**ELASTIC AND DURABILITY PROPERTIES OF CONCRETE INCORPORATING QUARRY DUST**

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**CHAPTER ONE**

**INTRODUCTION**

**1.1 Background of the study**

Concrete’s versatility, durability, elasticity, sustainability, and economy have made it the world’s most widely used construction material. About four tons of concrete are produced per person per year worldwide and about 1.7 tons per person in the United States. The term concrete refers to a mixture of aggregates, usually sand, and either gravel or crushed stone, held together by a binder of cementitious paste (Kosmatka, Steven & Kerkhoff, Beatrix & Panarese, William, 2002). Concrete is a structural product, possessing incredible design versatility and flexibility. Sustainable design means incorporating a responsible balance of elements in the choice of suitable products that combine to achieve design goals (Glanville, & Neville; 1997). In the same vein, tremendous efforts have been made in the area of concrete engineering and technology to research and study the utilization of by-products, waste materials and naturally occurring materials in the production of concrete (Ephraim, & Ode, 2006; Ephraim & Rowland-Lato, 2015;, Ilangovana, Mahendrana, & Nagamanib, 2010; Jayawardena, & Dissanayake, 2006; Khamput, 2005, Muhit, Haque, & Rabiul, 2013). Among this materials is 10mm all-in gravel aggregate occurs in great abundance in areas such as the low lying riverine areas of the Niger Delta region of Nigeria and is easily available all year round and quarry dust is a by-product from the crushing process during quarrying activities in Akamkpa area of Cross River state. Historically, the oldest concrete discovered dates from around 7000 BC. It was found in 1985 when a concrete floor was uncovered during the construction of a road at Yiftah El in Galilee, Israel (Kosmatka, 2002). It consisted of a lime concrete, made from burning limestone to produce quicklime, which when mixed with water and stone, hardened to form concrete (Brown 1996 and Auburn 2000). A cementing material was used between the stone blocks in the construction of the Great Pyramid at Giza in ancient Egypt around 2500 BC. Some reports say it was a lime mortar while others say the cementing material was made from burnt gypsum. By 500 BC, the art of making lime-based mortar arrived in ancient Greece. The Greeks used lime-based materials as a binder between stone and brick and as a rendering material over porous limestones commonly used in the construction of their temples and palaces (Kosmatka, 2002). Natural pozzolans have been used for centuries.

The term “pozzolan” comes from a volcanic ash mined at Pozzuoli, a village near Naples, Italy, following the 79 AD eruption of Mount Vesuvius. Sometime during the second century BC the Romans quarried a volcanic ash near Pozzuoli. Believing that the material was sand, they mixed it with lime and found the mixture to be much stronger than previously produced (Kosmatka, 2002). This discovery was to have a significant effect on construction. The material was not sand, but a fine volcanic ash containing silica and alumina. When combined chemically with lime, this material produced what became known as pozzolanic cement. However, the use of volcanic ash and calcined clay dates back to 2000 BC and earlier in other cultures. Many of the Roman, Greek, Indian, and Egyptian pozzolan concrete structures can still be seen today. The longevity of these structures attests to the durability of these materials. Examples of early Roman concrete have been found dating back to 300 BC. The very word concrete is derived from the Latin word “concretus” meaning grown together or compounded. The Romans perfected the use of pozzolan as a cementing material. This material was used by builders of the famous Roman walls, aqueducts, and other historic structures including the Theatre at Pompeii, Pantheon, and Colliseum in Rome. Building practices were much less refined in the Middle Ages and the quality of cementing materials deteriorated (Kosmatka, 2002). Quarry dust can be defined as residue, tailing or other non voluble waste material of size less than 4.75mm resulting from the extraction and processing of rocks. The composition of quarry dust depends on the mineral composition of the parent rock. It may also depend on the type of crusher and its reduction ratio, i.e. the ratio of the size of the material fed into the crusher to the size of the finished products (Khamput, 2005). The successful utilization of these materials is expected to result in benefits such as reduction of environmental load, waste management and concrete production cost in addition to enhancement of the properties of concrete in both fresh and hardened state.

Durability may be regarded as a measure of the ability of material to sustain its distinctive Characteristics and resistance to weathering under conditions of use for the duration of the service lifetime of the structure made from it (Glanville, & Neville, 1997; Sjostrum, 1996). Applicable to concrete, it is the ability of concrete to resist deteriorating agents; maintain its original form, be serviceable and environmentally compatible. Present survey shows that in industrialized countries, more than 40% of the total resources of the building industry is spent on repairs and maintenance of concrete structures (Ephraim, & Ode, 2006; Gettu, Garcia-Alvarez & Aguado, 1998). It is therefore necessary to carry out a detailed study of these properties; review existing literature concerning the use of quarry dust in structural concrete production; ascertain the suitability of the use of Akamkpa quarry dust in structural concrete considering their physical and chemical properties; determine the workability of fresh concrete incorporating quarry dust as fine aggregate; determine the compressive, flexural and tensile strengths of the hardened concrete, and several other issues associated with concrete.

**1.2 Research problem**

The adhesive nature of quarry dust powder makes it difficult for its transportation which develops the need for it to be utilized at the site itself. This requirement has opened an opportunity for quarry dust powder to be partially used in concrete building blocks which is an effective way of utilization. Quarry dust powder was not considered for a detailed analysis in the past, whereas several studies were done using materials like quarry dust, limestone, granite, marble etc which has similar properties. The quantity of waste produced due to Construction and Demolition (C&D) nowadays is huge and at the same time, scarcity of aggregates is a major problem faced by the construction industry. Utilization of C&D waste as aggregates is thus an economic and effective method in reducing the problems caused by these wastes (Michael, and Athanasia, 2016; Kala, 2013; Senthil, Selvarani, Saranya, Suganya, and Suganya, 2015).

Studies were conducted on materials like quarry dust, granite and marble slurry, laterite, concrete slurry etc. for various applications and their properties were evaluated in the past. Strength properties like compression, split tension, flexural, impact etc. have shown improved results using these materials up to certain percentage of replacements [6–10]. Stress–strain characteristics, micro structural and durability properties of these materials were also studied in detail (Ernest, and Juan, 2012; Ribeirode, Leonardo, Ramosda, Weliton, and Marta, 2013; Diogo, Filipe, Jorge, 2013; Manpreet, Anshuman, Dipendu, 2017). It was found that granite powder is coarser than cement particles, whereas the finer powder is smaller than cement particles in size (Telma, Ana, Bruno, João, and Joana, 2013). Building blocks with fine granite powder was found to show higher Ultrasonic Pulse Velocity (UPV) than conventional bricks which indicates an improved quality of concrete (Nuno, Fernando, Jorge, José, 2007). A possible replacement of cement with marble slurry was also studied because of its higher surface area and the presence of calcite and dolomite (Praveen, & Dhanya 2016; Vijayalakshmi, and Sekar, 2013; Ilangovana, Mahendrana, & Nagamanib, 2008).

Finer granite powder was found to improve resistance to chloride and sulphate attacks when the percentage replacement of fine aggregate is 30% in concrete (Dongxing, Baojian, Chi, Wei, 2016; Dehwah, 2012; Vincent, Eric, Cédric, Philippe, 2016). Apart from strength and durability properties, acoustic and thermal conductivity properties were also evaluated and found that addition of new materials into concrete mixes has noticeable changes in their thermal and acoustic properties (Bishwajit, & Krishnamoorthy, 2004; Kodur, & Sultan, 2003; Adam, Eric, Kristy, Jason, & Jan, 2004). The previous studies have shown that addition of waste materials like granite powder, marble slurry, laterite dust into concrete mixes have positively altered the mechanical and durability properties (Senthil, Selvarani, Saranya, Suganya, & Suganya, (2015). These past results open opportunities for quarry dust powder to be considered for incorporation in concrete building blocks, thus bringing a possible solution for the problems caused by the same. To the researcher’s knowledge only limited studies were reported on the use of quarrying dust for the preparation of concrete building blocks with special reference to Akampka. The present work reports a detailed study on the examination of elastic and durability properties of concrete incorporating quarry dust with specific reference to Akamkpa, Cross River state.

**1.3 Aim and Objectives of the Study**

**Primary Aim**

The aim of this research is to investigate the elastic and durability properties of concrete incorporating quarry dust as fine aggregate.

**Objectives the study**

1. To review existing literature concerning the use of quarry dust in structural concrete production.
2. To ascertain the suitability of the use of Akamkpa quarry dust in structural concrete considering their physical and chemical properties.
3. To determine the workability of fresh concrete incorporating quarry dust as fine aggregate.
4. To determine the compressive, flexural and tensile strengths of the hardened concrete.
5. To determine the modulus of elasticity of the hardened concrete.
6. To determine the water absorption capacity and sorptivity of the concrete.
7. To determine the chloride penetration resistance of the concrete.

**1.4 Significance of Research**

Strength of concrete is one of the most important characteristics of hardened concrete mix besides its durability, and the compressive strength represents the best indication to the state of strength of a particular concrete. The findings of this study is significant as it explores the effect of quarry dust as partial replacement material to river sand, resulting in significant effects to the compressive strength of concrete. The results will affirm or disprove the suitability of the use of Akamkpa quarry dust in structural concrete and the modulus of elasticity of the hardened concrete. The results will establish the compressive strengths of concrete when Akamkpa quarry dust is incorporated. The overall findings of this study will be helpful to construction professionals. More so, the future studies may find the results of this study helpful as its results are a rethought in the light of contemporary significance.

**1.5 Research Scope**

This study focuses on establishing the suitability of Akamkpa quarry dust when incorporated in concrete. It particularly observes chloride penetration resistance of the concrete and therefore seeks to establish the water absorption capacity and sorptivity of the concrete. The scope of this academic investigation is defined within the specific parameters of compressive, flexural and tensile strengths of the hardened concrete when mixed with quarry dust. Also, this study is regional based as Akamkpa has been adopted as the specific site for this study. The implication of this selection is that the findings from this study may not be applied to all quarry sites, hence, user caution is advised when applying the result of this study to other quarry sites.

**1.6 Research Limitations**

Limitations for a study refers to the encumbrances that may limit the full dividends of a certain undertaken. It can also mean the shortfalls of a study which creates a knowledge gap for further studies. Whilst this study paid huge attention to quarry dust, the specificity gives precision to the result of the study but is a shortfall for this study. More concrete elements and properties could be considered to expand the findings. More so, this study is limited to a selected quarry site. Further studies might consider examining other quarry sites and investigating the accompanying differences, all in a bid to expand the frontiers of construction knowledge.

**CHAPTER TWO**

**REVIEW OF LITERATURE**

**2.1 Preamble**

Concrete is made up of two main ingredients: aggregates and paste. The paste, which is made up of portland cement and water, hardens and binds the aggregates (typically sand and gravel or crushed stone) into a rocklike mass as the cement and water react chemically. Cementitious ingredients, water, and entrapped or purposefully entrained air make up the paste. The paste makes up around a quarter to a third of the overall volume of concrete.

**2.2 Review of Previous Studies**

Varun, Harish, and Hanumesh (2008) compared the properties of control concrete to those of concrete prepared with quarry dust and foundry sand when it was fresh and hardened. Slump cone and compaction factor tests were performed to test the fresh properties, whereas compression and split tensile tests were performed for 7 and 28 days to evaluate the hardened properties. The M30 grade control concrete was designed utilizing the 10262:2009 provision. The study discovered that incorporating foundry sand into concrete results in a systematic decline in workability. In addition, the addition of quarry dust to concrete reduces workability, and the combination of natural sand, foundry sand, and quarry dust reduces workability as compared to conventional concrete prepared with natural sand.

Cement can be partially replaced with aluminum dross and fly ash, while natural sand can be partially replaced with quarry dust, according to Mohamed, Ali, Ishak, and Ahmed (2020). For the creation of nine concrete combinations, aluminum dross, cement, sand, and quarry dust were mixed in various quantities with a constant percentage of fly ash. Aluminum dross was replaced with 5, 10, 15, and 20% of the cement mass, respectively. Based on the strength data, the best replacement of aluminum dross without utilizing quarry dust was initially found at a constant percentage of fly ash-15 percent. Later, the quarry dust was partially replaced at 10, 20, 30, and 40% of river sand by introducing the ideal substitution of aluminum dross with cement and fly ash to find the overall optimum mix. The concrete's mechanical and durability properties were studied utilizing the three combinations. The mechanical and durability qualities of a concrete mixture comprising 15% fly ash, 10% aluminum dross, and 20% quarry dust were found to be superior to those of conventional concrete. Concrete made from industrial waste has the potential to lower infrastructure construction costs while also reducing environmental concerns.

The usefulness of quarry dust as a partial substitute for sand in high-strength concrete (HSC) containing rice husk ash was investigated by Raman, Ngo, Mendis, and Mahmud (2011). (RHA). Two grades of HSC mixes were developed, one with and one without RHA, to attain 60 MPa and 70 MPa at 28 days. Quarry dust was then employed as a partial substitute for sand in RHA-containing mixtures, with amounts ranging from 10% to 40%. The fresh concrete's slump and compressive strength growth were tracked for up to 28 days. Based on the findings, the mixes containing 20% quarry dust were determined to be the best mix design for both grades of concrete, which would subsequently be tested for strength and mechanical qualities for one year. The results obtained in the next stage reveal that, while using quarry dust as a partial substitute for sand has some minor negative impacts on concrete compressive strength and other mechanical properties, these effects may be easily offset by using an appropriate mix design and adding RHA. According to the findings, quarry dust can be utilized as a suitable substitute for sand in the production of high-strength RHA concrete.

Ramana, Zain, Mahmuda, and Tan (2005) investigated the impact of partially replacing sand with quarry dust and cement with fly ash on the development of concrete compressive strength. Except for the control concrete mix, two types of sand replacement proportions with quarry dust, 20 percent and 40 percent, were used in the concrete mixes. In addition, in some concrete mixes, a replacement percentage of 10% cement content with fly ash was used. Throughout the investigation, two types of curing procedures, water curing and air curing, were used under controlled laboratory circumstances. The compressive strength of water-cured specimens was determined on the 7th, 28th, 56th, and 91st days, whereas compressive strength of air-cured specimens was determined on the 28th, 56th, and 91st days. The concrete integrating quarry dust but not fly ash had lower compressive strength than the control concrete at all ages, according to the data. The incorporation of fly ash into the quarry dust concrete was used to overcome this weakness, which resulted in increased compressive strength under practically all conditions. In the presence of fly ash, quarry dust can be used as a partial replacement material for sand to generate concretes with a wide range of compressive strengths.

Febin, Abhirami, Vineetha, Manisha, Ramkrishnan, Sathyan, and Mini (2019) evaluated the strength, durability, acoustic, and thermal properties of quarry dust powder in the creation of concrete building blocks. At greater percentages of M Sand substitution, the mixtures were very dry, and workability was kept constant to identify the best blend. After determining the ideal combination, M Sand was substituted with quarry dust powder in the test specimens at varied percentages of 0, 15, 30, 45, and 60, and tests were undertaken to investigate these qualities. When comparing the results, it was discovered that replacing M Sand with quarry dust powder boosted compressive and split tensile strength while decreasing impact strength. At 30% replacement, abrasion resistance, acoustic absorption, and sorptivity characteristics improved, whereas thermal conductivity increased with increasing percentages of M Sand substitution. The study's findings demonstrated that quarry dust powder can be used to manufacture concrete construction blocks in a cost-effective, efficient, and long-term manner.

Ephraim and owland-Lato (2015) investigated the elasticity, tensile strength, and durability of concrete made with quarry dust instead of sand and 10mm washed aggregate instead of traditional granite. Three mixes with typical strengths of 8.88N/mm2, 28.23N/mm2, and 38.29N/mm2 (by weight) and water-cement ratios (w/c) of 0.65, 0.55, and 0.45, respectively. The static modulus of elasticity of the 1:2:3 mix is much lower than the theoretical value of 24kN/mm2, whereas the results of 1:112:2 and 1:1:2 are very near to the theoretical values. It was discovered that as concrete's strength grows, its durability increases, and 1:2:3 and 1:112:2 mixtures have a better capacity to absorb water than the 1:12 mix. Water absorption varies between 2 and 8%. The workability value was superior than that of standard concrete. Concrete has a lower aggregate/cement ratio than traditional concrete. As a result, the 10mm washed aggregate and quarry dust met the requirements of code provision in properties studies and may be used in place of traditional granite and natural river sand.

Safiuddin, Zain, and Yusof studied the feasibility of making high-performance concrete (HPC) utilizing quarry dust as a fine aggregate (2000). Their goal was to figure out which curing procedure would give them the best compressive strength, elasticity, and durability. On the hardened specimens, tests for compressive strength, dynamic modulus of elasticity, and initial surface absorption (ISA) were performed. Normal portland cement (NPC) concrete was used to make silica fume-quarry dust (SFQD) and silica fume (SF) concretes. The workability of the fresh composite was determined by measuring slump, slump-flow, and V-funnel flow. The workability requirement of HPC was met using SFQD concrete. Dry air and water curing were used to cure the hardened test specimens. At the ages of 28, 56, and 91 days, test findings demonstrated that water-cured SFQD concrete had good compressive strength and elasticity, which should be maintained in HPC (Kosmatka, Kerkhoff, & Panarese, 2002). In comparison to SF concrete, water cured SFQD concrete had lower ISA-values, though not the lowest. When compared to the maximum absorption of low absorptive concrete, these figures are quite low. As a result of this research, HPC can be generated by incorporating quarry dust into fine aggregates.

The influence of quarry dust and mineral additive on the strength and elasticity of concrete was investigated by Safiuddin, Zain, Mahamud, and Naidu (2001). Mineral admixtures included silica fume and fly ash, while quarry dust was included in the mining sand. Laboratory tests were conducted to measure the compressive strength and dynamic modulus of elasticity. The researchers looked at four different types of concrete with water-binder ratios of 0.40 and 0.45. These concretes are NPC, QD, SFQD, and FAQD. All of the concretes were cured in both water and dry air. The compressive strength and dynamic modulus of elasticity of QD concrete were found to be the lowest in the tests. At a later stage, FAQD concrete had somewhat higher compressive strength and dynamic modulus of elasticity than NPC concrete. In all conditions, however, SFQD concrete exhibited the highest compressive strength and dynamic modulus of elasticity.

**2.3 Conceptual Framework**

**Sustainable Development**

Concrete serves as the foundation for most of civilization's infrastructure and physical growth. Concrete is used twice as much as all other building materials combined around the world. It is an important component of municipal infrastructure, transportation infrastructure, office buildings, and residential structures. While cement production is resource and energy intensive, concrete's properties make it a very low-impact construction material in terms of environmental and sustainability (Kosmatka, Kerkhoff, & Panarese, 2002). In fact, the majority of concrete uses directly contribute to the creation of sustainable buildings and infrastructure.

**The Basics of Effective Concrete**

Workmanship, mix proportions, material characteristics, and curing adequacy all affect concrete's performance. Quality concrete is made up of a variety of materials and processes, including the production and testing of raw materials, determining the desired properties of concrete, proportioning of concrete constituents to meet design requirements, batching, mixing, and handling to achieve consistency, and proper placement, finishing, and adequate consolidation to ensure a long-lasting product.

Throughout the production of concrete, many people with various skills come into contact with it. The final product's quality is ultimately determined by their labor. It is critical that the workforce be properly prepared for this task. These factors can have a negative impact on the performance of both fresh and hardened properties if they are not carefully controlled.

**Quality and Adequacy of Materials**

Concrete is made up of two main ingredients: aggregates and paste. As the paste, which is made up of portland cement and water, hardens from the chemical reaction between cement and water, it binds the aggregates (usually sand and gravel or crushed stone) into a rocklike mass. The paste may also contain additional cementitious materials and chemical admixtures. Entrapped air or air that has been purposefully entrained may also be present in the paste. The paste makes up around a quarter to a third of the overall volume of concrete.

**Ratio of Water to Cementitious Materials**

Duff Abrams provided data in 1918 that indicated that the strength of concrete relies on the relative amount of water compared to cement for a given set of concreting components. In other words, the water to cement ratio (w/c) determines the strength, where w denotes the mass of water and c denotes the mass of cement. In current practice, however, w/cm is employed, with cm denoting the mass of cementing materials, which comprises portland cement as well as any supplemental cementing elements such as fly ash, slag cement, or silica fume. Unnecessarily high water content dilutes the cement paste (concrete's glue) and increases the volume of the finished concrete.

**Some advantages of reducing water content include:**

• Increased compressive and flexural strength

• Lower permeability and increased watertightness

• Increased durability and resistance to weathering

• Better bond between concrete and reinforcement

• Reduced drying shrinkage and cracking

• Less volume change from wetting and drying

The less water utilized, the higher the concrete quality, as long as the mixture can still be effectively consolidated. Smaller amounts of mixing water result in stiffer mixtures, which may be easily put with vibration. As a result, concrete quality can be improved through vibration consolidation. Increased strength and stiffness, as well as reduced creep, are achieved by lowering the water content of concrete and thereby lowering the w/cm. Drying shrinkage and the possibility of cracking will be reduced as well. The concrete will have a lower permeability or higher water tightness, making it more resistant to weathering and severe chemical attack. The bond between the concrete and embedded steel reinforcement is also improved by the decreased water to cementitious materials ratio.

**Design-Workmanship-Environment**

Concrete structures are designed to endure a wide range of loads and conditions, including seawater, deicing salts, sulfate-bearing soils, abrasion, and cyclic wetting and drying. The materials and quantities used to make concrete will vary depending on the loads it must carry and the conditions it will be subjected to. Concrete structures that are properly designed and built are robust and durable for the duration of their service life. Concrete hardens into a strong, non-combustible, durable, abrasion resistant, and watertight building material after the right proportioning, batching, mixing, putting, consolidating, finishing, and curing. Concrete is also an ideal building material since it can be shaped into a vast range of shapes, colors, and textures for use in an infinite number of applications.

**Chloride**

Concerns about high chloride levels in mixing water stem mostly from the possibility of chloride ions corroding reinforcing steel or prestressing strands. The protective oxide film generated on the steel by the very alkaline (pH greater than 12.5) chemical environment present in concrete is attacked by chloride ions. The threshold of acid soluble chloride ions at which steel reinforcement corrosion begins in concrete is around 0.2 percent to 0.4 percent by mass of cement (0.15 percent to 0.3 percent water soluble). Only around 50 to 85 percent of the total chloride-ion concentration in concrete is water soluble; the rest is chemically mixed in cement processes (Whiting 1997, Whiting, Taylor, and Nagi, 2002, and Taylor, Whiting, and Nagi 2000). Chlorides can enter concrete through the distinct combination constituents (admixtures, aggregates, cementitious materials, and mixing water) or from exposure to deicing salts, seawater, or salt-laden air in coastal locations. Given the numerous alternative sources of chloride ions in concrete, establishing an acceptable limit on chloride content for any one element, such as mixing water, is difficult. The type of building and the environment to which it is exposed over its service life determine a permissible limit in concrete.

A high dissolved solids content of a natural water is sometimes due to a high content of sodium chloride or sodium sulfate. Both can be tolerated in rather large quantities. Concentrations of 20,000 ppm of sodium chloride are generally tolerable in concrete that will be dry in service and has low potential for corrosive reactions. Water used in prestressed concrete or in concrete that is to have aluminum embedments should not contain deleterious amounts of chloride ion. The contribution of chlorides from ingredients other than water should also be considered. Calcium chloride admixtures should be avoided in steel reinforced concrete.

The ACI 318 building code limits water soluble chloride ion content in reinforced concrete to the following percentages by mass of cement:

Prestressed concrete (Classes C0, C1, C2) 0.06%

Reinforced concrete exposed to chloride in service (Class C2) 0.15%

Reinforced concrete that will be dry or protected from moisture in service (Class C0) 1.00%

Other reinforced concrete construction (Class C1) 0.30%

ACI 318 does not limit the amount of chlorides in plain concrete, that is concrete not containing steel. Additional information on limits and tests can be found in ACI 222, Corrosion of Metals in Concrete. The acid-soluble and water-soluble chloride content of concrete can be determined by using ASTM C1152 and C1218.

**Durability**

Concrete durability is described as the ability of concrete to withstand weathering, chemical attack, and abrasion while retaining its desired engineering qualities. Depending on the exposure environment and the required qualities, different concretes require varying degrees of durability. The ultimate durability and longevity of the concrete are determined by the concrete materials, proportioning of those ingredients, interactions between the ingredients, and laying and curing techniques (Kosmatka, Kerkhoff, & Panarese, 2002). Concrete used in constructions and pavements is supposed to have a long service life and require little maintenance. It must be tough enough to withstand the expected exposure conditions. The most damaging weathering factor is freezing and thawing when the concrete is wet, especially if deicing chemicals are present. The freezing of water and subsequent expansion in the paste, aggregate particles, or both causes deterioration.

Concrete is particularly resistant to this sort of deterioration when exposed to air entrainment. The water displaced by ice formation in the paste is accommodated so that it is not disruptive during freezing; the microscopic air bubbles in the paste create chambers for the water to enter and thus relieve the hydraulic pressure generated (Kosmatka, Kerkhoff, & Panarese, 2002). When concrete containing saturated aggregate freezes, disruptive hydraulic forces can be generated within the aggregate. Water displaced from aggregate particles during ice formation cannot escape to the surrounding paste quickly enough to relieve pressure. However, most aggregate particles will not become saturated under most exposure situations if a good-quality paste (low water-cement ratio) is used. Furthermore, if the paste is air entrained, it will accept small amounts of surplus water ejected from aggregates, saving the concrete from freeze-thaw damage.

**Strength**

The measured maximum resistance of a concrete specimen to axial loading is characterized as its compressive strength. At 28 days, it is usually stated in megapascals (MPa) or pounds per square inch (psi). One megapascal equals one newton per square millimeter (N/mm2) or one million N/m2. Other test ages are employed as well; nonetheless, it is critical to understand the link between 28-day strength and other test ages. Seven-day strengths are frequently estimated to be approximately 75% of 28-day strengths, whereas 56-day and 90-day strengths are approximately 10% to 15% more than 28-day strengths. The specified compressive strength is denoted by the symbol., and it should be more than the actual compressive strength,. The compressive strength of a concrete is determined by the water-cement ratio (or water-cementitious materials ratio), the degree of hydration, the curing and ambient conditions, and the age of the concrete. Since the late 1800s and early 1900s, researchers have been investigating the relationship between strength and water-cement ratio (Feret 1897 and Abrams 1918). It is worth noting that when the water-cement ratios decline, so do the strengths. These parameters also have an impact on the flexural and tensile strengths of concrete, as well as the bond between concrete and steel. When more accurate tangible values are necessary, graphs for the individual materials and mix proportions to be utilized on the task should be created. Air-entrained concrete requires less mixing water than non-air-entrained concrete for a given workability and cement amount. The lower water-cement ratio available with air-entrained concrete tends to compensate for the slightly lower strengths of air-entrained concrete, especially in lean to medium cement content mixtures.

**Compressive Strength**

Tests are performed on mortar or concrete specimens to determine compressive strength; in the United States, unless otherwise specified, compression tests of mortar are performed on 50-mm (2-in.) cubes, while compression tests of concrete are performed on cylinders 150 mm (6 in.) in diameter and 300 mm (12 in.) in height. Concrete is also made with smaller cylinders, 100 × 200 mm (4 x 8 in.). Concrete's compressive strength is a primary physical attribute that is commonly employed in bridge, building, and other structure design calculations. The compressive strength of most general-purpose concrete is between 20 and 40 MPa (3000 and 6000 psi). In particular bridge and high-rise building applications, compressive strengths ranging from 70 to 140 MPa (10,000 to 20,000 psi) have been utilised.

Concrete's flexural strength or modulus of rupture is used to design pavements and other slabs on the ground. Compressive strength, which is easier to measure than flexural strength, can be used as an index of flexural strength after an empirical relationship between them for the materials and size of the element involved has been established. The flexural strength of normal-weight concrete is commonly calculated to be 0.7 to 0.8 times the square root of the compressive strength in megapascals (7.5 to 10 times the square root of the compressive strength in pounds per square inch). Wood (1992) depicts the relationship between flexural and compressive strength for concretes exposed to moist curing, air curing, and outdoor exposure.

Concrete's direct tensile strength is around 8% to 12% of its compressive strength and is commonly calculated to be 0.4 to 0.7 times the square root of the compressive strength in megapascals (5 to 7.5 times the square root of the compressive strength in pounds per square inch). The splitting tensile strength is 8% to 14% of the compressive strength (Hanson 1968). Lange presents tensile strength splitting vs time (1994).

**Freshly Mixed Concrete**

Freshly mixed concrete should be plastic or semi-fluid and generally capable of being molded by hand. A very wet concrete mixture can be molded in the sense that it can be

cast in a mold, but this is not within the definition of “plastic”— that which is pliable and capable of being molded or shaped like a lump of modeling clay. In a plastic concrete mixture all grains of sand and pieces of gravel or stone are encased and held in suspension. The ingredients are not apt to segregate during transport; and when the concrete hardens, it becomes a homogeneous mixture of all the components. During placing, concrete of plastic consistency does not crumble but flows sluggishly without segregation.

In construction practice, thin concrete members and heavily reinforced concrete members require workable, but never soupy, mixes for ease of placement. A plastic mixture is required for strength and for maintaining homogeneity during handling and placement (Kosmatka, Kerkhoff, & Panarese, 2002). While a plastic mixture is suitable for most concrete work, plasticizing admixtures may be used to make concrete more flowable in thin or heavily reinforced concrete members.

**Workability**

The ease of placing, consolidating, and finishing freshly mixed concrete and the degree to which it resists segregation is called workability. Concrete should be workable but the ingredients should not separate during transport and handling. The degree of workability required for proper placement of concrete is controlled by the placement method, type of consolidation, and type of concrete. Different types of placements require different levels of workability.

Factors that influence the workability of concrete are:

(1) the method and duration of transportation;

(2) quantity and characteristics of cementitious materials;

(3) concrete consistency (slump);

(4) grading, shape, and surface texture of fine and coarse aggregates;

(5) entrained air;

(6) water content;

(7) concrete and ambient air temperatures; and

(8) admixtures. A uniform distribution of aggregate particles and the presence of entrained air significantly help control segregation and improve workability. Properties related to workability include consistency, segregation, mobility, pumpability, bleeding, and finishability. Consistency is considered a close indication of workability. Slump is used as ameasure of the consistency or wetness of concrete. A low-slump concrete has a stiff consistency. If the consistency is too dry and harsh, the concrete will be difficult to place and compact and larger aggregate particles may separate from the mix. However, it should not be assumed that a wetter, more fluid mix is necessarily more workable. If the mix is too wet, segregation and honey combing can occur. The consistency should be the driest practicable for placement using the available consolidation equipment. See Powers (1932) and Daniel (2006).

**Consolidation**

Vibration causes the particles in freshly mixed concrete to move, reducing friction and giving the mixture the mobility of a thick fluid. Because of the vibratory effect, a stiffer mixture with a higher proportion of coarse aggregate and a lower proportion of fine aggregate can be used (Kosmatka, Kerkhoff, & Panarese, 2002). With a well-graded aggregate, the higher the maximum size aggregate in concrete, the less volume to fill with paste and the less aggregate surface area to coat with paste; hence, less water and cement are required. Concrete that has been correctly graded will be easier to consolidate and lay. Consolidation of coarser and stiffer mixtures improves both quality and economy. Poor consolidation, on the other hand, might result in porous, weak concrete with poor durability.

Mechanical vibration offers numerous benefits. Vibrators enable the economical placement of mixes that would be impractical to consolidate by hand under many conditions.

**Drying Rate of Concrete**

Drying does not cause concrete to harden or cure. Concrete (or, more correctly, the cement contained within it) need moisture to hydrate and harden. When concrete dries out, it loses strength; the fact that it is dry does not imply that it has received enough hydration to meet the appropriate physical qualities. Understanding the characteristics or physical condition of concrete requires knowledge of the pace of drying.

For example, as previously stated, concrete must retain sufficient moisture throughout the curing phase to allow the cement to hydrate to the level necessary to obtain the specified qualities. Freshly cast concrete typically contains a lot of water, but when it dries from the surface inside, strength growth will continue at each level only as long as the relative humidity remains over 80%.

A common example of this is the surface of a concrete floor that has not received adequate moist curing. Because it dried rapidly, the surface of the concrete is fragile, and traffic on it causes dusting. Concrete, like wood and clay, shrinks as it dries as it loses water (though not as much). Drying shrinkage is the most common cause of cracking, and the breadth of cracks is determined by the degree of drying, the spacing or frequency of fissures, and the age of the cracks (Kosmatka, Kerkhoff, & Panarese, 2002).

While the top of a concrete part dries quickly, concrete in the interior takes significantly longer to dry. Due to climatic variables, size impacts, and concrete qualities, field concrete elements might have different drying profiles. The moisture content of concrete is determined by the elements of the concrete, the original water content, the drying circumstances, and the size of the concrete element (Hedenblad 1997 and 1998). After several months of drying in air with a relative humidity of 50% to 90%, the moisture content of the concrete is roughly 1% to 2% by mass. The size and shape of a concrete part have a significant impact on the rate of drying. Concrete elements with considerable surface area in comparison to volume (such as floor slabs).

**SPECIAL TYPES OF CONCRETE**

Special types of concrete are those with out-of-the-ordinary properties or those produced by unusual techniques. Some of them are discussed below:

**Structural Lightweight Concrete**

The density of structural lightweight concrete is lower than that of conventional weight concrete. It is built entirely of lightweight aggregates (all-lightweight concrete) or of a mix of lightweight and normalweight aggregates. Sand lightweight concrete is built from coarse lightweight aggregate and natural sand. Structural lightweight concrete has an air-dry density of 1350 to 1850 kg/m3 (85 to 115 pcf) and a compressive strength of more than 17 MPa after 28 days (2500 psi). Air-dry densities of up to 1920 kg/m3 are permitted in some project standards (120 pcf). In comparison, the dry density of normal-weight concrete including standard sand, gravel, or crushed stone ranges from 2080 to 2480 kg/m3 (130 to 155 pcf). ASTM C567 is a density test for structural lightweight concrete. Structural lightweight concrete is primarily utilized to reduce dead-load weight in concrete members such as high-rise building floors (Kosmatka, Kerkhoff, & Panarese, 2002).

**Compressive Strength**

The compressive strength of structural lightweight concrete is usually proportional to the cement content at a certain slump and air content, rather than a water-to-cement ratio. This is because it is difficult to determine how much of the overall mix water is absorbed by the aggregate and so unavailable for reaction with the cement. The ACI 211.2 standard specifies the relationship between compressive strength and cement content. Compressive strengths typically vary from 20 to 35 MPa (3000 to 5000 psi). Structural lightweight aggregates can also be used to make high-strength concrete.

For a given source of lightweight aggregate, the cement content and strength relationship is fairly consistent in well-proportioned combinations. However, the relationship will differ depending on the aggregate source or kind. When the aggregate manufacturer does not have information on this relationship, trial mixtures with varying cement contents are required to develop a range of compressive strengths, including the specified strength (Kosmatka, Kerkhoff, & Panarese, 2002). A 28-MPa (4000-psi) structural lightweight concrete mixture with an air-dry density of around 1800 kg/m3 (112 pcf), a combination of natural sand and gravel, and a lightweight rotary kiln expanded clay coarse aggregate is given below:

**Workability and Finishability**

Structural lightweight concrete mixtures can be properly proportioned to have the same workability, finishability, and overall look as a properly proportioned normaldensity concrete mixture. There must be enough cement paste to coat each particle, and coarse-aggregate particles must not separate from the mortar. A sufficient amount of fine aggregate is required to keep the freshly mixed concrete cohesive. If the aggregate lacks minus 600 m (No. 30) sieve material, finishability can be increased by utilizing a percentage of natural sand, increasing the cement content, or employing acceptable mineral fines. Because entrained air increases workability, it should be used regardless of the level of exposure.

**Entrained Air**

As with normal-weight concrete, entrained air in structural lightweight concrete guarantees resistance to freezing and thawing and to deicer treatments. It also enhances workability, decreases bleeding and segregation, and may compensate for small grading faults in the aggregate. The volume of entrained air should be sufficient to offer acceptable workability to the flexible concrete and enough freeze-thaw resistance to the hardened concrete (Kosmatka, Kerkhoff, & Panarese, 2002). Air concentrations are typically between 5 percent and 8 percent , depending on the maximum size of coarse aggregate (paste content) utilized and the exposure circumstances. Testing for air content should be conducted by the volumetric technique (ASTM C173 or AASHTO T 196). (ASTM C173 or AASHTO T 196). The freeze-thaw endurance is also considerably increased if structural lightweight concrete is allowed to cure before exposure to a freeze-thaw environment.

**Insulating And Moderate-Strength Lightweight Concretes**

Insulating concrete has an ovendry density of less than 800 kg/m3 (50 pcf) and is lightweight. Cementing materials, water, air, and aggregate and chemical admixtures are used to create it. The ovendry density ranges from 240 to 800 kg/m3 (15 to 50 pcf), with a 28-day compressive strength of 0.7 to 7 MPa (100 and 1000 psi). Thermal and sound insulation, roof decks, slab-on-grade subbase fill, leveling courses for floors or roofs, firewalls, and subterranean thermal conduit linings are some of the applications for cast-in-place insulating concrete. Lightweight concrete with a compressive strength of 7 to 17 MPa has a density of 800 to 1900 kg/m3 (50 to 120 pcf) ovendry (1000 to 2500 psi). Cementing materials, water, air, and aggregate and chemical admixtures are used to create it. It is referred to as fill concrete when used as a fill for thermal and sound insulation of floors, walls, and roofs. It's utilized in precast wall and floor panels, as well as cast-in-place walls, floors, and roofs (Kosmatka, Kerkhoff, & Panarese, 2002).

**Autoclaved Cellular Concrete**

Autoclaved cellular concrete (also known as autoclaved aerated concrete) is a lightweight construction material. It's made with pulverized siliceous material (sand, slag, or fly ash), cement and/or lime, and water, plus a gas-forming additive like aluminum powder. Aluminum reacts with alkaline water to produce hydrogen, which expands the mortar and generates macropores with diameters ranging from 0.5 to 1.5 mm (0.02 to 0.06 in.). Following that, the material is pressure steam cured (autoclaved) for 6 to 12 hours at 190°C (374°F) and 1.2 MPa (174 psi). This results in a calcium silicate hydrates-based hardened mortar matrix. This porous mineral building material offers compressive strengths ranging from 2.5 to 10 MPa (300 to 1500 lb/in2) and densities ranging from 300 to 1000 kg/m3 (19 to 63 lb/ft3). The thermal conductivity of autoclaved cellular concrete is only 0.15 to 0.20 W/(m•K) (1 to 1.4 Btu•in./[h•ft2•oF]) due to the high macropore concentration (up to 80% by volume). For the construction of residential or commercial buildings, autoclaved cellular concrete is available in block or panel form.

**High-Density Concrete**

Concrete with a density of up to 6400 kg/m3 is known as high-density (heavyweight) concrete (400 pcf). Heavyweight concrete is primarily used for radiation shielding, although it is also utilized for counterweights and other high-density applications. Heavyweight concrete acts as a shielding medium, protecting against the detrimental effects of X-rays, gamma rays, and neutron radiation. The kind and intensity of radiation are used to determine which concrete should be used for radiation shielding. When space is not an issue, normal-weight concrete will form the most cost-effective shield; when space is an issue, heavyweight concrete will allow for thinner shields without reducing shielding efficacy.

**Density**

The density and water content of shielding concrete are usually determined by the kind and intensity of radiation. A concrete shield's effectiveness against gamma rays is roughly related to its density; the heavier the concrete, the more efficient the barrier. A good shield against neutron radiation, on the other hand, requires both heavy and light components (Kosmatka, Kerkhoff, & Panarese, 2002). In concrete shields, hydrogen in water serves as an excellent light element. As part of their structure, some aggregates contain crystallized water, often known as fixed water. As a result, if both gamma rays and neutron radiation must be suppressed, heavyweight aggregates with large fixed-water contents are frequently utilized. To attenuate neutrons, boron glass (boron frit) is also used.

**No-Slump Concrete**

Concrete with a consistency comparable to a slump of 6 mm (1/4 in.) or less is known as no-slump concrete (Kosmatka, Kerkhoff, & Panarese, 2002). While the concrete is very dry, it must be workable enough to be laid and consolidated using the equipment that will be utilized on the job. The procedures described here are not always applicable to concrete masonry unit mixtures or spinning compaction. Many of the fundamental laws that govern the qualities of higher-slump concretes apply to no-slump concrete as well. The qualities of hardened concrete, for example, are mostly determined by the water-to-cement ratio, as long as the mix is adequately consolidated. Because the slump cone is impracticable for use with the drier consistencies, the consistency of no-slump concrete is measured differently from that of higher-slump concrete. Three methods for testing the consistency of no-slump concrete are described in ACI 211.3, Guide for Selecting Proportions for No-Slump Concrete: (1) the Vebe apparatus; (2) the compacting-factor test; and (3) the Thaulow drop table. In the absence of the foregoing test equipment, a trial mixture placed and compacted with the equipment and procedures to be used on the site can be used to assess workability. Where durability is essential, intentionally entrained air is recommended for no slump concrete (Kosmatka, Kerkhoff, & Panarese, 2002). The amount of air-entraining admixture typically recommended for higher-slump concretes will not yield air contents as high as those in higher-slump concretes in no-slump concretes. The reduced volume of entrained air, on the other hand, often provides adequate durability for no-slump concretes; even if there isn't enough entrained air, there are enough microscopic air spaces. For no-slump concretes, this divergence from traditional ways of designing and managing entrained air is required.

**2.4 RESEARCH GAP**

While the preceding literature reviewed concepts and previously conducted studies, the researcher contends that these findings and results must be reconsidered in light of contemporary significance. Furthermore, to the best of the researcher's knowledge, there is little literature on quarry sand in Akampka. As a result, there is a need to push academic boundaries even further by leveraging this location.

**CHAPTER THREE**

**MATERIALS AND METHODS**

**3.1 PREAMBLE**

The focus of this chapter is to present the various materials assembled for this investigation and elucidate on the approach adopted to achieve the objectives of this study. The quarry dust samples were collected at different levels both vertically and horizontally to have a better representation of samples in a particular location. They were kept in polythene bags which were sealed to prevent moisture so as not to affect the natural conditions of the samples. The quarry dust used for this study were sourced locally from Akampka area of Cross River state.

**3.2 MATERIALS**

**Cement**

In the present study an ordinary Portland cement (OPC 53 grade) was used. The physical properties of the cement tested according to Nigeria standards procedure confirms to the requirements of **IS 10262**.

**Table 1. Physical properties of cement.**

|  |  |  |
| --- | --- | --- |
| S/NO | PROPERTIES | RESULTS OBTAINED |
| 1 | Specific gravity |  |
| 2 | Initial Setting Time (minutes) |  |
| 3 | Final Setting Time (minutes) |  |

**Fine aggregate**

The river sand conforming to zone I as per **IS-383-1987** was used for making reference concrete and its specific gravity was found to be ( ). The loose and compacted bulk density values of sand were ( ) kg/M3 and ( ) kg/M3 respectively.

**Table 2. Physical properties of fine aggregate.**

|  |  |  |
| --- | --- | --- |
| S/NO | PROPERTIES | RESULTS OBTAINED |
| 1 | Specific Gravity |  |
| 2 | Fineness Modulus |  |
| 3 | Water Absorption |  |
| 4 | Surface Texture | Smooth |
| 5 | Particle Shape | Rounded |

**Quarry dust**

The basic tests on quarry dust were conducted as per **IS-383-1987** and its specific gravity was around **2.5.** Wet sieving of quarry dust through a 90 micron sieve was found to be **87%**.

**Table 3. Physical properties of quarry dust.**

|  |  |  |
| --- | --- | --- |
| S/NO | PROPERTIES | RESULTS OBTAINED |
| 1 | Specific Gravity |  |
| 2 | Fineness Modulus |  |
| 3 | Water Absorption |  |
| 4 | Surface Texture | Rough |
| 5 | Particle Shape | Fine powder |

**Coarse Aggregate**

Crushed granite coarse aggregate conforming to **IS 383-1987** of size 12 mm and down having a specific gravity of **2.632** was used. The loose and compacted bulk density values of coarse aggregate were **1483 kg/M3** and **1680 kg/M3** respectively.

**Table 4. Physical properties of coarse aggregate.**

|  |  |  |
| --- | --- | --- |
| S/NO | PROPERTIES | RESULTS OBTAINED |
| 1 | Specific Gravity | 2.632 |
| 2 | Fineness Modulus | 6.86 |
| 3 | Water Absorption | 0.6 % |
| 4 | Surface Texture | Rough |
| 5 | Particle Shape | Angular |

**Water**

Water is an important ingredient of concrete as it initiates the chemical reaction with cement, and the mix water was completely free from chlorides and sulfates. Ordinary potable water was used throughout the investigation as well as for curing concrete specimens.

**3.3 CONCRETE TEST TYPES**

1. **Test on Fresh Concrete**

The test conducted on fresh properties of control concrete and concrete made with quarry dust and foundry sand with different percentages. The tests conducted for workability of concrete were slump test and compaction factor test, results are represented respective tables in the next chapter.

1. **Test On Hardened Concrete**

**bi. Flexural strength**

The tensile strength of concrete otherwise known as modulus of rupture is much smaller than the compressive strength and is in most cases usually effectively eliminated by cracking, whether the crack is visible or not. Consequently, the tensile strength of concrete is not usually taken into account for design purposes, though it can be important inasmuch as it influences and contributes to the flexural strength of concrete paving (Shetty, 2005).

**bii. Compressive strength**

is the capacity of a material or structure to withstand loads tending to reduce size. In other words, compressive strength resists compression.

**biii. Split tensile strength**

Splitting tensile strength is one of the parameters that controls the rate of reinforcement corrosion and also indicates the potential for an increase in the usefulness of the service life of concrete. Abdullah (2012) confirmed that improvement in split tensile strength results in an increase in the useful service life of concrete by decreasing cracks due to reinforcement corrosion.

**biv. Water absorption capacity**

This refers to the ability of material to absorb water when immersed in it and is represented with water absorbing capacity. The absorption tests are not used frequently except for routine quality control of precast products.

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