EFFECT OF WATER-CEMENT RATIO ON PROPERTIES OF NORMAL CONCRETE
(Using 12.50 mm maximum size granite aggregates)

BY

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(PGD/CIVIL/2009/068)

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MARCH, 2012

DECLARATION

I hereby declare that this thesis titled: Effect of water-cement ratio on the properties of normal concrete (using 12.50 mm maximum size granite aggregates), is a collection of my original research work and it has not been presented for any other qualification anywhere. Information derived from other sources (published and unpublished) has been duly acknowledged.

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CERTIFICATION

This is to certify that this thesis titled: Effect of water-cement ratio on the properties of normal concrete (using 12.50 mm maximum size granite aggregates) by SHAIBU, Abutu Ukwenya Favour Reg. no PGD/CIVIL/2009/068, meets the regulations governing the award of PGD in Civil Engineering of the Federal University of Technology, Minna and it is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

This project work is specifically dedicated to ALMIGHTY GOD for his mercy, loving kindness and favour bestowed upon me throughout my period of studies and to my darling wife, Mrs Martha Ejura Shaibu who have to endure all forms of hardship for this course to be possible along with our dear children – Philip, Joy, Peace, Gift and Fortunate.

May the almighty god pay them for their endurance and cause them to eat the fruit of their labour and sacrifice in JESUS name. Amen.

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May the good LORD bless you all Amen.

ABSTRACT

This project examines the effect of water cement ratio on the properties of normal concrete using coarse aggregates of 12.50 mm maximum size. In all, 33 concrete cubes were prepared, 3 each of different water cement ratios in the range of 0.40-0.60 with all the other concrete mix ingredients kept constant. The mix ratio adopted was 1:2:4, the cubes were cured for 28 days and were subsequently crushed to determine the compressive strength at the various water cement ratios. Other tests conducted on the concrete and its ingredients are: Sieve analysis, Slump & Density test. Test results shows that an increase in water-cement ratio leads to an increase in the workability of fresh concrete. Also an increase in water-cement ratio between 0.4 and 0.5 leads to an increase in compressive strength and density. An increase in water cement ratio in the range 0.5 – 0.6 leads to a decrease in compressive strength and density. The work provides a data bank for concrete properties within the limit of the scope considered in this work.

TABLE OF CONTENTS

CHAPTER FOUR

CHAPTER FIVE

LIST OF TABLES

CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND OF THE STUDY

The purpose to which concrete is used as a structural material varies from one situation to another, hence its strength vis a vis the proportion of the basic constituents and other inherent characteristics are predetermined in a process of design to produce concrete to certain maximum properties economically possible. The task involved in designing a concrete mix consist of selecting suitable ingredients of the concrete and determining the correct proportions of the cement, fine and coarse aggregates and water to produce an economically concrete having the specified properties. (Neville and Brooks, 2005)

When water is added to the mixture of cement and aggregates (fine and coarse), hydration of cement takes place. This will cause the whole mixture to set and when hardened, forms a solid rock like mass. According to Elices & Rocco (2008) in their write up on the effect of aggregate size on the fracture and mechanical properties of a simple concrete it is well known that the concrete strength is influenced by the ratio of mixing water, the ratio of cement to aggregates the bond between mortar and aggregates and the grading, shape, strength and size of the aggregate. The influence of water-cement ratio and to some extent, the aggregate size is the subject matter of this project.

The volume of water used in the mix should be such needed to ensure full hydration into a paste which makes the concrete workable. The excess water left in the paste after hydration remains free and is redistributed in the paste and whole mass. The excess water must be kept to a minimum compatible with adequate workability for the job to be done.

In determining the total water cement ratio, the total mass of water absorbed by the aggregates (coarse and fine) in the batch is added to the volume of water introduced during the mixing. The total water/cement ratio is the total mass of water to the total mass of cement in the mix, hence when deciding how much water that is required, allowance must be made for the absorption by the dry and porous aggregates and for the free surface of water. The amount of water used should be the amount sufficient for workability to ensure thorough compaction of the concrete.

There are 2 types of aggregates used in concrete manufacturing – fine and coarse aggregates. The coarse aggregates compose mainly of gravel, crushed rock or granite, broken bricks, air cooled blast furnace slag while the fine aggregates are composed of sand and weathered rock.

The properties of coarse aggregates which constitute a large percentage of concrete constituents is however affected by many factors such as shape and texture, strength, toughness, hardness, specific gravity, bulk density, porosity and absorption, moisture content, chemical reactivity, elastic modulus and thermal characteristics. The properties mainly specified are:

(i) Workability for fresh concrete

(ii) The compressive strength at a specified age,

(iii) The durability of the hardened concrete.

If the percentage of water used is less than sufficient, there will not be enough water for the cement hydration process. It will result in weak and porous concrete. If on the other hand too much water is used, it will result in segregation of the aggregates which gives porous concrete of low strength and low density and poor durability.

Because the strength of concrete is adversely and significantly affected by the presence of voids in the compacted mass, it is vital to achieve maximum possible density. This requires sufficient workability for virtually full compaction to be possible using a reasonable amount of work under given conditions. The presence of voids in concrete reduces its strength such that just 5% of voids can lower the strength of concrete by as much as 30%. The volume of voids in hardened concrete due to spaces left after excess water has been removed depends solely on the water/cement ratio of the mix.

The porosity of the aggregates affects both fresh and hardened concrete. The volume of void in hardened concrete due to bubbles of entrapped air is dependent on the grading of the fine aggregates. This is an important fact in concrete mix design.

This project deals with the determination and analysis of the effects of water/cement ratio on the properties of normal concrete using coarse aggregates of maximum size of *12.5 mm.* Special concrete properties emphases was on the slump, density and compressive strength at 28 days.

In engineering practice, the strength of concrete at a given age and cured at a prescribed temperature is assumed to depend primarily on 2 factors only – the water-cement ratio and the degree of compaction (Rajput, 2008).

The water-cement ratio is the ratio of water to cement in a concrete mix and is expressed as the ratio of the weight or volume of water to the weight or volume of cement in the concrete mix.

Since the amount of water in the mix has a direct bearing on the compactibility and workability of concrete hence the strength of the hardened concrete, there is need to study and ascertain the right quantity of water to use in a concrete mix to give the required maximum strength and other properties of the concrete.

1.2 AIM AND OBJECTIVES OF THE PROJECT.

The aim of this work is to determine the effect of water-cement ratio on the properties of normal concrete.

The objectives of this work are to:

(i) determine the physical properties of the mix composition of concrete.

(ii) determine the properties of the concrete produced.

1.3 PROBLEM STATEMENT

1:2:4 mix ratio is well known and mostly used in the construction of super structures in buildings. This mix ratio however, does not guarantee the target strength. The ingredients of concrete are variable and they in turn have effect on varying the properties of concrete such as slump and strength. The variation in the properties of concrete leads concrete mix proportioning adjustment and trial and error being done to come up with concrete of the designed strength.

The project works also adopts the concrete mix of 1:2:4 as against other mix ratios which might give results other than the ones gotten from the tests carried out in his project work.

1.4 SIGNIFICANCE OF THE STUDY

The most important property of concrete is the strength of the cured concrete. The major determinants of the strength are: the water-cement ratio and the degree of compaction.

It is also noticed that the water-cement ratio affects the degree of compaction, hence the water-cement ratio is of much importance in the production of concrete hence the study of the effect of varied water-cement ratio on the other properties of normal concrete cannot be over emphasized. In this work, concretes are produced at different water-cement ratios while maintaining the other ingredients. This produces concrete of different properties. This work has the potential of producing a data bank of properties of concrete as a function of mix composition. This would be useful to the concrete community and users of concrete in deciding the appropriate mix ingredients required for specific job taking into cognizance the target strength.

1.5 SCOPE OF THE PROJECT

The scope of this project covers the following areas:

(i) Sampling, collection and grading of coarse and fine aggregates.

(ii) Preparation of normal mix proportions of 1:2:4 mix using the graded aggregates.

(iii) Performing slump test and compaction factor test of the various mix.

(iv) Preparation of cube samples (3No) each for the various mix.

(v) Curing the properly identified cube samples (33 No) by submerging under water in a tank where they are left for 28 days.

(vi) Performing the compressive crushing strength test on the samples after curing them for 28 days in the tank.

CHAPTER TWO

LITERATURE REVIEW

2.1 Concrete and its constituent materials

Concrete is a composite material wherein a binding material is mixed with water and on solidification, binds the inert particles as well as graded fine and coarse aggregates. The common cementing material used is cement. (Franklin & Cetrong, 1975)

A number of cement types are available for use but the most common being the ordinary Portland cement (OPC). Other types of cement in use include; blast furnace slag, high alumina cement, super sulphate cement among others.

Various materials may be used as aggregates, the most common being the natural occurring sand and gravel. Manufactured aggregates are also used particularly those of low density, certain other aggregates are also used for special purposes such as the shielding for atomic or nuclear reactors.

Concrete is used for a wide variety of purpose such as;

(a) Foundation and structural materials.

(b) Walling materials.

(c) Light weight materials for insulation.

(d) Construction of roads, airfields, buildings, water retaining structures, dock yards, harbours and sea defences.

It follows therefore that all the various properties of concrete are of interest to the engineer. These properties include strength, durability, density, workability, shrinkages, segregation and bleeding. Their relative importance depends on the use to which the concrete is put to. Concrete is made from water, cement and aggregates.

2.1.1 Water

Water is used to effect the chemical action in cement known as "hydration". It is this action which causes the concrete to set and harden. The quality of water used in concreting is therefore very important because impurities in water may interfere with the cement, and may adversely affect the strength of the concrete or cause staining of its surface and the things it comes in contact with. It may also lead to the corrosion of the reinforcement used in the concrete with its attendant consequences. For this reason, a suitable water to be used in the production and curing of concrete should be considered.

It will therefore readily be appreciated that only good, clean water free from organic impurities should be used for concrete works. If stream water is to be used, care should be taken that it does not contain decaying and other organic contaminants. (Jackson, 1975).

In many specifications, the quality of water is covered by a clause indicating that water to use must be water fit for drinking. Such water rarely contains dissolved solids in excess of 2000 parts per million (ppm) and as a rule, less than 1000 ppm. The criterion of portability of water is not absolute because even drinking water may be unsuitable for the production of concrete when such water has high concentration of sodium or potassium and there is the danger of alkali-aggregate reaction.

Sea water or any water containing large quantities of chlorides tend to cause persistent dampness and efflorescence. Such water should not be used where appearance of the concrete is of importance or where plaster finish is to be applied. In the case of reinforced concrete, sea water increases the risk of corrosion of the reinforcement. In rural areas, water from stream and pond may contain stagnant water, liquid manure, etc and should be regarded with suspicion and small trial mix of concrete should be tested before embarking on a larger mix with the water.

2.1.2 Cement

Cement can be defined in general term as a material that has both cohesive and adhesive properties which enable it to effect strong bond between mineral fragments to form a compact mass. The basic materials for Portland cement manufacturing are the mixing together of calcareous and argillaceous or other silica, alumina and iron oxide bearing materials, burning them at a clinkering high temperatures and grinding the resulting clinker. From the above it can be seen that cement is made primarily from a combination of calcareous materials, such as limestone or chalk and of silica and alumina found in clay or shale. The process of manufacture consist essentially of grinding the raw materials into a very fine powder, mixing them intimately in predetermined proportion and burning them in a rotary kiln at a temperature of about 1400 degrees Celsius when the material sinters and partially fuses into clinker. The clinker is cooled and ground to a fine powder with gypsum added, and the resulting product is the commercial Portland cement used throughout the world.

Table 2.1 Main compound compositions in ordinary Portland cement are:

Calcium oxide (CaO)	60 – 65%
Silica (SiO2)	20 – 25%
Aluminium oxide (Al2O3)	4 – 8%
Ferrous oxide (Fe2O3)	2 – 4%
Magnesium oxide (MgO)	1 – 3%

Tri-calcium silicate is the best cementing material and the more of it present in cement, the better. Cement having lesser aluminates shall have less initial strength but a higher ultimate strength. Hydraulic cement is those that have the property of setting and hardening under water. For construction purpose, the meaning of cement is restricted to the bonding material used with stones, sand, brick, building block etc.

2.1.2.1 Types of cement

There are different types of cement manufactured to suit the various specific requirements. Below is the list of some of the different types of cement.

1. Ordinary Portland cement.
2. Rapid hardening Portland cement.
3. Portland blast furnace cement.
4. Low heat Portland cement.
5. High Alumina cement.
6. Sulphate resisting Portland cement.
7. Coloured cement.
8. Air entraining Portland cement.
9. Portland pozolana cement.

Ordinary Portland cement: Ordinary Portland cement is the commonest type of cement having medium rate of strength development and heat evolution. It is suitable for normal concrete work.

Rapid hardening Portland cement: This cement gains strength faster than ordinary Portland cement. Its initial and final setting times are the same as those of ordinary Portland cement. It contains more tri-calcium silicate and is more finely grounded. It gives out more heat while setting and is as such unsuitable for mass concreting. It is used for such structures as are to be subjected to loads early like in the repair of roads and bridges.

Portland Blast furnace cement: Portland blast furnace cement has very similar properties to ordinary Portland cement but evolves less heat and it is highly more resistant to chemical attack. It is made by grinding a mixture of cement clinker, gypsum and blast furnace slag in proper proportions and grinding it finely. This cement can advantageously be used in marine works; Manufacture of Portland slag cement is aimed primarily at profitably utilizing blast furnace slag – a waste product from the production of iron in blast furnace.

High Alumina Cement: It is manufactured by fusing together, a mixture of bauxite and limestone in correct proportions and at high temperatures. The resulting product is grounded finely. It develops strength rapidly. It is black in colour and resists well, the attack of chemicals especially of sulphates and sea water. The ultimate strength is much higher than that of ordinary PORTLAND CEMENT. Its initial setting time is more than two hours and the final setting time take place immediately. It is the most expensive of all cement. It is used extensively for refractory purposes – to line the furnace where moderately high temperature id encountered.

Low heat Portland cement: Heat generation by cement while setting may cause cracks in structures. In the case of concrete, heat generation is controlled by keeping the percentage of tri-calcium silicate low. Its initial and final setting times are nearly the same as those of ordinary Portland cement but the rate of its development of strength is very slow. It is used for large dam construction where there is danger of high temperature building up.

Sulphate resisting Portland cement: Sulphate resisting Portland cement is very similar to ordinary Portland cement but as its name implies, has a much higher resistance to sulphate attack. In certain soils, concentration of sulphate chemical exist which will cause concrete made with ordinary Portland cement to crumble. Where such condition exists, the concrete in contact with the soil should be made with high alumina cement or with sulphate resisting Portland cement.

Air entraining Portland cement: This is ordinary Portland cement mixed with small quantities of air entraining materials at the time of grinding. Usually, air entraining materials used are resin***; vinsol resin and darek*** are most commonly used. These materials have the property of entraining air in the form of air bubbles in concrete. These bubbles render the concrete more plastic, more workable and more resistance to freezing. However, because air entraining, the strength of concrete reduces and as such the quantity of air so entrained should not exceed five percent.

Coloured cement: For architectural purposes, white concrete, or particularly in tropical countries, a pastel colour paint finish is sometimes required. For this purpose, white or coloured cement is used. It is also used because of its low content of soluble alkalis so that straining is avoided. Coloured cement is made from china clay which contains little iron oxide and manganese oxide together with chalk or limestone free from specified impurities.

Portland Pozzolana Cement: Portland pozzolana cement is produced either by grinding together Portland cement clinker and pozzolana or by intimately and uniformly blending Portland cement and fine pozzolana. This cement has properties similar to those of ordinary Portland cement and can therefore be used for all general purposes where the latter is employed with no change of proportion of fine or coarse aggregates and cement. Gypsum is added in both cases.

Portland pozzolana cement produces less heat of hydration and offer greater resistance to chemical attack. It takes little longer to gain strength. The ultimate strength of this cement is more than that of ordinary Portland cement but the initial and final setting times are the same.

2.1.2.2 Properties of cement.

Cement quality is vital for the production of good concrete; hence the following properties of cement are usually tested in the laboratory to ascertain the level of acceptability:

(a) Setting time: There are two setting times – initial and final setting times. Initial indicates the beginning of noticeable stiffening of the fresh concrete. The final setting time on the other hand indicates the point from which the paste starts to harden and gain strength. Broadly speaking, setting refers to a change from fluid to a rigid state. It is mainly caused by selective hydration of C3A and C3S and is accompanied by temperature rise in the paste. Initial set corresponds to a rapid rise while final set corresponds to the peak temperature. These setting times should be distinguished from false set which occurs within a few minutes of mixing with water.

(b) Soundness: the soundness of cement refers to its ability to maintain a constant or consistent volume. Unsoundness occurs in cement by delayed or slowed hydration or the presence of free lime in hardened cement. The presence of magnesium or calcium sulphate which expands under restrained conditions can lead to destruction of hardened cement paste. The soundness of cement refers to its ability or otherwise to maintain a constant volume.

(c) Fineness: Since hydration starts at the cement particles, it is the total surface area of cement that represents the material available for hydration. Thus the rate of hydration depends on the fineness of the cement particles and for a rapid development of strength, a high degree of fineness is necessary. However, the cost of grinding on the other properties like workability of fresh concrete must be borne in mind. Finer cement promotes stronger reaction with alkali reactive aggregates to produce a paste exhibiting a higher shrinkage and is liable to more cracking. The fineness of cement is specified in terms of specified surface, which is the calculated surface area of the particles in square centimetre per gram of cement (cm2/g). A control of the fineness will help keep its properties uniform.

(d) Strength: Strength tests are not carried out on neat cement paste because of difficulties in obtaining good specimen and in testing with a consequent large variability of test results. Cement sand motar and in some cases, concrete of prescribed properties made with specified materials under strictly controlled conditions are used for the purpose of determining the strength of concrete. The strength of motar or concrete depends on the cohesion of concrete paste, its adhesion to the aggregates.

2.1.3 Aggregates and its Classification

Aggregate may be defined as non-cementious particles such as natural sand, gravel, crushed rock or a combination of these materials which are mixed with cement and water to produce concrete. Aggregate constitute the bulk of the volume of concrete and influence its properties such as strength and shrinkage. The properties of aggregates greatly affect the durability and confer considerable technical advantages of stability and better durability than the cement paste alone.

The characteristics of concrete aggregates include uniformity, permeability, specific gravity, grading, and resistance to weathering, frost action, liability to oxidation and hydration and coefficient of thermal expansion. Depending upon the size of their particles, aggregates are classified as fine, coarse and cyclopean aggregates.

1) Fine aggregates: Particles of fine aggregates pass through the 4.75mm mesh and are entirely retained on the 0.15mm mesh. Most commonly used fine

aggregates are sand and crushed stones. Sand consists of small grain of silica and is formed by the disintegration of rocks caused by weather. Depending on the source from which sand is obtained, it is classified as; (i) Pit or quarry sand, (ii) River sand and (iii) Sea sand.

The following are the qualities of good sand for concrete production purposes:

(a) Good sand should have coarse and angular grains of pure silica.

(b) The grain of sand should be hard, strong and durable.

(c) It should be free from silt, clay and salts.

(d) It should be well graded – it should contain suitable proportion of all the various sizes.

(e) It should not contain any organic matter.

(f) It should not contain any hygroscopic matter.

To check the suitability of sand for being used in motar or concrete, it may be put to the following tests:

(i) Rub a little sand between the fingers; stain left on fingers will indicate presence of undesirable clay or silt impurities.

(ii) Taste of sand shall provide a suitable check for the presence of salts.

(iii) Vigorously stir a sample of sand in a glass of water and allow it to rest. Amount of clay or silt present in it will settle on the sand.

2) Coarse Aggregates: Aggregates whose particle sizes is bigger than 4.75mm but smaller than 75mm are known as coarse aggregates. The main coarse aggregates in use in Nigeria are gravels and crushed granites and rocks.

3) Cyclopean Aggregates: The size of this aggregate is 7.5cm – 15cm. It is used for special foundation works.

2.1.3.1 Further Classification of aggregates

Concrete aggregates can also be classified under the following heading:

1) Heavy weight: These may be defined as those having high specific gravity (usually high density concrete for radiation shielding construction of biological shield and for concrete counter weight.
2) Normal weight: The normal weight aggregates are the aggregates which have specific gravity of between 2.50 and 3.00 and bulk density in the range of 1450 to 1750kg/m3.
3) Light weight aggregate: These are either natural or man made porous aggregates used for the production of light weight concrete. The light weight aggregates have lower thermal conductivity, density and strength.

Grading of aggregates

The grading of aggregates indicates the proportion of the different sizes of aggregate or size distribution of the aggregates. It is accomplished by sieve analysis and it is given in terms of percentage weight passing the various sieves. Grading of a given aggregate contains particles ranging from the largest to the smallest. Gap grading occurs where some intermediate sizes are missing or omitted. This may be necessary to obtain a certain surface finish.

Aggregate grade sizes commonly used in Nigeria are of two types which are:

a) Fine Aggregates: An aggregate that contains a high proportion of small particles is referred to as finely grained. Fine aggregates have a maximum particle size of 4.75 mm. The most commonly used fine aggregate is sand, crushed stone and cinders.

b) Coarse Aggregates: This is an aggregate that contains high proportion of large particles. The various types of coarse aggregates are as follows:

(i) Gravel: They are obtained from riverbeds, quarries and seashore. It is hard and durable. They are extensively used as coarse aggregates in concrete work.

(ii) Stone Ballast: Stone that are free from undesirable mineral constituents are broken to stone ballast used in concrete production. It is a excellent coarse aggregate. It should be free from organic matter before being used.

(iii) Brick Ballast: It is reasonably a good substitute for stone aggregate when available in sufficient quantity. It is used as coarse granite in concrete where aggregates from natural resources are not available or expensive. It can also be used in places where lower strength is required or where it is exposed to less severe conditions of service. The brick ballast should be free from dust and also be thoroughly saturated with water before usage in concrete works.

(iv) Lateritic Rock: The lateritic rocks are those in which laterzation is the dominant soil formation process. The process of their formation is through the leaching silica under hot and moist condition. They are residual soil from tropical regions.

(v) Granite: These can also be obtained from quarries. They hard, strong and durable. They are used extensively as coarse aggregates when making concrete. They should be free from impurities such as clay, salts.

2.1.3.2 Properties of Aggregates:

The properties of aggregates known to have significant effect on quality of concrete are its bond, strength, durability, toughness, volume change, specific gravity, bulk density, porosity and moisture content.

a) Bond: Both the shape and surface texture of aggregate influence considerably, the strength of concrete. Especially so for high strength concrete, flexural strength is more affected from compressive strength. A rough texture results in greater adhesion or bond between the particles and the cement matrix. Likewise the larger surface area of a more angular aggregate provides a greater bond. Generally, when the bond is good, a crushed specimen should show some aggregate particles broken right through, in addition to the more numerous ones separated from the paste matrix.

b) Strength: Clearly, the compressive strength of concrete cannot significantly exceed that of the major part of the aggregate contained therein, although it is not easy to determine the crushing strength of the aggregate itself. A few weak particles can certainly be rated; after all, air voids can be viewed as aggregate particles of zero strength. The required information about the aggregate particles has to be obtained from indirect tests: crushing strength of prepared rock samples, crushing value of bulk aggregate and performance of aggregate in concrete. The later simply means either previous experience with the given aggregate or a trial use of the aggregate in a concrete mix known to have certain strength with previously proven aggregates.

c) Toughness: Toughness can be defined as the resistance of aggregate to failure by impact, and it is usual to determine the aggregate impact value of bulk aggregate. Full details of the prescribed tests are given in BS 812: part 112 of

1990. The apparatus for the test is portable, cheap and simple to operate and it is rapid in application. It can be used in the field for quality control purposes. This property is mostly used in road pavement works.

d) Hardness: Hardness or resistance to wear is an important property of aggregate used in roads and floor surfaces subjected to heavy traffic. The aggregate abrasion value of the bulk aggregate can be assessed using BS 812 part 113 of 1990. Aggregate particles between 14.0 and 20.0 mm are made up in a tray in a single layer, using a setting compound. The sample is subjected to abrasion in a standard machine. The aggregate abrasion value is defined as the percentage loss in mass on abrasion so that a high value denotes a low resistance to abrasion.

e) Durability: This is the resistance of concrete to weathering, chemical attack, abrasion, frost and fire. It depends largely on the quality of mineral composition of the aggregate.

f) Volume Change: Volume changes due to limestone movement in aggregate derived from sand stones and sand basalts may result in considerable shrinkage of concrete. If the concrete is restrained, it will produce internal tensile stresses thereby causing tensile cracking and subsequent deterioration of the concrete. If the coefficient of thermal expansion of the aggregate differs considerably from that of cement paste, it will cause cracking that may adversely affect the concrete performance.

g) Specific Gravity: This is the ratio of the unit weight of the aggregate to the unit weight of water. The specific gravity affects the density of the resulting concrete. BS 812: part 107 uses the term particle density for the specific gravity or relative density. If the mass of the oven dried sample is D, the mass of the vessel full of water is C, and the mass of the vessel with the sample topped with water is B, then the mass of water occupying the same volume as the liquid is D-(B-C). The apparent specific gravity or relative density is then: r.d = D/[D-(B-C)].

h) Bulk Density: The bulk density of an aggregate is the ratio of the total mass or weight of aggregate to the volume disregarding the voids. The absolute density refers to the volume of the individual particles only, and of course it s not physically possible to pack these particles so that there are no voids between them. Thus when aggregate is to be batched by volume, it is necessary to know the bulk density which is the actual mass that would fill a container of unit volume and this density is used to convert quantities by mass to quantities by volume. The bulk density depends on how density of the aggregate is packed and consequently the size distribution and shape of the particles. BS 812 part 2: 1975 recognises two degrees; loose and compacted bulk density.

i) Porosity: Porosity of aggregate affects the quality of both fresh and hardened concrete. The porosity, permeability and absorption of aggregate influence the bond between it and the cement paste, the resistance of concrete to freezing and thawing as well as chemical stability and resistance to abrasion.

j) Moisture content: Since absorption represents the water contained in the aggregate in a saturated, surface dry condition, we can define the moisture content as the water in excess of the saturated surface dry condition. Thus the total water content of a moist aggregate is equal to the sum of the absorption and moisture content. The moisture content must be allowed for in the calculation of batch quantities and of the total water requirement of the mix. In effect, the mass of water added to the mix has to be decreased and the mass of aggregate must be increased by an equal amount of the moisture content. BS 812: part 109: 1990 prescribed the following method for determination of moisture content. If A is the mass of an airtight container, B the mass of the container and sample, and C the mass of container and sample after drying to a constant mass, the total moisture content (percent) of the dry mass of aggregate is given by; M.C = (B-C)/(C-A)*100%

2.2.0 PROPERTIES OF CONCRETE.

2.2.1 Workability: workability can be defined as the amount of useful internal work necessary to produce full compaction. It is the ease with which concrete can be placed and compacted. Workability of concrete increases with the addition of water but it reduces the strength and as such it is not a very desirable way of increasing workability. Use of aggregates which are round and have smooth surface increases the workability. Slump test gives idea of only the flowing property of wet concrete and not of workability. Workability of concrete is better determined by compaction factor test.

2.2.2 Durability: Durability of concrete is the property of concrete to withstand alterative weather conditions of wetness, dryness and frost.

2.2.3 Strength: Strength of concrete is commonly considered to be the most valuable property. Strength of concrete usually gives overall picture of the quality of concrete because it is directly related to the structure of the cement paste. The strength of concrete is usually measured in 7, 14, 21 and 28 days after it has been cast and thoroughly cured. The compressive strength of concrete is its ability to withstand squeezing and crushing forces. Flexural strength is the ability to withstand bending and resulting tension.

2.2.4 Shrinkage: Shrinkage takes place principally in the cement paste as concrete dries. The amount of shrinkage depend on the amount of water added to the mixture. the cement content, the maximum size of the aggregate, its shape. grading and cleanliness. The lower the water content the lower the shrinkage.

2.2.5 Segregation: Segregation can be defined as the separation of the constituents of a heterogeneous mixture so that their distribution is no longer uniform. In this case of concrete, it is the differences in the size of particles (and sometimes in the specific gravity of the mix constituents) that are the primary cause of segregation, but its extent can be controlled by the suitable grading and by care of handling. Other causes of segregation are due to excess water in the mix and over compaction.

2.2.6 Bleeding: Bleeding is the separation from the wet concrete of water and cement which may be associated with wet segregation. It is known as water gain, it is a form of segregation in which some water in the mix tends to rise to the surface of freshly placed concrete. This caused by the inability of the solid constituents of the mix to hold all the mixing water when they settle downwards. When the cement paste has stiffened sufficiently, bleeding of concrete ceases.

2.2.7 Density: It is common to determine the density of a compacted fresh concrete when measuring workability or the air content. Density is easily obtained by weighing the compacted fresh concrete in a standard container of known volume and mass. BS 1881: part 107: 1983 describe the procedure. If the density, D*, is known, the volume of concrete can be found from the mass of the ingredients. When these are expressed as quantities in one batch put into the mixer, we can calculate the yield of concrete per batch. Let the masses of per batch of water, cement, fine aggregate and coarse aggregate be, respectively, W, C, Af, and Ac. Then, the volume of the compacted concrete obtained from one batch is: V = (C+Af+Ac+W)/D*

Also, the cement content (mass of cement per unit volume concrete) is C/V=D*-(Af+Ac+W)/D*

2.3.0 Production of Concrete

Concrete is produced by mixing together cement, mineral aggregates and water. This mixture is placed in a suitable container or mould, compacted and allowed to harden. The processes of production are listed below:

2.3.1 Batching: Concrete consist of a mix of cement, fine aggregates (sand), coarse aggregates (granite) and water. The mix must be properly designed and the right amount of each material correctly batched must be used.

There are two methods of batching the ingredients of concrete; (i) by weight and (ii) by volume. Except for very large projects, batching by volume would be acceptable though it will not be as accurate as batching by weight. The basis of batching by volume is generally one part of cement to n parts of sand and 2n parts of granite. The coarse aggregate is usually twice the fine aggregate whereas the ratio of cement to fine aggregate depends upon the designed strength of concrete. The ratio being less when the strength needed is great and vice versa.

The proportion of cement to aggregate depends on the strength, permeability and durability required. In general concrete works, the equivalent of 1:2:4 concrete mix is suitable for general construction for economical mix of moderate strength.

Today, except in small sites, batching is by weight.

Table 2.2 The mix ratios with specific characteristic strength are listed below.

1:2:4	20N/mm2
1:1.5:3	25N/mm2
1:1:2	30N/mm2

2.3.2 Mixing of concrete: The mixing operation consists essentially of rotation and stirring, the objective being to coat the surface of all the aggregate particles with cement paste and to blend all the ingredients of concrete into a uniform mass, this uniformity must not be disturbed by the process of discharging from the mixer.

The usual type of mixer is a batch mixer, which means that one batch of concrete is mixed and discharged before any more materials are put into the mixer. There are four types of mixers as follows:

(i) Tilting drum mixer.

(ii) Non tilting drum mixer

(iii) Pan type mixer and

(iv) Dual drum mixer.

The other form of mixing of concrete is by hand mixing (for very small projects), which place the measured quantities of fine and coarse aggregates on a platform or a layer of lean concrete worked to a flat surface. The measured cement is placed on the fine aggregate and mixed together to obtain even colour with the aid of shovel. The measured coarse aggregate is then spread evenly on the already mixed and spread sand and cement. Water is then added and the whole mixed with shovel into a plastic state without being too wet.

2.3.3 **Mixing time**: On site, there is often a tendency to mix concrete as rapidly as possible and hence, it is important to know the minimum mixing time necessary to produce a concrete of uniform composition and consequently of reliable strength. The optimum mixing time depends on the type and size of mixer, on the speed of rotation, and on the quality of blending of ingredients during charging of the mixer. Generally a mixing time of less than 1 or 1.25 minutes produce appreciable non uniformity in composition and significantly lower strength.

Table 2.3 below, gives recommended minimum mixing times for various capacity mixers.

Capacity of mixer (m3)	Mixing time (minutes)
0.8	1
1.5	1.25
2.3	1.5
3.1	1.75
3.8	2
4.6	2.25
7.6	3.25

2.3.4 Conveyance of concrete

There are many methods of conveying concrete from the mixing point to where it is placed. Whatever may be used, it must ensure that the concrete is quickly and cheaply transported and that it does not change in proportion during drying out, by segregation or by bleeding. Some of the means by which concrete are being conveyed are as listed below:

1) By lorry,
2) By steel skips and buckets,
3) By the use of wheel barrows,
4) By pipelines,
5) By cranes and
6) By monorail transporters

2.3.5 Placing concrete

After mixing the concrete with water it should be used up within 30 minutes ie before the initial setting of cement starts. Concrete should be properly placed to ensure that it can be well compacted into a homogeneous mass. For uniform result, the operation should be directed by an experienced supervisor. Improper placing results in serious defects such as segregation, bleeding and honeycombing.

2.3.6 Compaction of concrete

The process of compacting concrete by vibration consists essentially of elimination of entrapped air and forcing the particles into a closer and denser configuration. Both compaction by hand and compaction by vibration can produce good quality concrete with the right mix and workmanship. Adequate compaction increases the density of concrete and also prevents abrasion in concrete structures.

2.3.7 Curing

The condition under which concrete is allowed to set and harden after being placed and compacted in formwork is referred to as curing. After concrete has been placed and compacted, the construction cannot be regarded as finished until a period of time has elapsed to allow the concrete to reach a suitable strength. This can only be possible if the curing conditions after placing are suitable to allow strength to develop properly.

Control of curing conditions must be properly exercised to achieve the desired result. The conditions to be controlled are those which have effect on the hydration of concrete namely, temperature and moisture content. Concrete should be protected during the first stage of hardening, from low temperature in cold weather and from drying conditions such as wind and hot sunshine. Curing may be done using any of the following methods:

a) By submerging under water,
b) By sprinkling of water at intervals,
c) By spreading wet sand on the surface of the concrete slab until the curing period elapses,
d) By spreading lessians* on top of the slab and making them overlap well on each other,
e) By spreading burlap on top of the slab until the curing period elapses and
f) By drying under air at controlled ambient temperature.

3.3 Method of grading the aggregates

The grading of aggregates (both fine and coarse) was done using sieve analysis method. The British standard (BS) sieve of 4.75mm and 12.5mm diameters were used. The grading of fine aggregates (sand) was carried out by passing the aggregates through the 4.75mm sieve and those that passed through were used as fine aggregates. The coarse aggregates used were those that passed the 12.5mm sieve but were retained by the 4.75mm sieve.

Complete sieve analysis of both the fine and the coarse aggregates was completely carried out by passing a known weight of the various aggregates through a set of sieves and recording the weight retained on each sieve. The result of the sieve analysis was plotted on a graph with the particle size on the horizontal and the cumulative percentage passing on the vertical. The graph for both the fine aggregates and the coarse aggregates were plotted accordingly.

3.4 Measurements for batching

By using the scale balance for weighing, the batching was carried out as by varying the water content while retaining the weight of the other ingredients. A total of 11 batches were made with mix proportions by weight – 1:2:4 as follows:

Table 3.1 Batching constituents of the concrete

Batch No	Composition of concrete (kg)	
1, w/c = 0.40	Weight of cement	5.00
	Weight of fine aggregates	10.00
	Weight of coarse aggregates	20.00
	Weight of water	2.00

2, w/c = 0.42	Weight of cement	5.00
	Weight of fine aggregates	10.00
	Weight of coarse aggregates	20.00
	Weight of water	2.10
3, w/c = 0.44	Weight of cement	5.00
	Weight of fine aggregates	10.00
	Weight of coarse aggregates	20.00
	Weight of water	2.20
4, w/c = 0.46	Weight of cement	5.00
	Weight of fine aggregates	10.00
	Weight of coarse aggregates	20.00
	Weight of water	2.30
5, w/c = 0.48	Weight of cement	5.00
	Weight of fine aggregates	10.00
	Weight of coarse aggregates	20.00
	Weight of water	2.40
6, w/c = 0.50	Weight of cement	5.00
	Weight of fine aggregates	10.00
	Weight of coarse aggregates	20.00
	Weight of water	2.50

Batch No	Composition of concrete (kg)	
7, w/c = 0.52	Weight of cement	5.00
	Weight of fine aggregates	10.00
	Weight of coarse aggregates	20.00
	Weight of water	2.60
8, w/c = 0.54	Weight of cement	5.00
	Weight of fine aggregates	10.00
	Weight of coarse aggregates	20.00
	Weight of water	2.70
9, w/c = 0.56	Weight of cement	5.00
	Weight of fine aggregates	10.00
	Weight of coarse aggregates	20.00
	Weight of water	2.80
10, w/c = 0.58	Weight of cement	5.00
	Weight of fine aggregates	10.00
	Weight of coarse aggregates	20.00
	Weight of water	2.90
11, w/c = 0.60	Weight of cement	5.00
	Weight of fine aggregates	10.00
	Weight of coarse aggregates	20.00
	Weight of water	3.00

3.4.1 Moisture content test for sand: Three tests were carried out to ascertain the average natural moisture content for the fine aggregates to be used thus:

A container was weighed and recorded as (W1)g

Weight of container + wet sample = W2 (g)

Weight of container + oven dried sample = W3 (g)

Weight of moisture = (W2 – W3)g

Weight of oven dry sample = (W3 –W1)g

Moisture content = (W2-W3)/(W3-W1)x100%

3.4.2 Water absorption test for coarse aggregates: Here too, three tests were carried out to ascertain the average water absorption for the coarse aggregates for use.

Weight of container	W1(g)
Wt of container + wet sample	W2(g)
Wt of container + dry sample	W3(g)
Wt of dry sample	(W3-W1)g
Increase in moisture	(W2-W3)g
Moisture absorption	(W2-W3)/(W3-W1)x100%

3.4.3 Method of mixing and preparation

Hand mixing method was used. It was carried out by pouring the weighed fine aggregates on the mixing platform. The weighed cement is then spread on it and thoroughly mixed until the mixture is grey in colour. The mixture is then evenly spread on the platform and the measured coarse aggregate (12.5mm crushed granite) is evenly spread on the cement sand mixture. The measured water is gradually poured evenly on the cement-aggregate mixture. The entire mixture is then turned evenly with the hand held shovel until a flowing concrete is achieved ready for placement. It is usually limited to.six (6No) turnings.

3.5 Workability test.

The following two (2No) tests are used as a measure of workability of concrete – compaction factor test and slump test.

3.5.1 Compaction factor test:

The best method of measuring workability is the inverse approach of the degree of compaction achieved by a standard amount of work done in achieving full compaction.

The degree of compaction, called the compaction factor, is measured by the density ratio in other words; the ratio of density actually achieved in the test of density of the same concrete fully compacted.

The apparatus consist essentially of two hoppers and one cylinder, the former being above one another. The hoppers have hinged doors at the bottom. These are cleaned and oiled before carrying out the test set as detailed below.

The hopper is filled with concrete, this being gently so that, at this stage, no work is done on the concrete to produce compaction. The bottom door of the hopper is then released and the concrete falls into the lower hopper. This lower hopper is smaller than the upper one and is therefore filled to overflowing and this always contains approximately the same amount of concrete in a standard state.

The bottom door of the lower hopper is released and the concrete falls into the cylinder. Excess of concrete is cut by two floats slid across the top of the mould, and the net mass of concrete in the known volume of the cylinder is determined. The use of two hoppers helps to reduce any inconsistencies caused by the uneven loading of the hopper.

The weight of the concrete in the cylinder was found and referred to as compacted concrete. It is found by a refilling the container in layers of approximately 50mm each and each layer being compacted 25 blows using the standard compacting rod and trowel the concrete to level with the rim. The concrete in the cylinder is weighed again and the compacted weight is recorded. The higher the value of the compacted weights in comparison with that of not compacted weight, the greater the workability.

3.5.2 Slump test

Apparatus:

1 A grucated slump metal cone in form of a frustum

2 A metal base plate

3 A 600mm long rod

4 A steel rule for slump measurement

5 A straight edge

Procedure: The apparatus and the surrounding were properly cleaned to keep off impurities before the test commences. In making the test, the cone was oiled and then filled with concrete in three (3No) layers. Each layer is tapped 25 times with a standard 16mm diameter steel rod, rounded at the end, and top surface is struck off by means of a screeding and rolling motion of the tamping rod. The mould must be firmly held against its base during the entire operation. This is facilitated by handles or foot rest brazed to the mould.

Immediately after the filling, the cone is slowly lifted and the unsupported concrete will now slump. The decrease in the height of the centre (the highest part of the concrete BS 1881: part 102:83) of the slumped concrete is called the slump and is measured to the nearest 5mm.

3.6 Strength test

3.6.1 Density test.

It is common to determine the density of compacted fresh concrete when measuring workability or the air content. It is obtained by weighing the compacted concrete in a standard container of known volume and mass.

Let the mass of container be M1,

Mass of container + fresh concrete = M2,

Volume of container = V,

Then mass of concrete = M2 – M1,

Therefore density of concrete = (M2 – M1)/V

3.6.2 Specific Gravity test

Two tests each were carried out to ascertain the specific gravity of both the fine and the coarse aggregates and the average value taken on each case.

Weight of cylinder	W1(g)
Wt of cylinder + sample	W2(g)
Wt of cylinder + Water + sample	W3(g)
Wt of cylinder + water	W4(g)
Wt of water	(W3-W2)g
Wt of sample	(W2-W1)g
Wt of water displaced by the sample	(W4-W1)-(W3-W2) = w(g)
Specific gravity	(W2-W1)/w

3.6.3 Bulk Density test on coarse aggregates

The test was carried out on compacted and un-compacted aggregate samples. Two tests were carried out in each case and a simple arithmetic average taken of the results.

Weight of empty container	W1 (kg)
Volume of container	V (m3)
Weight of container + sample	W2 (kg)
Weight of sample	(W2-W1)kg
Bulk density	(W2-W1)/V (kg/m3)

3.6.3.1 Test for aggregate crushing value (ACV)

Mass of mould + aggregates	M1 (g)
Mass of mould only	M2 (g)
Mass of Aggregates	(M1-M2)g
Mass of aggregate retained on 2.3mmsieve	M3(g)
Aggregate crushing value (ACV)	M3/(M1-M2)x100%

3.6.3.2 Aggregate impact value (AIV) of granite: Two tests were carried out and the average value taken.

Mass of mould + aggregates	M1 (g)
Mass of mould only	M2 (g)
Mass of Aggregates	(M1-M2)g
Mass of aggregate passing the 2.3mmsieve	M3(g)
Aggregate crushing value (AIV)	M3/(M1-M2)x100%

3.6.4 Mixing time

On mixing the concrete, it is ensured that the cubes were cast within a very short time to avoid the concrete from setting. To ensure a standard mix and mix time for all the batches, we regulated the mixing method and mix time to 6No turnings each.

3.6.5 Cube production

Apparatus

1 Steel mould

2 Metal base

3 Steel rod

4 Metal float

5 Trowel

Procedure: Before the test was carried out, the inner parts of the moulds were cleaned and oiled. The nuts and bolts were properly fastened to avoid leakage of mortar through the joints. Concrete was cast in the cube of 150X150X150 mm size in three (3No) layers and each layer is compacted with the steel rod. Each layer was rammed with 25 blows of the rod. The final layer of the cube is smoothened at the tip with the use of the hand trowel. The cubes were allowed to set and harden for 24 hours before they are removed from the moulds. They were then transferred to bath tube filled with water where they are left to cure in the curing tray for 28 days. At the end of the 28 days of curing, the cubes are then removed and the crushing test is done.

3.6.6 Curing

The object of the curing under wet conditions at normal temperature is to keep the concrete saturated until the originally water filled space in the fresh cement paste has been occupied to the desired extent by the products of hydration of cement. This curing period lasted for 28 days.

3.6.7 Crushing

The crushing of the cubes was carried out using the electrically powered crushing machine in the FUT laboratory. The cubes were crushed on the 28^{th} day and the readings were taken for further analysis by calculations.

CHAPTER 4

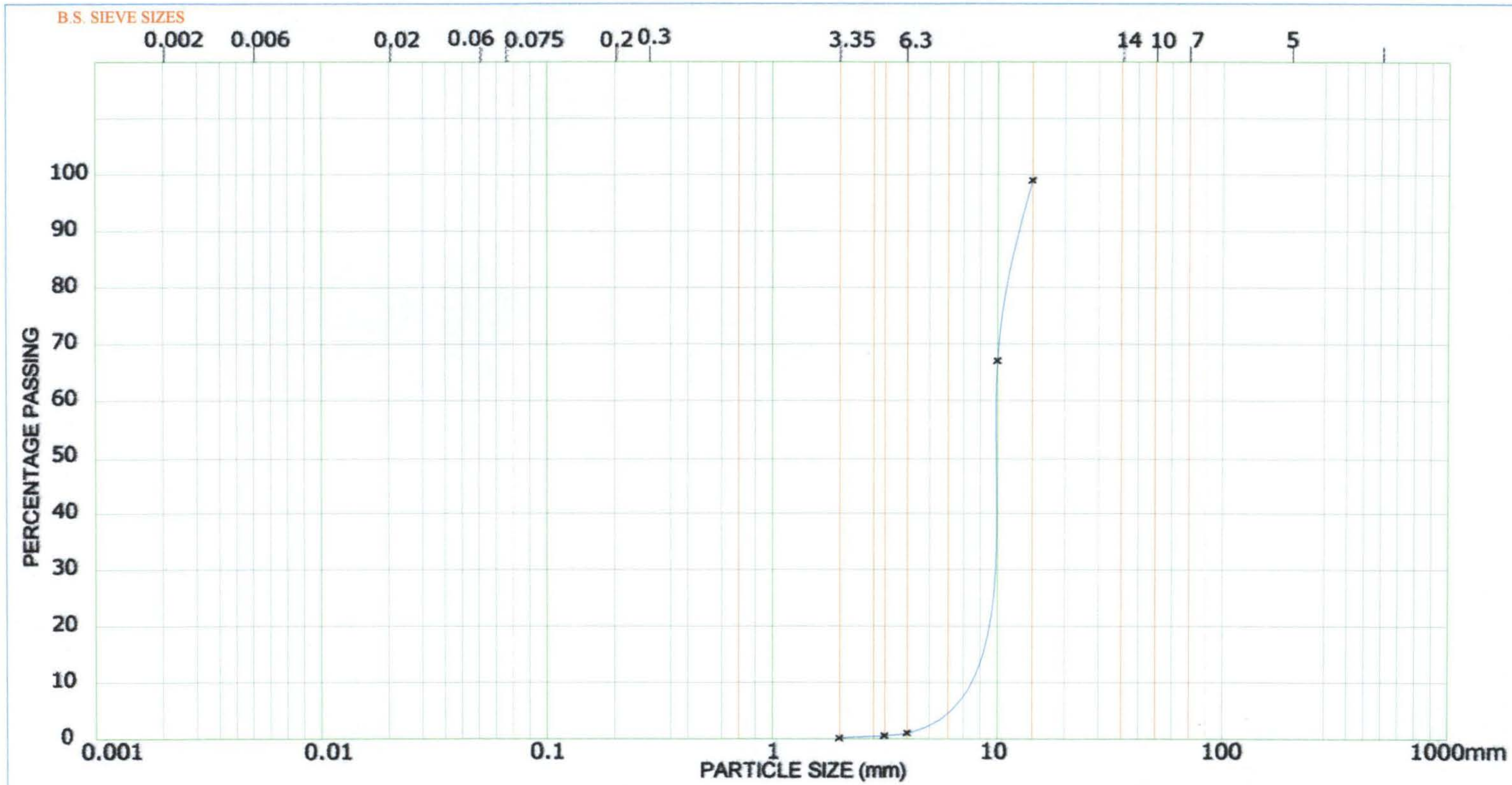
4.00 RESULTS AND DISCUSSION

Table 4.1 Sieve analysis of coarse aggregates (12.50 mm) – total sample weight 500g

Sieve No	Wt retained (g)	% retained	% passing
14mm	3.60	0.72	99.28
10mm	160.40	32.08	67.20
6.3mm	329.00	65.80	1.40
5.0mm	4.20	o.84	0.56
3.25mm	2.00	0.40	0.16
Pan	0.80	0.16	0.00

Table 4.2 sieve analysis of fine aggregates – total sample weight 500g

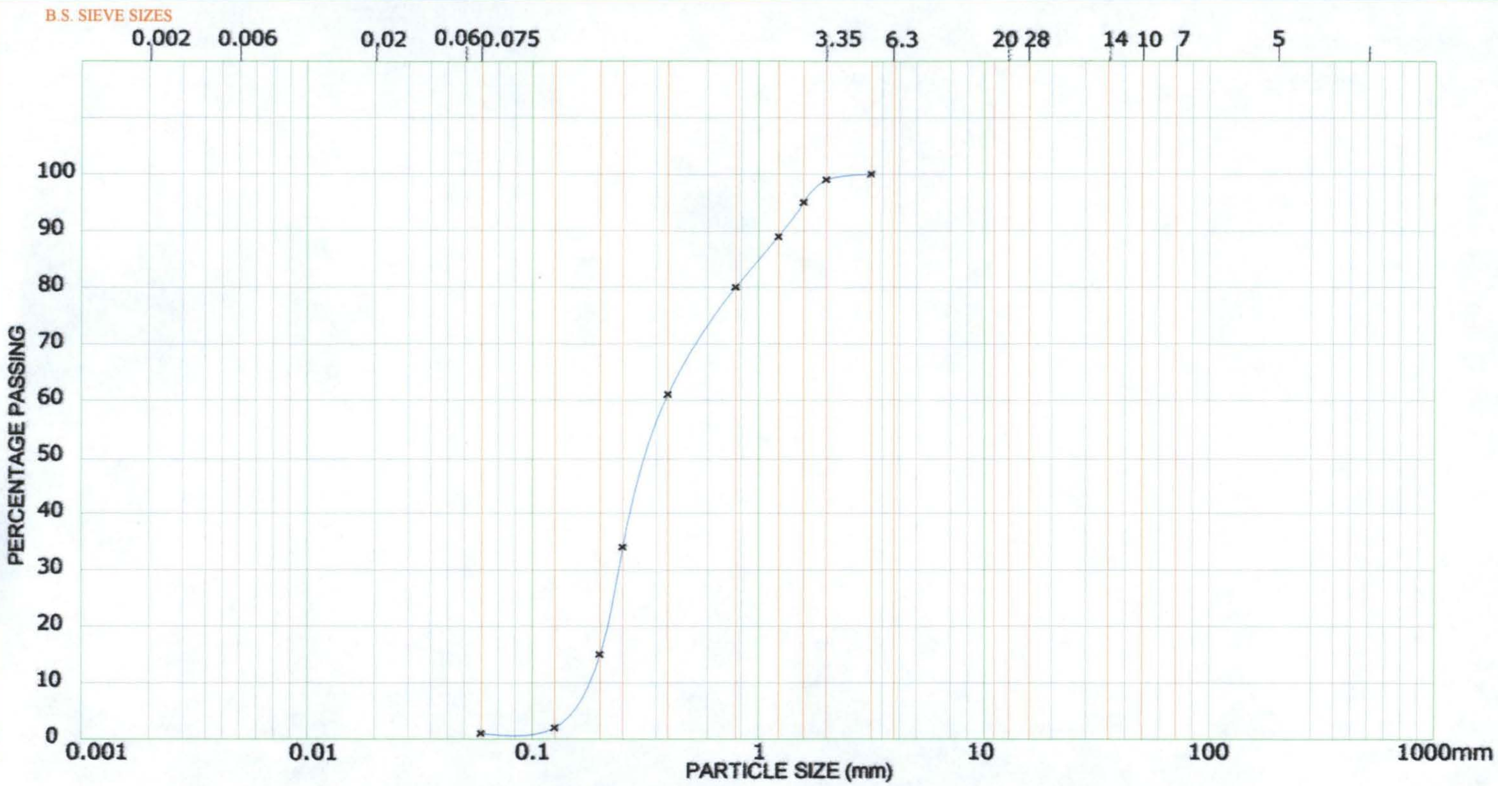
Sieve No	Wt retained (g)	% retained	% passing
5.0mm	0.00	0.00	100.00
3.25mm	4.40	0.88	99.12
2.00mm	17.40	3.48	95.64
1.18mm	34.40	6.88	88.76
850um	41.20	8.24	80.52
600um	98.10	19.62	60.90
425um	137.00	27.40	33.50
300um	95.00	19.00	14.50
150um	64.40	12.88	1.62
75um	5.00	1.00	0.62
Pan	3.10	0.62	0.00



CLAY	FINE SILT	MEDIUM SILT	COARSE SILT	FINE SAND	MEDIUM SAND	COARSE SAND	FINE GRAVEL	MEDIUM GRAVEL	COARSE GRAVEL	COBBLES	BOULDERS

Specimen Identification	Description of sample	Sample Depth (m)	EMC %	LL %	PL %	PI %	No. 5	No. 7	No. 10	No. 14	No. 18	No. 25	No. 36	No. 52	No. 72	No.100	No.150	No.200	CLAY %	C KN/m	Ø	Perme-ability mm/sec	Specific Gravity (mg/m³)
GRAVEL	CRUSHED GRAVEL	0.6						93.7	89.0	86.9		81.3	80.8		73.1	71.2		67.7					2.58

APPENDIX A: PARTICLE SIZE DISTRIBUTION CURVE



CLAY	FINE SILT	MEDIUM SILT	COARSE SILT	FINE SAND	MEDIUM SAND	COARSE SAND	FINE GRAVEL	MEDIUM GRAVEL	COARSE GRAVEL	COBBLES	BOULDERS

Specimen Identification	Description of sample	Sample Depth (m)	EMC %	LL %	PL %	PI %	No. 5	No. 7	No. 10	No. 14	No. 18	No. 25	No. 36	No. 52	No. 72	No.100	No.150	No.200	CLAY %	C KN/m	Ø	Perme-ability mm/sec	Specific Gravity (mg/m³)
SAND	SHARP SAND	0.6						93.7	89.0	86.9		81.3	80.8		73.1	71.2		67.7					2.58

APPENDIX B: PARTICLE SIZE DISTRIBUTION CURVE

Specific Gravity Test on aggregates

Table 4.3 Computations for specific gravity test for Coarse Aggregates

	Test 1	Test 2
Wt of cylinder (W1)g	552.30	552.30
Wt of cylinder + sample (W2)g	827.00	799.10
Wt of cylinder + H2O + sample (W3)g	1718.30	1700.10
Wt of cylinder + H2O (W3)g	1547.00	1547.00
Wt of H2O (W4 – W1)g	994.70	994.70
Wt of sample (W2 –W1)g	274.70	246.80
Wt of H2O displaced by sample (W4-W1)-(W3-W2) = (w)g	103.40	93.70
Specific gravity = (W2-W1)/w	2.66	2.63
Arithmetic average of specific Gravity SG =	2.65	

Table 4.4 Computations for Specific gravity test – Fine Aggregates

	Test 1	Test 2
Wt of cylinder (W1)g	114.40	114.40
Wt of cylinder + sample (W2)g	172.00	168.20
Wt of cylinder + H2O + sample (W3)g	398.20	390.80
Wt of cylinder + H2O (W3)g	362.50	360.50
Wt of H2O (W4 – W1)g	248.10	246.10
Wt of sample (W2 –W1)g	57.60	53.80
Wt of H2O displaced by sample (W4-W1)-(W3-W2) = (w)g	21.90	23.5
Specific gravity = (W2-W1)/w	2.63	2.29
Arithmetic average of specific gravity SG =	2.46	

Table 4.7 computations for Water Absorption test for 12.50 mm aggregates

Details	Test 1	Test 2	Test 3
Wt of container (W1)g	129.60	125.00	123.80
Wt of container + wet sample (W2)g	214.40	177.90	190.20
Wt of container + dry sample (W3)g	213.70	177.50	189.70
Wt of dry sample (W3-W1)g	84.10	52.50	65.90
Increase in Weight (W2-W3)g	0.70	0.40	0.50
Absorption (W2-W3)/(W3-W1)x100%	0.83	0.76	0.76
Average Absorption		0.78%	

Table 4.8 Computations for Aggregate crushing Value (ACV) Test on 12.50mm coarse aggregates

Wt of mould + aggregates (W1)g	15,911.00
Wt of mould (W2)g	12,670.00
Wt of Aggregates (W1-W2)g	3,241.00
Wt retained on sieve 2.3mm (W3)	762.00
Aggregate Crushing Value W3/(W1-W2)x100%	23.51

Table 4.9 Computations for Aggregate Impact Value (AIV) Test on 12.50mm coarse aggregates

Details	Test 1	Test 2
Wt of mould + Aggregates (W1)g	3,401.00	3,399.00
Wt of mould (W2)g	2,632.00	2,632.00
Wt of Aggregates (W1-W2)g	769.00	767.00
Wt passing sieve 2.3mm (W3)g	76.80	76.50
AIV = W3/(W1-W2)x100%	9.99	9.97
Therefore Average AIV = 9.98%	9.98%	

Table 4.10 Computations for Compaction Factor Test on concrete from 12.50mm coarse aggregates

0.40 Water/Cement ratio	
Wt of partially compacted Sample + cylinder (W1)kg	11.41
Wt of fully compacted sample + cylinder (W2)kg	13.41
Compaction factor CF = W1/W2	0.85
0.42 Water/Cement ratio	
Wt of partially compacted Sample + cylinder (W1)kg	11.96
Wt of fully compacted sample + cylinder (W2)kg	13.60
Compaction factor CF = W1/W2	0.88
0.44 Water/Cement ratio	
Wt of partially compacted Sample + cylinder (W1)kg	12.28
Wt of fully compacted sample + cylinder (W2)kg	13.80
Compaction factor CF = W1/W2	0.89

0.46 Water/Cement ratio	
Wt of partially compacted Sample + cylinder (W1)kg	12.18
Wt of fully compacted sample + cylinder (W2)kg	13.84
Compaction factor CF = W1/W2	0.88
0.48 Water/Cement ratio	
Wt of partially compacted Sample + cylinder (W1)kg	12.50
Wt of fully compacted sample + cylinder (W2)kg	13.93
Compaction factor CF = W1/W2	0.90
0.50 Water/Cement ratio	
Wt of partially compacted Sample + cylinder (W1)kg	12.60
Wt of fully compacted sample + cylinder (W2)kg	14.16
Compaction factor CF = W1/W2	0.96
0.52 Water/Cement ratio	
Wt of partially compacted Sample + cylinder (W1)kg	12.72
Wt of fully compacted sample + cylinder (W2)kg	13.90
Compaction factor CF = W1/W2	0.92
0.54 Water/Cement ratio	
Wt of partially compacted Sample + cylinder (W1)kg	12.72
Wt of fully compacted sample + cylinder (W2)kg	13.56
Compaction factor CF = W1/W2	0.94
0.56 Water/Cement ratio	
Wt of partially compacted Sample + cylinder (W1)kg	13.20
Wt of fully compacted sample + cylinder (W2)kg	14.00
Compaction factor CF = W1/W2	0.94

0.58 Water/Cement ratio	
Wt of partially compacted Sample + cylinder (W1)kg	12.60
Wt of fully compacted sample + cylinder (W2)kg	13.80
Compaction factor CF = W1/W2	0.91
0.60 Water/Cement ratio	
Wt of partially compacted Sample + cylinder (W1)kg	13.38
Wt of fully compacted sample + cylinder (W2)kg	13.94
Compaction factor CF = W1/W2	0.96

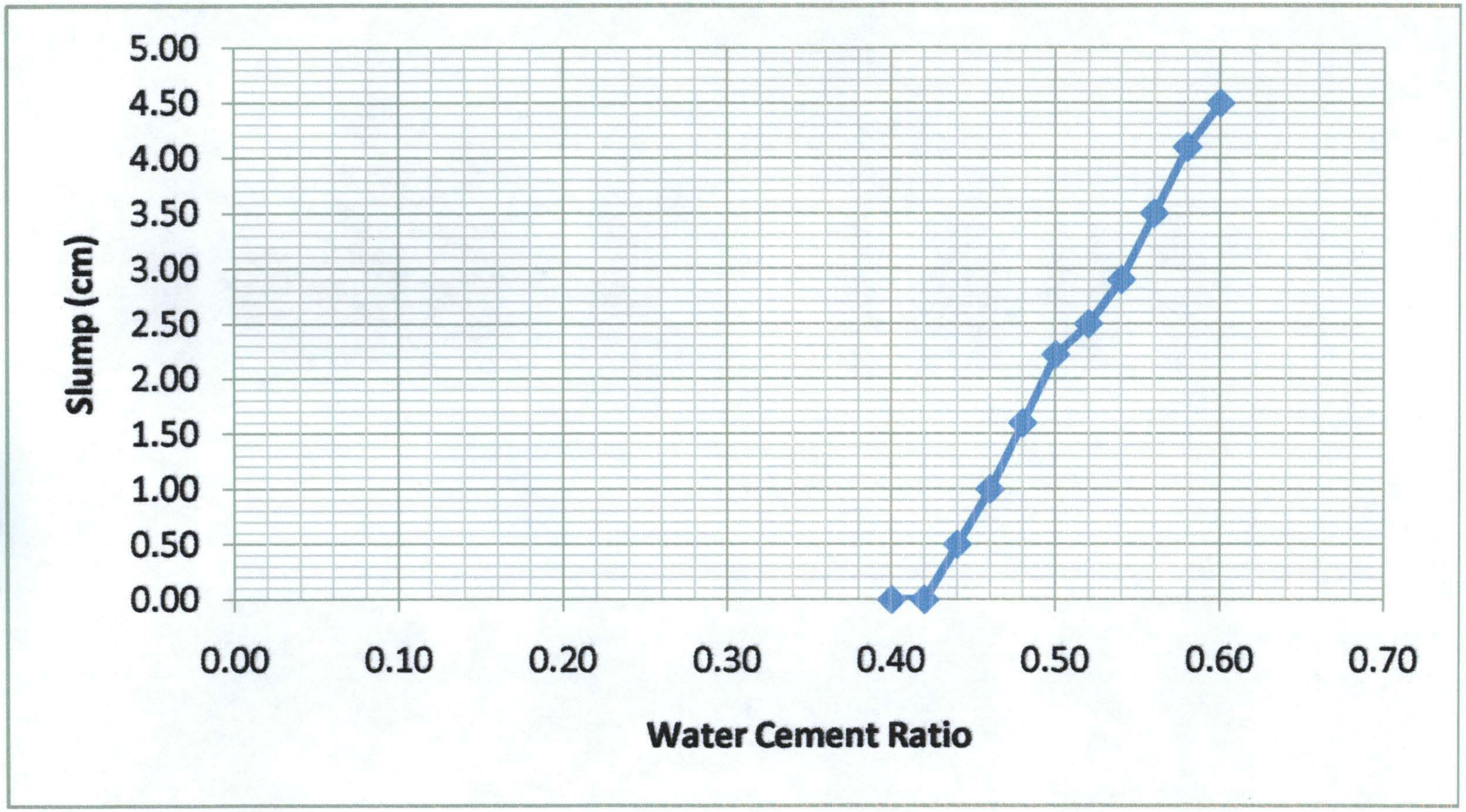

Slump (cm)
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
Water Cement Ratio

Table 4.12 Summary of Density of Concrete using 12.5mm aggregates as computed in Appendix I

Water cement ratio	Average Density (kg/m3)
0.40	2365
0.42	2400
0.44	2405
0.46	2412
0.48	2416
0.50	2417
0.52	2413
0.54	2409
0.56	2396
0.58	2390
0.60	2384

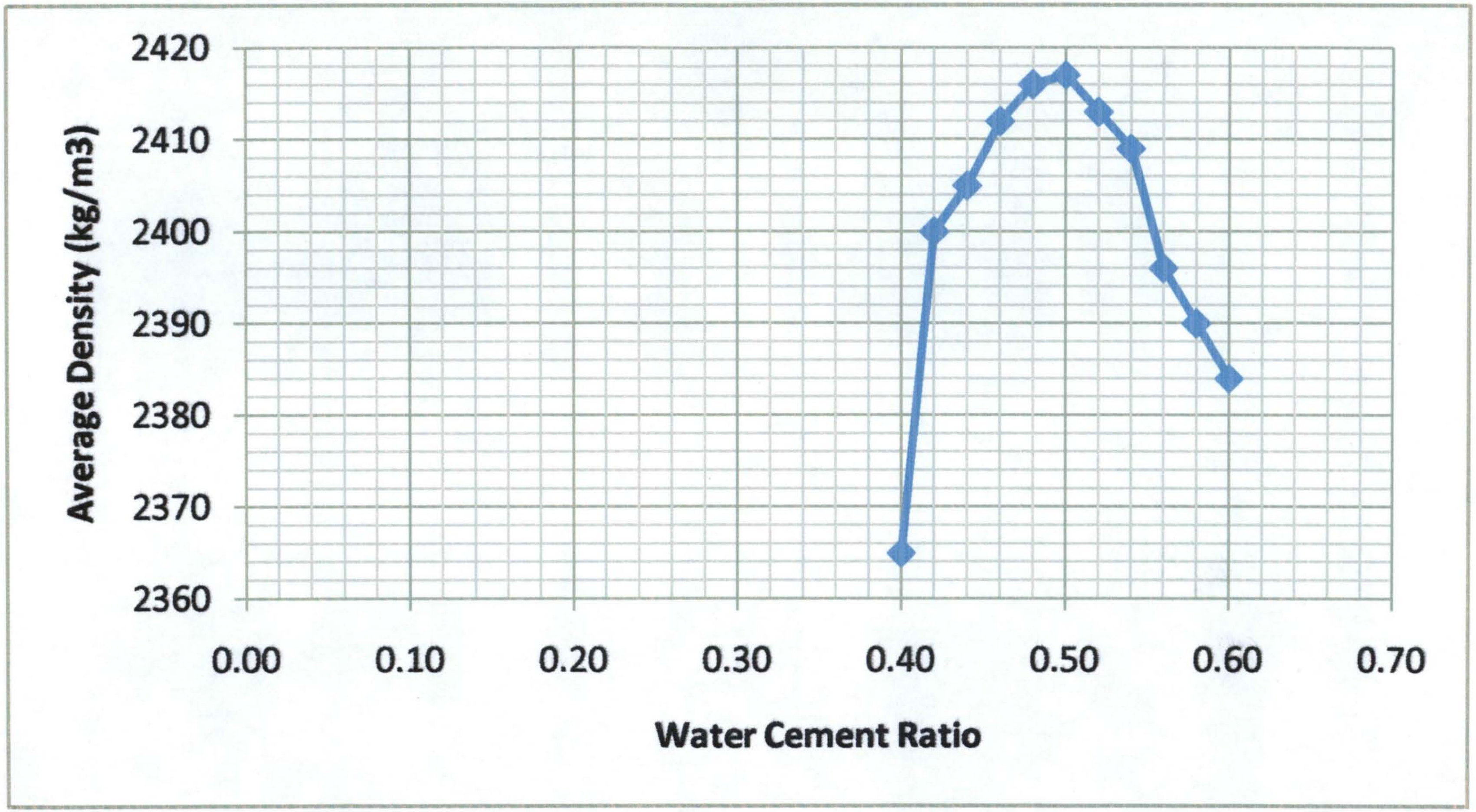
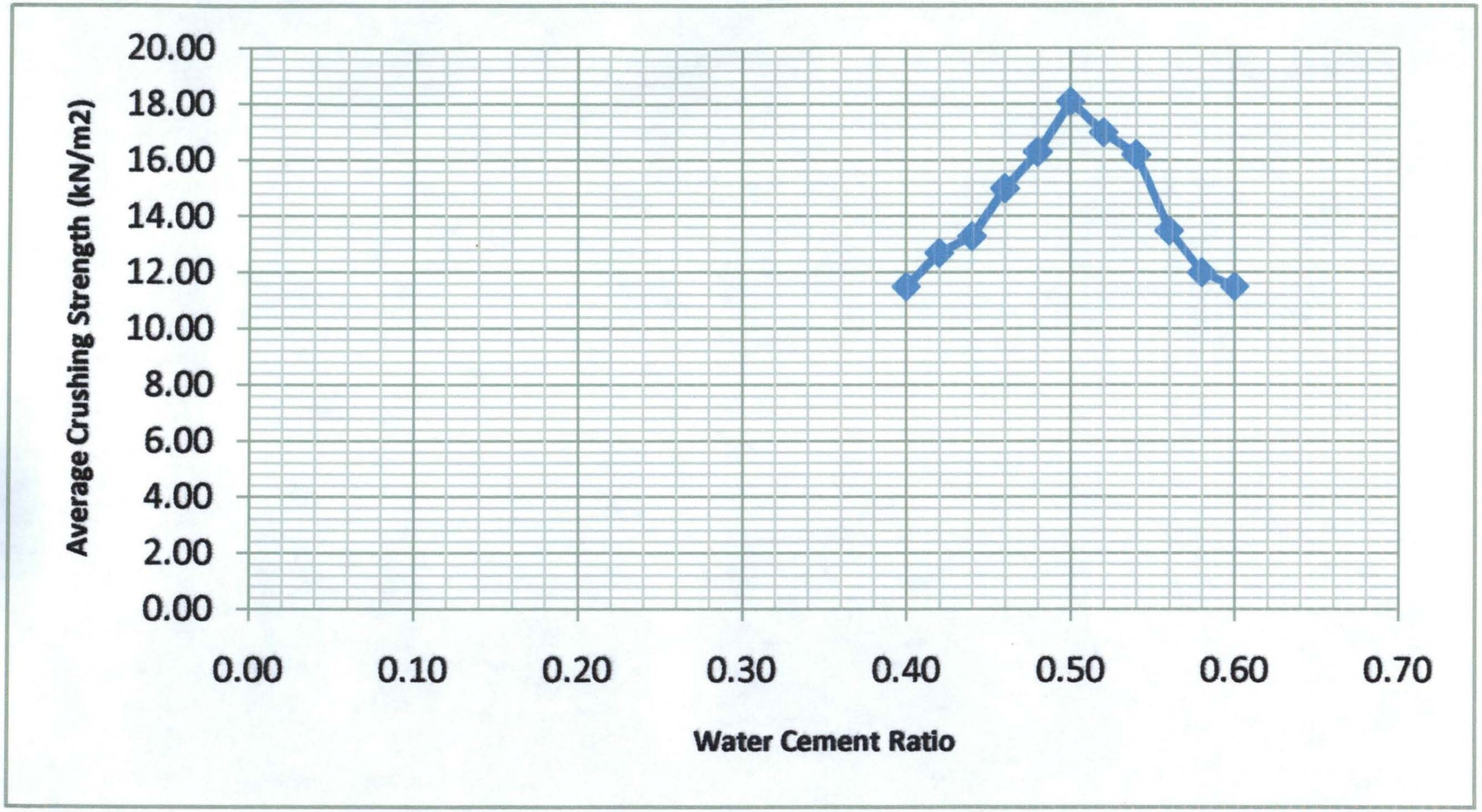

Average Density (kg/m3)
2420
2410
2400
2390
2380
2370
2360
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
Water Cement Ratio

Table 4.13 Summary of compressive strength for each water-cement ratio as computed in Appendix II

Water cement ratio	Average compressive strength (KN/m2)
0.40	11.50
0.42	12.70
0.44	13.30
0.46	15.00
0.48	16.30
0.50	18.10
0.52	17.00
0.54	16.20
0.56	13.50
0.58	12.00
0.60	11.50


Average Crushing Strength (kN/m2)
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
Water Cement Ratio

4.1.0 DISCUSSION OF RESULTS

The following facts were observed: That the water cement ratio of concrete affect a) The workability vis-à-vis the slump of fresh concrete, b) The density of compacted concrete and c), The strength of the hardened concrete among other parameters like void ratio, porosity, bleeding, segregation of concrete etc.

1) Workability: It is observed that the higher the water cement ratio, the workability and hence the higher the slump. However, workability should not be satisfied at the expense of strength and durability of hardened concrete of which too high water cement ratio negates.
2) Density: The density of compacted concrete is observed to increase as the water/cement ratio is increasing up to a point but beyond which a further increase in the water/cement ratio results in the continuous decline of the concrete density. This is due to the fact that any extra water added after that required for the hydration of cement is left as free water. This free water only swells the concrete leading to a reduction of density – mass per unit volume. The mass of concrete being constant while the volume continues to increase.
3) Strength: Concrete needs water for hydration which aids the development of strength of the hardened concrete. Water added over and above that required for the hydration of cement does not contribute positively to the strength of concrete. In the test under review, it is observed that the strength of hardened concrete increases as the water/cement ration is increased from 0.4 to about 0.5 after which a decline sets in. It means therefore that cement hydration

requires water/cement ratio of between 0.45 - 0.50 to be completed. Beyond this point additional water tends to be counter productive.

Other areas where water/cement ratio has effect in concrete are as follows:-

a) Void ratio: When the water/cement ratio goes above the water needed for cement hydration, the excess water remains as free water and rather swells the concrete. After concrete curing, the water dries up leaving air voids, hence high void ratio.
b) Porosity: When the air voids are connected to one another, the concrete becomes porous and water and other liquids seeps through with ease. This in turn negatively affects the durability of the concrete.
c) Bleeding: With too much water in the concrete being batched, the cement paste in the concrete leaks through any little hole/opening in the form work leaving behind, only the aggregates. This results in weak concrete by all standards.
d) Segregation: With high and excess water/cement ratio, the tendency of separation of the aggregates from the cement paste (known as segregation) during transportation is very high. This means non homogenous concrete being batched with the attendant poor concrete work out put.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

From the research carried out, the following conclusion can be reached:

(i) That for normal concrete, the higher the water-cement ratio the higher the workability of the fresh concrete.

(ii) That the water-cement ratio needed to be increased up to the volume that will be enough for hydration and compaction, thereafter will reduce the strength of the hardened concrete.

(iii) That as the water-cement ratio increased, the density of the concrete start increasing up to a maximum point and start declining.

5.2 RECOMMENDATION

The following recommendations are made based on the research work done on the normal concrete:

(i) From the study of the graph of the water-cement ratio against the crushing strength at the age of 28 days, it is recommended that the water-cement ratio of normal concrete be between 0.46-0.54 for maximum strength and effective workability.

(ii) It is recommended that where high amount of water is needed, the amount of cement in the mix should be increased like using 1:1.5:3 mix instead of the 1:2:4.mix.

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Appendix I computations for the Density of Concrete using 12.50 mm aggregates

For water cement ratio of 0.40; vol. of cube (V) = 0.15x0.15x0.15 = 0.003375m3

Sample	Mass, M (Kg)	Density, P = M/V	Density, P (Kg/m3)
A	8.00	8.00/0.003375	2370
B	8.00	8.00/0.003375	2370
C	7.95	7.95/0.003375	2356
Average			2365

For water cement ratio of 0.42; vol. of cube (V) = 0.15x0.15x0.15 = 0.003375m3

Sample	Mass, M (Kg)	Density, P = M/V	Density, P (Kg/m3)
A	8.20	8.20/0.003375	2430
B	8.10	8.10/0.003375	2400
C	8.00	8.00/0.003375	2370
Average			2400

For water cement ratio of 0.44; vol. of cube (V) = 0.15x0.15x0.15 = 0.003375m3

Sample	Mass, M (Kg)	Density, P = M/V	Density, P (Kg/m3)
A	8.13	8.13/0.003375	2409
B	8.05	8.05/0.003375	2385
C	8.17	8.17/0.003375	2421
Average			2405

For water cement ratio of 0.46; vol. of cube (V) = 0.15x0.15x0.15 = 0.003375m3

Sample	Mass, M (Kg)	Density, P = M/V	Density, P (Kg/m3)
A	8.16	8.16/0.003375	2418
B	8.09	8.09/0.003375	2397
C	8.17	8.17/0.003375	2421
Average			2412

For water cement ratio of 0.48; vol. of cube (V) = 0.15x0.15x0.15 = 0.003375m3

Sample	Mass, M (Kg)	Density, P = M/V	Density, P (Kg/m3)
A	8.12	8.12/0.003375	2406
B	8.18	8.18/0.003375	2424
C	8.16	8.16/0.003375	2418
Average			2416

For water cement ratio of 0.50; vol. of cube (V) = 0.15x0.15x0.15 = 0.003375m3

Sample	Mass, M (Kg)	Density, P = M/V	Density, P (Kg/m3)
A	8.13	8.13/0.003375	2409
B	8.15	8.15/0.003375	2415
C	8.19	8.19/0.003375	2427
Average			2417

For water cement ratio of 0.52; vol. of cube (V) = 0.15x0.15x0.15 = 0.003375m3

Sample	Mass, M (Kg)	Density, P = M/V	Density, P (Kg/m3)
A	8.10	8.10/0.003375	2400
B	8.17	8.17/0.003375	2421
C	8.16	8.16/0.003375	2418
Average			2413

For water cement ratio of 0.54; vol. of cube (V) = 0.15x0.15x0.15 = 0.003375m3

Sample	Mass, M (Kg)	Density, P = M/V	Density, P (Kg/m3)
A	8.09	8.09/0.003375	2397
B	8.10	8.10/0.003375	2400
C	8.11	8.11/0.003375	2430
Average			2409

For water cement ratio of 0.56; vol. of cube (V) = 0.15x0.15x0.15 = 0.003375m3

Sample	Mass, M (Kg)	Density, P = M/V	Density, P (Kg/m3)
A	8.08	8.08/0.003375	2394
B	8.08	8.08/0.003375	2394
C	8.10	8.10/0.003375	2400
Average			2396

For water cement ratio of 0.58; vol. of cube (V) = 0.15x0.15x0.15 = 0.003375m3

Sample	Mass, M (Kg)	Density, P = M/V	Density, P (Kg/m3)
A	8.07	8.07/0.003375	2391
B	8.06	8.06/0.003375	2388
C	8.07	8.07/0.003375	2391
Average			2390

For water cement ratio of 0.60; vol. of cube (V) = 0.15x0.15x0.15 = 0.003375m3

Sample	Mass, M (Kg)	Density, P = M/V	Density, P (Kg/m3)
A	8.05	8.05/0.003375	2385
B	8.05	8.05/0.003375	2385
C	8.04	8.04/0.003375	2382
Average			2384

Appendix II Computations for the compressive Crushing Test on Concrete from 12.50 mm aggregates

For water cement ratio of 0.40; area of cube (A) = 0.15x0.15 = 0.0225m2

Sample	Force, F (KN)	Stress = F/A	Stress (KN/m2)
A	252	252/0.0225	11.20
B	260	260/0.0225	11.60
C	265	265/0.0225	11.80
Average			11.50

For water cement ratio of 0.42; area of cube (A) = 0.15x0.15 = 0.0225m2

Sample	Force, F (KN)	Stress = F/A	Stress (KN/m2)
A	274	274/0.0225	12.20
B	290	290/0.0225	12.89
C	295	295/0.0225	13.10
Average			12.70

For water cement ratio of 0.44; area of cube (A) = 0.15x0.15 = 0.0225m2

Sample	Force, F (KN)	Stress = F/A	Stress (KN/m2)
A	299	299/0.0225	13.30
B	298	298/0.0225	13.20
C	304	304/0.0225	13.50
Average			13.30

For water cement ratio of 0.46; area of cube (A) = 0.15x0.15 = 0.0225m2

Sample	Force, F (KN)	Stress = F/A	Stress (KN/m2)
A	324	324/0.0225	14.40
B	344	344/0.0225	15.30
C	341	341/0.0225	15.20
Average			15.00

For water cement ratio of 0.48; area of cube (A) = 0.15x0.15 = 0.0225m2

Sample	Force, F (KN)	Stress = F/A	Stress (KN/m2)
A	360	360/0.0225	16.00
B	372	372/0.0225	16.50
C	368	368/0.0225	16.40
Average			16.30

For water cement ratio of 0.50; area of cube (A) = 0.15x0.15 = 0.0225m2

Sample	Force, F (KN)	Stress = F/A	Stress (KN/m2)
A	395	395/0.0225	17.60
B	399	399/0.0225	17.70
C	426	426/0.0225	18.90
Average			18.10

For water cement ratio of 0.52; area of cube (A) = 0.15x0.15 = 0.0225m2

Sample	Force, F (KN)	Stress = F/A	Stress (KN/m2)
A	380	380/0.0225	16.90
B	385	385/0.0225	17.10
C	383	383/0.0225	17.00
Average			17.00

For water cement ratio of 0.54; area of cube (A) = 0.15x0.15 = 0.0225m2

Sample	Force, F (KN)	Stress = F/A	Stress (KN/m2)
A	362	362/0.0225	16.10
B	368	368/0.0225	16.40
C	360	360/0.0225	16.00
Average			16.20

For water cement ratio of 0.56; area of cube (A) = 0.15x0.15 = 0.0225m2

Sample	Force, F (KN)	Stress = F/A	Stress (KN/m2)
A	300	300/0.0225	13.30
B	312	312/0.0225	13.90
C	298	298/0.0225	13.20
Average			13.50

For water cement ratio of 0.58; area of cube (A) = 0.15x0.15 = 0.0225m2

Sample	Force, F (KN)	Stress = F/A	Stress (KN/m2)
A	275	275/0.0225	12.20
B	270	270/0.0225	12.00
C	263	263/0.0225	11.70
Average			12.00

For water cement ratio of 0.60; area of cube (A) = 0.15x0.15 = 0.0225m2

Sample	Force, F (KN)	Stress = F/A	Stress (KN/m2)
A	265	265/0.0225	11.80
B	258	258/0.0225	11.50
C	251	251/0.0225	11.20
Average			11.50