EFFECT OF SUGAR AS ADMIXTURE ON THE PHYSICAL PROPERTIES OF CONCRETE

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CERTIFICATION

I hereby certify that this report on the " EFFECT OF SUGAR AS ADMIXTURE ON THE PHYSICAL PROPERTIES OF CONCRETE" was prepared by and compiled by NKAMA SAMUEL (Matric Number: ENG1804978) a student from the department of Civil/Structural Engineering, University of Benin, Ugbowo Campus, Edo State in Partial Fulfillment for The Award of The Degree of Bachelor of engineering(B.Eng.), Civil Engineering, University of Benin, Edo State. Nigeria

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DEDICATION

This research is dedicated to God Almighty the giver of life and protector of men, my beloved brother, Mr. Nkama Dick Ichie, my parents, Mr. and Mrs. Nkama, and my friends for their support throughout my studies.

This research work is also dedicated to my project supervisor ENGR. MUSA Aaron for his support and simplicity during this research.

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ABSTRACT

This research delves into the integration of diverse admixtures in concrete, aiming to augment its mechanical and durability traits. Specifically, it focuses on investigating the unconventional use of sugar as an admixture and its impact on concrete's physical properties, including compressive strength, workability, and durability. Experimental tests, encompassing compressive strength, slump, and durability assessments, explore the effects of varying sugar concentrations as a percentage of cement weight. The study seeks optimal proportions for enhanced performance, offering insights into the feasibility and effectiveness of sugar as a sustainable and economically viable concrete admixture. The findings gotten with a mix design from the experiment was 1:1.68:3 with w/c ratio of 0.48 with sugar added to the concrete at different percentage of 0.05,0.5, 1, 5, and 10. Slump test was carried out for all the batches to determine its workability, after 24hrs curing was carried out for 7 days, 14 days and 28 days .These cubes specimens were of dimension 100x100x100mm. These findings of this study indicate that mixing sugar with concrete results in a noticeable alteration of its properties. Consequently, it can be inferred that as the percentage of sugar increases up to 1%, the setting time of the concrete increases. After surpassing a 1% sugar content, there is a significant decrease in the setting time of concrete. Hence sugar acts as a retarder when used beyond this threshold in concrete proportions. A sugar content equivalent to 0.05% by weight of cement has been observed to enhance compressive strength. There was no detrimental effects observed on the concrete and cement paste at the sugar level of 0.05% for the concrete cube analyzed. Sugar content exceeding 1% by weight of cement accelerated the setting time with a slight decrease in initial strength, Additionally, excessive volume expansion resulted in the visible cracks within the sample itself. Thoughtfully incorporating sugar can offer an economic contribute to advancing concrete technology, providing a novel approach to improve physical properties while addressing environmental concerns associated with traditional admixtures. This research holds implications for innovative materials in the construction industry, potentially influencing sustainable and resilient infrastructure development.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF STUDY

Concrete is tremendously used man made construction material worldwide and obtain by mixing cement, fine aggregate, coarse aggregates and water, and sometime admixtures is required in suitable proportions as per requirements. The strength, durability and other characteristics of concrete depends up on the mix properties of its ingredients, on the proportion of mix, the method of compaction and other control during placing, compaction and curing.

Concrete has its superior properties like binding, strength and durability, but it cannot be used in all places due to different weather conditions in different countries. Variation in weather condition and sessions causes changes in the initial setting time of concrete.

Retarder and Accelerator are used to increase and decrease the initial setting time of concrete especially in winter sessions and summer sessions respectively .With the help of different type of admixture used such as Retarder-sugar and gypsum etc. and Accelerator-calcium chloride (cacl2) etc.

By going through studying to various review papers and research papers sugar is good admixture to increasing the initial setting time. Sugar is a carbohydrate, a composition of carbon, oxygen and hydrogen. It can be useful when concreting used in hot weather conditions, when the normal setting time of concrete is shortened by the higher surrounding temperature, such as Sokoto which has annual average temperature of 28.3 ^{o}C (82.9 ^{o}F) making it the hottest of Nigeria, Ondo states etc.

Very small dosage of the order of 0.06 to 0.1 per cent of the mass of the concrete is enough. 0.06 per cent of sugar can delay initial setting time by about 3hours. Usually different percentage of sugar admixtures were taken as by weight of cement.

Construction activities are accomplished through laid down procedures and parameters such as temperature and humidity. In practice, desired quality may not be achieved except the exact sets of procedures are carefully followed. Concreting in hot weather above 100°F

accelerates the early hydration of cement and produce concrete with high strength at early ages but later, the strength is reduced considerably. The rapid evaporation of water causes plastic shrinkage in concrete and subsequent cooling cause tensile stresses and cracking (Neville and Brooks, 2006; Usman, Idusuyi, Emeso, and Simon, 2012).Similarly, concreting in cold weather is also detrimental.If water in plastic concrete sets, the volume of concrete increases. This delays the setting and hardening of the concrete as no water is available for chemical reaction; ultimately resulting to large volume of pores, hence low strength is gained (Neville and Brooks, 2006; Usman, Adebitan, Kwari and Gyang, 2013).

However, in maintaining standard, admixtures are used. Retarders are admixture that extend the hydration induction period, thereby lengthening the setting times (Lea, 1988). Sugar, carbohydrate derivatives, soluble zinc salts, soluble borates exhibits retarding action (Neville and Brooks, 2006).

Lea (1988) asserts that sugar is a coating admixture which in the presence of water, cement particle sends out a swarm of calcium ions into the surrounding water and any substance capable of immobilizing or delaying this surge slows down the interchanges between the water and the particle, thus, retarding the hydration process.

Set-retarding admixture generally delays the setting-time and reduces the subsequent rate of hydration of cement (BS5075). Several compounds have been found to exhibit retarding action in concrete in its performance (Part 1 of the British Standard, BS5075).

Some of these compounds include soluble zinc salts, soluble borates and carbohydrate derivatives. Studies have shown that while investigating concrete admixtures, the concentration (dosage) of the admixture that will have impact on the concrete is usually difficult (Usman et al., 2013, Dupke, 2010, Okafor, 2008).

Usually, admixture dosages are less than 5% by mass of cement and are added to the concrete at the time of batching/mixing (Dupke, 2010).

1.2 PROBLEMS STATEMENT

The importance of concrete to the construction industries cannot be over emphasis, because large volume of concrete is being used every day during construction processes.

Concrete refers to a mixtures of fine aggregate, coarse aggregate, cement and water in the right proportion, however for the past, men has sought to alter the properties of concrete by adding substances known as admixtures.

In this practical experiment, sugar is the admixture being used. Despite the potential benefits of using sugar as a retarder in concrete mixes, there is a critical need to address the associated challenges, including the observed compromise in long-term compressive strength and increased permeability.

This research aims to investigate the impact of sugar as an admixture on the concrete properties, seeking to strike a balance between extended setting time and maintaining structural integrity. The study will explore optimal usage levels, potential mitigations for strength loss, and practical considerations to ensure the feasibility of employing sugar as viable and sustainable admixtures in construction projects.

1.3 AIMS AND OBJECTIVES;

The aim of this experiment is to assess the effect of sugar as an admixture on the physical properties of concrete.

The objectives are;

1. Determine the optimal concentration of sugar as an admixture to achieve the desired extended setting time without compromising early or long-term compressive strength.

2. Evaluate the influence of sugar on the workability and rheological properties of fresh concrete during mixing and placement.

3. Investigate the correlation between sugar content and permeability characteristics, exploring potential measures to mitigate any negative effects.

4. Assess the environmental impact and sustainability considerations associated with the use of sugar as an admixtures, considering factors such as insect attraction and overall structural performance.

1.4 SCOPE OF STUDY

The study concentrate on exploring how the inclusion of sugar as an admixture impacts the characteristics of concrete.

To achieve the goals, the tests aimed at fulfilling the research objectives which covers a wide range of investigation such as the setting time of concrete, the workability, compressive strength, concrete mix, and sieve analysis. This study delves into investigating how incorporating sugar as an admixture into concrete mix will alter the physical properties in relation to compressive strength, workability, and setting time of concrete.

1.5 JUSTIFICATION

Utilizing sugar to slow down the swift setting of cement paste and adjust the workability of fresh concrete on construction sites appears justified, given its cost-effectiveness and easy availability compared to other retarding admixtures (Rana, 2014). Therefore the need for its usage as an admixture in concreting becomes necessary due to the fact that its retarding effects depends on the percentage of sugar being added.

The results of this research work could provide some basic information to professionals in construction industry in Nigeria on the best and appropriate optimum dosage of sugar to be used as a retarding admixture when concreting in hot dry regions in Nigeria. Another importance of this investigation is to improve the quality of concrete produce in hot regions in Nigeria.

This could be attained by using sugar as a retarding admixture in concrete during the production stage of concrete so that to prevent it from adverse effects of temperature.

CHAPTER TWO

LITERATURE REVIEW

2.1 ADMIXTURE

Admixtures refers to materials beyond the standard mix of Portland cement, water, coarse aggregate and fine aggregates in concrete, aiming to enhance various properties such as workability, strength, setting time, frost resistance, impermeability and color (Oladiran et al., 2012). Adefemi et al. (2013) note that these additives play a role in improving concrete and mortar properties in both plastics and hardened states. These enhancements encompass modifying properties like compressive and flexural strength, durability, minimizing shrinkage, adjusting setting times, improving slump and workability, optimizing cement efficiency, and enhancing overall mixture economy.

Shetty (2009) emphasized that concrete serves diverse purposes but may lack the necessary performance or durability in certain conditions. To address this, admixtures are employed to alter the properties of ordinary concrete, adapting it to specific situations. It is crucial to evaluate the effects of an admixture on concrete before use, and careful control is necessary to ensure the appropriate quantity during the concrete production process (Shetty, 2009).

2.1.1 HISTORY OF ADMIXTURE

Throughout history, the use of admixtures in concrete has been evident since its inception. Romans, for instance, incorporated animal's fat, milk, and blood to enhance concrete properties, with blood serving as an effective air-entraining agent that potentially contributed to the durability of Roman concrete. Similarly, the Chinese utilized polished glutinous rice paste for similar purposes and Boiling bananas and the historical use of cactus juice and latex from rubber plants mark early practices. Calcium chloride emerged as a common accelerator for cement hydration, and the study of admixtures took root in the 1930s with the accidental discovery that beef tallow as a grinding aid improved cement resistance to freezing and thawing (Li, 2011).

Moreover, Shetty (2009) emphasized the expansive influence of admixtures in the construction domain. Water reducers, commonly known as plasticizers, retarders, and superplasticizers, gained prominence, particularly with their development in Japan and Germany around 1970. Subsequently, these innovations found widespread use in the USA, Europe, and even the Middle East. Presently, admixtures stand as indispensable components in modern concrete technology, offering the potential to modify or enhance concrete properties in both fresh and hardened states. However, predicting the outcomes of admixture use can be somewhat challenging due to variables such as changes in cement brand, aggregate grading, and mix proportions that may alter concrete properties.

2.1.2 CHEMICAL ADMIXTURES

As per ASTM C494 (1999), chemical admixtures encompass any additives to the concrete mixture that enhance its properties in the fresh or hardened state. General-purpose chemicals include those reducing water demand, termed water reducers, and those controlling setting time and strength gain rate, known as accelerators and retarders. ASTM C494 (1999) categorizes chemical admixtures into Type A (water-reducing), Type B (retarding), Type C (accelerating), Type D (water-reducing and retarding), Type E (water-reducing and accelerating), Type F (water-reducing, high range), Type G (water-reducing, high range and retarding) and Type S (Specific Performance) admixtures.

2.1.2.1 WATER-REDUCING ADMIXTURES

Water-reducing admixtures, sometimes referred to as plasticizer admixtures, aim to decrease the water content in concrete mixes, typically by 5 to 10%, and occasionally, in highly workable concrete, up to 15%. The purpose of employing water-reducing admixtures is to enable a reduction in the water-cement ratio while maintaining the desired workability or, alternatively, to enhance workability at a specified water-cement ratio. The extent of water reduction depends on the admixture dosage, cement content, and the type of aggregate used (Li, 2010). Neville and Brooks (2010) outline the reasons for using water-reducing admixtures as follows:

1. .Achieve Higher Strength: By reducing the water/cement ratio while maintaining workability.

2. Increase Workability: Facilitate placing in challenging locations, beneficial when concrete pores are restricted due to congested reinforcement or thin sections.

3. Save Cement Quantity: Up to 10% reduction can be achieved while maintaining the same water/cement ratio and workability.

2.1.2.2 RETARDING ADMIXTURES

Retarding admixtures are capable of delaying or extending the setting of cement paste, keeping the concrete plastic and workable for a more extended period compared to normal concrete without altering its mechanical properties. This type of admixture is also effective in counteracting the accelerated setting caused by hot weather. It operates by coating the surface of tricalcium silicate (C3S) components, thereby delaying their reaction with water (Greesan et al ., 2014).

2.1.2.3 ACCELERATING ADMIXTURE

These additives, when introduced into concrete or mortar, enhance the pace of hydraulic cement hydration, reduce the setting time, and expedite the hardening or strength development of the concrete or mortar. Accelerating admixtures operate by interacting with the tricalcium silicate (C3S) component of the cement, thereby amplifying the reaction between cement and water. The motivations for utilizing accelerating admixtures include:

1. Reducing the setting time of cement, thereby accelerating the strength gain.

2. Facilitating earlier removal of concrete formwork, expediting production.

3. Mitigating segregation, enhancing density, and increasing compressive strength.

4. Lowering water requirements, minimizing bleeding, shrinkage, and the time needed for the initial set.

2.1.2.4 SUPERPLASTICIZER ADMIXTURES

Superplasticizer admixtures, also known as high-range water reducers, enable a substantial reduction of water in the concrete mix, up to 30%, without adversely affecting workability. The reasons for employing superplasticizer admixtures, as specified by Gupta and Gupta (2012) are:

1. Producing more workable concrete than concrete without superplasticizer at the same water/cement ratio.

2. Significantly reducing the water/cement ratio while maintaining the same cement content and workability, leading to increased strength.

3. Allowing a greater reduction in cement content while maintaining the same water/cement ratio, resulting in cost savings.

2.2 RETARDING ADMIXTURE

Chemicals added to the cement-water mix can influence the rates of cement hydration reactions. Retarding admixtures, a category of chemical additives, exert an impact on these reactions, causing a delay in the cement paste stiffening process (Myrdal, 2007). Retarders decelerate the pace of the reaction between cement and water by influencing the growth of hydration products and/or reducing the rate of water penetration to the cement particles. The introduction of a retarder extends the setting time, potentially reducing early strength but enhancing the ultimate strength of the concrete (EFCA, 2005). Some retarders, such as sugar (Greesan et al., 2014) and lignosulphonates (Ramachandran, 1999), may possess additional characteristics, including water reduction properties across a wide range of dosages.

As per ASTM C 494 (1999), these retarders fall under Type B, possessing set-retarding properties and finding extensive use in hot weather conditions. Consequently, they can be categorized as both retarding and water-reducing admixtures. Since the concrete stiffening rate can be excessively fast in hot weather, allowing sufficient time for transportation and placement before setting is crucial. In such conditions, retarding admixtures prove highly beneficial. Effective retardation in setting time, up to 8-10 hours, is achievable through the judicious use of retarders. ASTM 494 (1999) outlines the physical requirements for retarding admixture (Type B), as presented in table 2.1

Table 2.1 Physical Requirements for Retarding Admixture

Property	Requirements
Setting time, allowable deviation	Initial: at least1 hour later
From control	not more than 3:30min later
	Final: at least…….
	Not more than 3:30min later
Compressive Strength	3 days: 90
Min % control	7 days: 90
	28 days: 90
	6 months: 90
	1 year: 90
Flexural Strength	
Min % control	3 days: 90
	7 days: 90
	28 days: 90
Length change, max, Shrinkage (max)	
% of control	135
Increase over control	0.010
Relative durability factor min	80

SOURCE: ASTM C494 (1999)

As per Myrdal (2007), retarding admixtures can be categorized based on their chemical composition, and the key components of these retarders include:

1 .Lignosulphonates, acids, and their salts.

2 Hydroxycarboxylic acids and their salts.

3. Carbohydrates, specifically sugar.

4. Inorganic compounds, including phosphates.

2.2.1 Lignosulphonates

Lignosulphonates encompass a range from raw sodium and calcium salts of lignosulphonic acids to refined, sugar-free lignosulphonates, and even modified versions blended with small amounts of alkanolamines to counteract set retardation (Ramachandran, 1999). These retarding admixtures contain approximately 30% carbohydrates (reducing sugars), making them less efficient in retarding cement paste (Myrdal, 2007).

2.2.2 Hydroxycarboxylic Acid Salts (Fruit Acid)

Hydroxycarboxylic acids and their salts share chemical properties with sugars, and some promote the retardation of cement hydration similar to sugars (Ramachandran, 1999). However, a drawback noted by Dransfield (2012) is that these retarding admixtures may reduce cohesion in the mix, potentially enhancing bleeding and segregation in the concrete. Hydroxycarboxylic acids, characterized by carboxyl groups and hydroxyl groups interacting with the cement, exhibit optimal retardation properties among the α-hydroxycarboxylic acids (those with a hydroxyl group adjacent to the carboxyl group). Retarders based on salts of hydroxycarboxylic acids were developed in the 1950s. Salicylic acid, a phenolic carboxylic acid, has been utilized as a model compound to study the interaction between cement and hydroxycarboxylic acids (Dransfield, 2012).

2.2.3 Phosphates

Phosphates fall under the category of inorganic retarding admixtures. Most phosphates retard cement setting through a precipitation mechanism. For instance, the adsorption of phosphate ions at the surface of the clinker phase or on the first hydration product is believed to lead to the precipitation of Ca-phosphates. Once insoluble and dense coatings form, they contribute to the retardation of cement setting. Upon the formation of coatings around the cement grains, hydration significantly slows down, leading to the retardation of cement paste setting (Myrdal, 2007). Dransfield (2012) notes that phosphate-based retarding admixtures are designed for a more linear effect of dosage on setting time. The dosage rate may be relatively high compared to other retarders, with a typical range of 0.1 to 3.0% by weight of cement required to achieve significant retardation results.

2.2.4 SUGAR

Refined white sugar (sucrose) stands out as an effective retarding admixture, serving as both a water reducer and set retarder (Greesan et al., 2014). Capable of reducing the necessary mixing water by up to 15%, it maintains the mix's workability. This contributes to the production of higher-strength concrete with reduced shrinkage.

2.2.5 BENEFITS OF RETARDING ADMIXTURE

According to Schaeffel et al. (2014), retarders find use in delaying concrete setting for various purposes:

1. Counteracting the accelerating effect of hot weather without resorting to expensive cooling.
2. Facilitating long transport distances.

3. Addressing difficult or unusual placement conditions.

In the casting of massive concrete structures, retarders prove beneficial:
1. Preventing construction joints or lack of bond between concrete layers.
2. Achieving uniform strength development.

3. Reducing maximum hydration heat, thereby lowering the risk of cracking.

2.2.6 GENERAL MECHANISM OF RETARDING ADMIXTURES

Retarding admixtures in cement-water systems operate through four different types of interaction between the retarder and the cement grain. Most retarders operate through multiple mechanisms, including:

1. Adsorption: Admixture molecules are adsorbed on the surface of cement particles, hindering further reactions between cement and water, thus retarding the setting of cement paste (Gadzama et al., 2015).

2. Complexation: The admixture forms complexes with calcium ions liberated during hydration, enhancing the early hydration sheath around cement grains.

3. Precipitation: The admixture reacts with cement components, forming a precipitate on cement particles that imparts a low-permeability coating. This protective skin slows down hydration, thereby retarding the setting of cement paste (Khan and Baradan, 2002).

4. Nucleation: Retarding compound adsorption on the nuclei of calcium hydroxide defers growth essential for the hydration process, resulting in the retardation of concrete setting time (Greesan et al., 2014).

2.3 HISTORY OF SUGAR

Sucrose, commonly known as table sugar, is a disaccharide carbohydrate composed of one glucose unit and one fructose unit with the molecular formula $C_{12}H_{22}O_{11}$. Naturally found in fruits and vegetables, sugar is most abundant in sugar beets and sugar cane. According to Duna (2014), the term "sucrose" was coined in 1857 by English chemist William Miller, derived from the French word "sucre" meaning sugar and the generic chemical suffix for sugars, "-ose." The abbreviation "Suc" is often used for sucrose in scientific literature.

2.3.1 Origin of Sugar

Sugar (sucrose) is present in the stems of sugar cane and the roots of sugar beet. It also naturally occurs alongside fructose and glucose in other plants, particularly fruits and certain roots like carrots. The varying proportions of sugars in these foods determine their sweetness. Sucrose molecules are formed by combining a molecule of fructose with a molecule of glucose.

2.3.2 Sugarcane

Sugar cane (Saccharum spp.) is a perennial grass in the family Poaceae, cultivated in tropical and sub-tropical regions for the sucrose found in its stems. Thriving in a frost-free climate with sufficient rainfall during the growing season, sugarcane maximizes its growth potential. The crop is harvested either mechanically or by hand, cut into lengths, and swiftly transported to the processing plant. Here, it undergoes milling with water extraction or diffusion extraction. The extracted juice is clarified, heated to neutralize enzymes, and the resulting thin syrup undergoes concentration in a series of evaporators. Additional water removal is achieved through evaporation in vacuum containers. The supersaturated solution is seeded with sugar crystals, which crystallize out, are separated from the fluid, and then dried. The byproduct includes molasses, and the stems' fiber, known as bagasse, is burned to provide energy for sugar extraction. Raw sugar crystals have a sticky brown coating and can be used as is or bleached with sulfur dioxide or treated in a carbonatation process to produce a white product.

Sugar extraction from sugarcane is achieved through the mill extraction process. Mills extract raw sugar from freshly harvested cane, and mill-white sugar is sometimes produced immediately after the sugarcane extraction stage. Natural sugar crystals appear in this process white color to prevent the formation of color-inducing molecules and stabilize sugar juice during evaporation, sulfur dioxide is added.

2.3.3 Sugar Beet

Sugar beet (Beta vulgaris) is a biennial plant in the family Amaranthaceae, with its tuberous root containing a high sucrose proportion (Duna, 2014). Cultivated in temperate regions with sufficient rainfall and fertile soil, the crop undergoes mechanical harvesting in autumn, with the crown of leaves and excess soil removed. The roots, which do not deteriorate rapidly, can be stored in a clamp in the field for weeks before transportation to the processing plant. The processing involves washing and slicing the crop, followed by sugar extraction through diffusion. Raw juice is treated with milk of lime and carbonatated in stages for purification. Evaporation, conducted under a vacuum, removes water from the syrup. After cooling and seeding with sugar crystals, the resulting crystallized white sugar is separated in a centrifuge and dried, requiring no further refining.

2.3.4 Chemical composition of Sugar

Sugar, a carbohydrate composed of carbon, oxygen, and hydrogen, includes members such as sucrose, fructose, dextrose, lactose, and other 'Oses.' Found in sugar cane and sugar beet, the basic unit of a carbohydrate is a linear chain of four to seven carbon atoms, each with a hydroxyl group, with the terminal carbon being an aldehyde (Khan and Baradan, 2002). As per Myrdal (2007), the chemical composition of sugar (sucrose) is discussed below.

2.4 SUGARS AS A RETARDING ADMIXTURE IN CONCRETE

Sugar, a carbohydrate composed of carbon, oxygen, and hydrogen, is found in sugar cane and sugar beet, with the chemical structure $C_{12}H_{22}O_{11}$. Fructose and glucose, belonging to this chemical class, form its constituents. Classified as a non-reducing sugar with a five-membered ring structure, sugar serves as an efficient retarder admixture in concrete (Khan and Baradan, 2002).

Gupta and Gupta (2012) suggest that to achieve a retarding effect, the optimal dosage of sugar as a retarder ranges between 0.05 to 0.15% by weight of cement. This range delays the rapid setting of cement paste for 4 hours, leading to a reduction in early concrete strength. Nevertheless, the 28-day strength of concrete improves. The specific impact of sugar varies based on the chemical composition of the cement (Neville and Brooks, 2010). Using a higher

quantity of sugar, approximately 0.2 to 1.0% of the weight of cement, can virtually prevent cement setting, necessitating trial tests to determine the optimal dosage of sugar to be used.

Jayakumaran (2005) suggests that incorporating sugar as a retarder in concrete may decrease early strength, but beyond 7 days, a noticeable increase in strength, potentially attributed to the production of a denser cement gel through delayed setting, has been observed. Additionally, Kumar (2015) notes that improved strength may result from enhanced bonding within the concrete, indicating sugar's positive impact on bonding properties. Myrdal (2007) emphasizes that not all sugars impede cement hydration, with reducing sugars acting as moderate retarders, while non-reducing sugars, based on their chemical structures, prove highly effective as retarders. The sugar groups can be categorized as follows:

2.4.1 Reducing Sugars

1. Glucose

2. Fructose

3. Maltose (malt sugar)

4. Lactose (milk sugar)

2.4.2 Non-reducing Sugars

1. Sucrose (composed of glucose and fructose)

2. Trehalose (composed of two glucose units)

3. Reffinose.

Interestingly, sugar (sucrose) can serve as an accelerating admixture in concrete at high dosage levels. Abalaka's (2011b) study on the comparative effects of cassava and sugar in cement mortar and concrete revealed that a sugar content of 0.6% by weight of cement accelerates initial setting times to 54 minutes, meeting the requirement of BS EN 1971:1992, which mandates a maximum setting time of 60 minutes. Similarly, Khan and Baradan (2002) explored sugar's impact on the setting time of various cement types. Findings indicated that sugar incorporation retarded the setting time under all curing conditions. The extension in setting time increased up to a certain limit (around 0.15%), after which it began to decrease. Notably, higher sugar content (>0.3%) accelerated cement setting.

Sucrose:

Chemical formula: $C_{12}H_{22}O_{11}$

Composition: Sucrose is a disaccharide composed of one molecule of glucose and one molecule fructose. It is the most common types of sugar and is extracted from sugarcane or sugar beets.

Glucose:

Chemical formula: $C_6H_{12}O_6$

Composition: glucose is a monosaccharide, meaning it consists of a single sugar molecule. It is a primary source of energy for living organisms and is found naturally in various fruits and vegetables.

Fructose:

Chemical formula: $C_6H_{12}O_6$

Composition: fructose is also a monosaccharide and is similar in chemical composition to glucose. It is commonly found in fruits and honey.

In the context of using sugar as a set retarder in concrete, the specific type of sugar chosen for this purpose is often less critical than its overall composition. The goal is to introduce a substance that interferes with the hydration process of cement, leading to delayed setting time. Sucrose, being a readily available and affordable option, is commonly used in practice.

2.4.1 Sugar's Retardation Mechanism in Cement Hydration

The retardation of cement setting by sugar involves two key mechanisms:

1. Complex Formation with Calcium Ions Sugar forms complexes with calcium ions in solution, increasing their solubility. This discourages the formation of calcium hydroxide nuclei.
In this mechanism, when ordinary Portland cement hydrates in a sucrose solution, a sucrose-calcium complex (R -O –Ca+ -OH) is formed. This complex attaches the Ca+OH group to the five-membered ring (R) of the sucrose molecule. The sucrose-calcium complex inhibits the growth of the calcium hydroxide nucleus, slowing down hydration.

Slower hydration prevents the substantial formation of hydration products that give rigidity to the cement paste, keeping the concrete in a plastic state for a longer period. The formation of complexes increases cement solubility, leading to a higher concentration of Ca2+OH, Si, Al, and Fe in the aqueous phase of cement pastes when hydrated with sugar. This accumulation prevents the precipitation of calcium and hydroxyl ions to form calcium hydroxide (Khan and Ullah, 2004).

2. Precipitation Around Cement Particles, Sugar molecules react with cement components to form a precipitate around cement particles. This precipitate imparts a low-permeability coating on the cement particles. The interference with the cement binding process in concrete occurs as sugar molecules attach themselves to the hydrating cement, inhibiting chemical reactions (Khan and Ullah, 2004).

Sugar is recognized as an effective retarder in concrete, as it plays a role in stiffening the material and delaying the setting of cement paste (Otunyo et al., 2015). Refined white sugar, in particular, is considered one of the best retarders (Greesan et al., 2014). Giridhar et al. (2013) propose the coating theory, where sugar molecules are adsorbed on the cement particles' surface, forming a thin layer that acts as a diffusion barrier. This barrier impedes water molecules from reaching unhydrated cement grains, retarding the hydration of tricalcium silicate (C3A) and prolonging the dormant period (Ramachandran, 1999).

2.4.2 Effect of sugar as a retarding admixture on the properties of fresh concrete

Fresh concrete, also known as plastic concrete, is a recently blended substance that is moldable into various shapes. The proportions of cement, aggregates, and water combined determine the characteristics of concrete in both its wet and hardened states (Shetty, 2009). Giridhar et al. (2013) highlight the substantial impact of sugar as a retarding admixture on the properties of fresh concrete.

2.4.2.1 WORKABILITY
The workability of concrete is affected by many factors including initial slump, type and amount of concrete, temperature, relative humidity and presences of chemical admixtures (Gupta and Gupta, 2004). Also Neville and Brook (2010) defined Workability as being

characterized as the quantity of valuable internal work needed for complete compaction in concrete. This valuable internal work pertains specifically to concrete and represents the effort or energy essential to overcome the internal friction among its individual particles. Retarding admixtures, such as sugar, enable a decrease in concrete's water content without compromising its workability, with the reduction being particularly notable. (Greesan et al., 2014). Mixes with elevated slump values experienced a notable 30% increase in slump when a specific dose of retarding admixture was introduced (Maroliya, 2012). Giridhar et al. (2013) explored the impact of sugar and jiggery on concrete's strength properties, revealing a 50% improvement in workability with a 0.1% addition of sugar compared to the control sample. Additionally, concrete's compressive strength at 28 days saw a 12% enhancement. Alsadey (2013) emphasized that incorporating a retarder in concrete achieves good workability by delaying the setting time and facilitating proper compaction without segregation. However, excessive dosages of retarder admixture have the potential to compromise the cohesiveness of concrete.

2.4.2.2 SEGREGATION AND BLEEDING

Segregation involves separating mixture components based on differences in specific gravity and size, creating an uneven mixture. Bleeding, a specific type of segregation which occurs when mixing water rises to the surface, increasing the water-cement ratio in the upper concrete layer, leading to weaknesses and durability issues. While some bleeding is beneficial for removing excess water and preventing plastic shrinkage cracking, excessive bleeding can be problematic. Dransfield (2012) notes that concretes with sugar as a retarding admixture are more cohesive, reducing the likelihood of segregation. The degree of bleeding depends on the type of retarder used, with hydroxycarboxylic acids increasing bleeding rate and non-reducing sugars, especially sucrose (Sugar). The rate of bleeding of a particular retarder should be investigated before using it in the field in order to prevent plastic cracks due to high rate of evaporation especially under hot and windy weather conditions (Ramachandran, 1999).

2.4.2.3 SETTING TIMES

Retarding admixtures generally prolong both initial and final setting times, with the extent of delay influenced by the admixture dosage, cement type, mixing water quantity, and concrete temperature (Greesan et al., 2014). Dransfield (2012) highlights that delaying setting time helps prevent cold joint formation between concrete deliveries. Even when workability

diminishes, fresh concrete that hasn't set can still be vibrated and effectively bond with preceding pours.

Abalaka (2011b) conducted a study comparing the effects of cassava starch and simple sugar in cement mortar concrete. Results indicated increased initial and final setting times with 0.05% sugar content by weight of cement, with a 3.62% improvement in compressive strength at 28 days with 0.06% sugar concentration. Rana (2014) investigated sugar's impact on setting time and compressive strength in Portland cement paste, finding a 4% increase in strength at 0.07% sugar by weight of cement, along with a 3-hour and 35-minute delay in initial setting—beyond the 45-minute minimum specified by BS EN 1971 (2000). Khan and Baradan (2002) explored sugar's effects on setting time across various cement types, revealing that a 0.15% sugar content prolonged setting time while a 0.3% addition accelerated the setting process.

2.4.3 Effect of retarding admixture on the properties of hardened concrete

2.4.3.1 Compressive strength

Utilizing retarder and water reducer admixtures enables a reduction in water content within the mixture, leading to a lowered water/cement ratio and an enhanced compressive strength (Dias et al., 2010). Contrary to solely attributing strength improvement to reduced water content, Ramachandran (1999) suggests additional factors. Kumar (2015) emphasizes that sugar contributes to compressive strength enhancement through its bonding properties. Rana (2014) observes a slowed rate of strength gain within the first day when sugar is used as a retarding admixture, but notes higher compressive strength at 28 days compared to non-retarding concrete (Gupta and Gupta, 2012).

In an experiment by Suryawanshi et al. (2014) on the effects of sugar powder on cement strength, a 0.1% sugar addition by weight of cement increased both initial and final setting times and boosted compressive strength by 20% compared to the reference sample. Similarly, Otunyo et al. (2015) found that a 0.05% sugar addition increased compressive strength by approximately 17% at 28 days. However, Alsadey (2013) warns that while retarders don't enhance compressive strength and can even decrease it, their negative impact diminishes with time, slightly improving strength after 7 days due to delayed reactions of C_3S and C_3A. Also , some retarders, increase in dosage will increase the compressive strength for all ages (Alsadey, 2013).

2.4.3.2 Split tensile strength

The utilization of retarders leads to a slight increase in split tensile strength, with an observed 10 percent enhancement after 7 days. Previous studies indicate that retarding admixtures containing lignosulfonates and hydroxy-carboxylic acids don't affect the relationship between compressive and tensile strength. However, specific retarding admixtures like sugar were found to cause a minor alteration in this relationship (Ramachandran, 1999).

In Rathi and Kolase's (2013) research on the effect of cold joints on concrete strength, a 0.1% addition of sugar resulted in a 17.79% increase in split tensile strength, a 4.11% increase in compressive strength, and a 17.41% increase in flexural strength compared to normal concrete. Additionally, Naqash et al. (2014) observed that chemical admixtures increased split tensile strength by 33%, 14%, and 10% at 3, 7, and 28 days of age, respectively.

2.4.3.3 Abrasion Resistance

The use of a retarder typically enhances the abrasion resistance of concrete by decreasing water content. Additionally, the retarding effects of the admixture contribute to an improved resistance to abrasion. The delayed setting time facilitated by the retarder allows for superior finishing, particularly in hot weather conditions.

2.5 Climatic Problems in Concreting

Neville (2006) observed that concrete laboratory testing is typically conducted at a regulated temperature ranging from 18 to 27°C, and the relative humidity should not fall below 90%, as stipulated by BS EN 1973: 1995. However, when concreting occurs outside the laboratory, it must align with the existing environmental conditions. Unfavorable conditions for concrete placement include hot, sunny, windy, and dry weather with low relative humidity. Higher temperatures accelerate water evaporation from the fresh concrete mix, with a 10°C increase leading to approximately twice the evaporation rate. Reduced air humidity makes water evaporation easier and faster, causing rapid cement paste setting with detrimental effects on concrete.

In specific regions like the extreme Northeast and Northwest parts of Nigeria, such as Sokoto, Birnin Kebbi, Yola, and Maiduguri, characterized as hot dry zones, concreting faces

challenges due to mean maximum temperatures of 35 to 43°C and 40% relative humidity (Okereke, 2003). These areas experience low humidity and dry, dusty winds, adversely affecting concrete. The climatic conditions lead to a rapid loss of fresh concrete workability and faster hardening, influenced by the drying impact of the harmattan wind. This premature elimination of the cement hydration process hinders the normal strength development of concrete with age (Dahiru, 2010).

Standards such as B.S 53283 (1990) specify that the temperature of fresh concrete upon delivery into construction should not exceed 30°C. In hot, dry weather, B.S 5328-1 (1997) recommends modifying concrete properties by:

1. Using admixtures to retard hydration and enhance initial workability,

2. As well as selecting a cement or combination with low heat evolution,

3. Specific a maximum temperature of fresh concrete less than 30°C.

2.5.1 Hot Weather Concreting

Defining "hot weather" for concrete work is not solely based on a specific temperature limit; factors like humidity and wind conditions play a crucial role. A warm, humid, and calm day might not pose as many challenges as a cooler day with lower humidity and strong winds, as the latter encourages water evaporation from exposed concrete surfaces (Newman and Choo, 2003). ACI 305(1999) characterizes hot weather as a combination of high air temperature, low relative humidity, and wind speed that could compromise the quality of fresh or hardened concrete, resulting in abnormal properties. Neville and Brooks (2010) specify hot weather concreting as working at an atmospheric temperature above 35°C.

Rowland (2014) suggests that as concrete temperature rises, the rate of hardening increases and a 20-degree increase can reduce setting time by 35 minutes. Khan and Ullah (2004) observe that raising the temperature of cement mortar with a water/cement ratio of 0.6 from 27°C to 46°C halves both initial and final setting times. Hot weather can lead to various issues, including a rapid slump decrease, cold joint formation, plastic shrinkage cracking, challenges in air entrainment, increased permeability, reduced durability, and a decrease in ultimate strength.

Furthermore, high temperatures impact concrete at all production and placing stages, with consequences for long-term strength and durability. These effects result from elevated temperatures accelerating the hydration reaction and influencing moisture movement within and from the surface of concrete.

2.5.2 Potential Problems of Hot Weather on the properties of fresh concrete

The effects of hot weather on the properties of fresh concrete include the followings:

a. Higher Water demand

The workability of concrete, given a specific water content, is influenced by its temperature. An elevation in concrete temperature, moving from 27°C to 46°C, correlates with a slump reduction of around 25 mm. relying solely on water to achieve the necessary workability at elevated temperatures results in diminished strength and durability. Additionally, higher water content contributes to heightened drying shrinkage, as outlined by Rowland (2014).

b. Rapid decrease in workability

Elevated temperatures cause concrete to lose workability more rapidly due to a combination of water loss through evaporation and the accelerated rate of the hydration reaction. Cement hydration in concrete is an exothermic process, generating heat. Generally, the speed of an exothermic reaction doubles for every 10°C temperature increase. As the hydration reaction progresses more swiftly, the paste stiffens earlier, resulting in reduced workability. This may tempt compensatory measures such as adding water on-site, risking detrimental effects on strength and durability. Insufficient workability can pose challenges in achieving proper compaction, impacting the concrete's strength and durability, as highlighted by Khan and Ullah (2004).

c. Decrease in setting time

Due to the accelerated rate of the hydration reaction, concrete mixes exhibit a faster initial set at elevated temperatures, consequently reducing the available transit time. Placing and finishing of concrete are influenced by factors such as the rate of the hydration reaction, which varies with cement type, its physical properties (like fineness), and the presence of additional cementitious materials such as pulverized fly ash and ground granulated blast furnace slag (Li, 2011). Additionally, higher temperatures, as highlighted by Hassan (2010),

elevate the internal temperature of cement paste hydration, accelerating the chemical reaction and, consequently, the setting time.

d. plastic shrinkage

concrete mixes tend to exhibit the downward movement of denser constituents and upward movement of water, known as bleeding. This water, reaching the surface, may evaporate, with evaporation rates increasing in warmer temperatures and higher wind speeds, and decreasing relative humidity. If surface moisture loss surpasses the replenishment through bleeding, a volume reduction occurs in the surface layer, resisted by the underlying concrete, leading to tensile stresses and cracks—referred to as plastic shrinkage cracking.

e. hydration peak temperature/thermal cracking

hydration reaction generates heat, causing the concrete temperature to rise. A higher initial concrete temperature accelerates the reaction, increasing the rate of heat evolution and subsequently the peak temperature reached. This phenomenon is crucial in understanding the risk of thermal cracking during concrete hydration.

2.5.2 Potential Problems of hot weather on the properties of hardened concrete

The introduction of additional water to fresh concrete on-site to compensate for slump loss can have significant effects on the properties of hardened concrete, as noted by Alsadey (2013).
a. Ultimate Strength:

Concrete strength is predominantly influenced by the water/cement ratio, with strength decreasing as the ratio increases. The ultimate strength of concrete relies on the rate and extent of cement hydration. A higher rate of cement paste hydration results in increased early strength but lower ultimate strength, according to Rowland (2014).

b. Durability:

Various mechanisms of deterioration hinge on fluid or gas passage through the concrete pore structure. Enhancing concrete impermeability is crucial for achieving durability, often attained by maintaining a low water/cement ratio. However, high temperatures can impact

initial workability and the rate of workability loss, tempting the addition of more water at the mixer or on-site. This can lead to concrete susceptibility to freeze-thaw cycles, weathering, sulfate attack, and the penetration of carbon dioxide and chloride solutions, ultimately causing reinforcement corrosion (Rathi and Kolase, 2013). Reduced workability from high temperatures can also result in poor compaction, leaving the concrete more vulnerable to deterioration. Additionally, plastic shrinkage or early thermal cracks may compromise durability by allowing the ingress of deleterious agents such as moisture, carbon dioxide, oxygen or chlorides to gain easy access to the concrete or reinforcement (Newman and Choo, 2003).

2.6 Cement

Cement, a fundamental component of concrete, plays a crucial role in determining the properties of concrete based on the specific brand of cement used (Anejo et al., 2014). Duggal (2008) categorizes cement into hydraulic and non-hydraulic types, with non-hydraulic types like Plaster of Paris not requiring water to enhance strength. Hydraulic cement, such as ordinary Portland cement, sets and hardens in water. Ordinary Portland cement is the most common hydraulic type, crafted from lime, silica, alumina, and iron oxide. These raw materials are crushed, blended, and then subjected to high-temperature kiln burning. The resulting clinker is cooled, mixed with gypsum, and ground into a fine powder, constituting cement. Key chemical compounds in cement are calcium silicates and aluminates (Neville and Brooks, 2010).

When water is added to cement, and the constituents are mixed to form cement paste, chemical reactions occur, causing the mix to stiffen and set over time. The addition of gypsum serves to retard and control the setting time, ensuring that the concrete neither sets too quickly before placement nor too slowly, hindering construction progress (Yahaya et al., 2014).

2.6.1 Chemical composition of ordinary Portland cement

The raw materials—lime, silica, alumina, and iron oxide—interact at high temperatures in the kiln to form complex compounds. These compounds then react to produce the four key

components of Portland cement. The relative proportions of these oxide compositions significantly influence various properties of the cement, shaping its performance characteristics. Table 2.2 shows the approximate oxide composition limits of ordinary Portland cement.

Table 2.2 Approximate oxide composition limits of ordinary Portland cement

Oxide	Common name	Per cent content
CaO	Lime	60-67
SiO_2	Silica	17-25
Al_2O_3	Alumina	3.0-8.0
Fe_2O_3	Ferric Oxide	0.5-6.0
MgO	Magnesia	0.1-4.0
K_2O and Na_2O	Alkalis	0.4-1.3
SO_3	Sulfur tioxide	1.3-3.0

Source: Shetty (2009)

2.6.2 Composition of cement clinker

During the burning process, the diverse constituents combine to create cement clinker. These compounds, identified as Bogue compounds after Bogue who characterized them, possess the ability to set and harden in the presence of water. The major Bogue compounds of ordinary Portland cement, formed in the clinkering process, are detailed in Table 2.3 (Duggal, 1990).

Table 2.3 Composition of cement clinker

Composition	Formula	Symbol

Tricalcium silicate	$3CaO.SiO_2$	C_3S
Dicalcium silicate	$2CaO.SiO_2$	C_2S
Tricalcium aluminate	$3CaO.Al_2O_3$	C_3A
Tetracalcium aluminoferrite	$4CaO.Al_2O3.Fe_2O_3$	C_4AF

Source: Duggal (1990).

2.6.2.1 Tricalcium silicate

The tricalcium silicate is considered the most effective cementing material when well-burnt, constituting approximately 25-50% (typically around 40%) of cement. It enhances clinker grind ability, boosts resistance to freezing and thawing, enables rapid hardening for early strength, and facilitates a swift heat evolution. However, exceeding specified limits in C_3S content raises the heat of hydration and cement solubility in water. The hydrolysis of C_3S primarily influences 7-day strength and hardness. The rate of C_3S hydrolysis and the resulting gel's characteristics are key factors determining cement paste hardness and early strength.

2.6.2.2 Dicalcium silicate

 Comprising around 25-40% (typically 32%) of cement hydrates and hardens gradually, contributing to long-term strength (after a year or more) and enhancing resistance to chemical attack. Although C_2S in cement is not purely composed, containing minor oxides in solid solution, these oxides significantly affect atomic arrangements, crystal form, and hydraulic properties of the silicate. An increase in C_2S content makes clinker harder to grind, reduces early strength, diminishes resistance to freezing and thawing in early stages, and lowers heat of hydration. C_2S hydrolysis progresses slowly, with minimal influence on strength and hardness in the first month but becoming proportionally significant after a year.

2.6.2.3 Tricalcium aluminate

Constitutes about 5-11% (usually around 10.5%) of cement reacting rapidly with water and causing flash set in finely ground clinker. The rapid action is controlled by adding 2-3% gypsum during cement grinding. The presence of gypsum is essential to retard the rapid setting of cement paste, and the amount of gypsum added to the clinker is crucial. This

quantity depends on the C_3A content and alkali content of the cement. Increasing cement fineness augments C_3A content, necessitating a higher gypsum requirement. However, an excess of gypsum can lead to expansion and subsequent disruption of the set cement paste (Neville and Brooks, 2010).

Additionally, tricalcium aluminate is responsible for initial set, high heat of hydration, and has a greater tendency to cause volume changes, leading to cracking. Elevated C3A content reduces setting time, weakens resistance to sulfate attack and rapid hardening but lowers final strength. C_3A in cement powder hydration induces sudden hardening in the cement paste, typically mitigated by gypsum addition. A high C_3A content in cement is undesirable (Ibrahim et al., 2012).

2.6.2.4 Tetracalcium aluminoferrite

Constituting around 8-14% (typically about 9%) of cement induces flash set with less heat generation and imparts a grey color to the cement. It possesses the lowest cementing value, and increasing C_4AF content slightly reduces strength (Duggal, 1990).

The calculation of major compound percentages in clinker, based on Bogue's formula, is provided by ASTM C 150 (2005) through the following equations:

$C_3S = 4.07(CaO) - 7.60(SiO_2) - 6.72(Al_2O_3) - 1.43(Fe_2O_3) - 2.85(SO_3)$..........2.2

$C_2S = 2.87(SiO_2) + 0.754(3CaO. SiO_2)$...2.3

$C_3A = 2.65(Al_2O_3) - 1.69(Fe_2O_3)$...2.4

$C_4AF = 3.04(Fe_2O_3)$...2.5

2.6.2 Classification of Portland cement

As per the American Society of Testing and Materials (ASTM C150-05), Portland cement is categorized into the following types:

1. Type I - Ordinary Portland cement

2. Type II - Modified cement

3. Type III - Rapid Hardening Portland cement

4. Type IV - Low Heat Portland cement

5. Type V - Sulfate Resistance Portland cement

Table 2.4 Typical average values of compound composition of Portland cement of different types

Cement type	Compound composition, (per unit)							
	C3A	C2S	C3A	C4AF	CASO4	Free CaO	MgO	LOI
I	59	15	12	8	2.9	0.8	2.4	1.2
II	49	29	6	12	12	0.6	3.0	1.0
III	60	12	12	8	3.9	1.3	2.6	1.9
IV	30	46	5	13	2.9	0.3	2.7	1.0
V	43	36	4	2	2.7	0.4	1.6	1.0

Source: Neville and Brooks (2010)

2.6.2.1 Ordinary Portland (Type I) Cement

Ordinary Portland cement stands as the predominant choice for general concrete construction in scenarios without sulfate exposure in the soil or groundwater. A composition restriction stipulates that the (C_3A) content should not surpass fifteen percent. This cement type is manufactured by heating limestone and clay to approximately 1300°C, resulting in clinkers rich in calcium silicates. Subsequently, the clinker is finely ground into powder, with a small addition of gypsum to regulate the setting rate when the cement is mixed with water (Barry, 1999).

2.6.2.2 Modified (Type II) Cement

For applications where very low early strength might be a disadvantage, a modified cement was introduced in the USA. This cement exhibits a higher rate of heat development compared to Type IV cement, with a strength gain rate similar to that of Type I cement.

2.6.2.3 Rapid Hardening Portland (Type III) Cement

Similar to Type I cement and adhering to the same standards, Type III cement is characterized by rapid strength development due to a higher C_3S content, reaching up to 70 percent, and a minimum fineness of 325m²/kg. It is commonly employed when early removal of formwork for re-use is necessary or when quick strength for further construction is required. However, caution is advised in using it for mass concrete construction or large structural sections due to its elevated rate of heat development.

2.6.2.4 Low Heat Portland (Type IV) Cement

With relatively higher percentages of C_2S and C_4AF compared to C_3S and C_3A, Type IV cement restricts the maximum C_3A percentage to seven percent. This limitation slows down the rate of heat released during hydration, resulting in a gradual development of concrete strength.

2.6.2.5 Sulfate-Resisting (Type V) Cement

Designed to resist sulfate attack from external sources, Type V cement features a low C_3A content to prevent disruption of concrete caused by the formation of calcium sulfoaluminate and gypsum. Active sulfate agents, particularly magnesium and sodium sulfate, pose a significant threat, and the use of Type V cement is recommended to mitigate sulfate attack

2.6.3 Setting and hardening time of cement

Portland cement, being hydraulic, forms a paste when mixed with water, undergoing setting and hardening through chemical reactions with water. This process is independent of drying; in fact, Portland cement can harden underwater. Only a small portion of the added water is essential for the chemical hydration of cementitious compounds into hydrated calcium silicates. The additional water ensures the workability of the mix when aggregates are introduced, allowing successful placement of concrete within formwork containing steel

reinforcement. Excess water beyond hydration needs will eventually evaporate, leaving capillary pores in concrete and mortar products. A 1% increase in void space typically reduces crushing strength by 6%. Hence, it's crucial to carefully control the water content by referencing the water/cement ratio. A minimum ratio of 0.23 is necessary for complete cement hydration, but due to the expansion of hydrated cement powder, a ratio of 0.36 indicates the point where cement gel fills all water space. However, a more practical minimum water/cement ratio of 0.42 ensures full hydration without requiring additional water during the curing process (Lyons, 2007).

The setting and hardening processes are distinct. Setting refers to the stiffening of the cement paste, commencing immediately upon mixing cement with water. To differentiate the major cementitious constituents' varied setting rates, we identify initial set and final set. Initial set occurs when the cement paste significantly stiffens, signaling that further concrete mixing is detrimental. Final set, conversely, marks the point when the concrete starts gaining strength. Typically, initial set occurs within 1 hour, while final set takes 10 hours after initial water-cement contact (Duggal, 2008). Gypsum quantity added in the final production stage controls the setting process.

Hardening is the gradual strength gain of the set cement paste, extending over days, months, and years at a diminishing rate. The rate of hardening is influenced by the particle-size distribution of the cement powder. Finely ground cement hydrates more rapidly, initiating quicker setting and hardening (Lyons, 2007).

2.6.3.1 Factors Affecting Setting Time of Cement

Several conditions impact the setting properties of cement, including its composition, the percentage of retardant, degree of calcination, fineness of grinding, aeration post-clinker grinding, water percentage in cement paste, mixing water, cement temperature, atmospheric conditions during cement paste placement, and the extent of paste manipulation.

Gypsum increases the setting time of freshly ground cement; it is typically mixed with the clinker before final grinding or immediately after preliminary grinding. The addition of gypsum before calcination leads to its decomposition into lime and sulfur trioxide, influencing the setting time. Occasionally, under limed cement may become quick-setting after certain treatments.

To prevent the undesirable expansion of cement paste after setting, which could disrupt the hardened state, 1 or 2% of hydrated lime or a fraction of a percent of Plaster of Paris can be added to the cement during seasoning. The setting time of cement accelerates with increased fineness. When the mixing water used in testing cement paste exceeds that required for normal consistency by 1%, an increase of approximately 30 minutes or more is observed in the initial or final set (Gupta and Gupta, 2004).

2.6.3.1.1 Fineness of Cement

Irrespective of composition, fineness is a crucial property affecting the reaction rate of cement with water. Finely ground cement, with a greater surface area of particles compared to coarsely ground cement, influences the rate of reaction. A satisfactorily ground cement should typically have 1.1×10^{12} particles per kg. Overly fine grinding may lead to rehydration of particles by moisture, while coarser particles slow down the hydration rate (Gupta and Gupta, 2004).

2.6.3.1.2 Soundness of Cement

Maintaining the volume stability of cement paste post-setting is essential. Cement paste should not undergo significant expansion, as it could disrupt the hardened state. Potential expansion may result from the reaction of free lime, magnesia, and calcium sulfate. Cement exhibiting this type of expansion is classified as unsound (Neville and Brook, 2010). Free lime, present in the clinker and intercrystallized with other compounds, hydrates slowly, occupying a larger volume than the original free calcium oxide. Determining free lime through chemical analysis of cement is challenging.

Distinguishing between unreacted CaO and $Ca(OH)_2$ produced by partial hydration of silicates in cement, when exposed to the atmosphere, is challenging. Magnesia reacts with water similarly to CaO, but only the crystalline form is reactive in a harmful manner, leading to unsoundness. Calcium sulfate is the third compound that may cause expansion by forming calcium sulfoaluminate (ettringite) from excess gypsum not utilized by C_3A during setting (Neville and Brook, 2010).

CHAPTER THREE

METHODOLOGY

This chapter provides an in-depth overview of the materials utilized in the experimental program, along with the methods employed for conducting various tests.

3.1 Research Materials

The materials that will be employed in this experimental study encompassed Portland cement, fine aggregate, coarse aggregate, sugar, and water.

3.1.1 Cement

For this research, Portland cement brand, DANGOTE, 42.5 grades will be utilized, adhering to ASTM C150 (2005) standards. This will procure from accredited dealers in Oluku metropolis, Nigeria.

3.1.2 Fine Aggregates

the fine aggregate employed in the study consisted of natural sharp river sand sourced from Oluku. It underwent sieving using a 5mm BS 812 sieve to eliminate large aggregates and impurities, conforming to BS EN 933-1 (1997) standards.

3.1.3 Coarse Aggregates

Crushed granite, with a maximum normal size of 12mm and retained on a 3.75mm sieve minimum, served as the coarse aggregate. Sourced from a vendor along Oluku, Benin City it met the standards of BS EN 933-5: (1998) and was in a saturated surface dry condition before incorporation into the mix.

3.1.4 White Granulated Sugar (Sucrose-Admixture)

It was acquired from external vendors in Oluku, purchased, and then transported to the Civil and Structural Laboratory at the University of Benin, where it will undergo air-drying.

3.1.5 Water

the water utilized in this study will be sourced from the borehole at the Civil and Structural Engineering Laboratory of the University of Benin.

3.2 Tests Method

In this research various tests will be conducted and the test will be as follows:

3.2.1 Preliminary tests of materials

Conducting preliminary tests on the research materials aimed to ascertain the chemical composition of ordinary Portland cement brands and evaluate the physical properties of materials utilized in this experimental research.

3.2.1.1 Bulk density of materials

Bulk density, representing the weight of aggregate within a unit volume under specified compaction conditions, will be assessed following BS 812-2 (1995) standards. This test encompassed three materials—brands of Portland cement, sand, and granite, which is crucial for calculating experiment material quantities.

3.2.1.2 Initial and Final Setting Time

The setting times, describing cement paste stiffening, will be examined. The test involved cement pastes from Portland cement brand, incorporating sugar at 0.06% and 0.1% by weight of cement, alongside a 0% control. Utilizing the Vicat apparatus in accordance with BS EN1963 (1987), the setting times will be evaluated at both standard room temperature (27°C) and an oven temperature of 43°C—approximating the maximum ambient temperature.

3.2.2 Production of Concrete Specimens

3.2.2.1 Batch Calculation

The absolute volume approach in the nominal mix method, employing a 1:1.5:3 mix ratio with a water-cement ratio of 0.5, will be applied in this research to ascertain the material quantities for the experimental work. The water-cement ratio will be determined through a trial method conducted before the main experiment. The quantity of percentage addition of sugar will be determine base on the calculation from weight of cement.

3.2.2.2 Mixing of materials

Materials will be weighed and batched for the concrete using a mixing machine, following a mix ratio of 1:1.5:3 with a water-cement ratio of 0.5, adhering to B.S 1881-125 (1986). The sugar, dissolved in water before being added to the concrete mix water, varied in percentages 0%, 0.06%, and 0.1% based on studies by Abalaka (2011) and Rana (2014), indicating sugar's impact on cement paste setting times and concrete compressive strength.

3.2.2.3 Casting of Concrete Specimens

Concrete casting involved three layers, compacted manually with 25 blows per layer using a 25mm diameter steel rod. Cube specimens of dimensions 100mm × 100mm × 100mm, complying with BS EN 12390-1 (2000), will be used. A total of 54 concrete specimens will be produced, with 18 cubes designated for compressive strength testing at curing periods of 7, 14, and 28 days for each sugar percentage (0%, 0.05%, 0.5%,1%, 5%, 10%). Another 18 specimens will be allocated for split tensile testing for period of 7, 14, and 28 days for addition of percentage of sugar at 0%, 0.05%, 0.5%, 1%, 5%, 10%. Another 18 cubes will be used for abrasion resistance and water absorption test at the end of 14 and 28 days curing period.

3.2.3 Testing of fresh concretes

The workability of fresh concrete will be evaluated through the following tests:

3.2.3.1 Slump Test:

will be Conducted for every batch of fresh concrete, corresponding to each sugar percentage (0%, 0.05%, 0.5%,1%, 5%, 10%) across cement brand. The apparatus that will be utilized included a mould, scoop, sampling tray, trowel, tamping rod, and measuring ruler. The mould internal surface will clean, lubricated with engine oil, and place on the sampling tray. Fresh concrete, will be poured in three layers, which will be tamped 25 strokes per layer. The vertical removal of the mould allow measurement of the slump value—the difference between the mould height and the concrete slump. This test adhered to B.S EN 123502 (2009) standards.

3.2.3.2 Compacting Factor Test:

Assessing the compaction degree of fresh concrete, this test will be performed for each batch, corresponding to each sugar percentage (0%, 0.05%, 0.5%,1%, 5%, 10%) across brand. The test followed BS 1881: part 103 (1993) standards.

3.2.4 Curing of concrete specimens

Concrete specimens will be immersed in water for the prescribed hydration periods of 7, 14, and 28 days, conforming to BSEN 1008-2(2002).

3.2.5 Testing of Hardened Concrete Specimens:

3.2.5.1 Compressive Strength Test:

At varying curing ages (7, 14 and 28 days) and each sugar addition level (0%, 0.05%, 0.5%,1%, 5%, 10%) for cement brand, the compressive strength test followed B.S EN 123903 (2000). After removal from the curing tank, specimens will be surface-dried, weighed, and crushed using a manual hydraulic compression machine. The maximum load at failure will be recorded, and compressive strength will be calculated using the formula:

Compressive Strength = Maximum Load (kN) × 1000 / Cross-sectional Area (mm²).

3.2.5.2 Split Tensile Strength Test:

will be Conducted at different curing ages (7, 14, and 28 days) and each sugar addition level (0%, 0.06%, and 0.1%) for cement brand, the split tensile strength test adhered to B.S EN 123906 (2000). After removal from the curing tank, specimens will be surface-dried, weighed, and placed in a hydraulic manual compression machine for splitting. The load was applied diagonally on the square plate, afterward the value of the corresponding results will be recorded after failure. The maximum load will be recorded as P. the split tensile strength of concrete will be calculated using the formula below

$$\text{Split tensile strength} = \frac{0.518 \text{x} P}{S^2}$$

Where; P is load at failure and S is the side of the concrete cube

PROCEDURE FOR OBTAINING CONCRETE MIX DESIGN

$$f_m = f_c + ks$$

where f_m = the target mean strength

f_c = the specified characteristic strength ($30N/mm^2$) at 28 days

ks = the margin, which is the product of k * s

s = the standard deviation

k = a standard constant , with a 5% defective rate (1.64)

Portland cement class, 42.5

Slump required, 10-30mm

Maximum aggregate size, 12mm

Relative density of fine aggregate, 2.6

(1) The mean strength, $f_m = f_{c+} ks$

From the graph below the standard deviation(s) is $8N/mm^2$ since the results that is tested for is less than 20 during crushing .
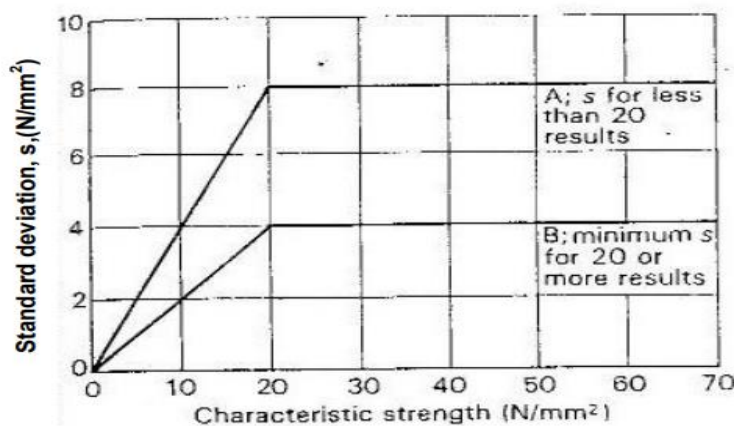

Figure 3.1: Relationship between standard deviation and characteristic strength.

According to BRE, 1997

The mean strength, $f_m = 30 + 4(1.64)$

$$= 30 + 6.56$$

$$= 30.56 N/mm^2$$

Table 3.1: Approximate compressive strength (N/mm^2) of concrete mixes made with a free water/cement ratio of 0.5 according BRE, 1997.

Type of Cement	Type of Coarse Aggregate	Compressive Strengths (N/mm2)			
		Age (days)			
		3	7	28	91
Ordinary Portland (OPC) or Sulphate Resisting Portland (SRPC)	Uncrushed	22	30	42	49
	Crushed	27	36	49	56
Rapid Hardening Portland (RHPC)	Uncrushed	29	37	48	54
	Crushed	34	43	55	61

SOURCE: (BRE, 1997)

From table 3.1 above the cement class is 42.5N/mm^2 since it is ordinary Portland cement that is used.

Figure 3.2: Approximate free – water contents (kg/m^3) required to give various levels of workability

Slump (mm)		0-10	10-30	30-60	60-180
Vebe Time (s)		>12	6-12	3-6	0-3
Maximum Size Aggregate (mm)	Type of Aggregate				
10	Uncrushed	150	180	205	225
	Crushed	180	205	230	250
20	Uncrushed	135	160	180	195
	Crushed	170	190	210	225
40	Uncrushed	115	140	160	175
	Crushed	155	175	190	205

Maximum size of coarse aggregate , 10mm

Condition, (uncrushed)

Slump(mm), 10-30

Therefore, free water content =180kg/m^3
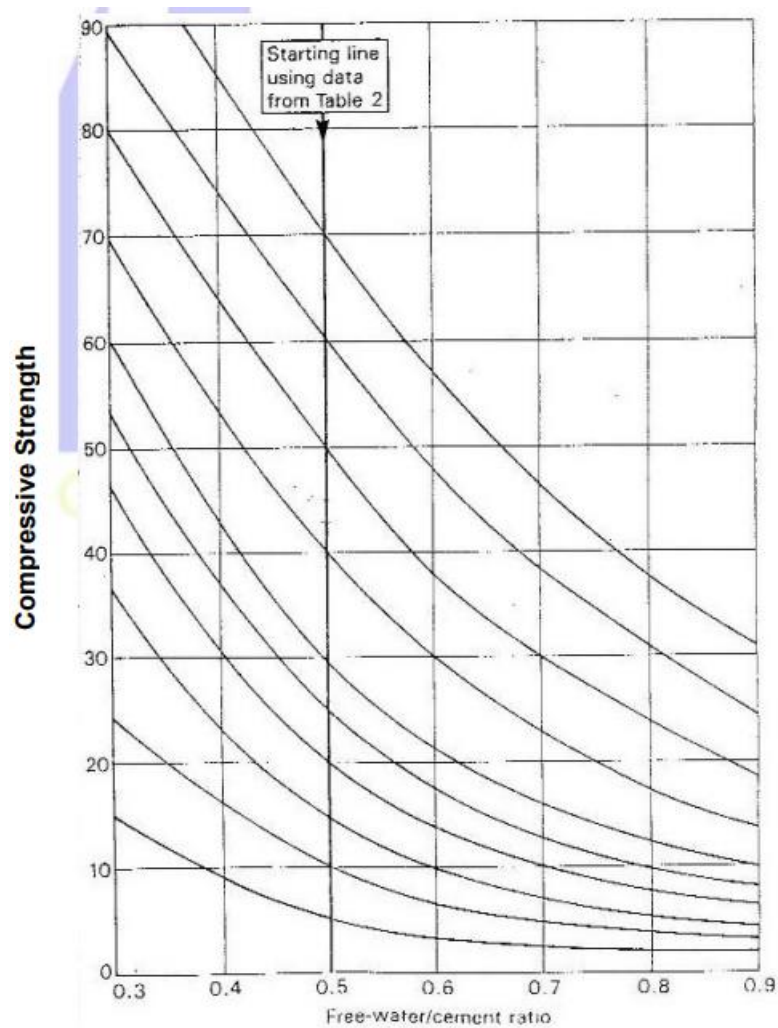
Figure 3.3: Relationship between compressive strength and free-water/cement ratio. According to BRE, 1997.

The maximum water-cement ratio is determined by the type of cement used, the climate conditions, and the required strength of the concrete. In general, the maximum water-cement ratio should not exceed **0.5** for normal strength and for higher strength concrete.

From the data provided above the free-water/cement ratio chosen is **0.48** for the calculation of the mix design.

Cement content = free-water content/free-water cement ratio

$$= 180/0.48$$

$$= \textbf{375kg/m}^\textbf{3}$$

Total aggregate determination, from the data provided the relative density of fine aggregate is **2.6** relating it to free water content to get the wet density of concrete from the figure below.
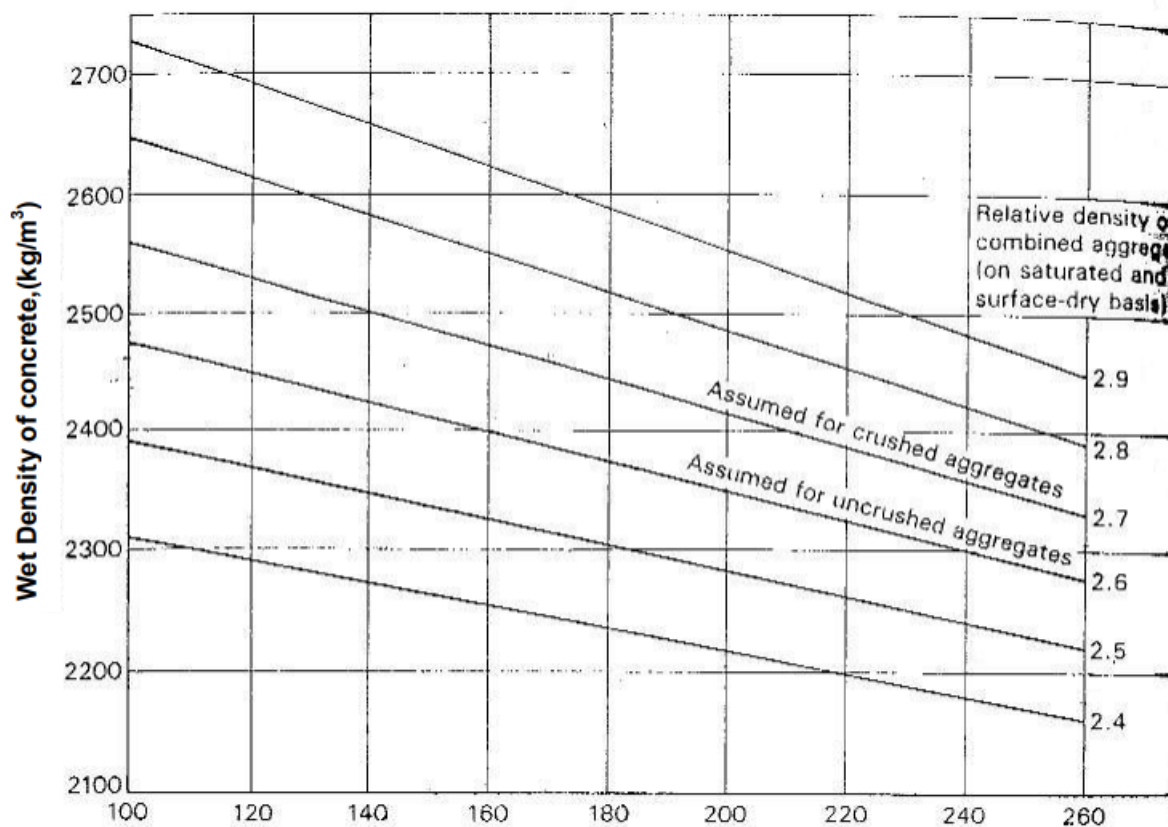
figure 3.4: Estimated wet density of fully compacted concrete. According to BRE, 1997.

Due to the relationship between relative density of fine aggregate and free- water content, from the figure above when traced carefully with free- water content value which is 180 to hit the assumed line for uncrushed aggregate traced to the vertical, the wet density of concrete chosen to be **2350kg/m³.**

Therefore new wet density of concrete is **2350kg/m³**

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Total aggregate = D – C – W

Where D = the wet density of concrete (kg/m^3)

    C = the cement content (kg/m^3)

    W = the free – water content (kg/m^3)

Total aggregate = 2350 – 375 – 180

Total aggregate = 1975

Selection of Proportion of fine aggregate from the figure below.

Since the maximum aggregate size is 10mm, slump 10 – 30mm with free – water cement ratio of 0.48, the proportion of fine aggregate is selected from the figure below.
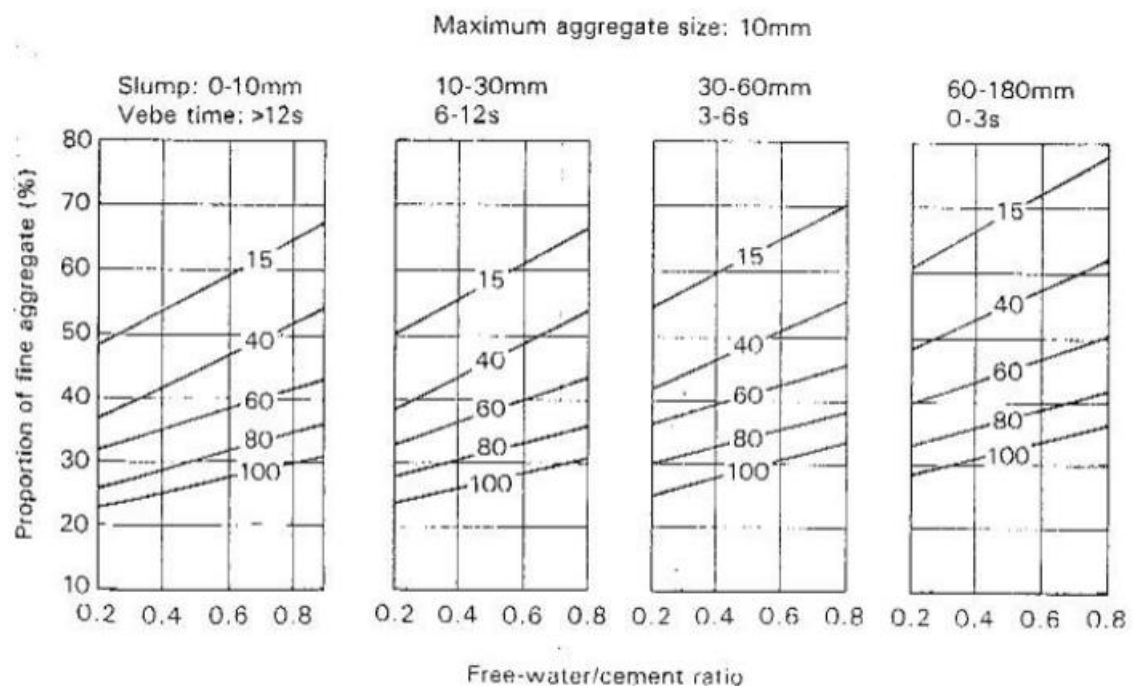
Figure 3.5: Recommended proportions of fine aggregate according to percentage passing 600 um sieve. According to BRE, 1997.

From the figure above the proportion of fine aggregate passing through 600um sieve is 35%

Henceforth we determine the quantity of fine aggregate.

Fine aggregate = 1795 x 35%

$$= 1795 \times 0.35$$

$$= 628.25 \text{kg/m}^3$$

Coarse aggregate = total aggregate content – fine aggregate content

Coarse aggregate = 1795 – 628.25

Coarse aggregate = 1166.75kg/m^3

Therefore,

Cement : fine aggregate : coarse aggregate

375   :   628.25   : 1166.75

Dividing through by 375, we have

1 : 1.68:3.1

Approximating, we have

1:1.68:3

Quantity of water = 180kg/m^3

Quantity of cement content = 375kg/m^3

Quantity of fine aggregate = 628.25kg/m^3

Quantity of coarse aggregate = 1166.75kg/m^3

Getting the values in kg.

Take wastage to be 1.2

Volume of cube = 100mm x 100mm x 100mm = 0.1^3 = 1×10^{-3}m^3 per cube

For 9 cubes

Water = 180 x 10^{-3} x 9 x 1.2 = 1.944 kg

Cement = 375 x 10^{-3} x 9 x 1.2 = 4.05kg

Fine aggregate = 628.25 x 10^{-3} x 9 x 1.2 = 6.785kg

Coarse aggregate = 1166.75 x 10^{-3} x 9 x 1.2 = 12.6kg

CHAPTER FOUR

RESULTS AND DISCUSSION

This chapter is associated with results obtained in all aspect of the test and experiments. It gives information on the physical properties of concrete in tabular form and figure chart.

4.1 TABLES AND DISCUSSION

Table 4.1 sieve analysis of fine aggregate

British standard sieve size (mm)	Retained samples (g)	Passing samples (g)	Percentage retained (%)	Percentage passing (%)
3.350	0	100	0	100
2.360	0	100	0	100
2.000	0	100	0	100
1.180	2.9	97.10	2.9	97.10
0.600	19.9	77.2	22.8	77.2
0.425	14.0	63.2	36.8	63.2
0.300	8.5	54.7	45.3	54.7
0.212	41.5	13.2	86.8	13.2
0.150	7.4	5.8	94.2	5.8
0.075	3.8	2.0	98	2.0

PAN =2   **TOTAL = 98**

Table 4.2 Specific Gravity Test for Fine Aggregate

Sample	AU	1112	Average
Weight of Bottle only (w_1)	16.0	12.6	14.3
Weight of bottle + Sample (w_2)	30.5	27.7	29.1
Weight of bottle + Sample +Water (w_3)	51.6	47.9	49.8
Weight of bottle + Water (w_4)	42.81	38.9	40.9

$$SG = \frac{(w2-w1)}{(w4-w1)-(w3-w2)}$$

$$SG = \frac{(30.5-16.0)}{(42.8-16.0) - (51.6-30.5)}$$

$$SG = \frac{14.5}{(26.8) - (21.1)}$$

$$SG = \frac{14.5}{5.6}$$

$SG = 2.60$

The specific gravity value above was used for concrete mix design.

Table 4.3 compressive strength test results of cubes at 7 days of water curing

% 0f sugar`	Date of casting	slump	Crushing date	Mass of cube in (kg)	Crushing force in (KN)	Compressive strength of concrete in (KN/mm^2)
0.0	04/03/24	10mm	11/03/24	2.488	240.56	24.06
0.0	04/03/24	10mm	11/03/24	2.505	324.71	32.47
0.0	04/03/24	10mm	11/03/24	2.510	216.69	21.67
10	04/03/24	25mm	11/03/24	2.515	44.20	4.42
10	04/03/24	25mm	11/03/24	2.517	41.98	4.20
10	04/03/24	25mm	11/03/24	2.475	41.58	4.16
5	06/03/24	19mm	13/03/24	2.588	23.31	2.33
5	06/03/24	19mm	13/03/24	2.506	26.15	2.62
5	06/03/24	19mm	13/03/24	2.577	24.85	2.49
1	15/03/24	15mm	22/03/24	0.00	0.00	0.00
1	15/03/24	15mm	22/03/24	0.00	0.00	0.00
1`	15/03/24	15mm	22/03/24	0.00	0.00	0.00
0.5	06/03/24	12mm	13/03/24	2.561	33.57	3.36
0.5	06/03/24	12mm	13/03/24	2.564	29.59	2.96
0.5	06/03/24	12mm	13/03/24	2.575	38.27	3.83
0.05	15/03/24	11mm	22/03/24	2.412	243.32	24.33

| 0.05 | 15/03/24 | 11mm | 22/03/24 | 2.410 | 230.67 | 23.07 |
| 0.05 | 15/03/24 | 11mm | 22/03/24 | 2.422 | 235.48 | 23.54 |

The compressive test performed above is in accordance with BS 1881-116:1983 standard.

Table 4.4 compressive strength test results of cubes at 14 days of water curing

% 0f sugar`	Date of casting	slump	Crushing date	Mass of cube in (kg)	Crushing force in (KN)	Compressive strength of concrete in (KN/mm^2)
0.0	04/03/24	10mm	18/03/24	2.547	319.15	31.92
0.0	04/03/24	10mm	18/03/24	2.560	300.17	30.02
0.0	04/03/24	10mm	18/03/24	2.544	285.82	28.58
10	04/03/24	25mm	18/03/24	2.546	43.96	4.39
10	04/03/24	25mm	18/03/24	2.529	44.69	4.47
10	04/03/24	25mm	18/03/24	2.480	40.53	4.05
5	06/03/24	19mm	20/03/24	2.552	23.42	2.34
5	06/03/24	19mm	20/03/24	2.519	20.70	2.07
5	06/03/24	19mm	20/03/24	2.512	21.45	2.14
1	15/03/24	15mm	29/03/24	2.465	104.11	10.41
1	15/03/24	15mm	29/03/24	2.407	100.54	10.05
1	15/03/24	15mm	29/03/24	2.423	112.87	11.23
0.5	06/03/24	12mm	20/03/24	2.589	197.64	19.76

0.5	06/03/24	12mm	20/03/24	2.576	188.77	18.88
0.5	06/03/24	12mm	20/03/24	2.553	138.98	13.89
0.05	15/03/24	11mm	29/03/24	2.463	284.56	28.46
0.05	15/03/24	11mm	29/03/24	2.501	296.32	29.63
0.05	15/03/24	11mm	29/03/24	2.489	300.68	30.07

The compressive test performed above is in accordance with BS 1881-116: 1983 standard.

Table 4.5 compressive strength test results of cubes at 28 days of water curing

% 0f sugar`	Date of casting	slump	Crushing date	Mass of cube in (kg)	Crushing force in (KN)	Compressive strength of concrete in (KN/mm^2)
0.0	04/03/24	10mm	02/04/24	2.558	249.34	24.93
0.0	04/03/24	10mm	02/04/24	2.534	366.59	36.66
0.0	04/03/24	10mm	02/04/24	2.448	397.98	39.80
10	04/03/24	25mm	02/04/24	2.525	41.30	4.13
10	04/03/24	25mm	02/04/24	2.581	46.34	4.63
10	04/03/24	25mm	02/04/24	2.522	41.60	4.16
5	06/03/24	19mm	03/04/24	2.497	19.41	1.94
5	06/03/24	19mm	03/04/24	2.607	20.71	2.07
5	06/03/24	19mm	03/04/24	2.614	21.00	2.10

1	15/03/24	15mm	12/04/24	2.455	17.03	1.70
1	15/03/24	15mm	12/04/24	2.423	15.56	1.56
1	15/03/24	15mm	12/04/24	2.430	11.62	1.16
0.5	06/03/24	12mm	03/04/24	2.589	269.23	26.92
0.5	06/03/24	12mm	03/04/24	2.476	407.34	40.73
0.5	06/03/24	12mm	03/04/24	2.606	402.48	40.25
0.05	15/03/24	11mm	12/04/24	2.529	389.12	38.91
0.05	15/03/24	11mm	12/04/24	2.494	342.58	34.26
0.05	15/03/24	11mm	12/04/24	2.553	382.04	38.20

Table 4.6 slump test results at different percentage addition of sugar

Sugar content at different % of weight of cement	Slump (mm)
0.00	10
0.05	11
0.5	12
1.00	15
5.00	17
10.00	27

The slump test performed above was in accordance with clause 6 of BS 1881-102: 1983,

In which the internal dimensions of the mould are bottom diameter 200mm, top diameter 100mm, and height 300mm. The mould was filled in with fresh concrete in three layers in with each layers was tampered with a tampering rod for twenty five times.

4.2 OBSERVATIONS DURING THE CAUSE OF THE EXPERIMENT

During the concrete mixing process, it was noted that the workability improves with higher doses of sugar added per batch. The highest slump was noted during the experimentation of at 10% of sugar.

After 24 hours of demolding, cracks were observed in the cubes specimens. Therefore, cautions and meticulous demolding techniques were employed to prevent damage to the entire cubes.

While curing, certain areas of the cubes developed cracks due to an uneven reaction between sugar and the cement compound. These reactions delayed the setting time, resulting in prolong setting.

During the curing process, some sugar mixes (ranging from 0.5% to 10%) exhibited excessive expansion or cracking, resulting in diminished compressive strength in the concrete at early stages. Conversely, certain sugar percentages showed minimal to no cracking. Additionally, a whitish, slippery membrane formed on the cube surfaces during curing, hindering faster curing compared to control cubes. The extent of this membrane increased with higher sugar dosages. Excessive expansion, cracking, and delayed setting time due to sugar admixture can lead to cube disintegration during immersion curing. To mitigate this issue, alternative curing methods such as water spraying or air curing should be considered. While sugar can act as a retarder in appropriate proportions, excessive amounts can reverse its effect, causing acceleration instead.

## 4.2 FIGURE CHARTS AND DISCUSSION

This section presents the experimental results concerning the physical properties of concrete in table format.
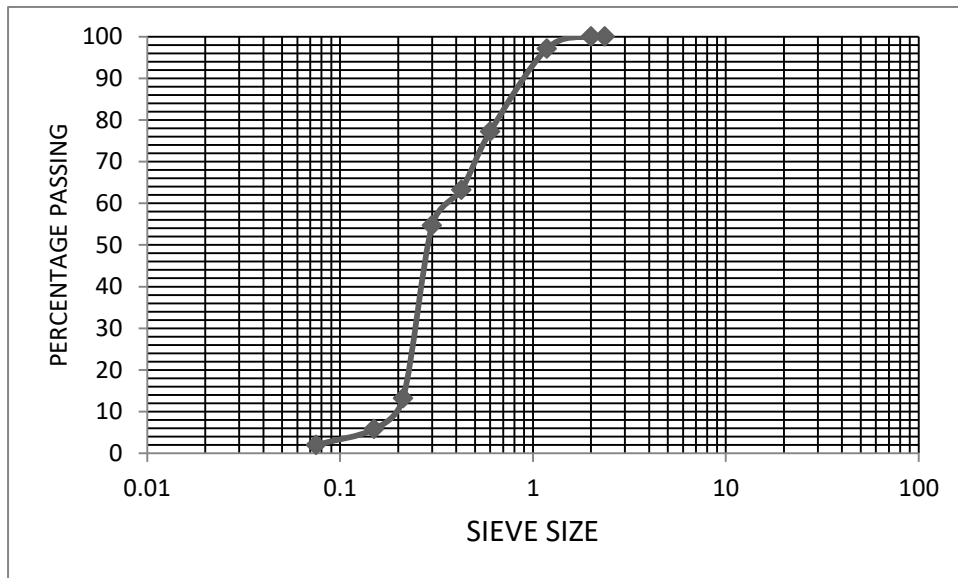
Figure 4.1 Particle size distribution curve of fine aggregate

From figure 4.1 above , based on the particle distribution standard zoning BS 812-103:1984

It can be inferred that according to standard, the above fine aggregate have 77% passing through 0.6mm sieve and 100% passing through 2.36mm sieve and belong to grading zone IV that has a percentage passing of 95%-100%.
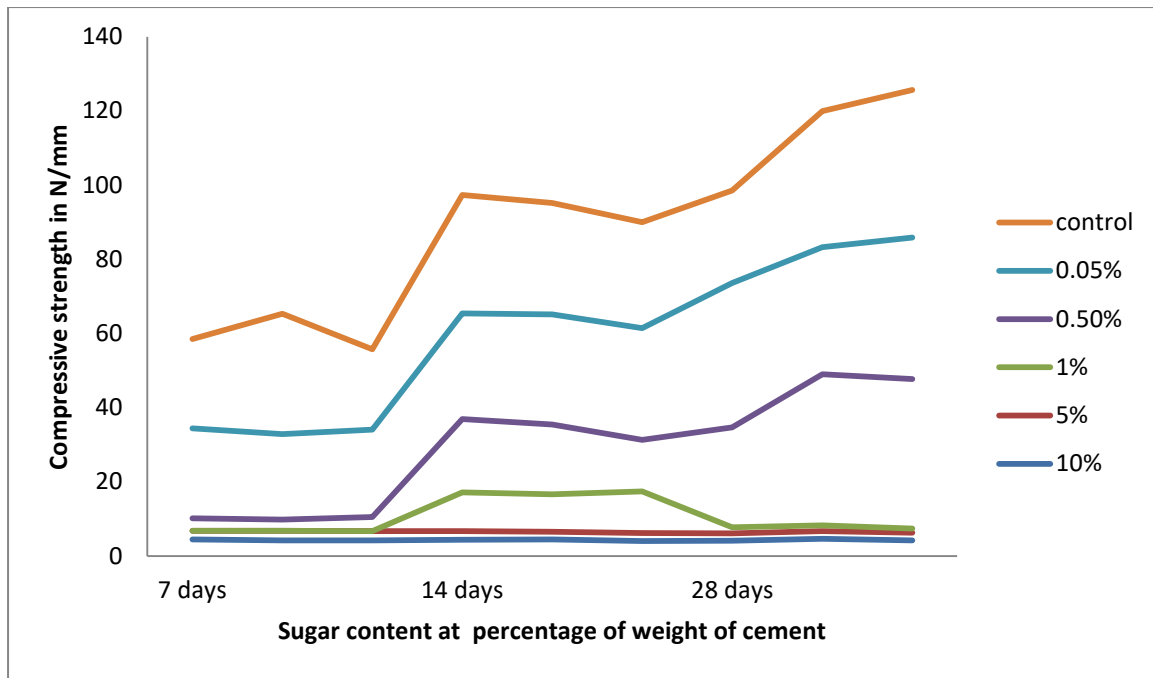
Figure 4.2: Comparison of compressive strength development at various sugar percentage of weight cement with control sample.

From figure 4.2 above the concrete strength obtained with respect to concrete age can be analyze as the control having the highest strength at early age of the concrete , it can also be said that at age 14 and 28 , 0.05% and 0.5% were almost having the same strength including the control. though there was seen some variation in strength of this percentages.

During the experiment, it was observe that before 7 days , there was failure in strength of 1% which is reflecting on the chart and a lot of cracking was seen in different percentage during the age of the concrete.
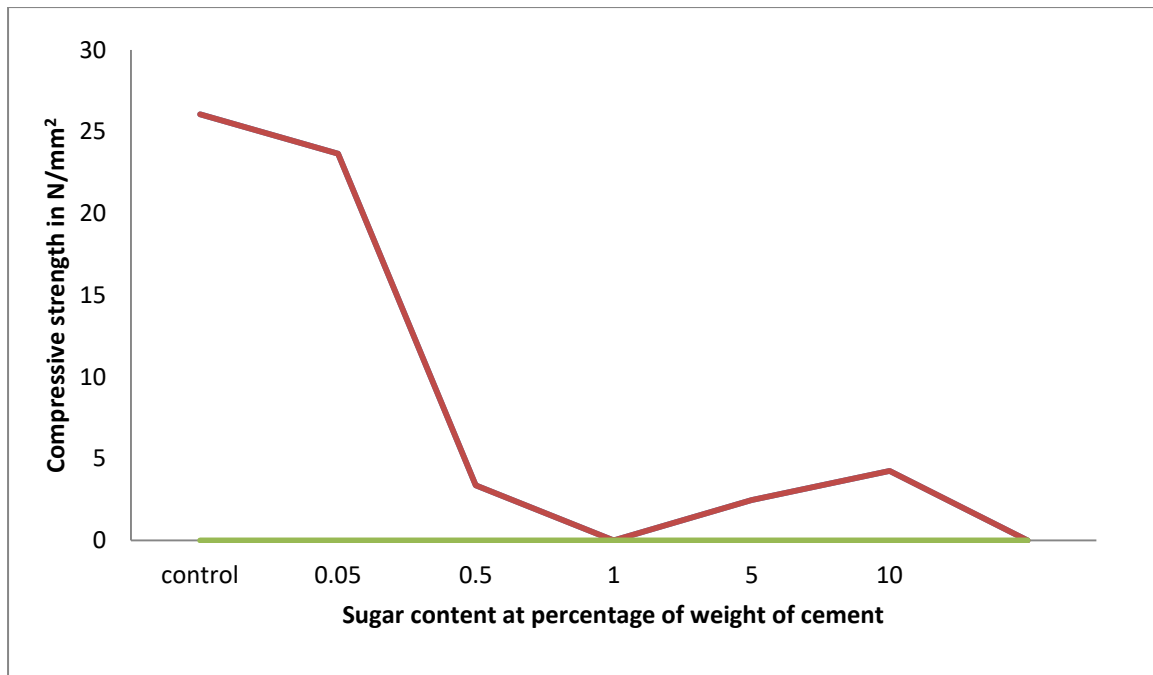
Figure 4.3: 7 days strength at various percentage of sugar

Figure 4.3 above show the percentage reduction of different percentage addition of sugar compare to the control. At 7 days no compressive strength value was recorded for 1% due to dissolving of the cube in water during curing.

There was also delay in setting time due to the formation of calcium silicate hydrate (CSH) which is mainly responsible for concrete strength at early age of curing.
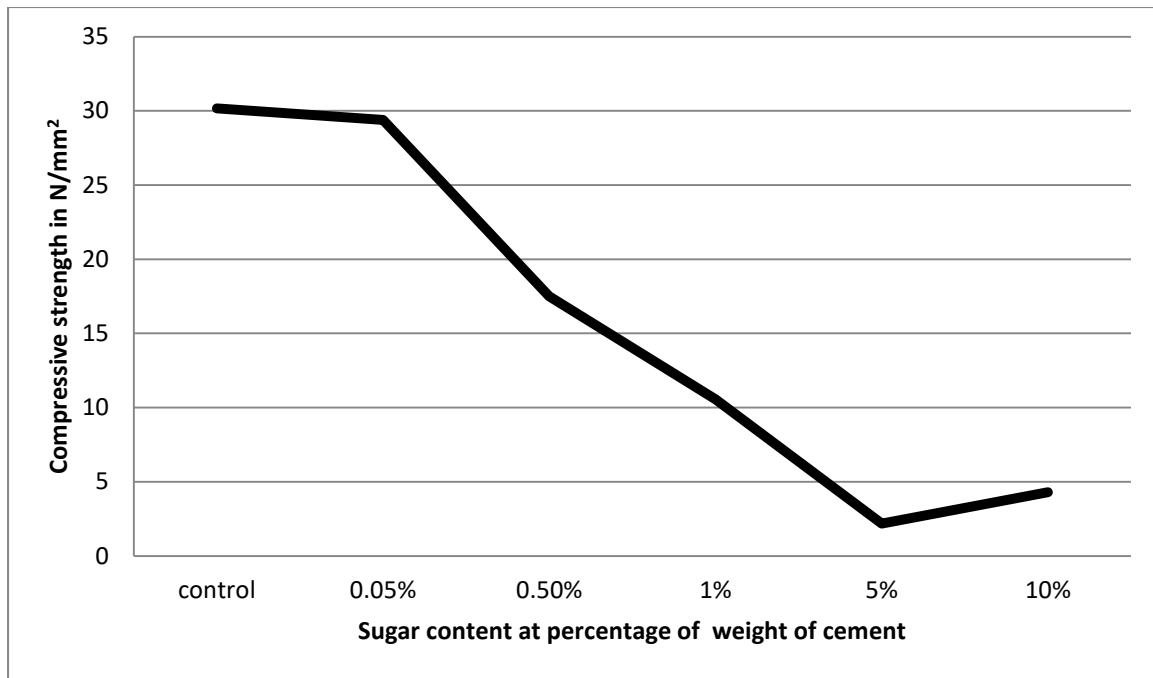
Figure 4.4: 14 days strength at various percentage of sugar

From figure 4.4 above, it can be deduce that there is an increment in compressive strength from the control and also there is increment in 0.05% with 5%, 10%, 1% having very low strength at 14 days dosage of sugar.
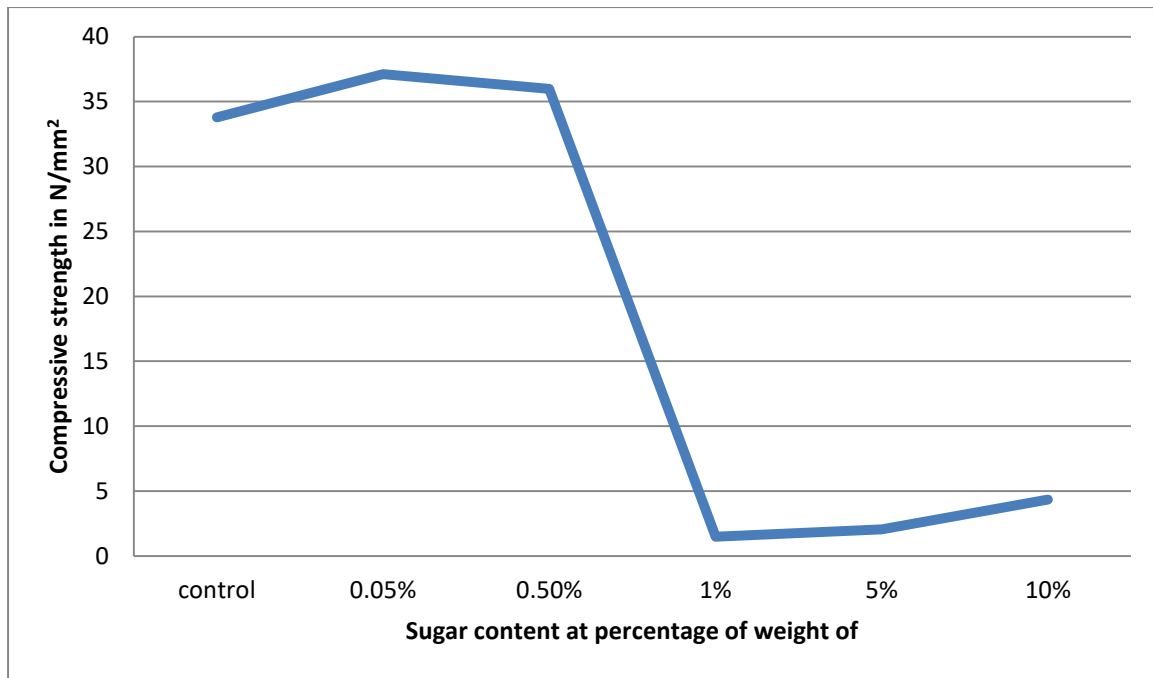
Figure 4.5: 28 days strength at various percentage of sugar

Figure 4.5 above show the graph of compressive strength in N/mm^2 against sugar percentage of weight of cement used. From the figure above there is an increase in strength of concrete starting from 0% of sugar dosage to 0.05% of sugar dosage which has the highest compressive strength, and there was a reduction in compressive strength starting from 1% to 10% sugar dosage.
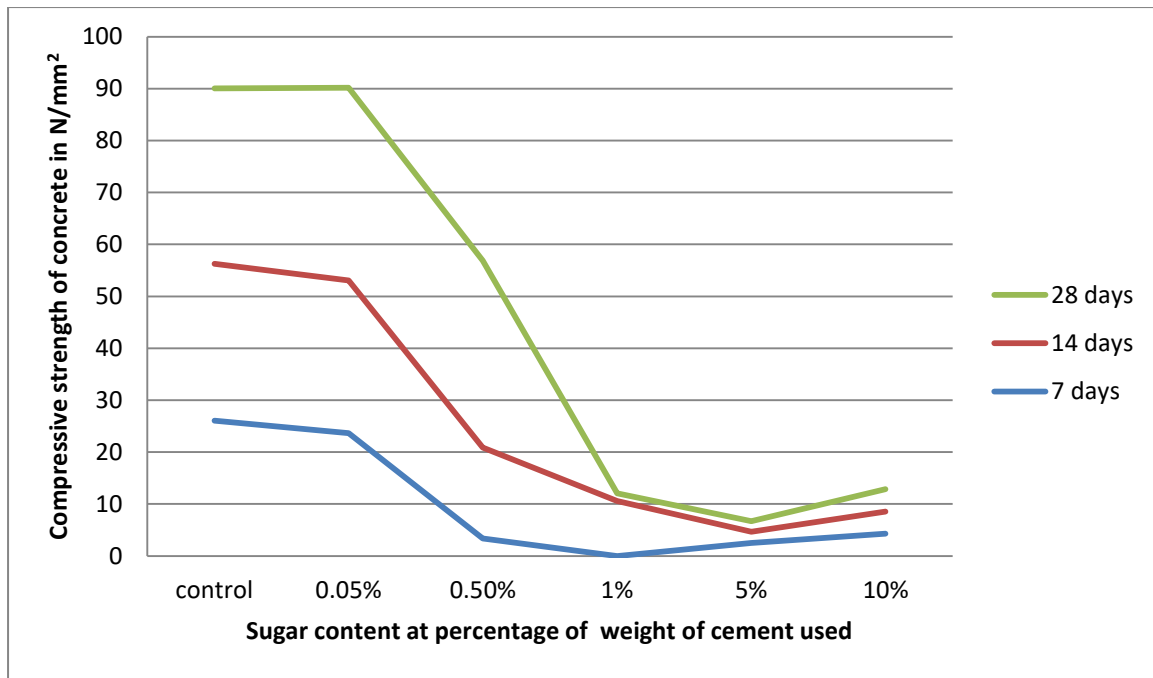
Figure 4.6: Concrete strength obtained at various age of concrete

Figure 4.6 above shows the variation in the compressive strength of concrete cubes at different percentages in different ages respectively. At 7 days there was no compressive strength recorded for 1%, this level of sugar concentration appear to have delayed the formation of calcium silicate hydrate (CSH) which is responsible for early setting of concrete.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The findings of this study indicate that mixing sugar with concrete results in a noticeable alteration of its properties. Consequently, it can be inferred that:

1. As the percentage of sugar increases up to 1%, the setting time of concrete increases. After surpassing a 1% sugar content, there is a significant decrease in the setting time of concrete. Hence, sugar acts as a retarder when used beyond this threshold in concrete proportions.

2. A sugar content equivalent to 0.05 by weight of cement has been observed to enhance compressive strength.

3. There were no detrimental effects observed on the concrete and cement paste at the sugar level of 0.05% for the concrete cubes analyzed.

4. The delay in concrete setting observed at sugar contents ranging from 0% to 0.5% could prove beneficial for preventing cold joints and mitigating premature cement setting, especially in hot weather concreting scenarios or when the construction site is located at distance from the batching plant.

5. Sugar content exceeding 1% by weight of cement accelerated the setting time with a slight decrease in initial strength. Additionally, excessive volume expansion resulted in visible cracks within the sample itself.

6. Thoughtfully incorporating sugar can offer an economical alternative compared to commercially available set retarders.

5.2 RECOMMENDATIONS FOR FURTHER RESEARCH

Further research is advised to explore the effects of sugar on concrete across a broader percentage range, spanning from 0% to 5%, in order to determine the precise peak compressive strength. It is anticipated that such investigation may lead to a notable increase in the compressive strength of the concrete.

Additionally, it is necessary to investigate the impact of sugar on other physical properties of concrete, including density, shrinkage, and permeability.

It is also advisable to explore alternative curing methods beyond water immersion and spraying for conducting similar experiments.

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APPENDIX