# A COMPARATIVE STUDY ON DIFFERENT CURING METHODS OF CONCRETE

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A thesis submitted to the Department of Civil Engineering in partial fulfillment for the degree of Bachelor of Science in Civil Engineering.




Department of Civil Engineering

Sonargaon University

147/I, Green Road, Dhaka-1215, Bangladesh

Section: 23B+23D

Fall 2024

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***Dedicated***

*to*

*“OUR PARENT’S & TEACHERS”*

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# ABSTRACT

The structural use of concrete depends largely on its strength, especially compressive strength. Various tests were carried out to ascertain the properties of concrete materials, whereas test performances of the concrete with different mix ratios at specific ages of curing were undertaken. The study determined the compressive strength of concrete using different curing methods. Four different methods of curing (ponding, continuous wetting, open-air curing and sprinkling with water) were used. Seventy-two (72) cubes were cast using a mix ratio of 1:2:4 with 0.55 water cement ratio and with 0.6 waters cement ratio respectively. The compressive strengths were determined after 7 days, 14 days and at 28 days of curing. Findings show that for 1:2:4 concrete, maximum of 28-day compressive was the highest for concrete cured by ponding and the least was by sprinkling water. Further findings show that for 1:3:6 concrete, maximum of 28-day compressive strength was obtained using ponding and the least was open air curing. Despite ponding method producing the highest compressive strength of concrete, it is practically impossible to cure cubes above ground structural elements. Wet-covering method is recommended for structural elements, such as columns, beams and slabs in other to produce concrete of a required compressive strength.

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# CHAPTER 1

# INTRODUCTION

## 1.1 General

To “cure” concrete is to provide concrete with adequate moisture and temperature to foster cement hydration for a sufficient period of time. Proper curing of concrete is crucial to obtain design strength and maximum durability, especially for concrete exposed to extreme environmental conditions at an early age.

[1] Others define curing as the process of controlling the rate and extent of moisture loss from concrete during cement hydration. High curing temperature (up to 212° F or 100° C) generally accelerates cement hydration and concrete strength gain at early age. Curing temperature below 50° F (10° C) are not desirable for early age strength development. When the curing temperature is below 14° F (-10° C) the cement hydration process may cease. Concrete needs to be kept for a longer time in formwork when cast in cold weather condition.

[2] On the whole, the strength of concrete, its durability and other physical properties are affected by curing and application of the various types as it relates to the prevailing weather condition in a particular locality, as curing is only one of many requirements for concrete production, it is important to study the effect of different curing method which best adapts to each individual casting process. This study presents the effects of different curing methods on the compressive strength of concrete cured for 7, 14, 21 and 28 days.

## 1.2 Research Background and Motivations

Concrete is a very versatile and widely used construction material. However, the production of concrete is a major source of greenhouse gas emissions. In concrete can create an opportunity to reduce environmental impact of the concrete industry.

Also, the natural elements used in concrete such as, sand are finite and over-mining the natural resources has a very dangerous effect on the environment. The demand of natural sand in concrete production, it can save on the cost of materials & it can also increase the strength of concrete.

However, the most effective methods of curing concrete are wet coverings or water spraying that keeps the concrete continually damp. Curing compounds should be able to maintain the relative humidity of the concrete surface above 80% for seven days to sustain cement hydration.

## 1.3 Research Objectives and Overview

### 1.3.1 Objectives

This study considered effect of curing methods on density and compressive strength of concrete. The compressive strength period is 7, 14, 21 and 28 days on different combination of the concrete curing. Used materials ratio is 1:2:4 and water cement ratio 55%. The testing steps are air curing, water-submerged curing, spray curing, polythene curing, moist sand curing and wet jut curing.

- To study the effect of different curing methods of concrete.
- To compare the compressive strength data of 7, 14, 21 and 28 curing days for different curing methods.

### 1.3.2 Overview

In this study, we prepare normal concrete mix and also a series of concrete mixtures with different proportions (45%, 50%, and 55%) of water as a partial replacement for fine aggregate. The concrete has casted in cylinder cured for 7, 14, 21 days and 28 days respectively and then did test for their compressive strength. We are use the locally available aggregate materials for the research to observe the ability and strength of the different concrete mixes for the practical use in construction works.

## 1.4 Organization of the Thesis

This section should have a brief description of the thesis outline of the thesis. It should contain chapter no. with a title and brief descriptions of the content of each chapter. An example guide is provided below.

**Chapter 1: Introduction and Objective.** This chapter provides the background and motivations of the research. The overall objectives and expected outcomes are also described in this chapter.

**Chapter 2: Literature Review.** This chapter reviews the related works in the study of Compressive strength of concrete field with a special focus on waste glass as fine aggregate replacement

**Chapter 3: Methodology.** This chapter describes the methodology adopted to carry out the research.

**Chapter 4: Results and Discussion.** This chapter describes the results of the test on a study on the compressive strength of structural concrete using water as a partial replacement for fine aggregate

**Chapter 5: Conclusions and Future Work.** This chapter summarizes the conclusions and major contributions of this study and provides recommendations for future studies.

# CHAPTER 2

# Literature Review

## 2.1 Introduction

Concrete curing is one of the most important and final steps in concrete construction though it is also one of the most neglected and misunderstood procedures. It is the treatment of newly placed concrete during the period in which it is hardening so that it retains enough moisture to immunize shrinkage and resist cracking (Lambert Corporation, 1999).

Curing of concrete is a pre requisite for the hydration of the cement content. For a given concrete, the amount and rate of hydration and furthermore the physical make-up of the hydration products are dependent on the time-moisture-temperature history (Neil Jackson et al, 1996).

The necessity for curing arises from the fact that hydration of cement can take place only in water-filled capillaries. This is why loss water must be prevented. Furthermore, water lost internally by self-dedication has to be replaced by water from outside, i.e. Ingress of water into the concrete must take place (Neil Jackson et al, 1996).

Thus, for complete and proper strength developments, the loss of water in concrete from evaporation should be prevented, and the water consumed in hydration should be replenished. This the concrete continues gaining strength with time provided sufficient moisture is available for the hydration of cement which can be assured only by creation of favorable conditions of temperature and humidity. This curing the temperature of steam should be restricted to a maximum of $75^0$ C as in the absence of proper humidity (about 90%) the concrete may dry too soon. In case of hot water curing, temperature may be raised to any limit, at $100^0$ C. At this temperature, the development of strength is about 70% of 28 days' strength after 4 to 5 hours. In both cases, the temperature should be fully controlled to avoid

non-uniformity. The concrete should be prevented from rapid drying and cooling which would form cracks Process of creation of an environment during a relatively short period immediately after the placing and compaction of the concrete, favorable to the setting and the hardening of concrete is termed curing (Gambier, 1986).

A proper curing maintains a suitably warm and moist environment for the developments of hydration products, and thus reduces the porosity in the hydrated cements paste and increases the density of microstructure in concrete. The hydration products extend from the surfaces of cement grains, and the volume of pores decreases due to proper curing under appropriate temperature and moisture (Safiudeen et al, 2007).

### 2.2 Summary

A proper curing greatly contributes to reduce the porosity and drying shrinkage of concrete, and thus to achieve higher strength and greater resistance to physical or chemical attacks in aggressive environments. Therefore, a suitable curing method such as water ponding (immersion), spraying or sprinkling of water, or covering with polythene sheet material is essential us order to produce strong and durable concrete. The study presents the effect of different curing methods on the compressive strength of concrete using Portland cement and finally identifies the most effective curing process for normal concrete.

Different curing methods are usually adopted to evaluate the compressive strength of concrete. This study reports the laboratory results of the effect of curing methods on the compressive strength as well as the density of concrete. A total of 25 nos cylinder mix ratio 1:2:4 was investigated after subjecting them to various curing conditions, with the aim of finding which of the curing method is best. The cubes were cured in the laboratory at an average temperature of 28° C (82.4° F). The results obtained showed that the average compressive strength values for 7, 14, 21 and 28 days, vary with curing methods. The results show that ponding had the highest compressive strength and density, followed by 1st highest water submerged curing, 2nd highest moist sand curing, 3rd polythene curing, 4th spry curing 5th wet jut curing and low strength air curing then uncured cylinder one nos with the totally uncured cylinder having the least compressive strength and density as well as highest water submerged curing. Ponding method of curing was recommended to be the best of all the curing methods.

# CHAPTER 3

# Methodology

## 3.1 Introduction

The concrete composition in this test satisfies various concrete design codes for high durability and impact load resistance. To study the behavior of concrete at different combinations of replacement of fine aggregate, 24 specimens were cast and tested for compressive or flexural strength. There were also some tests conducted on materials to see if they fulfill the minimum requirement of subjected code to be used in structural concrete. Tests such as fineness modulus, specific gravity, absorption capacity etc. were conducted and the data will be provided in later part in this chapter. A number of curing techniques can be applied depending on various factors considered on site or due to the construction method. They range from the most popular water-submerged curing to moist sand, water-spray curing, polythene membrane sealing and steam curing (autoclaving). Also, there has been the introduction of membrane-forming curing agents/compounds which are widely accepted in developed nations because they can be applied quicker than sheets and require least amount of curing protection. They work by sealing the surface of the concrete but do not prevent complete evaporation of mix water. It is against this background that this study seeks to assess the effect of different curing methods on the density and compressive strength of concrete and to determine method's that is/are unsuitable which may impair the quality of the concrete.

## 3.2 Materials Used

### 3.2.1 Cement

In 1824 Joseph Aspdin, a British bricklayer, patents a new type of cement that he calls "Portland cement" because its appearance resembles that of Portland stone, a limestone quarried on the Isle of Portland in Dorset, England. Aspdin's cement is made by heating a mixture of limestone and clay in a kiln to a higher temperature than Smeaton's cement. This process produces a more reactive cement that sets faster and is stronger. Later son of Joseph Aspdin improves the manufacturing quality of Portland cement which resulted in more durable and stronger cement. By 1850s, Portland cement started to be used in the USA. And by 1870, Portland cement became the most popular cement in the world and many famous infrastructures were built by Portland cement.

Cement, as it is commonly known, is a mixture of compounds made by burning limestone and clay together at very high temperatures ranging from 1400 to 1600 [ring] C [9].Cement is manufactured through a closely controlled chemical combination of calcium, silicon, aluminum, iron and other ingredients. Common materials used to manufacture cement include limestone, shells, and chalk or marl combined with shale, clay, slate, blast furnace slag, silica sand, and iron ores.



**Figure 3-1: Portland Composite Cement**

### 3.2.2 Chemical composition of Cement:

Concrete is prepared through a process of combining cement, water, and aggregate, resulting in a workable paste that can be molded or placed according to specific requirements. The substance is then consolidated and left to harden, contrary to popular belief that it must dry out in order to achieve the desired effect. Rather, concrete - and more specifically, the cement contained within it - requires moisture to hydrate and cure, ultimately leading to its hardening. It is worth noting that once concrete dries,

It ceases to become stronger. In instances where concrete contains insufficient water content, it may be dry but not fully reacted, leading to properties that are inferior to those of wet concrete. The reaction between water and cement is of paramount importance to the properties of concrete, as such reactions may continue for several years.

Portland cement consists of five major compounds and a few minor compounds. The composition of a typical Portland cement is listed by weight percentage in Table 3.1

**Table 3.1: Composition of Portland cement with chemical composition and weight percent.**

| Cement Compound | Weight Percentage | Chemical Formula |
|---|---|---|
| Tri-calcium silicate | 50 % | $Ca_3SiO_5$ or $3CaO.SiO_2$ |
| Di-calcium silicate | 25 % | $Ca_2SiO_4$ or $2CaO.SiO_2$ |
| Tri-calcium aluminate | 10 % | $Ca_3Al_2O_6$ or $3CaO.\ Al_2O_3$ |
| Alumina ferrite | 10 % | $Ca_4Al_2Fe_2O_{10}$ or $4CaO.Al_2O_3.Fe_2O_3$ |
| Gypsum | 5 % | $CaSO_4.2H_2O$ |

### 3.2.3 Aggregates:

Aggregates, which are composed of inert materials, are blended with binding substances like cement or lime to manufacture mortar or concrete. They are utilized as fillers in mortar and concrete and are also employed to decrease production costs. These granular materials comprise minerals such as sand, gravel, shale, slag, or crushed stone. Generally, aggregates occupy approximately 70% to 80% of concrete volume. Consequently, the significance of selecting the appropriate type of high-quality aggregate cannot be disregarded. Initially, aggregates were considered as an inexpensive material dispersed throughout the cement paste; however, an opposing viewpoint views aggregate as a building material that is integrated into a cohesive whole via the cement paste. In reality, aggregates are not completely inert, and their physical, thermal, and, in some cases, chemical properties have an impact on the performance of concrete. Aggregates may not only limit strength but also affect the durability of concrete. Natural aggregates are formed via the process of weathering and abrasion, whereas crushed aggregates are obtained by crushing quarry rock, boulders, cobbles, or large-sized gravel. Recycled concrete is a viable source of aggregate and has been successfully employed in granular sub-bases, soil-cement, and new concrete. Following extraction, aggregates are processed, crushed, screened, and washed to achieve the required cleanliness and gradation. If necessary, a benefaction process such as jigging or heavy media separation can be applied to enhance quality. Once processed, the aggregates are handled and stored to minimize segregation, degradation, and contamination. In the construction sector, aggregates are generally classified into two categories:

- Coarse Aggregates
- Fine Aggregates.

### 3.2.4 Coarse Aggregate:

As per the ASTM standards, any material that is held back by a No. 04 sieve (4.75 mm) is categorized as coarse aggregate. Nonetheless, in construction practices, the maximum allowable size of coarse aggregate is restricted to 19 mm. Crushed stone, gravel, and fragmented burnt bricks are among the most commonly utilized coarse aggregates. Gravel, in combination with crushed stone, makes up the bulk of the coarse aggregate that is used in concrete. The sizes of gravel have an impact on several aspects, particularly workability and strength.



**Figure 3-2: Sample of Coarse Aggregate**

### 3.2.5 Fine Aggregate:

According to ASTM Standards, fine aggregate is defined as material that passes through a No. 04 sieve (4.75 mm). This type of aggregate is primarily composed of naturally-occurring sand particles obtained from mining operations. Fine aggregate typically consists of natural sand or crushed stone particles that are ¼" or smaller. Often referred to as ¼" minus due to its size or grading, this particular aggregate is widely used in the construction industry. In construction, aggregate refers to sand that is typically considered to have a lower size limit of around 0.07 mm. The fine aggregate content is usually 35% to 45% by mass or volume of the total aggregate. Fine aggregates serve to fill all of the open spaces between coarse particles, reducing the porosity of the final mass and significantly increasing its strength.



**Fig 3-3: Sample of Fine Aggregate (Natural Sand)**

### 3.2.6 Water:

Water constitutes a pivotal ingredient that, upon mixing with cement, generates a paste that binds the aggregate together. Not only does water facilitate the workability of the mixture, but it is also crucial for the cement to hydrate. Water plays a critical role in the entire lifespan of concrete, with most actions on concrete, except loading, involving water, either in its pure form or carrying salts or solids. Apart from its impact on workability and strength, water significantly influences other aspects of concrete, such as setting, hydration, bleeding, drying shrinkage, creep, and ingress of salts. Impurities in water may disrupt the setting of concrete and adversely affect its strength, the quality of water assumes paramount importance. Although many specifications stipulate that water should be fit for drinking, drinking water may still be unsuitable if it contains a high concentration of sodium or potassium. As a general rule, water with a pH ranging from 6 to 8, and that does not taste saline or brackish, is deemed appropriate for use. Employing tested or treated water can augment the strength of cement concrete and enhance the longevity of buildings.

## 3.3 Methodology and Tests

### 3.3.1 Test on Materials

Various tests have been conducted on aggregates to determine if their standards meet the codes to be used in a concrete Mix. Fineness modulus, specific gravity, unit weight and absorption capacity. The procedures and details of the tests will be described below.

It is an index which gives an idea about fineness or coarseness of aggregate. The Fineness Modulus (FM) of fine aggregates (sand) is an empirical figure obtained by adding the total

percentage of the sample of a sand retained on each of a specified series of sieves, and dividing the sum by 100.

- FM is not an indication of grading of aggregates as an infinite number of grading can have same FM.
- FM for good Concrete-
  FM for FA is (2.25-3.25)
  FM for CA is (5.50-7.50)
- The smaller the value of FM, the more is smaller sizes in aggregate. Test sieve conforming ASTM C136 specification (#4, #8, #16, #30, #50, and #100) were used. All test procedure was executed and maintained according to the code.

### 3.3.2 FM of Fine Aggregate (Selection Sand)

The Sylhet sand was collected from the local market of farmgate. After bringing the sand to the laboratory we tested its fineness modulus test, and the data is given below:

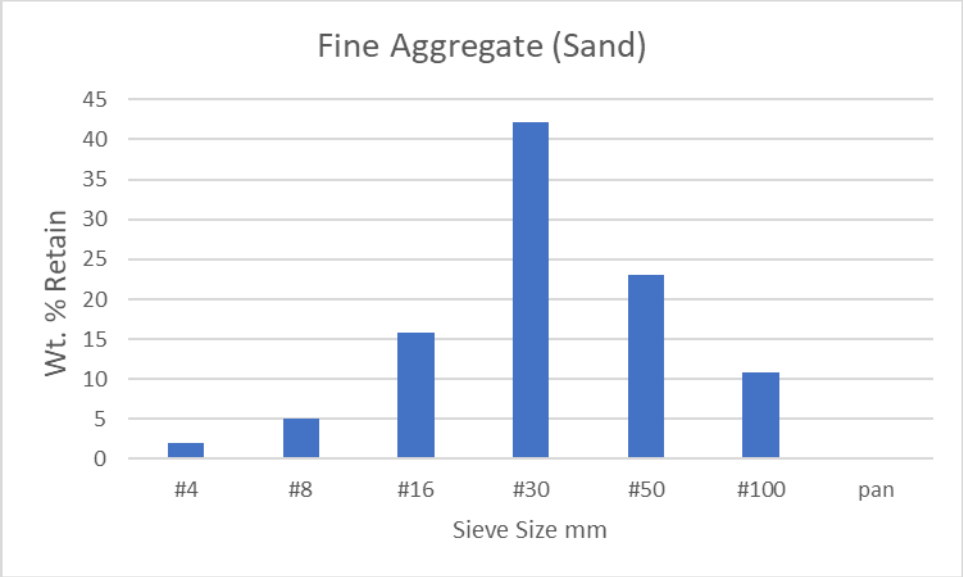



**Fig 3-4: Graph Fineness Modulus of Sand Used**

### 3.3.3 FM of the Coarse Aggregate

The Sylhet sand was collected from the local market of farmgate. After bringing the sand to the laboratory we tested its fineness modulus test, and the data is given below.

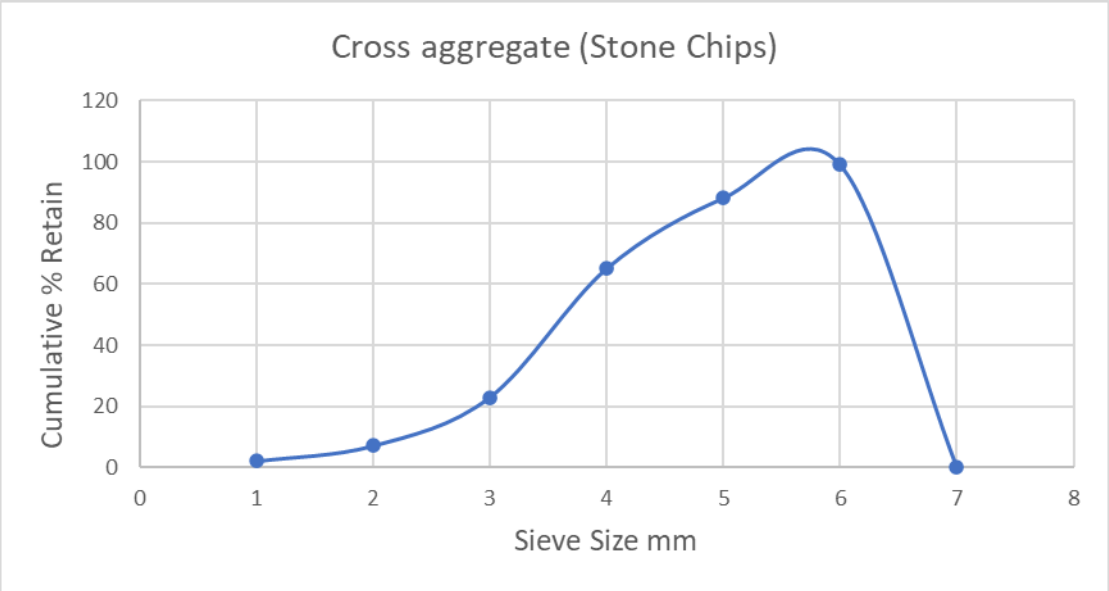



**Fig 3-5: Graph of coarse aggregate**

### 3.3.4 Sieve Analysis

The results of the sieve analysis for fine and coarse aggregates used are presented in Figure. It could be observed from the grading curves that the coefficient of uniformity (Cu) and coefficient of curvature (Cc) for the fine aggregates are 2.63 and 0.82 respectively. Thus, the sand can be said to be well graded. For the coarse aggregates, Cu and Cc are 2.1 and 1.1 respectively. According to Smith (1970), the coarse aggregate is well graded since it has a coefficient of curvature, Cc that falls between 1 and 3. The coarse aggregate falls under the category of nominal size of graded aggregates ranging from 20 mm to 5 mm. The specific gravity of the sand is 2.66 while the moisture content is 16.8%.

### 3.3.5 Density of Concrete Specimens

The mean density recorded by each curing method, the range and standard deviation. The density of the specimens ranged from 2432.59 Kg/m$^3$ to 2502.72 Kg/m$^3$. This lies within the range of 2200 Kg/m$^3$ to 2600 Kg/m$^3$ specified as the density of normal weight concrete (Neville, 2000). The moist sand curing method produced concrete specimen with the highest

mean density of 2502.72 Kg/$m^3$, followed by the polythene and water submerged methods with mean values of 2484.94 Kg/$m^3$ and 2461.23 Kg/$m^3$ respectively. The polythene curing method produced the highest range of density and standard deviation indicating that the method is highly unreliable. The specimens cured by burlap method produced the lowest range of density and standard deviation indicating that the method is reliable.

### 3.3.6 Compressive Strength of Concrete Specimens

The compressive strength of air-cured concrete specimens. The air cured specimens showed a compressive strength of 7.76 N/$mm^2$, 9.29 N/$mm^2$, 11.71 N/$mm^2$ and 10.18 N/$mm^2$ after 7, 14, 21 and 28 days of curing. This study considered the effect of different methods of curing on density and compressive strength of concrete. Concrete cube specimens of mix 1:2:4 was prepared with water-cement ratio of 0.55. The cylinder was cured using six methods (air curing, water-submerged curing, spray curing, polythene curing, moist sand curing and wet jut curing) testing ages of 7, 14, 21 and 28 days. When their densities and compressive strengths were determined. The results showed that compressive strength specimens from 7.76 N/$mm^2$ to 19.35 N/$mm^2$. Also, water submerged curing method produced concrete specimens with the highest 28-day compressive strength of 19.35 N/$mm^2$ followed by the wet jut curing method with a value of 59.96 N/$mm^2$. Air curing method showed 13% reduction in strength after 21 days thereby resulting in the lowest 28-day compressive strength of 10.18 N/$mm^2$. It was concluded to make a weak correlation between density and compressive strength of concrete specimens.

### 3.3.7 Specific Gravity and Capacity of Aggregate

Aggregates are typically composed of permeable and impermeable pores, necessitating a meticulous definition of their specific gravity. By establishing the specific gravity of each constituent, the weight can be transformed into a solid volume, enabling a theoretical concrete yield per unit volume to be computed. Additionally, the specific gravity of the aggregate is indispensable in computing the compacting factor, which is crucial for workability measurements. This testing procedure encompasses the evaluation of both bulk and apparent specific gravity, at 23/23$^0$ C (73.4/72.4$^0$ F), as well as the absorption capacity of fine aggregate. This methodology serves several purposes, including:

i) The calculation of the volume occupied by the aggregate in various mixtures on an absolute volume basis,

ii) The computation of voids in the aggregate, and

iii) The determination of moisture content in the aggregate. The determination of the specific gravity of a porous solid necessitates the inclusion of both permeable and impermeable voids in the volume calculation. Bulk specific gravity, also referred to as bulk dry specific gravity, is a measurement of the weight in air of a unit volume of aggregate at a designated temperature in relation to the weight in air of an equivalent volume of gas-free distilled water at the same temperature. Apparent specific gravity, on the other hand, is the ratio of the weight in air of a unit volume of the non-permeable portion of aggregate, which excludes permeable pores, to the weight in air of an equal volume of gas-free distilled water at the specified temperature. The complete method of the test and details will be described below.

### 3.3.8 Apparatus

- **Balance**- Sensitive to 0.1gm or less.
- **Pycnometer**- A flask or other suitable container of 1000 ml capacity. The volume of the container filled to mark shall be at least 50% greater than the pace required to accommodate the sample of fine aggregate.
- **Mold**- A metal mold in the form of a frustum of a cone with dimensions as follows: 40 ± 3 mm inside diameter at the top
    - 90 ± 3 mm inside diameter at the bottom
    - 75 ± 3 mm in height
    - 0.8 mm minimum thickness of metal.
- **Tamper**- A metal tamper weighing 350 ± 15 gm and having a flat circular tamping face 25 ± 30 mm diameter.

### 3.3.9 Test of Sample

- Partially occupy the pycnometer with aqueous solution. Swiftly introduce into the pycnometer 500 ± 10 ml of supersaturated surface dry exquisite aggregate arranged and fill with supplementary aqueous solution to approach 90% of capacity. Roll, invert, and agitate the pycnometer to eradicate all gaseous inclusions. Modify the temperature to 23 ± $1.7^0$ C (73.4 ± $3^0$ F). If obligatory by immersion in circulating aqueous solution bring the aqueous solution level in the pycnometer to its calibrated capacity. Ascertain the aggregate weight of the pycnometer, specimen, and aqueous solution.

- Remove the fine aggregate from the pycnometer, dry to constant weight at a temperature of 110 ± $5^0$ C (230 ± $9^0$ F), cool in air at room temperature for 1 ± ½ hr. and weigh.
- Determine the weight of the pycnometer filled to its calibration capacity with water at 23 ± $1.7^0$ C (73.4 ± $3^0$ F)

### 3.3.10 Calculation

Bulk specific gravity (Dry) = A/ (B+S-C)

Bulk specific gravity (Saturated) = S/ (B+S-C)

Apparent specific gravity = A/ (B+A-C)

Absorption capacity (%) = (S-A) X 100/A

Were,

A = Weight of oven-dry specimen in air, gm

B = Weight of pycnometer filled with water, gm

S = Weight of the saturated surface-dry specimen, gm and

C = Weight of pycnometer with specimen and water to calibration mark, gm

Results of the samples is described in result and discussion chapter.

## 3.4 Unit Weight of Aggregate

This particular examination methodology encompasses the ascertainment of individual mass in a tightly compressed or lax state of both slender and bulky substances. The unit mass values of aforementioned substances are indispensable for implementation in numerous techniques of electing suitable ratios for cement admixtures. Moreover, they may be utilized to determine the mass/volume correlations for conversions and to compute the proportions of hollow spaces present in the substances. Hollow spaces within the particles, whether they are penetrable or impenetrable, are not incorporated in the hollow spaces ascertained by virtue of this examination methodology. This examination methodology is in accordance with the standard requirements of specification C29 as set forth by ASTM.

### 3.4.1 Apparatus

- Balance- accurate within 0.1% of the test load and graduated to at least 0.1 lb (0.05 kg)
- Tamping rod- a round, straight steel rod, 5/8 in. (16 mm) in diameter and approximately 24 in. (600 mm) in length, having one end rounded to a hemispherical tip.
- Measure- a cylindrical metal measure, preferably provided with handles, shall be watertight, with the top and bottom true and even, and sufficiently rigid to retain its form under rough usage. The measure shall have a height approximately equal to the diameter, but in any case, the height shall not be less than 80% nor more than 150% of the diameter. The capacity of the measure shall conform to the limits in table-1 for the aggregate size to be tested. The thickness of metal in the measure shall conform to the limits as described in table-3.4. The interior wall of the measure shall be smooth and continuous surface.

**Table 3.2: Capacity of Measures**

| Nominal maximum size of aggregate | | Capacity of measure | |
|---|---|---|---|
| inch | mm | $ft^3$ | liter ($m^3$) |
| 0.5 | 12.5 | 1/10 | 2.8 (0.0028) |
| 1.0 | 25.0 | 1/3 | 9.3 (0.0093) |
| 1.5 | 37.5 | 1/2 | 14 (0.014) |
| 2.0 | 75 | 1 | 28 (0.028) |
| 2.5 | 112 | 2.5 | 70 (0.070) |
| 3.0 | 150 | 3.5 | 100 (0.100) |

**Note:** The indicated size of measure shall be used to test aggregates of a nominal maximum size equal to or smaller than those listed. The actual volume of the measure shall be at least 95% of the normal volume listed

**Table 3.3: Requirements for Measures**

| Capacity of measures | Thickness of metal (minimum) | | |
|---|---|---|---|
| | Bottom remainder | Upper of wall | 1.5 in. or 38 mm of wall |
| Less than 0.4 $ft^2$ | 0.20 in | 0.10 in. | 0.10 in. |
| 0.4 $ft^3$ to 1.5 $ft^3$, in. | 0.20 in | 0.20 in | 0.12 in |
| Over 1.5 to 2.8 $ft^3$, in. | 0.20 in | 0.25 in. | 0.15 in. |
| Over 2.8 to 4.0 $ft^3$, in. | 0.40 in. | 0.30 in | 0.20 in. |
| Less than 11 liters | 0.50 in. | 2.5 mm | 2.5 mm |
| 11-to-42-liter, in. | 5.0 mm | 5.0 mm | 3.0 mm |
| Over 42-to-80-liter, in. | 10.0 mm | 6.4 mm | 3.8 mm |
| Over 80-to-133-liter in. | 13.0 mm | 7.6 mm | 5.0 mm |

**Note:** The added thickness in the upper portion of the wall may be obtained by placing a reinforcing bang around the top of the measure.

Calibration equipment- a piece of plate glass, preferably at least ¼ in. (6 mm) thick and at least 1 in. (25 mm) larger than the diameter of the measure to be calibrated. A supply of water pump or chassis grease that can be placed on the rim of the container to prevent leakage.

### 3.4.2 Test of Sample

The size of the sample shell be approximately 124% to 200% of the quantity required to fill the measure, and shall be handled in a manner to avoid segregation. Dry the aggregate sample to essentially constant mass, preferably in an oven at 230 ± $9^0$ F (110 ± $5^0$ C).

- Fill the measure with water at room temperature and cover with a piece of plate glass in such a way as to eliminate bubbles and excess water.
- Determine the mass of the water in the measure using the balance.
- Measure the temperature of the water and determine its density from Table-3.6, interpolating if necessary.

- Calculate the volume, V, of the measure by the dividing the mass of the water required to fill the measure by its density. Alternatively, calculate the factor for the measure F (=1/V) by dividing the density of the water by the mass required to fill the measure.

**Table 3.4: Unit Weight Density of Water**

| **Temperature** | | **Density** | |
|---|---|---|---|
| $^0$F | $^0$C | Ib/ft$^3$ | Kg/m$^3$ |
| 60 | 15.6 | 62.366 | 999.01 |
| 65 | 18.3 | 62.366 | 998.54 |
| 70 | 21.1 | 62.301 | 997.97 |
| 73.4 | 23.0 | 62.274 | 997.54 |
| 75 | 23.9 | 62.261 | 997.32 |
| 80 | 26.7 | 62.216 | 996.59 |
| 85 | 29.4 | 62.166 | 995.85 |

### 3.5 Selection of Procedure

Three different procedures are generally followed for the determination of unit weight.

They are:

a) Shoveling procedure

b) Rodding procedure

c) Jiggling procedure;

The shoveling procedure for loose unit weight shall be used only when specifically stipulated. Otherwise, the compact unit weight shall be determined by the Roding procedure for aggregates having a nominal maximum size of 1.5 in (37.5 mm) or lesser, by the jiggling procedure for aggregates having a nominal maximum size greater than 1.5 in. (37.5 mm) and not exceeding 6 in. (150 mm).

### 3.5.1 Shoveling Procedure

1) Overflow the measure by utilizing a shovel or scoop, discharging the aggregate from a height no more than 2 in. (50 mm) above the top of the measure. It is crucial to exercise prudence to forestall, to the greatest extent feasible, the segregation of the particle sizes of which the sample is comprised. Even out the surface of the aggregate with either the fingers or a straightedge in a manner that any minor protrusions of the larger pieces of the coarse aggregate approximately offset the larger voids in the surface below the top of the measure.

2) Determine the mass of the measure plus its contents, and the mass of the measure alone, and record the values to the nearest 0.1 lb. (0.05 kg).

### 3.5.2 Rodding procedure

1) Fill the measure one-third to the brim and equilibrate the exterior with the fingertips. Employ the tamping rod to even out the layer of aggregate with 25 strokes, dispersed uniformly across the exterior. Satisfy the measure two-thirds to the brim and once more equilibrate and even out using the tamping rod, as previously done. Ultimately, satisfy the measure to the point of overflowing and again employ the tamping rod in the manner aforementioned. Equilibrate the exterior of the aggregate with the fingertips or a straightedge in a manner that approximates the slight protrusions of the larger pieces of the coarse aggregate with the larger voids in the exterior below the summit of the measure.

2) In the process of rodding the initial stratum, it is imperative to exercise caution and refrain from forcefully impacting the base of the measurement. In the subsequent two layers of rodding, it is recommended to exert considerable force whilst being mindful not to apply excessive pressure that may result in the tamping rod infiltrating the preceding layer of aggregate.
3) Determine the mass of the measure plus its contents, and the mass of the measure alone, and record the values to the nearest 0.1lb (0.05kg).

### 3.5.3 Jiggling procedure

1) Fill the gauge in three roughly equivalent strata as previously delineated, compressing each stratum by situating the gauge on a sturdy foundation such as a cement concrete floor, elevating the opposite edges reciprocally roughly 2 in. (50 mm), and permitting

the gauge to fall in such a way as to hit with a sharp, smacking impact. The particles of the aggregate, through this process, will align themselves in a densely compacted state. Compress each stratum by dropping the gauge 50 times in the manner depicted, 25 times on each side. Even out the surface of the aggregate with the digits or a straightedge in a manner so that any minor protrusions of the larger fragments of the coarse aggregate roughly equalize the larger cavities in the surface beneath the apex of the gauge.

Determine the mass of the measure plus its contents, and the mass of the measure alone, and record the values to the nearest 0.1 lb. (0.05 kg).

Test results and data will be provided in the result and discussion chapter.

### 3.6 Concrete Mixture Design

For this study, 33 grade Portland composite cement were used. For coarse aggregate, graded angular aggregates Bricks chips of 3/4" downgrade size was used as coarse aggregate. Specific gravity, absorption and unit weight were determined according to ASTM C127, ASTM C29 testing standards respectively. Sylhet sand confirming to ASTM C33 was of angular in nature and. the fine aggregate used here is in the form of Selection sand. The physical properties of both coarse and fine e conformed to requirements specified in Mix proportion was calculated on saturated surface dry (SSD) condition of aggregates. Workability of 130 mm slump Based on coal provisions of IS 456:2000 and IS design mix proportions for M20 grade concrete for different ingredient compositions were calculated. In nominal mix (control mix) M20 grade concrete, graded angular coarse aggregate of nominal size 20 mm (3/4") m zone II Selection sand, 33 grade PCC were used in conventional ratio 1.00 (cement): 2 (sand): 4.0 (CA). For required workability, w/c was maintained as 0.55. A control mix was produced containing only natural aggregate, fine aggregates in proportions of Water Cement Ratio 55%. As the exhibited a higher fineness modulus than the natural aggregate, no adjustments were needed to other mix designs to ensure that strength and workability design parameters remained constant.

### 3.6.1 Estimating Cylinder Materials

Cylinder height, h = 8''

Cylinder dia, D = 4''

Cylinder volume = $\pi/4*D^2*h$

= 3.1416/4*0.33*0.33*0.67

= 0.0573 cft

Nos of cylinder =25

Need volume = 25*0.0573

= 1.432 cft

Dry volume = 1.432*1.50

= 2.148 cft

Ratio = Cement: Fine aggregate: Cross aggregate brick chips

= 1:2:4

Need cement = 2.148/7*1

=0.306 cft

=12.24 kg

Need fine aggregate = 2.148/7*2

=0.613Cft

Cross aggregate brick chips = 2.148/7*4 =1.22 cft

Per cylinder need materials

Need cement =12.24/25 = 540 gm

Fine aggregate = 0.613/25= 1216 gm

Cross aggregate brick chips = 1.22/25= 2442 gm

Water cement ratio = 55%

### 3.7 Experimental Procedure

In this study, all the material tests and concrete preparation was performed in civil engineering lab in Sonargaon University. All preparation of concrete was undertaken according to ACI 318 (ASTM standard). Six specimens were made for each percentage replacement of Concrete Cylinder, where three were used for fourteen and twenty-eight-day compressive strength test, respectively. Mixing of the concrete were carried out manually with safety. As per ASTM C39, Concrete molds used were cylindrical, being 100 mm (4 in.) In diameter and 200 mm (8 in.) In height. To prevent adhesion, all molds were coated with a thin layer of concrete release, which consisted of 93% liquid hydrocarbons in preparing the

final samples, concrete was added to the concrete molds incrementally. Each layer was subjected to manual compaction with a rod according to code, and was ceased once visibly trapped air was eliminated. Concrete was allowed to air-cure for a period of 24 hours, before being removed from the molds and transferred to a water bath set at 23 degrees for the remainder of the curing period.

### 3.8 The Experiment Process




**Fig 3-6: Typical Concrete Materials**



**Fig 3-7: Ordinary (Control Mix) Concrete Mixing with Traditional Materials**

### 3.9 Curing Methods

The concrete specimens were cured using six different techniques until when their compressive strengths were determined at ages 7, 14, 21 and 28 days. The curing techniques that were applied are: 1. Water submerged curing (WSC): This involved the submersion of the concrete cube specimens in water. 2. Spray curing (SC): This involved the spraying of water on the concrete cube specimens twice daily. 3. Polythene curing (PC): The specimens were covered with at least two layers of polythene membrane to prevent moisture movement from the concrete specimens. 4. Jut wet curing (JC): This involved covering the concrete cube specimen's underneath burlap which was kept wet periodically. 5. Moist sand curing (MSC): This involved burying the entire concrete cube specimens in wet sand which was kept moist by wetting with water on a daily basis. 6. Air curing (AC): This served as the control. It involved no form of active curing by just exposing the specimens to ambient air in the laboratory. All the curing methods, except that of moist sand were carried out in the laboratory under the same environmental conditions of 27°C temperature and 75% relative humidity. Moist sand curing was done outside the laboratory and exposed to varying environmental condition.

### 3.10 Preliminary Tests

The grading of fine and coarse aggregates was determined in accordance with procedure in BS 1377 (1990), Part 2:9.2. The specific gravity and moisture content of the fine aggregates were also determined according to procedure in B.S. 1377 (1990).

# CHAPTER 4

# Results and Discussion

## 4.1 Introduction

Completely the test results and graphs will be provided here and some discussions will be provided where it is needed. Various material tests have been done in this test; all the data will be described in table format. 7 days & 28-day compressive strength test result of different day and their comparison will also be provided.

## 4.2 Fine Modulus (FM) Test

### 4.2.1 FM of Fine Aggregate (Selection Sand)

The Sylhet sand was collected from the local market of Farmgate. After bringing the sand to the laboratory we tested its fineness modulus test, and the data is given below.

**Table 4.1: Fineness Modulus of Sand Used**

| Sieve No. | Wt. Retain (gm) | % Retain | Cumulative % Retain | FM |
|---|---|---|---|---|
| #4 | 15 | 1.5 | 1.5 | 263.44/100= 2.63 |
| #8 | 48 | 4.8 | 6.3 | |
| #16 | 172 | 17.2 | 23.5 | |
| #30 | 213 | 21.3 | 44.8 | |
| #50 | 437 | 43.7 | 88.5 | |
| #100 | 103 | 10.3 | 98.8 | |
| Pan | 12 | | | |
| **Total** | **1000** | | **263.44** | |

FM of sand has found to be 2.63, which is allowable by the ACI code.

### 4.2.2 FM of the Coarse Aggregate

The Sylhet coarse aggregate was collected from the local market of farmgate. After bringing the sand to the laboratory we tested its fineness modulus test, and the data is given below:

**Table 4.2: FM of coarse aggregate**

| Sieve No. | Wt. Retain (gm) | % Retain | Cumulative % Retain | FM |
|---|---|---|---|---|
| 3/4” | 508 | 50.8 | 50.8 | 750.3/100 = 7.50 |
| 3/8” | 487 | 48.7 | 99.5 | |
| #4 | 5 | 0.5 | 100 | |
| #8 | 0 | 0 | 100 | |
| #16 | 0 | 0 | 100 | |
| #30 | 0 | 0 | 100 | |
| #50 | 0 | 0 | 100 | |
| #100 | 0 | 0 | 100 | |
| Pan | 0 | 0 | 0 | |
| Total | 1000 | 100 | 750.3 | |

Allowable FM value for coarse aggregate is 6.75 to 8.00. So, the value 7.50 is within the allowable limit for FM of coarse aggregate.

### 4.3 Specific Gravity and Absorption Capacity

#### 4.3.1 Specific Gravity and Absorption Capacity of Coarse Aggregates

**Table 4.3: Specific Gravity and Absorption Capacity of Coarse Aggregates**

**DATA SHEET**

| Wt. of S.S.D Sample in Air, B (gm) | Wt. of S.S.D sample in Water, C (gm) | Oven Dry Wt. Of sample in Air, A (gm) |
|---|---|---|
| 2000 | 1190 | 1930 |

| Tests | Formula | Calculation | Results |
|---|---|---|---|
| Apparent Specific Gravity | A/A-C | 1930/1930-1190 | 2.60 |
| Bulk Specific Gravity (Oven Dry Basis) | A/B-C | 1930/2000-1190 | 2.38 |
| Absorption Capacity, D% | B-A/A X 100 | 2000-1930/1930 X 100 | 3.62 |
| Bulk Specific Gravity (S.S.D Basis) | B/B-C | 2000/2000-1190 | 2.46 |

#### 4.3.2 Specific Gravity and Absorption Capacity of Fine Aggregates

**Table 4.4: Specific Gravity and Absorption Capacity of Fine Aggregates**

**DATA SHEET**

| Wt. of pycnometer filled with water to calibration mark, B (gm) | Oven Dry Wt. in Air, A (gm) | Wt. of pycnometer with specimen and water to Calibration mark, C (gm) | Wt. of S.S.D. sample in Air, S (gm) |
|---|---|---|---|
| 653 | 284 | 831 | 300 |

**Table 4.5: Specific Gravity and Absorption Capacity of Fine Aggregates**

**DATA SHEET**

| Tests | Formula | Calculation | Results |
|---|---|---|---|
| Apparent Specific Gravity | A/B+A-C | 284/653+284-831 | 2.67 |
| Bulk Specific Gravity (Oven Dry Basis) | A/B+S-C | 284/653+300-831 | 2.32 |
| Absorption Capacity, D% | S-A/A X 100 | 300-284/284 X 100 | 5.63 |
| Bulk Specific Gravity (S.S.D Basis) | S/B+S-C | 300/653+300-831 | 2.45 |

### 4.4 Unit Weight of Aggregates

### 4.4.1 Unit Weight of Fine Aggregates

**Table 4.6: Unit Weight of Fine Aggregates**

| Unit Weight – Sand | | | | | |
|---|---|---|---|---|---|
| A. Shoveling-7395 (Bucket + Material) | | | | | |
| B. Rodding- 7723 (Bucket + Material) | | | | | |
| C. Jiggling- 8113 (Bucket + Material) | | | | | |
| Volume Of Bucket = 0.00278 $m^3$ | | | | | |
| **Condition** | **Wt. of Bucket (gm)** | **Wt. of Bucket Material (gm)** | **Wt. of Material (gm)** | **Volume of Bucket $m^3$** | **Unit Weight $gm/m^3$** |
| Shoveling | 4000 | 7395 | 3395 | 0.00278 | 1221 |
| Rodding | 4000 | 7723 | 3723 | 0.00278 | 1339 |
| Jiggling | 4000 | 8113 | 4113 | 0.00278 | 1479 |
| **Average Unit Weight = 1346 $gm/m^3$** | | | | | |

### 4.4.2 Unit Weight of Coarse Aggregates

**Table 4.7: Unit Weight of Coarse Aggregate**

**DATA SHEET**

| **Unit Weight – Stone** | | | | | |
|---|---|---|---|---|---|
| A. Shoveling-7992 (Bucket + Material) | | | | | |
| B. Rodding- 8570 (Bucket + Material) | | | | | |
| C. Jiggling- 8713 (Bucket + Material) | | | | | |
| Volume Of Bucket = 0.00278 m3 | | | | | |
| **Condition** | **Wt. of Bucket (gm)** | **Wt. of Bucket Material (gm)** | **Wt. of Material (gm)** | **Volume of Bucket $m^3$** | **Unit Weight $gm/m^3$** |
| Shoveling | 4000 | 7922 | 3922 | 0.00278 | 1410 |
| Rodding | 4000 | 8570 | 4570 | 0.00278 | 1643 |
| Jiggling | 4000 | 8713 | 4513 | 0.00278 | 1695 |
| **Average Unit Weight = 1582 $gm/m^3$** | | | | | |

### 4.5 Cylinder Test Results Crushing Value/Compressive strength

**Table 4.8 Cylinder Test Results Crushing Value/Compressive strength**

| Curing Method | Curing Days | Dia of Cylinder (mm) | Height of Cylinder (mm) | Weight of Cylinder (kg) | Crushing Value (kn) | Area $(mm)^2$ | Compressive Strength (L/A) $(N/mm^{2)}$ |
|---|---|---|---|---|---|---|---|
| Air- Curing | 7 | 100 | 203 | 3.252 | 61 | 7853.98 | 7.76 |
| | 14 | 100 | 202 | 2.925 | 73 | 7853.98 | 9.29 |
| | 21 | 100 | 201 | 3.166 | 92 | 7853.98 | 11.71 |
| | 28 | 100 | 201 | 2.991 | 80 | 7853.98 | 13.18 |
| Water submerged curing | 7 | 100 | 200 | 3.386 | 75 | 7853.98 | 9.54 |
| | 14 | 100 | 203 | 3.554 | 113 | 7853.98 | 14.38 |
| | 21 | 100 | 202 | 3.387 | 132 | 7853.98 | 16.80 |
| | 28 | 100 | 200 | 3.429 | 152 | 7853.98 | 19.35 |
| Moist. sand curing | 7 | 100 | 202 | 3.382 | 65 | 7853.98 | 8.27 |
| | 14 | 100 | 201 | 3.513 | 101 | 7853.98 | 12.85 |
| | 21 | 100 | 200 | 3.504 | 119 | 7853.98 | 15.15 |
| | 28 | 100 | 200 | 3.453 | 134 | 7853.98 | 17.06 |

It is observed from the test results that the Water Submerged curing method of curing gave better.

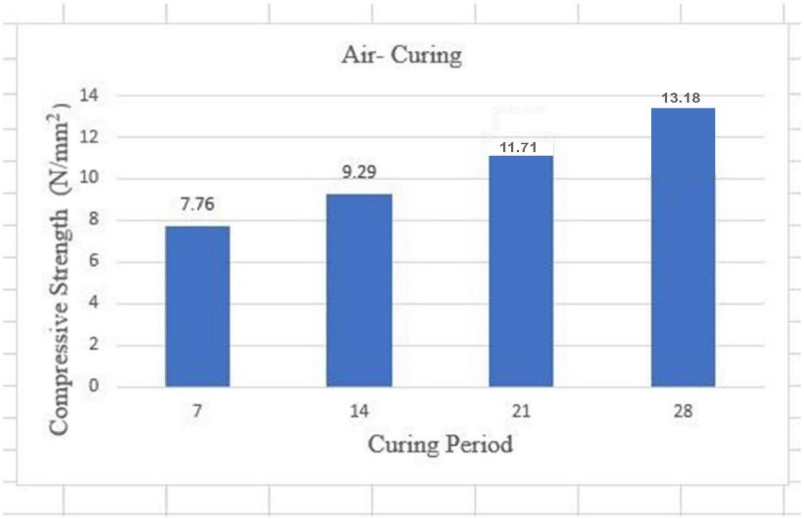



**Figure 3-8: Effect of Air-Curing on the Compressive Strength of Concrete**

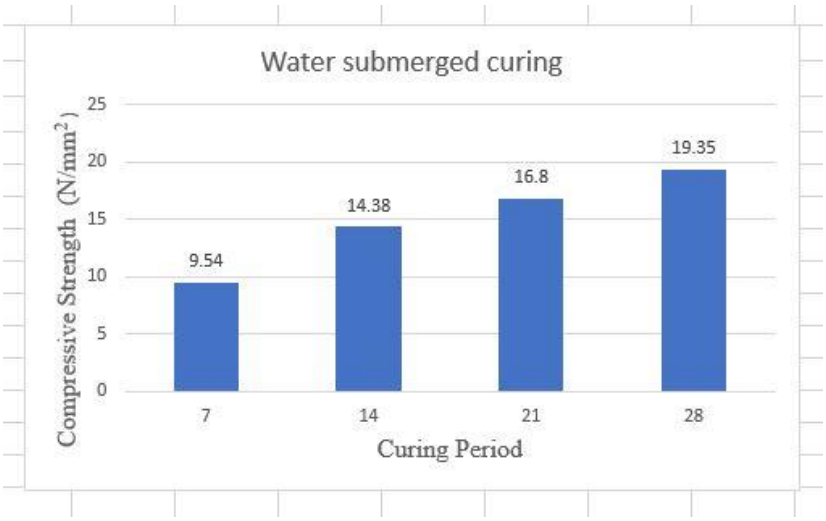



**Figure 3-9: Effect of Water-Submerged Curing on the Compressive Strength of Concrete**

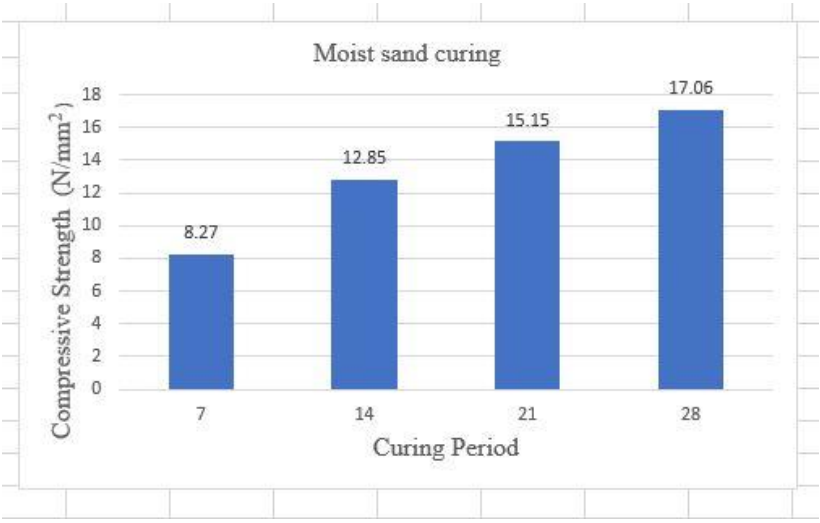



**Figure 4-1: Effect of Moist Sand Curing on the Compressive Strength of Concrete**

### 4.6 Compressive Strength of Concrete Specimens

Showed the compressive strength of air-cured concrete specimens. The air cured specimens showed a compressive strength of 7.76 N/mm$^2$, 9.29 N/mm$^2$, 11.71 N/mm$^2$ and 10.18 N/mm$^2$ after 7, 14, 21 and 28 days of curing. This is similar to the results obtained in which the specimens were exposed to outside environmental conditions and 15% reduction in strength was recorded between the 7 and 28-day strength. The reduction in strength recorded between the 21st and 28th day of curing can be attributed to the total consumption of all the mix water in the concrete specimen which halted the cement hydration process. In figure 4.1.

The compressive strength of concrete specimens cured by submersion in water is presented. It could be observed from the figure that an average compressive strength of 9.54 N/mm$^2$, 14.38 N/mm$^2$, 16.80 N/mm$^2$, and 19.35 N/mm$^2$ were recorded after 7, 14, 21 and 28 days of curing respectively. Effect of water-submerged curing on the compressive strength of concrete the strength of the specimens continually increased during the 28 days of curing as water, which allows continuous cement hydration was present in abundance thereby ensuring 100% relative humidity. In figure 4.2.

The compressive strength of concrete specimens cured using the moist sand method is presented. The compressive strength recorded are 8.27 N/mm$^2$, 12.85 N/mm$^2$, 15.15 N/mm$^2$, and 17.06 N/mm$^2$ at 7, 14, 21 and 28 days respectively. Effect of moist sand curing on the compressive strength of concrete. This method was the only one executed outside the laboratory and was prone to varying environmental conditions. The high compressive strength recorded at the 28th day can be attributed to the suitable weather condition (average

daily ambient temperature of 32° C which was higher than that of the laboratory of 27° C) witnessed throughout the curing period. However, the concrete cube specimens cured by this method had their entire surface marred by the color of the sand grains. The discoloration of the concrete surface makes the method unsuitable for pre-cast concrete members which usually do not require any finishing. In figure 4.3.

All the methods of curing, except air curing (the control) produced concrete specimens that met the minimum compressive strength of 10.18 N/mm2 at 28 days specified by National Building Code (2020). Air curing with compressive strength of 10.18 $N/mm^2$ has the lowest strength while Water Submerged curing recorded the highest strength of 19.35 $N/mm^2$.

### 4.7 Summary

The material tests that are conducted were sieve analysis, specific gravity, and unit weight and absorption capacity. All the test result was conforming to the ACI and BNBC (2020) codes. In 7 days, compressive test only 12% replacement got more strength than the original mix. But in 28 days' test 24% replacement got the highest strength, 2.5% more strength than the Cylinder Concrete mix.

# CHAPTER 5

# Conclusions and Future Works

## 5.1 Conclusions

The following conclusions are drawn based on the results obtained from the various tests and discussion of findings:

1. Based on the density, the specimens fall into the category of normal weight concrete.
2. Water submerged curing method produced specimens with the highest compressive strength while Air curing produced the lowest.
3. All the methods of curing considered, except air curing (the control) produced concrete specimens that met the minimum compressive strength specified by the available code.

## 5.2 Limitations and Recommendations for Future Works

### 5.2.1 Limitations

- Only compressive strength of the concrete is determined in this study.
- Only 7, 14, 21, days & 28 days' compressive strength test has been committed.

### 5.2.2 Recommendations

- Durability and tensile strength test can be done to observe how effective this concrete is for structural use.
- 7 days compressive strength test can be done to determine the early strength.
- 60 days and other long period compressive test can be done to see the behavior of concrete.

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