IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 18, Issue 4 Ser. III (Jul. – Aug. 2021), PP 54-69
www.iosrjournals.org

The Effect of Algae Infested Water on the Compressive Strength of Concrete

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Abstract:
Background:
The failures in most structures in many countries have brought about a lot of problems in the construction industry. In a bid to find a lasting solution to this problem, stakeholders in the Engineering sector suspected the use of unqualified personnel, sub-standard, and un-recommended materials as the likely causes of the issues. Water is one of the vital materials used in the construction industry. Therefore its specification must be strictly adhered to according to BS3148 for countries using the British Standard and ASTM C94 for American or International Standard. Non-drinkable or unclean water has been used as an alternate choice for potable water in concrete mixing either because of the need to save freshwater or the supply of potable water to construction sites is inadequate or expensive. On many occasions, waste water, sewage water, unclean river water, or any other unfit water sources which are likely to have been infested with algae and some other harmful bacteria is used. The adverse effect of such water on a structure is neglected. This research work is geared towards highlighting the likely consequences involved in the production of low-quality concrete with such infested water. Therefore it is advisable for the site engineer to ensure that recommended materials are used to achieve a structure that will serve its engineering purpose. In this research, the effect of algae infested water on the compressive strength of concrete was investigated.
The mix ratio of 1:3:6 was used during the experiment to produce the concrete cubes. Drinkable water and algae infested water were used for mixing and curing (7and 28 days).
The tests conducted were carried out in accordance with some British Standard (BS 1377: 1975, BS 410: 1980, BS 812: 168, BS 3148: 1980). The average compressive strengths of non-infested water for 7 and 28 days are 10.371 N/mm^2 and 15.370 N/mm^2, while that of infested water for 7 and 28days are 9.911 N/mm^2 and 14.837 N/mm^2.
These results show that algae infested water has a negative impact on the compressive strength of concrete because it reduces the strength of the concrete.
Keywords: *Structures failures; Algae Infested Water; Construction Industry; Concrete Compressive Strength; potable water.*

Date of Submission: 04-08-2021 Date of Acceptance: 18-08-2021

I. Introduction

Concrete is the most commonly used artificial material created by man for construction purposes. By definition, concrete is a mixture of cement, water, aggregates, and at times admixtures, in the right proportions. As the mixtures (cement, water, aggregates, and admixtures) are set, they turned into a shape named concrete. Concrete hardens through a chemical reaction between water, and cement and it becomes stronger with time. Its durability, strength, or other qualities depends on the amount of mixtures used, ingredients, the way it is been compacted, and other factors that might influence it during placing, compacting, and curing. Concrete can be grouped as either design mix concrete or nominal mix concrete. On some occasions, they are classified as ordinary concrete and control concrete which depends on the method used for proportioning the concrete mixes and the measure of control applied in the works. Good concrete has to meet the requirements in any state. In the plastic state, concrete has to be free from bleeding and segregation. Also, in the hardened state concrete should be impermeable, strong, and durable with minimum dimensional changes (Murari Lal Gambhir, 2013). Concrete is used to build architectural structures, pavements, parking structures, foundations, overpasses, etc.

Cement is one of the most important materials used for mixing concrete. It is manufactured using raw materials such as Silica, lime, iron oxide, and alumina. Although there are some factors influencing the choice of cement selection which includes design parameters, the functional requirement of a structure, durability characteristics, speed of construction, etc. but the most commonly used cement is the Ordinary Portland Cement (Shetty M.S. & Jain A.K, 2019). According to Jure et al. in 10.000.000, BC the Israelites used limestone and oil shale to create a natural deposit of cement compounds. Also, in 9.000 BC, there was evidence of burning gypsum in the Asian part of Catal Huyuk, which was used as cement. Dating back to 3000 BC, the Egyptians utilized mortars of lime and gypsum mortars in building the pyramids. The Chinese used cementitious materials to construct the Great Wall also to clench bamboo together in their boats. The Assyrians & Babylonians were also known for using bitumen to bind bricks and stones.

Aggregate also plays an important role in concrete mixing, and it forms more than 60% of a concrete mix. The strength of concrete depends on the aggregate source, size, and type. Also, aggregates grading, size, and shape can influence concrete workability (Abdullahi, 2012; Hassan, 2014: Aginam et al. 2013; Jimoh and Awe 2007: Odinaka Okonkwo, Emmanuel Arinze, 2016).

An admixture is sometimes added when mixing concrete but is not necessary. Sadaqat et al. stated that admixtures are included in a concrete mix to improve the concrete's quality. Admixture can increase the workability, heat of hydration, reactivity, and setting time of a concrete and could also do the opposite.

Water is also a key constituent in concrete mix because it affects the properties of a concrete. In a concrete mix design, water binds all constituents together. Adding the required amount of water to a concrete mix improves the compressive strength and durability of the concrete. The quality of water is also essential in a concrete mix because any impurities in water might influenced the setting of the cement and will affect the concrete strength in a negative way or bring about the corrosion of the reinforcement or staining of the concrete surface. This is why water specification must be strictly adhered to according to BS3148 when using alternate water such as wastewater, sewage water, stagnant water (pond) or unclean river water or any other unfit water sources which are likely to have been infested with algae and some other harmful bacteria. The adverse effect of such water on structure should not be neglected, which is the reason for carrying out this research work.

This research is mainly concerned with the effect of algae infested water on the compressive strength of concrete. Therefore a considerable amount of algae infested water is used to make concrete in the study, while concrete made with potable water (drinkable water) as specified on BS 3148: 1980, serves as the non-infested water (control). The research is geared towards highlighting the likely consequences involved in the production of low- quality concrete with such infested water. Therefore, it is advisable for the site engineer to ensure that recommended materials are used in order to achieve a structure that will serve its engineering purpose.

Algae are defined as a functional class of organisms that go through oxygenic photosynthesis. Algae include both eukaryotic and bacterial organisms, and a majority of them are photosynthetic and live in aquatic habitats, while some are found on desert crusts and soil. They interact negatively in green tides in estuaries, garden ponds, etc. They have different sizes and shapes, and their cells sizes range from 0.50 μm in diameter to 60 meters in length multicellular thalli. There are approximately 72,500 species of algae and the ones that are commonly found in water are the green and blue-green algae (John and Mario, 2014).

Many studies have been carried out on the effects of using alternative (non- potable) water on the properties of concrete. Results show that some of the water used has little or no effects on concrete while others have negative effects on most occasions on the strength of concrete. Al-Jabri et al. researched on the influence of wastewater obtained from car washing stations on the strength of concrete. The concrete compressive strength was determined after curing the cubes for 7 days. Also, the compressive, slump, flexural and tensile strength were determined after 28 days of curing. In conclusion, the results reveal that the wastewater has no effect on the strength of the concrete. In similar research, Gabriel Cook (2017) conducted a research to determine if the compressive strength of concrete could be affected by reusing concrete wash water, which is the water obtained during concrete production. He added that using this water will save millions of gallons of fresh water each year. The study reveals that the water can be used for concrete mixing because it does not in any way have influence on the compressive strength of concrete. Samson et al. investigated the effect of water contaminated with chloride on the compressive strength of concrete. In the experiment, distilled water was mixed with Sodium chloride ($NaCl$), and the concrete cubes were cured for 7, 28, and 56 days, the compressive strength was determined. The research shows that water contaminated with Sodium Chloride has negative effects on the compressive strength of concrete. In an experiment conducted by Dauda et al. to find out if the compressive strength of concrete might possibly be affected by qualities of water used in curing. Potable water and water collected from wastewater stabilization pond were used for the curing. According to the study, the strength of concrete immersed in the wastewater has less strength when compared to the concrete cured in freshwater. Ayoup et al. in their study found that reusing raw and treated grey water can be used as a substitute to drinking water for mixing concrete because they have no effects on it. A research was carried out by Qingyong et al. on the effect of using sea water for mixing and curing of concrete. Sums of hundred and ninety two concrete cubes were used during the experiment and the result shows that the compressive strength of the concrete was reduced by approximately 15% at ninety days when compared to concrete mixed and cured with potable water. Wanda Kokoszka (2019) found that using sewage water for concrete mixing affect concrete compressive strength therefore it should be avoided. Onesmus et al investigated the effects of bacteria called

Thiobacillus intermedius on mortar's mechanical properties. The study indicates an enormous reduction in the compressive strength of the mortar.

These previous studies reveal that non-drinkable water should be investigated before using for concrete mixing, though, some have no effect on concrete but we cannot assume which is the reason for carrying out this research.

II. Material And Methods

The aim of this research is to determine the effects of algae infested water on the compressive strength of concrete. To achieve useful results the mix ratio used in the production of concrete cube was 1:3:6 so as to check the variation in the strength of the concrete cubes. Physical property tests were also carried out to find out the quantity of materials required for the mix.

Materials used for this research work are -

(i) Portable Water (Drinkable Water)
(ii) Ordinary Portland cement
(iii) Fine Aggregates (Sand)
(iv) Algae Infested Water

2.1 Source of Drinkable Water

The drinkable water used was collected from the Civil Engineering Laboratory Pump of the Federal University of Technology Minna, which is a product of Niger State Water Board, Nigeria.

2.2 Source of Algae Infested Water

The Algae Infested Water used was collected from stagnant water infested with algae in the concrete tank of Federal University of Technology Minna, Engineering Complex Gidan Kwanu Campus.

2.2.1 How Algae Infested Water was Identified

Physical means or more physical observation: - Since algae plants are macroscopic organisms with no true roots or leaves and they are also chlorophyllous plants, they possess green pigment that in turn changes whichever water they infest into a greenish coloration.

Chemical Means: - PH test was conducted and the result was ensured that it coincides with the range of values stated by G.B.B Thomas and M.F.S Thomas (1978), as one of the ways of identifying algae infested water.

2.3 Testing of Materials

During the research work, the following tests were carried out:-

(i) Moisture content test
(ii) Specific gravity test
(iii) Bulk density
(iv) Sieve analysis
(v) PH value test
(vi) Void ratio
(vii) Porosity

2.3.1 Moisture Content

This is the water in excess of the saturated and surface dry condition. Therefore the overall amount water content of moist sand is equal to the summation of moisture content and absorption.

(i) Apparatus used
- (a) Electric oven
- (b) Moisture content cans
- (c) Samples of materials
- (d) Weighing balance

(ii) Test Procedure

The weight of the empty can was first determined as W1 after which the weight of the sample plus the can was also measured as W2. The can and the sample were then placed in the oven for a period of 24hours and the weight of the can and the oven dried sample was taken as W3.

The moisture content of the aggregate is given by the expression:

MC = (W2- W3)/ (W3- W1) x 100 …… (equation 1).

Where MC = Moisture Content
W1 = Container weight (g)
W2 = Container weight plus wet sample (g)
W3 = Container weight plus oven dry sample (g)

2.3.2 Specific Gravity

This is the weight of a sample over the weight of the same volume of water. Specific gravity is used to calculate the quantities of materials used.

(i) Apparatus

(a) A wide mouthed glass vessel, which should be water tight.

(b) A weighing balance that is less than 3kg, readable with an accuracy of 0.5g

(c) Two soft and dry absorbent pieces of cloth which is between 75cm by 45cm.

(d) An airtight container

(e) An oven of not less than 100°C

(f) A tray that is not up to 325cm2

(ii) Test Procedure

The samples were first screened on a 100mm BS sieve and washed because of the tiny particles of dust that might be attached and are then immersed in clean water, in the glass vessel. The aggregates stayed at a temperature of about 20°C for a whole day and it was then immersed in water. At the end of the soaking period, bubbles on the surface of the aggregate were removed by gentle agitation. More water was added and the vessel overflowing, Plane glass disc was allowed to run over the mouth just to be sure that no air is found in the vessel. The outside of the vessel was dried and weighed (M3) and the weight of the empty vessel after drying was labeled as (M1).

The aggregate was later dried using a dry cloth and a second cloth was used as the first one could not remove moisture further. The aggregates were then spread out to dry but are not exposed to any kind of direct heat for 20 minutes until they appeared to be completely surface dried and turnover. They were left in the oven for 24 hours at a temperature of 100°C. It is allowed to cool down in an air tight container and the weight was measured as M1. The weight of the vessel plus water only was recorded as M4.

$$\frac{M_2 - M_1}{(M_4 - M_1) - (M_3 - M_2)} \quad \text{----------------------------- (Equation 2)}$$

2.3.3 Bulk Density

It is the mass of material in a given volume. There are two types of bulk densities i.e. compacted and uncompacted or loose bulk density which are explained in the procedure below.

(i) Apparatus

(a) Weighing balance

(b) A straight metal Tamping Rod

(c) A water rigid container with accurate internal measurements.

(ii) Procedure

(a) Compacted weight: - The metal sample divider was filled to approximately one-third full with the thoroughly mixed sample and tamped with twenty-five strokes using a rod. The same amount of sample is added and additional tamping of twenty-five strokes was done. The samples divider was later filled to overflowing and tamped twenty-five times and excess sample (sand) was struck with a tamping rod. The net weight was taken as (W). This procedure was then followed for the trials and bulk density.

Bulk density = W/V ……….. (Equation 3)

Where

W = Weight of compacted sample (kg)

V= Volume of sample divider (m3)

(b) Uncompacted Weight: - The sample divider was filled to over following by using a shovel, the sample was removed from a height that is not above 5cm from the top of the divider. Rod was used to level the surface of the sample. The weight of the sample in the divider was determined as (W). This procedure also was repeated for two more trials and the loose bulk density was calculated using equation (3) as shown in the chapter (3) (Results and Discussion).

2.3.4 Sieve Analysis

This is the process of separating materials into different fractions. The sieves are set on top of one another with the large one at the top and the smallest sieve at the bottom. The sieve undergoes shaking and the particle size distribution curve is drawn for both the coarse and fine aggregates. Good grading curves show good workability and little segregation.

(i) Apparatus

(a) Head Pan

(b) Scoop

(c) Electrical Sieve Shaker

(d) Cover for the sieve and the pan which is the bottom.

(e) Sieves according to British standard with sizes from 5.00mm to 75.00mm
(f) A balance readable and accurate to 0.1 percent of the weight of the test sample
(g) Iron Brush

2.3.4.1 Sieve analysis for Coarse Aggregate

(i) Apparatus
(a) Electric Sieve Shaker
(b) Weighing Balance
(c) Set of Sieves ranging from 5.00mmto 75.00nm
(ii) Procedure

The sieves holes were cleaned using the iron brush to ensure that there was no entrapped particle. The weights of the various sieve sizes were taken and recorded and the sample was then weighed using a weighing balance and the accuracy was about 0.1%. The sieves were then placed in order with the largest at the top and the pan at the bottom. The weighed sample is poured into the topmost sieves and covered with a lid to avoid splashing during vibration and removal. It was then placed in the sieve shaker and shake for ten minutes. Each of the sieves plus the sample was weighed. The weight of coarse aggregates on each sieve was calculated by subtracting the initial weight of the sieve from the final weight of the sieve plus the sample that remained on them.

2.3.4.2 Sieve Analysis for Fine Aggregates

The same procedure, apparatus, and mechanical process were used as that of coarse aggregates. Results obtained and graphs are shown in chapter 3 (Results and Discussion).

2.3.5 pH. Value Test

It is a scale used in measuring the amount of acidity or alkalinity of a solution. It is based on the concentration of hydrogen ions in the solution. More number of hydroxyl ions per unit volume in a solution gives greater alkalinity. The point of neutrality on the pH scale is taken as 7 and numbers less than 7 are used to indicate degrees of acidity while numbers above 7 are used to indicate alkalinity i.e. the point of neutrality occurs if the number of hydrogen ions in a solution equals the number of hydroxyl ions.

(i) Apparatus
(a) Beakers
(b) Buffer tablets
(c) Distilled water sample
(d) PH meter (digital)
(e) Algae infested sample
(ii) Test procedure

For accuracy, the beakers were first rinsed with distilled water and the buffer tablets (PH 7 and PH 4) dissolved separately in an airtight bottle using distilled water of 100ml. The buffer solutions were used to calibrate the PH meter. That of PH 7 buffer was used to calibrate the PH meter to 7.0, while that of PH 4 to 14 meter readings respectively. The beaker was then half-filled with the sample (water) to be tested and the PH meter reading was then taken. After the reading had been taken, the water sample was poured away and the beaker was rinsed with distilled water, preparing it for the test. The same procedure was repeated for the other samples and their respective readings were taken.

The results obtained are shown in chapter 3 (Result and Discussion)

2.3.6 Void Ratio

This is the volume of voids divided by that of solids. The void ratio is used to measure the quantity of mortar that is required in a mixture.

The void ratio can be obtained using the formula below.

VR = BD/ Gs x UWW................ (Equation 4)

Where VR =Void Ratio
Gs = Specific Gravity
BD = Bulk Density
UWW = Unit Weight of Water

The result of is display in chapter 3 (Result and discussion)

2.3.7 Porosity

This affects the bond between cement pastes and aggregates, resistance to abrasion, resistance to thawing and freezing of concrete, and specific gravity. The formula below can be used to calculate percentage porosity.

$$PP = 1 - \frac{\text{lose weight}}{\text{Compacted weight}} \times 100\% \quad \text{.......(Equation 5)}$$

Where PP = Percentage Porosity

The result obtained is shown in chapter 3 (Results and discussion)

2.4 Trial Mix Design

This is the selection of the most relevant materials such as aggregates and cement and the most economical part of the materials used for the mix to manufacture concrete having the needed physical properties. The water cement law applies to concrete made with light weight aggregates concrete which makes the mix design method easy to follow. But, it is hard to determine the amount of occupied space within the concrete, and to measure the overall water in the mix absorbed by the aggregate.

2.5 Design of Concrete Mix

The following quantities are known from the physical test that was carried out.
Density of cement =1440 kg /m3 (Standard value)
Specific gravity of cement =3.15 (Standard value)
Density of sand or fine aggregates = 654.52kg/m3
Specific gravity of sand or fine aggregates = 2.31
Density of coarse aggregates = 844.33kg/m3
Specific gravity of coarse aggregates = 2.65
Mix ratio used = 1:3:6
Water/Cement ratio = 0.5
Absolute volume of Water = 0.5 x 1440/1 = 720 L
Absolute volume of Cement = 1 x 1440/3.15 = 457.143 L
Absolute volume of Fine aggregates = 3x 654.52/2.31= 850.026 L
Absolute volume of Coarse aggregates = 6 x 844.33/2.65 = 1911.691 L
Total absolute volume = 3938.86m3
Cube Volume =0.15 x0.15 x 0.15 = 0.00338m3
Volume of 48 cubes = 0.162m3
Quantities of materials for 48 cubes:
Water = 0.5 x 1440x 0.162/ 3.939 = 29.61kg
25% increment = 29.61 x 1.25 = 37.03kg
Cement = 1 x 1440x 0.162/ 3.939 =59.22kg
25% increment =59.22 x1.25 = 74.025kg

III. Results And discussion

Table 1: Moisture Content for Aggregate (Sand)

Can Number	Weight of Can Only (g) (w_1)	Weight of Can + wet Sample (g) (w_2)	Weight of Can + Oven Dry Sample (g) (w_3)	Moisture content (%)
H_{14}	23.80	75.80	72.60	6.56
A_{15}	24.10	74.30	70.50	8.19
C_3	26.20	72.40	69.20	7.44

Moisture content = W2 – W3/ W3 – W1 ………………… (Equation 1)
Where W1 is the mass of container (g)
W2 is the mass of container and wet sample (g)
W3 is the mass of container and oven dry sample (g)
Average (w) = 6.56 +8.19+7.44/3
22.19/3 = 7.40%

3.1 Concrete Mixing

The two methods of mixing concrete are:
Manual method: - In this method, the use of hand is employed in mixing the concrete constituents and it is mostly used if the quantity of concrete is not large enough.
Mechanical Method: - It is employed if the quantity of concrete is large. A concrete plant mixer is used for mixing the concrete.
(i) Apparatus
(a) Slump cone
(b) Tamping rod
(c) Head pan
(d) Iron and wooden mould (150mm x 150mm x 150mm)
(e) Meter rule
(f) Tray
(g) Shovel

(h) Hand trowel
(i) Compacting factor machine
(ii) Test Procedure
The materials were ensured available in excess (cement, water, fine and coarse aggregates) during mixing.
The quantities of each material were measured as calculated in the trial mix design. The aggregates were first spread on the tray, followed by the cement and dry materials, and they were thoroughly mixed and cut with a shovel until a uniform mix was achieved. Water was then added and it was done in such a way that neither water nor cement was allowed to escape by flowing away. The mix was turned over again to ensure a uniform mix. During turning or mixing, uniform color and consistency were achieved before proceeding further.

3.2 Properties of Fresh Concrete

Fresh Concrete is a mixture of water, aggregate, cement, and at times admixture. The important properties of fresh concrete are workability and stability. In workability, concrete passes through mixing, transporting, placing, compacting, and finishing. The ease with which a concrete mix can be bounded in the process above is called its workability. Workability can be measured through compacting factor, slump test, etc. The two tests mentioned were carried out during the research work.

3.3 Compacting Factor Test

Compaction is carried out in order to remove trapped air. It is also designed to give a figure as a measure of workability for any kind of concrete mix aggregate, not over 38mm maximum size.
(i) Apparatus
(a) Scoop
(b) Trowel
(c) Compacting factor machine
(d) Weighing balance capable of weighing 7.0kg and accuracy of 1.0g
(ii) Test Procedure
At first, the hoppers doors were closed, and the bottom cylinder was set. The upper part of the hopper was then fixed with a sample of the fresh uncompacted concrete. The concrete was dropped into the cylinder which is at the bottom of the hopper. The cylinder was then removed and weighed but before that, all excess concretes were taking out. The result shows the partially compacted weight of the concrete. The same procedure was carried for compacted concrete.

$CF = W_f / W_p$

Where CF = Compacting Factor
W_p = Weight or Mass of partially compacted concrete
W_f = Weight or Mass of fully compacted concrete
The result is display in chapter 3.

3.4 Slump Test

Slump test is used to calculate the consistency of concrete and the ease to control the water content of concrete in the fields. It is used to determine whether the required degree of workability is met without putting much water in the concrete.
Apparatus
(a) Tray
(b) Tamping rod
(c) Meter rule
(d) Slump cone
(e) Trowel
(iii) Test Procedure

The samples were taken directly from the already mix concrete and placed in three (3) layers in a slump of dimension 300mm high, 200mm round at the base, and 100mm round at the top. Each of the layers was tamped twenty five-times with a rounded steel rod. This last layer was removed from the top of the cone and leveled, and the cone was raised off the concrete gently. The top of the concrete settles (or slumps) and the vertical distance from the 300mm high cone down to the highest point on the slumped concrete was measured and called the slump. This process was repeated 2 more times and the average was calculated.
The result obtained is given in chapter 3.

3.5 Casting of Cubes

Iron moulds and wood moulds were used for this casting with dimensions 150mm x 150mm. The moulds were first polished and lubricated to ease the removal of hardened cubes and filled in 3 layers with each layer tamped twenty-five times. The moulds filled with concrete were left for 24 hours so that the cubes can set properly before the commencement of curing. The cubes were cured in the curing tanks. Curing by immersion of curing cubes in water was the method adopted in the research work. The curing was done at room temperature.

3.6 Crushing Test

Crushing test was conducted to determine the compressive strength of concretes of varying days of intervals.

(i) Apparatus

(a) Crushing machine

(b) Weighing balance

(c) Wheel

(ii) Test Procedure

After the cubes had spent the required members of days in water, they were removed and dried in air for at least 3 hours. Then they were carefully placed in the weighing balance and the weights were taken. Then the cubes were placed in the machine and crushed. As the cubes fails, the machine dial reading stops. Compacting load was then taking and recorded. The results obtained are given in chapter 3 (Results and Discussion).

Table 2: Moisture content of gravels (coarse aggregates)

Can No	Can Weight only (g) W_1	Can Weight + wet sample (W_2)	Can Weight + oven dry sample (W_3)	Moisture content (%)
D_3	24.40	105.40	105.20	0.25
C_1	24.10	114.50	114.30	0.22
C_2	25.10	102.70	102.60	1.29

Average (w) =0.25+0.22+1.29/3

= 1.76/3

= 0.59%

3.7 Specific gravity

Table 3: Result of the specific gravity of sand (fine aggregate)

	First trial (g)	Second trial (g)	Third trial (g)
Weight of vessel only (M_1)	600.70	600.70	600.70
Weight of vessel + dry sample (M_2)	1016.70	1026.70	1089.40
Weight of vessel containing sample and filled with water (M_3)	1830.50	1834.10	1867.10
Weight of vessel filled with water (M_4)	1592.50	1592.50	1592.50
Specific gravity (g)	2.34	2.31	2.28

Specific Gravity =

$$\frac{M_2 - M_1}{(M_4 - M_1) - (M_0 - M_2)}$$

Specific Gravity Average = $\frac{2.34+2.31+2.28}{3}$ = 2.31

Table 4: Specific gravity results of coarse aggregates (gravels)

	1st trial (g)	2nd trial (g)	3rd trial (g)
Weight of vessel only (M_1)	600.70	600.70	600.70
Weight of vessel + dry sample (M_2)	985.20	1012.50	1031.50
Weight of vessel containing sample and filled with water (M_3)	1834.60	1849.10	1857.90
Weight of vessel filled with water (M_4)	1592.50	1592.50	1592.50
Specific gravity (g)	2.70	2.65	2.60

Specific Gravity =

$$\frac{M_2 - M_1}{(M_4 - M_1) - (M_3 - M_2)}$$

$$\text{Average specific gravity} = \frac{2.70+2.65+2.60}{3} = 2.365$$

$$\text{Specific gravity} = \frac{M_2 - M_1}{(M_4-M_1) - (M_3-M_2)}$$

$$\text{Average} = \frac{2.34+2.31+2.28}{3} = 2.31$$

Table 5: Specific gravity results of coarse aggregates (gravels)

	1st trial (g)	2nd trial (g)	3rd trial (g)
Weight of vessel only (M_1)	600.70	600.70	600.70
Weight of vessel + dry sample (M_2)	985.20	1012.50	1031.50
Weight of vessel plus sample and water (M_3)	1834.60	1849.10	1857.90
Weight of vessel filled with water (M_4)	1592.50	1592.50	1592.50
Specific gravity (g)	2.70	2.65	2.60

$$\text{Specific gravity (Gs)} = \frac{M_2 - M_1}{(M_4-M_1) - (M_3-M_2)}$$

$$\text{Average specific gravity} = \frac{2.70+2.65+2.60}{3} = 2.365$$

3.8 Bulk density

Table 6: The Result of the Bulk density test for sand (fine aggregate)

Trial Number	Dimension of Container (m)	Loose Weight (kg)	Loose Density (kg/m^3)	weight (kg) (Compacted)	Bulk Density (Compacted) (kg/m^3)
1st trial	0.085 0.191 0.133	1.095	629.31	1.824	1048.28
2nd trial	0.085 0.181 0.133	1.188	682.76	1.888	1085.06
3rd trial	0.085 0.181 0.113	1.133	651.15	1.890	1086.21

$$\text{Average weight of loose sample} = \frac{1.095+1.188+1.133}{3} = 1.14\text{kg}$$

$$\text{Average weight of compacted sample} = \frac{1.824+1.88+1.890}{3} = 1.87\text{kg}$$

$$\text{Average bulk density loose sample} = \frac{629.31+682.76+651.15}{3} = 654.41\text{kg}$$

Table 7: The result of the bulk density test for the coarse aggregate (gravel)

Trial number	Dimension of Container (m)	Loose Weight (kg)	Loose Density (kg/m^3)	Compacted Weight (kg)	Bulk Density (Compacted) (kg/m^3)
1st trial	0.085 0.181 0.133	1.456	836.78	1.880	1080.46
2nd trial	0.085 0.181 0.133	1.472	845.98	1.884	1082.76
3rd trial	0.085 0.181 0.113	1.480	850.57	1.888	1085.06

Average weight of loose sample = $\frac{1.465+1.472+1.480}{3}$ = 1.47kg

Average weight of compacted sample = $\frac{1.880+1.884+1.8880}{3}$ = 1.88kg

Average bulk density loose sample = $\frac{826.78+845.98+850.57}{3}$ = 844.447kg

Average bulk density of compacted sample = $\frac{1080.46+1.082.75+1085.06}{3}$ = 1082.76kg

3.9 Void Ratio

$$VR = \frac{BD}{Gs \times WW}$$

Where VR = Void Ratio
BD = Bulk Density
Gs = Specific Gravity
WW = Weight of Water

For coarse aggregates = $\frac{844.44}{2.31 \times 1000}$

= 0.32

For fine aggregates = $\frac{654.41}{2.31 \times 1000}$

= 0.28

3.10 Porosity

$$\text{Porosity} = 1 - \frac{\text{Loose Bulk Density}}{\text{Compacted Bulk Density}} \quad \text{…..… From (Equation 5)}$$

Percentage porosity = porosity x 100%

$$\text{Coarse aggregates} = 1 - \frac{844.44}{2.31 \times 1000}$$

= 0.22.1

Percentage porosity = 0.2201 x 100% = 22.01%

$$\text{Fine aggregates} = 1 - \frac{654.41}{2.31 \times 1000}$$

= 0.39

Percentage porosity = 0.39 x 100%

= 39.00%

3.11 Sieve Analysis

Table 8: Sieve analysis result for fine aggregates

Bs. 410 1986 sieve size	Mass retained (g)	Percentage retained (%)	Cumulative percentage retained	Cumulative percentage passing
5.00(mm)	52.90	5.29	5.29	94.71
3.35(mm)	39.20	3.92	9.21	90.79
2.00(mm)	363.90	36.39	45.60	54.40
1.18(mm)	413.80	41.38	86.98	13.02
850(mm)	106.80	10.68	97.66	2.34
600(mm)	15.30	1.53	99.19	0.81
425(mm)	3.00	0.30	99.49	0.51
300(mm)	2.50	0.25	99.47	0.26
150(mm)	1.90	0.19	99.98	0.07
75(mm)	0.50	0.05	99.98	0.02
Pan	0.20	0.02	100.00	-

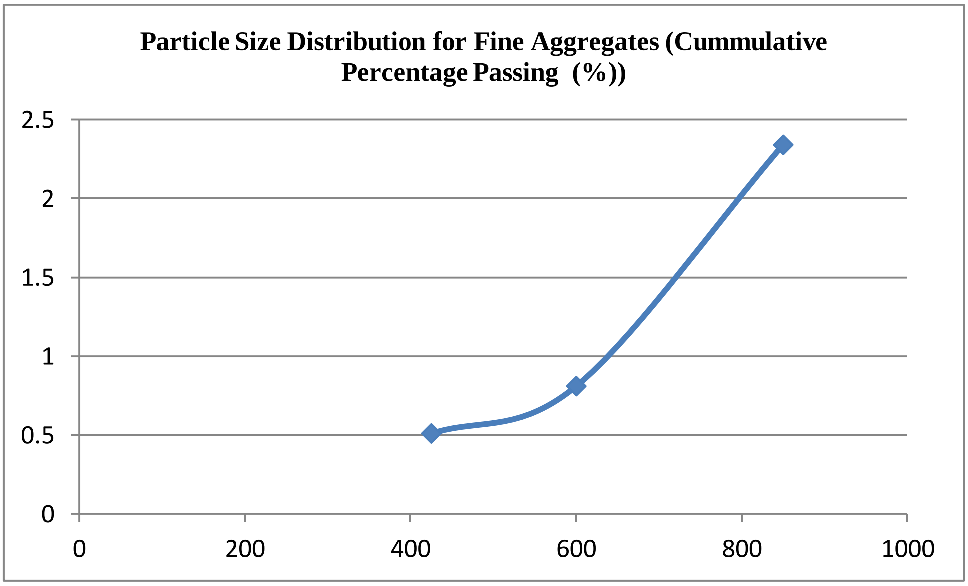

Fig. 1: Particle Size Distribution for Fine Aggregates

$$\text{Percentage Retained} = \frac{\text{Mass Retained}}{\text{Total measurement}} \times 100$$

Commutative percentage passing = 100 – cumulative percentage retained

i. Coefficient of Uniformity (Cu) $= \frac{D_{60}}{D_{10}}$

$$= \frac{2.10}{1.00} = 2.10$$

ii. Coefficient of concavity (Cc) $= \frac{D_{30}^2}{D_{10} \times D_{60}}$

$$= \frac{1.65^2}{1.00 \times 2.10}$$

$$= 1.30$$

Where D_{10}, D_{30} and D_{60} are points where cumulative percentage passing at 10, 30 and 60 cuts the curve on particle size

Table 9: Results of Sieve analysis for coarse aggregates (gravel)

Bs. 410	Mass retained (g)	Percentage retained (%)	Cumulative percentage	Cumulative percentage
20(mm)	223.10	14.87	14.87	85.13
14(mm)	1195.70	79.68	94.55	5.45
10(mm)	76.00	5.06	99.61	0.39
Pan	5.80	0.39	100.00	0.00

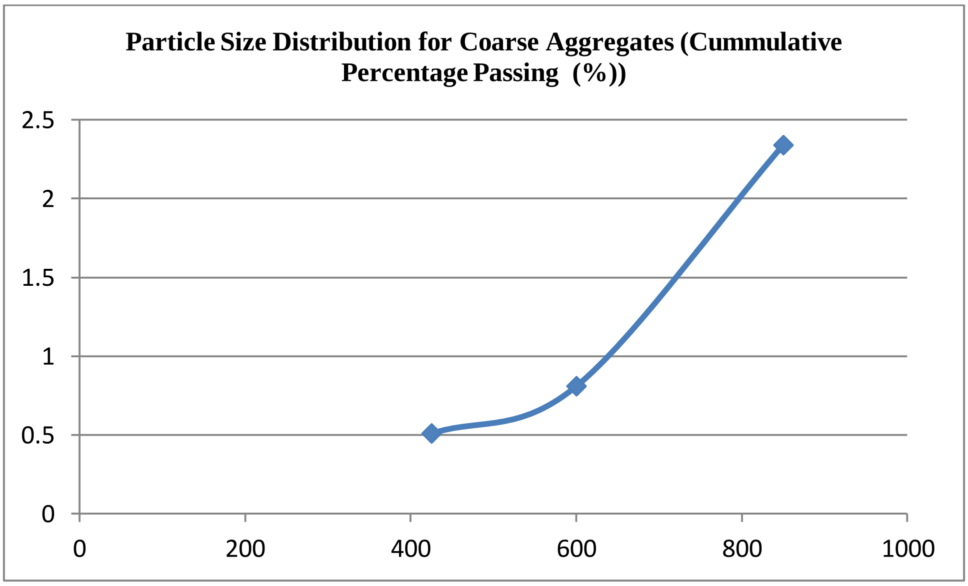

Fig. 2: Particle Size Distribution for Coarse Aggregates

$$\text{Percentage retained} \quad \frac{\text{Mass Retained}}{\text{Total measurement}} \times 100$$

Commutative percentage passing = 100 – cumulative percentage retained

iii. Coefficient of Uniformity (Cu) = $\frac{D_{60}}{D_{10}}$

$= \frac{0.021}{0.017}$

$= 1.24$

iv. Coefficient of concavity (Cc) = $\frac{D_{30}^2}{D_{10} \times D_{60}}$

$\frac{0.0215^2}{0.017 \times 0.0210} = 1.29$

Table 10: Result of P^H value test

Trial Number	PH Value algae infested water	PH value for non-infested water
1st trial	8.15	6.66
2nd trial	8.20	6.82
3rd trial	8.17	6.67

Average PH value for algae infested water = $\frac{24.52}{3}$

$= 8.17$

Average PH value for non-infested water = $\frac{20.15}{3}$

$= 6.72$

3.12 Compacting Factor Test

Table 11: Compacting factor value for the non-infested water

Mix Ratio	Water/cement ratio	Partially compacted concrete (Mass) (kg)	Fully compacted concrete (Mass)(kg)	Compacting factor
1:3:6	0.5	13.55	14.63	0.93

Table 12: Compacting factor value for the infested water

Mix Ratio	Water/cement ratio	Partially compacted concrete (Mass) (kg)	Partially compacted concrete (Mass) (kg)	Compacting factor
1:3:6	0.5	13.48	14.59	0.92

3.13 Shear Slump Test

Table 13: Shear Slump test result for the non-infested water

Mix ratio	Water/cement ration	Shear slump (mm)
1:3:6	0.5	41.67

Table 14: Shear Slump test result for the algae infested water

Mix ratio	Water/cement ration	Shear slump (mm)
1:3:6	0.5	39.33

3.14 Result of compressive strength tests

Table 15: Strength of cubes cured with non-infested water (1:3:6)

Cube marks	Age (days)	Weight (kg)	Cube Density (kg/m^3)	Load (KN)	Compressive strength (N/mm^2)
SN1	7	8.10	2400.00	210.00	9.333
SN2	7	8.24	2441.48	206.00	9.156
SN3	7	7.98	2364.44	198.00	8.500
SN4	7	8.52	2524.44	250.00	11.111
SN5	7	8.34	247.11	242.00	10756
SN6	7	8.72	2583.70	268.00	11.911
SN7	7	8.26	2447.41	246.00	10.933
SN8	7	8.16	2417.78	238.00	10.578
SN9	7	8.68	2571.85	204.00	9.067
SN10	7	8.42	2494.81	242.00	10.756
SN11	7	8.64	2560.00	260.00	11.156
SN12	7	8.14	2411.85	236.00	10.489
SN13	28	9.10	2696.30	292.00	12.978
SN14	28	8.42	2492.81	304.00	13.511
SN15	28	8.76	2515.56	336.00	14.933
SN16	28	8.92	2642.96	352.00	15.644
SN17	28	9.02	2672.59	358.00	15.911
SN18	28	8.58	2542.22	322.00	14.311
SN19	28	7.96	2358.52	298.00	13.244
SN20	28	8.84	2619.26	376.00	16.711
SN21	28	8.86	2625.19	376.00	16.711
SN22	28	9.36	2773.33	388.66	17.244
SN23	28	8.92	2642.96	364.00	16.178
SN24	28	8.88	263.11	384.00	17.067

$$\text{Density of cube} = \frac{\text{Weight of Cube}}{\text{Volume of Cube}}$$

Where volume = (0.15 x 0.15 x 0.15) m^3

$$\text{Compressive strength} = \frac{\text{Load}}{\text{Area of the Cube}}$$

Where Area = (0.15 x 0.15) m^2

Average compressive strength from 7 days = 10.371N/mm^2

Average compressive strength for twenty eight days = 15.370N/mm^2

Table 16: Strength of cube cured with non-infested water (1:3:6)

Cube marks	Age (days)	Weight (Kg)	Density of cube (kg/m^3)	Load (KN)	Compressive strength (N/mm^2)
SA1	7	7.94	2352.59	202.00	8.978
SA2	7	8.46	2506.67	240,00	10.667
SA3	7	8.18	2423.70	234.00	10.400
SA4	7	7.76	2299.26	192.00	8.533
SA5	7	8.34	2471.11	238.00	10.578
SA6	7	8.08	2394.07	234.00	10.400
SA7	7	8.32	2465.19	246.00	10.933

SA8	7	7.64	2263.70	204.00	9.067
SA9	7	8.40	2488.89	252.00	11.200
SA10	7	8.22	2435.56	236.00	10.489
SA11	7	7.88	2334.81	200.00	8.889
SA12	7	8.02	2376.30	198.00	8.800
SA13	28	8.36	2477.04	304.00	13.511
SA14	28	8.62	2554.07	316.00	14.044
SA15	28	9.08	2690.37	338.00	15.022
SA16	28	8.84	2619.26	332.00	14.756
SA17	28	8.36	2477.04	340.00	15.111
SA18	28	8.56	2536.30	318.00	14.133
SA19	28	8.92	2642.96	366.00	16.267
SA20	28	9.02	2672.59	324.00	16.222
SA21	28	8.24	2441.48	314.00	13.956
SA22	28	9.20	2725.93	380.00	16.889
SA23	28	8.86	2571.85	292.00	12.978
SA24	28	8.72	2583.70	332.00	14.756

$$\text{Density of cube} = \frac{\text{Weight of Cube}}{\text{Volume of Cube}}$$

Where volume = $(0.15 \times 0.15 \times 0.15)\ m^3$

$$\text{Compressive strength} = \frac{\text{Load}}{\text{Cube Area}}$$

Where Area = $(0.15 \times 0.15)\ m^2$

Average compressive strength from 7 days = $9.11 N/mm^2$

Average Compressive strength for twenty eight days = $14.837 N/mm^2$

IV. Discussion of Results

4.1 Moisture contents

The values obtained for the moisture content of fine and coarse aggregate are 7.40% and 0.59%. This shows that they are low enough to allow the concrete to absorb a high amount of water as provided in the water/cement ratio to achieve consistency, mobility, as well as compatible mix.

4.2 Specific Gravity

According to the standard, the specific gravity of aggregates varies between 2.6 to 2.7. From the result obtained the specific gravity of the aggregates was 2.65 this shows that it falls within the range. The specific gravity of fine aggregate is given less consideration in terms of specification.

4.3 Bulk Density

The average bulk density for a loose sample of aggregates is 855.44kg/m3. This indicates that they are less densely packed and a higher quantity of cement paste will be needed to fill in the voids created by the aggregates.

4.4 Void Ratio

The results obtained for coarse aggregates, which is 0.32 reveals that there was an uneconomical use of mortar since mortar is required to fill in the space created by the aggregates.

4.5 Porosity

Porosity affects the strength of the bond between aggregates and cement paste. According to the result acquired for coarse aggregates, which is 22.01%, the porosity is okay.

4.6 Sieve Analysis

The coefficient of uniformity of coarse and fine aggregates has a large range of particle size distribution compared to that of coarse aggregates.

A well-graded soil has a co-efficient of concavity ranging from 1 to 3, and the values of co-efficient of concavity obtained in this research work are 1.30 for fine aggregates sand 1.29 for coarse aggregate, which shows that the samples are well graded. Also in this research work, fine aggregates size ranges from 5mm and below while coarse aggregates range from 5mm and above.

4.7 Compacting Factor Test

The values obtained for composition factors are 0.93 for non-infested water and 0.92 for algae infested water, this result indicates that algae infested water has a lower compacting factor than the non-infester water. So therefore the degree of workability for the algae infested water is slower than that of the non-infested water.

4.8 Shear Slump

The value of shear slump obtained for algae infested water and non-infester water are 39.33 and 41.67, which shows that the degree of workability is okay.

4.9 Compressive strength of algae infested water cubes and the non-infested water cubes.

From the compressive strength tables shown earlier, the compressive strength of cubes cured with algae infested water for 7 days varies with just some little difference, but as the days increase to 28 the difference in strength increase more, so also for cubes cured with non-infested water, the same changes in strength occurred.

Also from tables 3.10 and 3.11 the compressive strengths of algae infested water concretes are less than that of cubes cured with portable water. This reveals that algae infested water concrete has lesser strength than cubes cured with portable water. Also as the days for curing increases the strength of the cubes increased.

4.10 PH Value Test

The result obtained in table 4.9 shows that algae-infested water is alkaline water because it PH value is greater than 7 which is not advisable to use for concrete production.

V. Conclusion

According to the results obtained in chapter three (Result and Discussion) for compressive strength of concrete, it shows that algae infested water reduces the strength of concrete. This reduction must have been due to the presence of alkali in the water since alkaline is present. So therefore the higher the amount of algae in water for mixing and curing of concrete, the greater will be the reduction in strength of the concrete cubes.

Reduction in strength for algae infested water for 7 and 28 days are 0.46 N/mm^2 and 0.53 N/mm^2.

The concluding remarks are listed below:

i. The use of algae infested water should be avoided either for mixing or curing because it has a negative impact on concrete

ii. Only drinkable water should be used in making concrete because of safety purposes else a study should be carried out before using any alternate choice of water.

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