INVESTIGATION INTO THE USE OF PERIWINKIE SHELIS AS LIGEHWEIGHT AGGREGATE FOR CONCRETE CONSTRUCTION

BY

BUKATA, OTEJIRI BENJAMIN

A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL AHMADU BELLO UNIVERSITY, ZARIA, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE MASTER OF SCIENCE (M.Sc.) IN CONSTRUCTION TECHNOLOGY

DEPARTMENT OF BUILDING
FACULTY OF ENVIRONMENTAL DESIGN
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OCTOBER, 1989

DECLARATION

I, BUKATA, O.B. hereby declare that this thesis is purely the record of my own work and has not been presented anywhere for a higher degree.

All sources of information have been acknowledged in the references at the end of the thesis.



BUKATA, OTEJIRI BENJAMIN

OCTOBER, 1989

Date

D E D I C A T I O N

This thesis is dedicated to my parents:

CHIEF JOHN GESIMISI BUKATA

AND

MRS. ALICE OTITI BUKATA

CERTIFICATION

This thesis entitled investigation into the use of periwinkle shells as lightweight aggregate for concrete construction, by Bukata Otejiri Benjamin meets the regulations governing the award of degree of Master of Science (in Construction technology) of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

_____ Date:_____
Chairman, Supervisory Committee

_____ Date:_____
Member, Supervisory Committee

_____ Date:_____
Member, Supervisory Committee

_____ Date: 22/12/89
Head of Department

_____ Date: 25/6/90
Dean, Postgraduate School

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May God be with them in all their endeavour in Jesus Name, Amen.

ABSTRACT

With the high cost of construction materials coupled with the need for adequate housing in Nigeria, the need to investigate the possibilities of using other forms of local building materials becomes eminent.

This thesis investigated the properties of lightweight concrete made with periwinkle shells.

The elemental analysis performed on the shells using the neutron generator (14 MeV) energy, indicates the presence of magnesium, calcium, silicon, potassium and annihilation.

The compressive strength of the shells were obtain using two mixes, the maximum compressive strength obtained for 7, 14 and 28 days were 18.2, 21.9 and 23.6 N/mm^2 respectively.

The tensile strength were between 1/16 - 1/12 of both mixes and this is within the range of 1/20 - 1/8 of the Cube Crushing Strength (as given by Murdock 1968).

The bond strength test carried out shows that the Material can effectively be used for a reinforced concrete construction the bond strength range is between 3.71 - 5.3 N/mm^2, about 18% lower than that for normal concrete of between 10 and 12mm diameter plain and deformed bars.

The concrete made with Periwinkle Shells is of medium weight in terms of density, and adequate for Construction, since the unit weigth is about 1911 - 1967kg/m^3, compared to the range of normal and lightweight concrete of between 23549 - 25632kg/m^3 and 400.5 - 1850kg/m^3 respectively.

The statistical analysis performed on the cubes strength shows that the deviation in strengths of test cubes are within the limits permitted.

Finally, from the test result carried out, it can be said that, the use of perwinkle shells as a building material for construction is comparable with other building materials like gravel and crushed brick/stone for construction work.

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CHAPTER - ONE

INTRODUCTION

1.1 GENERAL INTRODUCTION

In recent years, there has been an increase in the use of lighter materials for the construction of building works.

A Variety of factors, in addition to research work and operational enterprise, have led to the gradual acceptance of lightweight concrete as a common place building material, for example, there is a growing need in built-up areas for the reduction in the dead weight of tall buildings, widespan concrete girders, roofing construction and spatial structures generally.

As lightweight concrete can be made with a wide range of specific characteristics, there is ample scope for its selective use in modern building construction.

Orchard (1956), Proclaimed that Tightweight concrete falls into several categories according to variation in physical properties. In this regard, the bulk density ranges between 400.5 - 1850kg/m^3.

Taylor (1977), found that the drying shrinkage varies from less than that of ordinary concrete to several times more. Similarly the insulating value was found to run from three to over twelve times that of ordinary concrete.

Lightweight concrete also can be manufactured not only on account of its lightweight, but also because of the high thermal insulation compared with normal concrete.

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Orchard (1958), Proposed three methods of producing lightweight concrete.

i. By omitting the fine aggregate, this called 'no-fines' concrete.

ii. By using air as an aggregate and producing what is generally known variously as "aerated, cellular, gas, porous and foamed slag" Concrete.

iii. By using a lightweight aggregate.

This research is concerned with the use of "Periwinkle Shells" as aggregates for the production of lightweight concrete.

The Periwinkle Shells constitute a great disposal problem in areas in areas where they are found. Presently they are mostly used in filling depressions in roads and in raising embackment on river banks.

In crude form periwinkle shells are also used locally for strip foundation, floor screed and lintels in building in the riverine areas. However tests have not been carried out to determine the characterstics and suitability for other application.

The physical properties of the periwinkle shells were determined, and element analysis was made to establish their composition.

Concrete mixes were designed and produced. The compressive strengths of the mixes were determine at the ages of 7, 14, and 28 days. Test were also carried out to determine the tensile and bond strengths the mixes.

1.2 NEED FOR THE STUDY

The study of periwinkle shell as a lightweight aggregate is necessitated by the high cost of housing construction. Some building materials are very expensive for example a large quantity of the cement used for the Construction is imported from abroad, Even the ones manufactured locally are costly because most of their components are imported. Crushed stone which is extensively used as course aggregate, for construction is expensive, because the machinery to work with are brought from abroad, in addition to their high cost.

Since construction with materials like crushed stone, is costly, the introduction of materials like crushed bricks, periwinkle and palm Kernel Shell, will generally lead to a reduction in cost of construction.

And lastly to check on the strength of concrete made with periwinkle shell as an aggregate cast to cubes, and to ascertain if it is within the permitted range using statistical analysis.

1.3 OBJECTIVES

The objectives of this study are:

i) To find out if periwinkle shells can be effectively used as an aggregate for concrete.

ii) If it can be used in combination with steel rod for reinforced concrete.

1.4 METHODOLOGY

Trial mixes were produced using different. Water/Cement ratio to determine the optimate water/cement ratio cubes were cast for each trial mixes and tested for compression strength at the ages

of 7, 14 and 28 days. The water and cement ratio for the mix that gave the highest strength was adopted for the design of the final mix.

The mixes were based on the structural use of reinforced concrete in Buildings British standard CP 114: Part 2: 1969. The mixes designed were 1:1½:3 and 1:2:4. Ninety cubes and Twenty four cylinders were produce for each of the mixes. The cubes were bured and tested for compressive strength at the ages of 7, 14 and 28 days. While the split tensile and bond strengths test were carried out at the age of 28 days only.

Statistical analysis were performed on the results of the compressive strengths obtained for the cubes at the ages of 7, 14 and 28 days to ascertain the variation in strength.

1.5 SCOPE AND LIMITATION

The study of this material entails a broad investigation into its use as a materia for concrete production that can be used in a similar way as crushed stones and gravels for building works.

In this research the tests performed include those for determining the physical properties of the periwinkle shells for establishing its suitability for concrete production. Such tests include, Sieve analysis, Specific gravity, Bulk density, porosity, Absorption and moisture content. The concrete produced with the Periwinkle Shells was tested for compressive and tensile strengths. Tests were also carried out to determine the compressive, tensile and bond strength of the concrete. Limited facilities did not allow the determination of such properties as drying shrinkage and moisture penetration.

CHAPTER TWO

LITERATURE REVIEW

2.1 PERIWINKLE SHELLS

The periwinkles found in the delta areas of Nigeria, has a heavy, squat, Conical shell with six or seven whorls, a pointed apex, and rounded aperture, it may reach a length of 3.8 cm and above.

According to Encyclopedia Americana Volume 21 (1966), they belong to the family LITTORINIDAE. They are widely distributed shore snails Chiefly herbivorous usually found on rocks or pilings between high and low tide marks.

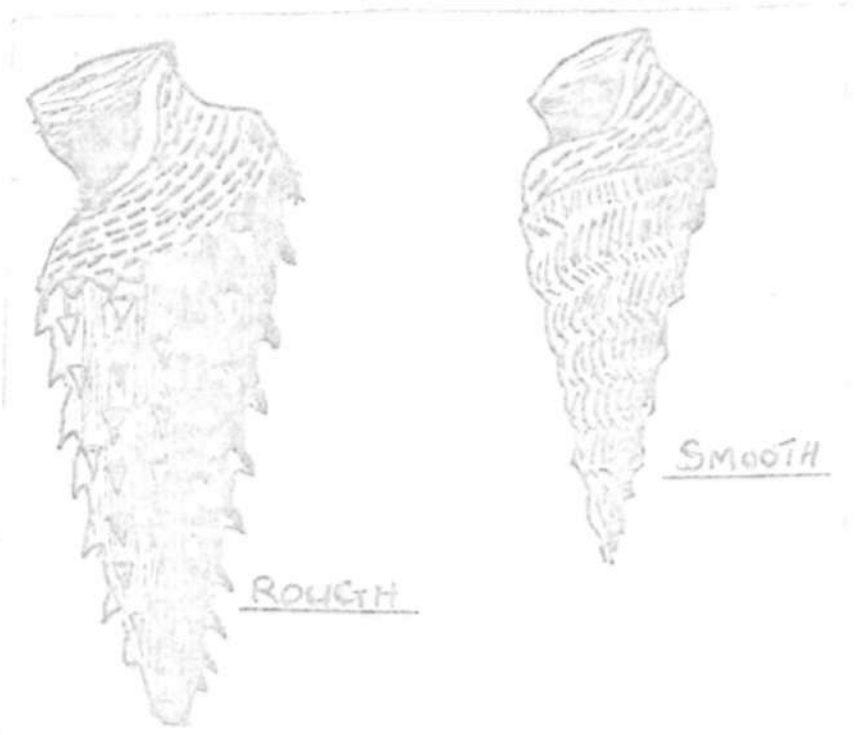
During breeding the periwinkles often move out of water for a long period of time, they hold their eggs in a broad Sac until the young and fully develop ones, emerge as tiny crawling replica of the adult. (Encyclopedia Britannica, Volume 17, 1969).

Periwinkles are an important source of food for the poorer classes in riverine areas of Nigeria. In these areas the snails are usually boiled in a small amount of heavily salted water (the salt tends to loosen the animal from the shell) the meat is then used in preparing food. They are called by various names, the urhobos called it Imekpe, Ibos called it Isam, Calabars called it Mfi etc.

The shells of the animals are usually spread on the surroundings of houses, used in filling depression and pot holes on roads in areas around the riverine areas. However, in some towns in Rivers and Bendel States a limited amount is used for preparing concrete for houses and roads.

An actual specimen of the aggregate is shown in plate -1 below.

Plate-1 PERIWINKLE SHELLS



2.2 CHARACTERISTICS OF LIGHTWEIGHT CONCRETE

Neville (1973), states that: the essential characteristics of lightweight aggregate is its high porosity which results in a low apparent specific gravity. This results in the production of lighter concrete with a reduction in the weight structures.

Some lightweight aggregates occur naturally while others are manufactured, the natural aggregate includes punice, scoria, palm kernel and saw dust e.t.c. While the artificial aggregates which are known by a variety of trade names, but are best classified on the bases of raw materials used includes expanded clay, shale, slate, clinker, fly ash or pulverized-fuel ash and expended blast - furnace slag.

2.3 PROPERTIES OF LIGHTWEIGHT CONCRETE

The Chief properties of lightweight concrete are:-

i) Sound insulation

ii) The ease with which it can be cut, nailing and Rendering

iii) Permeability and resistance to weathering

iv) Thermal Conductivity

v) Durability

2.3.1 SOUND INSULATION

Lightweight concrete which are unrendered are often used for internal walls because they are believed to have good sound absorbing qualities. They reduce the transmission of sound depending on the weight and size of concrete block.

2.3.2 The Ease With Which It Can be Cut, Nailing, And Rendering

With the exception of no-fines concrete all lightweight concrete can be easily cut with normal bricklayer's tools, Engraves for pipe runs etc., can also easily be formed and they will accept and hold nails of all type to provide a good key for rendering.

2.3.3 Permeability And Resistance To Weathering

Lightweight concretes have a low permeability although, it is normal to protect them by rendering if they are used in exposed position.

Orchard (1958) was of the view that some of them have a good resistance to weathering and frost action, but in wet climate, they are seldom used without adequate protective rendering, since their thickness can be increased to enhance the water exclusive ability.

2.3.4 Thermal Conductivity

This is the ability of materials to conduct heat. Taylor (1977) found that: In lightweight concrete the thermal conductivity is related to its unit weight and mineralogical composition and proportion of lightweight aggregate in the concrete. Values for oven-dry materials are listed in (Table 2.1).

It increases considerably as the moisture content increases. Coated expanded clay aggregate impregnated with

bitumen improves insulation under damped condition.

Table 2.1 THERMAL CONDUCTIVITY (TAYLOR 1977)

Thermal Conductivity K (W/M°C)	Bulk Density, Dry (Kg/M³)
0.48 - 1.27	1900
0.35 - 0.81	1600
0.27 - 0.52	1300
0.18 - 0.36	1000
0.13 - 0.22	700
0.07 - 0.14	400

2.3.5 Durability

Lightweight concrete can be durable, when properly designed. Taylor (1977) found that: It resist deterioration as dense ordinary concrete and also if covered adequately, it protects the corrosion of steel reinforcement.

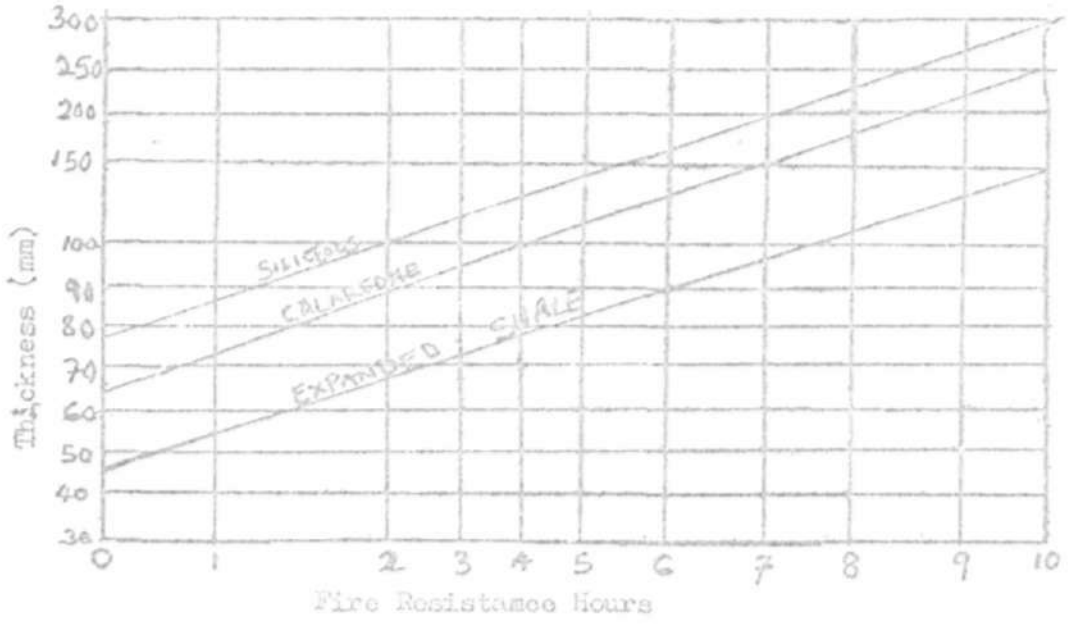
Kenneth (1979) states that, lightweight concrete that is well compacted tends to carbonate to only a small extent than ordinary concrete. And due to its vesicular nature, the concrete has a high resistance to frost action. The abrasion resistance of lightweight concrete, which is less than dense concrete makes it quite sufficient for bridge decks.

Taylor (1977) was of the opinion that, the fire protection value of lightweight concrete is particularly advantageous in high rise building construction. The fire resistance of a 100mm thick lightweight concrete having expanded-shale as aggregate is approximately the same as 150mm thickness of ordinary concrete.

Figure 1, shows the relationship of fire resistance and thickness of concrete.

Figure 1

Relationship of Fire Resistance and Thickness of Concrete



2.4 USES OF LIGHTWEIGHT CONCRETE

The principal uses of lightweight concrete depends on its weight and low density in concrete construction of various structures and this has an adverse effect on cheaper and lesser complicated foundation. Some of their application are:-

1. Mainly for the construction of screeds and thickening for general purposes, especially when such screed or thickening add weight to floors and roofs etc.

2. They are used for casing structural steel to protect it against fire, corrosion, and for heat insulation on roofs, water pipes and for general insulative walls.

3. They are used for the construction of partition walls, panel walls in frame structures and for fixing bricks to receive nails from joinery, principally in domestic type construction.

4. It is used for surface rendering for external walls of small houses and also they are being used to a small but progressive extent for reinforced concrete.

2.5 PHYSICAL PROPERTIES OF LIGHTWEIGHT AGGREGATE

2.5.1 SPECIFIC GRAVITY

Murdock (1968), defined specific gravity as the ratio of the weight in air of a permeable material in a saturated surface-dry condition to the weight in air of an equal volume of water.

The specific gravity differs depending on the sizes of the aggregate, and also the specific gravity of an aggregate depends on the specific gravity of the materials of which the aggregate is composed and inrelation to the amount of voids.

Specific gravity are used in the calculation of yield of concrete or of the quantity of aggregate required for a given volume of concrete. The specific gravity value of lightweight aggregate is between (1.0 - 34).

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2.5.2 Bulk Density

For most materials used as course aggregate such as stone of given specific gravity, Neville (1973), states that a higher bulk density means that there are fewer voids to be filled by sand and cement, and the bulk density test has at one time been used as a basis of proportioning of mixes for concrete work.

The bulk density of an aggregate is affected by several factors, including the amount of moisture present and the amount of compactive effort used in filling the container.

The test for determining the bulk density are performed in two ways, these are loose (uncompacted) and compacted.

In the field, the uncompacted bulk density are normally used. Due to the fact that in practice the material will not be compacted before they are used for concrete work. Sometimes in mix design, the proportioning of concrete is based on void content of the aggregates and a measurement of voids is useful in certain cases. It indicates if an aggregate is well graded or not, for most material if the aggregate is well graded the void ratio will be small.

2.5.3 Porosity

Neville (1973), states that, the presence of pores in an aggregate influences such properties as the bond between it and the cement and thawing as well as its chemical stability and resistance of abrasion.

In concrete work pores smaller than 4mm affects the durability of an aggregate and subjects it to alternative freezing and thawing. Pores in particles are found either wholly within the solid or on the surface of the particle. Cement paste cannot penetrates the pores to a great extent, due to its viscosity. But however water can pass through the pores, the amount and rate of penetration depends largely on the size, continuity and total volume.

2.5.4 Absorption

Absorption is a physical process by which an aggregate draws water into its pores or surfaces. However, is difficult to determine how much water that is absorbed by the aggregate and how much occupies space within the concrete.

Neville (1977), proclaimed that, in most design if the aggregate is saturated before mixing the strength of the concrete is about 5 to 10 percent lower than when it is dry for the same amount of cement content and workability. This is due to the fact that mixing water is absorbed at the time of setting, and this water contributes to the workability at the time of placing.

Damp lightweight aggregate contains more absorbed water after a short immersion in water than dry aggregate place for the same length of time. This is due to the fact that a small amount of water that moistan an aggregate particle

does not remain in the surface pores but [illegible] to fill the small pores inside.

2.5.5 Moisture Content

Neville (1973) states that, the moisture content of an aggregate is the surface moisture expressed as a percentage of the weight of the saturated and surface dry condition of the aggregate, and it changes from one place to another depending on the weather to which the stockpile is expressed.

Elvery (1963) states that moisture content is the excess water held by the aggregate. While absorption represent water contained in the aggregate in a saturated and surface-dry condition, the total water content of a moist aggregate is equal to the sum of absorption and moisture content.

According to Murdock (1968) in large works due to changes which occure in the moisture content of an aggregate from the upper to the bottom of a stockpile, it is essentially necessary for sampling test to be done on different parts of the stock-pile and mixed. At least three samples should be taken and tested and the average value recorded.

2.6 GRADATION OF AGGREGATE

Grading of an aggregate which is the distribution of particle-size of an aggregate is an important characteristic, because it determines the amount of cement required for a workable concrete, since cement is quite expensive, it is desirable to minimize the cost of concrete by using the smallest amount of cement consistent with the production of a concrete that can be handled,

compacted and finished to provide the necessary strength and durability.

Sidney (1977), was of the view that, the significance of gradation is best appreciated by considering concrete as a slightly compacted assembly of aggregate particles bonded together with cement paste, with the voids between the particles completely filled with paste.

In most design the amount of paste required greatly depends on the void space and the total surface area of the aggregate that must be coated, so using a larger maximum aggregate size can reduce the void space, thereby reducing the amount of cement.

2.6.1 Sieve Analysis

Neville (1973), defines sieve analysis as the operation of dividing a sample of aggregate into fractions, each of the fraction consisting of particles of the same sizes between specified limits. For coarse aggregate test sieves are 4mm and above with a screening area of about twice the size the aperture of the next larger one.

Before performing the sieve analysis, the aggregate sample must be dry to avoid lumps of fine particles been classified as large particles.

2.6.2 Grading Curve

When the sieve analysis is completed the result are plotted in graphs, the purpose of using graphs is to check if the grading curve falls within or conforms to that specified, belonging to either coarse or to fine aggregate grading.

2.7 CHEMICAL REQUIREMENTS OF AGGREGATES

An aggregate is defined as the principal structure of concrete, consisting of relatively inert fine and coarse materials usually stone. According to La Londe (1973), from the defination it is required that its chemical activity be minimized so that no distruption effects occur during the setting of the concrete or subsequently because of the service condition. The chief sources of chemical action in aggregate is as follows:-

1. Solubility. Aggregates containing [illegible] other substances that are readily soluble in water may be leached out, resulting in efflorescence and scaling of the surface.

2. Oxidation, Hydration and Carbonation. The presence of these substances lead to the failure of aggregates containing the following substances: pyrite, ferrous and ferric oxides, and magnesia.

3. Reaction with Portland Cement. Calcium and magnesium sulphates present in aggregate react with hydrated aluminates of cement, causing expansion and failure of cement bonds.

4. Base - Exchange Reaction. Concrete may also be adversely affected by a base-exchange between components on the aggregate and the caustic solution within the cement paste, though tests have been performed that indicates zeolitic rock as a possible source of trouble.

5. Alkali Reactivity. Some rocks and minerals react with alkalies released by setting of cement with subsequent expansion and disruption of the bonds outwardly the concrete exhibits pattern cracking which may be accompanied by exudation of gelatinous substances. Though alot of aggregate causes this type of reaction, but extensive tests by the bureau of reclaimation have only shown that all silicate and silica minerals reacts to a certain extent with alkalies in cement, but with most of them the effects are insignificant. Test work have also shown that with reactive aggregates, the alkali content of the cement should be 0.6 percent or less and this percentage is normally taking into consideration by most cement manufacturers.

2.8 MIX DESIGN

Neville (1973) defined mix design as the process of selecting the most suitable materials of concrete and determining their relative quantities with the object of producing as economical as possible concrete of certain minimum properties such as consistence, strength and durability.

In concrete work a period of 28 days is given for curing, for concrete to achieve a high strength. Sidney (1977), found that, there are two fundamentals of mix design, the choice of water cement ratio and the aggregate grading, which must be taken into account when desiging a mix.

Duff Abrams (1919), states the water and cement ratio law for the strength of concrete, that the strength of any materials depends on the ratio of water to cement. This he expressed by

$$\sigma_c = \frac{A}{B^{1.5(W/C)}}$$

where,

σ_c = Compressive strength

A = Emperial constant taken to be 14,000

B = Constant that depends on cement properties

W/C = Water/Cement by weight

While the aggregate grading was based on the packing characteristic of granular materials, it was carried out by Fuller and Thompson (1907), their results is obtain from graph grading curve (for minimum voids).

2.8.1 Mix Design For Trial Mixes

The design of trial mixes from which the precise mix for any concrete work can be determined is usually carryout by varing the amount of water to be used in a fixed mix, so that the known proportion to give a high strength can be obtain after making a series of test cubes.

The idea of this is to ensure that better and more precise results are obtained for the final mix design.

2.9 WORKABILITY

Newman, proposes the definition of workability based on three separate concrete properties;

Compactibility, the ease with which the concrete can be compacted and the air Voids removed.

Mobility, the ease with which concrete can flow into moulds around steel and be remoulded.

Stability, the ability of concrete to remain a stable, coherent, homogeneous mass during handling and viberation without constituents segregation.

The workability of concrete is affected by the water/cement ratio, the size and type of aggregate and the grading of the aggregate. It can also be affected by voids present inform of small holes or pores, which reduces both the density and the strength. Two kinds of voids are present in concrete air and water voids.

Elvery (1963) states that concrete containing air voids is due to insufficient compaction of the freshly place concrete and also if concrete contains 2% of air voids the strength will be reduced by more than 10%. While concrete containing water voids is due to insufficient dryness of the concrete.

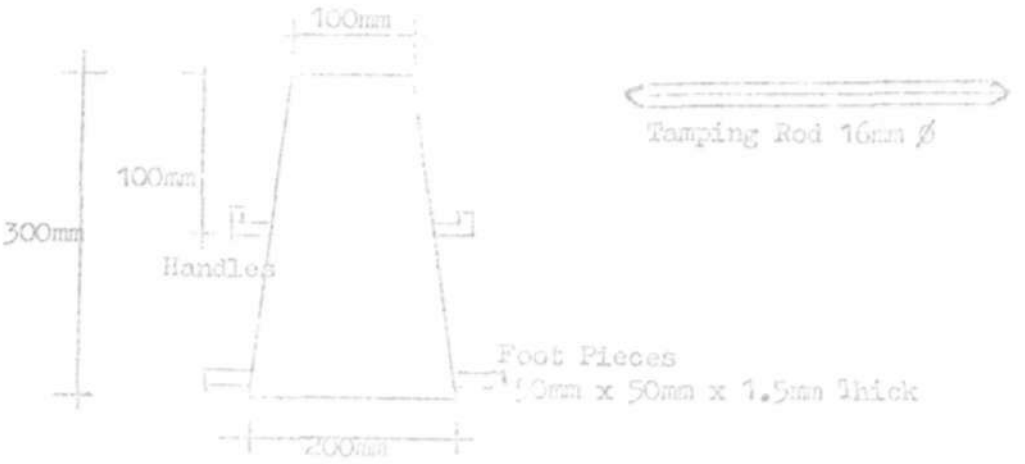
Workability plays an important role in the ultimate strength of concrete, as such the consistence of the concrete must be such as to allow it to be transported, placed and finished sufficiently easily with out segregation.

2.9.1 Slump Test

The slump test provide a simple practical method for maintaining reasonable uniformity in the consistency of concrete produced.

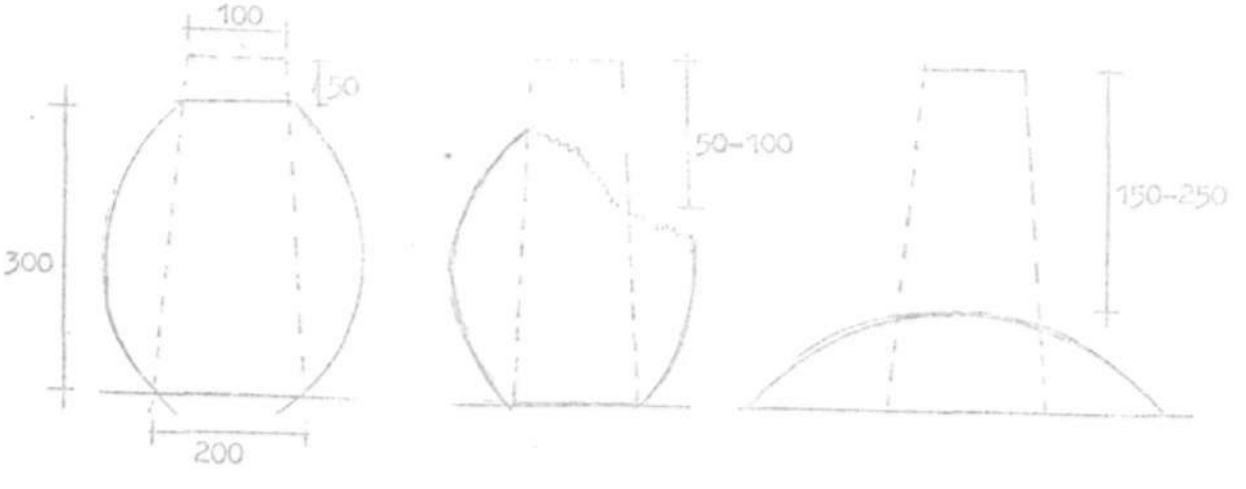
The method of making the slump test is described in B.S. 1881 (1968). The test is made with a metal cone 300mm high, having a bottom diameter 200mm and a top diameter 100mm. Figure 2 and 3 show slump test mould and various types of slumps respectively.

Figure 2 - Slump Test Mould



In slump test if shear or collapse slump occur the test has to be repeated, the figure below shows the various types of slumps.

Figure 3 - Shape of Slump



2.9.2 *Compacting Factor*

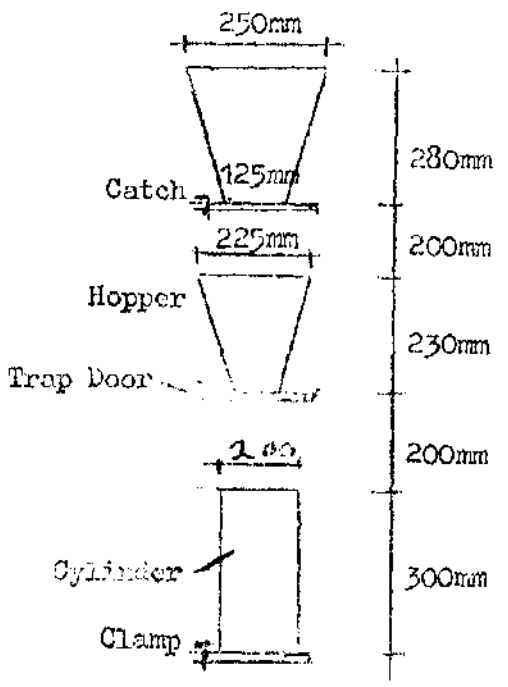
The compacting factor is a devise for measuring the degree of compaction obtained by doing a standard amount of work on the concrete and therefore bears a close relation to workability, since it provides a good measure of workability.

The test was developed in B.S. 1881: Part 2 (1970), the apparatus consist of two hoppers, each in the shape of a frustrum of a cone and one cylinder as shown in figure 4 below.

The compaction factor apparatus is not often used outside precast concrete works and large site.

The main principle behind the test shows that in a mix a compacting factor less than about 0.75 cannot be compacted satisfactory by hand, while less than 0.60 cannot always be compacted by vibreration unless pressure is applied.

Figure 4



Compacting Factor Apparatus

2.10 HARDENED CONCRETE

2.10.1 Density of Concrete

The density of a concrete cubes is usually expressed as its mass per unit volume and is calculated based on the following relation;

$$\text{Density} = \frac{\text{Mass(Kg)}}{\text{Volume}(m^3)}$$

According to Orchard (1973), the density of normal concrete ranges from 2354.9 - 2563.2kg/m3 while that of lightweight concrete ~~600~~ -1850kg/m^3.

In any concrete work the density of the concrete is normally affected by density of aggregate, grading, degree of compaction, water-cement ratio, moisture content of the concrete at the time of testing. With the above influence on density of concrete care should be taken when carrying any concrete work to minimise such influence as much as possible to increase the density of the concrete work.

2.10.2 Crushing Strength

Budinski (1979), define crushing strength as the maximum compressive stress that a material is capable of withstanding (based upon original area) before segregation on applied force.

Murdock (1968) states that concrete can be made to have a strength in compression of up to about 40N/mm^2 and above depending mainly on the relative proportions of water/cement ratio and the degree of compaction.

The crushing strength of concrete are influenced by a number of factors in addition to those stated above, the more important factors are, the type of cement and its quality, the surface testure of the aggregate inrelation to smoothness, the efficiency of curing after casting, temperature within the environment of curing, increase temperature increases the strength of concrete, while at freezing temperature the crushing strength may remain low for some time. And lastly age, under normal condition concrete strength with portland cement increases in strength up to 28 days, but although hardening continues after 28 days but at a much slower rate for a number of years.

2.10.3 Tensile Strength

Tensile strength is the ratio of maximum load to original cross-sectional area. According to Murdock (1968), it varies in concrete from one-eighth of the compressive strength at early ages to about one-twentieth later and in most cases is not usually taken into account in the design of reinforced concrete structures. The tensile strength is only of considerable importance in resisting cracking due to changes in temperature.

There are two methods of measuring tensile strength, one gives tensile strength in bending, usually termed flexural strength B. S. 1881 1968, gives details of making and curing of flexure test specimens and of the method of test.

While the other test, which is used in the thesis, a load is applied through two parkings placed at the top and bottom on the plane of loading and a load is applied until the specimen breaks and the failure load recorded.

2.10.4 Bond Between Concrete and Reinforcement

In any concrete work, an effective bond between the concrete and reinforcement is required, since the efficient use of the combinations of steel and concrete is dependent on the transfer of stresses from the concrete to the steel.

Murdock (1968) states that: the bond strength between the concrete and the steel is best defined as the stress at which a very small slip occurs.

Bond is due initially to adhesion and frictional resistance, which changes the bar stress from point to point, but as soon as slipping begins the adhesion fails and the subsequent, bond is due to friction and mechanical resistance.

The development of bond strength is most rapid under moist curing conditions, but its strength can be improved by increasing the crushing strength of the concrete.

Deformed bars has increase bond strength than plain round bars by 25 per cent or more, although a slight slip is likely to occur before the full bond strength of the deformed bar is developed.

Bars in tension must exceed for a sufficient distance from any stressed section to develop a satisfactory resistance to failure of the bond between the bar and the concrete.

The test method used in the research for finding the permissible bond stress is the pullout test.

CHAPTER THREE

LABORATORY PROCEDURE AND TESTING

3.1 SELECTION OF MATERIALS

The material used for lightweight concrete consist of water, cement, sand and periwinkle shells as coarse aggregate.

3.1.1. Water

Water plays an important role in concrete construction. In using water for making concrete it must be free from deleterious materials such as silt, clay, alkalines and other salts. According to Sidney (1977) if such impurities are present in a mixing water, it would affect such properties like durability, setting time and drying shrinkage etc.

3.1.2. Cement

The cement used throughout for the research is the normal portland cement produced in Nigeria. The brand used is the Ashaka cement from Gombe in Bauchi State. It is obtained from some of the local dealers within Zaria.

3.1.3. Sand

River sand dredged within the Zaria environment was used throughout for all the mixes as fine aggregate. The sand is clean and free from impurities.

3.1.4. Coarse Aggregate

The periwinkle shells used for the study were obtained from the riverine areas of Warri in Bendel State. The aggregate includes both the rough backs and the smooth back shells. The tests below were performed on the periwinkle shells in order to establish the properties

3.1.4.1. Specific Gravity

The determination of specific gravity is based on B.S. 812; the sample of the aggregate was placed in a glass jar covered with water, stirred to remove air bubbles, and allowed to stand for 24 hours, the aggregate sample was then surface dried by placing it under a blowing air from a ceiling fan, then the weight determines.

The determination of specific gravity was carried out on three different pycnometer bottles and the average result obtained.

The calculation is based on the followings:

C = Weight of the saturated and surface dry sample, in this case the aggregate can absorb no more water and non forming on the surface, this means the aggregate neither contributes to non-absorbs water from the concrete.

B = Weight of the vessel full of water.

A = Weight of the vessel with sample topped up with water.

D = Weight of the empty vessel.

B - (A+D) = Weight of the water occupying the same volume of the solid.

The vessel referred above is called a pycnometer.

From the above data:

S.G on saturated surface dry (S.S.D) = $\frac{C}{B - A+C}$

First pycnometer reading:

A = 1805gm

B = 1660gm

C = 390gm

D = 602.5gm

$\therefore$ S.G. on S.S.D = $\frac{400}{1660-1805+400}$ = 1.54

Second pycnometer reading:

A = 1797.5gm

B = 1660gm

C = 445gm

D = 602.5gm

$\therefore$ S.G. on S.S.D = $\frac{445}{1660-1797.5+445}$ = 1.48

Third pycnometer reading:

A = 1777.5gm

B = 1640.0gm

C = 457.5gm

D 592.5gm

$$\therefore \text{ S.G. on S.S.D} = \frac{457.5}{1640-1777.5+457.5} = 1.46$$

$\therefore$ Average result of the three readings

$$= (A + B + C)/3$$

$$= \frac{1.54 + 1.48 + 1.46}{3} = 1.49$$

3.4.4.2 Bulk Density

Murdock (1968), defines bulk density as the weight of material held by a container of unit volume, when filled and compacted under a given condition.

The determination is based on air dry condition. And the test is performed in two ways, these are loose (uncompacted) and compacted.

For the determination of loose bulk density the aggregate is gently placed on a cylinder 150mm diameter by 300mm height, to over flow and then a rod is rolled across the top to level it. While the compacted bulk density the container is filled in three stages, each stage is tamped 25 times with a 16mm diameter rod. Again the overflow is removed. The net weight of the aggregate in the container divided by its volume gives the bulk density for either ways.

Table 3.1 shows the bulk density calculation for periwinkle shells.

Table 3.1 RESULTS OF BULK DENSITY

NO.	VOLUME OF CYLINDER	WEIGHT OF CYLINDER (kg)	UNCOMPACTED WEIGHT (kg)	UNCOMPACTED BULK DENSITY(kg/m^3)	COMPACTED WEIGHT (kg)	AVERAGE COMPACTED BULK DENSITY(kg/m^3)
1.	Q = 15cm, H = 30cm V = 5.3 x 10^3 m^3	28.6	2.4	452.8	2.9	547.2
2.	"	28.6	2.4	452.8	2.9	547.2
3.	"	28.6	2.4	452.8	2.9	547.2

The void ratio of an aggregate is calculated using the specific gravity for saturated and surface dry condition (P). The expression is based on:

$$\text{Void ratio} = 1 - \frac{\text{Bulk density}}{\text{P x Unit weight of water}}$$

$$\text{For uncompacted, void ratio} = 1 - \frac{452.8}{1.49 \times 1000} = 0.70$$

$$\text{For compacted, void ratio} = 1 - \frac{547.2}{1.49 \times 100} = 0.63$$

From the calculation the values of the void ratio shown that the shells are well graded.

3.1.4.3 Porosity

The determination of percentage porosity is based on the result obtained from the bulk density test. Using the expression.

$$\text{Percentage porosity} = (1 - A/B)\ 100$$

Where

A = Uncompacted bulk density

B = Compacted bulk density

$\therefore$ Percentage porosity = $(1 - \frac{452.8}{547.2}) \times 100 = 17.3\%$

This indicates a high degree of porosity, which is common to lightweight concrete.

3.1.4.4. Absorption

The absorption of an aggregate is determined by measuring the increase in weight of an oven dry sample, when immersed in water for 24 hours (the surface moisture being removed). The ratio of the increase in weight to the weight of the dry sample expressed as a percentage gives absorption of the sample. The rate of absorption affects the water content of the mix. In Table 3.2., the results of the absorption of periwinkle shells is shown below.

Table 3.2. Results of Absorption

SAMPLE	WEIGHT OF CONTAINER (gm)	WEIGHT OF OVEN DRY SAMPLE A (gm)	WEIGHT OF SOAKED SAMPLE B (gm)	INCREASE IN WEIGHT (B-A) (gm)	% ABSORPTION
Periwinkle Shell	602.5	370	377.5	7.5	2.0%

3.1.4.5. Moisture Content

The determination of moisture content is performed by the pycnometer method, the test is carried out using the bulk specific gravity of the aggregate.

Using the following expression:

A = Weight of pycnometer with sample topped up with water.

B = Weight of the pycnometer full of water.

P = Specific gravity.

From the expression:

$$\text{Moisture content} = \left(\frac{C}{A-B}\left(\frac{P-1}{P}\right) - 1\right) \times 100$$

Table 3.3 Results of Moisture Content

SAMPLE	SPECIFIC GRAVITY	WT. OF PYCNO-METER FULL OF WATER B (gm)	WT. OF MOIST. SAMPLE C (gm)	WT. OF PYCNO-METER WITH SAM-PLE TOPPED UP WITH WATER(A)(gm)	MOIST. CON-TENT OF THE AGGREGATE IN %	AVERAGE
1.	1.49	1660	445	1797.5	6.8%	7.2
2.	1.49	1637.5	457.5	1777.5	7.5%	

Murdock (1968), proposes the following precautions when using the pycnometer method:

(i) Weighing must be very accurate.

(ii) The outside of the bottle must be carefully wiped free of any drops of water.

(iii) It is not easy to get rid of air bubbles and any carelessness in this respect upsets the results.

(iv) Care must be taken when testing coarse aggregate, since the bottle can easily be broken by it (it is necessary to use glass bottle in order to see if there is any air bubbles).

The use of this method has the advantage that it can be used when no source of heat for drying are available.

advantage is due to the slowness of the test, since it takes about two days to complete the test.

3.1.4.6 Sieve Analysis

The sieve analysis was performed based on the provision of the British standard BS410 (1969), the test of the actual sieving operation is mostly performed by hand in a series of successive sieves nesting one after the other, with the largest sieves at the top, each sieve in turn being shaken until not more than a trace continues to pass. The mode of shaking is backwards and forwards, sideways left and right, circular clockwise and anticlockwise, all this process are done one after another so that every particule has a chance of passing through the sieve. The arrangement of the sieves is shown below in plate 2, while the results of the sieve analysis is presented in table 3.4.

During the sieving care must be taken in order to make sure that no sieve is over loaded.

Table 3.4 Sieve Analysis Performed on the Shell

SIEVE NO. (mm)	WT. RETAINED (kg)	WT. PASSING (kg)	% PASSING	% RETAINED
19.0	1.4	7	100	20
9.5	3.0	5.6	80	64
4.75	1.8	2.6	46	69
2.36	0.6	0.8	31	75
1.18	0.16	0.2	25	80
Pan	0.04	0.04	20	-
TOTAL	7			

3.1.4.7 Grading Curve

Based on the above result, the grading curve was plotted in figure 5. In plotting the grading curve for the periwinkle shells, the ordinate represent percentage passing and abscissae the sieve opening plotted to a longarithmic scale. From the graph it could be concluded that the aggregate can be used for a good concrete mix.

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Figure 5 - Grading Cure

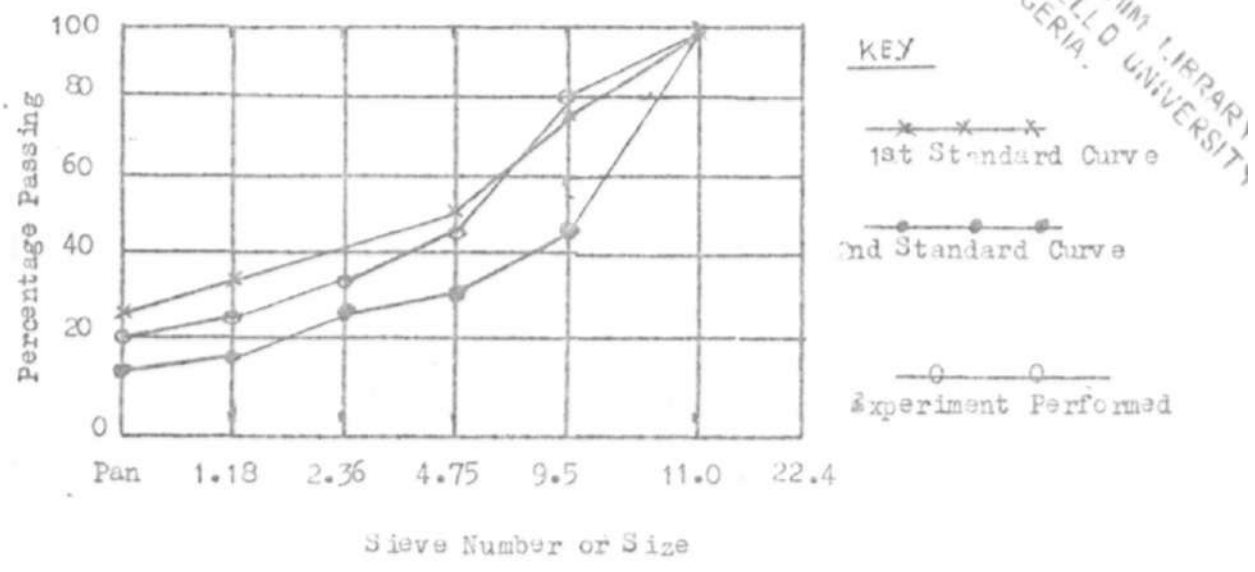




Plate 2 BRITISH STANDARD TEST SIEVES

3.2. Elemental Analysis of Periwinkle Shells

Elemental analysis of the shells was carried out by fast neutron activation analysis. The analysis was performed at the Centre for Energy Research and Training (CERT), ABU., Zaria.

Neutron activation analysis involves the activation of stable elements that make up the composition of a sample and the detection of unique signals given out by activated samples. The process of activation involve the introduction of a neutron into the necleus of the atom. In this case the neutrons are produced from a neutron generator which produce high energy neutrons (at 14 MeV energy). Upon activation, the necleus becomes unstable and emit radiation signals that are unique to the individual elements. These signals are used to identify the presence of element in samples. Quantitative and qualitative analysis of samples are possible with appropriate standard sample.

The detection of the signals was done via a germanium - litium drifted semiconductor detector. The detection system

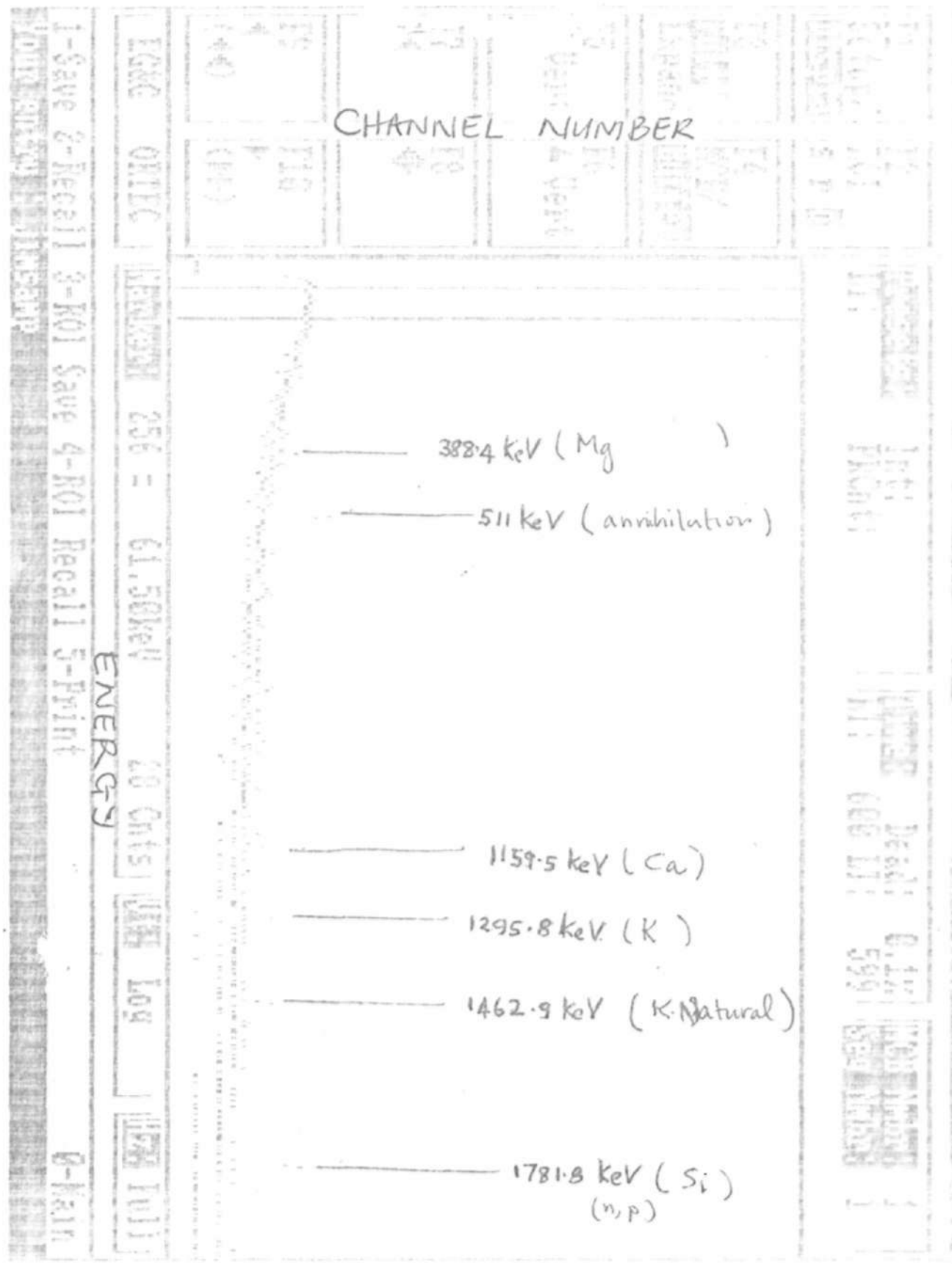


FIGURE 6 ELEMENTAL COMPOSITION OF PERIWINKLE SHELLS

has a very high resolution of about 1.7 KeV for cobalt 60, 1332 Kev peak.

Sample preparation involve the grinding to finess the periwinkle shells and sealing 3gm of samples in polythelene vials. The sample was irradiated in the vials.

Results obtained from the analysis, identified the presence of silicon, magnesium, calcium and potassium. Only qualitative analysis was performed on these samples. The quantitative analysis was not performed due to limited facilities. Figure 6 shows the major element present in the shells.

3.3. Mix Design

The method of mix design used is that developed at the road research laboratory, which is based on water and cement ratio. In this method the mix is designed for a given compressive strength, as most of the desirable properties of concrete improves as its strength is increased.

3.3.1. Mix Design for Trial Mixes

The specific gravity method of batching was used for finding the amount of materials required for the trial mixes. In designing the concrete for these specimen two mix proportion were used 1:1½ : 3 and 1:2:4. Five different water/cement ratios of 0.4, 0.5, 0.6, 0.7 and 0.8 was used in checking the optimum water/cement ratio for the two mixes.

The calculation of the trial mixes were based on the test data shown below. These datas were used for knowing the quantity of

materials for each mix. A total of fifteen cubes were produced for the trial mixes, five of each were tested at the ages of 7, 14 and 28 days.

Density of cement = $1440 kg/m^3$
Density of sand = $1600 kg/m^3$
Density of shell = $452.8 kg/m^3$
Density of water = $1000 kg/m^3$

Specific gravity of cement = 3.15
Specific gravity of sand = 2.65
Specific gravity of shell = 1.49
Specific gravity of water = 1.0

Volume of 15 cubes = $0.15 \times 0.15 \times 0.15 \times 15 = 5.06 \times 10^{-2} m^2$.

The procedure for calculating the amount of material for the trial mixes is as follows:

For nominal mix $1:1\frac{1}{2}:3$, W/c = 0.4

Absolute Volume of Material (A.V)

A.v. for cement = $\frac{1440 \times 1}{3.15} = 457L$

A.v. for sand = $\frac{1600 \times 1.5}{2.65} = 906L$

A.v. for shell = $\frac{452.8 \times 3}{1.49} = 912L$

A.v. for water = $\frac{1440 \times 0.4}{1} = 576L$

Total A.V. = $2851L = 2.851m^3$

Quantity of Material for 15 cubes

Cement = $\frac{1410 \times 1 \times 5.06 \times 10^{-2}}{2.851}$ = 25.6kg

Plus 10% for waste = 25.6 x 1.1 = 28.2 kg.

Sand = $\frac{1600 \times 1.5 \times 5.06 \times 10^{-2}}{2.851}$ = 42.6 kg.

Plus 10% for waste = 42.6 x 1.1 = 46.9kg

Shell = $\frac{452.8 \times 3 \times 5.06 \times 10^{-2}}{2.851}$ = 24.1 kg

Plus 10% for waste = 24.1 x 1.1 = 26.5kg

Water = $\frac{1440 \times 0.4 \times 5.06 \times 10^{-2}}{2.851}$ = 10.2 kg.

Plus 10% for waste = 10.2 x 1.1 = 11.22kg.

For Norminal Mix 1:2:4. W/c = 0.4

A.v for cement = $\frac{1440 \times 1}{3.15}$ = 457L

A.V for sand = $\frac{1600 \times 2}{2.65}$ = 1208L

A.V. for Shell = $\frac{452.8 \times 4}{1.49}$ = 1216L

A.v. for water = $\frac{1440 \times 0.4}{1}$ = 576L

Total A.V. = 3457 = $3.457m^3$

Quantity of Material for 15 Cubes

$$\text{Cement} = \frac{1440 \times 1 \times 5.06 \times 10^{-2}}{3.457} = 21.1\text{kg}$$

Plus 10% for waste = 21.1 x 1.1 = 23.2kg

$$\text{Sand} = \frac{1600 \times 2 \times 5.06 \times 10^{-2}}{3.457} = 46.8\text{kg}$$

Plus 10% for waste = 46.8 x 1.1 = 51.5kg

$$\text{Shell} = \frac{452.8 \times 4 \times 5.06 \times 10^{-2}}{3.457} = 26.5\text{ kg}$$

Plus 10% for waste = 26.5 x 1.1 = 29.2kg.

$$\text{Water} = \frac{1440 \times 0.4 \times 5.06 \times 10^{-2}}{3.457} = 8.43\text{ kg}$$

Plus 10% for waste = 8.43 x 1.1 = 9.27kg.

The procedure for calculating the amount of material for the trial mixes for the other water and cement ratios is the same as that shown above.

3.3.2 Preparation of Concrete Cubes Made with the Shell

The test was carried out in the laboratory using a steel moulds 150 x 150 x 150mm.

The quantity of cement, sand, shells and water calculated were weighed. And each amount poured into the mixer, starting with the periwinkle shells, sand and cement, this quantities

were first mixed before the measured quantity of water, and mixing continues for 3 minutes in the mixer. The moulds onto which the concrete is to be placed for testing were cleaned and oiled before assembling to prevent bonding between the inner surface of the moulds and the concrete

After mixing of the various mixes a total of 150 cubes were cast for the trial mix design, 75 for 1:1½:3 and 75 for 1:2:4. This was done by filling the mould into 3 layers and each in turn compacted 25 times with a 16mm diameter rod. The moulds were covered with a wet sac for 24 hours to prevent rapid evaporation, after which they were removed from the moulds.

Before curing, the cubes were identified, for 1:1½:3 the identification mark was "A" and 1:2:4 as "B", the various water/cement ratios were mark as 1, 2, 3, 4 and 5, that is for mix 1:2:4 and a water/cement ratio of 0.6 the identification mark for the cubes was B3.

The cubes after being identified, were stored in a curing tank, (see plate 3) for a period of 7, 14 and 28 days.

The cubes to be tested after the respective days were removed from the curing tank, wiped with cloth, weighed and crushed.

The weighing of the cubes was necessary in order to determine the bulk density of the concrete since the volume of the cube is known.

$$\therefore \text{ Bulk density} = \frac{\text{Mass } (kg)}{\text{Volume } (m^3)}$$

The result of the trial mixes on the cube tests performed are summarized in table 3.5 and 3.6

Table 3.5 - Summary of the Trial Mixes Performed to determine the Optimum Water/Cement Ratios for 1:1½:3

MIX	WATER/CEMENT RATIO	AGE AT TEST DAYS	COMPREHENSIVE STRENGHT N/mm^2
1:1½:3	0.4	7	16.88
		14	17.22
		28	21.24
	0.5	7	17.52
		14	20.84
		28	24.36
	0.6	7	16.90
		14	22.20
		28	24.76
	0.7	7	13.62
		14	20.88
		28	20.20
	0.8	7	8.98
		14	17.32
		28	18.76

Table 3.6 - Summary of the Trial Mixes Performed to Determine the Optimum Water/Cement Ratios for Mix 1:2:4

MIX	WATER/CEMENT RATIO	AGE AT TEST DAYS	COMPREHENSIVE STRENGTH N/mm^2
1:2:4	0.4	7	6.68
		14	6.96
		28	9.80
	0.5	7	18.76
		14	22.66
		28	24.06
	0.6	7	17.49
		14	20.38
		28	20.86
	0.7	7	17.42
		14	19.30
		28	17.76
	0.8	7	14.48
		14	17.22
		28	18.32

Figures 7 - Showing Optimal W/C Ratio Curve for 7 Days

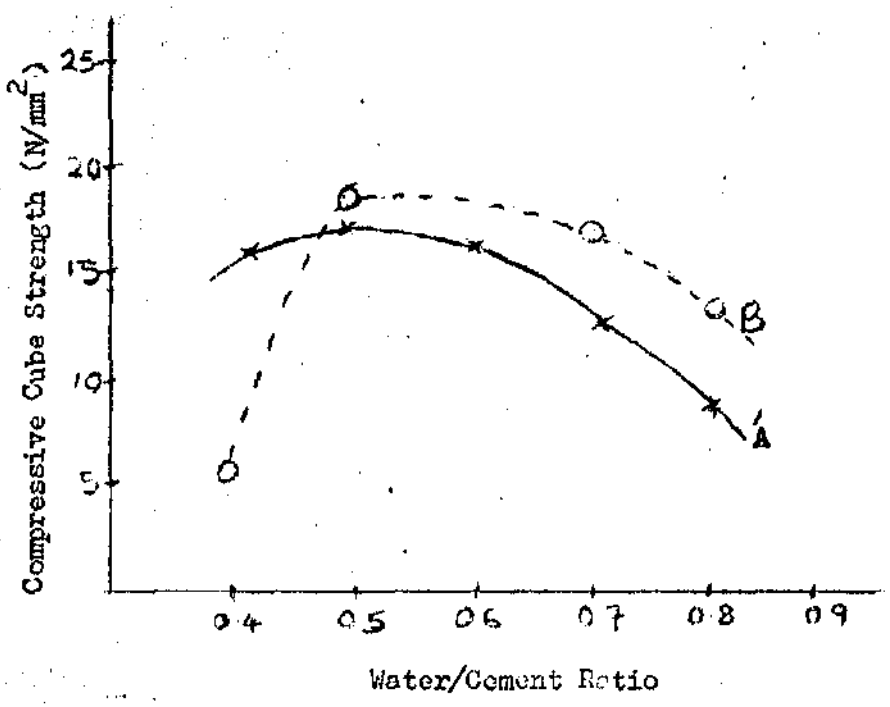


Figure 8 - Optimal Water/Cement Ration Curve for 14 Days

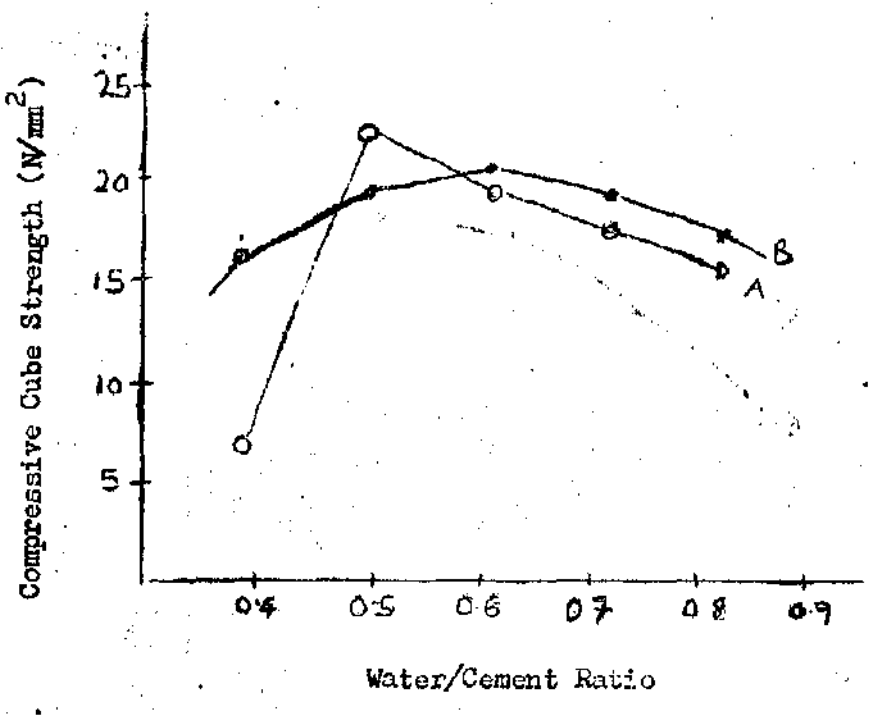
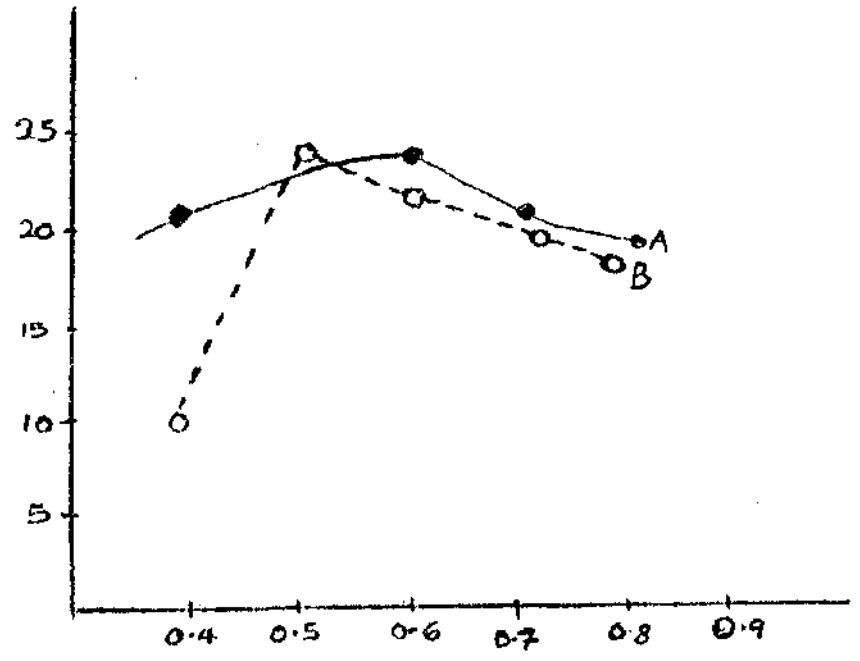


Figure 9 - Optimal Water/Cement Ration Curve for 28 days



3.3.5 Optimum Water Cement Ratio

The optimum water cement ratio is a ratio were the concrete achieves its highest strength in relation to the water added. From the graph in figure 7, the optimum water cement ratios for the different mixes are shown on table 3.5 and 3.6; while table 3.7 shows the optimal water/cement ratios.

Table 3.7 - Optimal Water/Cement Ratios

MIX	WATER/CEMENT RATIOS
1:1½:3	0.6
1:2:4	0.5

3.4 Final Mix

The mix design for 0.6 and 0.5 water and cement ratios were selected as the optimal for 1:1½:3 and 1:2:4 respectively.

3.4.1: Workability

The degree of workabilities of the concrete mixes of 1:1½:3 and 1:2:4 were determined by the slump test.

3.4.1.1 Slump Test

The test procedure was conducted as described in B.S. 1881 and involves first inspecting the internal surface to make sure it is clean, dry and free from cement. There after the cone is placed on a steel plate, it is filled by representative sample of concrete in four equal layers, each layer is tamped with 16mm diameter steel rod 25 times, the top level is truck off with a towel and the leakage around the base of the mould is cleaned off. The mould is carefully raised in a vertical direction and the slump is measured. In slump test if shear or collapse slump occur the test in repeated

The results of the slump test for the concrete mixes are shown in table 3.8 below:

Table 3.8 - Result of Slump Test

MIX	W/C RATIO	SLUMP (mm)	DEGREE OF WORKABILITY
1:1½:3	0.6	145.0	High
1:2:4	0.5	15.0	Low

From the table above, the type of slumps obtained were shear slump for mix 1:1½:3 and a true slump for that of 1:2:4.

3.4.1.1 Compaction Factor

The compaction factor test consist essentially of two inverted cone-shaped hoppers and a cylindrical container, in making the test the top hopper is filled, a hinged door at the bottom is released and the concrete drops into the second hopper to fill it, the concrete is similarly allowed to drop from the second hopper and falls into the cylindrical container. Surplus concrete is struck off, the cylinder is then weighed to the nearest 10g, giving the weight of partially compacted concrete.

While that of the fully compacted concrete, the cylinder is filled with concrete from the same sample in layers of about 5cm deep and the layers rammed heavily and the weight determined.

The compaction factor is calculated using the following expression:

$$\frac{\text{Weight of partially compacted concrete}}{\text{Weight of fully compacted concrete}}$$

The result of the compaction factor for the two mixes is shown in table 3.8 below.

Table 3.9 - Result of Compaction Factor

MIX	W/C RATIO	WEIGHT OF CYLINDER	UNCOMPACTED WEIGHT OF FRESH CONCRETE	COMPECTED WEIGHT OF FRESH CONCRETE	COMPACTED FACTOR
1:1½:3	0.6	6kg	9.4kg	9.7kg	0.97
1:2:4	0.5	6kg	7.0kg	8.8kg	0.8

3.5. MIX DESIGN FOR THE REQUIRED WATER/CEMENT RATIOS

This is carried out by using the optimal water/cement ratio from the trial mix design. The calculation of the required mix design is the same procedure, for that shown in page 37. When designing for a water and cement ration of 0.4. A total of 75 cubes were made for each and 25 of these cubes were crushed after 7, 14 and 28 days respectively for both mixes.

3.6 TEST OF HARDENED CONCRETE

3.6.1 Density of Concrete

The density of the concrete cubes was determined based on saturated surface dry condition of the concrete aggregate. The density were determined by weighing a 150mm x 150mm concrete cubes on five cubes, and the average taken for the two mixes and for each period of curing.

The densities for each is calculated using the following expressions.

Density = Mass/Volume

Table 3.9 - Shows the Density Calculations

MIX	AGE AT TEST	VOLUME (m^3)	AVERAGE MASS(kg)	AVERAGE DENSITY (kg/m^3)
1:1½:3	7	3.38×10^{-3}	6.5	1926
	14	"	6.46	1914
	28	"	6.5	1926
1:2:4	7	"	6.48	1911
	14	"	6.64	1967
	28	"	6.46	1914

3.5.2 Compressive Strength

The crushing loads of cubes specimens were determined using the compression machine. The 1520kw capacity machine applies load usually on the cube specimen until a maximum load (which correspond to the ultimate compressive strength of the concrete cube) is reached after which the specimen experiences failure (by crushing) and the load at failure recorded. Plate 4 shows the cube crushing machine.

The compressive strength at failure is got by dividing the failure load by the surface area of the cube, i.e.

$$\text{Compressive strength} = \frac{\text{Load at failure (N)}}{\text{Surface area (mm}^2\text{)}}$$

Plate 4 - Crushing of Cubes



A summary of the compressive strength test performed on the mixes are shown in table 3.11. The specimens used for this test were cubes of size 150mm x 150mm x 150mm. A total of 180 cubes were crushed for the period of 7, 14 and 28 days. The following precaution were taken in order to avoid variations in results.

1. The cubes were placed centrally in-between the platens to avoid eccentricity in loading.

2. Uniform rate of loading was applied.

3. Projections from the faces in contact with the platens scrapped off.from the cubes.

4. The loading applied through two smooth surfaces.

Table 3.1↑ - Summary of Average Compressive Strength Test

MIX	AGE (DAYS)	W/C RATIO	COMPRESSIVE STRENGTH (N/mm^2)
1:1½:3	7	0.6	16.2
	14	0.6	21.3
	28	0.6	23.5
1:2:4	7	0.5	18.45
	14	0.5	21.9
	28	0.5	23.6

Appendix 2 shows a detail computation of the cubes crushed for the respective mixes.

3.6.3 Tensile Strength

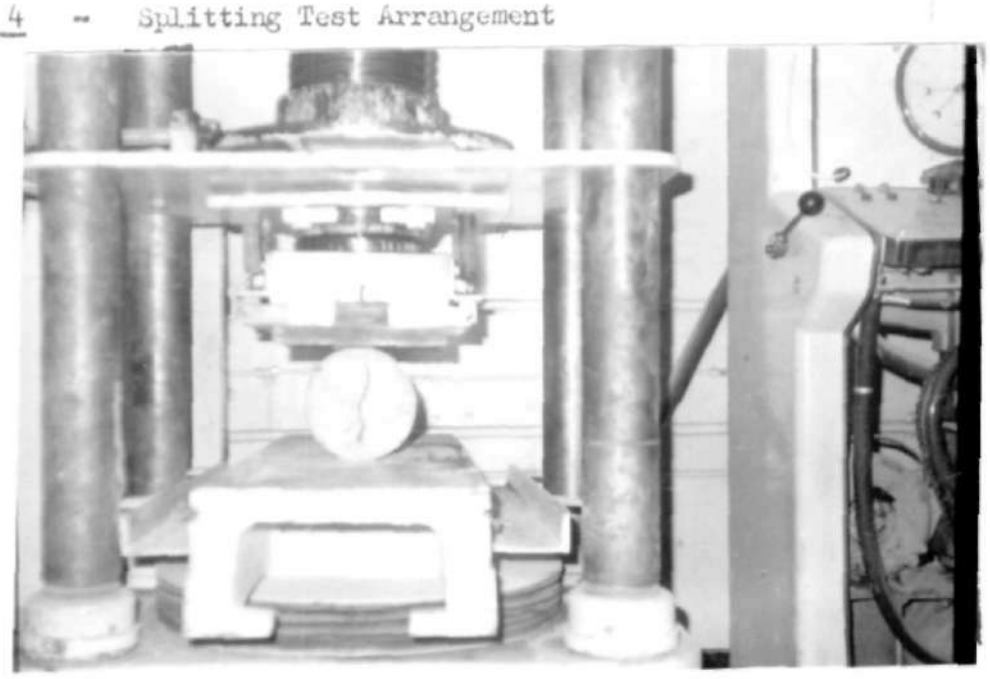
The determination of tensile strength test of the concrete made with periwinkle shells was conducted as described in B.S. 1881 (1970), using the cylinder splitting method and the test was carried out at the end of 28 days after curing in a water tank.

The test involves loading a 150mm diameter by 300mm long cylinders along a generator until the cylinder splits.

The loading was applied through two parkings of size 30mm x 300mm place at the top and bottom.

A total of 10 cubes were made for both mix, the loading of the cylinder for the test is shown in plate 4 below.

Plate 4 - Splitting Test Arrangement



The splitting tensile strength of the concrete mixes was computed using the following expression:

$$\sigma = \frac{2P}{DL}$$

Where σ = Split tensile strength (N/mm^2)

P = Failure load (N)

L = Length of cylinder (mm)

D = Diameter of cylinder (mm)

The summary of the splitting test after 28 days is shown in table 12, while detail result of the cylinder split test is shown in Appendix B.

Table 3:11 - Tensile Strength of the Mixes After 28 Days

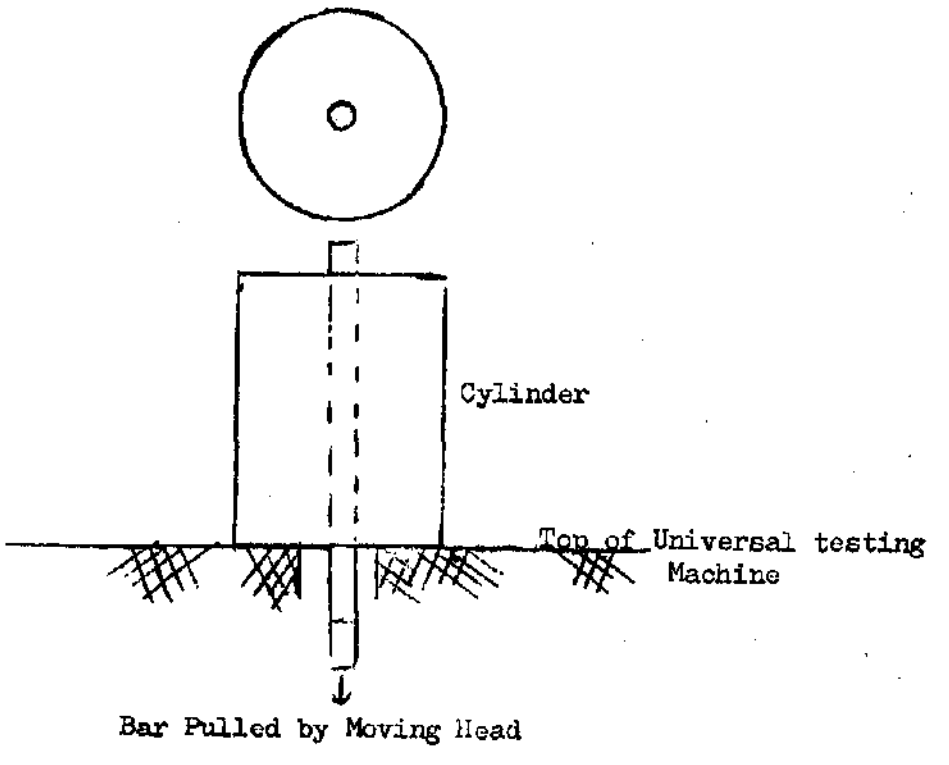
MIX	W/C RATIO	AGE (DAYS)	WEIGHT OF CYLINDER(kg)	FAILURE LOAD (kw)	SPLIT TENSILE STRENGTH(N/mm^2)
1:1½:3	0.6	28	10.52	102.8	1.45
1:2:4	0.5	28	10.68	137.6	1.95

3.6.4 Bond Between Concrete and Reinforcement

The determination of bond strength is carried out in the laboratory using a 150mm x 300mm cylinder. The test method used is the "bond pull out test". The sizes of rods (bars) used as reinforcement were 10 and 12mm diameter plain bars and deformed bars. 12 cylinders of each mix proportion were cast, i.e. for mix 1:1½:3, 12 cylinders for plain and deformed bars were cast, the same applied to 1:2:4.

In all the casting a bar is embedded centrally in a cylinder of concrete with part of it projecting from both ends of the concrete specimen as show in figure 8 below.

Figure 8



After casting, the concrete cylinder are cured for 28 days under a standard curing condition before testing.

According to Watstorn D (1941), during testing using the pull out method, one end of the bar is gripped in the shackle jaws of the machine.

The tension load applied to the bar is balanced by a compression load on the end of the concrete cylinder, applied axially through the movable cross-head of the machine. A dial guage with 1/10,000 in (0.00254mm) markings is attached to the unloaded end of the bar with the spindle dressing lightly on the underside of the concrete cylinder. With this arrangement the load applied tends to pull-out the bar from the concrete and careful observation is made of any slip between the two materials.

The following observations were recorded:

1. The load at slip of 0.00254mm (0.0001 in)
2. The load at slip of 0.00254mm (0.0001 in)
3. The load at slip of 0.254mm (0.01 in)
4. The maximum load and type of failure.

The following precautions were observed throughout the testing period.

1. The end of the bar at which the pull is applied is that which project from the top face of the cylinder as cast.
2. The bar is pull axially from the cylinder.

3. The spindle of the dial guage is in contact with the concrete.
4. Correct reading are taken and recorded.
5. The machine is always check and maintained before further testing.
6. Readings at the free end were continued until just before failure.

The advantages of the pullout is that, it is relatively simple to conduct and more economical than most of the other tests available for bond strength determination. It is one of the few tests available which quantitatively measures the strength of bond between concrete and steel and this alone is sufficient reason for its use in this research.

The test results and their analysis for the pullout test are shown in Appendix C and the summarized results in tables 3.14 while plate 5, 6, 7, and 8 shows the mounting of pullout specimen on universal testing machine, the dial guage fixed at the (sensitivity 1/10,000 in), observing and recording is slips and corresponding loads, and tensile fracture and splitting of concrete of bar pullout specimens respectively.

Plate 5 - Mounting of Pullout Specimen on Universal Testing Machine



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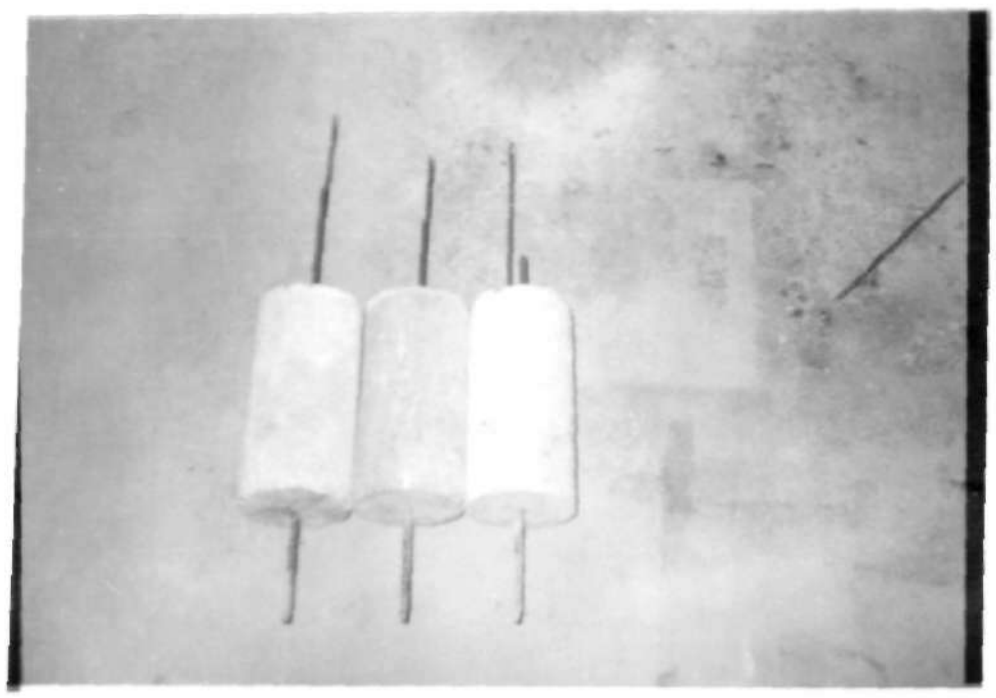
Plat 6 - The Dial Guage Fixed at the (Sensitivity 1/10,000 in.)



Plate 7 - Observing and recording of slips and corresponding loads



Plate 8 - Tensile Fracture and Splitting of Concrete of bar pullout specimens.



The state of stresses in the pullout test is rather complex and difficult to analysis. The test measures the longitudinal shear stress at the surface of the embedded bar in the concrete.

The 28 days, average pullout strength for diameter 12mm plain bar for 1:1½:3 is 3.49N/mm^2, while that for 1:2:4 is 3.68N/mm^2.

In crushed stone concrete, the 28 days pullout strength of diameter 12mm plain bar is 3.833N/mm^2 which is about 3 - 5% above that of shell concrete.

The 28 days average pullout strength for diameter 12mm deformed bar for 1:1½:3 is 4.7N/mm^2 and 1:2:4 is 5.3N/mm^2 (see table 3:13).

The average pullout strength of 10mm diameter deformed and plain bars for 1:1½:3 is 3.71 and 3.56mm^2 respectively.

While that of 1:2:4 is 3.73 and 3.90N/mm^2 for both deformed and plain bars.

Table 3:14 - Summary of Cylinder Pullout Specimens

MIX	BAR		EMBEDDED LENGTH		150 x 300mm CONCRETE CYLINDERS				
					AVERAGE BOND STRESS N/mm² AT SLIP OF			AVERAGE BOND STRENGTH N/mm²	TOTAL NUMBER OF SPECIMEN
	TYPE	DIAMETER (mm)	(mm)	SURFACE AREA (mm²)	0.00254mm	0.0254mm	0.254mm		
1:1½:3	Deformed Bar	10	300	9425	2.44	2.92	3.53	3.71	3
		12	300	11309.7	3.66	4.0	4.58	4.70	3
	Plain Bar	10	300	9425	2.37	2.95	3.25	3.56	3
		12	300	11309.7	2.99	3.14	3.27	3.49	3
1:2:4	Deformed Bar	10	300	9425	2.72	3.15	3.72	3.73	3
		12	300	11309.7	4.29	4.82	4.99	5.3	3
	Plain Bar	10	300	9425	3.06	3.44	3.78	3.90	3
		12	300	11309.7	3.32	3.54	3.66	3.68	3

CHAPTER FOUR

4.0 STATISTICAL ANALYSIS OF CUBE RESULTS

The statistical analysis of result is use to obtain the maximum amount of accurate information from the limited number of test results, which are obtained during testing since they are subjected to errors due to lack of precision in the equipment used to obtain them and human weakness of the operator making the tests. Mcintosh (1963), states that, the strength of concrete should be such that only a small proportion of its result fall below its minimum strength requirement, if a good control and careful operation during test is carried out.

The analysis was only conducted for the results of 7, 14 and 28 days compressive strength of cubes. Other test results were not considered due to the limited number of specimens involved.

For the purpose of considering statistical analysis of result the following terms were used:

4.1 Mean Strength

The mean strength is the average of all the strengths obtained for a given mix crushed for either 7, 14 and 28 days. It is usually expressed as:

Mean strength $(\bar{X}) = X/n$

Where $\bar{X}$ = Mean strength

X = Sum of individual value

n = Number of specimen

4.2 Standard Deviation

The deviation for the average value of each result is usually measured by standard deviation, is defined by the following mathematical relationship:

$$\sigma = \sqrt{\frac{\Sigma(x-\bar{x})^2}{n-1}}$$

Where σ = Standard deviation

X = Sum of individual strength

$\bar{X}$ = Mean strength

n = Number of specimens

Values of standard deviation for different degree of control is shown in table 4.1.

Table 4.1 - Standard Deviation for Different Degree of Control

DEGREE OF CONTROL	STANDARD DEVIATIONS N/mm^2
Laboratory Test	5
Excellent	10
Good	15
Fair	18
Bad	25

4.3 Co-Efficient of Variation

Co-efficient of variation is mostly considered when variation of sets of significant different average strengths is to be assessed, and it is given as:

$$V = \sigma/\bar{x}$$

Where V = Co-efficient of variation

σ = Standard deviation

$\bar{X}$ = Mean strength

Values of co-efficient of variation for different degree of control is shown in table 4.2.

Table 4.2 - Co-efficient of Variation for Different Degree of Control

DEGREE OF CONTROL	CO-EFFICIENT OF VARIATION
Laboratory	2.0 - 3.5
Excellent site	3.5 - 4.5
Average site	5.0 - 6.0
Poor site	7.0 - 8.0

4.4. ANALYSIS OF RESULTS

The statistical analysis calculations, graphs for histograms and normal probability curves are to be found in Appendix for 7 days only for both mixes. While the table below shows summaries of results performed on the strengths of concrete cubes for mix 1:1½:3 and 1:2:4 after 7, 14, and 28 days.

Table 4.3 - Summary of Statistical Analysis on Strength of Concrete Cubes

MIX	AGE (DAYS)	MEAN STRENGTH (N/mm^2)	STANDARD DEVIATION	CO-EFFICIENT VARIATION (%)
1:1½:3	7	16.1	0.75	4.66
	14	21.4	0.8	4.33
	28	23.7	0.59	2.5
1:2:4	7	18.5	0.81	4.38
	14	22.1	0.42	2.6
	28	23.74	0.85	3.6

The results obtained from the statistical analysis of the cube strength, for the mixes after 7, 14, and 28 days, shows that, they are within the accepatble range given in table 4.1 and 4.2, since the degree of control are within excellent and good site.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

From the foregoing research results conducted from the laboratory tests of the material, for a lightweight concrete, the following conclusion can be made:

1. The specific gravity of the periwinkle shell aggregate is 1.49, this make it a lighter material since it is between the range of 1.0 - 2.4 of lightweight aggregates.

2. The elemental analysis carried out on the periwinkle shells indicates the presence of calcium, magnessium, silicon, potassium and annihilation. These chemicals are found in the composition of cement.

3. The workability test performed on the concrete made with this material, shows that the mix 1:1½:3 can effectively be used in areas were reinforcement is needed, like lintel, floor slab and beams, while that of 1:2:4 can not be used in such areas, but for general flooring work and strip foundation where reinforcement is not needed.

4. The density range of the periwinkle shell concrete obtained is between 1914 - 1967kg/m^3 slightly higher than lightweight concrete of bwtween 400.5 - 1859kg/m^3 and far below that of normal concrete of between 2355 - 2563kg/m^3, thus making the periwinkle shell concrete a medium density group of concrete.

5. The compressive strength of the shell concrete is between 16.2 - 23.6N/mm^2 which is above lightweight concrete and comparable to the strength of normal concrete of between 21 - 40N/mm^2, this property alone makes it a good material for concrete work, since the minimum strength required for normal reinforced concrete work is 21N/mm^2.

6. The tensile strength at the age of 28 days is betweem 1.45 and 1.59N/mm^2 of both mixes and this is within the range of 1/8 and 1/20 of the cube crushing strength, (as given by Elvery 1963).

7. In the bond strength test all specimen containing the plain bars of 10mm and 12mm diameter pullout leaving a round hole in the concrete, indicating low adhesion and frictional resistance or bond failure. While specimen containing the deformed bars of 10mm and 12mm pullout loose mostly by bar fracture and in two cases by splitting of concrete into two segment and splitting of the concrete indicates high adhesion between the steel and the concrete.

From the above test, it shows that periwinkle shell concrete can be used successfully for cast insity structural members of two-three storey building. But for better results it is adviseable to use deformed bars for reinforcement.

5.2 RECOMMENDATIONS

After careful study of the various properties of the material and the test on concrete made with the material, inrelation to its application as a construction material. The use of periwinkle shell concrete for reinforced concrete construction of simple storey buildings should be encouraged as it does not only reduce the dead loads on the foundations, it is also expected to improve sound, thermal insulation as well as durability and at the same time provide a cheaper accommodation for the ever-growing populace.

The use of periwinkle shell concrete is however, not recommended for construction of bases (foundations) in multi storey building as a result of the punching effect on the bases, due to the low density of the concrete.

Lastly, further research should be carried out in the near future on other properties of lightweight concrete made with periwinkle shells, such as: the percentage of chemical composition in the periwinkle shells, the static modulus of elasticity, dry shrinkage and in bond strength, the use of beam test method, the influence of bar cover and bond test under repeated loading condition.

As these will furthermore improve our understanding of the behaviour of periwinkle shell concrete.

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APPENDIX A: RESULT OF CRUSHING STRENGTH OF CUBES.

Table A1 - Crushing Strength of Cubes for Mix 1:1½:3. W/C = 0.6 for 7 Days

S/NO.	MARK	DATE OF CAST	WEIGHT OF CUBE (kg)	TEST DATE	AGE AT TEST (DAYS)	FAILURE LOAD (KN)	CUBE STRENGTH (N/MM^2)
1.	A1	11-2-89	6.6	18-2-89	7	380	16.9
2.	"	"	6.7	"	"	360	16.0
3.	"	"	6.6	"	"	384	17.1
4.	"	"	6.5	"	"	416	18.5
5.	"	"	6.6	"	"	360	16.0
6.	"	24-3-89	6.7	31-3-89	"	340	15.1
7.	"	"	6.4	"	"	350	15.6
8.	"	"	6.6	"	"	360	16.0
9.	"	"	6.6	"	"	350	15.6
10.	"	"	6.4	"	"	345	15.3
11.	"	"	6.4	"	"	385	17.2
12.	"	"	6.5	"	"	380	16.2
13.	"	"	6.5	"	"	320	14.2
14.	"	"	6.7	"	"	360	16.6
15.	"	"	6.3	"	"	315	14.0
16.	"	"	6.4	"	"	390	17.3
17.	"	"	6.3	"	"	400	17.8
18.	"	"	6.6	"	"	350	15.6
19.	"	"	6.4	"	"	345	15.3
20.	"	"	6.5	"	"	410	18.2
21.	"	"	6.6	"	"	340	15.1
22.	"	"	6.6	"	"	380	16.9
23.	"	"	6.7	"	"	375	16.7
24.	"	"	6.3	"	"	360	16.0
25.	"	"	6.4	"	"	360	16.0
26.	"	"	6.3	"	"	350	15.6
27.	"	"	6.6	"	"	312	13.9
28.	"	"	6.5	"	"	375	16.7
29.	"	"	6.5	"	"	410	18.2
30.	"	"	6.4	"	"	355	15.8

Table 42 - Crusging Strength of Cubes for Mix 1:2:4, W/C = 0.5 for 7 Days

S/NO.	MARK	DATE OF CAST	WEIGHT OF CUBE (kg)	TEST DATE	AGE AT TEST (DAYS)	FAILURE LOAD (KN)	CUBE STRENGTH (N/mm^2)
1.	B1	15-2-89	6.7	22-2-89	7	450	20.0
2.	"	"	6.5	"	"	400	17.8
3.	"	"	6.6	"	"	430	19.1
4.	"	"	6.5	"	"	380	16.9
5.	"	"	6.7	"	"	450	20.0
6.	"	25-3-89	6.5	1-4-89	"	440	19.6
7.	"	"	6.5	"	"	400	17.8
8.	"	"	6.7	"	"	440	19.6
9.	"	"	6.4	"	"	440	19.6
10.	"	"	6.5	"	"	400	17.8
11.	"	"	6.5	"	"	420	18.7
12.	"	"	6.4	"	"	410	18.2
13.	"	"	6.7	"	"	420	18.7
14.	"	"	6.3	"	"	390	17.3
15.	"	"	6.3	"	"	398	17.7
16.	"	"	6.2	"	"	440	19.6
17.	"	"	6.1	"	"	410	18.2
18.	"	"	6.7	"	"	420	18.7
19.	"	"	6.3	"	"	360	16.0
20.	"	"	6.4	"	"	390	17.3
21.	"	"	6.6	"	"	450	20.0
22.	"	"	6.5	"	"	420	18.7
23.	"	"	6.5	"	"	360	16.0
24.	"	"	6.4	"	"	380	16.9
25.	"	"	6.5	"	"	410	18.2
26.	"	"	6.7	"	"	410	18.2
27.	"	"	6.2	"	"	480	21.3
28.	"	"	6.3	"	"	430	19.1
29.	"	"	6.4	"	"	400	17.8
30.	"	"	6.4	"	"	420	18.7

Table 93 - Crushing Strength of Cubes for Mix 1:1½:3, W/C = 0.6 for 14 Days

S/NO.	MARK	DATE OF CAST	WEIGHT OF CUBE (kg)	TEST DATE	AGE AT TEST (DAYS)	FAILURE LOAD (KN)	CUBE STRENGTH (N/mm^2)
1.	A2	11-2-89	6.4	25-2-89	14	510	22.7
2.	"	"	6.7	"	"	460	20.4
3.	"	"	6.5	"	"	500	22.2
4.	"	"	6.6	"	"	480	21.3
5.	"	"	7.0	"	"	520	23.1
6.	"	22-3-89	6.5	5-4-89	"	500	22.2
7.	"	"	6.6	"	"	480	21.3
8.	"	"	6.7	"	"	480	21.3
9.	"	"	6.6	"	"	460	20.4
10.	"	"	6.4	"	"	500	22.2
11.	"	"	6.6	"	"	484	21.5
12.	"	"	6.4	"	"	504	22.4
13.	"	"	6.6	"	"	460	20.4
14.	"	"	6.4	"	"	480	21.3
15.	"	"	6.6	"	"	480	21.3
16.	"	"	6.4	"	"	460	20.4
17.	"	"	6.3	"	"	440	19.6
18.	"	"	6.5	"	"	470	20.9
19.	"	"	6.6	"	"	420	18.7
20.	"	"	6.6	"	"	500	22.2
21.	"	"	6.5	"	"	510	22.7
22.	"	"	6.6	"	"	480	21.3
23.	"	"	6.4	"	"	480	21.3
24.	"	"	6.4	"	"	450	20.0
25.	"	"	6.7	"	"	500	22.2
26.	"	"	6.5	"	"	510	22.7
27.	"	"	6.5	"	"	480	21.3
28.	"	"	6.6	"	"	450	20.0
29.	"	"	6.7	"	"	470	20.9
30.	"	"	6.5	"	"	480	21.3

Table 4 - Crushing Strength of Cubes for Mix 1:2:4, W/C = 0.5 for 14 Days

S/NO.	MARK	DATE OF CAST	WEIGHT OF CUBE (kg)	TEST DATE	AGE AT TEST (DAYS)	FAILURE LOAD (KN)	CUBE STRENGTH (N/mm^2)
1.	B2	15-2-89	6.8	1-3-89	14	520	23.1
2.	"	"	6.7	"	"	500	22.2
3.	"	"	6.6	"	"	500	22.2
4.	"	"	6.5	"	"	510	22.7
5.	"	"	6.9	"	"	520	23.1
6.	"	23-3-89	6.6	"	"	520	23.1
7.	"	"	6.5	"	"	480	21.3
8.	"	"	6.5	"	"	460	20.4
9.	"	"	6.8	"	"	500	22.2
10.	"	"	6.6	"	"	480	21.3
11.	"	"	6.8	"	"	500	22.2
12.	"	"	6.5	"	"	510	22.7
13.	"	"	6.7	"	"	480	21.3
14.	"	"	6.6	"	"	460	20.4
15.	"	"	6.8	"	"	500	22.2
16.	"	"	6.8	"	"	500	22.2
17.	"	"	6.8	"	"	462	20.6
18.	"	"	6.8	"	"	480	21.3
19.	"	"	6.8	"	"	500	22.2
20.	"	"	6.6	"	"	480	21.3
21.	"	"	6.5	"	"	510	22.7
22.	"	"	6.5	"	"	490	21.8
23.	"	"	6.6	"	"	500	22.2
24.	"	"	6.7	"	"	450	20.0
25.	"	"	6.9	"	"	480	21.3
26.	"	"	6.8	"	"	530	23.6
27.	"	"	6.7	"	"	470	20.9
28.	"	"	6.6	"	"	500	22.2
29.	"	"	6.5	"	"	510	22.7
30.	"	"	6.6	"	"	500	22.2

Table 05 - Crushing Strength of Cubes for Mix 1:1½:3, W/C = 0.6 for 28 Days

S/NO.	MARK	DATE OF CAST	WEIGHT OF CUBE (kg)	TEST DATE	AGE AT TEST (DAYS)	FAILURE LOAD (KN)	CUBE STRENGTH (N/mm^2)
1.	A3	11-2-89	6.7	11-3-89	28	560	24.9
2.	"	"	6.6	"	"	540	24.0
3.	"	"	6.5	"	"	560	24.9
4.	"	"	7.0	"	"	560	24.9
5.	"	"	6.8	"	"	565	25.1
6.	"	28-3-89	6.4	25-4-89	"	540	24.0
7.	"	"	6.5	"	"	560	24.9
8.	"	"	6.5	"	"	540	24.0
9.	"	"	6.4	"	"	510	22.7
10.	"	"	6.5	"	"	520	23.1
11.	"	"	6.4	"	"	560	24.9
12.	"	"	6.4	"	"	520	23.1
13.	"	"	6.7	"	"	530	23.6
14.	"	"	6.6	"	"	540	24.0
15.	"	"	6.4	"	"	500	22.2
16.	"	"	6.5	"	"	500	22.2
17.	"	"	6.6	"	"	520	23.1
18.	"	"	6.3	"	"	520	23.1
19.	"	"	6.6	"	"	490	21.8
20.	"	"	6.7	"	"	500	22.2
21.	"	"	6.4	"	"	510	22.7
22.	"	"	6.5	"	"	560	24.9
23.	"	"	6.5	"	"	530	23.6
24.	"	"	6.7	"	"	520	23.1
25.	"	"	6.6	"	"	480	21.3
26.	"	"	6.5	"	"	500	22.2
27.	"	"	6.4	"	"	550	24.4
28.	"	"	6.3	"	"	540	24.0
29.	"	"	6.7	"	"	540	24.0
30.	"	"	6.5	"	"	520	23.1

Table 96 - Crushing Strength of Cubes for Mix 1:2:4. W/C = 0.5 for 28 Days

S/NO.	MARK	DATE OF CAST	WEIGHT OF CUBE (kg)	TEST DATE	AGE AT TEST (DAYS)	FAILURE LOAD (KN)	CUBE STRENGTH (N/mm^2)
1.	B3	15-2-89	6.8	15-3-89	28	500	22.2
2.	"	"	6.4	"	"	520	23.1
3.	"	"	6.5	"	"	560	24.9
4.	"	"	7.0	"	"	568	25.2
5.	"	"	6.6	"	"	560	24.9
6.	"	29-3-89	6.5	26-4-89	"	560	24.9
7.	"	"	6.5	"	"	540	24.0
8.	"	"	6.6	"	"	520	23.1
9.	"	"	6.4	"	"	508	22.6
10.	"	"	6.4	"	"	540	24.0
11.	"	"	6.5	"	"	520	23.1
12.	"	"	6.4	"	"	480	21.3
13.	"	"	6.7	"	"	520	23.1
14.	"	"	6.6	"	"	560	24.9
15.	"	"	6.5	"	"	520	23.1
16.	"	"	6.6	"	"	550	24.4
17.	"	"	6.7	"	"	560	24.9
18.	"	"	6.4	"	"	540	24.0
19.	"	"	6.5	"	"	520	23.1
20.	"	"	6.5	"	"	540	24.0
21.	"	"	6.6	"	"	560	24.9
22.	"	"	6.4	"	"	480	21.3
23.	"	"	6.5	"	"	470	20.9
24.	"	"	6.8	"	"	510	22.7
25.	"	"	6.6	"	"	550	24.4
26.	"	"	6.8	"	"	500	22.2
27.	"	"	6.4	"	"	570	25.3
28.	"	"	6.5	"	"	540	24.0
29.	"	"	6.6	"	"	520	23.1
30.	"	"	6.4	"	"	550	24.4

APPENDIX B: RESULTS OF CYLINDER SPLIT TEST

Table B1 - Tensile Split Strength for 28 Days

S/NO.	MARK	DATE OF CAST	WEIGHT OF CYLINDER(kg)	TEST DATE	AGE AT TEST (DAYS)	W/C RATIO	FAILURE LOAD (KN)	TENSILE STRENGTH (N/mm^2)
1.	A	28-3-89	10.5	23-4-89	28	0.6	105	1.49
2.	"	"	10.6	"	"	"	100	1.41
3.	"	"	10.4	"	"	"	99	1.40
4.	"	"	10.6	"	"	"	110	1.56
5.	"	"	10.5	"	"	"	100	1.41
1.	B	29-3-89	10.9	12-4-89	28	0.5	135	1.91
2.	"	"	10.7	"	"	"	140	1.98
3.	"	"	10.5	"	"	"	135	1.91
4.	"	"	10.7	"	"	"	138	1.95
5.	"	"	10.6	"	"	"	140	1.98

APPENDIX C

Table C1 - Observed Loads and Slips in Pullout Specimens

MIX	SPECIMEN MARK	BAR TYPE	BAR DIAMETER (mm)	EMBEDDED LENGTH (mm)	EMBEDDED LENGTH SURFACE AREA (mm^2)	150x300mm CONCRETE CYLINDER LOAD (KN) AT SLIP OF 0.00254mm	0.0254mm	0.254mm	MAXIMUM LOAD(KN)	MANNER OF FAILURE
1:1½:3	A1	Deformed Bar	10	300	9425	24.75	28.00	35.0	35.5	Bar Fracture
	"		"	"	"	20.50	26.75	31.75	34.75	"
	"		"	"	"	23.75	27.70	33.00	34.50	"
	A2	Plain Bar	10	"	"	22.50	28.75	30.00	32.00	Bond Failure
	"		"	"	"	23.50	27.00	32.00	32.75	"
	"		"	"	"	21.00	27.75	29.75	31.00	"
1:2:4	B1	Deformed Bar	10	"	"	22.25	27.50	35.00	35.00	Bar Failure
	"		"	"	"	30.00	32.50	34.50	34.50	"
	"		"	"	"	24.75	29.00	35.75	36.00	"
	B2	Plain Bar	10	"	"	28.00	32.50	36.50	36.50	Bond Failure
	"		"	"	"	30.00	34.75	35.00	36.75	"
	"		"	"	"	28.50	30.00	35.50	37.00	"

Table C2 - Corresponding Bond Stress for Table 15 C.1

MIX	SPECIMEN MARK	BAR TYPE	BAR DIAMETER (mm)	EMBEDDED LENGTH (mm)	EMBEDDED LENGTH SURFACE AREA (mm^2)	150x300mm CONCRETE CYLINDER BOND STRESS N/mm AT SLIP OF 0.0025mm	0.0254mm	0.254mm	BOND STRENGTH N/mm^2
1:1½:3	A1	Deformed Bar	10	300	9425	2.63	2.97	3.71	3.77
	"	"	"	"	"	2.18	2.84	3.37	3.69
	"	"	"	"	"	2.52	2.94	3.50	3.66
	A2	Plain Bar	"	"	"	2.39	3.05	3.18	3.40
	"	"	"	"	"	2.49	2.87	3.40	3.98
	"	"	"	"	"	2.23	2.94	3.16	3.29
1:2:4	B1	Deformed Bar	"	"	"	2.36	2.92	3.71	3.71
	"	"	"	"	"	3.18	3.45	3.66	3.66
	"	"	"	"	"	2.63	3.08	3.79	3.82
	B2	Plain Bar	"	"	"	2.97	3.45	3.87	3.87
	"	"	"	"	"	3.18	3.69	3.71	3.89
	"	"	"	"	"	3.02	3.18	3.77	3.93

Table C3 - Observed Loads and Slips in Pullout Specimens

MIX	SPECIMEN MARK	BAR TYPE	BAR DIAMETER (mm)	EMBEDDED LENGTH (mm)	EMBEDDED LENGTH SURFACE AREA (mm^2)	150x300mm CONCRETE CYLINDER LOAD (KN) AT SLIP OF 0.00254mm	0.0254mm	0.254mm	MAXIMUM LOAD (KN)	MANNER OF FAILURE
1:1½:3	A3	Deformed Bar	12	300	113097	39.0	40.0	45.75	50.5	Bar Failure
	"		"	"	"	40.0	48.0	55.0	55.0	"
	"		"	"	"	45.0	47.75	53.0	54.0	"
	A4	Plain Bar	"	"	"	32.5	35.0	36	36	Bond Failure
	"		"	"	"	38	36	38	40	"
	"		"	"	"	34	35.50	37	38.5	"
1:2:4	B3	Deformed Bar	"	"	"	48.0	54.0	58.75	58.75	Bar Failure
	"		"	"	"	47.5	-	54.5	60.0	Splitting of Concrete
	"		"	"	"	50.0	55.0	56.0	62.5	"
	B4	Plain Bar	"	"	"	38.0	40.5	44	44.5	Bond Failure
	"		"	"	"	36.5	40.0	45.0	45.0	"
	"		"	"	"	38	39.5	45.5	46.0	"

Table C4 - Corresponding Bond Stresses for Table C·3

MIX	SPECIMEN MARK	BAR TYPE	BAR DIAMETER (mm)	EMBEDDED LENGTH (mm)	EMBEDDED LENGTH SURFACE AREA	150x300mm CONCRETE CYLINDER BOND STRESS N/mm AT SLIP OF 0.00254mm	0.0254mm	0.254mm	BOND STRENGTH N/mm²
1:1½:3	A3	Deformed Bar	12	300	11309.7	3.45	3.54	4.2	4.47
	"		"	"	"	3.54	4.24	4.86	4.86
	"		"	"	"	3.98	4.22	4.69	4.78
	A4	Plain Bar	"	"	"	2.87	3.10	3.18	3.18
	"		"	"	"	3.10	3.18	3.36	3.54
	"		"	"	"	3.01	3.14	3.27	3.56
1:2:4	B3	Deformed Bar	"	"	"	4.24	4.78	5.2	5.20
	"		"	"	"	4.2	-	4.82	5.30
	"		"	"	"	4.42	4.86	4.95	5.53
	"	Plain Bar	"	"	"	3.36	3.58	3.89	3.94
	"		"	"	"	3.23	3.54	3.98	3.98
	"		"	"	"	3.36	3.49	4.02	4.07

APPENDIX D: STATISTICAL DETERMINATION OF RESULTS

The statistical analysis, calculations, graphs for histograms and normal probability curves are only shown for compressive strengths of 7 days for mix 1:1½:3 and 1:2:4. Since the procedures are the same for that of 14, and 28 days, but the summaries of the results are shown in table 4.3

For Mix 1:1½:3 (7 Days)

CLASS	X	n	nX	X-$\bar{X}$	(X-$\bar{X}$)
13 - 14	13.50	1	13.50	-2.60	6.76
14 - 15	14.50	2	29.00	-1.60	1.26
15 - 16	15.50	15	252.50	-0.60	0.36
16 - 17	16.50	5	82.50	0.40	0.16
17 - 18	17.50	4	70.00	1.40	1.96
18 - 19	18.50	3	55.50	2.40	5.76
		300	483.00		16.27

Mean strength ($\bar{X}$) = $nx/n = \frac{483}{30} = 16.10$

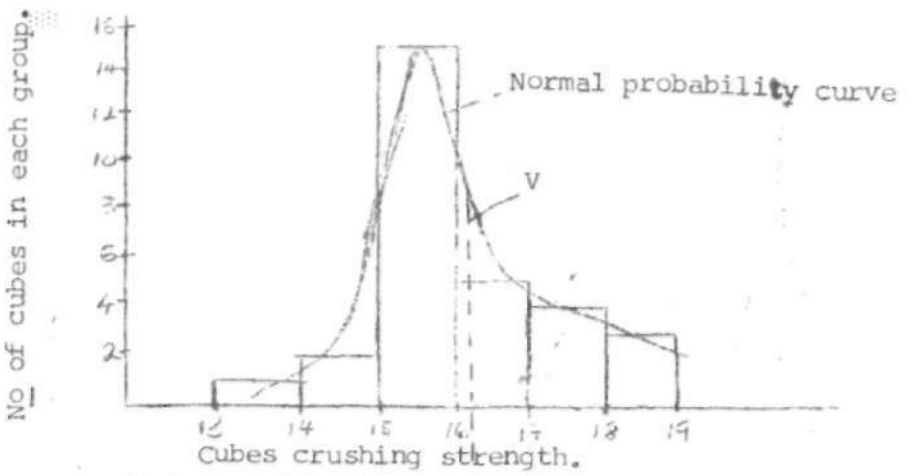
Standard deviation (σ) = $\sqrt{\frac{\Sigma(x-\bar{x})^2}{n-1}}$ $\sqrt{\frac{16.27}{30-1}}$

= $0.75 N/mm^2$

Co-efficient of variation (V) = $\frac{\sigma}{\bar{x}} \times \frac{100}{1}$

= $\frac{0.75}{16.10} \times \frac{100}{1}$ = 4.66%

Graphs for Histogram



For Mix 1:2:4 (7 Days)

CLASS	x	n	nx	$x-\bar{x}$	$(x-\bar{x})^2$
16 - 17	16.50	4	66.00	-2.00	4.00
17 - 18	17.50	7	122.50	-1.00	1.00
18 - 19	18.50	9	166.50	0.00	0.00
19 - 20	19.50	6	117.00	1.00	1.00
20 - 21	20.50	3	61.50	2.00	4.00
21 - 22	21.50	1	21.50	3.00	9.00

Mean strength $(\bar{x})$ = nx/n = 555/30 = 18.50

Standard deviation (S) = $\sqrt{\frac{\Sigma(x-\bar{x})^2}{n-1}} = \sqrt{\frac{19.00}{30-1}}$ = 0.81N/mm^2

Co-efficient of variation (V) = $\frac{S}{\bar{x}} \times \frac{100}{1}$

= $\frac{0.81 \times 100}{18.50\ 1}$ = 4.38%

Graphs for Histogram

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