



**EFFECT OF IMPROPER CURING ON THE STRENGTH AND TRANSPORT  
PROPERTIES OF LOW GRADE RHA CONCRETES**

**BY**

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**CERTIFICATION**

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## **DEDICATION**

I dedicate this work to God Almighty, who has provided me with support in all facets of my life, including this program. I also dedicate this work to my parents, who have taken care of me, supported me along the way, and made sure I gave it everything I had to accomplish what I had started.

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God's blessings on you sir.

Last but not least, I want to express my appreciation to my classmates for helping to make my time at this institution both interesting and bearable. I wish for all of us luck in realizing our aspirations. Also, may peace be granted to the brothers and sisters we lost on the way.

## ABSTRACT

This project work was created in order to highlight and present the findings from a study on the "EFFECT OF IMPROPER CURING ON THE STRENGTH AND TRANSPORT PROPERTIES OF LOW GRADE RICE HUSK ASH (RHA) CONCRETE" with the goal of understanding how various curing techniques for 3, 7, 14 and 28 days affect the achievable compressive strength and other structural properties of a low grade concrete such as 20MPa having Ordinary Portland Cement (OPC) (an agriculturally based pozzolanic material, lying in abundance around the globe most times as waste, found suitable by researchers to partially replace OPC in the production of concrete).

After designing a low grade concrete mix with a goal mean strength of 20N/mm<sup>2</sup>, a number of concrete mixtures cast into 100mm metallic cubes were made in the lab using OPC as the binder (partially substituted with RHA at various percentages). In a fog/curing room with ambient temperatures between 30 and 20 °C and low relative humidity (RH), three different types of "curing methods" (a moisture management balancing act) were used for these samples. The first series of cubes cast after demoulding were fully submerged in water and cured at 100% RH for the duration of its curing period (signifying wet curing). The final set of cubes cast were completely cured out in open air without any water submerging after demoulding (signifying dry/air curing), while the other set of cubes stayed in water for 3 days after demoulding as well and then continued to cure for the remaining curing period at a relatively low humidity.

Therefore, performance was assessed in terms of compressive strength, transport properties, and other tests conducted. It was found that while the strength of RHA concrete continued to decline after the addition of 15% RHA, the replacement level of

5% RHA gave the strongest results overall and demonstrated the greatest potential to be used as a useful material for various building materials. The partial replacement of RHA with OPC can be seen to have a positive impact on the environment by reducing the amount of agricultural waste produced, which results in more cost-effective and environmentally friendly concretes than those currently used in the industry.

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## **NOMENCLATURE**

OPC	-	Ordinary Portland Cement
RHA	-	Rice Husk Ash
MPa	-	Mega Pascal
N/mm <sup>2</sup>	-	Newton per square millimeter
mm	-	Millimeter
RH	-	Relative Humidity
SCMs	-	Supplementary Cementitious Materials
ASTM	-	American Society for Testing and Materials
BS	-	British Standard
GGBS	-	Ground Granulated Blast Furnace Slag

## **CHAPTER ONE**

### **1.0 INTRODUCTION**

#### **1.1 Background of study**

In many nations around the world, particularly in Africa, the concrete mixture of sand, cement, and water is commonly employed for the construction of everyday constructions like buildings. Cement is a major cost factor for the most typical buildings in various areas of Nigeria. Due of the high and rising cost of cement, both urban and rural residents are unable to obtain suitable housing. Therefore, the availability of substitutes for these building materials is highly desirable in both the short and long terms as a catalyst for socioeconomic development. Particularly readily available locally sourced materials with pozzolanic qualities that may be used to complement sand and little to no cement in the short term, especially if they are less expensive, will be of significant interest. Pozzolan is a siliceous and aluminous substance that, when finely split from and in the presence of moisture, reacts with calcium hydroxide, which is released during the hydration of Portland cement at ordinary temperature, to generate compounds having cementitious characteristics, according to ASTM (618C2). Millions of tons of rice husk ash (RHA), an agricultural waste, are produced annually. Over the years, waste managers have struggled to dispose of this agro-waste. It has been discovered that rice husk ash (RHA), which is produced when rice husk is burned, is a hyper pozzolanic substance. RHA is a highly reactive pozzolanic substance that can be used to replace Portland cement in lime-pozzolan mixtures. Due to its non-crystalline silica content and unique surface, RHA is highly reactive with lime due to its high silicon dioxide content. This substance is essentially a super-pozzolan due to its high silica content, which ranges from 85% to 90%. Making "high performance concrete," which has a high workability and long-term durability, is a useful usage for this material.

This study will investigate a substitute substance that could completely or partially replace cement in a concrete mixture made with locally sourced fine and coarse

aggregate. Its goal is to determine the effect of improper curing on the strength and transport properties of low grade Rice Husk Ash (RHA) concrete.

## **1.2 STATEMENT OF PROBLEM**

In the days following construction, there have been reports of sporadic cracking in concrete pavements. Concrete curing is intimately tied to this issue. The curing of

concrete is one of many elements that affect concrete's strength. Concrete that is given a rapid drying time experiences significant early age drying shrinkage. One of the main causes of a weak, powdering surface with low resistance is improper or insufficient curing.

Concrete's permeability and absorptiveness both have an impact on how long it lasts. These are, in general, related to the concrete's porosity and the presence or absence of capillaries and pores. Although the quantity and size of pores and capillaries in cement paste are directly connected to the water-to-cement ratio, they are also proportional to how much curing has occurred. Water curing over time enables hydration products to partially or completely fill the pores and capillaries that are already present, which reduces the porosity of the paste.

In order to maximize the compressive strength and durability of concrete, the appropriate curing technique must also be identified.

### **1.3 AIM OF THE STUDY**

The main aim of this work is to investigate the effects of improper curing on the strength and transport properties of low grade rice husk ash (RHA) concretes at 0%, 5%, 10% and 15% RHA replacements.

#### **1.4 OBJECTIVES OF THE STUDY**

The objectives of this study are as follow:

- a....To examine the maximum compressive strength and durability of concrete cured in water bath and open air in the laboratory under room temperature
- b....To assess the improper curing methods by identifying the most suitable means of curing
- c....To achieve a relationship between methods of curing and compressive strength of concrete
- d....To compare the compressive strength of concrete made of grade 20MPa cement and Rice husk ash at different curing periods
- e....To analyze the permeability and durability of concrete made of 20MPa cement and Rice husk ash under the different curing methods.

### **1.5 SCOPE OF THE STUDY**

The scope of this research encompasses the following but not limited to;

- a. Rice husk ash (RHA) is ground to the smallest possible particle size in comparison to the OPC it is to partially replace.
- b. The degree of carefully regulated combustion carried out in the University of Benin's production workshop furnace is necessary to properly manufacture the right amount of rice husk aggregate (RHA), which can be mixed with cement to create concrete cubes.
- c. The mix design, employing all essential tables, charts, and figures, for a low-grade concrete with a target mean strength of 20N/mm<sup>2</sup>.
- d. Casting and curing of control samples with no RHA at the beginning.
- e. In order to achieve strength growth comparable to the control specimens requiring no replacement, multiple cement replacement percentages by weight with rice husk ash (RHA) were used.
- f. The numerous curing techniques used for varied curing times.
- g. Compressive strength of each cured cube, expressed in N/mm<sup>2</sup>.
- h. The test for water absorption on a fresh batch of 100mm cubes cast.

## **1.6 JUSTIFICATION OF THE STUDY**

Concrete's ability to acquire strength and durability is significantly influenced by curing. The current study examines how poor curing techniques affect low grade RHA concretes prepared with 20MPa cement in terms of their strength and transport qualities (Ordinary Portland Cement). It will assist us in determining the least effective and best ways to cure concrete under specific circumstances in order to maximize the concrete's compressive strength and durability.

## CHAPTER TWO

### 2.0 LITERATURE REVIEW

#### 2.1 RICE HUSK ASH (RHA)

The most crucial component of any construction and a material that is frequently utilized in the business is concrete. The choice of concrete is influenced by a number of variables, including the environment, energy usage, finances, and technical considerations. Therefore, concrete technology contributed to the creation of alternative building materials that may meet these requirements and are readily available locally in order to lower construction costs. For these objectives, a variety of materials are employed, including fly ash, silica fume, ground granulated blast furnace slag (GGBS), and rice husk ash (RHA). All of these substances fall under the category of pozzolanic or mineral admixtures. They are sometimes referred to as an additional cementitious material. Here, we'll talk about rice husk ash, its production process, characteristics, benefits, and drawbacks, as well as applications and how it affects the properties of concrete.

A by-product of agriculture, rice mills produce rice husk ash. The covering of rice seeds or grains is known as the "rice husk" or "rice hull." During the growth season, this layer shields the seed or grain. The husk transforms into hard substances like lignin and opaline silica. Rice husk contains significant amounts of silica when burned properly ( $\text{SiO}_2$ ). As a result, it can be utilized as an additional cementitious material along with cement to create concrete products. When paddy is milled, rice makes up 80% of the weight, while husk makes up 20% of the weight. Additionally, this husk can be utilized as fuel for the creation of steam or electricity, among other things. The globe produces roughly 649.7 million tons of rice annually, according to "Habeb et al" (Published in Materials Research). When paddy is milled, approximately 200kg (20%) of husk is

produced, and when this husk is burned in boilers, approximately 40kg (20%) of rice husk ash is created. Due to its close resemblance to silica fume or micro silica in terms of characteristics, RHA produces an excellent pozzolanic material. Therefore, employing RHA as a concrete admixture has a lot of potential.

### **2.1.1 Manufacturing Procedure of Rice Husk Ash**

About 75% of the material in rice husk is biological unstable stuff. During the burning process, the remaining 25% of the weight of this husk is transformed into ash. The name of this ash is "rice husk ash" (RHA). It also goes by the name "rice hull ash."

The maximum amorphous silica could be produced, according to "Fapohunda et al" (Published in International Journal of Sustainable Built Environment), by burning rice husk at temperatures between 500°C and 700°C.

An active pozzolana with numerous uses in the cement and concrete industries is rice husk ash. Because using RHA minimizes the need for cement and lowers the overall cost of producing concrete, it is less expensive. Reduced cement needs result in reduced environmental pollution from cement plants, which improves both the economy and the environment. They also offer a practical means to dispose of this agricultural waste product, which has few alternate uses.

### **2.1.2 Advantages of Rice Husk Ash**

- a) Because rice husk ash is a by-product, it aids in reducing environmental pollution and gives concrete strong compressive strength.
- b) It is an excellent supplemental cementitious material or pozzolanic additive because to the high silica concentration.
- c) Concrete containing rice husk ash has a density that is comparable to regular weight concrete, making it suitable for general-purpose applications as well.

- d) Rice husk ash concrete offers superior resistance to sulphate attack, chloride intrusion, carbonation, etc. because of its impermeable microstructure.
- e) Rice husk concrete boosts concrete durability by having good shrinkage properties.

### **2.1.3 Disadvantages of Rice Husk Ash**

- a) The usage of rice husk ash causes concrete to become increasingly impractical. In order to create concrete that is workable for placement and compaction, water-reducing admixtures should be employed.

### **2.1.4 Uses of Rice Husk Ash**

The main uses of rice husk ash are as follows:

- a) Rice husk ash is used to make high-performance concrete.
- b) Rice husk ash is used as an insulator.

Rice husk ash is also used in:

- a) In a ceramic glaze
- b) In roofing shingles
- c) In waterproofing chemicals
- d) In oil spill absorbents
- e) In special paints
- f) Flame retardants
- g) In insecticides and bio-fertilizers etc.

### **2.1.5 Chemical Properties of Rice Husk Ash**

- a)  $\text{SiO}_2$ : 78–86
- b)  $\text{Al}_2\text{O}_3$ : 1–2.0
- c)  $\text{Fe}_2\text{O}_3$ : 16–1.85

- d) CaO: 55–4.81
- e) MgO: 35–4.5
- f) SO<sub>3</sub>: 24–1.18
- g) Na<sub>2</sub>O: 1–1.14
- h) K<sub>2</sub>O: 54–3.68
- i) Loss in ignition: 4–8.55

### 2.1.6 Physical Properties of Rice Husk Ash

The physical properties of rice husk ash vary depending on the temperature of burning and grinding of the rice husk.

- a) Colour: Grey
- b) Specific Gravity: 05-2.53
- c) Specific Surface Area: 40-100 m<sup>2</sup>/g
- d) Bulk Density: 200-300 kg/m<sup>3</sup>

### 2.1.7 Effect of Rice Husk Ash on the Properties of Concrete

- a) **Concrete setting time:** In order to examine the behavior of concrete containing RHA for both the initial and final setting times, "Namrata Verma et al." (Published in International Journal of Engineering Research & Technology (IJERT)) did an experiment. They came to the conclusion that as the RHA content is increased, the initial setting time of RHA concrete increases and the ultimate setting time reduces. The slow rate of hydration in the RHA-containing paste may be the cause of this behaviour.
- b) **Workability:** According to "Mehta P.K." (Published in Proceedings of the CANMET/ACI International Symposium on Advances in Concrete Technology), lower is the workability of new concrete mix the higher the percentage

replacement of cement with RHA. However, the application of water reducers or super plasticizers might make the concrete more workable.

- c) **Strength:** Rice husk ash concrete strengthens the concrete's compressive strength. Tests were conducted by "Syed Mehdi Abbas et al" (published in International Journal of Scientific & Engineering Research) to determine the appropriate RHA replacement amount with Ordinary Portland cement in order to maximize concrete's compressive strength. They replaced RHA at 5%, 10%, and 15% with OPC when casting concrete cubes, and they found that the concrete with 10% rice husk ash had the highest compressive strength. It is due to amorphous silica and the rice husk ash's small particle size.
- d) **Permeability and Chemical Stability:** The most crucial element affecting concrete's longevity is its resistance to the penetration of chlorides and other chemicals. The pozzolanic effect of rice hull ash in concrete is imparted. It produces additional C-S-H gel and significantly reduces the amount of calcium hydroxide. As a result, the concrete matrix is strengthened and made more solid, which reduces concrete permeability and increases resistance to the penetration of chlorides and other chemicals.

### **2.1.8 How to Use Rice Husk Ash?**

There are two methods for using rice husk ash in the concrete.

- a) It is possible to combine the rice husk ash with regular Portland cement.
- b) Rice husk ash can be used in place of ordinary Portland cement to a specific extent.

The results of the numerous experimental investigations showed that using rice husk ash as a partial replacement for cement increases the concrete's compressive strength. By the weight of cement, the replacement percentage for rice husk ash ranges from 5% to 30%. Additionally, adding by-products like rice husk ash to concrete increases its quality, lowers pollution, and lowers construction costs. It has been shown to be an effective way for disposing of vast amounts of waste that would otherwise harm the land, air, and water. To strengthen the strength of concrete, it can be added to the cement at a weight percentage of 5 to 30%. Consequently, it is a green product that also saves money.

### **2.1.9 Rice Husk Ash as a Supplementary Binder**

The rice husk ash has good reactivity when used as a partial substitute for cement. These are prominent in countries where the rice production is abundant. The properly rice husk ashes are found to be active within the cement paste. So, the use and practical application of rice husk ash for concrete manufacturing are important.

### **2.1.10 The Burning of Rice Husk**

The kind of burning procedure used has a significant impact on the quality of rice husk. Burning is done in a variety of ways, some of which are listed below:

#### **a) Open - Field Burning**

Poor grade rice husk ashes are produced by this process of open burning rice husk ash. These result in highly crystalline, less reactive form structures.

#### **b) Fluidized -Bed Furnace Burning**

This process of burning rice husk is controlled. Electricity is produced using the heat from the combustion of rice husk. By keeping the time-temperature parameter constant, the controlled operation is carried out. a burning temperature of 500° to 700°C. This is done for a longer period of time to ensure that all of the carbon is removed. Alternately, the temperature is raised from 700 to 800oC for a minute. Rice husk ashes made by the

fluidized bed furnace process include 80–95% silicon dioxide, 1%–2% potassium dioxide, and 3–18% unburned carbon. This approach results in rice husk ash that has a more complex cellular structure.

#### **c) Industrial Furnace**

This approach is suggested for economic and environmental reasons. The amount of silica dioxide produced by combustion would be between 90 and 95%. This technique makes it simpler to produce rice husk ashes with amorphous silica and cellular structure products. This process results in extremely pozzolanic rice husk ash.

### **2.1.11 Variation of Properties of Concrete with Rice Husk**

Concrete becomes a more environmentally friendly additional cementitious ingredient when rice husk ash is added to it. With the inclusion of rice husk, the following characteristics of the concrete are changed:

- a) Hydration produces less heat: This alone aids in drying shrinkage and enhances the concrete mix's durability.
- b) The decrease in the concrete structure's permeability: This will aid in the penetration of chloride ions and prevent the structure's concrete from disintegrating.
- c) The resistance to chloride and sulfate attack increases further.
- d) The calcium hydroxide and rice husk ashes in the concrete react to produce additional hydration products. Calcium hydroxide usage will reduce the reactivity of chemicals from the environment.

### **2.1.12 Applications of Rice Husk Ash**

Ash from rice husks is a green additive that can be used on a small- to large-scale. It has waterproofing use. It is additionally added to concrete as an additive to make it resistant

to chemical penetration. The following are the principal uses of rice husk ash in construction:

- a) Ultra-efficient Concrete
- b) Insulator
- c) Green concrete
- d) Bathroom floors
- e) Industrial factory floorings
- f) Concreting the foundation
- g) Swimming pools
- h) Waterproofing and rehabilitation

## **2.2 CEMENT**

Neville claims that it can be classified as a substance having adhesive characteristics capable of joining mineral fragments into a compact whole. Additionally, cement is only utilized as a bonding agent with stones, sand, bricks, and building blocks in construction. Since the main component of cement is a compound of lime, calcareous cement is what we are most interested in when constructing concrete since it has high setting and interest under water due to a chemical reaction with it. Cement may be divided into two categories: natural cement and artificial cement.

### **2.2.1 CEMENT CONSTITUENCY OF CONCRETE PARTIALLY REPLACED WITH RHA**

It is a cement-based combination with certain amounts of rice husk ash, sand, granite, and water that, when set in forms and given time to cure, hardens into stone. The chemical reaction between the cement and water is what causes the hardening. Additionally, the cement and water combine to create a paste that, when it hardens, fuses the aggregates into a continuous mass.

## **2.2.2 TYPES OF CEMENT**

### **PORTLAND CEMENT**

#### **a) Ordinary Portland cement**

This cement, which has a moderate rate of strength development and heat generation, is by far the most widely used. It also resists dry shrinkage and cracking adequately, but it is less resistant to chemicals.

#### **b) Modified Portland cement**

When this cement sets, it produces more hydration heat than regular Portland cement. Due to the reduced heat of hydration it had, it can be used in hot areas and for the building of massive abutments and retaining walls when sulphate content is not high.

#### **c) Rapid Hardening Portland cement**

This has a high concentration of lime and other Portland cement-related ingredients. It is made with greater care and burned at a higher temperature than regular Portland cement. Additionally, the curing time is shorter and lighter than that of regular Portland cement, which is employed when a quick increase in strength is necessary.

## **2.2.3 CEMENT PRODUCTION PROCESSES**

The main steps in making cement are grinding the raw materials, which are calcareous and argillaceous stones that contain silica, alumina, and iron oxide, mixing them thoroughly in a specific ratio, and then burning the mixture at a temperature of between 1300 and 1900 degrees Celsius until the material sinters and partially fuses into balls known as clinker. The outcome is the commercial Portland cement that is so commonly used around the world. The clinker is cooled and ground to a fine powder with some gypsum added. Portland cement is produced using two different techniques: wet processes and dry processes.

## **2.2.4 WET PROCESS**

### **a) Collection of raw materials**

Calcareous substances Stones like limestone, marl, and chalk are quarried using blasting. Clay state or other argillaceous material is delivered to the location via dumping trucks or wire ropeways.

### **b) Crushing, grinding and mixing of raw materials**

In a wash mill, a circular pit with rotating radial arms bearing rakes that break up the solid matter lumps, chalk is employed and is finely broken up depressed in water. The clay is likewise broken up, and after mixing in a predetermined proportion and passing through a number of screens, the two mixes are pumped together. The resulting cement slurry, which has a water content of between 35 and 45 percent and has a creamy consistency, flows into storage tanks. The slurry is typically kept in several storage tanks, where sedimentation of the suspended solid is prevented by mechanical stirrers or bubbling by compressed air. The slurry then moves into silos where the proportioning is precisely adjusted to ensure the correct chemical composition before being pumped into the kilns.

### **c) Burning**

A minor gradient was created in the fine slurry that was injected into the rotary kiln's higher end. The rotary kiln is an enormous steel cylinder with refractory lining that can be up to 4 meters in diameter and up to 150 meters long. It rotates slowly about its axis. The coal used must not have a high ash content; occasionally, oil and gas are used in place of coal. The slurry is fed at the upper end of the kiln, while pulverized coal is flung in the air by blast at the bottom end, where the temperature reaches 1400 to 1500 degrees centigrade.

### **2.2.5 DRY PROCESS**

The materials are crushed and fed into a grinding mill in the proper amounts for the dry or semi-dry operations, where they are dried and shrunk down to a fine powder. The raw meal, which is a dry powder, is then pumped to a blending silo, where the amount of the ingredients needed to make cement is finely adjusted. The raw meal is blended to create a consistent final product, typically using compressed air to transport the powder higher and reduce apparent density. One quadrant of the silo is pumped with air at a time, allowing the supposedly heavier contents from the unsaturated quadrant to escape. The mixture created by evenly aerating each quadrant for a total of around an hour has a tendency to act almost like a liquid. This is achieved in some work through the use of continuous blending. Now that the meal has been blended, it is sieved and put into a spinning dish called a granulator, where water that makes up roughly 12% of the meal is added simultaneously. In this way, a rigid pallet with a diameter of 1.25 cm is created. This is crucial because feed fed directly into a kiln would not allow for the air flow and heat exchange required for the chemical processes that result in cement clinker production. In a pre-heating grate, the pallets are hard baked using hot gases from the kiln. The next steps are the same as those in the wet phase of manufacturing after the pallets enter the kiln. The dry process kiln is much smaller and requires much less heat because only about 12% of the moisture needs to be driven off since additional heat has already been used to remove the original moisture content of the raw materials. In contrast, the moisture content of the pallets is only 12% as opposed to the 40% moisture content of slurry used in the wet process.

### **2.2.6 CHEMICAL COMPOSITION OF CEMENT**

The following principal chemicals are found in cement.

S/N	Compounds	Abbreviation	Common Proportion
1.	Tricalcium Silicate ( $3\text{CaOSiO}_2$ )	$\text{C}_3\text{S}$	40%
2.	Dicalcium Silicate ( $2\text{CaOSiO}_2$ )	$\text{O}_2\text{S}$	32%
3.	Tricalcium Aluminate ( $3\text{CaOAl}_2\text{O}_3$ )	$\text{C}_3\text{A}$	10.5%
4.	Tetracalcium Aluminate ferrite ( $4\text{CaOAl}_2\text{O}_3\text{Fe}_2\text{O}_3$ )	$\text{C}_4\text{AF}$	9%

**TABLE 2.1 Chemical composition of cement**

The properties of the compound are discussed below:-

**a) Tricalcium Silicate ( $\text{C}_3\text{S}$ )**

It produces heat more quickly.

It hydrates quicker.

Its resistance to chemical attack is lower.

It grows strong early on.

**b) Dicalcium silicate ( $\text{C}_2\text{S}$ )**

It gives the cement absolute strength.

It provides greater protection against chemical attack

It is slower to harden

Hydrates gradually

**c) Tricalcium Aluminate ( $\text{C}_3\text{A}$ )**

Vulnerable to sulphate attacks

Reacts quickly and produces a lot of heat

It doesn't aid in gaining strength.

**d) Tetra calcium Aluminate ferrite ( $\text{C}_4\text{AF}$ )**

Unsatisfactory cement value

Reacts slowly and produces little heat

Comparatively Dormant

### **2.2.7 HYDRATION OF CEMENT**

It is a chemical process that occurs when cement and water are combined. When cement is mixed with water (ranging from 25% to 35% by weight), a stiff and sticky paste forms that initially retains its flexibility for a brief length of time before becoming still owing to early hydration of the cement. The process by which the plastic cement paste that has been fully set gains strength is referred to as cement hardening.

### **2.2.8 HEAT OF HYDRATION**

Additionally, cement sets and hardens as it reacts with water, creating heat in the process. The ratios of the various cement compounds have an impact on how quickly cement sets and hardens, how quickly heat evolves, and how resistant cement is to sulfate attack.

### **2.2.9 EFFECT OF HYDRATION OF STRENGTH OF HARDENED CONCRETE**

The amount of time that the form work should be left in place before being loaded onto the structure depends on how quickly cement hardens.

### **2.2.10 WATER REQUIREMENT OF HYDRATION**

Cement when mixed with water formed a still and sticky paste and hardens. According to Shetty (2005), it has been said earlier that calcium hydroxide ( $C_3S$ ) requires 24% of water by weight of cement and  $C_2S$  requires 21% and also estimated that on an average 23% of water by weight of cement is required. For chemical reaction with Portland cement compounds. This 23% of water chemically combines with cements and certain

quantity of water is received and retain within the gel pores. Therefore, if the quantity of water is inadequate to fill up the gel pores, the formations of gel itself will stop and if the formation of gel stops, there, is no question of gel pores being present. It can be seen that the capillary cavities grew larger with increasing water cement ratio and the cement particle are closer together with reduced water cement ratio when more than 38% of water is used. If more than 38% of water is used, the excess water will generate undesired capillary cavities. When the amount of hydrous cement has increased during the hydration process, the results of hydration have also increased. Upon a water cement ratio of 0.6, the volume increase of the gel due to complete hydration could fill the space previously occupied by water. However, if the water cement ratio is higher than 0.7, the volume increase of the hydrated product would never be enough to fill the voids created by water, clearing such concrete with a porous mass. According to estimates, the volume of gel would be around twice that of anhydrite cement.

### **2.3 AGGREGATES**

The most crucial component of concrete is aggregate. The body of mortar and concrete is composed of a mixture of stones of various sizes that have been graded so that the smaller stones perfectly fit between the larger ones and leave no gaps or holes in the mass. Aggregate for a good concrete mix aggregate need to be clean, hard, strong particles of absorbed or coating of clay and other fine materials that would cause the deterioration of concrete. Inert granular materials such as sand and gravel, or crushed stone that along with water and Portland cement (RHA replacement) are as essential ingredient in concrete. The light weight, heavy weight, and normal weight aggregates are the most typical categories for aggregates based on the fundamentals of bulk specific gravity. Lightweight concrete comprises natural or synthetic aggregates that weigh less than 1.100 kg/m<sup>3</sup>, and heavyweight concrete has natural or synthetic aggregates that

weigh more than 2080 kg/m<sup>3</sup>. However, normal weight concrete contains aggregates that weigh between 520 and 1,680 kg/m<sup>3</sup>.

These normal weights are further classified as natural and artificial aggregate:

Natural	Artificial
Sand, gravel crushed	Broken Brick
Rock such as granite	Air cooled slag
Quartzite, basalt	Sintered Fly Ash
Sand stone	Bloated clay

**TABLE 2.2: Classification of normal weight aggregates**

### **2.3.1 CLASSIFICATION AND SOURCE OF AGGREGATES**

#### **Classification of aggregates according size**

According to their size, aggregates are divided into two categories: coarse aggregates and fine aggregates. These aggregates make up between 60 and 75 percent of the overall volume of concrete. The majority of the particles in fine aggregates usually pass through a 3/8-inch (9.5mm) sieve and are often made of natural sand or crushed stone. Any particle larger than 0.19 inches (4.75 mm) is considered a coarse aggregate, which typically has a diameter between 3/8 and 1.5 inches (9.5 mm to 7.5 mm). Natural gravel and sand are typically extracted or dredged from a pit, river, lake, or sea bed. Gravels make up the bulk of the coarse aggregate used in concrete while crushed stone makes up the majority of the remaining amount. By crushing quarry rock, boulders, cobbles, or big amounts of gravel, crushed aggregate is created. Recycled concrete has been successfully used in granular sub-bases, cement, and fresh concrete, making it a viable source of aggregate. In order to achieve suitable clean lines and gradation, aggregates are crushed, screened, and washed. If more improvement is required, a benefaction procedure like jigging or heavy media separation can be performed. After processing, the aggregates are

handled and stored in a way that reduces segregation and degradation and guards against contamination. Aggregates have a significant impact on the economy, mixture proportions, and qualities of freshly mixed and hardened concrete.

### **Particles Shape and Texture**

Concrete's characteristics can be impacted by aggregate shape and surface roughness in both its plastic and hardened phases. By seeing the aggregate particles and classifying their shape and texture in accordance with the table below from BS 812: part 1 1975, these exterior properties may be evaluated.

Classification	Description	Examples
Rounded	Fully Water-worn or completely shaped by attrition	River, or sea shore, gravel, dessert, sea shore and wind worn sand
Irregular	Naturally, irregular or partly shaped and by attention and having rounded edges	Other gravel, land or dug flint
Flaky	Material of which the thickness is small relative to the other two dimensions	Laminated next (e.g, Slate & schist)
Angular	Processing well defined edge formed at the intersection of roughly planer faces	Crushed rocks of all types
Elongated	Material usually angular in which the length is considerably longer than the other two dimensions	Crushed rocks of all types

Flaky and Elongated	Material, having the length considerably larger than the width and the width considerably larger than the thickness	
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**TABLE 2.3: Classification of aggregate particles shape, size and texture**

When it comes to crushed aggregate, the type of parent material, the type of crusher, and the reduction ratio between the size of the materials fed into the crusher and the size of the finished product all affect how the particles are shaped. The sphericity of the aggregate, which is determined by the relationship between the surface area of the particles and its volume sphericity, is another feature of its shape. When the size of the particles has been artificially reduced, this is affected by the type of crushing machinery. It is important to emphasize that the texture of aggregates depends on how polished, dull, smooth, or rough the surface of the particles is.

### **2.3.2 CONDITIONS OF AGGREGATES**

#### **a) Cleanliness**

When used with soft particles, aggregates need to be relatively clean; clay lumps, excessive dust, and vegetable matter should not be present because they often influence performance by deteriorating quickly, leading to a hole in the structural support and preventing binder aggregate bonding. Sand equivalent testing, clay slump testing, and friable particle testing are related tests that can be performed.

#### **b) Soundness of Aggregate**

Shetty defines soundness as an aggregate's capacity to withstand excessive volume variations brought on by modifications in the external environment. The freezing is one of these natural phenomena that has an impact on collective soundness. Alternate wetting and drying under typical conditions and wetting and drying in saturated water are caused

by the thawing temperature change. Unsound aggregates are those that experience a volume change greater than the allowed threshold.

### **2.3.3 UNWANTED MATERIALS IN AGGREGATES**

#### **Clay and Silt**

In addition to weak bond qualities, excessive silt and clay in the fine or coarse aggregate can occasionally cause shrinkage or permeability. Increased water requirements are necessary for the given workability due to the excessive use of silt and clay. The sedimentation process, which mostly depends on the caliber of cement paste, affects the amount of clay, fine silt, and fine dust. The bond between the cement paste and the aggregate also affects its strength. No matter how strong the rock or aggregate, if the paste's strength or the bond between it and the aggregate is weak, poor-quality concrete will be formed; nevertheless, when good-quality cement paste is produced, the bond between the paste and the aggregate will be sufficient. The strength of concrete will then depend on the mechanical characteristics of the rock or material. As a result, it is clear that while strong aggregate cannot be used to create concrete, strong aggregate are a necessary component. This simply indicates that strong concrete can be manufactured from a weak rock or aggregate, therefore naturally occurring mineral aggregate are strong enough to make standard strength concrete. It is necessary to do the aggregate strength test in the following circumstances:

- a) For the manufacturing of concrete with a high and ultra-high strength.
- b) When thinking about using aggregate made from weathered rocks.
- c) When considering the use of weathered rock aggregate.

### **2.3.4 AGGREGATE CRUSHING VALUE**

As previously stated, the compressive strength of the aggregate is made by using a sample of bulk aggregate in a standardized manner. It is discovered that different rock samples give different compressive strengths that range from a minimum of around 45Mpa to a high of 545Mpa. The aggregate crushing value test is the name of this procedure. It provides a comparative assessment of an aggregate sample's resistance to crushing under a gradually increased compressive load. Cylindrical measure and plunger, a compression testing machine, and sieves in the diameters of 12.5 mm, 10 mm, and 2.36 mm are the apparatuses employed.

### **Weight and Moisture content characteristics**

The regulation of concrete quality, particularly with regard to workability and strength, depends heavily on the weight and moisture content of the aggregate. Although measuring the moisture content of aggregates is essentially a pretty straightforward process, there are a number of aspects that make it more difficult. Depending on the porosity of the material, the aggregate will absorb a specific amount of water. This water content can be expressed in terms of the weight of the material when it is completely dry, surface dry, or wet. It is also known as free water or water held on the surface of the material. The total water content includes both the absorbed water and the free water or the water held in the interior portion of the aggregate particles.

### **2.4 WATER**

Water used in concrete facilitates mixing, pouring, and compacting of the new concrete in addition to causing cement and cement-cement reaction to set and harden concrete. Additionally, it is used to wash the aggregate and cure things. It is crucial to understand how water content affects the characteristics of first-stage hardened concrete. Concrete can be mixed with any water that is safe for drinking, such as top water. The impurities, such as silt, clay, acids, alkalis, and other salts, organic matter, and selva, that are

likely to have a negative impact when present in sizable numbers. The use of sea water appears to have no negative effects on the strength and longevity of cement concrete made with pot lands, but it is known to cause staining, efflorescence, and coarse surface dam prices, so it should be avoided. Sea water also raises the danger of reinforced concrete, thus it is not advised. Testing for both the type and level of contamination is preferred when the suitability of mixing water is in issue. The setting time and soundness of cement pastes created with water of known quality and water whose quality is dubious can both be used to determine the water's quality. If dangerous elements are left on the surface of the partials after washing aggregate with refining water, this can have a negative impact on the partials' strength and durability. Although it could ruin the appearance of concrete, the presence of contaminants in water often has no negative impact. Avoid drinking water that contains significant amounts of acid or organic compounds. Testing for both the type and level of contamination is preferred when the suitability of mixing water is in issue. The setting time and soundness of cement pastes created with water of known quality and water whose quality is dubious can both be used to determine the water's quality. If dangerous compounds are left on the surface of the aggregate particles after washing them with unclean water, this could have a negative impact on their strength and durability. Although it could ruin the appearance of concrete, the presence of contaminants in water often has no negative impact. Avoid drinking water that contains significant amounts of acid or organic compounds.

## **2.5 ADMIXTURES**

Admixtures, according to (Bresler, 1974), are compounds added to concrete mixtures to change, enhance, or improve the qualities of the freshly mixed concrete, the hardened

concrete, or both. In general, these changes are impacted by the admixtures' effects on hydration, heat release, pore creation, and gel structure development. Only when the required alterations cannot be made by changing the composition and proportion of the basic constituent materials, or where the admixtures may more efficiently create the desired effects, can the use of concrete admixtures be considered. Since admixtures could have negative consequences, it is important to thoroughly consider if they are appropriate for a certain concrete before using them. This can be done by understanding their primary active ingredients, consulting performance data, and using test mixes.

### **2.5.1 TYPES OF ADMIXTURES**

According to the ACI committee 212 report, admixtures have been divided into 15 classes based on the kind of materials that make them up. (Shelty2005)

- a) Plasticizers
- b) Super plasticizers
- c) Retarders and retarding plasticizers
- d) Accelerators and accelerating plasticizers

When added to the mixture, the surfactants in the water reducing and retarding admixture are absorbed onto the surface of the cement particles. As a result, the cement particles become charged, which prevents flocculation. The water that is so released increases the surface area of cement that is available for rapid hydration, improving workability.

### **2.5.2 RETARDERS OR (RETARDING PLASTICIZERS)**

When working periods are shortened due to elevated ambient temperatures beyond what is reasonably possible for routine installation and finishing operations, this is employed to slow the first set of concrete. Retarders function best to offset unintentional working

time acceleration brought on by temperature fluctuations, cement hardening, or other adverse impacts of admixtures.

### **2.5.3 ACCELERATORS**

Accelerating admixtures are frequently used in pre-stressed or precast applications, where delays cause customers or precasters to incur significant costs and inconveniences, to speed up normal set times in order to provide the earliest service that would be possible with an unaccelerated mix design.

#### **2.5.3.1 ENTRAINING ADMIXTURES**

Air-entraining agents are offered as cement that has been already been mixed with air (air-entraining cement) or as an additive whose addition can be customized for each batch. These chemicals give the paste incredibly tiny, evenly spaced air bubbles that are necessary for design. In the cured mix, they serve as localized stress reducers.

#### **2.5.3.2 AIR-ENTRAINING AGENTS**

##### **A. Some of the air-entraining agents are as follows:**

- a) Natural wood resins
- b) Animal and vegetable fats and oils
- c) Water soluble soaps of resin acids, and animal and vegetable fatty acids

##### **B. Factors affecting the amount of air-entraining**

The following are the variables that determine the quantity of air-entrainment:

- a) The type and quantity of air entraining agent used
- b) The water/cement ratio of the mix
- c) Type and grading of aggregates IV
- d) Mixing time
- e) The temperature
- f) Type of cement

- g) Influence of compaction
- h) Admixtures other than air-entraining agent used

### **C. Effect of air entrainment on the properties of concrete**

The following concrete properties will be impacted by air entrainment:

#### **a) On workability**

The ability of air-entrained concrete to place leads in more homogeneous concrete with less segregation and bleeding, which improves workability without sacrificing strength. Concrete containing entrained air is more pliable and fatty and may be handled more readily than regular concrete. The volume of air entrained, the richness of the mix, and the type of air engraining agent utilized are the three variables that determine how air entertainment affects strength. According to the findings of Cordon's tests on the impact of air entrainment on the compressive strength of concrete, the strength of concrete uniformly declines as the amount of air in fresh concrete increases.

#### **b) On Segregation and bleeding**

By incorporating a system of air bubbles, which buoy the aggregates and cement and thereby slow the rate at which sedimentation occurs in freshly placed concrete, air entrainment significantly reduces segregation and bleeding. It also reduces the effective area through which the differential movement of water may occur. These actions are likely the result of physical phenomena.

#### **c) On permeability**

The following factors affect concrete's permeability:

- a) Due to its higher workability, concrete with entrained air has a greater degree of uniformity
- b) Concrete's air-entrained pore structure has been modified.
- c) Water channel narrowing as a result of less bleeding

- d) On sand and Cement content
- e) A study by Blanks and Cordon demonstrates that if air was entrained, it was possible to lower the cement content for mass concrete work.

#### **D. Optimum Air content in Concrete**

The following factors determine the acceptable air content in a particular concrete mixture:

- a) The use of the concrete, its location, and the weather conditions
- b) The largest possible aggregate size
- c) The mixture's richness
- d) The optimum air content is between 3% and 6%.

#### **E. Measurement of air content**

Due to its impact on the many qualities of concrete, such as how much air results in low strength and how little results in inadequate workability, the measurement of air content in concrete is of utmost importance. When determining the air content of new concrete, there are three basic methods employed. These are what they are:

- a) Grametric method
- b) Volumetric method
- c) Pressure method

## **2.6 CONCRETE**

### **2.6.1 PROCESS OF MANUFACTURE OF CONCRETE**

At every stage of the concrete manufacturing process, careful consideration must be exercised to produce excellent concrete. It's noteworthy to note that both good and terrible concrete include the same components. Concrete produced without exercising painstaking care and following appropriate guidelines won't be of high quality. If

extreme care is taken to exercise control at every stage while using the same material, good concrete will be produced. We must therefore be aware of the good guidelines to be followed at each stage of the creation of high-quality concrete. The various phases of concrete production are as follows:

- a) Batching
- b) Mixing
- c) Transporting
- d) Placing
- e) Compacting
- f) Curing
- g) Finishing

### **2.6.2 SETTING TIME OF CONCRETE**

The time it takes for concrete to set is significantly different from the time it takes for cement to set and is not the same as the time it takes for the cement used to make the concrete. The water/cement ratio, temperature, cement type, mineral additive use, and plasticizer use all affect how quickly concrete sets.

### **2.6.3 COMPACTION OF CONCRETE**

The method used to release the trapped air from concrete is called compaction.

#### **a) Hand compaction**

When a significant amount of reinforcement is utilized, which cannot often be compacted mechanically, this sort of compaction is used. It is also used in a small-scale concrete project. Roding, ramming, or tamping are the methods used for hand compaction.

### **b) Compaction by vibration**

This method of compacting concrete vibration basically entails releasing trapped air and pushing the particles into a more compact arrangement. Utilizing mechanically driven vibrating apparatus, such as a plate vibrator, table vibrator, electric needle vibrator, and needle vibrator (petrol).

### **c) Duration of vibration**

The height of the layer, the size and properties of the vibrator, and the workability of the concrete mix all affect how long vibration lasts in each insertion location. The vibrator head must remain stationary until the concrete under its influence has fully solidified, which will be demonstrated by the production of a circular cement grout on the concrete's surface, the appearance of a flattened gliding surface, and the cessation of the rise of trapped air. The coarse aggregate particles must be vibrated continuously until they have merged with the surface but have not vanished.

## **2.6.4 FINISHING OF CONCRETE**

The duration of vibration in each insertion position depends on the layer height, the size and characteristics of the vibrator, and the workability of the concrete mix. The vibrator head must stay still until the concrete it is affecting has entirely solidified, which will be visible as the appearance of a flattened gliding surface, the stoppage of trapped air rising, and the formation of a circular cement grout on the concrete's surface. It is necessary to constantly vibrate the coarse aggregate particles until they have blended with the surface but have not disappeared.

### **Surface Treatment**

One of the popular techniques for surface polishing is this one. The concrete pavement slab, like the ones on roads and airfields, must be level but rough to demonstrate skid resistance.

These guidelines should be followed in order to get a nice surface finish on concrete:

- a) The composition of the dead should resemble that of concrete.
- b) Before the base concrete is firm and scraped smooth, a thin coating should be applied.
- c) Dry cement should not be sprinkled on top of good characteristics; nevertheless, a tiny amount may be allowed to lessen the negative effects of bleeding.

### **2.6.5 REQUIREMENTS OF A GOOD FINISH**

The surface of a good concrete floor should be resilient, non-absorptive, the right texture, free of cracks, crazing, and other flaws. It should be easy to clean, slip-resistant, and have a texture that matches the desired appearance.

### **2.6.6 CURING OF CONCRETE**

In order to properly cure concrete, it must be kept moist and warm enough for cement to continue to hydrate until the desired qualities have been produced to the point where they are ready for use. The amount and pace of hydration of the binder paste are determined by curing, with some blenders being particularly sensitive to curing. The final strength of concrete increases with the length of time it is submerged in water.

#### **Duration of curing**

However, AC1308-92 specifies a minimum of 3 days for rapid-hardening Portland cement (type II) and a minimum of 7 days for conventional Portland cement (type 1) if the temperature is over 10 degrees. However, the needed curing time is also influenced by the temperature. According to Shetty (2005), the duration should be as long as practical or must be cured until it reaches roughly 70% of the specified strength because all the beneficial qualities of concrete are improved by curing.

### **2.6.7 PROPERTIES OF HARDENED CONCRETE**

**a) Water / cement ratio**

The strength of concrete depends on the strength of cement paste, which in turn depends on the dilution of the paste, in accordance with Neville's (2010) water-to-cement ratio law, which stipulates that the ratio only matters if the mixture is workable.

**b) Effective water in mix**

When paste has more cement, it is stronger; when it contains more air or water, it is weaker.

**c) The gel/space ration**

This is the proportion between the volume of the cement gel and the total volume of the capillary pores. It is possible to use it to calculate the bare minimum water-to-cement ratios needed for the cement gel to fill the available area.

**d) Porosity**

This is dependent on the water to cement ratio and hydration level. It can be characterized as the proportion between the entire volume of cement paste and the sum of the volumes of the capillary pores and gel pores.

**e) Effect of the maximum size of aggregate**

Large maximum size aggregate reduces the surface area available for the formation of gel bonds and increases heterogeneity in the concrete, preventing a uniform distribution of load under stress. These factors reduce the concrete's strength.

**f) Effect of aggregate/cement ratio**

A leaner mix (a mix with a high aggregate/cement ratio) has been proven to lead to high strength of the concrete.

## **2.6.8 CHARACTERISTICS OF CONCRETE STRENGTH**

**a) Gain of strength with age**

Concrete gets stronger as it keeps getting wet. The rate of strength development is initially rapid but slows with aging; the strength at 28 days is typically taken to be the maximum strength of concrete.

**b) Maturity concept of concrete**

Strength is a function of the sum of the products of time and temperature since the growth of concrete's strength depends on both time and temperature. Concrete maturity is what is meant by this summary. Adulthood = E (time X temperature). Shetty (2005). (2005).

**c) The relationship between compressive and tensile strength**

The ratio of the two strengths depends on the overall degree of concrete strength; there is a close relationship between them but no direct correspondence. The higher the compressive strength, the lower the tensile strength to compressive strength ratio typically is.

**d) Bond strength**

Friction and adhesion play a major role in how strong the bond is between the steel reinforcement and the concrete. Steel and concrete characteristics, as well as relative movements brought on by volume changes, all have an impact on the bond (e. g. shrinkage of concrete).

## **2.6.8 THE TENSILE STRENGTH OF CONCRETE**

### **A. Aggregate-cement bond**

The strength of concrete is significantly influenced by the aggregate's form and surface texture. Greater adhesion or bonding between the particles and the cement matrix is the result of a rough texture. Softer, porous, and mineralogically diverse particles bond better

because they generally have better textural features that allow the paste to penetrate their surfaces. Neville (1987). (1987).

### **B. Micro-cracking**

This is a reference to tiny bond cracks that form where coarse aggregate and hydrate cement paste meet. Due to differences in volume changes between the cement paste and the aggregate, this happens.

### **2.6.9 DURABILITY OF CONCRETE**

Concrete must also be durable in addition to its capacity to support loads. Concrete's resistance to deterioration brought on by both internal and external factors is referred to as durability. The impacts of concrete's exposure to environmental and service conditions, such as weathering, chemical reactions, and wear, are included among the external factors. The results of constituent materials interacting, such as the alkaline aggregation reaction, volume changes, absorption, and permeability, are the internal causes. Care should be taken to choose appropriate constituent materials in order to manufacture lasting concrete. Additionally, it's critical that the mix contains sufficient amounts of each component in ratios that will result in a homogeneous mass of fully compacted concrete. Relationship between durability and strength Early strength concrete has been found to be more prone to cracking, which impacts the concrete's long-term durability.

### **2.6.10 IMPACT OF WATER CEMENT RATIO ON DURABILITY OF CONCRETE**

The use of a high water-to-cement ratio causes the concrete to be porous, which results in volume variations and fissures that eventually cause the concrete to break and disintegrate. Therefore, the lowest water/cement ratio is ideal for lasting concrete.

### **2.6.11 WATER PERMEABILITY OF CONCRETE**

### **Permeability of cement paste**

The extent and size of capillary cavities, which in turn depend on the water/cement and hence increase permeability, determine how permeable cement paste is.

### **Water penetration test**

A quick laboratory test can be used to determine the permeability of concrete. In this test, a concrete specimen's sides are sealed, and water is only delivered to the top surface under pressure. The amount of water flowing through a given thickness of concrete in a given time is measured once steady state conditions have been attained (this may take about 10 days) Neville (1987).

### **Interaction between permeability**

Concrete's permeability, volume change, and cracking are to blame for the longevity of concrete and concrete structures. Even though permeability is frequently cited as the fundamental reason of concrete's lack of durability, it can be challenging to identify the exact cause because heat from the concrete's hydration process can produce volume changes that can lead to cracks. Concrete might begin to deteriorate due to microcracks as well. As a result, the three elements are in charge of influencing concrete's durability. Shetty (2005).

## **2.6.12 ABSORPTION IN CONCRETE**

### **Sorptivity**

This capillary effect-related feature is the gradient between the amount of water absorbed per unit surface area and the square root of the absorption time. Misra and co. (2007).

### **Surface absorption test**

A concrete cube is oven dried and coated with epoxy on four faces after being cured for 28 days. One face of the specimen is in touch with water after it has been weighed. At

intervals of up to 48 hours, the weight gain brought on by water absorption is monitored. The amount of water absorbed per unit cross section serves as the basis for calculating sorptivity.

### **2.6.13 TESTING OF CONCRETE**

#### **a) Compressive strength test**

Since the majority of concrete's desirable features are qualitatively related to its compressive strength, this test is the most often carried out one on hardened concrete. Typically, 250mm cubes and a 150c 30mm cylinder are used to calculate it.

#### **b) The Cube Test**

150 x 150 x 150 mm cubes are used for the test; the moulds should be constructed of steel or cast iron and should be thick enough to prevent distortion. A temporary rod is a steel bar that is 60mm long, 16mm in diameter, and has a bullet tip on one end. The remaining specimens are housed in a space with little vibration for 24 hours while the temperature and humidity are monitored. kept submerged in clear, pure water until being removed for the test. Every seven days, the water in which the specimens are submerged is changed, and the specimens are not to be allowed to dry up before being tested.

### **2.6.14 COMPARISON OF STRENGTH OF CUBES**

The cubes appear to produce more consistent outcomes than the cube because they are less impacted by the end restraints brought on by platens. Because they are cast and tested in the same location as opposed to cubes, which are cast in one direction and tested from another, they mimic the situation of the actual structural member in the field with regard to the direction of load. Other hand cubes are capless and have a shape similar to the structural part that is frequently encountered on the ground.

## **CHAPTER THREE**

### **3.0 METHODOLOGY**

#### **3.1 GENERAL OVERVIEW OF METHODOLOGY**

In this experiment, cement is partially replaced with rice husk ash using three different curing techniques.

A total of 186 cubes were cast, and these cubes were then cured for 3, 7, 14, and 28 days.

The concrete mix design used in these cubes had a target strength of 20 MPa and used

replacement percentages of 5%, 10%, and 15% for rice husk ash. Open air curing (dry), immersion curing (wet), and a mixture of wet and dry curing were all used to cure the cubes. In the combination of wet and dry curing, the cubes were first completely submerged for three days before being open-air cured for the requisite amount of time. At the ages of 3, 7, 14, and 28 days in a row, the compressive strength of 168 specimens was tested, and their weights were recorded. While the water absorption of 18 of the cubes is being evaluated.

After this experiment, the impact of the various curing techniques on the compressive strength, transport characteristics, and partially replaced RHA concrete was examined.

## **3.2 MATERIALS**

the following materials were used in the mixing of concrete:

1. Finely grounded and sieved Rice Husk Ash burnt to a temperature of 600°C
2. Ordinary Portland Cement
3. Fine Aggregate
4. Coarse Aggregate (1/2 inches)
5. Water

### **3.2.1 Rice Husk Ash**

Locally procured rice husk from rice paddies was burned at a temperature of 600°C. As a result, rice husk ash was created, a silica-rich powder with adequate structure for usage as pozzolanic material. In order to obtain the fineness with cement powder, the rice husk ash was sieved using a 90-micron sieve.

### **3.2.2 Cement**

This is the substance that holds concrete together. Limestone, clay, and various silicate combinations are heated to high temperatures ( $>1500^{\circ}\text{C}$ ) in a revolving kiln to create this Ordinary Portland Cement. In this investigation, Dangote Portland Cement, which is widely available in Nigeria, was used. It was bought from a Nigerian cement depot at Oluku, Benin City.

### **3.2.3 Aggregates**

#### **Fine Aggregate:**

This is made out of crushed stone or natural sand, with the majority of the particles passing through a 3/8-inch filter. To confirm compliance with the required standards, sieve analysis was performed after local river sand was procured for this experiment from an Oluku quarry site.

#### **Coarse Aggregate:**

These are circular gravels that are either naturally occurring or have an uneven shape. They are particles that the 4.75mm sieve retains. The granite employed as the coarse aggregate for this investigation ranged in particle size from 10 mm to 20 mm. The concrete's shape, size, grading, density, and other characteristics that affect its strength, workability, and volume stability were taken into account. From a quarry site in Oluku, Benin City, Nigeria, granite was obtained.

### **3.2.4 Water**

Alkalis, silt, sugar, oils, organic debris, and plant growth were removed from the water used for this experiment since they could impact the cement's hydration and reduce the structural qualities of the concrete, such as durability, workability, compressive strength, and permeability. Therefore, it is vital not to use contaminated water or water that contains substances that could weaken the concrete. The Civil Engineering Laboratory at the University of Benin in Nigeria's Edo state provided the water for this experiment.

**Table 3.1 Details of the specimen casted**

0 % Replacement with Rice Husk Ash (Control)					
S/N	Duration of Curing (days)	Method of Curing	No of Cubes	Designation of Specimen	Test
	3	Immersion (Wet)	3	(W3)1-3	Crushing Strength
		Immersion and Air (Wet + Dry)	3	(W3)1-3	Crushing Strength
		Air (Dry)	3	(D3)22-24	Crushing Strength
	7	Immersion (Wet)	3	(W)4-6	Crushing Strength
		Immersion and Air (Wet + Dry)	3	(W+D7)13-15	Crushing Strength
		Air (Dry)	3	(D7)25-27	Crushing Strength
	14	Immersion (Wet)	3	(W14)7-9	Crushing Strength
		Immersion and Air (Wet + Dry)	3	(W+D14)16-18	Crushing Strength
		Air (Dry)	3	(D14)28-30	Crushing Strength

	28	Immersion (Wet)	3	(W28)10-12	Crushing Strength
		Immersion and Air (Wet + Dry)	3	(W+D28)19-21	Crushing Strength
		Air (Dry)	3	(D28)31-33	Crushing Strength
5 % Replacement with Rice Husk Ash					
S/N	Duration of Curing (days)	Method of Curing	No of Cubes	Designation of Specimen	Test
	3	Immersion (Wet)	3	(W3)1-3	Crushing Strength
		Immersion and Air (Wet + Dry)	3	(W3)1-3	Crushing Strength
		Air (Dry)	3	(D3)22-24	Crushing Strength
	7	Immersion (Wet)	3	(W7)4-6	Crushing Strength
		Immersion and Air (Wet + Dry)	3	(W+D7)13-15	Crushing Strength
		Air (Dry)	3	(D7)25-27	Crushing Strength
	14	Immersion (Wet)	3	(W14)7-9	Crushing Strength

		Immersion and Air (Wet + Dry)	3	(W+D14)16-18	Crushing Strength
		Air (Dry)	3	(D14)28-30	Crushing Strength
	28	Immersion (Wet)	6	(W28)10-12	Crushing Strength Water Absorption
		Immersion and Air (Wet + Dry)	3	(W+D28)19-21	Crushing Strength
		Air (Dry)	6	(D28)31-33	Crushing Strength Water Absorption
10 % Replacement with Rice Husk Ash					
S/N	Duration of Curing (days)	Method of Curing	No of Cubes	Designation of Specimen	Test
	3	Immersion (Wet)	3	(W3)1-3	Crushing Strength
		Immersion and Air (Wet + Dry)	3	(W3)1-3	Crushing Strength
		Air (Dry)	3	(D3)22-24	Crushing Strength

	7	Immersion (Wet)	3	(W7)4-6	Crushing Strength
		Immersion and Air (Wet + Dry)	3	(W+D7)13-15	Crushing Strength
		Air (Dry)	3	(D7)25-27	Crushing Strength
	14	Immersion (Wet)	3	(W14)7-9	Crushing Strength
		Immersion and Air (Wet + Dry)	3	(W+D14)16-18	Crushing Strength
		Air (Dry)	3	(D14)28-30	Crushing Strength
	28	Immersion (Wet)	6	(W28)10-12	Crushing Strength Water Absorption
		Immersion and Air (Wet + Dry)	3	(W+D28)19-21	Crushing Strength
		Air (Dry)	6	(D28)31-33	Crushing Strength Water Absorption
15 % Replacement with Rice Husk Ash					

S/N	Duration of Curing (days)	Method of Curing	No of Cubes	Designation of Specimen	Test
	3	Immersion (Wet)	3	(W3)1-3	Crushing Strength
		Immersion and Air (Wet + Dry)	3	(W3)1-3	Crushing Strength
		Air (Dry)	3	(D3)22-24	Crushing Strength
	7	Immersion (Wet)	3	(W7)4-6	Crushing Strength
		Immersion and Air (Wet + Dry)	3	(W+D7)13-15	Crushing Strength
		Air (Dry)	3	(D7)25-27	Crushing Strength
	14	Immersion (Wet)	3	(W14)7-9	Crushing Strength
		Immersion and Air (Wet + Dry)	3	(W+D14)16-18	Crushing Strength
		Air (Dry)	3	(D14)28-30	Crushing Strength
	28	Immersion (Wet)	6	(W28)10-12	Crushing Strength Water

					Absorption
		Immersion and Air (Wet + Dry)	3	(W+D28)19-21	Crushing Strength
		Air (Dry)	6	(D28)31-33	Crushing Strength Water Absorption

### 3.3 Equipment Used

The equipments used for this study include:

- a) Shovels
- b) Sieves
- c) Sieve Shaker
- d) Weighing Machine
- e) Weighing Pans
- f) Shovels

- g) Water Storage
- h) Buckets
- i) Tamping rod
- j) Oven
- k) Head pan
- l) Hand trowel
- m) Slump cone
- n) Aggregate Impact Value Equipment
- o) Concrete mixer
- p) Concrete cube mould
- q) Vibrating table
- r) Curing tank
- s) Measuring cylinder
- t) Lubricating oil
- u) Compression testing machine

### **3.4 Experiments and Tests**

The following tests were carried out during this analysis.

- a) Pretreatment of aggregates
- b) Particle size distribution of aggregates
- c) Aggregate Impact Value Test
- d) Slump test for the workability of concrete
- e) Initial Compressive Strength test for trial mix design.
- f) Compressive strength test

- g) Water Absorption test
- h) Ultra-pulse velocity test

### **Pretreatment of aggregates**

This procedure is carried out to ensure that the aggregate ingredients are appropriate and of higher quality since they have an impact on the binding and reaction process of concrete and, consequently, the quality of the concrete. To eliminate the moisture, the fine aggregate from the quarry site in Oluku was placed in the sun for three days. Then, in the lab, it was subjected to sieve analysis using a 75mm micron sieve and a typical mechanical sieve shaker.

Water was used to thoroughly clean the site's granite and gritty aggregate. This was done to improve the surface area for reaction and binding with the cement by removing the clayey soils adhered to the granite.

### **Particle size distribution of aggregates**

The distribution and grading of aggregates play a crucial role in determining how easily concrete may be worked. The quantity of vacant spaces present and the total surface area that would be covered determine how much cement paste is needed. When particle sizes are uniform, there is a bigger gap between them, making concrete more difficult to handle and compact.

To make sure the void spaces are effectively filled and so improve the workability, strength, and durability of the concrete cubes, a variety of granite sizes were employed for this analysis.

### **Aggregate Impact Value Test**

Resistance, also known as the aggregate's resistance to failure brought on by an abruptly applied stress, is the capacity of aggregates to absorb unexpected impact or shock loads.

This process is known as figuring out the aggregate's impact value.

The purpose of this test was to evaluate the resistance and strength of the aggregate. The percentage of penalties extracted from the aggregate sample after an amount of effect has been administered is known as the aggregate impact value. After compacting the aggregate in the impact testing device's cup, the hammer was elevated, and 15 strikes were delivered at intervals of one second. The crushed sample's entire weight was noted. The 2.36mm sieve was used to sift the aggregate sample, and the weight of the percentage that passed through was observed and recorded. Following that, the Aggregate Impact Value (AIV) was determined using;

$$AIV = \frac{M2}{M1} \times 100\%$$

M1

M1 = weight of crushed sample

M2 = weight of (fines) sample passing the 2.36mm sieve.

AIV (%)	Quality of Aggregate
---------	----------------------

< 10	Exceptionally strong
10 - 20	Strong
20 - 30	Satisfactory
> 35	Weak

### **Initial trial mix design for Compressive Strength test**

The process of selecting the appropriate concrete components and figuring out their relative amounts is known as concrete mix design. The objective is to produce concrete with the appropriate strength and durability while also making sure that the ingredients are mixed in the best possible proportions to meet the needs of the proposed project. During the mix design process, the workability, strength, and durability of the concrete must be taken into account. The design mix is the name given to this concrete mixture created under quality-controlled circumstances.

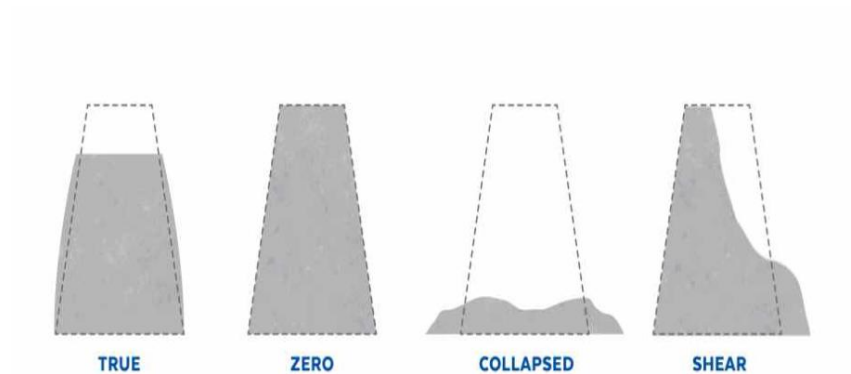
An initial concrete mix design was done because the analysis's goal mean strength was 20N/mm<sup>2</sup>. This mix ratio of concrete was cast, and three 100x100mm steel molds were filled with the concrete after casting. The compressive strength at 7 days was achieved after these cubes underwent full immersion curing for 7 days. The compressive strength discovered using the compressive testing apparatus was insufficient. The water to cement ratio, the slump, and the needed cement content were then taken into account in the computation of another mix design.

### **Slump test for the workability of concrete**

Concrete that has just been produced needs to be tested to make sure it meets standards before it is used. A concrete test called a "slump test" gauges the consistency of recently

constructed concrete. Before the concrete hardens, it is done to test the workability, or how easily freshly made concrete will flow.

A slump cone is utilized during the procedure. The cone needs to be supported on both sides and placed on a flat, smooth surface. Three layers of newly mixed concrete are poured into the cone, and then each layer is compacted with a 16mm tamping rod by tamping it 25 times to make sure the surface is even and smooth. The cone was raised gently and gradually in a vertical orientation once it had been filled all the way to the top. The cone was then turned upside down and set beside the concrete. The height at which the concrete slumps, or drops, is then noted. The slump test should not be used if the slump collapses since this indicates that the mixture is either too wet or extremely workable. Typically, 50 to 90 mm slumps are used when vibrating conventional reinforced concrete.



**FIG 4.1: SLUMP TEST ILLUSTRATION DIAGRAM**

### **Compressive Strength test**

The qualities of hardened concrete are assessed and determined using a range of tests. Destructive and non-destructive tests are separated out. In this project, the Universal

Compression Machine was utilized together with the destructive testing technique. A planned structure must be tested to make sure it can support the loads placed on it.

Thus, a material or structure's ability to withstand weights on its surface without splitting or deflecting is known as compressive strength. Using the Universal Compressive Testing Machine, a concrete cube is subjected to an extremely high compressive force, and the maximum load at which the concrete cube collapses or cracks is then recorded.

The weight of the concrete cubes is measured using the weighing balance before crushing commences. The cubes were centered on the machine's base plate, and the compression machine delivered the weights gradually.

The failure load is then divided by the cube's cross-sectional area to determine the compressive strength. This was done to guarantee that the concrete mix we used and the resulting concrete that was cast fulfilled the specifications for our goal strength. The compressive strength of concrete tends to reach its maximum value as the age of the material increases. Concrete is said to have reached its full strength at 28 days.

Age Of Concrete (Days)	Strength Percent
1	16%
3	40%
7	65%
14	90%
28	99%

$$\text{Compressive Strength (N/mm}^2\text{)} = \frac{\text{Load at failure (N)}}{\text{Cross sectional Area (mm}^2\text{)}}$$

(3.1)

Cross sectional Area (mm<sup>2</sup>)

Where the Cross-sectional Area of the cube = 100mm x 100mm

Three cubes were casted for each curing method and rice husk ash replacement percentage. The average of the three individual compressive strength was then recorded.

For Example; the Average Compressive Strength for three cubes is computed as;

$$= \frac{A + B + C}{3} \quad (3.2)$$

A, B and C being the individual compressive strength of the three cubes.

### **Water Absorption Test**

This test is performed to determine how much water the concrete has absorbed. It is a common technique for determining how much water penetrates a concrete sample after being submerged in water for a predetermined amount of time. The outcome will be better the less water the concrete absorbs. After 28 days of drying, the weight of the concrete cubes was recorded. To remove any moisture or water, the cubes were oven dried for 24 hours; the weight was recorded as  $W_d$ . After that, they could cool at room temperature. The concrete cubes were then placed in a deep bowl of water, making sure that there was at least 25mm of water above each cube. The mass of the samples was

noted at intervals of 10, 30, 60, and 120 minutes. The following formula was then used to calculate the water absorption percentage:

$$W_a = \frac{k (W_t - W_d)}{W_d} \quad (3.3)$$

$W_a$  = water absorption percent

$W_t$  = mass of the immersed concrete cube after the specified number of minutes

$W_d$  = mass of the dry concrete cube after removing from the oven

$K$  is the correction factor for the shape of the sample (1.33 for 100mm concrete cubes)

### **Ultra-pulse velocity test**

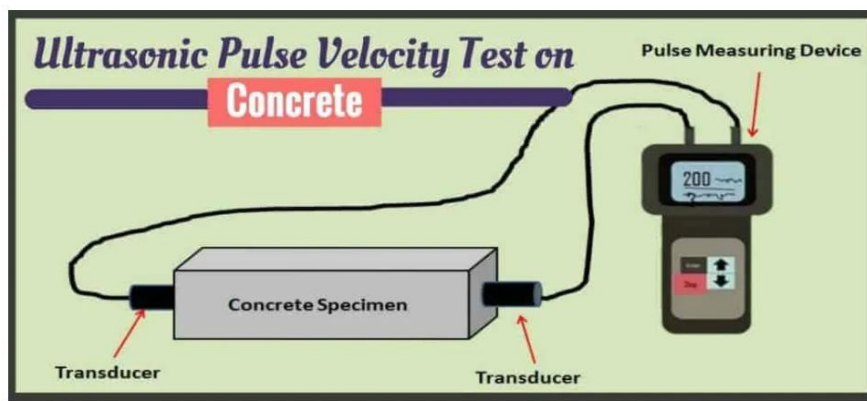
There are many tests available to determine the quality of concrete. A non-destructive test method for assessing the quality and strength of a concrete sample is the Ultra-Pulse Velocity Test. It is calculated by determining the pulse velocity, or the speed at which ultrasonic waves move through concrete. The method comprises timing how long an ultrasonic pulse travels through the concrete being tested. This test is primarily used to assess the homogeneity of the concrete, look for cracks or cavities, and assess the overall quality of the concrete. A comparative higher velocity is attained when the concrete quality is good in terms of density, uniformity, homogeneity, etc.

The pulse travels through a discontinuity with a low velocity if the concrete contains cracks or cavities (honeycombs).

The UPV's equipment consists of a pair of transducers, an amplifier, an electronic timing device, and an electronic pulse generator. The concrete cube's surface is smoothed, and two transducers are positioned on either side. Next, the pulse is delivered through the concrete cube to determine the time using an electrical timing device. This formula is then used to calculate the pulse velocity.

$$\text{Pulse Velocity} = \frac{\text{Width of Structure (Path Length)}}{\text{Time taken by the pulse to pass through the material}} \quad (3.4)$$

Time taken by the pulse to pass through the material



**Ultrasonic Pulse Velocity Test | UPV Test**

Pulse Velocity (km/second)	Concrete Quality (Grading)
Above 4.5	Excellent
3.5 to 4.5	Good
3.0 to 3.5	Medium
Below 3.0	Doubtful

### 3.5 Procedures undertaken in the laboratory

We've gathered the supplies we need for the job. The rice husk came from regional suppliers. After that, it was burned at a temperature of 600 °C to create rice husk ash (RHA). For easier reactivity with cement, this ash was subsequently ground into a very fine powder.

### **3.5.1 Casting of Cubes**

Cleaning and assembling the steel mold's components with the use of bolts and a spanner was done before the concrete was mixed. To avoid grout leakage, the molds were thoroughly tightened and greased with oil. This was essential to enable simple demolding of the concrete cubes after hardening. The amount of cement, water, and aggregates needed were then calculated, taking into account how many cubes will be cast. For mixing, the materials were brought to the concrete mixer. With the aid of the hand trowel, the freshly mixed concrete was immediately poured into the 100mm x 100mm x 100mm molds. After that, the cubes were put on the vibrating table for sufficient compaction to stop honeycombing and eliminate air spaces. The cubes' surfaces were sanded, the identifier was written on them, and they were then given time to dry. This procedure was repeated for the various concentrations of rice husk ash, each cube having the appropriate label inscribed on it.

### **3.5.2 Curing of Cubes**

The concrete cubes were demolded after 24 hours by carefully removing the nuts with a wrench without harming the specimen. The cubes were then separated into groups for curing in the air, in the water, and in both the water and the air.

#### **3.5.2.1 Curing by Immersion**

To facilitate the curing process, a water tank was purchased. The cubes designated for wet curing were then placed into the water tank after it had been filled with clean water.

They were given 3, 7, 14 and 28 days to heal, respectively. At the end of each curing period, the cubes were removed from the tank, their weight was recorded, and the necessary tests were conducted.

### **3.5.2.2 Open Air Curing**

The test cubes with the label "dry" were positioned in one area of the lab and spaced such that air flowed evenly around them. They were given 3, 7, 14 and 28 days to heal, respectively. At the end of each curing period, the weight of the cubes was recorded and the pertinent tests were conducted.

### **3.5.2.3 Curing by both Immersion and Open Air Curing**

The wet + dry cubes were put in the water curing tank, where they were allowed to cure for three days. They were then removed and exposed to the elements for the remaining curing times of 7, 14, and 21 and 28 days. The weight of the cubes was recorded after the dry curing period, and the necessary tests were conducted.

At the conclusion of the curing process, the failure load was determined for each cube and the average compressive strength was calculated.

## **CHAPTER FOUR**

### **4.0 RESULTS AND DISCUSSION**

This chapter's goal is to summarize and present the complete study project's findings. Tables and graphs are used to present these findings. The findings of the experimental investigations are thoroughly examined. Table 4.1 displays the cement grade 42.5 after curing using three different techniques: curing in water, curing outdoors, and combining both open-air and water-immersion curing techniques. Plotted are the variances in corresponding compressive strengths for the various curing techniques.

#### **4.1.PARAMETERS**

##### **4.1.1Evaluation of compressive strength**

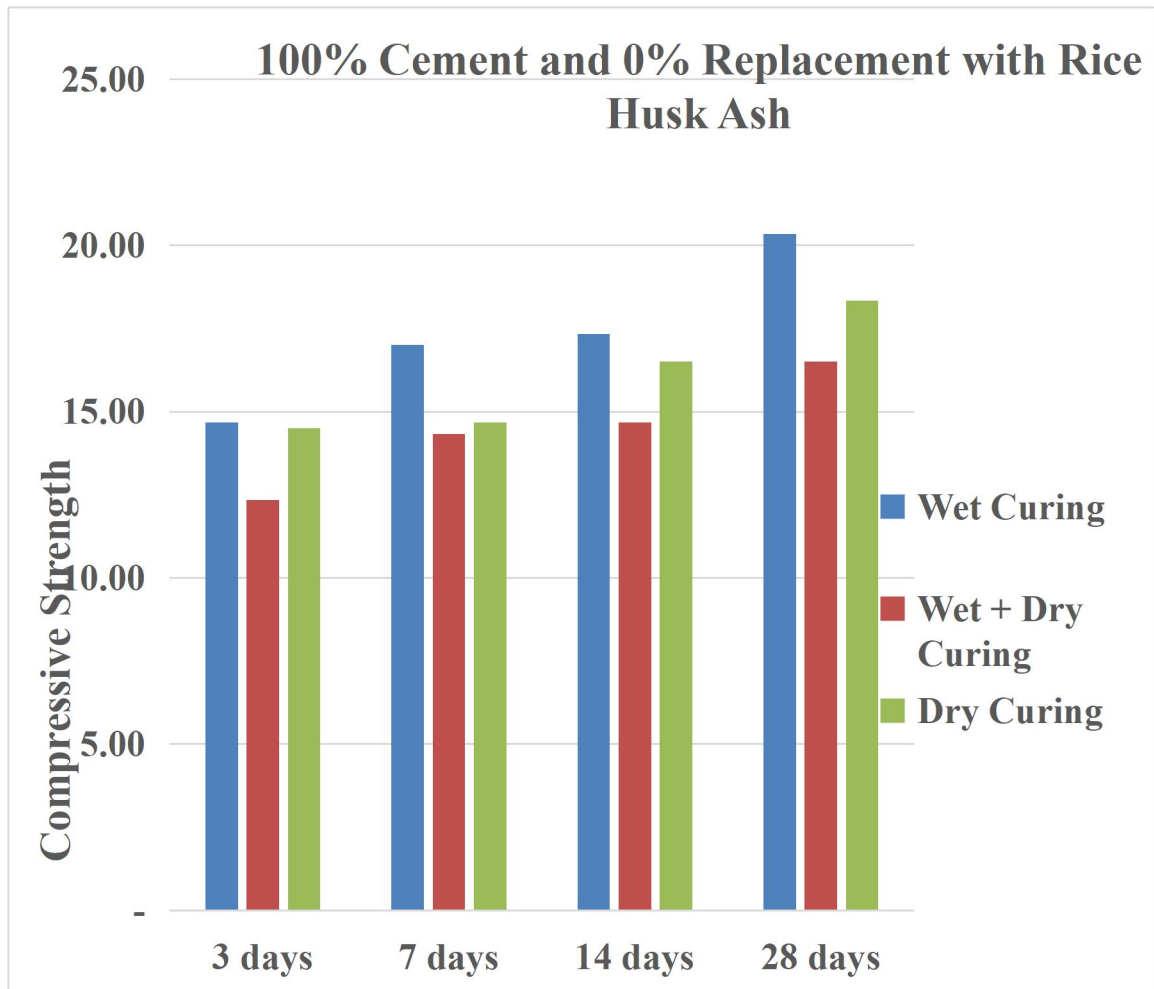
$$\text{Compressive strength } f \text{ (N/mm}^2\text{)} = \frac{\text{load at failure (N)}}{\text{cross-sectional area}} \quad (4.1)$$

Where cross sectional Area of cube= 100mm x 100mm = 10000mm<sup>2</sup>

$$\text{Average Compressive strength } f \text{ (N/mm}^2\text{)} = \frac{\text{sum of compressive strength of samples (N)}}{\text{number of cube samples}} \text{ (4.2)}$$

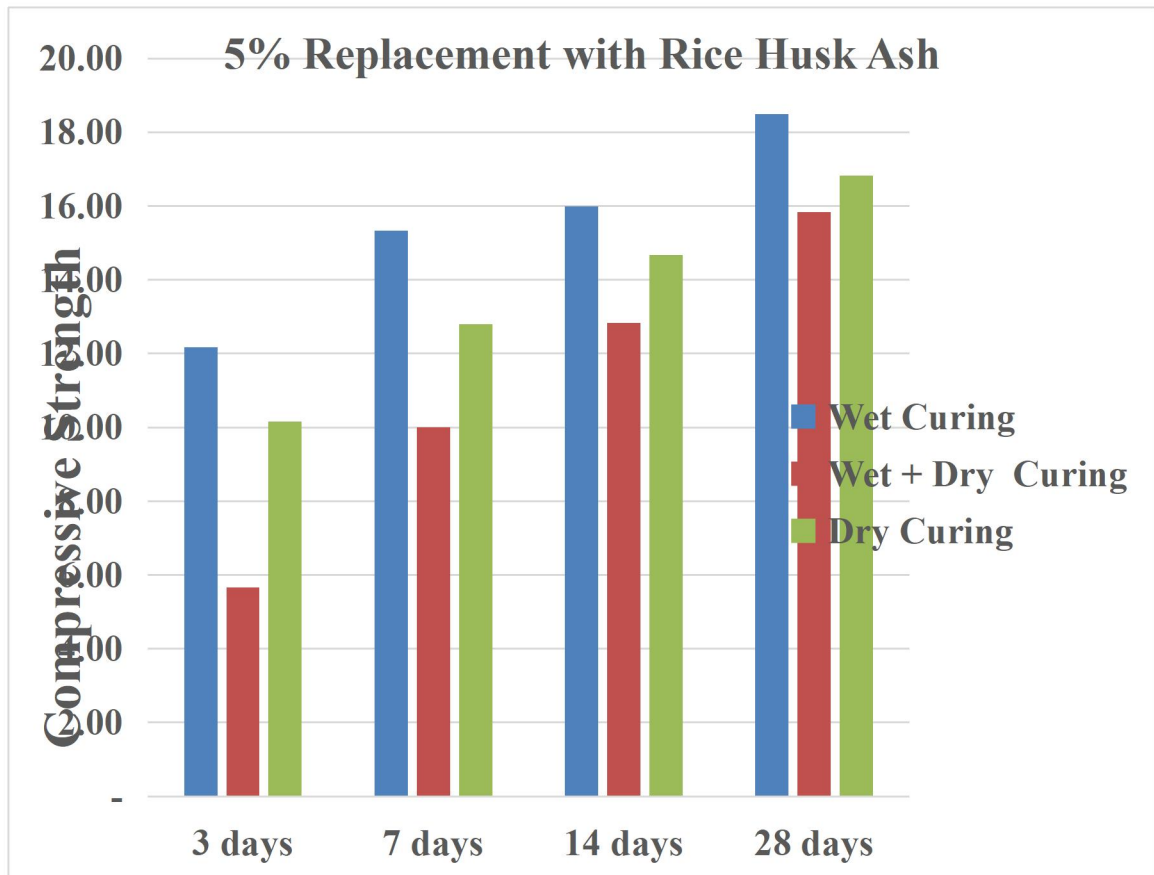
<b>Control (100% Cement and 0% Rice Husk Ash)</b>						
Method of Curing	Cube Age	Designation	Weight of Cube (kg)	Failure Load (KN)	Compressive Strength	Average Compressive Strength
Immersion (Wet)	3	1	2.50	110.00	11.00	<b>14.67</b>
		2	2.42	150.00	15.00	
		3	2.43	180.00	18.00	
	7	4	2.47	210.00	21.00	<b>17.00</b>
		5	2.34	150.00	15.00	
		6	2.49	150.00	15.00	
	14	7	2.41	150.00	15.00	<b>17.33</b>
		8	2.52	170.00	17.00	
		9	2.38	200.00	20.00	
	28	10	2.60	190.00	19.00	<b>20.33</b>
		11	2.41	210.00	21.00	
		12	2.46	210.00	21.00	
Immersion and Air (Wet + Dry)	3	1	2.50	120.00	12.00	<b>12.33</b>
		2	2.42	125.00	12.50	
		3	2.43	125.00	12.50	
	7	13	2.60	110.00	11.00	<b>14.33</b>
		14	2.51	160.00	16.00	
		15	2.66	160.00	16.00	
	14	16	2.54	170.00	17.00	<b>14.67</b>
		17	2.44	140.00	14.00	
		18	2.25	130.00	13.00	
	28	19	2.45	130.00	13.00	<b>16.50</b>
		20	2.23	185.00	18.50	
		21	2.37	180.00	18.00	
Air (Dry)	3	22	2.43	140.00	14.00	<b>14.50</b>
		23	2.52	155.00	15.50	
		24	2.41	140.00	14.00	
	7	25	2.35	140.00	14.00	<b>14.67</b>
		26	2.37	135.00	13.50	
		27	2.46	165.00	16.50	
	14	28	2.21	180.00	18.00	<b>16.50</b>
		29	2.31	140.00	14.00	
		30	2.24	175.00	17.50	
	28	31	2.13	165	16.50	<b>18.33</b>

	32	2.52	200	20.00
	33	2.22	185	18.50



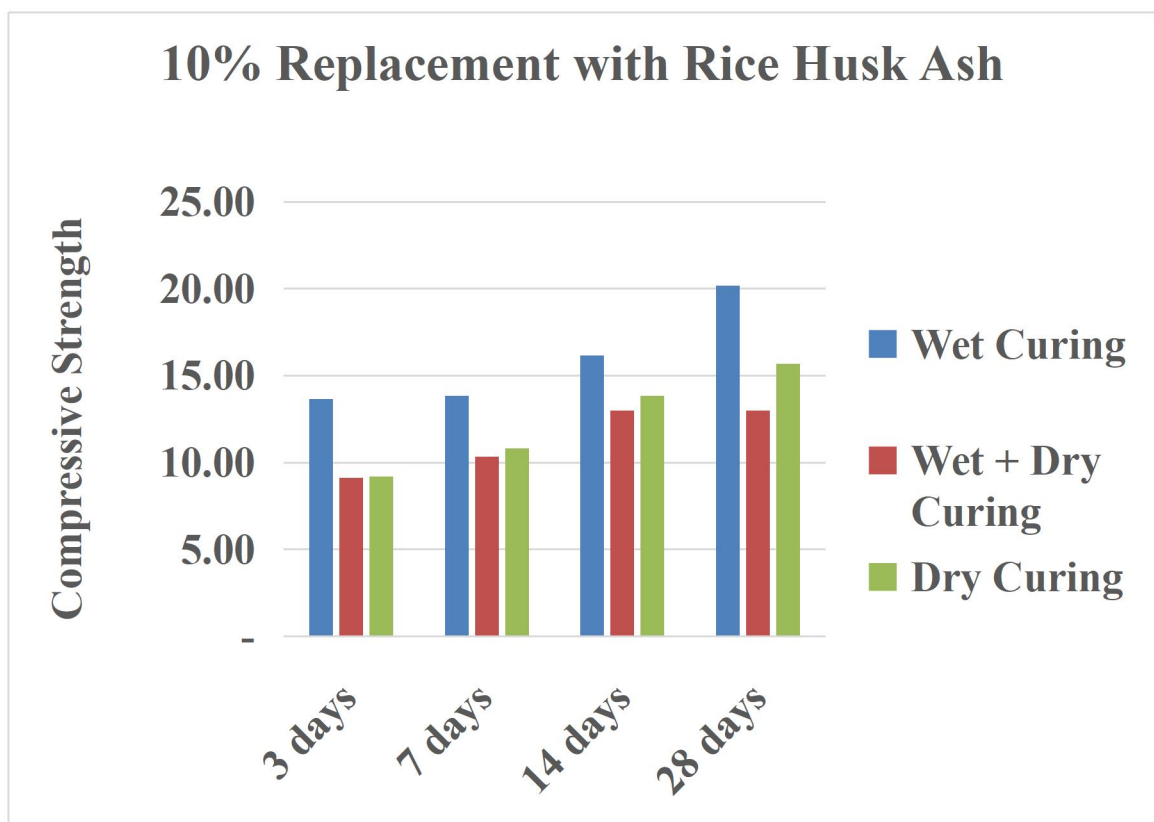
<b>5% Replacement with Rice Husk Ash and 95% Cement</b>						
<b>Method of Curing</b>	<b>Cube Age</b>	<b>Designation</b>	<b>Weight of Cube (kg)</b>	<b>Failure Load (KN)</b>	<b>Compressive Strength</b>	<b>Average Compressive Strength</b>
Immersion (Wet)	3	34	2.47	140.00	14.00	<b>12.17</b>
		35	2.58	105.00	10.50	
		36	2.61	120.00	12.00	
	7	37	2.37	150.00	15.00	<b>15.33</b>

		38	2.49	155.00	15.50	
		39	2.30	155.00	15.50	
	14	40	2.43	120.00	12.00	
		41	2.43	160.00	16.00	
		42	2.71	200.00	20.00	<b>16.00</b>
	28	43	2.49	185.00	18.50	
		44	2.52	190.00	19.00	
		45	2.55	180.00	18.00	<b>18.50</b>
Immersion and Air (Wet + Dry)	3	34	2.47	47.52	4.75	
		35	2.58	65.59	6.56	
		36	2.61	56.95	5.70	<b>5.67</b>
	7	46	2.50	130.00	13.00	
		47	2.36	110.00	11.00	
		48	2.52	60.00	6.00	<b>10.00</b>
	14	49	2.43	130.00	13.00	
		50	2.41	115.00	11.50	
		51	2.31	140.00	14.00	<b>12.83</b>
	28	52	2.23	185.00	18.50	
		53	2.36	160.00	16.00	
		54	2.47	130.00	13.00	<b>15.83</b>
Air (Dry)	3	55	2.55	90.00	9.00	
		56	2.50	100.00	10.00	
		57	2.45	115.00	11.50	<b>10.17</b>
	7	58	2.30	125.00	12.50	
		59	2.39	135.00	13.50	
		60	2.13	124.00	12.40	<b>12.80</b>
	14	61	2.28	115.00	11.50	
		62	2.37	145.00	14.50	
		63	2.24	180.00	18.00	<b>14.67</b>
	28	64	2.38	155	15.50	
		65	2.46	175	17.50	
		66	2.30	175	17.50	<b>16.83</b>

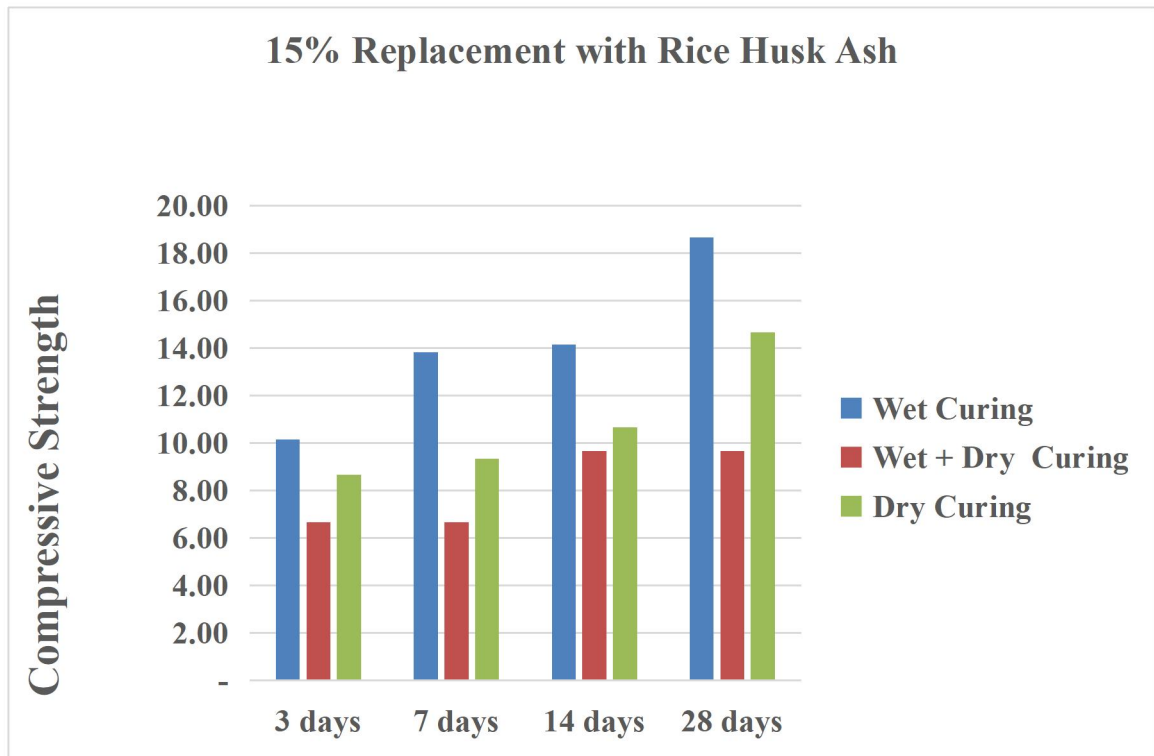


10% Replacement with Rice Husk Ash and 90% Cement						
Method of Curing	Cube Age	Designation	Weight of Cube (kg)	Failure Load (KN)	Compressive Strength	Average Compressive Strength
Immersion (Wet)	3	67	2.72	155.00	15.50	<b>13.67</b>
		68	2.43	125.00	12.50	
		69	2.57	130.00	13.00	
	7	70	2.51	140.00	14.00	<b>13.83</b>
		71	2.51	145.00	14.50	
		72	2.28	130.00	13.00	
	14	73	2.33	150.00	15.00	<b>16.17</b>
		74	2.69	170.00	17.00	
		75	2.61	165.00	16.50	
	28	76	2.37	220.00	22.00	<b>20.17</b>
		77	2.54	175.00	17.50	
		78	2.42	210.00	21.00	
Immersion and Air (Wet +)	3	67	2.72	106.10	10.61	<b>9.12</b>
		68	2.43	87.66	8.77	
		69	2.57	79.84	7.98	

Dry)	7	79	2.37	115.00	11.50	<b>10.33</b>
		80	2.34	90.00	9.00	
		81	2.43	105.00	10.50	
	14	82	2.67	150.00	15.00	<b>13.00</b>
		83	2.47	135.00	13.50	
		84	2.42	105.00	10.50	
	28	85	2.36	130.00	13.00	<b>13.00</b>
		86	2.42	150.00	15.00	
		87	2.55	110.00	11.00	
Air (Dry)	3	88	2.43	88.41	8.84	<b>9.18</b>
		89	2.28	83.98	8.40	
		90	2.47	102.94	10.29	
	7	91	2.29	115.00	11.50	<b>10.83</b>
		92	2.42	110.00	11.00	
		93	2.44	100.00	10.00	
	14	94	2.82	160.00	16.00	<b>13.83</b>
		95	2.47	135.00	13.50	
		96	2.22	120.00	12.00	
	28	97	2.36	160	16.00	<b>15.67</b>
		98	2.29	170	17.00	
		99	2.40	140	14.00	



<b>15% Replacement with Rice Husk Ash and 85% Cement</b>						
<b>Method of Curing</b>	<b>Cube Age</b>	<b>Designation</b>	<b>Weight of Cube (kg)</b>	<b>Failure Load (KN)</b>	<b>Compressive Strength</b>	<b>Average Compressive Strength</b>
Immersion (Wet)	3	100	2.61	100.00	10.00	<b>10.17</b>
		101	2.31	95.00	9.50	
		102	2.51	110.00	11.00	
	7	103	2.64	150.00	15.00	<b>13.83</b>
		104	2.59	145.00	14.50	
		105	2.31	120.00	12.00	
	14	106	2.60	145.00	14.50	<b>14.17</b>
		107	2.57	130.00	13.00	
		108	2.72	150.00	15.00	
	28	109	2.32	190.00	19.00	<b>18.67</b>
		110	2.52	210.00	21.00	
		111	2.41	160.00	16.00	
Immersion and Air (Wet + Dry)	3	100	2.61	80.00	8.00	<b>6.67</b>
		101	2.31	40.00	4.00	
		102	2.51	80.00	8.00	
	7	112	2.11	90.00	9.00	<b>6.67</b>
		113	1.97	60.00	6.00	
		114	2.20	50.00	5.00	
	14	115	2.32	90.00	9.00	<b>9.67</b>
		116	2.28	90.00	9.00	
		117	2.44	110.00	11.00	
	28	118	2.41	80.00	8.00	<b>9.67</b>
		119	2.53	90.00	9.00	
		120	2.36	120.00	12.00	
Air (Dry)	3	121	2.36	85.00	8.50	<b>8.67</b>
		122	2.19	85.00	8.50	
		123	2.45	90.00	9.00	
	7	124	2.42	90.00	9.00	<b>9.33</b>
		125	2.54	100.00	10.00	
		126	2.27	90.00	9.00	
	14	127	2.33	100.00	10.00	<b>10.67</b>
		128	2.29	100.00	10.00	
		129	2.10	120.00	12.00	
	28	130	2.57	180	18.00	<b>14.67</b>
		131	2.09	120	12.00	
		132	2.47	140	14.00	



## DISCUSSION

Comparing the average compressive strength of 0% Rice Husk Ash plus 100% Original Portland Cement with the average compressive strength of 5% Rice Husk Ash plus 95% Original Portland Cement with the average compressive strength of 10% Rice Husk Ash plus 80% Original Portland Cement with the average compressive strength of 15% Rice Husk Ash plus 75% Original Portland Cement, therefore, we can say that 10% and 15% Rice Husk Ash mixed with Original Portland Cement is not a suitable alternative of cement for concrete production. 5% Rice Husk Ash mixed with OPC can be used as the strength required was reached.

## **CHAPTER FIVE**

### **5.0 CONCLUSION AND RECOMMENDATION**

#### **5.1 Conclusion**

The following conclusion has been drawn from the experimental study;

- a) The compressive strength decreases with each increase in the percentage of Rice Husk Ash, this was witnessed from the experiment results. This proves that the higher the percentage of Rice Husk Ash mixed with the cement, the less suitable it is for use as the required compressive strength becomes more and more less satisfied.
- b) RHA as a material is very much similar to sand in terms of physical properties and it is very available and it is a waste by product from burnt materials. Cost of RHA is almost 10% of the cost of cement.

- c) The maximum compressive strength was obtained by mixing 5% RHA with 95% OPC, but it was less than the compressive strength of the conventional concrete mix (i.e without the addition of cement replacements) but as the cost of RHA is very less compared to the current cost of sand due to its shortage, 5% RHA can be seen as a suitable alternative for the replacement of cement in concrete.
- d) By using RHA as a replacement in concrete, the emission of greenhouse gases can be reduced to an extent. As a result, there is a possibility of gaining more number of carbon credits.

In summary, the use of RHA in civil construction works will reduce environmental pollution, improve eco-friendly concrete, improve the quality of concrete, and reduce its cost of production as well as solving the problem of agro-waste management by putting into use this locally found additive (RHA). Adding RHA to concrete resulted in increased water demand, increase in workability and suitable strength compared to the control sample. The study also shows that Ordinary Portland cement could be partially substituted with Rice Husk Ash to a level of 5% using locally sourced aggregates which could be easily assessed by rural dwellers.

## **5.2 Recommendation**

- a) Other levels of replacement with Rice husk ash and Quarry Dust can be researched.
- b) Some tests relating to durability aspects such as water permeability, resistance to penetration of chloride ions, corrosion of steel reinforcement, resistance to sulphate attack durability in marine environment etc, with Rice husk ash needs investigation.

- c) For use of Rice husk ash as a structural material, it is necessary to investigate the behavior of reinforced Rice husk ash concrete under flexure, shear, torsion and compression.

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## Appendix



Fig 1; Preparing the crushing machine to crush cubes that have been cured.



Fig 2; Lubricating of moulds before filling with concrete mix.



Fig 3; Packing coarse aggregates to measure them for concrete mix.



Fig4; Mixing of concrete mix in the concrete mixing machine.