EFFECT OF CEMENT: LATERITE RATIO ON THE COMPRESSIVE STRENGTH OF CEMENT-STABILIZED LATERITE BLOCKS.

BY

DURUCHUKWU, LAMBERT I.S.
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A PROJECT REPORT

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CERTIFICATION

This is to certify that this project was carried out by Duruchukwu Lambert I. S. in the Department of Agricultural Engineering, Federal University of Technology, Minna.

21.08.03

Dr. D. Adgidzi — Date

Supervisor

Dr. D. Adgidzi — Date

Head of Department

External Examiner — Date

DECLARATION

The effect of cement/laterite ratio on the compressive strength of cement – stabilized laterite blocks is a project carried out by me.

I declare that all the tests and experiments contained in this work were actually carried out. Acknowledgement and references of all published and unpublished works of other authors were also carried out.

LAMBERT I.S. DURUCHUKWU

PGD/AGRIC.ENGR./2000/2001/130

JANUARY, 2003.

DEDICATION

This project work is dedicated to my grandmother Late Madam Elizabeth Nwaemume Duruchukwu whose love for knowledge fired my desire to proceed with this course.

ACKNOWLEDGEMENT

I wish to thank the Almighty God for the life he gave me to be able to complete this work. My thanks also go to Dr. D. Adgidzi who is both my Head of Department and project Supervisor. I am also indebted to the entire academic Staff of the Department of Agricultural Engineering of the Federal University of Technology, Minna.

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LAMBERT I.S. DURUCHUKWU
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ABSTRACT

The study is about the effect of cement-laterite ratio on the compressive strength of cement-stabilized laterite blocks. Analysis of existing works as well as characteristics of laterite necessary for block making in addition to all the factors that could affect laterite block making were carried out.

Comparative study of existing conventional methods of blocks making such as sandcrete blocks and burnt bricks was also done.

Experimental analysis of the compressive strength of ordinary laterite blocks showed that strength increased as water content approached optimum moisture content. The highest strength being at the optimum moisture content. Addition of cement increased the compressive strength of ordinary laterite blocks by as much as 800%.

Varying the cement content at constant moisture content of 36% showed that the maximum compressive strength of $8.60KN/mm^2$ is achieved at 22.5% cement content. Therefore a mix ratio of 1:4 (20% cement against 80% laterite) with a compressive strength of $8.444KN/mm^2$ is recommended for cement-laterite blocks.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

Over time, man has spent immeasurable amount of energy on the provision of housing, one of his basic needs. As extensive as these efforts are, the problem of inadequate housing delivery has persisted. Rising cost of living, high cost of building materials, defective conceptualization have all contributed to the prohibitive cost of housing delivery.

The concept of adaptable habitation is a new area of building engineering that deals with the adaptability of local resources, technologies, skills and manpower in the provision of affordable houses specific to particular communities. It studies the primordial housing delivery characteristics of individual communities with a view to understanding the limitations in terms of technology, skill, and resources. Improvements on existing methods, materials etc to meet minimum standard of shelter, aesthetics, and health are then introduced. By this concept, houses are delivered as affordable as possible while preserving the cultural and traditional peculiarity of the communities.

Therefore, except there is a deliberate policy designed towards adopting the above concept with a view to bringing down the cost of houses viz–a viz the cost of building materials as well as available delivery technologies, the problem of inadequate housing will definitely persist.

The use of laterite soil as both blockwork and cladding material is widespread in Nigeria. The use cuts across both geographical and ethnic boundary almost making it the most widely used of all local building materials.

In some localities, laterite is used as both load-bearing and cladding material. This in cases where the soil is not made into blocks leads to very thick walls. In other areas, the soil is used as a composite material, being reinforced by bamboo sticks or other local reinforcing materials.

It is therefore of immense economic and scientific benefit to initiate studies dealing with the use of laterite as building materials. Scientific research is necessary to either introduce new discoveries or contribute significant improvements to existing knowledge.

The project does not necessarily entail comparing laterite blockwork with existing conventional methods such as sandcrete blocks and burnt clay bricks. It is mainly concerned with the improvement of laterite for durable house building since already the use of laterite as a building materials is not in doubt. Addition of cement, it is believed may improve the compressive strength of laterite blocks. If this is true, it becomes necessary to determine what proportion of cement and laterite should be mixed together to achieve the strongest and most cost effective blocks.

1.2 OBJECTIVES

The study is to investigate the effect of cement stabilization on the compressive strength of laterite blocks. The objectives include:

1 Study of the characteristics of laterite soil necessary for block making.

2. Determination of the strength of ordinary laterite blocks.

3. Determination of the effect of cement on the strength of ordinary laterite blocks.

4. Determination of the effect of cement/laterite ratio on the compressive strength of cement-stabilized laterite blocks.

It is believed that the study will lead to improved quality of laterite blocks thereby leading to such improvements in construction as:

1. Thinner walls that ensure reduction of the weight of the superstructure.

2. Increased strength and durability of structure.

3 Better resistance of walls to weather.

4. Improved receptability of finishing where necessary.

1.3 JUSTIFICATION

In building delivery, blockwork forms between 20-30% of the total cost of the project. If plastering, rendering, and dressing costs are added to cost of procurement, delivery, and placement of blocks, the cost of blockwork could be as high as 40% of the structure. Laterite blocks have several advantages over other types of block which include:

1. Laterite is readily available.
2. Technology abound nationwide although it varies from locality to locality
3. Blocks are cheaper than conventional ones.
4. They are lighter in weight when cement-stabilized.
5. They can be made into thinner cross-sections.

This research work studies the effect of cement stabilization on the compressive strength of laterite blocks with a view to manufacturing laterite blocks that are strong, durable, and cost effective. The overall cost of construction is reduced thereby making ownership of houses easier for the generality of our citizenry.

CHAPTER TWO
LITERATURE REVIEW

2.1 LATERITE:

Laterite is a highly weathered material, rich in secondary oxides of iron or aluminum or both (Lamber and Whitman, 1979), that abound in humid tropical environment. Laterite soil may contain clay minerals in association with silts gravels, or sand in different proportions. This gives rise to the terms associated with clays: laterite, lateritic, and non-lateritic soils. These are distinguishable from the ratio of silica to sesquioxide represented by

$$\frac{S_1O_2}{(Fe_2\,0_3 + Al_2\,0_3)}$$

Ratio of 1.33 or less refers to laterite; between 1.33 and 2.00 refers to lateritic soils, whereas above 2.00 refers to non-lateriitic soils (Ola 1978 as in Adekunle 2002).

Laterite is formed as a result of intense weathering. High temperatures, wet and dry conditions, solar radiation and the absence of humid acids favour the formation of laterite. Physio-chemical breakdown of primary minerals is followed by hydrolysis in which water in the form of H^+ and OH^- ions acts on other substances. When water acts on carbon dioxide, carbonic acid is formed. During hydrolysis of feldspars, micas, and minerals of ferro-magnesian family, clay minerals are formed. (Adekunle 2002).

2.1.1 IDENTIFICATION OF LATERITE SOIL

Laterite soils can be identified from both physical and chemical examination. The colour of laterite varies from reddish-brown, red, brown, to pink. It is the mixture of differently coloured substances that cause colour variation in lateritic soil. Hematite ($Fe_2 O_3$) imparts red or pink colur to laterite, while limonite or geothite produces yellow colouration.

The density of laterite varies from 2.65-2.82 (Teng 1988). Density of most laterite and lateritic soils increases with the alumina content. This is within expectation since iron is many times heavier than aluminum.

The process by which laterite soil grows hard is termed induration. The degree of induration depends on whether the material can be broken easily by hand, with spade, or split with a hammer. (Lamber, 1951)

The chief oxides present in laterite are silicon iv Oxide (SiO_2), aluminium III oxide ($Al_2 O_3$), and iron III oxide ($Fe_2 0_3$) in that order. Other elements present in their oxide forms include manganese, magnessium, calcium, potassium, and sodium.

2.1.2 MOISTURE CONTENT IN LATERITE

Water in laterite soils may be present in its natural form as when filling or partly filling the voids of a soil mass, or it may be present in the form of absorbed water existing as films surrounding the separate soil particles or group of particles, as in the case of water remaining in a partially dried clay mass. The water films existing in the latter case may have properties sharply differing from those exhibited by water in its normal form. Properties of fine-grained soils are greatly dependent upon the properties and behaviour of the absorbed water films.

Laterite soils are naturally impermeable, therefore they contain a large amount of water necessary for strength. As a matter of fact the strength of an oven-dry soil increases proportionally with increasing moisture content up to a limit called the optimum moisture content (OMC). Any further application of water in excess of the optimum moisture content leads to reduced compressive strength.

The natural moisture content is the moisture content of soil at undisturbed state whereas the optimum moisture content is the moisture content at maximum dry density. Determination of both moisture contents is necessary in the study of laterite blocks as they determine the amount of water needed by the soil during mixing, as well as the behaviour of the compressive strength of the soil around the vicinity of the optimum moisture content.

2.1.3 CONSISTENCY AND SENSITIVITY OF COHESIVE SOIL

The consistency of clays and other cohesive soils is usually described as soft, medium, stiff, or hard, each boundary corresponding to a range of unconfined compressive strength.

Cohesive soils share with other colloidal substances the property that kneading or working at unaltered water content makes the material softer. The process of kneading or working is commonly referred to as remoulding (Ingles and Metealf, 1972).

The softening effect is probably due to two different causes: destruction of the orderly arrangement of the molecules in the different layers, and injury to the structure that the soil acquired during the process of sedimentation. That part of the loss of strength caused by the disturbance of different layers may be gradually regained at unaltered water content after the working has ceased. The remainder, probably caused by permanent alteration of the structure is irrecoverable unless the water content is reduced.

The term sensitivity indicates the effects of remoulding on the consistency of cohesive soils regardless of the physical nature of the causes of the change. The degree of sensitivity varies between soils and within soils at different moisture contents. If a cohesive soil is sensitive, a slide may turn it into a mass of lubricated chunk capable of flowing on a gently sloping base, whereas similar slide in a soil with low sensitivity merely produces a conspicuous local deformation.

After a cohesive soil has been remoulded, its consistency can be changed at will by increasing or decreasing the water content. Thus, for instance, if the water content of a laterite slurry is gradually reduced by desiccation, the soil passes from a liquid state through a plastic and finally to a solid state. The water content at which these changes occur varies with different cohesive soils.

Therefore, the water contents of these transitions can be used to identify and compare different cohesive soils. However the transition from one state to another does not occur abruptly as soon as some critical water content is reached. It occurs gradually over a fairly large range in the value of the water content. For this reasons, every attempt to establish criteria for the boundaries between limits of consistency involves some arbitrary elements. The method that has proved most suitable for engineering purposes was borrowed from the science of agronomy. It is known as Attterberg's method and the water contents that correspond to the boundaries between the states of constituency are called the Atterberg limits These limits include liquid limit, plastic limit, and shrinkage limit.

2.1.4 CLASSIFICATION OF LATERITE SOIL

Gradation of soil particles refers to the study of the characteristic grain-size distribution of the soil with a view to appropriately identifying the soil. Laterite soil could contain a considerable amount of silt (as in silty clay soils,), finely – divided organic matter (as in organic clay soils), and at times could contain considerable amount of sand (as in sandy clay soils). Grains - size distribution of laterite soil is extremely necessary in the manufacture of laterite blocks as soils with large amounts of sand will be less plastic and therefore less suitable for block making.

Gradation should take serious note of the amount of fines, and colloidal particles present in the soil as well as all other parameters necessary for effective identification and classification of the soil using the grain-size distribution method. Grade classification of clay soil is carried out using methods which entail mechanical separation as well as routine tests that determine the Altterberg limits. In all, the classifications is based on the following methods:

1. Amount of material finer than 0.075mm (No. 200) sieve in aggregate.
2. Sieve analysis of fine and coarse aggregates.
3. Mechanical analysis of soils.
4. Determination of the liquid limit
5. Determination of the plastic limit and plasticity index.

2.2 CEMENT

Portland cement may be defined in a number of ways with possible descriptions varying from involved technical descriptions relative to the chemical make-up of the material and its physical properties, to simple statements regarding its physical appearance and behavior when combined with water. Wright and Pacquette (1979), defined Portland cement as a chemical combination of lime, silica, alumina, and iron oxide, together with small amounts of other materials and gypsum, that is added in the final grinding process to control the setting time of the cement.

Raw materials commonly used in the manufacture of Portland cement include calcareous substances such as limestone, oyster shells that are used in combination with argillaceous materials like clay, slate, shale or blast – furnace slag. The manufacture of cement from these raw materials involves a series of complex operation in which the various processes and the proportions of the materials used are carefully controlled. In a typical process, raw materials are successively crushed and mixed under high temperatures of up to 1200°C to form clinker. The clinker is then ground and combined with small amounts of gypsum to form cement.

Three types of cement are easily distinguishable for engineering purposes. Type I, which is, termed the standard or normal Portland cement is intended for general construction where cement is not required to have certain special properties.

Type II is also regarded as standard type of Portland cement, which is recommended for use in situations where a moderate heat of hydration is required or where the surface is exposed to moderate sulphate action.

Type III cement is high early strength cement. It differs from the standard types in that concrete made from it attains in much shorter period of time, compressive and flexural strengths that are comparable to those attained by concrete in which the same amount of one of the standard types is used. It is useful for construction under water or where completed work is to be opened for use almost immediately.

2.2.1 WATER – CEMENT RATIO

A typical concrete mix consists of coarse aggregates, five aggregates, cement, and water. Concrete for block – making however does not contain coarse aggregates. Water – cement ratio is defined as the ratio of water to one bag of cement expressed either by weight or volume that is necessary to produce a concrete that is consistent with the desired durability and compressive strength. Typical values range from 25 litres -30 litres of water to a bag of cement or 0.70 – 0.84 by weight of cement.

Generally speaking, both the durability and compressive strength of any given concrete mixture increase with a decrease in the water - cement ratio; that is, the lower the water - cement ratio, the higher will be the compressive strength and the greater the durability assuming water-cement ratio is the only factor considered. The major essence of ensuring a satisfactory water-cement ratio is to produce concrete:

1. of the stiffest consistency that can be placed efficiently in moulds to provide a homogenous mass.
2. of adequate durability to withstand satisfactorily the weather and other destructive agencies to which it may be exposed.
3. of the strength required to withstand the loads to be imposed on it without danger of failure.

2.3 CURING

The hardening of blocks either of cement - sand or cement – clay is not really a drying out process. Water is absolutely necessary in the proper hydration of cement. Steps then must be taken to prevent loss of water from the blocks during the curing period. Preliminary wet curing should start on the second day of moulding and last for about three days. Curing could continue afterwards for between seven and fourteen days when it is expected that blocks would have attained adequate compressive and flexual strength.

Wet curing process involves the spraying of fine jets of water on blocks twice or thrice daily. However in very hot and humid conditions, it might be necessary to cover block with straw or other membrane which must continuously be kept wet throughout the duration of curing.

2.4 SANDCRETE BLOCKS

Sandcrete blocks are made from a mixture of cement, sand, and water. The process involves the mixing of cement and sands into a thorough mixture to which little amount of water is added and mixed further together. The mixture is fed into mould in a vibrating machine where it is vibrated and compacted to make the block. The block are carefully placed on level surface and allowed to set. After setting, which may take from few minutes to a few hours the blocks begin to harden and gain strength. During this period of hardening, curing is introduced to enable the blocks gain as much strength as possible without necessarily drying out. Curing could last for up to seven days or more, after which the blocks are ready for use.

Sandcrete blocks are usually made hollow by introducing two equal holes at the centre of the blocks. The hollow so introduced serves several purposes some of which are:

1. Reduces the weight of the block without affecting the load bearing capacity.
2. Helps reduce sound transmission.
3. Reduces the temperature of the wall inside the house
4. Serves as a conduit for passing other essential construction services.

Sandcrete hollow blocks could be load-bearing as in bungalows or partition as in framed construction. When used in foundations, they are usually filled solid with concrete to increase their load bearing capacity as well as resistance to water contained in the adjoining soil. The blocks are usually 450mm long and 225mm high. Thickness range from 100mm to 225mm depending on the thickness of the wall. Special blocks which do not conform to the above specification could be made if expressly desired.

Sandcrete hollow blocks are the commonest form of blockwork in Nigeria. Experience has shown however that they require a lot of cement to mould since sand, which is the other raw material, is completely non-plastic. Because of the cost of cement, sandcrete blocks tend to be expensive and this cost imparts heavily on the cost of the building. In addition, walls made from sandcrete hollow block always require additional finishing which include plastering, rendering, and painting. These are costs which directly affect the cost of housing delivery. Also in some communities, sharp sand is scarce. Deposits, where they exist are mined mostly to depletion. In such a situation, scarcity leads to high cost of sharp sand with an attendant high cost of the blocks made therefrom. Generally speaking, the compressive strength required of sandcrete blocks range in the neighbourhood of $2.5KN/mm^2$.

2.5 BURNT BRICK

Burnt bricks are made from clay soil. The process involves the selection of adequate class of clay soil; pulverizing the clay soil and removing of inpurities; mixing the pulverised soil with water; moulding the plastic clay soil in moulds; passing the moulded clay through a stream of cold air to gently dry them and thereafter burning the blocks in a kiln at temperatures of up to 1200^oC. Burning of the clay blocks makes them rock –solid in strength. Burnt clay bricks produce a sound of extremely high pitch when struck with an iron bar as a testimony to their dryness and strength. The entire process of brick production takes place in a plant specially designed for it.

Burnt bricks could be produced in different rectangular shapes and sizes. Plants are designed to take an array of customised moulds that produce different sizes of bricks. Hollow burnt bricks which have properties similar to hollow sandcrete blocks are also possible. They are produced by introducing spikes corresponding to the size and number of holes desired in the mould. These spikes create holes in the brick after moulding.

Burnt bricks have the advantage of not requiring additional finishing when used in construction. Therefore the cost of plastering, rendering, and painting usually associated with sandcrete blocks is completely eliminated. Another advantage of burnt bricks has to do with the possibility of producing jointing bricks which are used instead of cutting whole bricks as obtained in sandcrete blockwork. Joints are usually pointed. Burnt bricks are durable and present an admirable aesthetic view when used in a row of houses.

The use of burnt bricks is not as widespread as that of sandcrete blocks despite its obvious advantages. Although the unit cost of burn brick could be slightly higher than that of sandcrete blocks, the overall consequence of finishing makes brickwork construction far cheaper than sandcrete hollow blocks. The major drawback of burnt bricks is:

1. High initial investment cost
2. Cost of plants and machinery
3. Non-availability of local manufacturing technology.
4. Cost of plant maintenance and spare parts.
5. Requires large distribution network.

Although clay, the basic raw material is readily available, most burnt brick factories in Nigeria established some 20 years ago were forced to stop production as a result of the above factors, thereby making bricks unavailable. It is this and other factors mentioned above that make the use of burnt bricks less popular than it should normally have been considering its numerous advantages over sandcrete blocks.

CHAPTER THREE

METHODOLOGY

3.1 SOIL CLASSIFICATION

These experiments are designed to classify the laterite soil available with a view to ascertaining it class as well as confirm its suitability or otherwise for block making. The principle factors here deal with the following:

a. Sieve analysis to determine the grade distribution of the soil.

b. Liquid limit

c. Plastic limit and plasticity index.

3.1.1 SIEVE ANALYSIS

Laterite soil contain fine materials which adhere to coarser particles. Therefore a combination of both sieve analysis and hydrometer analysis is necessary to determine the grain size distribution of the soil sample. The principle information needed from the sieve analysis is the percentage of the soil passing the No 200 sieve which is the practical lower limit for the use of sieve. Therefore, for the purpose of this study a single dry sieving would be adequate.

The soil to be sieved was first dry in the oven for 24hours at 105°C. A set of sieves of increasing fineness (i.e successively smaller openings) previously weighed were arranged on top of a receiving Pan. The oven-dry soil sample was placed inside the topmost sieve (ie sieve No. 4). The entire set-up was agitated by a sieve shaker for 10 minutes. The weight of soil retained on each sieve was recorded and the percentages determined with particular reference to that retained on the No. 200 (0.075mm) sieve.

3.1.2 LIQUID LIMIT.

A representative sample of the soil passing No. 40 sieve was mixed with water until a uniform paste was obtained. The paste was filled into the liquid limit crucible and the surface smoothened out to flush with the surface of the crucible. A standard grooving device was used to make a groove in the sample and the crank of the device was turned corresponding to the blows. The number of blows taken for the groove to completely close as well as the moisture content was recorded. The test was repeated a further four times. The result was plotted on a standard liquid limit graph and the moisture content corresponding to 25 blows was taken as the liquid limit of the soil.

3.1.3 PLASTIC LIMIT

A representative sample of the soil passing the No.40 sieve was mixed with water until it becomes moist. After thorough mixing, the sample was rolled on a plane glass surface with the palm. Rolling was continued until the rolled thread shows signs of breaking. The thickness of the thread was taken. When the thickness of the thread was 3mm, the moisture content of the sample was determined. The test was repeated another four times and the average moisture content is the plastic limit of the soil. Plasticity index is the numerical difference between the liquid limit and the plastic limit.

3.2 NATURAL MOISTURE CONTENT

The natural moisture content of a soil sample is the mount of water contained in a known mass of the soil at its natural state expressed as a percentage of the soil dry unit weight. It is necessary to determine the natural moisture content as this will help determine the amount of water to be added to the soil during mixing to make up the desired degree of moisture content.

Three representative samples of the soil were weighed and oven-dried for 24 hours at 105°C. The weight of the oven-dry soil was then determined thereafter the weight of water determined.

3.3 OPTIMUM MOISTURE CONTENT

Practically every soil has an optimum moisture content (OMC) at which the soil attains maximum dry density (MDD). It is important to determine the optimum moisture content of the soil in order to understand the behaviour of the soil under the weight of compactive effort.

In determining the optimum moisture content, the standard Proctor compaction test was employed. Under this procedure, the standard Proctor mould was weighed. About 3kg of the soil passing the No. 4 sieve was mixed with about 100ml of water. Two portions of the mixed soil was taken for moisture content determination whereas a third portion was put into standard Proctor mould in three layers. Each layer was compacted by 25 blows of 3.5kg Proctor hammer falling a distance of 300mm. The weight of the compacted soil and mould was taken. The test was repeated another four times with varying moisture contents. A graph of dry density against moisture content was plotted. The optimum moisture content is taken as the moisture content at which the dry density is at the maximum level.

3.4 COMPRESSIVE STENGTH OF ORDINARY LATERITE BLOCKS

A representative sample of the soil was weighed and placed into a large bowl. 30% by weight of water was added whose value will include the natural moisture content of the soil. The soil and water were turned together until a thorough mixture was obtained. The mixture was placed into three separate moulds (150mm x 150mm x 150mm) and compacted properly. The surface was trimmed off and smoothened by a trowel. The test was performed an additional four times using water content of 32%, 34%, 36%, 38%. The 15 blocks obtained were allowed to cure under atmospheric conditions for 28 days. At the expiration of the curing period, the blocks were first weighed before they were placed in the loading machine. The load at which each block failed when loaded by the machine was recorded. Thereafter the densities and compressive strengths of the blocks were determined by analysis.

3.5 EFFECT OF CEMENT ON THE COMPRESSIVE STRENGTH OF ORDINARY LATERITE BLOCKS.

As in experiment 3.4 above, a representative sample of the soil was weighed and place into a large bowl. Water corresponding to particular experiments in 3.4 above was added to the soil to which have previously been added 10% by weight of cement. The substances were thoroughly mixed, placed into three moulds measuring 150mm x 150mm x 150mm and well compacted. The 15 blocks obtained were air-cured at room temperature for 28 days. At the expiration of the curing period, the blocks were weighed before being placed in the loading machine. The load at which each block failed when loaded by the machine was recorded. Thereafter the densities and compressive strengths of the blocks were determined by analysis.

3.6 EFFECT OF CEMENT-SOIL RATIO ON THE COMPRESSIVE STRENGTH OF LATERITE-CEMENT BLOCKS

Five separate samples of the soil of uniform weight was measured. To one of these samples was added 5% by weight of cement and mixed together. Water equivalent to the desired consistency of 36% was added to the mixture and turned over until a thorough mixture was obtained. The mixture was then fed into three separate moulds measuring 150mm x 150mm x 150mm. The experiment was repeated with the remaining four samples with 5% increments in the weight of cement for successive experiments. The water content was constantly maintained at the initial level of 36% for all the four repetitions. The 15 blocks obtained were allowed to set, and harden for 28 days under room temperature. At the end of the 28 days of curing, the blocks were weighed before being placed in the loading machine. The load at which each block failed when loaded by the machine was recorded. The densities and compressive strengths of the blocks were thereafter determined by analysis.

CHAPTER FOUR

RESULT AND DISCUSSION

4.1 SOIL CLASSIFICATION

The soil used for the experiments was collected from a borrowpit currently being used for the dualization of the Abuja-Keffi Road. The borrowpit is located in a village called Addo in Karu Local Government Area of Nassarawa State about 17.44km from Abuja.

Results of sieve analysis, liquid limit/plastic limit are given below in tables 4.1a, 4.1b, and 4.1c respectively.

Table 4.1a Sieve Analysis Result

SIEVE SIZE (mm)	WEIGTH RETAINED (gm)	PERCENTAGE RETAINED	PERCENTAGE PASSING
20.0	-	-	100.00
14.0	12.0	2.40	97.60
10.0	32.7	6.54	93.46
6.3	68.3	13.66	86.34
5.0	98.9	19.78	86.34
2.00	230.4	46.08	53.92
1.18	257.2	51.44	48.56
600um	275.3	55.06	44.94
425um	283.7	56.74	43.26
300um	294.7	58.94	41.06
150um	328.8	65.76	34.27
75um	357.1	71.42	28.58
Total Weight of Dry sample	500.0gm		

Table 4.1b Liquid Limit Result

Minimum mass of test particle Passing 425um sieve	= 150 – 200gm			
Test Number	1	2	3	4
No of Blows	11	20	30	40
Container No	10	42	69	11n
Weight of container	16.12	15.99	16.22	16.32
Wt. Wet soil + container	50.58	52.81	48.08	'49.12
Wt. Dry soil + container	39.78	41.58	38.67	39.71
Weight of moisture	10.80	11.23	9.41	9.41
Weight of dry soil	23.66	25.59	22.45	23.39
Moisture content	45.60	43.90	41.90	40.20

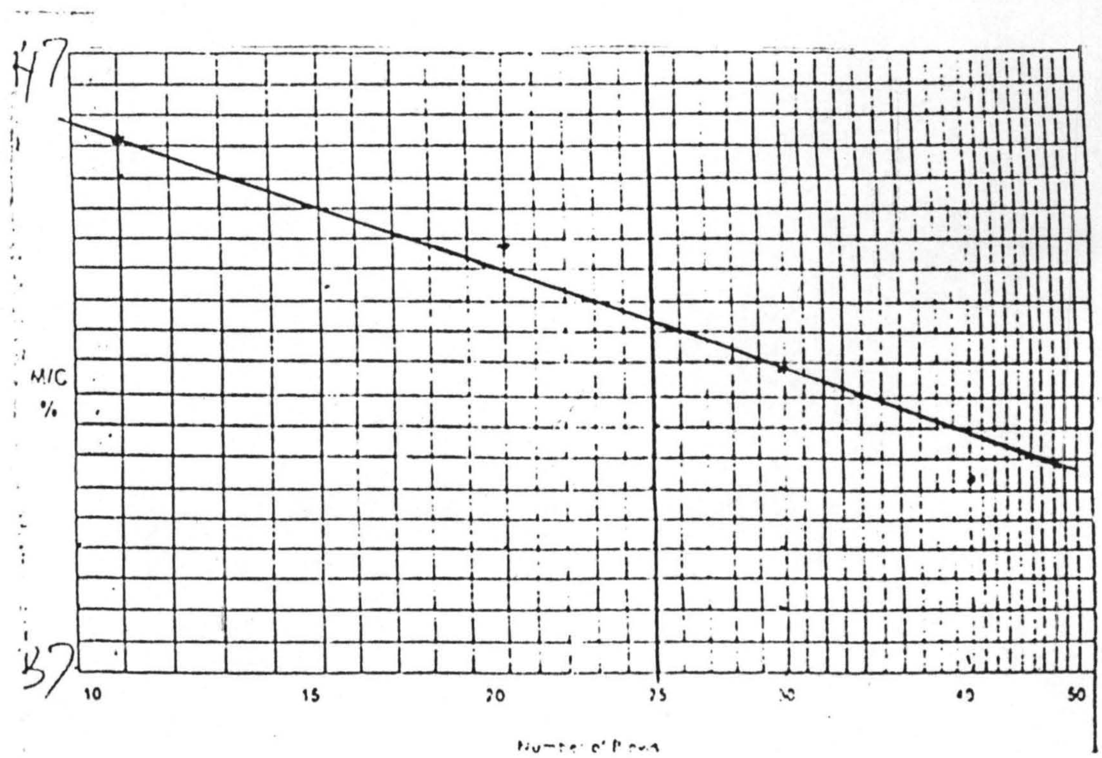

Fig. 4.1 Numbers of Blows/Moisture Content Graph

Table 4.1c Plastic Limit Result

Minimum mass of test particle Passing 425um Sieve	= Approx. 20gn	
Test No	1	2
Container No	CK	CN
Weight of container	15.73	15.90
Wt. Wet soil container	21.42	21.85
Wt. Dry soil + container	20.12	20.51
Weight of moisture	1.30	1.34
Weight of dry soil	4.39	4.61
Moisture content	29.60	29.20

GROUP INDEX AND SOIL DESCRIPTION

The group index of soil whose characteristic physical properties are described by the liquid limit, plastic limit and sieve analysis is given by

Group index= (F-35) (0.2+0.005(LL-40))+0.01(F-15)(PI-10)

Where

F= Percentage passing 0.075mm (No 200) sieve expresses as a whole number

LL= Liquid Limit

PI Plasticity index

Now,

F = 29

LL = 43

PI = 43 – 30 =13

: Group Index = (29-35)(0.2+0.005(43-40))+0.01(29-15)(13-10)

= -10

since the soil belongs to the A-2-7 group the plasticity index part of the formula is applicable

therefore,

group index = 0.01 (29-15)(13-10) = 0.042

therefore, the soil class is A-2-7$^{(0)}$, the zero superscript shows that the group index is zero.

Typical materials of this soil class include large amounts of silly or clayey gravel and sand. The soil has both high liquid limit and plasticity index indicative of adequate amount of clay necessary for block mounding.

In summary, class A-2-7 soils have the following basic characteristics.

1. Maximum of 35% passing No200 (0.075mm) Sieve
2. Minimum Liquid Limit of this group is 41
3. Minimum plasticity index is 11

4.2 OPTIMUM MOISTURE CONTENT

The optimum moisture content and maximum dry density were both determined using the standard Proctor test method. The result of the Proctor (compaction) test is given in the table 4.2a and fig 4.2a

Table 4.2a Optimum Moisture content and maximum dry density determination.

No of layer – 5				Blow per layer –21			Wt. Of hammer – 45kg			
Volume of mould – 2269cm^3										
MOISTURE CONTAINED DETERMINATION										
Moisture can No	1	2	3	4	5	6	7	8	9	10
Wt. Soil + wet soil	76.90	80.76	71.09	68.95	71.69	76.34	70.35	76.62	74.10	81.68
Wt. Soil + Dry Soil	72.08	75.79	65.94	63.89	65.61	69.72	63.77	68.66	65.93	72.62
Wt. Of Water	4.82	4.97	5.15	5.06	6.08	6.62	6.58	7.96	8.17	9.06
Wt. of Can	15.98	15.88	15.92	15.81	15.91	15.96	15.88	15.87	16.32	16.56
Wt. of Dry soil	51.18	59.91	50.02	47.97	49.80	53.70	47.89	52.79	49.61	56.06
Moisture content %	8.6	8.3	10.30	10.50	12.2	12.3	13.7	15.0	16.5	16.2
	-	-	-	-	-	-	-	-	-	-
Av. Moisture content	85		10.40		12.3		14.4		16.4	

Density Determination

Wt. of soil + mould	8707	8993	9222	9191	9070
Wt. Of mould	4305	4305	4305	4305	4305
Wt. Of soil in mould	4402	4688	4917	4885	4765
Wet. Density gm/km3	1.94	2.07	2.17	2.15	2.10

$$\text{Dry density} = \frac{\text{Wet Density}}{\frac{(100 \pm W\%)}{100}}$$

Where W = Water Content

W = 8.5; Wet. Density = 1.94

$$DD = \frac{100\,(1.94)}{100 + 8.5} = 1{,}79$$

W = 10.4

W.D = 2.07

$$DD = \frac{100(2.07}{100+10.4} =1.88$$

W = 12.3

W.D = 2.17

$$DD = \frac{100\,(2.17)}{100+12.3} = 1.93$$

W = 14.4

W.D = 2.15

$$DD = \frac{100(2.15)}{100+14.4} = 1.88$$

W = 16.4

WD = 2.10

$$DD = \frac{100(2.10)}{100+16.4} = 1.80$$

Moisture content	8.5	10.4	12.3	14.4	16.4
Dry Density	1,79	1.88	1.93	1.88	1.80

A graph of dry density against moisture content is shown in figure 4.2a

Maximum dry density =1.93

Optimum moisture content - 12.3

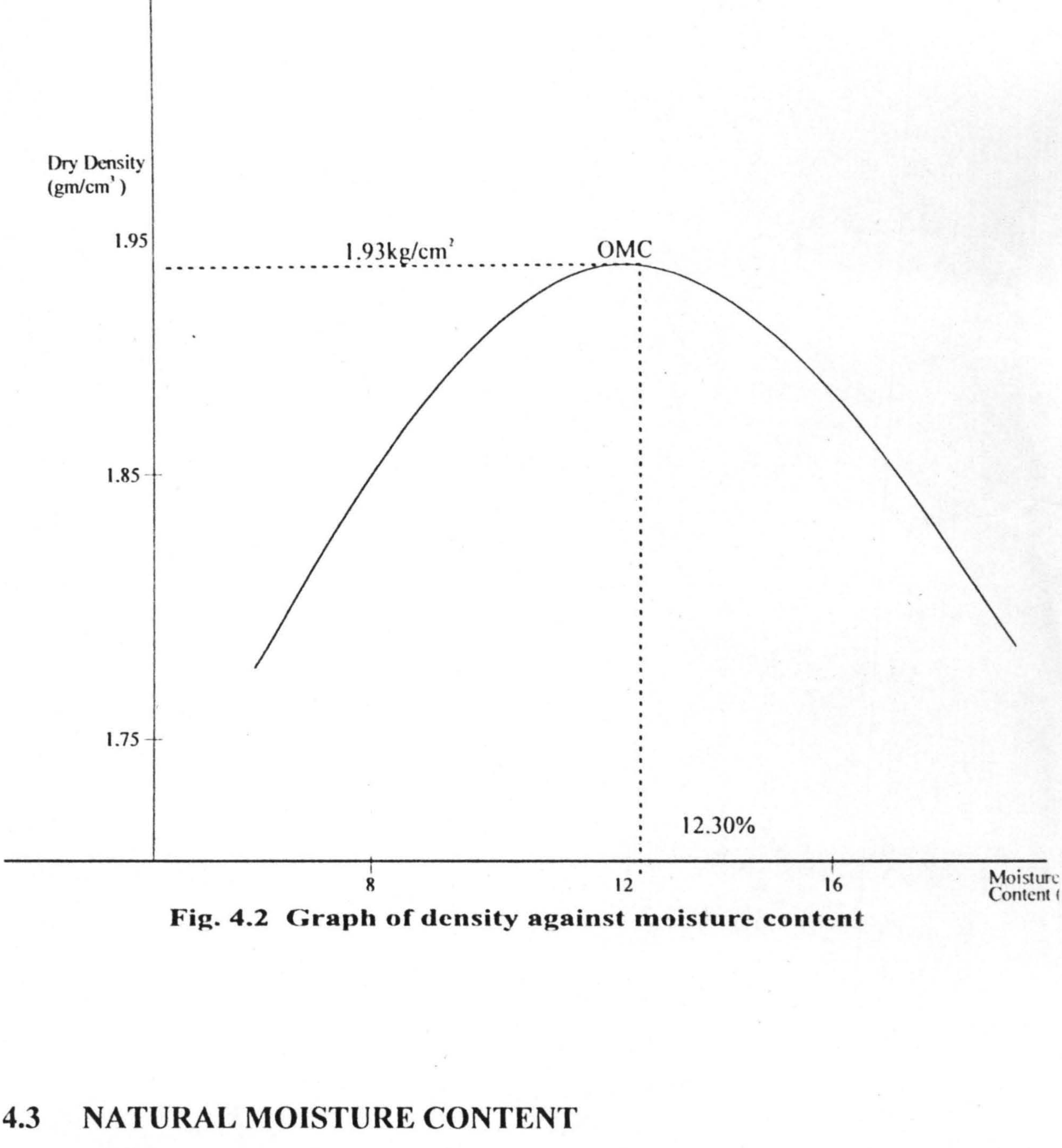

Fig. 4.2 Graph of density against moisture content

4.3 NATURAL MOISTURE CONTENT

The natural moisture content of the sample is determined in order to ascertain the amount of water to be added during actual experimentation.. the result are as shown below.

Table 4.3 Natural Moisture content results.

Experiment No	1	2	3
Weight Pan (kg)	0.60	0.60	0.60
Weight of pan + wet soil (kg)	1.050	1.100	1.000
Weight of pan + dry soil (kg)	0.970	1.000	0.930
Weight of Water (kg)	0.080	0.100	0.070
Weight of dry soil (kg)	0.370	0.400	0.330
Moisture content %	21.62	25.00	21.21
Average moisture content %		21.61	

The average natural moisture content is 22.61% indicating that whatever water that is added to the sample during mixing contains in addition 22.61% of water already.

4.4 COMPRESSIVE STRENGTH OF ORDINARY LATERITE BLOCKS

The compressive strength of the cubes decreased with increasing moisture content. Obviously, the highest compressive strength of the cubes would lie at the optimum moisture content of (OMC) 12.83% therefore, further deviation from this moisture content led to reduced strength.

The relationship between strength and moisture content is linear. Table 4.4 gives details of the results.

Table 4.4 Compressive Strength of Ordinary Laterite Blocks.

Area of Cube: 22,500mm^2; Volume of Cube = 3.375.dm^3

Experiment No	Weight of Cube (kg)	Average Weight	Density of Cube (kg/dm^3)	Failure Load (KN)	Average Failure Load	Moisture Content (%)	Compress strength(K m^2)
A11	5,700			15.000			
A12	5.705			15.000			
A13	5.700	5.702	1.689	15.000	15.000	30	0.661
B11	5.850			15.000			
B12	5.865			14.500			
B13	5.720	5.815	1,723	14.000	14.500	32	0.664
C11	5.600			10.000			
C12	5.240			10.000			
C13	5.450	5.430	1.609	10.000	10.000	34	0.444
D11	5.100			10.000			
D12	5.150			8.500			
D13	5.200	5.150	1.526	10.000	9.500	36	0.442
E11	5.260			5.000			
E12	5.200			5.000			
E13	5.180	5.213	1.545	5.000	5.000	38	0.222

4.5 COMPRESSIVE STRENGTH OF LATERITE BLOCK WITH CEMENT CONTENT

The previous experiments in 4.4 was repeated with 10% by weight of cement added to each one. It was discovered that compressive strength increased by an average of 800% over the strength of the corresponding ordinary blocks.

Therefore, addition of cement increased the load bearing capacity of laterite blocks. Relationship between moisture content (cement content) and strength is still linear.

Table 4.5 gives details of the results.

Table 4.5 Compressive Strength of Laterite Blocks with Cement Content.

Area of Cube =22,500mm²; Volume of Cube = 3.375dm³

Experiment No	Weight of Cube (kg)	Average Weight	Density of Cube (kg/dm³)	Failure Load (KN)	Average Failure Load	Moisture Content (%)	Compre strength (KN/m
A21	6.580			110.000			
A22	6.500			106.000			
A23	6.200	6.567	1.946	104.000	106.667	30	4.741
B21	6.140			110.000			
B22	6.120			108.000			
B23	6.160	6.140	1.819	112.000	110.000	32	4.889
C21	6.040			75.000			
C22	6.100			73.000			
C23	6.000	6.047	1.792	74.000	74.000	34	3.289
D21	5.960			62.000			
D22	6.020			65.000			
D23	5.980	5.987	1.774	65.000	64.000	36	2.844
E21	5.880			59.000			
E22	5.860			62.000			
E23	5.880	5.873	1.740	60.000	60.33	38	2.681

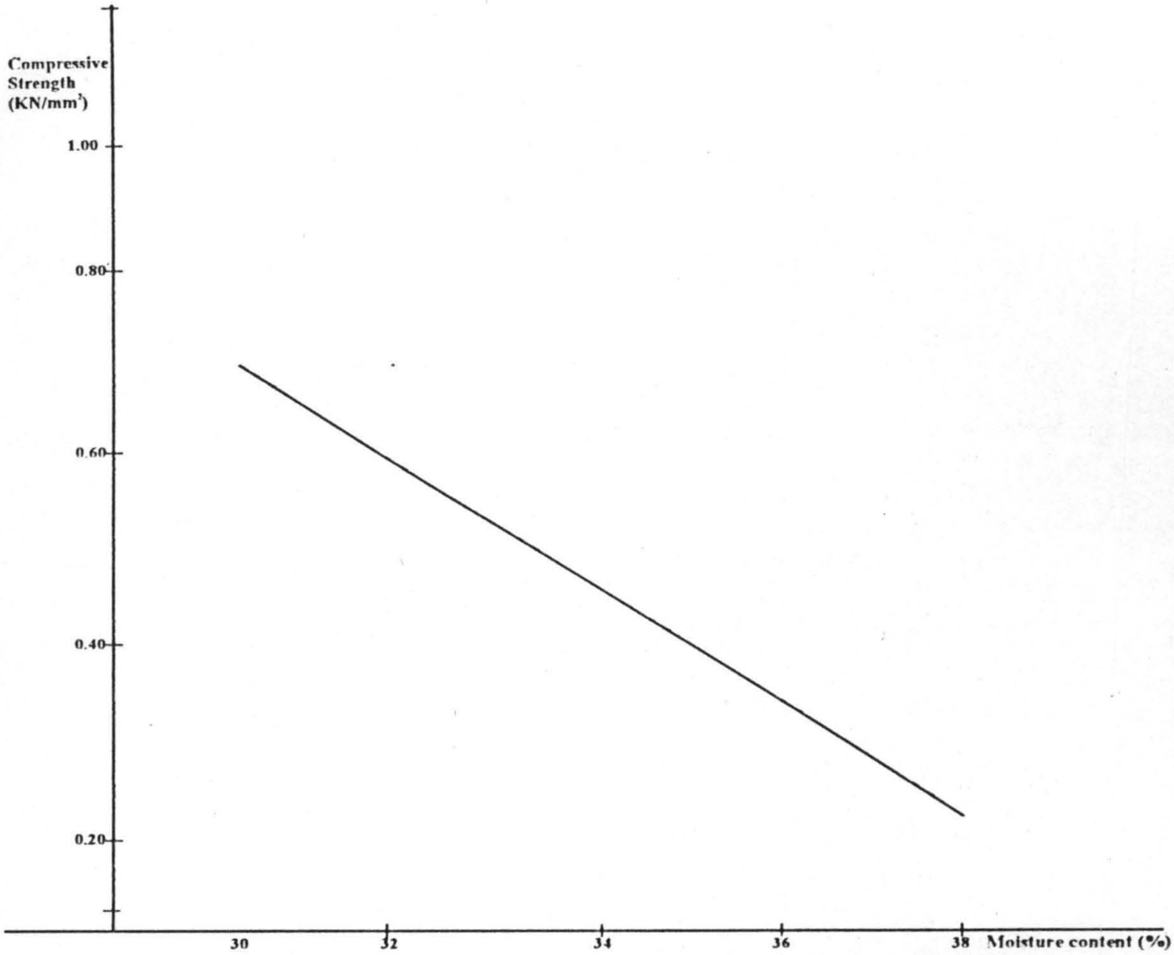

Fig. 4.3. Compressive Strength of ordinary laterite blocks

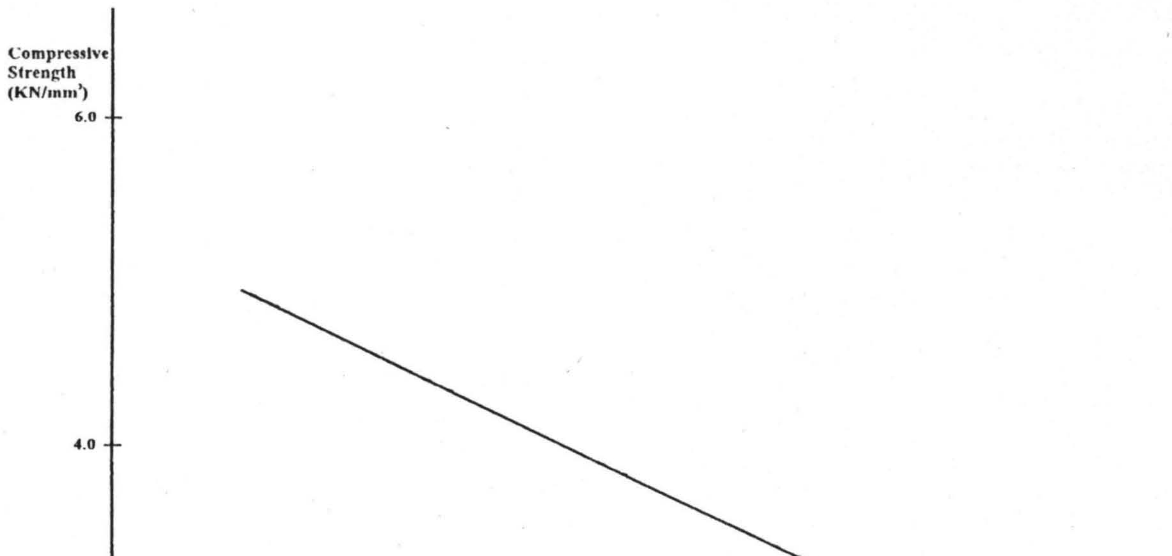

Fig. 4.4 Compressive Strength of ordinary laterite blocks with 10% cement content

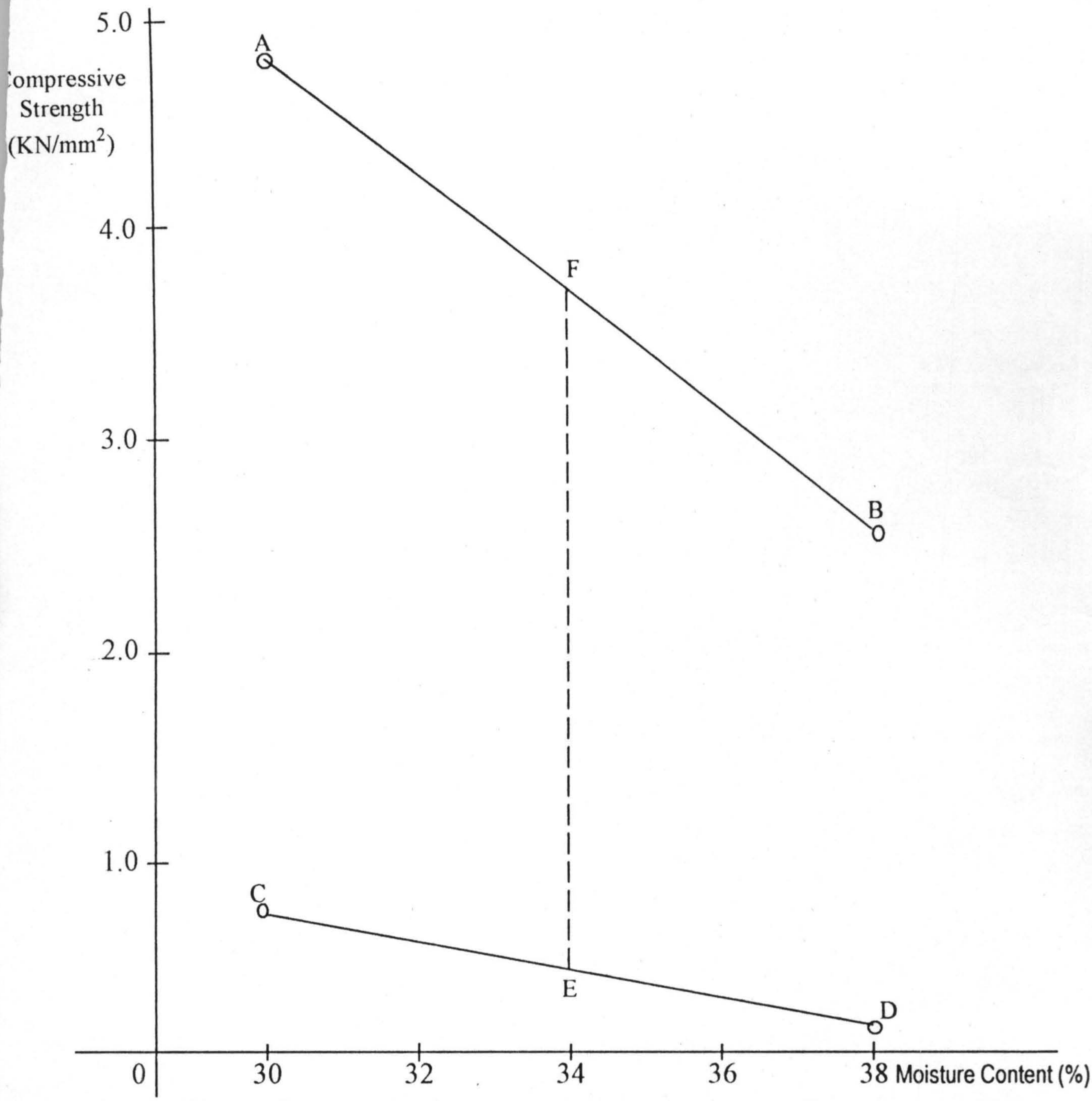

Fig. 4.5 Effect of cement on the Compressive strength of Ordinary Laterite blocks.

Fig. 4.5 is a comparative analysis of the effect of cement-stabilization on the compressive strength of ordinary laterite blocks. In the figure line CD represents the compressive strength of ordinary laterite blocks when water content is the only variable as in fig. 4.3 above.

When 10% by weight of cement is added to all the samples at the previous water contents, line AB is obtained. The maximum strength of 0.667KN/mm^2 for ordinary laterite blocks was obtained at 30% water content. When 10% by weight of cement was added to the samples, the maximum strength of 4.889KN/mm^2 was obtained at 32% water content.

The space represented by line EF is therefore the effect of cement-stabilization on the compressive strength of ordinary laterite blocks. On the average, this space represents an increase in strength of about 800% in cement-stabilized laterite blocks over their corresponding values in ordinary laterite blocks.

Therefore, cement-stabilization has a tremendous positive effect on the strength of ordinary laterite blocks. The next analysis will show at what ratio of cement and soil, this effect is most pronounced both technically and economically.

4.6 EFFECT OF CEMENT-LATERITE RATIO ON THE COMPRESSIVE STRENGTH OF LATERITE BLOCKS

Strength and cement content has a parabolic relationship which peaked at 22.5% cement content and a compressive strength of $8.6KN/mm^2$. Therefore, a mix ratio of 1:4 (20% cement and 80% Laterite) with a moisture content of 36% will give the most efficient and economical ratio.

Table 4.6 and figure 4.6 give details of the results.

Table 4.6 Compressive Strength of Laterite Blocks with varying Cement Content

Area of cube=22,500mm^2; volume of cube =3.375dm^3; Moisture content of cube: 36%

Experiment No	Cement Content (%)	Weight Of Cube (kg)	Average Weight of Cube	Density of Cube (kg/dm^3)	Failure Load (KN)	Average Failure Load	Compressive strength (KN/mm^2)
D11		5.600			30.000		
D12		5.620			28.000		
D13	5	5.620	5.613	1.663	30.000	29.333	1.304
D21		5.960			65.000		
D22		6.020			65.000		
D23	10	5.980	5.987	1.774	62.000	64.000	2.844
D31		6.180			140.000		
D32		6.300			138.000		
D33	15	6.280	6.253	1.853	138.000	138.667	6.163
D41		6.400			190.000		
D42		6.390			190.000		
D43	20	6.400	6.397	1.895	190.000	190.000	8.444
D51		6.520			190.000		
D52		6.480			188.000		
D53	25	6.580	6.527	1.934	186.000	188.000	8.356

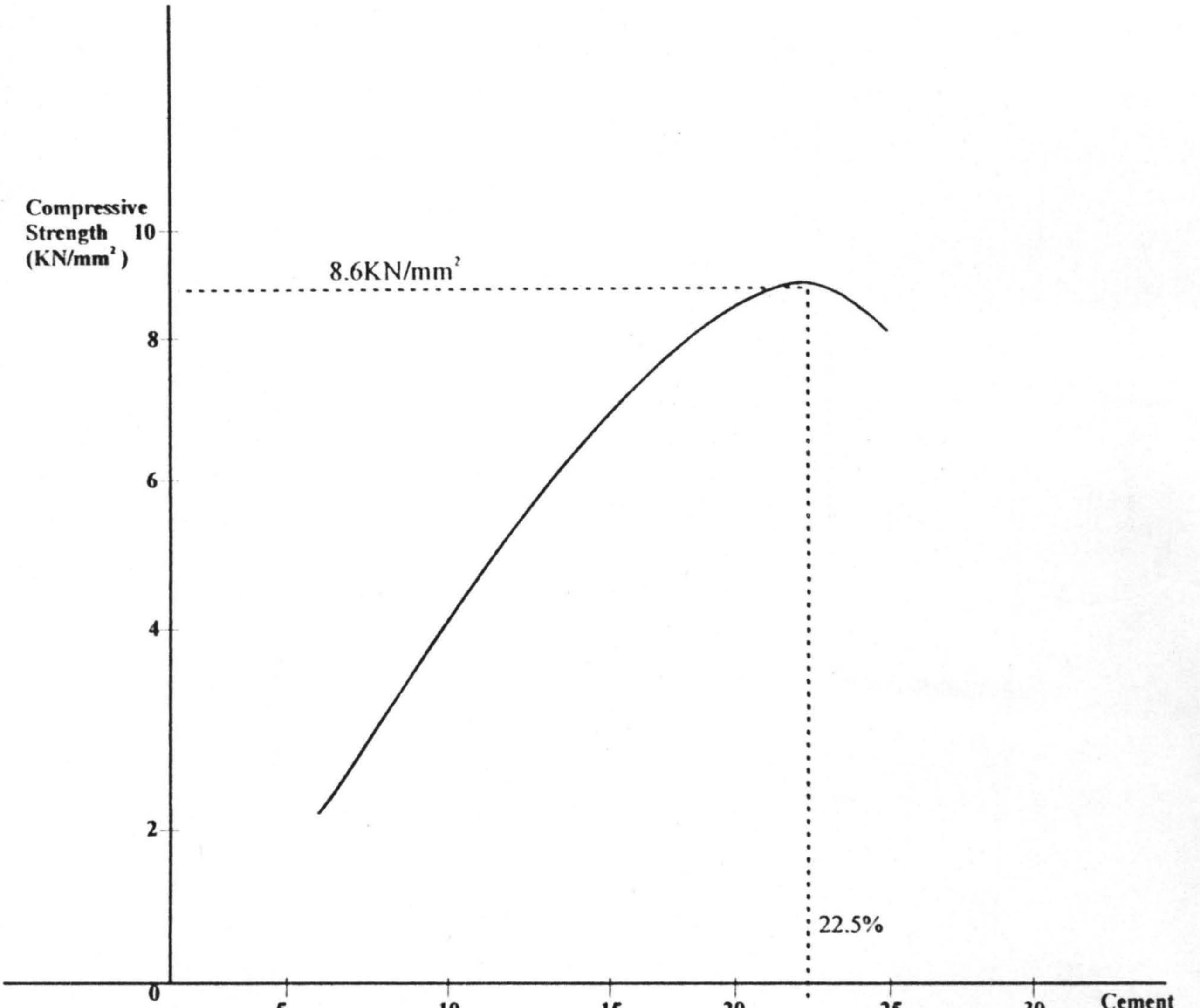

Fig. 4.6 Graph of compressive strength against cement content

CHAPTER FIVE

OBSERVATIONS AND RECOMMEDATIONS

5.1 OBSERVATIONS

The experiment is limited to the class of laterite soil examined. Therefore the results can only be reproduced accurately, if the actual class of laterite is obtained. The soil is a highly plastic soil with high moisture content.

The natural moisture content of the soil was discovered to be far higher than the optimum moisture derived from laboratory Proctor test. This meant that the soil was already too wet as the time it was removed for experimental purposes. The optimum moisture content can therefore be obtained by drying.

In the three different compressive strength tests carried out, it was observed that strength increased with density for all the experiment. In 4.4, density has a linear relationship with moisture content. Addition of water simply increased the weight of the cubes at the same compactive effort. The same effect was expectedly obtained in 4.5 where the same amount of cement was added to experiments.

Increase in compressive strength of ordinary laterite blocks was astronomical when cement was added. An average increase of 800% indicated that addition of cement would greatly increase the load bearing capacity of the blocks.

In 4.6, the increase in compressive strength achieved by increasing cement content indicated a rapid reaction of strength to cement. At 20% cement content, strength virtually peaked. When considered against the 2.5KN/mm^2 strength recommended for sandcrete blockwork, a compressive strength of 8.444KN/mm^2 is obviously high. Therefore laterite cement blocks could be used in the construction of houses without fear of failure with regard to load bearing. The drop in strength of the blocks at cement contents higher than 22.5% could be explained in terms of the brittleness of cement. Cement being brittle on its own and therefore weak in compressive could have been in excess quantity resulting in general brittleness of the cubes thereby making them unable to carry load.

Maintaining the entire repetitions at the moisture content of 36% completely eliminated the effect of moisture on the strength of the blocks. However, in the determination of the strength of ordinary laterite blocks where moisture content is the only variable, the highest strengths are obtained well below 36% water content.

5.2 RECOMMENDATIONS.

The experiment has been able to determine the strength characteristics of class of soil examined at 36% moisture content with varying cement content within the limit of experimental error. A cement soil ratio of 1:4 is adequate both structurally and economically for laterite blockswork. However there are a lot of other factors that affect both the strength and character of laterite blockwork which should be studied in general before an acceptable standard is reached for cement soil blockworks.

The moisture content of 36% adopted for experiment 4.6 is empirical as ordinarily, laterite blocks are stronger at water contents far below 36%. It is possible to examine the strength characteristics of ratios taken at several water contents between optimum moisture content (OMC) and 36%. This work has shown that for values of water content more than 36% lower ranges of compressive strengths are expected to be obtained. However, at 36% water content, consistency is much higher thereby giving the blocks a smooth outer surface that eliminates painting when the walls are finished.

Smoothness however is not a function of water content only. Compactive effort is another factor that contributes to the smoothness of the outer surfaces of the blocks. Type of mould as well as the nature of the interior of the mould also contributes to smoothness. It is ordinary necessary to maintain water content at the optimum level. This will however lead to much higher compactive effort almost to the level of mechanical vibration. Whereas this can be investigated to ascertain the effect of density on strength, higher compactive efforts may make the blocks difficult to mould by local people who are the main target of the work.

Since the experiment considered only one class of laterite, efforts in future works should be set at other classes of laterite to ascertain the behaviour of laterite generally when cement-stabilized. This will make the final work more acceptable throughout the country irrespective of the type of laterite available in the locality. Studying the effect of classification of laterite on the experiment would not be a difficult task as there are not more than seven classes of laterite whose characteristics differ narrowly.

One of the major drawbacks of laterite blockwork is its lack of adequate resistance to weather (especially rainfall) and its limited use as a foundation material. It is believed that the problem of weakness in foundation occasioned by the presence of ambient moisture could be overcome by both cement and sand stabilization. This process can be scientifically, investigated.

Cement stabilization naturally should increase the blocks resistance to weather. This also should be investigated to determine at which ratio the greatest resistance to water could be achieved.

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