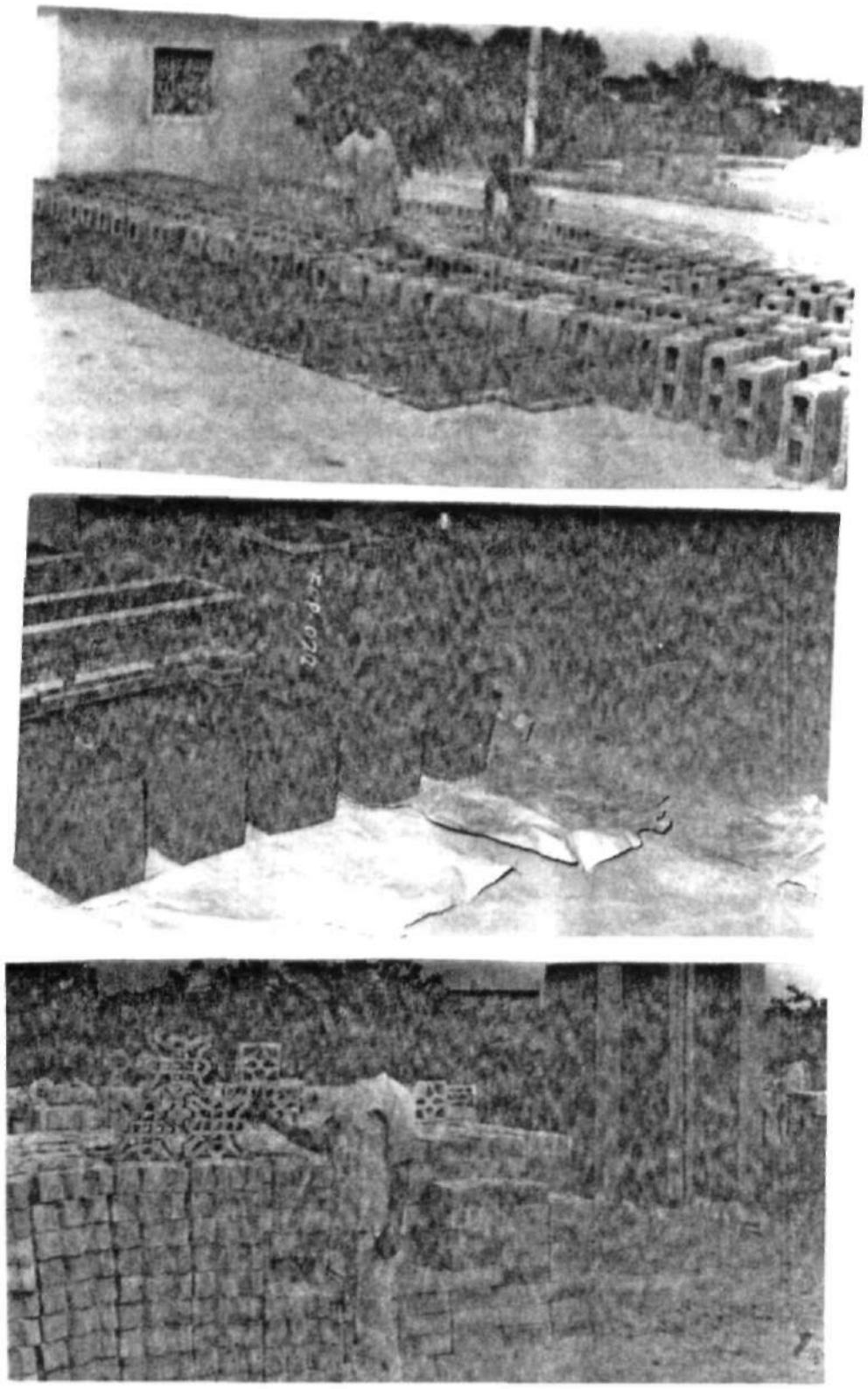


PLATE - II: Types of Blocks

2.8.7 Durability

Durability of factory made concrete products is generally very high.

(Everette 1984) observed that blocks made with dense aggregates complying with BS 882 or 1047, or having an average compressive strength of at least 7.0N/mm^2, or blocks for which manufacturers provide evidence of suitability, can be used for the external leaves of cavity walls above and below ground floor damp proof course.

An open textured blocks is less likely to suffer from frost attack than smooth blocks which may develop micro cracks.

2.8.8 Finishes and Appearance

The appearance of blockwork depends upon both the choice of blocks and mortar in terms of colours and textures, including the form of mortar joint. For good appearance, the bonding pattern and quality of workmanship are also important.

A wide range of surface tectures include 'as cast', sawn and split creating a rock-like appearance.

Tamped blocks of 1:4 cement-hull ratio were suitable for non-loadbearing structures. Compressive strengths meeting British Standards were obtained with 1:2 ratio, pressures of 50 to 150 P.S.I and size 127mm x 203mm x 305mm (Houston 1972).

2.10 CONCRETE MASONRY UNIT TESTING

A representative sample (six per 100,000) of full-size units is tested for compression, absorption, and dimension according to (Whitney Clark and Co. 1981). In the compression test the block is capped and compressed to determine its ultimate strength. The compressive unit force is calculated and recorded in N/mm^2. The absorption test requires immersion in water for 24 hours and periodic drying times. The building materials are weighed before and after immersion in the water. The moisture percentage absorbed and the moisture content of the CUM is calculated.

Thus blocks of good appearance need not be plastered or even painted, and the sound absorption of exposed open-textured blocks is good.

The manufacturers advice should be obtained as to the best procedure for plastering and rendering proprietary lightweight concrete blocks.

2.9 RICE HUSKSCRETE BLOCKS

According to (Houston 1972) incorporation of Rice husks or hull in building materials concerns such items as concrete blocks, bricks, tile, slate, and soft or hard panel board. Important aims have been to produce light weight concrete or brick and to provide higher insulating properties.

As reported further by (Houston 1972) "Feather-crete" was developed in Pakistan in the ratio of 3:1 cement-to-hull and had good insulating properties, but low strength. Possible decay of the hulls was also noted. Cement-rice hull panels in metal frames for house construction in lovisian met strength requirements but were too costly.

Despite the generally negative results, recent tests by the Tropical Products Institute London have yielded blocks that are suitable for erection of one-or two-storey buildings.









PLATE - III: Equipments for Manufactur[illegible]

CHAPTER - THREE

LABORATORY PROCEDURES

3.1 SELECTION OF MATERIALS

Rice huskscrete blocks is relatively made up of dry mixture of cement, sand, Rice husks and water. The cement and water combine chemically, forming a paste that sets and hardens, binding the aggregates into a rocklike mass.

3.1.1 Cement

Ordinary portland cement called "Sokoto .cement" was used for the research. It is manufactured by a cement industry in Sokoto.

Normal portland cement is a finely powdered, greyish material which consists chiefly of calcium and aluminium silicates. The common raw materials from which it is made are lime-stones, which provide cao, and clays or shales, which furnish Sio_2 and Al_2O_3. These are ground, tblended, fused to clinkers in a kiln, cooled and ground to required fineness. The material is shipped in bulk or in bags containing 50kg of cement. Four main components are basically present in the cement clinker and there are listed in Table 3.1.

TABLE 3.1: Main Constituents of Cement

Name of Compound	Abbrev-ration	Approxi-mate percent	Effect on Finished cement
Tricalcium silicate	C_3S	55	Produces much heat and early strength. A greater proportion in rapid-harddening cement than in low-heat cement.
Dicalcium silicate	C_2S	17	Slower hydration and less heat with later strength development.
Tricalcium Aluminate	C_3A	11	Rapid reaction without high heat production. Responsible for flash setting if gypsum omitted. Attacked by sulphates and so less is contained by sulphate resisting cements.
Tetra-calcium alumina ferrile	C_4AF	9	Acts as a flux in manufacture. Produces little heat or strength. Acts as a flux assisting the manufacturing stage.

Source: (Edwin Walker and Co. 1971).

3.1.1.1 Cement Action

The properties of cement depend partly on the presence of compounds as shown in Table 3.1.

C_3S is the principal active hydraulic compound of the cement and the early strength of cement is dependent almost entirely on C_3S. C_2S is slowly hydraulic especially in the B - form, but catches up with C_2S in strength and hydraulicity eventually. (Chong 1977) vividy showed this in graphic and is reproduced as below:

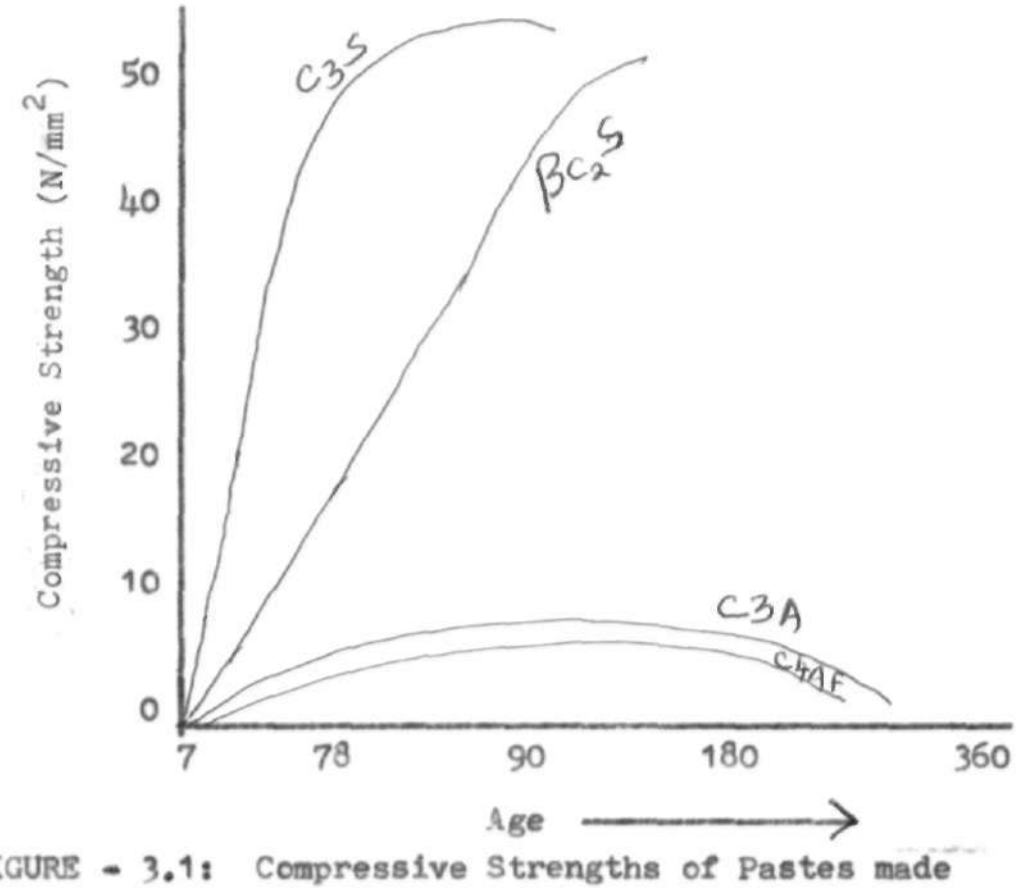


FIGURE - 3.1: Compressive Strengths of Pastes made from C_3S, BC_2S, C_3A and C_4AF

Source: (Edwin Walker and Co. 1971).

The hydration products of C_3S and C_2S are the tobermorite gel and calcium hydroxide. According to (Chong 1977) the fineness of the tobermorite particles, having a specific surface of the order or $300m^2/g$, other important engineering properties (such as strength,skrinkage, permeability and resistance to the stresses of freezing and thawing). Calcium hydroxide provides the alkaline medium which is beneficial for the protection against corrosion of reinforcing steels.

C_3A is rapidly hydrated with water with evolution of considerable heat, but the product has little cementing value.

C_3A in cement clinker is responsible for the flash setting of the cement on addition of water. In order to control this flash hydration, calculated amounts of gypsum ($CaSo_4.2H_2O$) of the order of 1 - 5 percent by weight of cement are added. This leads to the formation of an expensive compound - calcium sulpho-aluminate hydrate. The durability of concrete in sulphate water is therefore governed by the C_3A content.

C_3AF has also no cementing value. It hydrates in the same way as C_3A.

Hydration. The term "hydration" is used to include all reactions of cement with water, that is to say, to both true hydration and hydrolysis. (Chong 1977) gives that the cement components react with water as follows (abbreviated notations are used):

C_3S: $2C_3S + 6H - C_3S_2H_3 + 3CH$

tobermorite gel — calcium hydroxide

C_2S: $2C_2S + 4H - C_3S_2H_3 + CH$

C_3A: $C_3A + 6H - C_3AH_6$

Calcium aluminate Hydrate (stable)

C_3A + gypsum + water - Calcium sulphoamide

$(3C_9O \cdot Al_2O_3 \cdot 3C_9SO_4 \cdot 31H_2O)$

"Ettringite" (an expansive compound)

C_4AF ($C_6A_2F - C_6AF_2$): $C_4AF + 2CH + 10H$ -

$C_3AH_6 + C_3FH_6$

Ferrite hydrate

C_4AF + gypsum + water --

Calcium sulphoaluminate + calcium sulphoferrite.

TABLE 3.2: Hydration of Cement Components (Chong 1977)

Types of reaction	Heat of hydration (KTIkg)	Rate of reaction (80% hydration) Time (days)
$C_3S + H_2O$	504	10
$C_2S + H_2O$	252	100
$C_3A + H_2O$	869	-
C_3A + gypsum + H_2O	1365	-
$C_3A + H_2O + C_9(OH)_2$	840	6
$C_4AF + H_2O + C_9(OH)_2$	420	50

Setting and hardening. When water is added to cement to form a cement paste, this gradually changes with time from fluid to a rigid state. The term "setting" is used to describe this stiffening state. Once set, the cement paste gradually develops strength and forms a hard mass. This is referred to as "hardening".

3.1.1.2 Tests on Cement

Owing to the complex nature of Potland cement, strigent of the cement produced. Therefore various tests are carried out on cements grouped into chemical tests and physical tests.

Chemical Tests (BS 12, 4550). Chemical tests are based on the gravimetric determination of the following oxides: C_9O, S_1O_2, Al_2O_3, Mgo, K_2O, $N_{92}O$. The cement sample is digested in an acid solution, followed by selective precipitation and ignition into the oxides.

Physical Tests

The following physical tests are carried on cement.

Strength (BS.12). Portland cement hardens by a chemical action when mixed with water.

Hardened specimens are tested after specified curing periods. Two standard methods exists of testing the compressive strength of cement: the cement mortar test and the concrete test.

In the mortar test, a 1:3 cement and sand mortar with a water/cement ratio of 0.4 is used. 70.7mm cubes are made, each cube requiring a mix proportion of 0.185kg cement, 0.555kg sand and 0.074kg water. They are compacted on a standard i vibrating table for two minutes at a frequency of 200 hertz (vibrating for second).

The cubes are kept moist for 24 hours before demoulding and immersed in water at room temperature until tested in a wet condition.

In the concrete test, 101mm cube moulds are used. Each cube is made by mixing 0.325kg of cement, 0.195kg of water (corresponding to a water/cement ratio of 0.60) and an appropriate amount of fine and coarse aggregates (i.e sand and crushed stone) so as to give a workable concrete with a slump of 12.7 - 50.8mm. The cubes are curred tested in a wet condition as in the mortar test.

Fineness: Fineness is measured in terms of specific surface, which is the total surface area of all the particles per unit mass of cement (kg/m^2).

The method described in the British standards is the air-permeability method developed by lea and Nurse and it is based on the relationship between the flow of air through a layer of cement and specific surface of the particles (BS 12).

Another test is a sieve test. A sieve test is conducted to determine the fineness of cement. This test is carried out by sieving, for 15 minutes, 0.110kg of portland cement on a BS No. 170 sieve (0.09mm mesh).

The residue was not more than 10 percent which is okay.

Setting time: Two stages of setting are arbitrarily chosen - the initial set (corresponding to a rapid rise in temperature when cement and water are mixed) and the final set (corresponding to the peak temperature obtained).

In the test for setting time the time for a neat cement paste of standard consistency to reach the two defined conditions of stiffness is determined by periodically checking the penetration of a needle into it. The vicat apparatus is used for this. It has three attachments.

(a) A cylinder plunger, 10mm in diameter with a flat end. This is used to establish the amount of water needed to produce a cement paste of standard consistency.

(b) A needle of square or round-section with a cross-sectional area of $1mm^2$. This is used to determine the initial setting time.

(c) For final setting time a needle of the same cross-section with a sharp bell shaped attachment 5mm in diameter is used. The sharp rim of this attachment is 0.5mm above the end of the needle.

In the determination of setting time of cement using the vicat apparatus.

Neat cement is filled into the mould at strike-off level. The mould is placed on the glass plate under the rod carrying the plain needle. The needle is lowered gently until it comes in contact with and pierces the specimen completely. The needle is released. This operation was repeated at intervals of about 20 to 30 minutes until the needle is incapable of penetiating the specimen.

The period that elapses from when water was first added to when needle cannot penetrate the specimen completely, but settles at a given distance above the base of the mould was 44 minutes. And this is the initial setting time.

In determining the final setting time the plain needle is replaced with the one fitted with the metal attachment that is shaped to give a cutting edge.

The final setting was reached when the needle has made an impression in the cement but the rim of the metal attachment does not. The final setting time is attained in nine hours.

Soundness: According (Ezeji 1984) if the cement is unsound, it means that it contains impurities liable to react chemically with moisture (water). Such chemical reactions may lead to expansion which can cause cracking and disintegration of moulded and set cement.

Unsoundness in cement may be attributed to the existence of exccess calcium, aluminium or sulphate compounds.

There are two methods of testing for soundness of cement;

(a) By boiling

(b) By use of the Le chatelier apparatus.

Boiling test, 0.450kg of cement with just sufficient water to make it into a paste was taken. It is moulded into a 75mm square pat, 25mm thick, on a glass plate.

After the final set, the pat is boiled in water for an hour. The boiled mould did not soften or crack thus the cement is sound.
Le chatelier method. The apparatus looks like a split-ring mould with pointers attached to it. It works on the principle that the width of the split in the mould increases if the cement expands.

Other apparatus for the test were cement, ruler, vaseline, two glass plates and a weight.

Vaseline was applied thinly inside the mould and on the glass plates to reduce the surface tension between the mould and cement paste. The edges of the mould is kept together.

The mould was placed upon a small piece of glass or metal and fill with cement paste which has standard consistency.

The split is closed temporily by gentle pressure between two fingers.

The mould is covered with the second glass plate and a weight put on it.

The distance between the pointer ends was measured to be 0.4mm thus okey.

The mould with the specimen is placed in warm water at 15°C for 24 hours. Bring the mould out and measure the distance between the pointer and the mould after left immersed in warm water.

The water was heated to reach the boiling point in 27 minutes.

The mould is then submerged with the specimen in the water and boiled for 60 minutes. The specimen was allowed to cool in the water and after it has been brought out another measurement of the distance between the pointer ends was taken.

The difference between the first and last measurements was 8mm, thus the cement is sound,

3.1.2 Sand

The natural sand obtained from inland deposits was used. It is normally referred to as sharp, or coarse, sand. It is an inert mineral filler that

occupies 70 - 75 percent of the total volume of a sandcrete blocks and 30 - 75 percent of Rice husks concrete blocks.

Sand is a natural sediment made up mainly of silcon compounds in granular form which are the products of rock weathering. It is gritty with no real plasticity. The particles normally range between 0.06mm and 2.00mm in diameter (Ezeji 1984).

3.1.2.1 The Role of Sand in Sandcrete and Rice husk-screte Blocks

Sand is dispersed throughout a cement paste and, when the cement sets and hardens it become part of a cohesive mass. The sand limits the strength of blocks, as weak aggregate cannot produce strong sandcrete blocks or Rice husks-crete blocks. Its properties greatly affect the durability and structural performance of blocks.

Sand is used in the blocks for any of the reasons stated below:
Economy. Sand is cheaper than cement and may be regarded as an extender.
Durability. Incorporation of a suitable sand increases the resistance of the product to weathering and abrasion.
Volume-stability. Sand restrain the amount of shrinkage.

According to (Edwin Walker and Morgan 1971) a larger aggregate permits the use of a leaner mix of concrete and mortar and so reduces the drying shrinkage. For a given mix strength (water/cement ratio) an increase in the aggregate proportion reduces the shrinkage. The expansion on setting is also reduced by the presence of sand.

Adjustment of density. Sand present in blocks makes possible for the production of blocks of adequate density.

Special characteristics. With the use of sand in the blocks requirements such as the thermal insulation, acostic, fire resistance, appearance, colour, and texture of the blocks are modified.

3.1.2.2 Tests on Sand

Sand for building purposes should be clean and free from excessive silt and chemical impurities, well graded and not too fine or desty. The sand should be examined before use and if, when rubbed between fingers, it tends to stain the hands, a field test should be conducted to determine its suitability for building purposes.

Field setting test

For doubt to be cleared as regard the cleanliness of the sand a settling test was carried out.

About 50mls of a solution of common salt in water (1 teaspoonful to 0.5 litre of water) is placed in a 250ml B$. Measuring cylinder. Sand is added gradually until the volume of sand become about 100mls. The volume was made up to 150ml by addition of more salt solution. The mixture is well shaken up and the clylinder placed on a level surface and gently tapped until the sand is levelled. After 3 hours the silt settles out on top of the sand and is expressed as a percentage of the height of the sand itself.

The amount of clay and silt was 6 percent. And according to BS 882 the percentage should not exceed 8 percent. Therefore the sand used was clean.

Bulking test

Dry sand and saturated sand have approximately the same volume. Damp sand however will show a considerable increase in volume. (Sam Smith 1978) state that increase in volume of sand is most marked when the water content is 5 percent to 10 percent of the dry weight, when the increase in volume may be as mush as 30 percent. This phenomenon is known as 'Bulking' and is more pronounced in fine sand.

For the test, the damp sand was poured into the measuring cylinder until it is about two - third full. The depth of the sand was measured as H = 180ml. The sand is removed onto metal tray.

The measuring cylinder is then half filled with water and the sand replaced i carefully. Tamping rod was used to ensure that no air bubbles were tapped.

The depth of this saturated sand is measured as h = 150ml. And percentage of bulking found.

$$\text{Percentage of bulking} = \frac{H - h}{h} \times 100$$

$$= \frac{180 - 150}{150} - \frac{30}{150} \times 100$$

$$= 20 \text{ percent.}$$

Grading

The proportions of the different sizes of particles is known as the grading of an aggregate which is usually expressed as percentages by weight passing various sieves conforming to BS 410: 1976. Test sieves i.e 75, 63, 37.5, 20, 14, 10, 5, 2.36 and 1.18mm, 600, 300 and 150mm.

Conventionally, aggregate which is mainly retained on a 5mm BS sieve (eg natural gravel and crushed gravel and stones) is called coarse aggregate and aggregate which mainly pass through a 5mm sieve is called fine aggregate.

(Everette 1984) observed that aggregates are often described by their maximum size with the qualification 'down', meaning that they contain appropriate proportions of the smaller sizes.

BS 882: 1973 coarse and fine aggregate from natural sources gives grading limits for the various particle sizes. Fine aggregate gradings are given in four zones.

TABLE 3.3: Grading Zones for Fine Aggregate (BS 882)

Test sieve mm	Percentage by weight passing BS Sieves			
	Grading Zone 1	Grading Zone 2	Grading Zone 3	Grading Zone 4
9.52	100	100	100	100
4.76	90 - 100	90 - 100	90 - 100	95 - 100
2.40	60 - 95	75 - 100	85 - 100	95 - 100
1.20	30 - 70	55 - 90	75 - 100	90 - 100
0.600	15 - 34	35 - 59	60 - 79	80 - 100
0.300	5 - 20	8 - 30	12 - 40	15 - 50
0.150	0 - 10	0 - 10	0 - 10	0 - 15

In a well graded aggregate the various sizes of particles interlock, leaving the minimum volume of voids to be filled with the more costly cement. The particles also flow together readily, i.e the aggregate is workable, reducing labour in placing mortar for blocks and enabling a lower water: cement ratio to be used.

The procedure for determining the grading of an aggregate is given in BS 812: 1975. It is termed sieve analysis and involves sieving the aggregates through a nest of standard BS sieve (BS 410) and calculating the percentage by weight passing the various sieves.

The sieves were arranged in order of size pacing the sieve pan on the botton and the largest mesh sieve on the top.

350g of sand was weighed and placed on the top of the nest of sieves.

Sieves were shaken very throughly to ensure that finer particles get down through larger sieves. In this exercise all particles of approximately the same size were deposited on a given layer of a sieve.

The quantity of sand deposited on each sieve is weighed and recorded as the percentage of the total sample.

TABLE 3.4: Result of Sieve Analysis

BS Sieve	Weight retained (g)	Percentage retained	Cumulative (Percentage retained)	(Percentage passing)
9.52mm	0	0	0	100
4.76mm	0	0	0	100
No.7 2.40mm	18.00	5.1	5.1	94.9
No.14 1.20mm	100.1	28.6	33.7	66.3
No. 25600Um	189.0	54.0	87.7	12.3
No. 52300Um	30.6	8.7	96.4	3.6
No. 100 150Um	6.0	1.7	98.1	1.9
Passing No.100	6.3	1.8	99.9	0.1
TOTAL	350			

From the grading zones for fine aggregate (BS 882) as produced in Table 3.3, the grading of the sand used for the research is approximately Grading Zone 1.

A57600

3.1.3 Rice Husks or Hulls

As a by products of Rice, the husks is discrete finely divided material.

(Grist 1972) observed that Rice husks constitute about one-fifth the weight of the total Rice products. This figure, however, vary with variety of Paddy, its age and moisture content and with the degree of milling and polishing.

Further observation by (Grist 1975) as regard hulls are that they are valueless as food, not only because of their low nutritive value, but because of their high silicon content renders them harmful to the digestive and respiratory organs of animals.

Analysis of Rice husks is given as follows in percentage.

TABLE 3.5: Analysis of Rice Husks

Constituent	Percentage
Moisture	9.02
Crude protein	3.27
Fats	1.18
Carbohydrates (by difference)	33.71
Crude fibre	35.68
Ash	17.40

Source: (Grist 1975)

Nigeria has the challenging problem of utilisation or disposal of this low-value by-product within the framework of our economic structure. (Houston 1972) said that use or disposal has frequently proved difficult because of the tough, woody abrasive nature of the hulls, their low nutritive properties, resistance to weathering, great bulk, and high ash content.

3.1.3.1 Tests on Rice Husks

Colour, Size and shape: The hulls of most Nigerian Rice varieties are straw or gold in colour, and weather to a greyish brown.

Rice husks have lengths of about 5mm and below and occured as boat-shaped particles.

(Houston 1972) observed that as with other organic materials, hulls absorb or lose moisture and tend to come into equilibrium with the relative humidity of the surrounding air.

Bulk density: The bulk density of a material is the weight of the material held by a container of unit volume when filled or compacted under defined conditions. It is normally expressed in kg/m^3 (murdock and Blackledge 1968).

Bulkdensity is used to convert quantities by weight to quantities by volume.

The bulk density clearly depends on how densely the aggregate is packed, and it follows that for a material of a given specific gravity the bulk density depends on the size distribution and shape of particles: argued (Neville 1981).

The actual bulk density of aggregate depends not only on the various characteristics of the material which determine the potential degree of packing, but also on the actual compaction achieved in a given case. Compacted bulk density of Rice husks; The test was performed in metal cylinder. The container is filled in three stages using a scoop, each third of the volume being tamped 25 times with a 16mm diameter round-nosed rod. The overflow was removed. The nett weight of the Rice husks in the container found and with the known volume of the metal cylinder the bulk density was derived. The resultswere as follows:

Weight of metal container = 1.6kg

Weight of container + Rice husks = 2.9kg

Weight of Rice husks = 1.3kg

Volume of metal container = $0.003225m^3$

$$\text{Bulk density} = \frac{\text{weight of Rice husks}}{\text{volume of metal container}}$$

$$= \frac{1.3}{0.003225} = 403.10077$$

$\therefore$ Bulk density of Rice husks = $403kg/m^3$.

Specific gravity: Specific gravity expresses the number of times 'heavier' the material is than water, for equap volumes of the two. For this reason it is sometimes referred to as the relative density.

According to (Adams 1975) the term specific gravity is defined by the following formulae:

(a) Specific gravity = $\frac{\text{Mass of a volume of material}}{\text{Mass of an equal volume of water}}$

or

(b) Specific gravity = $\frac{\text{density of material}}{\text{density of water}}$

Determination of specific gravity of Rice husks using the Gas jar method.

The apparatus used was a gas jar, 1 litre capacity, fitted with a rubber stopper; a glass plate for closing the gas jar; precision balance; and a thermometer.

Neat dried gas jar was weighed as W_1
0.150kg of Rice husk was placed in the gas jar and weighed as W_2.

About 500ml of water was added to the Rice husks in the jar. The rubber stopper is then insert and the jar was agitated for 20 minutes.

The stopper was then removed and any Rice husks adhering to the stopper or the upper part of the gas jar was washed carefully into the jar. Additional water was introduced into the container to the brim and the contents allowed to settle for 20 minutes.

The ground glass plate was placed on top of the jar taking care ■ not to trap any air bubble. The gas jar and plate outside were dried and the whole weighed as W_3

The contents of the gas jar were replaced wholly by water after being throughly cleaned. With the full water to the brim of the jar and carefully -placed glass plate on top and dried on the outside the contents was weighed W_4.

The procedure as above was repeated for the third time running. The experimental room temperature was 24°C. The results are as follows:

Weight of gas jar + ground glass plate W_1 = 0.680kg

- II - - II - + ground glass plate + Rice husks W_2 = 0.830kg

Weight of gas jar + glass pate + husks + water W_3 = 1.842kg

Weight of gas jar + plate + water W_4 = 1.810kg

From the expression $G_S = \frac{W2 - W1}{(W_4-W_1) - (W_3-W_2)}$

The specific gravity $= \frac{0.830 - 0.680}{(1.810-0.680) - (1.842-0.830)}$

$= 1.27.$

∴ The specific gravity of Rice husks = 1.27.

Water absorption: Rice husks is a highly porous material. The porosity, permeability, and absorption, influence such properties of aggregate as the bond between it and the cement paste, the resistance to abrasion and chemical stability.

When all the pores in the aggregate are full it is said to be saturated and surface - dry. If aggregate in this condition is allowed to stand free in dry air, e.g in laboratory, some of the water contained inn the pores will evaporate and the aggregate will be less than saturated, i.e air-dry. Prolonged drying in an oven would reduce the moisture content of the aggregate still further until, when no moisture whatever is left, the aggregate is said to be bone - dry.

The water absorption of aggregate this time Rice husks was determined by measuring the increase in weight of an oven-dried sample when immersed in water.

Rice husks was allowed to suck for 24 hours and the surface water removed.
The following results were got:-

Weight of oven - dry Rice husks = 0.195kg

Weight of Rice husks after being sucked in water and surface dried = 0.510kg

Weight of absorbed water = 0.315kg

$$\text{Absorption rate} = \frac{0.315}{0.195} \times \frac{100}{1} = 161.53846$$

Water absorption of Rice husks by weight

= 162 percent

Grading: The proportions of the different sizes of particles is known as the grading of an aggregate which is usually expressed as percentages by weight passing various sieves conforming to BS : 410 1976.

The sieve analysis was carried out by shaking the Rice husks on a series of sieves.

Test sieves were 9.52mm down to 150Um. The sieves were arranged in order of size placing the sieve pan on the botton and the largest mesh sieve on the top.

350g of Rice husks was weighed and placed on top of the nest of sieves.

The lid is fitted and manually vibrated throughly for 20 minutes, and the material retained on each sieve and on the pan weighed.

The result is as below.

TABLE 3.6: Result of Sieve Analysis of Rice Husks

BS Sieve	Weight retained (g)	Percentage retained	Cumulative Percentage retained	Cumulative Percentage passing
9.52mm	0	0	0	100
4.76mm	0	0	0	100
No. 7 2.40mm	10,8	3.1	3.1	96.9
No.14 1.20mm	9.0	2.6	5.7	94.3
No. 25 600Um	289.1	82.6	88.3	11.7
No. 52 300Um	30.6	8.7	97.0	3.0
No.100 150Um	4.3	1.2	98.2	1.8
Passing No. 100	6.2	1.8	100.0	0
TOTAL	350			

From the grading zones for fine aggregate (BS : 882) as produced in Table 3.3, the grading of the Rice husks for the research is approximately in zone 1.

Fuel value and thermal conductivity: (Houston 1972) gave the fuel value as 3,300 to 3,600 Kcal. per kg. These values are nearly one-half that for bituminous coal. Hulls as reported further by (Houston 1972) burn at 800° to 1,000°C.

Conduction is the direct transmission of heat through a material. (Burberry 1983) observed that the rate of conduction, i.e conductivity, depends partly upon the density of the material.

Metals have a high conductivity, wood has low, and gases have even less conductivity.

(Innocent 1977) defines Thermal conductivity, K, (W/M degc) of a solid material as the quantity of heat conducted through a cross-sectional area of $1m^2$ to depth of 1m in one second, if the temperature differential between the faces is maintained at 1 degc.

Values of K determined by fieger and co-workers is reported by (Houston 1972) for Rice husks in various thicknesses and is produced in Table 3.7 below.

TABLE 3.7: K Values for Rice Husks in various Thicknesses

Thickness (mm)	K Values (W/Mdegc)
25	0.034804
50	0.046032
75	0.058576
100	0.074312
125	0.083902

Source: (Houston 1972)

3.1.4 Water

Water acts as lubricant for the aggregates and acts chemically with the cement to form the binding paste for the aggregate.

For complete hydration of a given amount of cement, according to (H. Riisch 1979), an amount of water equal to about 25 percent of that cement, by weight is needed chemically. (George 1979) said further that an additional 10 to 12 percent must be present, however, to provide mobility for the water in the cement paste during the hydration process so that it can reach the cement particles. And (Everette 1984) observed that water for hydration of cement is about 4.7 litres per 50kg for portland cement and 0.5 litres for high - alumina cement.

The major requirement for water used in manufacture of cencrete blocks and curing is that it should be free from salts and other impurities.

To meet this requirement, pipe - borne water for drinking was used for the research works.

The water was used in sufficient quantity to make the mass of mortar for blocks workable.

3.2 MANUFACTURE OF RICE HUSKSCRETE BLOCKS

3.2.1 Trial Mixes

Trial mixes were used to determine the optimum strength obtainable as regard the arbitrary ratio to be adopted.

The mixes considered were:-

(a) Sandcrete cubes. Cement/sand ratios used were 1:2, 1:3, 1:4, 1:5, 1:6 and 1:7.

(b) Huskscrete cubes. Cement/Rice husks ratios used were 1:2, 1:3, 1:4, 1:5, and 1:6.

The unit weight of cement and sand are taken as 1,440kg/m^3 and 1,600kg/m^3 respectively. For Rice husks the unit weight is 403kg/m^3.

In making sandcrete blocks the required mixed material is semi-dry mortar. The semi-dry state was reached by gradual addition of water and calculating the total amount used.

During the laboratory tests the water/cement ratio arrived at were:-

Sandcrete blocks W/C = 0.5 and

Rice-huskscrete blocks W/C = 0.9.

Sandcrete cubes.

Mix 1:2. Cement : Sand

This implies one part of cement to two parts of sand by weight. The mix can be described as ½ cement : 1/1 sand.

Therefore the mix becomes 0.5 cement : 1 sand.

Cement quantity.

0.5 x 1140kg/m^3 = 720kg/m^3

Volume of 1 cube = 0.15x0.15x0.15

= 0.003375m^3

Volume of 10 cubes = 0.03375m^3

∴ Quantity of cement required for 10 cubes

= 24.3kg

Add 10% for waste = 2.43kg

Total = 26.73kg

Sand quantity.

0.03375m^3 x 1600kg/m^3 = 54kg

Add 10% for waste = 5.4kg

Total = 59.4kg

Water quantity.

W/C = 0.5, W = 0.5 x 26.73 = 13.365

Water = 13.4kg

Mix 1:3, Cement : Sand

Cement quantity = 17.82kg

Sand quantity = 59.4kg

Water quantity = 8.91kg

Water = 8.91kg

Mix 1:4, Cement : Sand.

Cement quantity = 13.4kg

Sand quantity = 59.4kg

Water quantity = 6.7kg

Mix 1:5, Cement : Sand.

Cement quantity = 10.7kg

Sand quantity = 59.4kg

Water quantity = 5.4kg

Mix 1:6, Cement : Sand.

Cement quantity = 9kg

Sand quantity = 59.4kg

Water quantity = 4.5kg

Mix 1:7, Cement : Sand.

Cement quantity = 7.5kg

Sand quantity = 59.4kg

Water quantity = 3.7kg

Water = 3.7kg

Rice-huskscrete cubes.

Mix 1:2, Cement : Rice husks

Cement quantity

0.5 x 1440kg/m^3 = 720kg/m^3

Quantity of cement required for 10 cubes

= 24.3

Add 10% for waste 2.43

Total = 26.73kg

Rice husks quantity

$0.03375 \times 403 kg/m^3$	=	13.6
Add 10% for waste	=	1.36
Total	=	14.96 kg

Water quantity

W/C = 0.9, W = 0.9 x 26.73

Water = 24kg

Mix 1:3, Cement:Rice husks

Cement quantity	=	17.8kg
Rice husks quantity	=	15kg
Water quantity	=	16kg

Mix 1:4, Cement : Rice husks.

Cement quantity	=	13.4kg
Rice husks quantity	=	15kg
Water quantity	=	12kg

Mix 1:5, Cement : Rice husts.

Cement quantity	=	10.7kg
Rice husks quantity	=	15kg

Water = 9.6kg

Mix 1:6, Cement : Rice husks

Cement quantity	=	8.9kg
Rice husks quantity	=	15kg
Water quantity	=	8.0kg

3.2.1.1 Mixing

In the trial tests, mixing was done manually on a steel plate, 2m x 2m in size. Sand and cement as well as Rice husks and cement as the case may be in appropriate proportions were mixed first in a dry state. The ingredients were mixed thoroughly with the help of shovels. The predetermined amount of water was then sprinkled over the mixes. The masses were turned till the colour of mortar obtained was homogeneous and semi-dry mix result.

It should be noted here that unlike concrete where workable mix is determined mortar for blocks should be semi-dry mix.

3.2.1.2 Casting of Cubes

Using the cube moulds (150mm) (10), in number mould oil, Tamping bar (380mm) long, 25mm square ramming face, (weight 1.8kg), Trowels, matting or sackcloth, polythene sheets, curing tank, mixing trays, measuring cylinder (500ml) and balance the cubes were made.

Prepared mixes one at a time were placed in oiled moulds and base plate.

Moulds in layers of approximately 50mm deep were filled. Each layer was compacted 35 times with the tamping bar. level was strike off.

The moulds were labelled and covered with damp matting and then with polythene sheet and allowed to stand for 24 hours.

After 24 hours the specimens were removed from moulds, and immersed in water tanks until air bubbles ceased to rise.

The specimens were placed in polythere bags for 5 days and allowed to air-dry until they are 7 days up to 30 days old from placing in the moulds.

Tests for compressive strength were conducted at 7 days, 14 days and 30 days as the case may be.

A summary of the compressive strength test performed on different mixes are show in table 3.8.



PLATE - V : Crushing Test

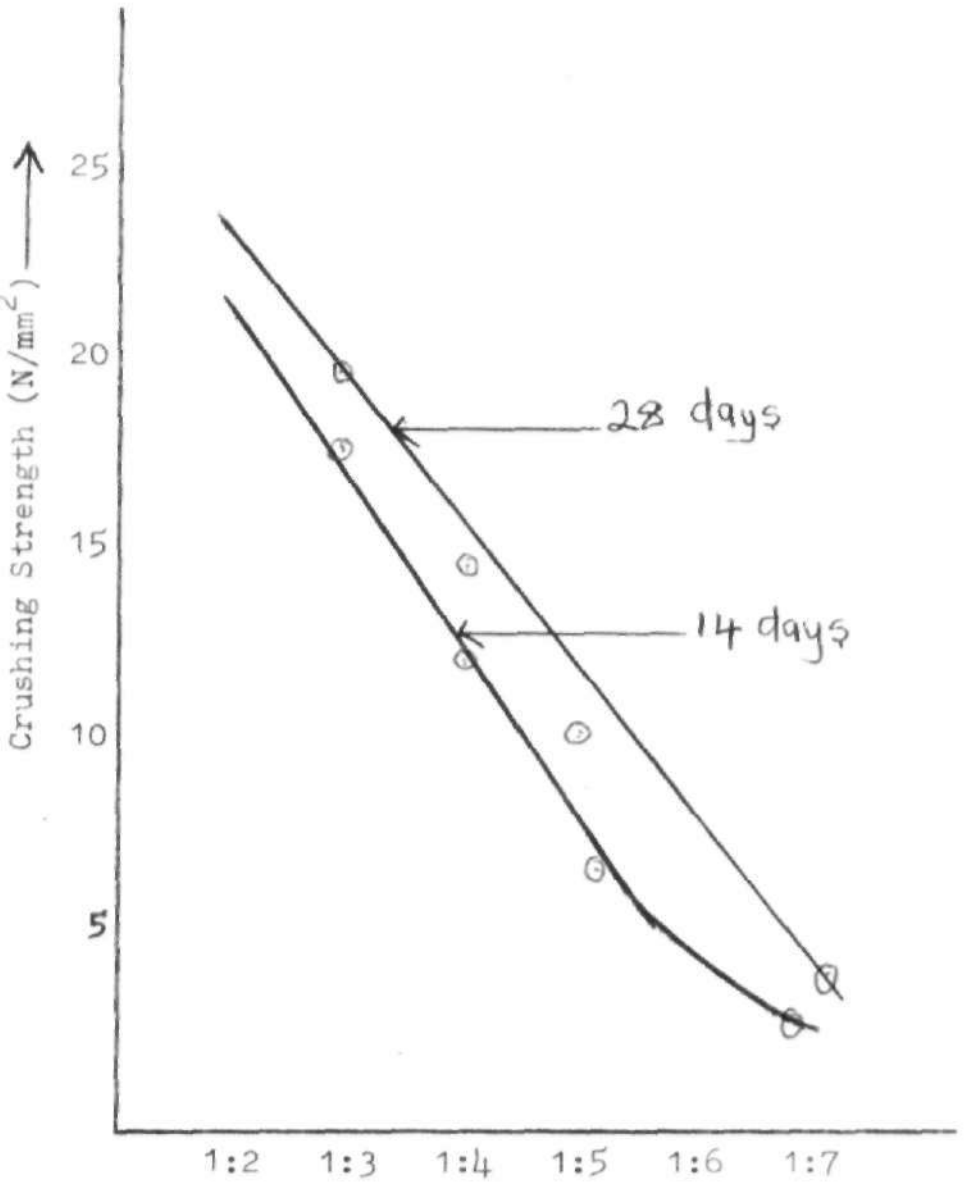


FIGURE - 3.2: Relation Between Compressive Strength and Mixes of Various Proportions for 150mm Sandcrete Cubes

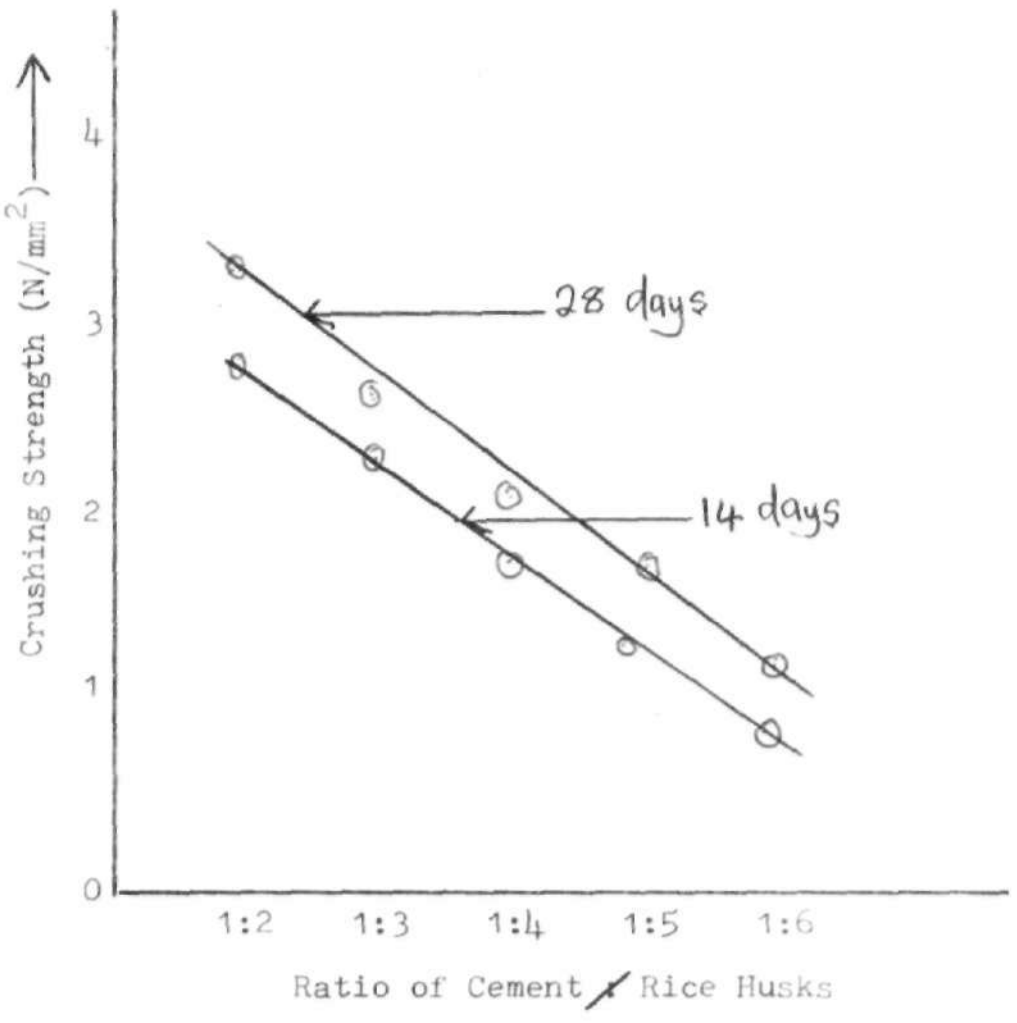


FIGURE - 3.3: Relation Between Compressive Strength and Mixes of BVarious Proportions for 150mm Rice-huskscrete Cubes

TABLE 3.8: Average Compressive Strength for the Trial Tests

(a) Sandcrete Cubes

Mix Proportion by weight	Average dry weight (kg)	Average Compressive Strength	
		14 days (N/mm^2)	28 days (N/mm^2)
1:2	7.6	21.11	23.33
1:3	7.4	17.15	19.12
1:4	7.2	10.47	13.37
1:5	6.8	5.11	6.30
1:6	6.7	4.64	5.59
1:7	6.5	3.20	4.10

TABLE 3.9: Average Compressive Strength for Rice Huskscrete Cubes

Mix Proportion by weight	Average dry weight (kg)	Average Compressive Strength	
		14 days (N/mm^2)	28 days (N/mm^2)
1:2	3.8	2.9	3.3
1:3	3.4	2.3	2.5
1:4	2.5	1.6	2.0
1:5	2.5	1.0	1.6
1:6	2.3	0.7	1.0

3.2.2 Moulding of Blocks

3.2.2.1 Proportioning

The arbitrary method was adopted. The combined aggregate should be dense and should have least voids.

The unit weight of cement, sand and Rice husks are 1,440kg/m^3, 1,600kg/m^3 and 403kg/m^3 respectively.

For sandcrete blocks W/C = 0.5 and
that of Rice husks W/C = 0.9

For varying quantities of sand and Rice husks ratios W/C ranges from 0.65 to 0.8.

The detailed laboratory tests involves the following ratio:-

Sandcrete block

1:5 cement : sand mix

Huskscrete blocks

1:3 cement : Rice husks

1:4 cement : Rice husks

1:2.5 : 2.5 cement : sand : Rice husks

1:1.25 : 3.75 cement : sand : Rice husks

1:3.75 : 1.25 cement : sand : Rice husks

Sandcrete blocks

Mix 1:5 Cement : Sand

This is one part of cement to five part of sand by weight. The mix can be described as 1/5 : 1, which is equivalent to 0.2:1.0.

Cement quantity

$0.2 \times 1440 = 288 kg/m^3$

Volume of solid block = $0.46 \times 0.15 \times 0.225$

= $0.015525 m^3$

Volume of hollow = $0.155 \times 0.65 \times 0.225$

= $0.002266875 m^3$

Volume of hollow block = volume of solid block less

Volume of hollow = $0.0132581 m^3$

Volume of 1 block = $0.0132581 m^3$

Volume of 40 blocks = $0.530324 m^3$

Quantity of cement required for 40 blocks

= $288 kg/m^3 \times 0.530324 = 152.73331$

cement required = 152.73

Add 10% for waste = 15.273

Total 168.003kg

Sand quantity

quantity of sand for 40 blocks

= 0.530324×1600

= 848.5184

Sand required = 848.5

Add 10% for waste = 84.85

Total = 933.35kg

Water quantity

W/C = 0.5, W = 0.5 x 168.003

Water = 84kg.

Huskscrete blocks

Mix 1:4 Cement : Rice husks

Cement quantity

0.25 x 1440 = 360kg/m^3

Quantity of cement for 40 blocks = 360x0.530324

Cement required = 190.917

Add 10% for waste = 19.0917

Total = 210.0087kg

Rice husks quantity

Quantity of Rice husks for 40 blocks

403 x 0.530324 = 213.72057

Rice husks required = 213.7

Add 10% for waste = 21.37

Total = 235.07kg.

Water quantity

W/C = 0.9, W = 0.9 x 210.0087

water required = 189kg

Mix 1:3 Cement : Rice Husks

Cement quantity = 280.0kg

Rice husks quantity = 235.1kg

Water quantity = 252kg

Mix 1:2.5 : 2.5 Cement : Sand : Rice husks

This is one part of cement to two and half parts of sand to two and half parts of Rice husks. Measured by weight. This gives 50% sand and 50% Rice husks of the total weight of aggregates.

Quantity of materials for 40 blocks gives total volume of $0.530324m^3$.

Absolute volume = $\frac{\text{weight of the material}/m^3}{\text{specific gravity}}$

Cement = $\frac{1440 \times 1}{3.1}$ = 465L

Sand = $\frac{1600 \times 2.5}{2.6}$ = 1538.5L

Rice husks = $\frac{403 \times 2.5}{1.27}$ = 793.3L

Water = $\frac{1440 \times 0.7}{1}$ = 1008L

Total absolute volume = 3804.8L

= $3.81m^3$

Quantity of materials for $1m^3$ of mortar for Huskscrete blocks

Cement = $\frac{1440 \times 1}{3.81}$ = 378kg

Sand = $\frac{1600 \times 2.5}{3.81}$ = 1050kg

Rice husks = $\frac{403 \times 2.5}{3.81}$ = 264.4kg

Water = $\frac{1440 \times 0.7}{3.81}$ = 264.6kg

Quantity of material for $0.530324m^3$ of mortar for huskscrete blocks.

Cement	=	378 x 0.530324	= 200.5kg
	Add 10% for waste		= 20.05
		Total	= 220.55kg
Sand	=	1050x0.530324	= 556.8
	Add 10% for waste		= 55.68
		Total	= 612.48kg
Rice husks	=	264.4x0.530324	= 140.22
	Add 10% for waste		= 14.022
		Total	= 154.242kg.
Water	=	264.6x0.530324	= 140.32

Water = 140kg.

Mix 1: 1.25 : 3.75 Cement : Sand : Rice husks

Cement	=	234.6kg
Sand	=	325.9kg
Rice husks	=	246.3kg
Water	=	170.7kg

Mix 1: 3.75 : 1.25

Cement = 204.9kg

Sand = 853.7kg

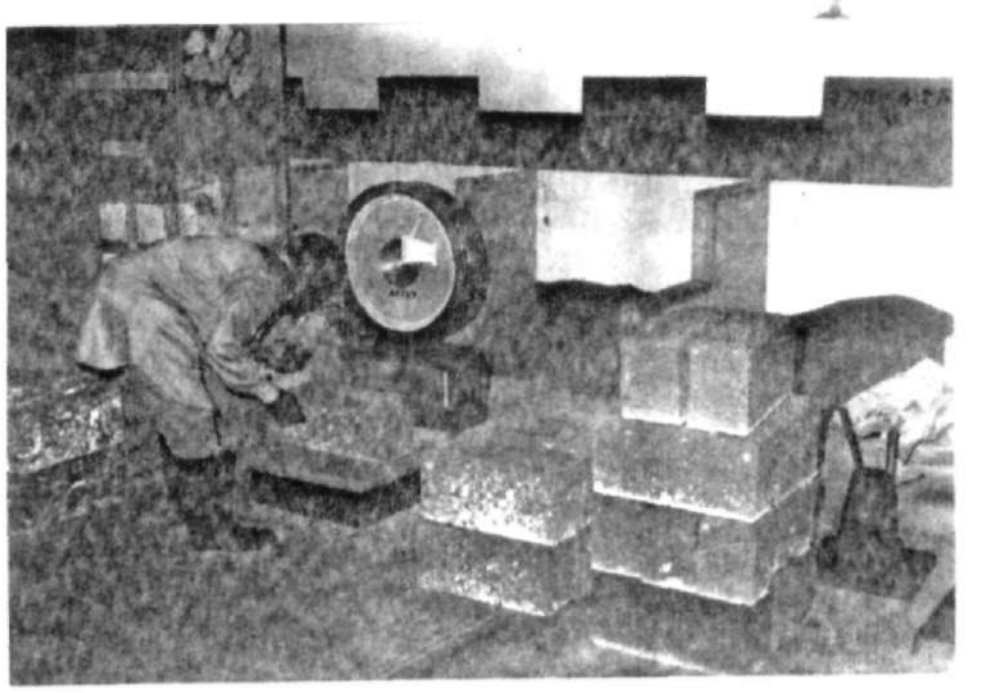
Rice husks = 71.72kg

Water = 12kg

The quantity of mixing water is higher in Huskscrete mix because of the absorptive nature of Rice husks.

TABLE 3.10: Quantity of Materials for Sandcrete and Huskscrete Blocks 40 in Number Respectively

Size of Blocks	Mixes by weight	Cement (kg)	Sand (kg)	Rice husks (kg)	Water (kg)
460x150x230mm	1:5	168.003	933.35	-	84
	1:3	280	-	235.1	252
	1:4	210	-	235.1	189
	1:2.5:2.5	220.55	612.4	154.242	140
	1:1.25:3.75	234.63	325.93	246.3	170.7
	1:3.75:1.25	204.9	853.71	71.72	121



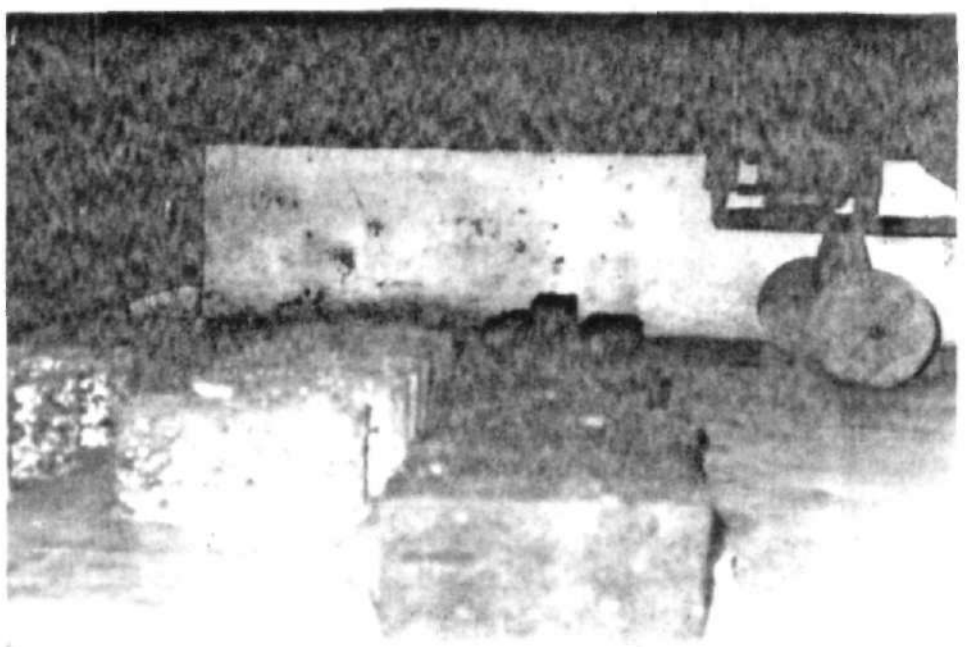


PLATE - VI: Hollow Rice Huskcrete block

3.2.2.2 Mixing

For the laboratory test for blocks Tilting drum mixer was used for mixing. It consists of a pear-shaped drum open only at the narrow top end and revolving on a tilting axis which permits the drum to be tilted in one direction for loading into the open end, and in the opposite direction for discharging the batch of mixed mortars. Blades are fixed to the inside of the drum and mixing takes place as they repeatedly pick up the materials and drop them to the bottom of the drum as it revolves.

The aggregate required for producing blocks was first placed and two-thirds of the water required for each batch of the mortar mix was added and mixed for about two minutes to obtain a surface-dry saturated aggregate. A calculated amount of cement was then added and the mixing was done in this semi-dry state for about two minutes. The remaining amount of water was finally added and mixing continued for another two minutes.

3.2.2.3 Moulding of Blocks

Simple steel mould, size 460 x 150 x 230mm for manual hollow blocking casting was used and it produces one block at a time.

The process involves filling the steel mould with the mortar, lifting and dropping it to attain partial consolidation. Further compaction is effected by tamping with wooden batten, size 50 x 50 x 200mm. The extra material is striked off and the green block is then de-moulded, i.e the block is cast and the steel mould lift free vertically.

The following precautionary measures were taken to ensure good moulding;

(i) the steel mould is oiled after three casts

(ii) the mould was filled in three equal layers and each layer tamped 25 times with steel rod

(iii) the removal of steel mould was done with a steady hand so as to avoid collapse of fresh blocks or cracks within

(iv) approximately levelled surface was used for casting.

3.2.2.4 Curing

After the blocks were moulded, they were kept under shade for 24 hours and then immersed in water tank for one week. The blocks were then stacked with cells horizontal to allow for a thorough dry before use.

CHAPTER - FOUR

TEST RESULTS AND DISCUSSION

4.1 PROPERTIES OF RICE-HUSKSCRETE BLOCKS

The blocks produced were tested for their compressive strength, drying shrinkage and water absorption.

4.1.1 Compressive Strength

B.S 6073 requires average crushing strength for ten blocks not less than 75mm thick, to be not less than 2.8N/mm^2 and the strength for any individual to be not less than 80% of the average. Everett (1981) state that preliminary design block strengths for CP 111 are : 2.8N/mm^2 for one and two storey houses; 3.5N/mm^2 for three storey houses, flats and maisonettes and 5.0 - 7.0N/mm^2 for four storey flats and maisonettes.

According to Fisher (1975) most lightweight concrete blocks have a crushing strength between 2.1N/mm^2 and 5.5N/mm^2, hollow blocks at the lower and solid blocks at the higher end of scale.

TABLE 4.1: Average Crushing Strengths of Products of this Research

(a) Sandcrete blocks

Mix proportion by weight	Average dry weight (kg)	Average Compressive Strength	
		at 14 days (N/mm^2)	at 28 days (N/mm^2)
1: 5	15.2	5.11	6.30

TABLE 4.2: Rice - Husksecrete Block

Mix proportion by weight	Average dry weight (kg)	Average Compressive Strength	
		at 14 days (N/mm^2)	at 28 days (N/mm^2)
1:3	8.9	2.3	2.8
1:4	8.2	1.3	1.8
1:1.25:3.75	13.0	3.3	3.8
1:2.5:2.5	13.8	3.7	4.3
1:3.75:1.25	14.1	4.4	5.2

The blocks crushed were placed with the smooth faces in contact with the upper and lower plates of the crushing machine. For proper contact another piece of metal plate was placed on the blocks upper surfaces. The load was then applied gradually until blocks collapsed.

The loads registered on the machine at the time of fracture points were recorded and compressive strength computed from:

Load failure (N)

Surface area (mm^2)

Average of each mix was then found.

4.1.2 Thermal Conductivity

The thermal conductivity of blocks varies mainly with density. Houston (1972) found that the thermal conductivity of Rice huskscrete blocks varied from 0.06 to 0.16 with average close to 0.14 compared with 1.10 - 1.75 for dense aggregate blocks.

Everett (1981) stated that the second amendment to part F of the Building Regulations issued in 1982 requires a maximum V value for walls of dwellings of $0.6W/m^2$ degc.

4.1.3 Drying Shrinkage

Due to their porous nature, Rice husks expand on wetting and contract on drying.

The Rice-huskscrete blocks have volume changes in the range of 0.09 to 0.1 percent.

4.2.4 Water Absorption

The water absorption of Rice-huskscrete blocks was found and compared with other Building materials.

The standard procedure was used, using apparatus such as curing tank, a balance, a clock.

Materials were weighed dry, fully immersed in water, and time taken in water noted. At given intervals of time the materials after removal from water were wiped with cloth, weighed and the test continued.

The following results were got.

The results indicates that the materials takes in water in large quantities in short times and the absorption reduces after sometimes and becomes zero.

Rice huskscrete blocks were more water absorbing.

The result is summarised in Table 4.3 below.

TABLE - 4.3: Results of Water Absorption Test

Material	At start	After 10mins.		After 20mins.		After 30mins.		After 40mins.		After 50mins.	
	weight (kg)	weight (kg)	inc. (kg)	weight (kg)	inc. (kg)	weight (kg)	inc. (kg)	weight (kg)	inc. (kg)	weight (kg)	inc. (kg)
Rice husks block	9.65	11.35	1.7	13.35	2.0	14.35	1.0	15.15	0.8	15.35	0.2
Concrete	7.8	7.9	0.1	7.95	0.15	8.0	0.2	8.01	0.21	8.02	0.22
Hollow Block	7.7	8.2	0.5	8.23	0.35	8.25	0.55	8.58	0.58	8.3	0.6
Ceramic Block	12.80	12.82	0.02	12.85	0.05	12.86	0.06	12.86	0.06	12.86	0.06

4.2 COST ANALYSIS

The cost analysis aims at bringing out the economic benefit or otherwise in the use of Rice-huskscrete blocks.

Using the leanest possible mix of sandcrete blocks the cost of producing satisfactory Rice-huskscrete was compared.

All the prices used were based on the market survey carried out in Bida, Niger State as at 2nd January, 1990. The Rice-husks is almost a free material and it is not cost.

4.2.1 Cost of Producing $1m^3$ of Mortar for Hollow Sandcrete Blocks, Mix 1:5, Cement : Sand

Material:

$1m^3$ cement 1440kg	= 28.8bags at ₦42.00	
	=	1209.60
$5m^3$ sand : ₦40 lorry	= ₦100 per m^3	
	=	500.00
Unloading 28.8bag at ₦0.30 per bag		
$7m^3$	=	8.64
		1718.24
$m^3 = \frac{1718.24}{6m^3}$	=	286.37
Add 25% void	=	71.60
Add 10% waste	=	28.673
		386.643

Labour: Producing blocks with a bag of cement at ₦3.50 per bag = 100.80

$1m^3$ = ₦487.443

4.2.2 Cost of producing $1m^3$ of Mortar for Hollow Rice-huskscrete Blocks 1:4 Cement : Rice husks Mix

Materials:

$1m^3$ cement as before	=	1209.60
$4m^3$ Rice husks almost free	=	50.00
Unloading Bags of cement as before	=	8.64
$5m^3$		1268.24
m^3 = $\frac{1268.24}{5m^3}$	=	253.65
Add 25% void	=	63.41
Add 10% waste	=	25.37
		342.43
Labour: as before	=	100.80
$1m^3$	=	₦443.23

4.2.3 Cost of Producing 1m of Mortar for Hollow Partial Rice huskscrete Blocks 1:1½:3 Cement : Sand : Rice husks Mix

Materials

$1m^3$ cement as before	=	1209.60
$1.25m^3$ sand : ₦40 lorry load = ₦100 per m^3	=	125.00

3.75m^3 Rice husks almost free	=	50.00
Unloading Bags of cement as before	=	8.64
6.0m^3	=	N1418.24
m^3 = $\frac{1418.24}{6.0}$	=	236.37
Add 25% void	=	59.10
Add 10% waste	=	23.64
		319.11
Labour : as before	=	100.80
1m^3	=	N419.91

From the cost analysis the cost advantage that could be gained in the partial use of Rice husks if not in the wholly use is seen.

The saving in the cost when large scale project is undertaken will be very much be appreciated.

However national instrinct for survival and self reliance makes it imperative for the country to develop its own resources, no matter at what cost.

4.3 DISCUSSION

4.3.1 Rice Husks Aggregate

Rice husks as an aggregate is lighter in weight when compared to normal weight aggregate such as crushed stone, gravel and sharp sand. This is indicated in the specific gravity. For Rice husks it is 1.27, while for gravel it ranges from 2.5 to 3.0.

It has higher water absorption of about 162 percent by weight which is much greater than that of gravel or sand. Neville (1981) observed that sand and gravel holds very much less water, has a less variable moisture content, and generally causes fewer difficulties.

The grading from sieve analysis of Rice husks indicates much quantity in the finer range. Therefore more quantities in the 300Um and 600Um sizes. This could be the reason for greater water absorption capacity.

The gross water cement ratio ranged from 0.65 to 0.95.

4.3.2 Huskscrete Blocks

Compressive strength

Average dry weight of huskscrete is 11.5kg compared to sandcrete block of 15.2kg.

Huskscrete blocks attained the compressive strength range of 2.8N/mm^2 to 5.2N/mm^2 at 28 days. This strength range meet up with B.S 6073 average crushing strength requirements as stated in 4.1.1 and as also observed by Fisher (1975) that "most lightweight concrete blocks have a crushing strength between 2.1N/mm^2 and 5.5N/mm^2, hollow blocks at the lower and solid block at the higher end of scale.

Density

Huskscrete blocks were compacted by hand pressure using wooden batten and water cured. The average density of Huskscrete blocks is 867.4kg/m^3. Which falls in the range for lightweight aggregates blocks as well as aerated blocks. See Table 2.3.

Though the results showed that Huskscrete blocks are suitable for building load and non-load bearing walls, the manufacture of hollow blocks was found to require comparatively greater skill than that of sandcrete blocks.

Other disadvantages of Huskscrete blocks were the likelihood of cracking at the junction of shell and web, and a greater number of rejects in the green state. When moulding.

The blocks are easier cut and sawn than sandcrete blocks.

CHAPTER - FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

(a) Rice-huskscrete blocks meet up with the minimum requirements of strength and other standards. Therefore they could be used for building load-bearing and non-loadbearing walls. Putting the statement further;

The wholly Rice huskscrete blocks can be used for the internal non-loadbearing walls especially if formed solid.

The partially Rice huskscrete blocks can be used as loadbearing external walls.

(b) Walls built of Rice huskscrete blocks will provide much more thermal insulation than bricks and sandcrete blocks walls since the thermal conductivity of Rice huskscrete blocks is less than that of the two latter masonry units.

(c) The moulding of Rice-huskscrete blocks was found to require comparatively greater skill than that of sandcrete blocks.

(d) Due to its high water absorption Rice-huskscrete will have low resistance to weather and impact.

(e) Mucor formation was noticed on the surfaces of Rice-huskscrete blocks, thus the possibility of decay may not be ruled out.

(f) The Rice huskscrete blocks can be easily and conveniently nailed and cut with saw than sandcrete blocks.

5.2 RECOMMENDATIONS

(a) The wholly hollow Rice huskscrete blocks should be used for the internal non-loadbearing walls. For loadbearing internal walls solid huskscrete blocks can be used.

Uses could also be found in areas such as single leaf and cavity walls, linning and curtain walls and infill panels.

(b) The poor crushing strength of Rice huskscrete blocks can be compensated for by introduction of sand in the mix rather than by increasing the quantity of cement, i.e. richer mix which would increase the drying shrinkage.

So that:-

i) 25% sand with 75% Rice husks

ii) 50% sand with 50% Rice husks

iii) 75% sand with 25% Rice husks,

are mix ratios for the purpose of improving in crushing strength.

Building blocks produced with these ratios can be used for loadbearing and non-loadbearing, internal and external walls.

However further tests need to be carried out to confirm the use of Rice husks mixed together with sand as aggregates for Building blocks.

(c) Walls built with Rice huskscrete blocks should be plastered with cement/sand mortar of 1:3 mix both sides for adequate wall requirements such as weather resistance, fire resistance and to obviate any suggestion of decay or mucor formation.

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STANDARDS

1. BS 12, 1978 - Portland Cement

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