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Assessment of the Properties of Fine Aggregates in Wudil, Nigeria

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Abstract:
The properties of fine aggregates from six sources (locations) commonly used for construction purposes in Wudil, Kano State were determined. Fine aggregates samples A, B, C and D were characterized as a zone II materials while samples E and F were characterized as zone IV. The fineness modulus of samples A, B, C and D were far above 3.0 indicating a coarser grading while those of samples E and F indicated a finer grading. The average specific gravities of the soil samples were found to be between 2.60 to 2.64 respectively which fall within the range of 2.4 – 2.9 as specified by (BS 882 2004). The average compacted bulk densities are between 1663.35kg/m3 to 1801.13kg/m3 and uncompacted (Loose) bulk densities are between 1065.34 kg/m3 to 1294.03 kg/m3 for all the fine aggregate samples. The deviation from the standard is reasoned to be due to sample disturbance.

Keywords: *Fine aggregates, bulk density, fineness modulus, specific gravity*

1. Introduction

1.1. Background of the Study

Aggregates are grouped into two categories, fine and coarse aggregates. Coarse and fine aggregates are available at various locations in Wudil and its environs. Both the irregular shape of crushed aggregates and small particle sizes of fines sand cause typical particle packing problems which may consequently yield a less durable concrete. In concrete production, the traditional solution is to add water and cement to aggregates, but far greater quantities are needed to attain the same workability as with coarse aggregates. Fine aggregates from various locations were used in producing normal concrete to enhance adequate particle packing of the resultant concrete. Generally, fine aggregates mostly used as fillers are found (Camp, 2009) to exert a possible effect on concretes, for reasons of both particles packing and physiochemical reactions in the interface zone. The use of fine aggregates increases concrete strength and this is mainly due to decrease in water cement ratio. Aggregates generally occupy 60% to 80% of the concrete volume thereby making their properties and selection are worth knowing (A.M. Neville 2010), as they influence the concrete's freshly mixed and hardened properties, mix proportions and economy. Some natural aggregates deposits called pit-run gravel consist of gravel and sand that can be readily used in concrete after minimal processing. Various types of fine aggregates are being used in concrete mixtures. The type of fine aggregate used changes the geometric properties of cement paste, and affect not only the shell formation during heat treatments but also the properties of concrete. Natural gravel and sand are usually dug or dredged from pit, river, lake and seabed. Manufactured sand is produced by crushing quarry rock, boulders, cobbles or large size gravel. Crushed air-cooled blast furnace slag is used as fine or aggregates previously. Aggregates are washed and graded at the pit or plant. Variation may arise in the type, quality, cleanliness, moisture content and other properties. Naturally occurring aggregates for concrete are a mixture of rocks and minerals. Crushed sand is produced by crushing a large parent mass of rock. Many aggregates properties depend on the properties of the parent rock (e.g., chemical and mineralogical composition, petrographic classification, specific gravity, hardness, strength, physical and chemical stability, pore structure and color). Some properties such as shape and size of particles and surface texture of crushed sands are not seen in the parent rock, while others properties such as absorption can change due to the crushing of the parent rock. The shape of aggregates depends on the nature and degree of stratification of rock deposit, the type of crushing plant used and the size reduction ratio. All these properties have an important influence on the quality of fresh and hardened concrete (Donza, et al., 2002). Concrete is a composite material resulting from a mixture of coarse aggregate, fine aggregates, cement and water in adequate proportions. The major constituent of which is the coarse and fine aggregates. Concrete today, has become one of the most popular construction materials, it has good compressive strength, can be cast to any shape, is readily available just about anywhere and is relatively cheap in comparison with other materials available for construction, such as steel or composite (Krinke, 2009). Concrete codes and standards specify the fine aggregates requirements necessary to obtain homogeneous, workable and durable concrete of adequate strength. The use of crushed sand is generally limited due to high paste volume needed to obtain adequate workability of concrete. The amount of additional paste content depends on shape, texture, grading and dust content of the crushed sand (Donza, Cabrera and Irassar, 2002). Aggregates were first considered to simply be filler for concrete to reduce the amount of cement required. However, it is now known that the type of aggregates used for concrete can have considerable effect on the plastic and hardened state properties of concrete. Aggregates can be broadly classified into four different categories, which includes; heavy weight, Normal weight, light weight and Ultra-light weight aggregates. However, in practice only normal and light weight aggregates are used. The other types of aggregates are of specialist uses, such as nuclear radiating shielding for heavy weight concrete and thermal insulation for ultra- light weight concrete (Alhozaimy, 2009).Although the relative high strength concrete (HSC) actually used in construction has been extremely small, there has been some growth in the number of structures using it, in the level of strength used, and, perhaps crucially, in the number of national codes of practice permitting design strengths well in excess of those for normal concrete. Furthermore, in some situations the use of HSC can provide clear economic advantages in reducing construction costs. Concurrently, there has been worldwide interest in characterizing the properties and performance of HSC. Systematic properties will then provide very useful guidelines for selecting appropriate mixes (Taylor, et al., 1996). A mineral is a naturally occurring solid substance with and orderly internal structure and a chemical composition which ranges within a narrow limit. Rocks which are classified as igneous, sedimentary, or metamorphic, depending upon origin and mode of formation, are generally composed of several minerals. Weathering, abrasion and erosion of rocks produced particles of stone, gravel, sand, silt and clay. Aggregates should be strong enough to provide resistance to exposure condition and also not be made to cause concrete's deterioration (M. Abdullahi, 2006). Fine aggregates consist of natural sand or crushed stone with most particles up to 5mm (BS 882, 1992). Fine aggregates must conform to standard for optimum engineering use, they must be cleaned, strong, hard, durable particles free from absorbed chemicals, coatings of clay and other materials that could affect bond and hydration of the cement past (Abrahams, D.A., 1918). Properties of fine aggregates are physical, chemical and mechanical. In this research work emphasis is laid on properties such as particles size distribution, bulk density, specific gravity, porosity and absorption, moisture content and finest modulus. These properties have greater influence on workability and strength of both fresh and hardened concretes. Although fine aggregates have been used for several decades for constructions, their properties have not been given due attention (M. Abdullahi, 2006). Fine aggregates are available in abundance in Wudil with different geological formation and history. It becomes imperative for researchers, engineers and the construction industry to characterized, classify and know these properties for economic and safer construction.

1.1. Problem Statement

Fine aggregates have different properties as they evolve from different parent rocks. Physical properties such as bulk density, specific gravity, porosity and absorption, moisture content, particle size distribution and fineness modulus are not well known before fine aggregates are being used for construction purposes. This brings difficulty in regulating the quantity of ingredients in unit volume, inability to ascertain the water absorption by fine aggregates, poor grading limit and poor knowledge about the volume of entrained air in fine aggregate.

1.2. Aim and Objectives:

1.2.1. Aim

The aim of this research work is to determine the properties of fine aggregates from six sources (locations) commonly used for construction purposes in Wudil, Kano State.

1.2.2. Objectives

The objectives of this work are to determine;

- Particle size distribution and fineness modulus of fine aggregates
- Moisture content of fine aggregates
- Water absorption of fine aggregates
- Bulk density of fine aggregates
- Specific gravity of fine aggregates
- Porosity and void ratio of fine aggregates.

1.3. Significance

Fine aggregates play a significant role in construction, as filling material they provide economy, reduce shrinkage and cracks as well as increasing concrete's strength (Fahim-Neshawy, 2000). Adequate knowledge about the properties of fine aggregates is paramount for suitability in various construction works. This work seeks to provide a reliable database about the properties of fine aggregates in Wudil for researchers, engineers and the construction industry at large.

1.4. Scope and Limitation

1.4.1. Scope

The scope of this work is to assess the properties of fine aggregates in Wudil.

1.4.2. Limitation

The research is limited to assess the properties of fine aggregates in Wudil.

1.5. Material and Methods

1.5.1. Material

Fine aggregates (Sand): Fine aggregates are aggregates in which the particles are not larger than 5mm in size. Sand which is naturally occurring, water or wind-borne pieces of weathered rock is the primary material employed as fine aggregate.

1.5.2. Methods

The research involves the assessment of the properties of fine aggregates in Wudil. For this, fine aggregates will be selected based on availability from six different sources. They are; Gangaren Ibro as (sample A), Garindau Gidan Sarki as (sample B), Kofar Yamma as (sample C), Babalon as (sample D), Gaban Komi as (sample E), Kogin Dafawa as (sample F). The methods include;

- Sieve analysis and fineness modulus determination test
- Moisture content test
- Water absorption test
- Bulk density test
- Specific gravity test
- Porosity and Void ratio test.

1.6. Justification

The research work seeks to provide enough data on the properties of fine aggregates in Wudil and its environs. Inadequate knowledge on the properties of fine aggregates in Wudil and its environs for proper classification and suitability of fine aggregates in various construction works.

1.7. Expected Outcome

At the end of this research, the result is expected to be used as a guide for engineers, researchers and the entire construction industries in Wudil for economic, safer design and construction.

2. Literature Review

2.1. Introduction

Aggregates are granular materials obtained by processing natural materials (BS 882, 1, 1992). Aggregates are natural, manufactured (crushed and artificial) or recycled. Sand and stones have been used for constructions of foundations for thousands of years. Significant refinement of the production and the use of aggregates occurred during the Roman Empire, which used aggregates to build its vast network of roads and aqueducts. The invention of concrete, which was essential to architecture utilizing arches, created an immediate, permanent demand for construction (Mikulic, and Pause 1993). Concrete is a material used in building construction consisting of hard, chemically inert particulate sustenance, known as an aggregate (usually made from various types of sands and gravels), but bonded together by cement and water. Concrete as a material of construction has played a very important and vital role in improving the quality of life in the twentieth century. From the mid 50's, concrete itself has gone through tremendous improvements. The Assyrians and Babylonians used clay as the bonding substances or cement. The Egyptian used lime and gypsum cement, However, the British engineer, John Smeaton, developed the first modern concrete also known as (hydrantic cement) by adding pebbles as coarse aggregates and mixing powered brick into the cement (Buckley, 2005). Another major constituent besides cement is the aggregates which include sands crushed stones, gravels, slag, ashes, burned shales and burned clay are used in making slabs and smooth surface, while the coarse portions are used for massive concrete (Tynes, 2010). The advent of modern blasting methods enabled the development of quarries, which are used throughout the world, whenever competent bedrock deposits of aggregates quality exists. In many places, good limestone, granite, marble or other quality stone bedrock deposits do not exist. In these areas, natural sands and gravels are mined for use as aggregate. Where neither stone, nor sand and gravel are available, construction demand is usually satisfied by importing in aggregates by rail, barges or trucks. Additionally, demand for aggregate can be partially satisfied through the use of slag and recycled concrete (Gunduz and Ugor 2005). However, the available tonnages and lesser qualities of these materials prevent them from being viable replacements for mined aggregates on a large scale (Kronlof, 2004).

2.2. Classification of Aggrigates

Different types of rocks are classified into following groups;

- Classification according to aggregates' source
- Classification according to unit weight
- Classification according to according to aggregates' size

2.2.1. Aggregates Source Classification

2.2.1.1. Natural Aggregates

Natural aggregates consist of rock fragments that are used in their natural state, or used after mechanical processing such as crushing, washing, and sizing. Some natural aggregates deposits, called pit-run gravel, consist of gravel and sand that can be readily used in concrete after minimal processing. Natural gravel and sand are usually dug or dredged from pit, river, or sea bed.

2.2.1.2. Crushed Rock Aggregates

Crushed rock aggregate is quarried excavated stone that has been crushed and screened to the desired standard particle size distribution. The particles of crushed aggregates are completely crushed. This gives the product good compaction and load bearing properties. Crushed stone aggregates are particularly suitable for use in the course of streets, roads and other areas exposed to traffic.

2.2.1.2. Artificial Aggregates

Artificial aggregates are made out of various waste materials. Artificial aggregates are sometimes produced for special purposes.

- For making of lightweight concrete; burned clays, artificial cinders, formed slag, expanded shales and slate, sintered fly ash exfoliated vermiculite are used.
- For making heavy-weight concrete; steel rivet punching and iron ore (Magentite) have been used.

2.2.1.3. Recycled Aggregates

Recycled aggregate is derived from crushing inert construction and demolition waste. It may be classified as recycled concrete aggregate (RCA) when consisting of primarily of crushed concrete or more general recycled aggregate (RA) when it contains substantial quantities of materials other than crushed concrete. Currently, only the use of coarse aggregate derived from construction or demolition waste is recommended for used in new concrete constructions. The characteristic of recycled aggregates could be different by its parent concrete because the parent concrete was designed for its purposes such as permeable, durable, and high strength concrete.

2.2.2. Aggregates' Unit Weight Classification

They are normal-weight aggregates, light-weight aggregates and heavy-weight aggregates. Normal-weight aggregates include for example sand, gravel and crushed stone. Normal-weight aggregates are used to produce normal-weight concretes 2200 to 2400kg/m³. Light-weight aggregates for example include expanded shale, clay, slag and slate. They are used in the production of structural light-weight concretes 1350 to 1850kg/m³. They are also used to produce light-weight insulating concrete 250 to 1450kg/m³. Heavy-weight aggregates include barite, limonite, magnetite, hematite and iron. They are used to produce high-density concrete up to 6400kg/m³. They are also used for radiation shielding.

2.2.3 Aggregate Size Classification

2.2.3.1. Coarse Aggregates

Aggregates mainly retained on a 5mm BS 410 test sieve and containing no finer material than is permitted for various sizes (BS, 882,1, 1992). The particle size ≥ 5mm.

2.2.3.2. Fine Aggregates

Aggregates mainly passing a 5mm BS 410 test sieve and containing no coarser material than is permitted for the various grading (BS, 882,1,1992). The particle size < 5mm. Fine aggregates usually content 35% to 45% by mass or volume of total aggregates. Fine aggregates are naturally occurring, water or wind-borne pieces of weathered rock is the primary material employed as fine aggregates. Also used as fine aggregates are fines from crushed rocks (known as quarry dust). The sand used in the production of concrete are often rounded with smooth surfaces, with other properties dependent of the parent rock. This may be washed to remove undesirable materials.

Usually fine aggregates make up approximately 50% of the total aggregates volume of concrete and hence its influence is extremely important on concrete properties. The fine aggregates should be free from organic impurities (Kumar, et al., 2007).

In practice, this issue is not being considered in the choice of fine aggregates for the production of concrete (Gunduz and Ugor 2004). This may subsequently result into lower strength concrete than that specified for the intended construction.

Various types of fine aggregates are being used in concrete mixtures. The type of fine aggregates used changes the geometric properties of cement paste and not only the shell formation during heat-treatment but also the properties of concrete. The quality of poured concrete must be determined to control the production quality during the time required to remove the form work.

2.3. Properties of Natural Fine Aggregates:

Aggregates are generally divided into two groups: fine and coarse aggregates. Fine aggregates consist of natural or manufactured sand with particles sizes up to 5mm. They consist of inert natural sand and conforming to specifications of (BS 882, 1, 1992). They should not contain more than a total of 5% by weight of the following: shale, silt and structurally weak particles (M. Abdullahi, 2006).

Aggregates make up or occupy 60% to 80% of the concrete volume thus making its selection highly important. Aggregates should consist of particles with adequate strength and resistance to exposure condition and should not contain materials that will cause deterioration of concrete (M. Abdullahi, 2006).

All-natural aggregate particles originally formed a part of a larger parent mass. This may have been fragmented by natural process of weathering and abrasion or artificially by crushing. Thus, many properties of the aggregate depend entirely on the properties of the parent rock, for example, chemical and mineral composition, petrologic character, specific gravity, hardness, strength, physical and chemical stability, pore structure and color (M. Abdullahi, 2006).

Fine aggregates provide support function to the finer solids by producing voids of a size which do not contain or support the finer particles. Particle shape affects the behavior of the water. Harsh angular aggregates do not pack well, and thus result in high void content. Such aggregates may have a high surface area, but because of a lack of contact between the particles, they do not effectively control the finer particles. Smooth rounded aggregates have the disadvantage that, although theoretically they should pack together and produce low voids, sometimes this does not necessarily occur in a graded material of this type (M. Abdullahi, 2006).

Aggregates for mortar must be clean, sharp and free from salt and organic contamination. Most natural aggregates contain a small quantity of silt or clay. A small quantity of silt improves workability. Marine or estuarine aggregates should not be used unless washed completely to remove the magnesium and sodium chloride salts which are deliquescent and attract moisture (M. Abdullahi, 2006).

The most suitable aggregates would appear to be those that are well graded with a balance between rounded and angular particles inclusive of and a surface texture that is not too smooth. In practice, it has been found that natural river aggregates with grading complying with the specifications of (B.S. 882,1,1992) is the most suitable. Sea-dredged and crushed aggregates produce more extreme types, either all smooth and rounded or harsh and angular and generally requiring greater care in design (M. Abdullahi, 2006).

The realization of the usefulness and effect of fine aggregate on the strength of concrete and sand in the building and construction industry has put into the minds of engineers and researchers to lay more emphasis on the study of civil engineering properties of aggregates and their usefulness. Emphasis is made on such properties as bulk density, specific gravity, silt content and particle size distribution (M. Abdullahi, 2006). Aggregates were originally viewed as inert materials dispersed throughout the cement paste largely for economic reasons. However, aggregates are not truly inert and their physical, thermal, and sometimes chemical properties influenced the performance of concrete (A.M. Neville, 2010). The properties of fine aggregates that will be considered in this study are physical, mechanical and chemical.

2.4. Effects of Fine Aggregates on Concrete's Strenght

The use of aggregates powder on the strength of concrete would more than be expected by lower the water/binder ratio. This is due to improved interaction of paste and aggregates, which can be seen as increase in value of efficiency factor (Kronlof, 2004).

(Kronlof 2004) reported some physical factors that improve interaction between the paste and aggregates phase as follows;

- Fine materials interfere with the formation and orientation of large crystals at the paste-aggregates interface.
- Large amount of small particles may alter the rheology, reducing the internal bleeding at interfaces.
- The wall effect does not weaken the contact between paste and fine filler; thus, the function of small aggregates particles approaches that of the unreacted cement particles core.
- The components (paste and aggregate) are homogeneously mixed, lowering the stress peaks.

Good packing of solid components in concrete with the use of fillers provides an effective way to improve concrete quality without increasing the consumption of binders

2.5. Effects of Fine Aggregate Grading on Properties of Concrete

A review of literature on the influence of aggregates grading on the properties of concrete reveals a diversity of opinions concerning the optimum grading of fine aggregates. In most of the investigations dealing with the amount of materials passing No. 100 sieve that will produce satisfactory concrete, it was indicated that less than 15% of this size material is desirable, and it was concluded (Tynes and Saucier, 2010) that 10% is optimum for mass concrete. In general, the consensus is that fines cause an increase in water requirement and influence air content. One of the studies (Tynes and Saucier, 2010) reported indicated that high air content does not decrease the strength excessively for mass concrete and actually seem to be beneficial. Therefore, it appears that a mass concrete mixture, low in fines and having a high air content may prove satisfactory. It is generally concluded (Tynes and Saucier, 2010) that fine-aggregates grading influences in varying degrees, the workability, durability, strength, water requirement, air content, bleeding and density of concrete (Tynes and Saucier, 2010).

Normal concrete is a composite material in which the constituent materials are cement, aggregates and water, and without any form of admixture at the point of mixing the constituent materials that gives the fresh concrete (Gunduz and Ugur 2004).

The process of selecting suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of the required strength, durability, workability as economically as possible, is termed the concrete mix design. The proportioning of ingredient of concrete is governed by the required performance of concretes in two states, namely, the plastic and the hardened states. If the plastic concrete is not workable, it cannot be properly placed and compacted. The property of workability therefore becomes a vital importance.

The compressive strength of hardened concrete which is generally considered to be an index of its other properties depends upon many factors, e.g. quality and quantity of cement; water and aggregates, batching and mixing, placing; compaction and curing. The cost of concrete is made up of cost of materials, plant and labor. The variation in the cost of materials arises from the fact that the cement is several times more expensive than the aggregate; thus, the aim is to produce as lean a mix as possible. From technical point of views, the rich mixes may lead to high shrinkage and cracking in structural concrete, and to evolution of high heat of hydration in mass concrete which may cause cracking (Mikulic, et al., 1993).

The actual cost of concrete is related to the cost of materials required for producing a minimum mean strength called characteristics strength of the concrete that is specified by the designer of the structure, which, depends on the quality control measures, and this adds to the cost of the concrete. The extent of quality control is often an economic compromise, and depends on the type and size of the job. The cost of labor depends on the workability of mix for example, a concrete mix with inadequate workability may result in a high cost of labor to obtain a degree of compaction with availably equipment (Camp, 2009).

2.6. Physical Properties of Fine Aggregates

Several common physical properties of aggregates are relevant to the behavior of aggregates in concrete and to the properties of concrete made with such aggregate. Some of these physical properties are given below.

2.6.1. Gradation of Aggregate

Gradation describes the particle size distribution of aggregate. The particle size distribution is an important attribute of the aggregates. Large aggregates are economically advantageous in Portland cement and asphaltic concrete, as they have less surface area and, therefore require less binder. However, large aggregates mixes, whether asphalt or Portland cement concrete, are harsher and more difficult to work into place. Hence, construction considerations, such as equipment capability, dimensions of construction members, clearance between reinforcing steel, and layer thickness, limit the maximum aggregates size. The process of dividing a sample of aggregates into fractions of same particle size is known as sieve analysis, ant its purpose is to determine grading or grading or particle size distribution.

Sieve Size		**Percentage by Weight Passing Sieves**				
BS 882: 2004						
BS	ASTM No.	Grading Zone I	Grading Zone 2	Grading Zone 3	Grading Zone 4	ASTM Standard C33-78
9.5mm	3/8in	100	100	100	100	100
5mm	3/16in	90-100	90-100	90-100	95-100	95-100
2.36mm	8	60-95	75-100	85-100	95-100	80-100
1.18mm	16	30-70	55-90	75-100	90-100	50-85
600µm	30	15-34	35-59	60-79	80-100	25-60
300 µm	50	5-20	8-30	12-40	15-50	10-30
150 µm	100	0-10	0-10	0-10	0-15	2-10

Table 1: Grading Requirements for Course and Fine Aggregates in Normal Weight Concrete.
Source: A.M. Neville, 2010

2.6.2. Specific Gravity (Relative Density)

Specific gravity of a sample is the ratio of the density of the sample to the density of water. Calculation with reference to concrete are generally based on the saturated and surface dry conditions of the aggregates because the water contained in all the pores in the aggregate does not take part in the chemical reactions of the cement and cannot, therefore, be taken as part of the aggregates (A.M. Neville, 2010).

The absolute specific gravity and particle density refer to the volume of the solid materials excluding all pores, while the apparent specific gravity refer to the volume of the solid mineral including the impermeable pores, but not the capillary ones. The apparent specific gravity is the one being used in concrete technology (Brooks, 2004).

The specific gravity of aggregates is used in the calculations of quantities, but the actual value of the specific gravity of aggregates is not a measure of its quality. Thus, the value of specific gravity should not be specified unless we are dealing with a, material of a given petrological character when a variation in specific gravity would reflect the porosity of the particles (A.M. Neville, 2010).

2.6.3. Bulk Density

Bulk density is the weight of a unit volume of a material. Among other factors, the bulk density of an aggregate sample depends on the void content of the sample being tested. The more the voids present in the sample, the smaller the bulk density will be. In the American or Imperial system, specific gravity has to be multiplied by the unit weight of water in order to be converted into absolute density (Brooks, 2004).

This absolute density, however, refers to the volume of individual particles only, and of course it is not physically possible to pack these particles so that there are no voids between them. Thus, when an aggregate is to be batched by volume, it is necessary to know the mass of aggregate that would fill a container of unit volume. This is known as the bulk density of the aggregates. The density is used to convert quantities by mass to quantities by volume (Brooks, 2004).
The actual bulk density of aggregates depends not only on the various characteristics of the materials which determine the potential degree of packing, but also on the actual compaction achieved in a given case (A.M. Neville, 2010).

2.6.4. Porosity and Absorption

The porosity, permeability and absorption of aggregates influence the bond between them and the cement paste, the resistance of concrete to freezing and thawing, as well as chemical stability, resistance to abrasion and specific gravity (Brooks, 2004).

Absorption is the amount of water contained in an aggregate in its saturated and surface-dry condition, expressed as a percentage of its dry mass. Absorption values are used in conjunction with moisture content of aggregates at the time of mixing in order to correct for any changes in the mixing water content.

2.6.5. Moisture Content

Since absorption represent the water contained in the aggregates in a saturated and surface dry condition, moisture content is defined as the water in excess of the saturated and surface dry conditions. Thus, the total water content of moist aggregates is equal to the sum of absorption and moisture content (Brooks, 2004). This is also expressed as a percentage of the dry mass of an aggregate.

2.6.6. Fineness Modulus

Fineness modulus is used in determining the degree of uniformity of the aggregate gradation. It is an empirical number relating to the fineness of the aggregate. It is defined as sum of cumulative percentages retained divided by 100, it is calculated for fine aggregate rather than coarse aggregate. Typical value ranges from 2.5 to 3.0. A higher value indicates a coarser grading. The usefulness of the fineness modulus lies in detecting slight variations in the aggregates from the same source, which could affect the workability of the fresh concrete.

2.7. Mechanical Properties

Although the various mechanical properties of an aggregate give an indication of the quality of the aggregates, it is not possible to relate the potential strength development of concrete to the property of the aggregates, and indeed it is not possible to translate the aggregate properties into its concrete-making properties.

Bond between aggregates and cement paste is an important factor in the strength of concrete, especially the flexural strength, but the nature of the bond is not fully understood. Bond is due, partly, to the interlocking of the aggregates and the hydrated cement paste due to roughness of the surface of the aggregates. A rougher surface, such as that of crushed particles, result in a better bond due to mechanical interlocking, better bond is also obtained with softer, porous, and mineralogical heterogeneous particles (A.M. Neville, 2010).

The determination of the quality of bond is rather difficult and no accepted test exists. Generally, when bond is good, a crushed concrete specimen should contain aggregate particles broken right through, in addition to the more numerous ones separated from the paste matrix. However, an excess of fractured particles suggests that the aggregate is too weak (Brooks, 2004).

2.7.1. Bond

Both shape and surface texture of aggregates influence considerably the strength of concrete, especially for high strength concretes, flexural strength is more affected than compressive strength. A rougher texture results in a greater adhesion or bond between the particles and the cement matrix. The larger surface area of a more angular aggregates provides a greater bond. Generally, texture characteristics which permit no penetration of the surface of the particles by the pastes are not conducive to good bond, and hence softer, porous and mineralogically heterogeneous particles result in a better bond. The determination of the quality of bond is rather difficult and no accepted test exists. Generally, when is good, a crushed concrete specimen should contain some aggregates particles broken right through, in addition to more numerous ones separated from the paste matrix. However, an excess of fractured particles suggests the aggregate is too weak.

2.7.2. Strength

Obviously, the compressive strength of concrete cannot significantly exceed that of the major aggregates contained therein, although it is not easy to determine the crushing strength of the aggregates itself. Indeed, it is difficult to test the crushing strength of individual aggregates particles, and the required information has to be obtained usually from indirect tests: crushing strength of prepared rock samples, crushing value of bulk aggregates, and performance of aggregates in concrete (A.M. Neville, 2010).

It should be noted that the required aggregates strength is considerably higher than the normal range of concrete strength because the actual stresses at the point of contact of individual particles may be far in excess of the nominal applied compressive stress. On the other hand, aggregates of moderate or low strength and modulus of elasticity can be valuable in preserving the integrity of concrete, because volume changes, for hygral or thermal reasons, lead to lower stresses in the cement paste when the aggregates are compressible, whereas rigid aggregate might lead to cracking of the surrounding cement paste (Brooks, 2004). The compressive strength of concrete has been accepted as the most important mechanical property of structural concrete. (Jin and Li 2000). The desired properties of hardened concrete are its compressive strength, tensile strength, shear strength, bond strength, density, impermeable and durability among these properties, the property that can be easily tested and perhaps the most valuable property from the structural view point is the compressive strength (Unnukrishna, et al, 2006). Compressive strength test is the most common test conducted on hardened concrete, partly because it is easy to perform, and partly because most of the desirable characteristic properties of concrete are qualitatively related to its compressive strength (A.M. Neville, 2010). The factors influencing the strength of concrete are the amount and type of cement, water-cement ratio, aggregates type and grading, workability of fresh concrete, mineral admixtures used, chemical additives, curing conditions and time (Kilic, et al., 2008). It is the mineralogy and strength of the coarse aggregates itself that control the ultimate strength of concrete (Al-Oraimi, Taha and Hassan, 2006). Water-cement ratio is defined as the mass of free water to that of cement in a mix. It is the major factor that controls the strength and many other properties of concrete such as density, impermeability, reduced shrinkage, creep, etc. In practice this ratio lies generally in the range of 0.35 to 0.65, although the purely chemical requirement for the purpose of complete hydration of the cement is only about 0.25-0.27 (Unnukrishna, et al., 2006). According to Abram's law, the compressive strength of hardened concrete is inversely proportional to water-cement ratio provided the mix is of workable consistency (Unnikrishna, et al., 2006). The strength of a concrete is controlled by three factors. These are; strength of the matrix, mostly cement paste; strength of the aggregates; and the strength of the bond between matrix and aggregates surface (Popovics,1987). (M. Abdullahi, 2012) investigated the effect of aggregate type on compressive strength of concrete. The analysis of the test indicates that aggregates type has effect on the compressive strength of normal concrete. The Highest compressive strength is achieved from concrete containing crushed quartzite, followed by concrete containing river gravel. (M. Abdullahi, 2012) Concrete containing crushed granite shows the least strength development at all ages.

2.7.3. Toughness

This can be defined as the resistance of aggregates to failure by impact. It is normal to determine the aggregates impact value of bulk aggregates. It is possible to determine the impact value of bulk aggregates, and the toughness determined in this manner is related to the crushing value, which can in fact be used as an alternate test.

One advantage of the impact test is that it can be performed in the field with some modifications, such as the measurement of quantities by volume rather than by mass, but the test may not be adequate for compliance purposes (A.M. Neville, 2010).

2.7.4. Hardness

In addition to the strength and toughness, hardness (resistance to wear) is an important property of concrete used in pavements and on floor surfaces subjected to heavy traffic. Several tests are available because it is possible to cause wear of aggregates by abrasion, that is, by rubbing of a foreign material against the stone under test, or by attrition of stone particles against one another (A.M. Neville, 2010).

2.8. Chemical Properties

The chemical properties of aggregates are of importance only when the aggregates contain materials that can undergo chemical changes or react with the cement paste in such a way as to cause deterioration or interference with the setting and hardening of the concrete. It does not necessarily follow that because some reactions occur between the cement paste and surface of the aggregate, which is harmful, as this may indeed improve the bond between them. Some ferric-compounds in aggregates appear to react with lime without deleterious effects, but there are evidences that oxidation of ferrous metals is one factor contributing to the deterioration of some dolerite concrete (Buckley, 2005).

2.8.1. Deleterious Substances

There are three broad categories of deleterious substances that may be found in aggregate: impurities which interferes with the process of hydration of cement, coatings that prevent development of good bond between the aggregates and cement paste, and individual particles which are weak or unsound in themselves (Brooks, 2004). All or part of aggregates can also be harmful through the development of chemical reactions between the aggregates and cement paste (A.M. Neville, 2010).

2.8.2. Organic Impurities

Natural aggregates may be sufficiently strong and resistance to wear and yet may not be satisfactory for concrete making if they contain organic impurities which interfere with chemical reactions of hydration. The organic matter found in aggregate consists usually of products of decay of vegetable matters and appears in the form of humus or organic loam. Such materials are more likely to be present in fine aggregate than in coarse aggregates which is easily washed.

Not all organic matter, however, is harmful and its best to check its effect by making actual compression test specimens. In some countries, the quantity of organic matter in aggregates is determined from the loss of a mass of a concrete sample on testing with hydrogen peroxide. It is also interesting to note that, in some cases, the effects of organic impurities may only be temporary (A.M. Neville, 2010).

3. Methodology

3.1. Material and Methods

3.1.1. Introduction

This research involves the assessment of the properties of fine aggregates in Wudil, Kano State, from six locations in Wudil. The fine aggregates used for this work were selected based on availability. Six samples were selected at various locations for this research, they include; Gangaren Ibro as (Sample A), Garindau Gidan Sarki as (Sample B), Kofar Yamma as (Sample C), Babalon as (Sample D), Gaban Komi as (Sample E) and Kogin Dafawa as (Sample F).

3.2. Material

3.2.1. Fine Aggregates

Fine aggregates are aggregates in which the particles are not larger than 5mm in size. Sand which is naturally occurring, water or wind-borne pieces of weathered work is the primary material employed as fine aggregates. Usually, fine aggregates make up approximately 50% of the total aggregates volume of concrete and hence its influence is extremely important on concrete properties. The specific gravities of the soil samples are between 2.60 to 2.70.

3.3. Methods

The tests carried out on fine aggregates include,

- Sieveanalys is and fineness modulus determination test
- Moisture content test
- Water absorption test
- Bulk density test
- Specific gravity test
- Porosity and void ratio test

These tests are described in details below;

3.3.1. Sieve Analysis Test

Sieve analysis is the determination of representative of distribution of the particle sizes in lump of aggregate. Sieves used for this work are the British Standard Sieves as prescribed by the (BS 410,1975).

The sieve analysis is the process of dividing a sample of aggregate into fractions of same particle size (A.M. Neville, 2010). Its purpose is to determine the grading or size distribution of the aggregate. A sample of air-dried aggregate is graded by shaking or vibrating a nest of stacked sieves, with the largest sieves at top, for a specified time so that the material retained on each sieve represents the fraction coarser than the sieve in question but finer than the sieve above.

3.3.1.1. Apparatus

- Set of BS Sieves (5mm,2.5mm,1.18mm,425µm,300µm,150µm,75µm, pan)
- Weighing Balance (accurately 0.1g)
- Electric Sieve Shaker.
- Iron Brush.

3.3.1.2. Procedure

- A dry sample of 1000g was taken from pile of fine aggregate
- The sample was weighted
- The test sieves were arranged
- The sieves were arranged according to size (descending)
- The sample was placed on top of the sieves
- The sieves were shaken satisfying that the aggregates have passed through the sieves
- The sieves were taken to the mechanical shaking machine and shaken for about 10 minutes
- The mass (weight) of aggregates that were retained on each sieves were weighted.

Coefficients of uniformity (C_u) and curvature (C_c) were found from the graph. Fineness modulus (FM) was also found. These were obtained from below;

$$C_u = \frac{D_{60}}{D_{10}} \quad (3.1)$$

$$C_c = \frac{(D_{30})^2}{D_{10} * D_{60}} \quad (3.2)$$

$$\text{Fineness Modulus (FM)} = \frac{\sum(\text{CummulativePercentageRetainedonSpecifiedSieves})}{100} \quad (3.3)$$

D_{10} =Diameter corresponding to 10% of the sample finer in weight on the grain size distribution curve.
D_{30} =Diameter corresponding to 30% of the sample finer in weight on the grain size distribution curve.
D_{60} =Diameter corresponding to 60% of the sample finer in weight on the gain size distribution curve.

3.3.2. Moisture Content Test (Mc)

Moisture content is the water in excess of the saturated and surface dry condition. Thus, the total moisture content of a moist aggregate is equal to the sum of absorption and moisture content.

The apparatus required are given below:

- Container
- Weighing Balance
- Oven

Moisture content = $\frac{X-Y}{Y}$ x 100% (3.4)

Where,

X = mass of sample (g)

Y = mass of oven-dry sample (g).

3.3.3. Water Absorption Test

Absorption is the moisture content of a saturated and surface-dry aggregate.

The apparatus required are given below,

- Container
- Weighing Balance (0.1g)
- Oven

3.3.3.1. Procedure

Absorption (%) = $\frac{A-B}{B}$ x 100% (3.5)

Where,

A = mass of saturated and surface-dry sample (g)

B = mass of oven-dry sample (g)

3.3.4. Bulk Density

Bulk density is the weight of a unit volume of a material and it is used to convert quantities by mass to quantities by volume. For this test, (BS 812, 2, 1975) recognizes two degrees of compaction: Loose (uncompacted) and Compacted. The apparatus for this test includes;

- Weighing Balance (accurate to 0.1g)
- Metal Cylindrical Container 300mm height, 150mm diameter and 2-4mm thickness
- A Straight Metal Tamping Rod 16mm in diameter, 60cm long.

Bulk density = $\frac{W}{V}$ (3.6)

W= weight of materials

V= volume of cylinder

3.3.4.1. Procedure (Loose) Astm C29, 2010

- The sample was poured into the metal container of a known volume, V
- Limit drop $< 5\text{cm above the rim of container}$
- Strike off aggregate level with top of container
- Determine weight of aggregate in container, W
- Compute bulk density using the above formula.

3.3.4.2. Procedure (Compacted) ASTM C29, 2010

- Pour the aggregate into metal container of known volume, V
- Fill to $^1/_3$ of volume
- Rod 25 times using tamping rod
- Repeat 3 times to fill container
- Strike off aggregate level with top of container
- Determine weight of aggregate in container, W
- Compute bulk density of aggregate using above formula.

3.3.5. Specific Gravity (Relative Density):

According to ASTM C 127-93, 2004 specific is gravity is defined as the ratio of mass (or weight) in air of a unit volume of material to the mass of equal volume of water at the stated temperature. The apparatus required are given below;

- A glass jar 1litre (300mm length glass type)
- Weighing Balance (accurate to 0.1g)
- Sealer
- Cover and rubber band

i. $G_s = \frac{M_2 - M_1}{(M_3 - M_1) - (M_4 - M_2)}$ (3.7)

Where,

m_1 = mass of empty cylinder (g)
m_2 = mass of cylinder plus sample (g)
m_3 = mass of cylinder and water (g)
m_4 = mass of cylinder, water and sample (g)

3.3.6. Void Ratio

Void ratio of an aggregate is the ratio of the volume of voids to the volume of solids. From the results obtained in sections 3.3.2 and 3.3.3 (Bulk density and Specific gravity), the void ratio of the samples can be obtained from the expression below;

Void ratio= $1- (\frac{Pu}{S.Gx\gamma w})$ (3.8)

Where,
P_u = Uncompacted Bulk Density kg/m^3
S.G = Specific Gravity
γ_{w} = unit weight of water 1000kg/m^3.

3.3.7. Porosity

Porosity is the ratio of the volume of voids to the total volume of the aggregates. This can be expressed as;

P= $1- (\frac{Pu}{Pc})$ x 100%(3.9)

Where;
P = Porosity (%)
P_u = Uncompacted (loose) Bulk density
P_c = Compacted Bulk density.

4. Results and Analysis

4.1. Results and Discussion

4.1.1. Result of Sieve Analysis (Sample A)

Sample A sieve analysis result shows that the fine aggregates belong to grading zone II which conformed with grading limits of fine aggregates in (BS 882, 2, 2004), From the grain size distribution curve in figure 1, C_u=2.36 and C_c = 0.88 this implies that the fine aggregate is uniformly graded since the coefficient of uniformity falls within the range of 1.0 – 5.0 which conform to the recommendation as specified by (BS 882,1,2004) and (BS 812,103,1985). The fineness modulus is 5.12 indicating a coarser grading (A.M Neville, 2010). The results are shown in appendix A1.

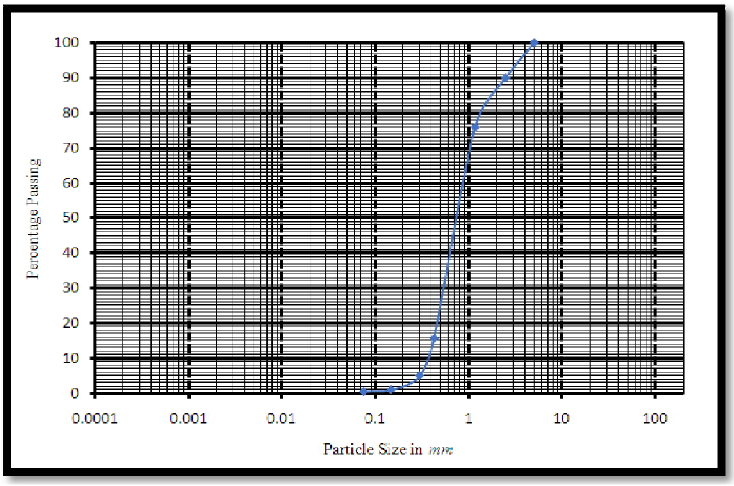

Figure 1: Grading Curve of Fine Aggregates (Sample A)

4.1.2. Result of Sieve Analysis (Sample B)

Sample B sieve analysis result shows that the fine aggregates belong to grading zone II which conformed with grading limits of fine aggregates in (BS 882,1, 2004). From the grain size distribution curve in figure 2, C_u = 2.31 and C_c =0.86, this implies that the fine aggregate is uniformly graded since the coefficient of uniformity falls within the range of 1.0 – 5.0 which conform to standard as specified by British standard (BS 882,2,2004) and (BS 812,103,1985). The fineness modulus is 5.15 indicating a coarser grading (A.M Neville, 2010). The results are shown in appendix A2.

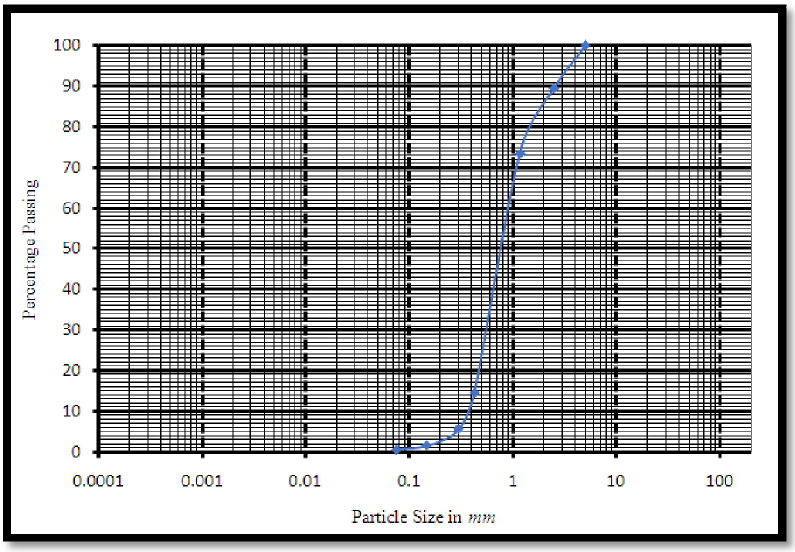

Figure 2: Grading Curve of Fine Aggregates (Sample B)

4.1.3. Result of Sieve Analysis (Sample C)

Sample C sieve analysis result shows that the fine aggregates belong to grading zone II which conformed with grading limits of fine aggregates in (BS 882,2,2004). From the grain size distribution curve in figure 3, C_u= 2.36 and C_c =0.88, this implies that the fine aggregate is uniformly graded since the coefficient of uniformity falls within the range of 1.0 – 5.0 which conform to the recommendations as specified by British (BS 882,1,2004) and (BS 812,103,1985). The fineness modulus is 5.14 indicating a coarser grading (A.M Neville, 2010). The results are shown in appendix A3.

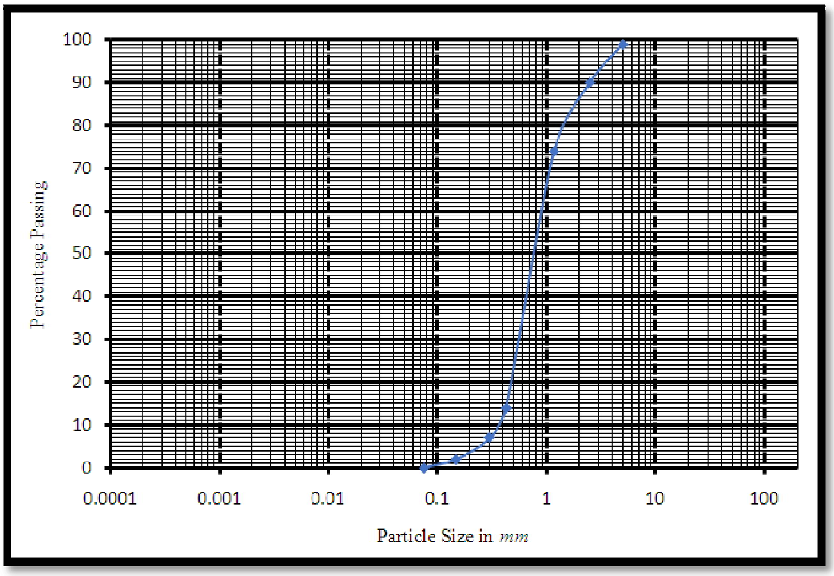

Figure 3: Grading Curve of Fine Aggregates (Sample C)

4.1.4. Result of Sieve Analysis (Sample D)

Sample D sieve analysis result shows that the fine aggregates belong to grading zone II which conformed with grading limits of fine aggregates in (BS 882,2,2004). From the grain size distribution curve in fig 4, C_u = 2.50 and C_c =0.90. This implies that the fine aggregates are uniformly graded since the coefficient of uniformity falls within the range of 1.0 – 5.0 which conform to the recommendation as specified (BS 882,1,2004) and (BS 812,103,1985). The fineness modulus is 5.18 indicating a coarser grading (A.M. Neville,2010). The results are shown in appendix A4.

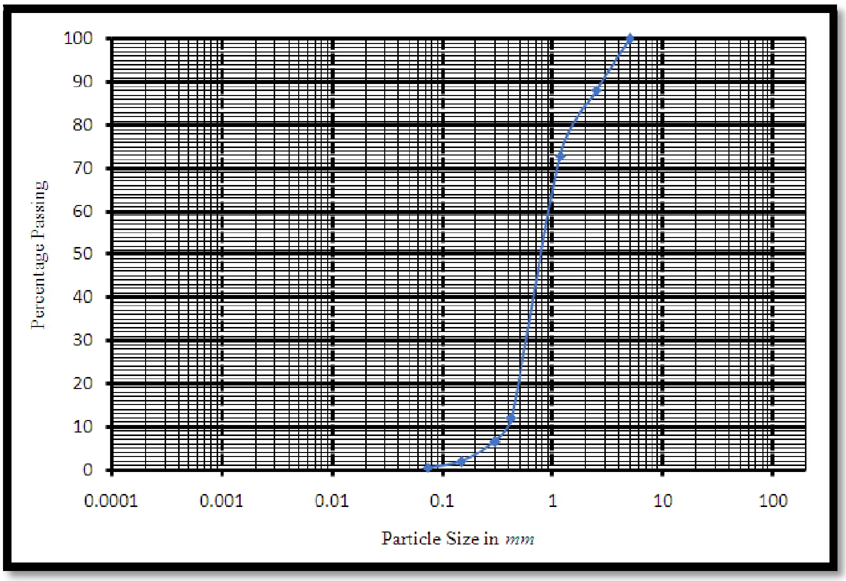

Figure 4: Grading Curve of Fine Aggregates (Sample D)

4.1.5. Result of Sieve Analysis (Sample E)

Sample E sieve analysis result shows that the fine aggregates belong to grading zone IV which conformed with grading limits of fine aggregates in (BS 882,2,2004). From the grain size distribution curve in fig 5, C_u = 3.11 and C_c =1.43, this implies that the fine aggregate is uniformly graded since the coefficient of uniformity falls within the range of 1.0 – 5.0 which conform to the recommendation as specified by (BS 882,1,2004) and (BS 812,103,1985). The fineness modulus is 3.27 indicating a finer grading (A.M Neville, 2010). The results are shown in appendix A5.

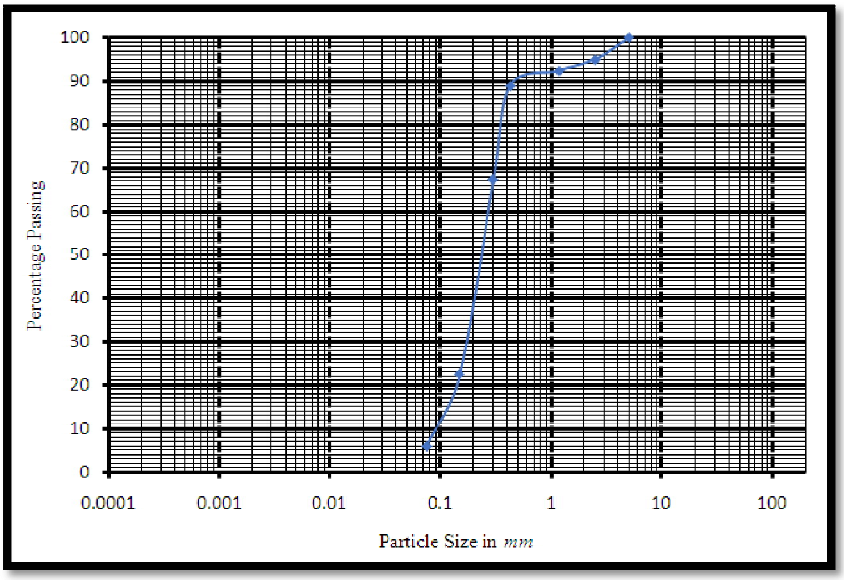

Figure 5: Grading Curve of Fine Aggregates (Sample E)

4.1.6. Result of Sieve Analysis (Sample F)

Sample E sieve analysis result shows that the fine aggregates belong to grading zone IV which conformed with grading limits of fine aggregates in (BS 882,2,2004). From the grain size distribution curve in fig 5, C_u = 2.67 and C_c =1.34, this implies that the fine aggregate is uniformly graded since the coefficient of uniformity falls within the range of 1.0 – 5.0 which conform to the recommendation as specified by (BS 882,1,2004) and (BS 812,103,1985). The fineness modulus (FM) is 3.06 indicating a finer grading (A.M Neville,2010). The results are shown in appendix A6.

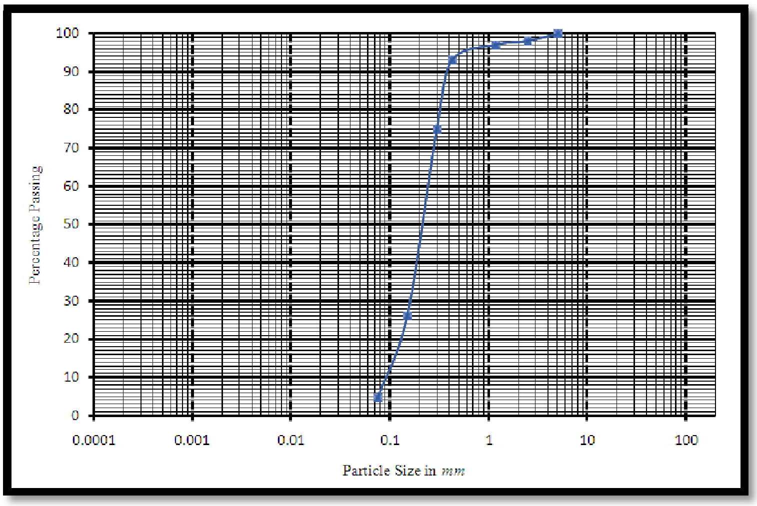

Figure 6: Grading Curve of Fine Aggregates (Sample F)

4.1.7. Moisture and Water Absorption

	Sample a	Sample b	Sample c	Sample d	Sample e	Sample f
Can No.	A_1 A_2 A_3	B_1 B_2 B_3	C_1 C_2 C_3	D_1 D_2 D_3	E_1 E_2 E_3	F_1 F_2 F_3
Wt of Can (g)	60 60 60	60 65 60	60 60 65	60 65 65	60 60 60	60 60 60
Wt of Can + Wet Sample (g)	160 165 164	155 150 155	140 130 135	145 145 150	130 125 125	125 120 120
Wt of Can + Dry Sample (g)	150 150 155	150 145 145	130 125 130	140 140 145	120 115 120	120 115 115
Wt of Dry Sample (g)= B	90 90 95	90 80 85	70 65 65	80 75 80	60 55 60	60 55 55
Wt of Wet Sample (g)=A	100 105 104	95 85 95	80 70 70	85 80 85	70 65 65	65 60 60
Absorption= (A-B)/Bx100	11.1 16.6 9.4	5.5 6.2 11.7	14.2 7.6 7.6	6.2 6.7 6.2	16.6 18.1 8.3	8.3 9.0 9.0
Average	12.36	7.8	9.8	6.36	14.33	8.76

Table 2: Moisture Content and Absorption of Fine Aggregate Samples

4.2. Bulk Density for Fine Aggregate (Sample A)

From the results, the compacted bulk density for sample A is higher than the loose bulk density. This is because the loose aggregates contain more voids within it. When the aggregates were compacted, some of the voids were replaced by more aggregates, thereby increasing the weight which eventually increased the bulk density. However, the ratio of uncompacted to compacted bulk density falls within the range of 0.61 – 0.87 (A.M. Neiville,1983) in standard ratio of loose bulk density to compacted bulk density.

Sample A	Un Compacted		Compacted	
	TEST 1	TEST2	TEST 1	TEST 2
Wt of Empty cylinder (W_1) (g)	625	625	625	625
Wt of cylinder and material (W_2) (g)	2765	2760	3705	3700
Wt of material only (W_3) (g)	2140	2135	3075	3075
Volume of cylinder (V) (m^3)	0.00176	0.00176	0.00176	0.00176
Bulk Density (W_3/V) Kg/m^3	1215.90	1213.06	1747.15	1747.15
Mean Bulk density Kg/m^3)	1214.48		1747.15	

Table 3: Bulk Density for Fine Aggregates (Sample A)

4.2.1. Bulk Density for Fine Aggregate (Sample B)

From the results, the compacted bulk density for fine aggregates indicated as sample B is higher than the loose bulk density, this is because the loose aggregates contain more voids within it. When the aggregates were compacted, some of the voids are replaced by more aggregate, thereby increasing the weight which eventually increased the bulk density. However, the ratio of uncompacted to compacted bulk density falls within the range of 0.61 – 0.87 (A.M. Neiville,1983) in standard ratio of loose bulk density to compacted bulk density. Table 4 shows the bulk density for fine aggregates denoted as sample B.

Sample B	**Un Compacted**		**Compacted**	
	TEST 1	**TEST2**	**TEST 1**	**TEST 2**
Wt of Empty cylinder (W_1) (g)	625	625	625	625
Wt of cylinder and material (W_2) (g)	2905	2900	3690	3700
Wt of material only (W_3) (g)	2280	2275	3065	3075
Volume of cylinder (V) (m^3)	0.00176	0.00176	0.00176	0.00176
Bulk Density (W_3/V) Kg/m^3	1295.45	1292.61	1741.47	1747.15
Mean Bulk density (Kg/m^3)	1294.03		1744.31	

Table 4: Bulk Density for Fine Aggregates (Sample B)

4.2.2. Bulk Density for Fine Aggregates (Sample C)

From the results, the compacted bulk density for sample C is higher than the loose bulk density; this is because the loose aggregates contain more voids within it. When the aggregates were compacted, some of the voids are replaced by more aggregate, thereby increasing the weight which eventually increased the bulk density. However, the ratio of uncompacted to compacted bulk density falls within the range of 0.61 – 0.87 (A.M. Neville, 1983) in standard ratio of loose bulk density to compacted bulk density. Table 4.6 shows the bulk density for fine aggregates denoted as sample C.

Sample c	**Uncompacted**		**Compacted**	
	TEST 1	**TEST2**	**TEST 1**	**TEST 2**
Wt of Empty cylinder (W_1) (g)	625	625	625	625
Wt of cylinder and material (W_2) (g)	2800	2805	3800	3795
Wt of material only (W_3) (g)	2175	2180	3175	3165
Volume of cylinder (V) (m^3)	0.00176	0.00176	0.00176	0.00176
Bulk Density (W_3/V) Kg/m^3	1235.79	1238.63	1803.97	1798.29
Mean Bulk density (Kg/m^3)	1237.71		1801.18	

Table 5: Bulk Density for Fine Aggregates (Sample C)

4.2.3. Bulk Density for Fine Aggregates (Sample D)

From the results, the compacted bulk density for sample D is higher than the loose bulk density; this is because the loose aggregates contain more voids within it. When the aggregates were compacted, some of the voids are replaced by more aggregate, thereby increasing the weight which eventually increased the bulk density. However, the ratio of uncompacted to compacted bulk density falls within the range of 0.61 – 0.87 (A.M. Neiville,1983) in standard ratio of loose bulk density to compacted bulk density. Table 6 shows the bulk density for fine aggregates denoted as sample D.

Sample d	**Uncompacted**		**Compacted**	
	TEST 1	**TEST2**	**TEST 1**	**TEST 2**
Wt of Empty cylinder (W_1) (g)	625	625	625	625
Wt of cylinder and material (W_2) (g)	2700	2700	3705	3700
Wt of material only (W_3) (g)	2075	2070	3080	3075
Volume of cylinder (V) (m^3)	0.00176	0.00176	0.00176	0.00176
Bulk Density (W_3/V) (Kg/m^3)	1178.97	1176.13	1750.00	1747.15
Mean Bulk density (Kg/m^3)	1177.55		1748.57	

Table 6: Bulk Density for Fine Aggregates (Sample D)

4.2.4. Bulk Density for Fine Aggregates (Sample E)

From the results, the compacted bulk density for sample E is higher than the loose bulk density; this is because the loose aggregates contain more voids within it. When the aggregates were compacted, some of the voids are replaced by more aggregate, thereby increasing the weight which eventually increased the bulk density. However, the ratio of uncompacted to compacted bulk density falls within the range of 0.61 – 0.87 (A.M. Neiville,1983) in standard ratio of loose bulk density to compacted bulk density. Table 4.8 shows the bulk density for fine aggregates denoted as sample E.

Sample E	Uncompacted		Compacted	
	TEST 1	TEST2	TEST 1	TEST 2
Wt of Empty cylinder (W_1) (g)	625	625	625	625
Wt of cylinder and material (W_2) (g)	2500	2550	3505	3600
Wt of material only (W_3) (g)	1875	1925	2880	2975
Volume of cylinder (V) (m^3)	0.00176	0.00176	0.00176	0.00176
Bulk Density (W_3/V) (Kg/m^3)	1065.34	1093.75	1636.36	1690.34
Mean Bulk density (Kg/m^3)	1079.54		1663.35	

Table 7: Bulk Density for Fine Aggregates (Sample E)

4.2.5. Bulk Density for Fine Aggregates (Sample F)

From the results, the compacted bulk density for sample F is higher than the loose bulk density; this is because the loose aggregates contain more voids within it. When the aggregates were compacted, some of the voids are replaced by more aggregate, thereby increasing the weight which eventually increased the bulk density. However, the ratio of uncompacted to compacted bulk density falls within the range of 0.61 – 0.87 (A.M. Neiville,1983) in standard ratio of loose bulk density to compacted bulk density. Table 4.8 shows the bulk density for fine aggregates denoted as sample F.

Sample e	Uncompacted		Compacted	
	TEST 1	TEST2	TEST 1	TEST 2
Wt of Empty cylinder (W_1) (g)	625	625	625	625
Wt of cylinder and material (W_2) (g)	2500	2500	3600	3550
Wt of material only (W_3) (g)	1875	1875	2975	2975
Volume of cylinder (V) (m^3)	0.00176	0.00176	0.00176	0.00176
Bulk Density (W_3/V) (Kg/m^3)	1065.34	1065.34	1690.34	1661.93
Mean Bulk density (Kg/m^3)	1065.34		1676.13	

Table 8: Bulk Density for Fine Aggregates (Sample F)

4.3. Specific Gravity of Fine Aggregate

The average specific gravity obtained for samples of fine aggregates are 2.64 and 2.66 respectively (BS 812,1, 2006). All the samples are normal weight aggregate as their specific gravities fall between $2.4 < G_s$ 2.8 (Fahim Al-Neshawy, 2000).

	Sample A		Sample B		Sample C		Sample D		Sample E		Sample F	
	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2
M_1	26.6	26.6	15.7	26.6	172.7	173.1	173.1	173.3	173.2	173.3	173.1	173.3
M_2	107.6	121.0	116.3	103.8	239.7	229.6	260.3	271.3	260.4	271.0	260.3	271.3
M_3	566.0	577.0	616.6	566.9	499.7	497.8	499.5	497.9	500.0	497.9	500.0	498.9
M_4	616.0	636.0	679.1	614.9	541.3	532.9	552.9	558.6	552.9	558.6	553.9	558.6
M_2-M_1 =A	81	94.4	100.6	77.2	67	56.5	87.2	98.1	87.2	97.7	87.2	98.0
M_3-M_1 =B	539.4	550.4	600.9	540.3	327	324.7	326.4	324.7	326.8	324.6	326.9	325.6
M_4-M_2 =C	508.4	515.0	562.8	511.1	301.6	303.3	292.6	287.3	292.5	287.6	293.6	287.3
B – C	31	35.4	38.1	29.2	25.4	21.4	33.8	37.3	34.3	47.0	33.3	38.3
G_S = A/B-C	2.61	2.67	2.64	2.64	2.64	2.64	2.58	2.62	2.54	2.64	2.64	2.55
Average	2.64		2.64		2.64		2.60		2.60		2.60	

Table 9: Specific Gravity of Fine Aggregate Samples

Where: M_1 = Mass of empty cylinder (g)
M_2 = Mass of cylinder + sample (g)
M_3 = Mass of cylinder and water (g)
M_4 = Mass of cylinder, water and sample (g)

4.4. Void Ratio of Fine Aggregate Samples

The void ratio of the fine aggregates was found to be between 0.51 and 0.60. This shows that the aggregates when compacted were packed more densely, this is due to the fact that they were dry and did not contain surface water, because surface water reduces how densely an aggregate may be packed due to bulking effect. Furthermore, sample F of fine aggregates has the highest value of void ratio (0.60). Table 4.3.1 shows the results for void ratios of the fine aggregate samples.

	Sample A	Sample B	Sample C	Sample D	Sample E	Sample F
P_u (Kg/ m^3) = A	1214.48	1294.03	1237.71	1177.55	1079.54	1065.34
G_s	2.64	2.64	2.64	2.60	2.60	2.60
$G_s\gamma w$ (Kg/ m^3) = B	2640.00	2640.00	2640.00	2600.00	2600.00	2600.00
A/ B	0.46	0.49	0.47	0.45	0.41	0.40
V.R= 1-(A/ B)	0.54	0.51	0.53	0.55	0.59	0.60

Table 10: Void Ratio of Granite and Fine Aggregate Samples

4.5. Porosity of Fine Aggregate Samples

The amount and rate of water penetration into an aggregate depends on the degree of its permeability. From the results of porosity, the porosity value ranges between 25.8% and 36.4% with sample F of fine aggregates being the most porous material due, largely to the voids between individual particles.

	Sample A	Sample B	Samplec	Sample D	Sample E	Sample F
P_u (Kg/ m^3)	1214.48	1294.93	1237.71	1177.55	1079.54	1065.34
P_c (Kg/ m^3)	1744.31	1744.31	1801.13	1748.57	1663.35	1676.13
P_u/ P_c	0.6951	0.7418	0.6871	0.6734	0.6490	0.6355
Porosity 1-(P_u/ P_c)	0.304	0.258	0.312	0.326	0.351	0.364
Porosity (%)	30.4	25.8	31.2	32.6	35.1	36.4

Table 11: Porosity of Fine Aggregate Samples

5. Conclusion and Recommendation

5.1. Conclusion

From the outcome of this work, the following conclusions are made:

- Fine aggregates samples A, B, C and D were characterized as a zone II materials while samples E and F were characterized as zone IV.
- The fineness modulus of samples A, B, C and D were far above 3.0 indicating a coarser grading while those of samples E and F indicated a finer grading.
- The average specific gravities of the soil samples were found to be between 2.60 to 2.64 respectively which fall within the range of 2.4 – 2.9 as specified by (BS 882 2004).
- The average compacted bulk densities are between 1663.35kg/m^3 to 1801.13kg/m^3 and uncompacted (Loose) bulk densities are between 1065.34 kg/m^3 to 1294.03 kg/m^3 for all the fine aggregate samples. The deviation from the standard is reasoned to be due to sample disturbance.

5.2. Recommendations

From the outcome of this research work, the properties of the fine aggregates samples assessed are adequate and recommended to be used for normal concrete production.

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Appendix

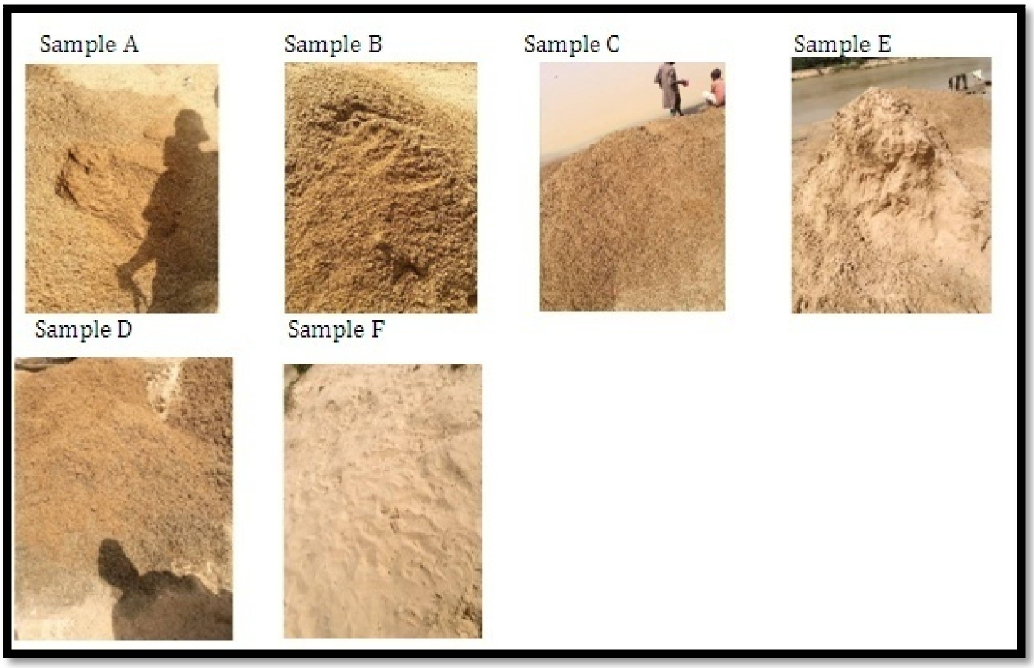

Figure 7