CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

Nigeria is a developing country; the construction industry is highly rising and Concrete is the most important construction material widely used for Sustainable development. The various source materials like river sand, quarry dust etc. are used along with the fresh and recycled aggregates for rural and urban small and high-rise buildings. For the purpose to make concrete a more sustainable construction material, efforts are being taken towards research on utilization of alternative recycled materials as whole or partial replacement of constituent materials in concrete. In Nigeria Sand and gravel represent the most widely consume draw material after water, and between 60-75% of aggregate mined each year is used for making concrete. Natural sand found in rivers and valleys has been commonly used as fine aggregate in concrete. Natural sand contains rounded or cubical particles with smooth surface texture which provide good workability in concrete, Sand consists around 35% volume in a concrete mix, the growing use of river sand as a raw material in production of concrete and other industrial applications indicates that depletion of deposits of natural sand is inevitable. Especially depletion in natural sand deposits, as well as the dredging and excavation processes used in obtaining natural fine aggregate, may cause negative environmental impact such as non-reversible landscape changes and threat to river ecosystems. Considering the environmental hazards associated with mining natural sand, concerned authorities in some areas have placed restrictions using measures such as legislation and taxation. A most suitable alternative to natural sand in production of concrete is quarry dust, a by-product of rock quarrying. Quarry dust generally has particle sizes in the range of 0.05-5 mm and forms around 20-25% of the total output of rock crushing. Considerable volumes of quarry dust are produced by rock quarrying industries which cause environmental problems. Only a small percentage of the quarry dust is used as filler in wearing courses of asphalt pavements. Use of quarry dust as an alternative to river sand in concrete can provide solutions to problems of waste management, environmental degradation, and depletion of natural resources.

Experiments have been performed on use of quarry dust as total or partial replacement of river sand in concrete. For 28 days of curing, partial replacement of fine aggregate with 20-50% quarry dust content resulted to optimum compressive strength of concrete for several mix ratios and water/cement ratios. Engineers have also used quarry dust as total replacement of sand in concrete. Quarry dust concrete for curing age of 28 days resulted higher compressive strength than river sand concrete. While a few studies showed lower compressive strength for quarry dust concrete in comparison with river sand concrete. Results on workability and density of quarry dust concrete are also different. This study compared the workability; density and compressive strength of quarry dust concrete with river sand concrete using the similar mix ratio and water/cement ratio, similar quantity and type of cement, water and coarse aggregate were used in this study.

1.2 STATEMENT OF PROBLEM

River sand, which is one of the constituents used in the production of conventional concrete, has become highly expensive and also scarce. In the backdrop of such a bleak atmosphere, there is large demand for alternative materials from industrial waste. The utilization of dust of quarry rock has been accepted as a building material.

1.3 AIM ANDOBJECTIVE OF STUDY

The aim of this project is to access the compressive strength of concrete made with river sand and quarry dust as fine aggregate on rigid pavement.

The objective of this study shows the compressive strength of concrete made with river sand and quarry dust as fine aggregate the concrete mix ratio will be batched by weight and volume. Water cement ratio for concrete will be obtain for the mix ratio selected for the experiment respectively and two separate group of concrete specimens will be prepared which will be cast on a concrete cube of size 150 x 150 x 150 mm and the concrete specimen will be cured for 7, 14, 21 and 28 days and this purpose slump, density and compressive strength test will be carried in order to the result of this work.

1.4 SIGNIFICANCE OF STUDY

Due to the increased level of construction in Nigeria, it is expected that fine aggregate suitable for use in concrete will become scarce or not economical to produce. However, there are some areas in Nigeria were river sand are scarce but such areas have quarry dust, so using quarry dust become affordable and economical to use.

As source of quality concrete aggregate become deplete, the use of more marginal aggregates will mean an increased used reactive aggregate in concrete. Quarry dust (solid waste) is considered a viable alternative to river sand in concrete. Crushed stone sand is a fine material formed during the process of conversion of rock into aggregate and has particle size ranging from 5mm to dust size (< 0.05mm). The crushed stone sand is a material of high quality, the fine particles and irregular shape of the crushed stone sand has harsh effects on the workability and finishability of concrete. These harsh effects have given crushed stone sand a poor reputation in the construction industry. However, recent studies have shown that this crushed stone sand can be used to produce concrete with higher compressive strengths “Bonavetti and others (1994)”, “celiket and others (1994)”.

1.5 SCOPE AND LIMITATION OF WORK

This project is limited to using river sand and quarry dust in making concrete and also the compressive strength of river sand and quarry dust are determined and their compressive strength is been compared.

CHAPTERTWO

LITERATURE REVIEW

2.1 CONCRETE DEFINITION AND HISTORICAL DEVELOPMENT

Concrete is a manmade building material that looks like stone. The word “concrete” is derived from the Latin *concretus*, meaning “to grow together.” Concrete is a composite material composed of coarse granular material (the aggregate or filler) embedded in a hard matrix of material (the cement or binder) that fills the space among the aggregate particles and glues them together.

Alternatively, we can say that concrete is a composite material that consists essentially of a binding medium in which are embedded particles or fragments of aggregates.

The simplest definition of concrete can be written as:

Concrete = filler + binder (1-1) Depending on what kind of binder is used, concrete can be named in different ways.

For instance, if a concrete in made with non-hydraulic cement, it is called non-hydraulic cement concrete; if a concrete made of hydraulic cement, it is called hydraulic cement concrete; if a concrete is made of asphalt, it is called asphalt concrete; if a concrete is made of polymer, it is called polymer concrete. Both non-hydraulic and hydraulic cement need water to mix in and react. They differ here in the ability to gain strength in water. Non-hydraulic cement cannot gain strength in water, while hydraulic cement does.

Non-hydraulic cement concretes are the oldest used in human history. As early as around 6500 BC, non-hydraulic cement concretes were used by the Syrians and spread through Egypt, the Middle East, Crete, Cyprus, and ancient Greece. However, it was the Romans who refined the mixture’s use. The non-hydraulic cements used at that time were gypsum and lime. The

Romans used a primal mix for their concrete. It consisted of small pieces of gravel and coarse sand mixed with hot lime and water, and sometimes even animal blood. The Romans were known to havemade wide usage of concrete for building roads. It is interesting to learn that they built some 5300miles of roads using concrete. Concrete is a very strong building material.

Historical evidence also points out that the Romans used pozzalana, animal fat, milk, and blood as admixtures for building concrete. To trim down shrinkage, they were known to have used horsehair. Historical evidence shows that the Assyrians and Babylonians used clay as the bonding material. Lime was obtained by claiming limestone with a reaction of

$CaCO_3$ 1000 °C $CaO + CO_2$

When CaO is mixed with water, it can react with water to form

$CaO + H_2O$ ambient temperature $Ca(OH)_2$ and is then further reacted with CO_2 to form limestone again: $Ca(OH)_3$+ CO_2+ H_2O ambient temperature$CaCO_3$+ $2H_2O$

The Egyptians used gypsum mortar in construction, and the gypsum was obtained by calcining impure gypsum with a reaction of $2CaSO_4{\cdot}H_2O$ 107−130◦C$2CaSO_4{\cdot}H_2O + 3H_2O$

When mixed with water, half-water gypsum could turn into two-water gypsum and gain strength: $2CaSO_4{\cdot}1/2H_2O + 3H_2O$ambient temperature $2CaSO_4{\cdot}1/2H_2O$

The Chinese also used lime mortar to build the Great Wall in the Qin dynasty (220 BC).A hydraulic lime was developed by the Greeks and Romans using limestone containing argillaceous (clayey) impurities. The Greeks even used volcanic ash from the island of Santorin, while the Romans utilized volcanic ash from the Bay of Naples to mix with lime to produce hydraulic lime. It was found that mortar made of such hydraulic lime could resist water. Thus, hydraulic lime mortars were used extensively for hydraulic structures from second half of the first century B.C to the second century AD However, the quality of cementing materials decline throughout the middle Ages. The art of burning lime was almost lost and siliceous impurities were not added. High-quality mortars disappeared for a long period. In 1756, John Smeaton was commissioned to rebuild the Eddystone Light house off the coast of Cornwall, England. Realizing the function of siliceous impurities in resisting water, Smeaton conducted extensive experiments with different limes and pozzolans, and found that limestone with a high proportion of clayey materials produced the best hydraulic lime for mortar to be used in water. Eventually,Smeaton used a mortar prepared from a hydraulic lime mixed with pozzolan imported from Italy. He made concrete by mixing coarse aggregate (pebbles) and powdered brick and mixed it with cement, very close to the proportions of modern concrete. The rebuiltEddystone Lighthouse lasted for 126 years until it was replaced with a modern structure. After Smeaton's work, development of hydraulic cement proceeded quickly James Parker of England filed a patent in 1796 for a natural hydraulic cement made by calcining nodules of impure limestone containing clay. Vicat of France produced artificial hydraulic lime by calcining synthetic mixtures of limestone and clay. Portland cement was invented by Joseph Aspdin of England. The name Portland was coined by Aspdin because the color of the cement after hydration was similar to that of limestone quarried in Portland, a town in southern England.

Portland cement was prepared by calcining finely ground limestone, mixing it with finely divided clay, and calcining the mixture again in a kiln until the CO_2 was driven off. This mixture was then finely ground and used as cement. However, the temperature claimed in Aspdin's invention was not high enough to produce true Portland cement. It was Isaac Johnson who first burned the raw materials to the clinkering temperature in 1845 to produce modern Portland cement. After that, the application of Portland cement spread quickly throughout Europe and North America.

The main application of Portland cement is to make concrete. It was in Germany that the first systematic testing of concrete took place in 1836. The test measured the tensile and compressive strength of concrete. Aggregates are another main ingredient of concrete, and which include sand, crushed stone, clay, gravel, slag, and shale. Plain concrete made of Portland cement and aggregate is usually called the first generation of concrete. The second generation of concrete refers to steel bar-reinforced concrete FranchCoignet was a pioneer in the development of reinforced concrete. (Day and was the first builder ever to use this technique as a building material (Encyclopedia Britannica, 1991). He decided, as a publicity stunt and to promote his cement business, to build a house made of *b´etonarm´e*, a type of reinforced concrete. In 1853, he built the first iron-reinforced concrete structure anywhere; a four-story house at 72 Rue Charles Michels (Sutherland et al.,2001). This location was near his family cement plant in St. Denis, a commune in the northern suburbs of Paris. The house was designed by local architect Theodore Lachez (Collins, 2004).Coignet had an exhibit at the 1855 Paris Exposition to show his technique of reinforced concrete. At the exhibit, he forecast that the technique would replace stone as a means of construction. In 1856 he patented a technique of reinforced concrete using iron tyrants. In 1861, he put out a publication on his techniques.

Reinforced concrete was further developed by Hennebiqueat the end of the 19th century, and it was realized that performance could be improved if the bars could be placed in tension, thus keeping the concrete in compression. Early attempts worked, with the beams showing a reduced tendency to crack in tension, but after a few months the cracks reopened. A good description of this early work is given in Leonhardt (1964). The first reinforced concrete bridge was built in 1889 in the Golden Gate Park in San Francisco, California.

To overcome the cracking problem in reinforced concrete, pre-stressed concrete was developed and was first patented by a San Francisco engineer as early as 1886. Pre-stressed means that the stress is generated in a structural member before it carries the service load. Pre-stress concrete was referred to as the third generation of concrete. Pre-stressing is usually generated by the stretched reinforcing steel in a structural member. According to the sequence of concrete casting, pre-stressing can be classified as pre-tensioning or post-tensioning. Pre-tensioning pulls the reinforcing steel before casting the concrete and pre-stress is added through the bond built up between the stretched reinforcing steel and the hardened concrete. In the post-tensioning technique, the reinforcing steel or tendon is stretched after concrete casting and the gaining of sufficient strength. In post-tensioning, steel tendons are positioned in the concrete specimen through preserved holes. The pre-stress is added to the member through the end anchorage.

Pre-stressed concrete became an accepted building material in Europe after World War II, partly due to the Lane Memorial Bridge in Philadelphia, Pennsylvania, was completed in 1951. Nowadays, with the development of pre-stressed concrete, long-span bridges, tall buildings, and ocean structures have been constructed. The Barrios de Lura Bridge in Spain is currently the longest-span pre-stressed concrete, cable-stayed bridge in the world, with a main span of 440 m. In Canada, the pre-stressed Toronto CN tower reaches a height of 553 m. shortage of steel. North America’s first pre-stressed concrete strucLane Memorial Bridge in Philadelphia, Pennsylvania, was completed in 1951.

As a structural material, the compressive strength at an age of 28 days is the main design index for concrete. There are several reasons for choosing compressive strength as the representative index. First, concrete is used in a structure mainly to resist the compression force. Second, the measurement of compressive strength is relatively easier. Finally, it is thought that other properties of concrete can be related to its compressive strength through the microstructure. Pursuing high compressive strength has been an important direction of concrete development. As early as1918, Duff Adams found that the compressive strength of a concrete was inversely proportional to the water-to-cement ratio. Hence, a high compressive strength could be achieved by reducing the*w*/*c* ratio. However, to keep a concrete workable, there is a minimum requirement on the amount of water; hence, the *w*/*c* ratio reduction is limited, unless other measures are provided to improve concrete's workability. For this reason, progress in achieving high compressive strength was very slow before the 1960s. At that time, concrete with a compressive strength of 30 MPa was regarded as high-strength concrete. Since the 1960s, the development of high-strength concrete has made significant progress due to two main factors: the invention of water-reducing admixtures and the incorporation of mineral admixtures, such as silica fume, fly ash, and slag.

Water-reducing admixture is a chemical admixture that can help concrete keep good workability under a very low *w*/*c* ratio; the latter are finer mineral particles that can react with a hydration product in concrete, calcium hydroxide, to make concrete microstructure denser. Silica fume also has a packing effect to further improve the matrix density. In 1972, the first 52-MPa concrete was produced in Chicago for the 52-story Mid-Continental Plaza. In 1972, a 62-MPa concrete was produced, also in Chicago, for Water Tower Place, a 74-story concrete building, the tallest in the world at that time .In the 1980s, the industry was able to produce a 95-MPa concrete to supply to the 225 West Whacker Drive building project in Chicago. The highest compressive strength of 130 MPa was realized in a 220-m-high, 58-story building, the Union Plaza constructed in Seattle, Washington (Caldarone, 2009).

Concrete produced after the 1980s usually contains a sufficient amount of fly ash, slag, or silica fume as well as many different chemical admixtures, so its hydration mechanism, hydration products, and other microstructure characteristics are very different from the concrete produced without these admixtures. Moreover, the mechanical properties are also different from the conventional concrete; hence, such concretes are referred to as contemporary concretes.

There have been two innovative developments in contemporary concrete: self-compacting concrete (SCC) and ultra-high-performance concrete (UHPC). SCC is a type of high-performance concrete. High-performance concrete is a concept developed in the 1980s. It is defined as a concrete that can meet special performance and uniformity requirements, which cannot always be achieved routinely by using only conventional materials and normal mixing, placing, and curing practices. The requirements may involve enhancement of the characteristics of concrete, such as placement and compaction without segregation, long-term mechanical properties, higher early-age strength, better toughness, higher volume stability, or longer service life in severe environments.

Self-compacting concrete is a typical example of high-performance concrete that can fill in formwork in a compacted manner without the need of mechanical vibration. SCC was initially developed by Professor Okamura and his students in Japan in the late 1980s “Ozama and others (1989)”. At that time, concrete construction was blooming everywhere in Japan. Since Japan is in an earthquake zone, concrete structures are usually heavily reinforced, especially at beam–column joints. Hence, due to low flow ability, conventional concrete could hardly flow past the heavy Rein forced rebar’s, leaving poor-quality cast concrete and leading to poor durability. Sometimes, the reinforcing steel was exposed to air immediately after demolding. To solve the problem, Professor Okamura and his students conducted research to develop a concrete with high flowability. With the help of the invention of the high-range water reducer or plasticizer, such a concrete was finally developed. They were so excited that they called this concrete “high-performance concrete” at the beginning. It was corrected later on to SCC, as HPC covers broader meanings.

Durability is a main requirement of HPC. It has been found that many concrete structures could not fulfill the service requirement, due not to lack of strength, but to lack of durability. For this reason, concrete with high performance to meet the requirement of prolonging concrete service life was greatly needed.

In the 1990s, a new “concrete” with a compressive concrete strength higher than 200MPa was developed in France. Due to the large amount of silica fume incorporated in such a material, it was initially called reactive powder concrete and later on changed to ultra-high-strength (performance) concrete (UHSC), due to its extremely high compressive strength “Richard and Cheyrezy, (1995)”. The ultra-high-strength concrete has reached a compressive strength of 800MPa with heating treatment. However, it is very brittle, hence, incorporating fibers into UHSC is necessary.

After incorporating fine steel fibers, flexural strength of 50 MPa can be reached. The first trial application of UHSC was a footbridge built in Sherbrooke, Canada “Aitcin and others (1998)”.

2.2 CONCRETE AS A STRUCTURAL MATERIAL

The term concrete usually refers to Portland cement concrete, if not otherwise specified. For this kind of concrete, the compositions can be listed as follows:

Portland cement

+ Water (& admixtures) →cement **paste**

+ Fine aggregate →**mortar**

+ Coarse aggregate →**concrete**

Here we should indicate that admixtures are almost always used in modern practice and thus have become an essential component of contemporary concrete. Admixtures are defined as materials other than aggregate (fine and coarse), water, and cement that are added into a concrete batch immediately before or during mixing. The use of admixtures is widespread mainly because many benefits can be achieved by their application. For instance, chemical admixtures can modify the setting and hardening characteristics of cement paste by influencing the rate of cement hydration. Water-reducing admixtures can plasticize fresh concrete mixtures by reducing surface tension of the water. Air-entraining admixtures can improve the durability of concrete, and mineral admixtures such as pozzolans (materials containing reactive silica) can reduce thermal cracking.

Concrete is the most widely used construction material in the world, and its popularity can be attributed to two aspects. First, concrete is used for many different structures, such as dams, pavements, building frames, or bridges, much more than any other construction material. Second, the amount of concrete used is much more than any other material. Its worldwide production exceeds that of steel by a factor of 10 in tonnage and by more than a factor of 30 in volume.

In a concrete structure, there are two commonly used structural materials: concrete and steel. A structural material is a material that carries not only its self-weight, but also the load passing from other members.

Steel is manufactured under carefully controlled conditions, always in a highly sophisticated plant; the properties of every type of steel are determined in a laboratory and described in a manufacturer's certificate. Thus, the designer of a steel structure need only specify the steel complying with a relevant standard, and the constructor needs only to ensure that the correct steel is used and that connections between the individual steel members are properly executed (Neville and Brooks, 1993).

On the other hand, concrete is produced in a cruder way and its quality varies considerably. Even the quality of cement, the binder of concrete, is guaranteed by the manufacturer in a manner similar to that of steel; however, the quality of concrete is hardly guaranteed because of many other factors, such as aggregates, mixing procedures, and skills of the operators of concrete production, placement, and consolidation. It is possible to obtain concrete of specified quality from a ready-mix supplier, but, even in this case, it is only the raw materials that are bought for a construction job. Transporting, placing, and, above all, compacting greatly influence the quality of cast concrete structure. Moreover, unlike the case of steel, the choice of concrete mixes is virtually infinite and therefore the selection has to be made with a sound knowledge of the properties and behavior of concrete.

It is thus the competence of the designer and specifies that determines the potential qualities of concrete, and the competence of the supplier and the contractor that controls the actual quality of concrete in the finished structure. It follows that they must be thoroughly conversant with the properties of concrete and with concrete making and placing.

In a concrete structure, concretes mainly carry the compressive force and shear force, while the steel carries the tension force. Moreover, concrete usually provides stiffness for structures to keep them stable.

Concretes have been widely used to build various structures. High-strength concrete has been used in many tall building constructions. In Hong Kong, grade 80 concrete (80MPa) was utilized in the columns of the tallest building in the region. International Finance Centre was built in 2003 and stands 415m (1362 ft) tall. Concrete has also been used in bridge construction. Sutong Bridge that spans the Yangtze River in China between Nantong and Changshu, a satellite city of Suzhou, in Jiangsu province. It is a cable-stayed bridge with the longest main span, 1088 meters, in the world. Its two side spans are 300m (984 ft) each, and there are also four small cable spans.

Dams are other popular application fields for concrete. The first major concrete dams, the Hoover Dam and the Grand Coulee Dam, were built in the 1930s and they are still standing. The largest dam ever built is the Three Gorges Dam in Hubei province, China. The total concrete used for the dam was over 22 million m3. Concrete has also been used to build high-speed railways. Shinkansen, the world's first contemporary high-volume (initially 12-car maximum), "high-speed rail," was built in Japan in 1964. In Europe, high-speed rail was introduced during the International Transport Fair in Munich in June 1965. Nowadays, high-speed rail construction is blooming in China. According to planning, 17,000 km of high-speed rail will be built in China by 2012.

In addition, concrete has been widely applied in the construction of airport runways, tunnels, highways, pipelines, and oil platforms. As of now, the annual world consumption of concrete has reached values such that if concrete wereedible; every person on earth would have 2000 kg per year to "eat." You may wonder why concrete has become so popular.

The consumption of cement content, workability, compressive strength and cost of concrete made with Quarry Rock Dust were studied by researchers “Babu K.K Nagaraj T.S. and others (1778)”. The mix design proposed by “Nagaraj and others (1978)”. Shows the possibilities of ensuring the workability by wise combination of rock dust and sand, use of super plasticizer and optimum water content using generalized lyse Rule. “Sahu A.K and others (2003)”. Reported significant increase in compressive strength, modulus of rupture and split tensile strength when 40 percent of sand is replaced by Quarry Rock Dust in concrete. Ilangovan and Nagamani reported that Natural Sand with Quarry Dust as full replacement in concrete as possible with proper treatment of Quarry Dust before utilization

2.3 CHARACTERISTICS OF CONCRETE

Advantages of concrete

(a) ***Economical*:** Concrete is the most inexpensive and the most readily available material in the world. The cost of production of concrete is low compared with other engineered construction materials. The three major components in concrete are water, aggregate, and cement. Compared with steels, plastics, and polymers, these components are the most inexpensive, and are available in every corner of the world. This enables concrete to be produced worldwide at very low cost for local markets, thus avoiding the transport expenses necessary for most other materials.

(b*)* ***Strength:*** Because cement is a low-temperature bonded inorganic material and its reaction occurs at room temperature, concrete can gain its strength at ambient temperature. No high temperature is needed.

(c) ***Ability to be cast***: Fresh concrete is flowable like a liquid and hence can be poured into various formworks to form different desired shapes and sizes right on a construction site.

Hence, concrete can be cast into many different configurations. One good example to show concrete stability is the Baha'I Temple located in Wilmette, Illinois, USA. The very complex configurations of the different shapes of flowers in the wall and roof are all cast by concrete.

(d) ***Energy efficient*****:** Compared with steel, the energy consumption of concrete production is low. The energy required to produce plain concrete is only 450–750 kWh/ton and that of reinforced concrete is 800–3200 kWh/ton, while structural steel requires 8000 kWh/ton or more to make.

(e) ***Excellent resistance to water***: Unlike wood (timber) and steel, concrete can be hardened in water and can withstand the action of water without serious deterioration, which makes concrete an ideal material for building structures to control, store, and transport water, such as pipelines, dams, and submarine structures. A typical example of a pipeline application is the Central Arizona Project, which provides water from the Colorado riverto central Arizona. The system contains 1560 pipe sections, each 6.7m long, 7.5m outside diameter, and 6.4m inside diameter. Contrary to popular belief, water is not deleterious to concrete, even to reinforced concrete; it is the chemicals dissolved in water, such as chlorides, sulfates, and carbon dioxide that cause deterioration of concrete structures.

(f) ***High-temperature resistance*****:** Concrete conducts heat slowly and is able to store considerable quantities of heat from the environment. Moreover, the main hydrate that provides binding to wood and steel. Even in a fire, a concrete structure can withstand heat for 2–6 hours, leaving sufficient time for people to be rescued. This is why concrete is frequently used to build up protective layers for a steel structure.

(g) ***Ability to consume waste***: With the development of industry, more and more by-products or waste has been generated, causing a serious environmental pollution problem. To solve the problem, people have to find a way to consume such wastes. It has been found that many industrial wastes can be recycled as a substitute (replacement) for cement or aggregate, such as fly ash, slag (GGBFS = ground granulated blast-furnaces slag), waste glass, and ground vehicle tires in concrete. Production of concrete with the incorporation of industrial waste not only provides an effective way to protect our environment, but also leads to better performance of a concrete structure. Due to the large amount of concrete produced annually, it is possible to completely consume most of industry waste in the world, provided that suitable techniques for individual waste incorporation are available.

(h) ***Ability to work with reinforcing steel*****:** Concrete has a similar value to steel for the coefficient of thermal expansion (steel 1.2×10^{-5}; concrete $1.0–1.5 \times 10^{-5}$). Concrete produces a good protection to steel due to existence of CH and other alkalis (this is for normal conditions). Therefore, while steel bars provide the necessary tensile strength, concrete provides a perfect environment for the steel, acting as a physical barrier to the ingress of aggressive species and giving chemical protection in a highly alkaline environment (Phvalue is about 13.5), in which black steel is readily passivity.

(i) ***Less maintenance required*****:** Under normal conditions, concrete structures do not need coating or painting as protection for weathering, while for a steel or wooden structure, it is necessary. Moreover, the coatings and paintings have to be replaced few years. Thus, the maintenance cost for concrete structures is much lower than that for steel or wooden structures.

2.4 TYPES OF CONCRETE

Classification in accordance with unit weight

According to the unit weight of concretes, they can be classified into four categories, as shown in Table 1.1. Ultra-lightweight concrete can only be used to build up nonstructural members.

Lightweight concrete can be used to build both nonstructural and structural members, depending on its specified composition. Normal-weight concretes are commonly used concretes.

Table 1.1 Classification of concrete in accordance with unit weight

Classification	**Unit Weight (Kg/m^3)**
Ultra-lightweight concrete	<1200
Lightweight concrete	1200 < UW < 1800
Normal-weight concrete	~2400
Heavyweight concrete	>3200

Heavyweight concrete is used to build some special structures, such as laboratories, hospital examination rooms, and nuclear plant, where radioactive protection is needed to minimize its influence on people's health. The main component that makes a concrete unit weight difference is the aggregate.

Classification in accordance with compressive strength

According to its compressive strength, concrete can be classified into four categories, as listed in Table 1-2. Low-strength concrete is mainly used to construct mass concrete structures, sub-grades of roads, and partitions. Moderate-strength concretes are the most commonly used concretes in buildings, bridges, and similar structures. High-strength concretes can be used to build tall building columns, bridge towers, and shear walls. Ultra-high-strength concretes have not yet been widely used in structural constructions. Only a few footbridges and some structural segments, such as girders, have been built using such concrete

Table 1.2 Concrete classified in accordance with compressive Strength

Classification	**Compressive Strength (MPa)**
Low-strength concrete	<20
Moderate-strength concrete	20–50
Ultra-high-strength concrete	>150

2.5 FACTORS INFLUENCING CONCRETE PROPERTIES

1. *w/c* ratio (or *w/b* or *w/p* ratio)

One property of concrete is the water/cement ratio. In contemporary concrete, *w*/*c* is frequently replaced with *w*/*b* (water/binder) or *w*/*p* (water/powder), since Portland cement is not the only binding material in such a concrete. The *w*/*c* or *w*/*b* ratio is one of the most important factors influencing concrete properties, such as compressive strength, permeability, and diffusivity. A lower *w*/*c* ratio will lead to a stronger and more durable concrete. The influence of *w*/*c* on the concrete compressive strength has been known since the early 1900s (Abrams, 1927), leading to Abrams's law:

fc =A..(2.1)

Where

fc is the compressive strength, *A* is an empirical constant (usually 97 MPa or 14,000 psi), and A is a constant that depends mostly on the cement properties. It can be seen from the formula that the higher the *w*/*c* ratio, the lower the compressive strength. Another form to show the influence of the *w*/*c* ratio to compressive strength of a concrete can be written as

$fc = Afce\ (w/c)$ ……………………………………………………….2.2

Where *f*c is the compressive strength, *A*is the empirical constants that depend on the aggregate and *f*ce is the compressive strength of specified cement at 28 days. *c/w* is the reverse of *w/c*.

2.6 CEMENT CONTENT

When water is added a concrete mix, cement paste will be formed. Cement paste has three functions in concrete: binding, coating, and lubricating. Cement paste provides binding to individual aggregates, reinforcing bars, and fibers and glues them together to form a unique material.

Cement paste also coats the surface of the aggregates and fibers during the fresh stage of concrete. The rest of the paste after coating can make the movement of the aggregates or fibers easier, rather like a lubrication agent. The cement content influences concrete workabilities in the fresh stage, heat release rate in the fast hydration stage, and volume stabilities in the hardened stage. The range of the amount of cement content in mass concrete is 160–200 kg/m3, in normal strength concrete it is less than 400 kg/m3, and in high strength concrete it is 400–600 kg/m3.

2.7 MANUFACTURED FINE AGGREGATES

Manufactured fine aggregate (MFA) is a process-controlled, crushed aggregate produced from quarried stone by crushing or grinding and classification to obtain a controlled gradation product that completely passes the 3/8-in. (9.5-mm) sieve. Due to variations in the rock type and crushing process the physical characteristics of the MFA, such as gradation, shape, dust-of-fracture content and texture, can change significantly and influence the performance of concrete. MFA is also referred to as stone sand, crusher sand, crushed fine aggregate, specification sand or manufactured sand.

Dust-of-Fracture

The dust-of-fracture is the by-product of the deliberate fracturing of rock for aggregate production. As the shape of the MFA becomes more spherical, the corners of the aggregates are removed creating the dust, which typically passes the No. 200 sieve (75mm). The content of dust-of fracture in MFA is due to the crushing process and can be expected to exceed 10% without having a detrimental effect on most concrete (Hudson, 1997). Without harmful materials such as clay, shale, coal, lignite or other impurities the dust should be considered clean and acceptable for use in concrete.

2.8 CHARACTERISTICS OF MANUFACTURED FINE AGGREGATES

The characterization of fine aggregates for concrete is important due to the new performance requirements from increasingly technical placement methods.
Fine aggregate that prevents segregation is easy to finish and provides equal hardened properties that are desirable for high volume applications.

Particle Shape

Particle shape, roundness, and sphericity are not usually determined for natural sands. The particle shape is influenced by the physical properties of the parent rock and by the method of production “McKeagney, (1984)”. The workability, flow, yield, air content, water requirement, bleeding and finishability of concrete are all influenced by the particle shape of the fine aggregate in the mortar. Crushed aggregates contain more angular particles with rougher surface textures and flatter faces than natural sands that are more rounded as a result of weathering experienced over time.

Researchers have become interested in quantifying particle shape as a way to explain variations in mixing water requirements and compressive strength for identically proportioned mixtures. In the 1960s, Wills (Wills, 1967) investigated the effects of both fine and coarse aggregate on water demand in concrete. The fine aggregate was found to have a more significant impact on water demand than the coarse aggregate.

2.9 HISTORY OF THE ORIGIN OF CEMENT

Early uses

An early version of cement made by lime, sand, and gravel was used in Mesopotamia in the third millennium B.C. and later in Egypt. It is uncertain where it was first discovered that a combination of hydrated non-hydraulic lime and a pozzolan produces a hydraulic mixture (see also: Pozzolanic reaction), but concrete made from such mixtures was first used by the Ancient Macedonian sand three centuries later on a large scale by Roman engineers .They used both natural pozzolans (trass or pumice) and artificial pozzolans (ground brick or pottery) in these concretes. Many excellent examples of structures made from these concretes are still standing, notably the huge dome of the Pantheon in Rome and the massive Baths of Caracalla. The vast system of Roman aqueducts also made extensive use of hydraulic cement.

Although any preservation of this knowledge in literary sources from the Middle Ages is unknown, medieval masons and some military engineers maintained an active tradition of using hydraulic cement in structures such as canals, fortresses, harbors, and shipbuilding facilities. The technical knowledge of making hydraulic cement was later formalized by French and British engineers in the 18th century.

Modern cements

Modern hydraulic cements began to be developed from the start of the Industrial Revolution (around 1800), driven by three main needs:

- Hydraulic cement render (stucco) for finishing brick buildings in wet climates.
- Hydraulic mortars for masonry construction of harbor works, etc., in contact with sea water.
- Development of strong concretes.

In Britain particularly, good quality building stone became ever more expensive during a period of rapid growth, and it became a common practice to construct prestige buildings from the new industrial bricks, and to finish them with a stucco to imitate stone. Hydraulic limes were favored for this, but the need for a fast set time encouraged the development of new cements. Most famous was Parker's "Roman cement this was developed by James Parker in the 1780s, and finally patented in 1796. It was, in fact, nothing like any material used by the Romans, but was “Natural cement" made by burning septaria – nodules that are found in certain clay deposits, and that contain both clay minerals and calcium carbonate. The burnt nodules were ground to a fine powder. This product, made into a mortar with sand, set in 5–15 minutes. The success of "Roman Cement" led other manufacturers to develop rival products by burning artificial mixtures of clay and chalk.

John Smeaton made an important contribution to the development of cements when he was planning the construction of the third Eddystone Lighthouse (1755–9) in the English

Channel. He needed a hydraulic mortar that would set and develop some strength in the twelve-hour period between successive high tides. He performed an exhaustive market research on the available hydraulic limes, visiting their production sites, and noted that the "hydraulicity" of the lime was directly related to the clay content of the limestone from which it was made. Smeaton was a civil engineer by profession, and took the idea no further. Apparently unaware of Smeaton's work, the same principle was identified by Louis Vicat in the first decade of the nineteenth century. Vicat went on to devise a method of combining chalk and clay into an intimate mixture, and, burning this, produced “artificial cement" in 1817.James Frost working in Britain, produced what he called "British cement" in a similar manner around the same time, but did not obtain a patent until 1822. In 1824, Joseph Aspdin patented a similar material, which he called Portland cement, because the render made from it was in color similar to the prestigious Portland stone. Setting time and "early strength" are important characteristics of cements. Hydraulic limes, "natural" cements, and "artificial" cements all rely upon their belite content for strength development. Belite develops strength slowly. Because they were burned at temperatures below 1250 °C, they contained no alite, which is responsible for early strength in modern cements. The first cement to consistently contain a lite was made by Joseph Aspdin's son William in the early 1840s. This was what we call today "modern" Portland cement. Because of the air of mystery with which William Aspdin surrounded his product, others (*e.g.*,Vicat and I.C. Johnson) have claimed precedence in this invention, but recent analysis of both his concrete and raw cement have shown that William Aspdin's product made at Northfleet,Kent was a true alite-based cement. However, Aspdin's methods were "rule-of-thumb": Vicat is responsible for establishing the chemical basis of these cements, and Johnson established the importance of sintering the mix in the kiln.

William Aspdin's innovation was counterintuitive for manufacturers of "artificial cements", because they required more lime in the mix (a problem for his father), a much higher kiln temperature (and therefore more fuel), and the resulting clinker was very hard and rapidly wore down the millstones, which were the only available grinding technology of the time. Manufacturing costs were therefore considerably higher, but the product set reasonably slowly and developed strength quickly, thus opening up a market for use in concrete. The use of concrete in construction grew rapidly from 1850 onward, and was soon the dominant use for cements. Thus, Portland cement began its predominant role.

In the US the first large scale use of cement was Rosendale cement natural cement mined from a massive deposit of a large dolstone rock deposit discovered in the early 19th century near Rosendale New York. Rosendale cement was extremely popular for the foundation of buildings (*e.g.*, Statue of Liberty, Capitol Building, Brooklyn Bridge) and lining water pipes. But its long curing time of at least a month made it unpopular after World War One in the construction of highways and bridges and many states and construction firms turned to the use of Portland cement. Because of the switch to Portland cement, by the end of the 1920s of the 15 Rosendale cement companies, only one had survived. But in the early 1930s it was soon discovered that, while Portland cement had a faster setting time it was not as durable, especially for highways, to the point that some states stopped building highways and roads with cement. Bertrain H. Wait, an engineer whose company had worked on the construction of the New York Citie, Catskill Aqueduct, was impressed with the durability of Rosendale cement, and came up with a blend of both Rosendale and synthetic cements which had the good attributes of both: it was highly durable and had a much faster setting time. Mr. Wait convinced the New York Commissioner of Highways to construct an experimental section of highway near newpaltz, New York using one sack of Rosendale to six sacks of synthetic cement, and it was proved a success and for decades the Rosendale-synthetic cement blend became common use in highway and bridge construction.

CHAPTER THREE

MATERIALS AND METHODOLOGY

3.1 CEMENT

Ordinary Portland Cement (OPC) was used as binder in this project. Dangote cement of manufactured standards was used throughout this project.

3.2 FINE AGGREGATE

Two deferent fine aggregate was used in this project namely

- **River sand**
- **Quarry dust**

River sand was dredged from river benue located in makurdi which will be used as concrete to cast cube, while The Quarry Rock Dust were obtained from local resource at makurdi benue state which will be used as concrete to cast test cubes and the workability of concrete made with quarry dust.

3.3 COARSE AGGREGATE

Crushed stone aggregates of 20 mm nominal size were obtained from a quarry plant in makurdi and used as coarse aggregate. Clean water was used for washing the aggregates, as well as mixing and curing the concrete specimens.

3.4 WATER

The water used in mixing the concrete is clean water which was gotten from borehole at joseph sarwuan tarka university makurdi.

Water is an important ingredient of concrete, and a properly designed concrete mixture, typically with 15 to 25% water by volume, will possess the desired workability for fresh concrete and the required durability and strength for hardened concrete. The roles of water here are known as hydration and workability. The total amount of water in concrete and the water-to-cement ratio may be the most critical factors in the production of good-quality concrete.

Too much water in concrete reduces concrete strength, while too little makes the concrete unworkable.

Because concrete must be both strong and workable, a careful selection of the cement-to-water ratio and total amount of water are required when making concrete (Popovics, 1992).

3.5 CURING

Curing is defined as the measures for taking care of fresh concrete right after casting. The main principle of curing is to keep favorable moist conditions under a suitable temperature range during the fast hydration process for concrete. It is a very important stage for the development of concrete strength and in controlling early volume changes. Fresh concrete requires considerable care, just like a baby. Careful curing will ensure that the concrete is hydrated properly, with good microstructure, proper strength, and good volume stability. On the other hand, careless curing always leads to improper hydration with defects in the microstructure, insufficient strength, and unstable dimensions. One of the common phenomena of careless curing is plastic shrinkage, which usually leads to an early age crack that provides a path for harmful ions and agents to get into the concrete body easily and causes durability problems. Curing is a simple measure to achieve a good quality of concrete.

The concrete cube was cured for 28 days in order to determine the maximum strength of the concrete.

3.6 DEFINITION OF WORKABILITY

Workability of concrete is defined in ASTM C125 as the property determining the effort required to manipulate a freshly mixed quantity of concrete with minimum loss of homogeneity (uniform).

The term manipulate includes the early-age operations of placing, compacting, and finishing. “Mindess and others (2003)” defined the workability of fresh concrete as “the amount of mechanical work, or energy, required to produce full compaction of the concrete without segregation.”

The effort required to place a concrete mixture is determined largely by the overall work needed to initiate and maintain flow, which depends on the rheological properties of the cement paste and the internal friction between the aggregate particles, on the one hand, and the external friction between the concrete and the surface of framework, on the other hand. Workability off rash concrete consists of two aspects: consistency and cohesiveness. Consistency describes how easily fresh concrete flows, while cohesiveness describes the ability of fresh concrete to hold all the ingredients together uniformly. Traditionally, consistency can be measured by a slump-conetest, the compaction factor, or a ball penetration compaction factor test as a simple index for fluidity of fresh concrete. Cohesiveness can be characterized by a Vebe test as an index of both the water-holding capacity (the opposite of bleeding) and the coarse-aggregate-holding capacity (the opposite of segregation) of a plastic concrete mixture. The flowability of fresh concrete influences the effort required to compact concrete. The easier the flow, the less work is needed for compaction. A liquid-like self-compacting concrete can completely eliminate the need for compaction. However, such a concrete has to be cohesive enough to hold all the constituents, especially the coarse aggregates in a uniform distribution during the process of placing.

Workability is not a fundamental property of concrete; to be meaningful it must be related to the type of construction and methods of placing, compacting, and finishing. Concrete that can be readily placed in a massive foundation without segregation would be entirely unworkable in a thin structural member. Concrete that is judged to be workable when high-frequency vibrators are available for consolidation would be unworkable if hand tamping were used.

The significance of workability in concrete technology is obvious. It is one of the key properties that must be satisfied. Regardless of the sophistication of the mix design procedures used and other considerations, such as cost, a concrete mixture that cannot be placed easily or compacted fully is not likely to yield the expected strength and durability characteristics.

3.7 MEASUREMENT OF WORKABILITY

Unfortunately, there is no universally accepted test method that can directly measure the workability as defined earlier. The difficulty in measuring the mechanical work defined in terms of workability, the composite nature of the fresh concrete, and the dependence of the workability on the type and method of construction makes it impossible to develop a well-accepted test method to measure workability. The most widely used test, which mainly measures the consistency of concrete, is called the slump test. For the same purpose, the second test in order of importance is the Vebe test, which is more meaningful for mixtures with low consistency. The third test is the compacting factor test, which attempts to evaluate the compact ability characteristic of a concrete mixture. The fourth test method is the ball penetration test that is somewhat related to the mechanical work.

3.8 TESTING OF AGGREGATES

The physical & engineering properties including particle size distribution of the fine aggregates were determined. Generally tested physical properties of the both fine and coarse aggregates were specific gravity and density. Fineness modulus was determined for both river sand and quarry dust, along with aggregate impact were tested.

3.9 SIEVE ANALYSIS TEST

Sieve analysis of river sand and quarry dust was conducted. Sieve analysis is a process of dividing a sample of aggregate into fractions of aggregate having sized similar sized grains or within a certain range of grains sizes. It is one of the non-destructive tests conducted to determine the particle size distribution of aggregate. Sieve analysis are used to determine particle size and shape which is used for preparing the grading curve of aggregates.

3.9.1 Apparatus Required:

- Stack of Sieves including pan and cover
- Balance (with accuracy to 0.01 g)
- Rubber pestle and Mortar (for crushing the soil if lumped or conglomerated)
- Mechanical sieve shaker
- Oven

3.10 SPECIFIC GRAVITY TEST

The specific gravity of a material is the ratio of its unit weight to that of water. The specific gravity test is conducted on a saturated and surface dry, base for the purpose of mix design. The specific gravity of both river sand and quarry dust was determined.

3.10.1 Apparatus Required For Specific Gravity Test Of Test Of Fine Aggregate.

- Pycnometer bottle of 1000ml capacity
- Taping rod
- Funnel
- Weighing balance

3.10.2 Procedure For Specific Gravity Test

1. Take a clean, dry pycnometer and determine its empty weight (w_1 g)
2. Take a clean sample of fine aggregate (about 1kg) for which specific is to be finding out and transfer that to the pycnometer and weight (w_2 g). The aggregate finer than 6.3mm are taken.
3. Pour distilled water in the pycnometer with aggregate sample at the temperation of 27 ^{0}c, to just immerse sample.
4. Immediately after immersion, remove the entrapped air from the sample by shaking or rotating the pycnometer, placing a finger on the hole at the top of the sealed pycnometer.
5. Wipe out the outer surfsce of pycnometer. Now the pycnometer is completely filled up with water till the hole at the top, and after confirming that there is no more entrapped air in pycnometer, weight it (w_3 g).

6. Transfer the aggregate of the pycnometer into a try care being taken to ensure that all the aggregate is transferred. Clean the pycnometer.
7. Refill the pycnometer with distilled water up to the top of the pycnometer, without any entrapped air. It should be completely dry from outside and take the weight (w_4 g).
8. For mineral filter, specific gravity bottle is used and the material is filled up to one-third of the capacity of bottle. The rest of the process of determining specific gravity is similar to the one described above.

Specific gravity of fine aggregate = $(w_2 - w_1)/ (w_2 - w_1) - (w_3 - w_4)$……………………………………………………………………3.1

Where w_1 = weight of pycnometer in air

W_2 = weight of pycnometer + fine aggregate

W_3 = weight of pycnometer + water + fine aggregate

W_4 = weight of pycnometer + water in air

3.11 AGGREGATE IMPACT VALUE TEST

The aggregate impact test is done to test the compressive strength of aggregate when sudden and immediate impact force acted on it. It is expressed in percentage (%).

3.11.1 APPARATUS REQUIRED

- Aggregate impact machine
- A cylindrical steel cup measuring the diameter of 75 mm and depth should be 50 mm.
- Another steel cup whose diameter should be 75 mm and depth should be 50 mm.
- The fall of the machine load on the aggregate cup
- Sieve of 12.5 mm.
- Second sieve of 10 mm

- Third sieve of 2.36 mm
- 6 digital measuring beam balances.
- Sample container.
- A tamping rod of 10 mm diameter.
- Bowl

3.11.2 Procedure For Aggregate Impact Value Test

- Take a sample of aggregate and sieve with the help of a 12.5 mm sieve and retain it into a 10 mm sieve.
- Sieving should be done in a circular motion.
- After that sample should be sieved with a 10 mm sieve and collect in a container.
- Now the collected sample of the aggregate is heated in an oven at 11o degree Celsius till 4 hours.
- Now take the aggregate sample from the oven and cool it at room temperature.
- Take the weight of the cylinder cup and fill the cup with an aggregate sample in three-layer.
- Compact the aggregate in each layer with the help of a tamping rod at least 25 tamp.
- Finally remove the upper portion of the aggregate and make the surface of the steel cup plain.
- Again take the weight of the cup with filled aggregate and weight should be noted.
- Transfer the aggregate sample to the aggregate impact machine cup.
- Tamp again at least 25 times with the help of a tamping rod. Lock the cup in the tamping machine with the help of a screw.
- Provide 15 blows to the aggregate with the help of the impact machine.

- Take out the sample from the impact machine take 2.36 mm sieve and sieve the impact aggregate through it.
- Take the bowl and measure it weight (x)
- Put the passed dust of aggregate through 2.36 sieve into a bowl.
- Take the weight of the bowl again with the aggregate sample (y)

The weight of passed dust, B = (X-Y)…………………………….3.2

Where X =weight of bowl

Y = weight of bowl with aggregate

Aggregate impact value = (B/A)*100%...3.3

Where A = weight of sample

B = weight of fraction dust of aggregate passing through 2.36 mm sieve

3.12 SLUMP TEST

Slump test of both quarry dust and river sand concrete was conducted in order to know their workability.

The equipment for the slump test is indeed very simple. It consists of a tamping rod and a truncated cone, 300mm in height, 100mm in diameter at the top, and 200mm in diameter at the bottom.

3.12.1 Procedure For Slump Test

To conduct a slump test, first moisten the slump test mold and place it on a flat, non-absorbent, moist, and rigid surface. Then hold it firmly to the ground by foot supports.

Next, fill 1/3 of the mold with the fresh concrete and rod it 25 times uniformly over the cross section. Likewise fill 2/3 of the mold and rod the layer 25 times, then fill the mold completely and rod it 25 times. If the concrete settles below the top of the mold, add more. Strike off any excessive concrete. Remove the mold immediately in one move. Measure and record the slump as the vertical distance from the top of the mold to average concrete level.

If slumping occurs evenly all around, it is regarded as a true slump. If one-half of the cone slides down along an inclined plane, it is regarded as shear slump. Shear slump is caused by insufficient cohesiveness and the concrete proportions should be adjusted. Mixes of very stiff consistency have zero slumps, so that in the rather dry range no slump can be detected between mixes of different workability. There is no problem with rich mixes, their slumps are sensitive to variations in workability; however, in a lean mix with a tendency to harshness, a true slump can be easily changed to the shear type, or even collapse with a non-uniform distribution of aggregates, especially coarse aggregates, and widely different values of slump can be obtained in different samples from the same mix. Thus, the slump test is unreliable for lean mixes.

3.15 COMPRESSIVE STRENGTH TEST

Out of the many test apply to the concrete this the most important because it give an idea about of the characteristics of concrete and by this single test one can judged that weather concreting has been done properly or not. For most of the works cubical moulds of size 150 by 150mm by 150mm are commonly used.

The compressive strength of both quarry dust and river sand concrete was determined by casting cubes and cured for 28days and crushed in the crushing machine to determine their respective strength.

This concrete is poured in the mould and tempered properly so as not to have any voids. After 24hours these moulds are removed and test specimens are put in water for curing. The top surface of this specimen should be even and smooth. This is done by putting cement paste and spreading smoothly on whole area of specimen.

The following are the procedure for compressive strength of concrete cubes.

3.13.1 Apparatus

Compression testing machines

3.13.2 Preparation of Concrete Cube Specimen

The proportion and material for making these test specimens are from the same concrete used in the field.

3.13.3 Mixing of Concrete For Cube Test

The mixing of the concrete will be carried out either by hand or in a laboratory batch mixer

Hand Mixing

1. Mix the cement and fine aggregate on a watertight none-absorbent platform until the mixture is thoroughly blended and is of uniform color.
2. Add the coarse aggregate and mix with cement and fine aggregate until the coarse aggregate is uniformly distributed throughout the batch.
3. Add water and mix it until the concrete appears to be homogeneous and of the desired consistency.

3.13.4 Sampling of Cubes For Test

1. Clean the mounds and apply oil.
2. Fill the concrete in the molds in layers approximately 5 cm thick.
3. Compact each layer with not less than 35 strokes per layer using a tamping rod (steel bar 16mm diameter and 60cm long, bullet-pointed at lower end).

4. Level the top surface and smoothen it with a trowel.

3.13.5 Procedure For Compressive Strength Test

1. Remove the specimen from the water after specified curing time and wipe out excess water from the surface.
2. Take the dimension of the specimen to the nearest 0.2m
3. Clean the bearing surface of the testing machine
4. Place the specimen in the machine in such a manner that the load shall be applied to the opposite sides of the cube cast.
5. Align the specimen centrally on the base plate of the machine.
6. Rotate the movable portion gently by hand so that it touches the top surface of the specimen.
7. Apply the load gradually without shock and continuously at the rate of 140 kg/cm^2/minute till the specimen fails
8. Record the maximum load and note any unusual features in the type of failure.

3.14 PREPARATION AND TESTING OF CONCRETE SPECIMENS

CMR (Concrete mix ratio) was batched by weight & volume. The mix ratio and water-cement ratio selected for the investigation were 1:2:4 and 0.55, respectively. Mix ratio 1:2:4 is a specified prescribed mix which correlates to normal concrete strength (14). Two separate groups of concrete specimens were prepared with one of the mixes containing 100% quarry dust as fine aggregate and another mix containing 100% river sand which served as content. No additives were used. The constituent materials were mixed manually. The cement and aggregates were first thoroughly mixed in dry state. Water of calculated quantity was gradually added to the dry mixture with continuous mixing. Concrete cubes of size 150 × 150 × 150 mm were prepared and cured. Sample specimens were put in the moulds for 24 hours to set before being demoulded and cured. The specimens were cured by immersion in a water tank for 7, 14, 21, and 28 days respectively. The slump cone test of fresh concrete, density of hardened concrete, and compressive strength of hardened concrete were tested and observed. Slump, density and compressive strength tests of the specimens were carried out respectively. Density and compressive strength results were obtained for the concrete cubes at 7, 14, 21, and 28 days of curing. The density and compressive strength are represented by the average values of three concrete cubes for each curing age.

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