A STUDY ON THE COMPRESSIVE STRENGTH OF CONCRETE USING WASTE GLASS AS PARTIAL REPLACEMENT OF FINE AGGREGATE

By

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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

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Section: 19D

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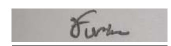
Md. Furkan Hasan	BCE2001019256	
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Dedicated

to

"Our Beloved Parents"

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ABSTRACT

Waste management is becoming one of the major concerns of the 21st century. As a nonbiodegradable solid waste, glass cannot be considered for landfill. So, recycling opportunities must be explored. On the other hand, the concrete industry is using finite natural resources and also harming the environment. Therefore, making concrete production more sustainable and recycling solid waste, using waste glass as a partial replacement for fine aggregates holds considerable appeal. This study sought to ascertain the degree of glass substitution that would yield the highest achievable compressive strength. Three concrete samples were tested at 14 days and 28 days, wherein the ratios of glass replacement were measured at 15, 20, and 25%. Compressive strength was increased by up to 20%, at which point the strength developed was 1.5% and 2.5% higher than the control after 14 and 28 days respectively. The findings indicate that the incorporation of fine glass aggregate in concrete up to a proportion of 20% leads to an increased development of compressive strength as compared to conventional concrete.

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CHAPTER 1

Introduction

1.1 General

One of the most threatening environmental problems the world is facing in the present day is waste management. And the production of waste is sky-rocketing as the population level grows high. One of these waste materials is glass, which happens to be bio-degradable. Therefore, it is often landfilled.

The global production of glass is more than 130 million metric tons per year and only 21% (27 million metric tons) are being recycled [1]. In Bangladesh, 1500 tons of glass waste are produced every day which results in about 0.55 million metric tons per year. And 60% of the waste glass are being recycled which is way higher than the global average [2]. But the percentage can be increased higher worldwide by using recycled glass as an aggregate in concrete as there is always a huge demand for concrete as a construction material.

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. Waste glass usage in concrete can create an opportunity to reduce the 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 [3,4]. Using recycled waste glass can help to reduce the demand of natural sand in concrete production, it can save on the cost of materials & it can also increase the strength of concrete.

Solid waste management is the one of the great challenges nowadays, especially over-populated countries like Bangladesh. Recycling waste glass by using them in concrete can decrease solid waste problem to some extent as all type of glass can be used in concrete without any bad effect.

Overall, using glass as a fine aggregate replacement can be a sustainable way to reduce the environmental impact of concrete production and help to combat climate change.

1.3 Research Objectives and Overview

1.3.1 Objectives

The study was, therefore, conducted to determine following objectives:

- To determine the optimum amount of waste glass that can be used as a fine aggregate replacement in concrete without compromising the compressive strength of concrete.
- To make the concrete more environmentally better and sustainable.
- To decrease the use of natural resources like sand on concrete mix.

1.3.2 Overview

In this study, we will prepare normal concrete mix and also a series of concrete mixtures with different proportions (15%, 20%, 25%) of waste glass as a partial replacement for fine aggregate. The concrete will be casted in cylinder and will be cured for 14 days and 28 days respectively and then will be tested for their compressive strength. We will 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.

There is also some scopes and limitations in the study that can be examined in the future works:

- Durability test of the concrete were not performed.
- The tensile strength of the concrete was not considered.
- Only 14 days and 28 days compressive strength of the concrete were considered.

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.

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 waste glass as a partial replacement for fine aggregate

Chapter 5: Conclusions and Recommendations 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

Various studies have been done earlier to determine the effects of incorporating waste glass into concrete focused on its sustainability as a replacement for both fine aggregate, and coarse aggregate.

The results of using waste glass as coarse aggregate replacement demonstrated that the larger particle size of glass caused excessive expansion and cracking of the concrete specimens, resulting in compromised compressive strength and structural integrity [5].

Whereas the results of the studies that has used waste glass as fine aggregate is hopeful as it shows more promising result in compressive strength of the concrete. But the compressive strength increases up to a certain level of replacement, and that level varies in different studies that has been conducted earlier. We are going to analyze these works to find out the research process, the result, various factor affecting the result, and the scope for more studies on this topic.

2.2 Literature Review

Matthew Adaway and Ying Wang (2015)

A study conducted by Matthew Adaway and Ying Wang in 2015 [6], investigates the effects of replacing fine aggregate with recycled glass powder on the compressive strength of structural concrete. The authors conducted an experimental study in which they prepared a series of concrete mixtures with different proportions in 15%, 20%, 25%, 30%, and 40% of recycled glass powder as fine aggregate replacement. The concrete mixtures were cured for a specified period of time and then tested for their compressive strength at 7 days and 28 days. The results of the study showed that the compressive strength of concrete increased by up to 30% when 30% of the fine aggregate was replaced with recycled glass powder which is 6% higher than the control mix after 28 days. However, the compressive strength of concrete decreased when more than 30% of the fine aggregate was replaced with recycled glass powder. They used a water-cement ratio of 0.42. The fineness modulus of fine aggregate was 2.61 and fineness modulus of glass were 2.11.

This study is very well written and easy to understand. The authors conduct a well-designed experimental study that provides valuable insights into the effects of recycled glass on the compressive strength of concrete. The paper is provide a clear and concise overview of the research on the use of recycled glass in concrete.

Like every other study, this study also has some limitations and scopes. The paper only considers the effects of recycled glass on the compressive strength of concrete. It would be interesting to see if recycled glass also has any effects on other properties of concrete, such as its durability. The paper only considers the use of recycled glass powder. It would be interesting to see if the results would be different if other forms of recycled glass, such as crushed glass, were used.

Sudhanshu Kumar and Bharat Nagar (2018)

In another study, conducted by Sudhanshu Kumar and Bharat Nagar in 2018 [7], inquired into the utilization of waste glass powder as a partial replacement of fine aggregate to get the optimum compressive strength. They used M20 nominal mix of concrete with different percentage of glass powder waste. The replacement percentage were 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, and 50%. They used a mix ratio of 1 (cement): 1.5 (Sand): 3 (Coarse Aggregate) for concrete mix with the cement-water ratio of 0.45. The fineness modulus of the sand used were 2.34 and the fineness modulus of the waste glass used were 2.15. They use super plasticizer admixture 2% of weight of cement.

After 28 days compression test, the compressive strength of the other samples were higher than the control mix with 0% replacement till 35% waste glass powder replacement for fine aggregates. But the optimum strength were found in 25% waste glass replacement sample, which is 11.5% higher than the control mix with 0% replacement.

In this study the authors tested a long range of sample mix combination. So it provides a broad insight of the effects of different amount of waste glass replacement on concretes compressive test. This paper tried provide a complete overview of the effects of using different combination of waste glass powder as replacement of fine aggregates in concrete.

This paper also tested the compressive strength of concrete. Durability, Tensile strength test can be done to get more idea about the usability of the concrete in practical work.

M. Iqbal Malik, Muzafar Bashir, Sajad Ahmad, Tabish Tariq, and Umar Chowdhary (2013) [8]

In this study, authors addressed the environmental and economic concerns of the concrete industry by using waste glass as a partial replacement of fine aggregates in concrete. Conducting experiments to test the compressive strength, splitting tensile strength, durability (water absorption), and density of concrete specimens with varying percentages of waste glass powder as a replacement for fine aggregates. Concluding that waste glass powder can be used as a partial replacement of fine aggregates up to 30% by weight for particle size of range 0-1.18mm, which can help reduce the disposal problems of waste glass and enhance the properties of concrete.

They used Khyber ordinary Portland cement of 43 grade, clean river sand maximum size of 4.75mm, coarse aggregates consisting of machine crushed stone angular in shape passing through 20mm IS sieve and retained on 4.75mm IS sieve. The specific gravity of sand found to be 2.6 and for coarse aggregate it was 2.7. In this study, varying percentages of 10%, 20%, 30%, and 40% glass powder by weight were employed to partially replace fine aggregates in M-25 mix concrete.

The implementation of a 20% substitution of fine aggregates with waste glass resulted in a notable enhancement of 15% in compressive strength within a 7-day period and a significant amplification of 25% in compressive strength within a 28-day duration. The incorporation of waste glass as a substitute for fine aggregates can be performed up to a maximum threshold of 30% of the weight of the mixture. This substitution yields a notable augment of 9.8% in compressive strength after 28 days of curing. Furthermore, as the proportion of waste glass enhances, the degree of water absorption diminishes proportionally. Moreover, as the waste glass content rises in the mixture, the average weight of the resulting concrete structure decreases by 5%. This reduction in weight is most prominently observed in the mixture containing 40% waste glass, thus effectively rendering it a lightweight concrete.

As for limitations, this study also focused on a particular concrete mix design (M-25) and the results could be different for other mix designs. The study only considered waste glass particles of a specific size range (0-1.18mm), it will be interesting to see how the concrete behaves when different size of glass particles are used. The study did not consider the effect of waste glass on other properties of concrete, such as shrinkage, creep, and modulus of elasticity.

2.3 Summary

There is a healthy amount of study that has been done on using glass as replacement of the fine aggregate in concrete. The studies focused on various factors especially on compressive and tensile strength. Different mix designs were adopted in different studies. Fineness modulus of fine aggregates ranged from 2.35 to 2.7 in these tests. And in all those tests glass powder were used which has maximum fineness modulus of 2.15. Most cases compressive strength of concrete with waste glass replacement of up to 25% to 30% has had higher compressive strength than the ordinary concrete mix.

But it will be very interesting to see how the concrete behaves if the fineness modulus of fine aggregate sand is higher than 2.6 as most of sand used in local construction works has higher fineness modulus than 2.6. Glass powder may help the concrete more strength but making huge production of glass powder can appear to be costly. So it will be very insightful to see how much change happens in the concrete strength if crushed glass is used, which is less costly to prepare.

CHAPTER 3

Methodology

3.1 Introduction

The concrete composition in this test satisfy 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.

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 1870s, 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 Aggregate

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 and
- Fine Aggregates.

3.2.2.1 Coarse Aggregate

As per the ASTM Standards, any material that is held back by a No.4 sieve (4.75mm) is categorized as coarse aggregate. Nonetheless, in construction practices, the maximum allowable size of coarse aggregate is restricted to 19mm. 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

3.2.2.2 Fine Aggregate

According to ASTM Standards, fine aggregate is defined as material that passes through a No.4 sieve (4.75mm). 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 0.07mm. 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)

3.2.3 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. Given that 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.

3.2.4 Glass

Glass, an inorganic solid material known for its transparency or translucency, hardness, brittleness, and resistance to the elements, has been utilized for both practical and ornamental purposes since ancient times, and continues to play a crucial role in various fields, ranging from construction and housewares to telecommunications. The manufacturing process of this versatile material involves the rapid cooling of melted components, including silica sand, to prevent the emergence of visible crystals [10].

Commercial glasses can be categorized into two types, namely soda–lime–silica glasses and special glasses. The majority of the produced tonnage is of the former category. Three primary materials are utilized in the production of these glasses, namely sand (silicon dioxide, or SiO2), limestone (calcium carbonate, or CaCO3), and sodium carbonate (Na2CO3). Although fused silica is an exceptional glass, the melting point of sand (crystalline silica) is above 1,700 °C (3,092 °F), and the attainment of such high temperatures is quite expensive. Therefore, its usage is confined to applications where its superior properties, such as chemical inertness and the ability to withstand sudden changes of temperature, are crucial and the cost is justified. Nevertheless, the production of fused silica glass is a significant industry. It is manufactured in various grades, and when it is meant for optical purposes, rock crystal is used as the raw material instead of quartz sand [10].

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.

3.3.2 FM (Fineness Modulus) Test

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.

3.3.2.1 FM of Sand

Table 3.1: Fineness Modulus of Sand Used

Sieve No.	Wt. Retain (gm)	% Retain	Cumulative % Retain	FM
#4	0	0	0	286.6/100 = 2.87
#8	40	4	4	
#16	252	25.2	29.2	
#30	334	33.4	62.6	
#50	291	29.1	91.7	
#100	74	7.4	99.1	
pan	9			
total	1000		286.6	

3.3.2.2 FM of Waste Glass

The Waste glass were bought and crushed from local market and bought to laboratory and Fineness modulus test was conducted right after. The FM data of crushed waste glass given below.

Table 3.2: Fineness Modulus of Crushed Waste Glass Used

Sieve No.	Wt. Retain (gm)	% Retain	Cumulative % Retain	FM
#4	0	0	0	337.6/100 = 3.38
#8	87	8.7	8.7	
#16	530	53	61.7	
#30	163	16.3	78	
#50	137	13.7	91.7	
#100	58	5.8	97.5	
pan	25			
total	1000		337.6	

3.3.3 Specific Gravity and Absorption Capacity of Aggregates

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 23/230C (73.4/72.40F), 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.

3.3.3.1 Apparatus

- **Balance**- sensitive to 0.1gm or less.
- **Pycnometer**- A flask or other suitable container of 1000ml 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 ± 15gm and having a flat circular tamping face 25 ± 30 mm diameter.

3.3.3.2 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 ± 1.70C (73.4 ± 30F). 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 ± 50C (230 ± 90F), 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 ± 1.70C (73.4 ± 30F)

3.3.3.3 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)x100/A

Where,

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.

3.3.4 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.

3.3.4.1 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-2. The interior wall of the measure shall be smooth and continuous surface.

Table 3.3: Capacity of Measures

Nominal Maximum size of Aggregate		Capacity of Measure	
inch	Mm	ft3	liter (m3)
0.5	12.5	1/10	2.8 (0.0028)
1.0	25.0	1/3	9.3 (0.0093)
1.5	37.5	½	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 3.4: 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 ft2	0.20 in	0.10 in.	0.10 in.
0.4 ft3 to 1.5 ft3, in.	0.20 in	0.20 in	0.12 in
Over 1.5 to 2.8 ft3 , in.	0.20 in	0.25 in.	0.15 in.
Over 2.8 to 4.0 ft3 , in.	0.40 in.	0.30 in	0.20 in.
Less than 11 liter	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.

3.3.4.2 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 ± 90F (110 ± 50C).

3.3.4.3 Calibration of Measure

- 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-3.5, 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 3.5: Unit Weight or Density of Water

Temperature		Density	
0F	0C	lb/ft3	Kg/m3
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

3.3.4.4 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).

3.3.4.5 Shoveling procedure

I. 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.

II. 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. (0.05kg).

3.3.4.6 Rodding procedure

i. 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.

ii. 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.

iii. 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).

3.3.4.7 Jiggling Procedure

i. 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 (0.05kg).

Test results and data will be provided in the Result and Discussion chapter.

3.3.5 Concrete Mixture Design

For this study, 33 grade Portland Composite Cement were used. For coarse aggregate, graded angular aggregates stone 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. And Sylhet sand confirming to ASTM C33 was of angular in nature and. the fine aggregate used here is in the form of river 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 codal 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 20mm (3/4") m zone II river sand, 33 grade PCC were used in conventional ratio 1.00 (cement) : 1.5 (sand) : 3.0 (CA). For required workability, w/c was maintained as 0.45. A control mix was produced containing only natural aggregate, with three resulting mixes incorporating waste glass as a partial replacement for fine aggregates in proportions of 15, 20, and 25 %. As the crushed glass 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. A summary of the individual mix designs is presented below in Table 3.

Table 3.6: Concrete mix design summery

	Glass replacement percentage			
	0%	**15%**	**20%**	**25%**
Water (gm)	285	285	285	285
Cement (gm)	632	632	632	632
Coarse Aggregate (gm)	1896	1896	1896	1896
Natural Fine Aggregate (gm)	948	806	758	711
Waste Glass Fine Aggregate (gm)	0	142	190	237

Fig 3.4: Typical Concrete Materials

Fig 3.5: Ordinary (Control Mix) Concrete Mixing with Traditional Materials

Fig 3.6: Concrete With Waste Glass As Partial Sand Replacement Mixing.

3.3.6 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 glass, 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 150 mm (6 in.) in diameter and 300 mm (12in.) 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.

Fig 3.7: Concrete specimen casting in Cylinder

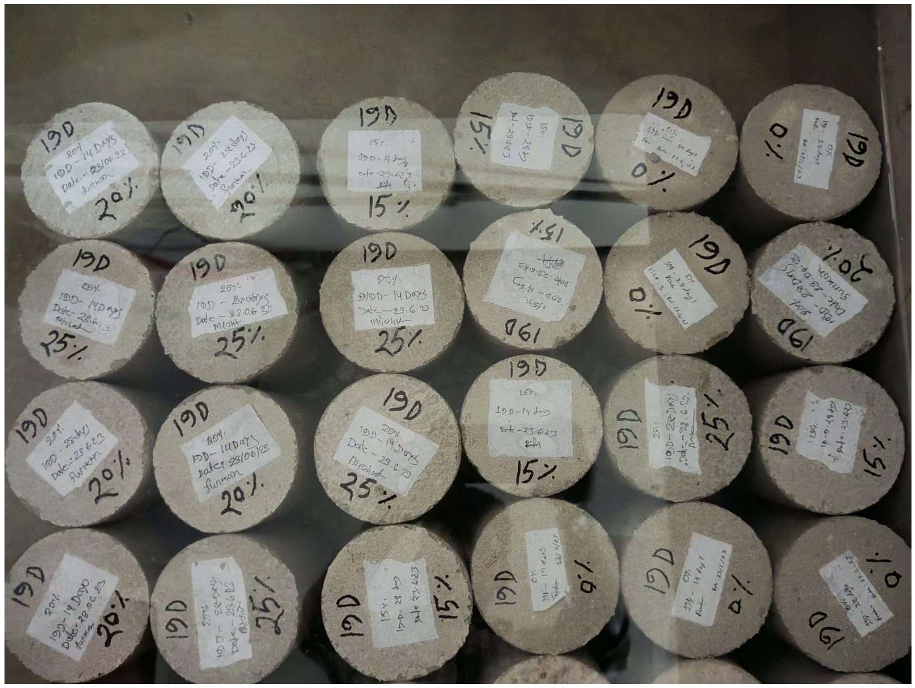

Fig 3.8: Specimen curing in water

Tests to determine the compressive strength of the concrete were carried out after both fourteen and twenty eight days. Universal Testing Machine (UTM) was used to determine the compressive strength. Once being removed from the water bath, the concrete cylinders were allowed to surface dry before their weight was measured. The samples were then placed within two steel caps, fit-ted with 15mm thick rubber mats. The rubber mats allowed for a tolerance of 4mm in level across the surface of the cylinder. The individual samples were then centered within the testing frame, with the troweled surface facing the top plate to further ensure that any differences in level did not affect test results.

To asses compressive strength of the samples, the load was gradually added to the specimens, at a rate of 20 MPa/min. Once the software detected that the load acting on the sample had decreased, the addition of load was automatically ceased and the test completed.

Fig 3.9: Measuring specimen before testing for compressive strength

Fig 3.10: Measuring the weight of specimen for unit weight calculation

Fig 3.11: Pictures of specimen testing of compressive strength using UTM

CHAPTER 4

Results and Discussion

4.1 Introduction

All 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. 14 day & 28 day compressive strength test result of different concrete mix and their comparison will also be provided.

4.2 Fineness Modulus (FM) Test

4.2.1 FM of Fine Aggregate (sand)

Table 4.1: FM of fine aggregate (sand)

Sieve No.	Wt. Retain (gm)	% Retain	Cumulative % Retain	FM
#4	0	0	0	286.6/100 = 2.87
#8	40	4	4	
#16	252	25.2	29.2	
#30	334	33.4	62.6	
#50	291	29.1	91.7	
#100	74	7.4	99.1	
pan	9			
total	1000		286.6	

4.2.2 FM of Fine Aggregate (Glass)

Table 4.2: FM of waste glass

Sieve No.	Wt. Retain (gm)	% Retain	Cumulative % Retain	FM
#4	0	0	0	337.6/100 = 3.38
#8	87	8.7	8.7	
#16	530	53	61.7	
#30	163	16.3	78	
#50	137	13.7	91.7	
#100	58	5.8	97.5	
pan	25			
total	1000		337.6	

4.2.3 FM of Coarse Aggregate

Table 4.3: FM of coarse aggregate

Sieve No.	Wt. Retain (gm)	% Retain	Cumulative % Retain	FM
¾"	426	28.4	28.4	726.2/100 = 7.26
3/8"	1056	70.4	98.8	
#4	17	1.13	99.9	
#8	0	0	99.9	
#16	0	0	99.9	
#30	0	0	99.9	
#50	0	0	99.9	
#100	0	0	99.9	
pan	0	0		
total	1000		726.2	

Allowable FM value for coarse aggregate is 6.75 to 8.00. So the value 7.26 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 Aggregate

DATA SHEET

Table 4.4: Specific Gravity and Absorption Capacity of Coarse Aggregates

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)
2040	1310	2000

Tests	Formula	Calculation	Results
Bulk specific Gravity (Oven dry Basis)	A / (B-C)	2000/(2040-1310)	2.7
Apparent Specific Gravity	A / (A-C)	2000/(2000-1310)	2.9
Bulk specific Gravity (S.S.D. Basis)	B / (B-C)	2040/(2040-1310)	2.8
Absorption capacity, D%	(B-A/A)*100	(2040-2000/2000)*100	2%

4.3.2 Specific Gravity and Absorption Capacity of Fine Aggregate

DATA SHEET

Table 4.5: Specific Gravity and Absorption Capacity of Fine Aggregates

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	290	834	300

Tests	**Formula**	**Calculation**	**Results**
Apparent Specific Gravity	A / (B+A-C)	290 / (653+290-834)`	2.7
Bulk specific Gravity (Oven dry Basis)	A / B + S -C	290/ 653+300-834	2.5
Bulk specific Gravity (S.S.D. Basis)	S / B+S-C	300 / 653+300-834	2.5
Absorption capacity, D%	(S-A/A)*100	(300-290/290)*100	3.4%

4.4 Unit Weight of Aggregates

4.4.1 Unit Weight of Fine Aggregates

Bucket Weight = 4000 gm

Bucket Dia = 6 in.

Bucket Height = 6 in.

Volume of Measure = $(3.1416/4)*0.5^2*0.5$

$= 0.1\ ft^3$

$= 0.002832\ m^3$

Temping Rod Dia = 16mm

Temping Rod Height = 240mm

Temping Rod Weight = 100gm

(a) Shoveling Procedure:

Bucket Weight = 4000 gm or 4 Kg

Bucket + Aggregate Weight = 8261 gm or 8.26 Kg

So Aggregate Weight = 8261 - 4000 = 4261 gm. Or 4.26 Kg

Unit Weight = 8.26-4/0.002832

= **1505 kg/m^3**

(b) Rodding Procedure:

Bucket Weight = 4000 gm or 4 Kg

Bucket + Aggregate Weight = 8669 gm or 8.67 Kg

So Aggregate Weight = 8669 - 4000 = 4669 gm. Or 4.67 Kg

Unit Weight = 8.67-4/0.002832

= **1649 kg/m^3**

(c) Jiggling Procedure:

Bucket Weight = 4000 gm or 4 Kg

Bucket + Aggregate Weight = 8816 gm or 8.82 Kg

So Aggregate Weight = 8816 - 4000 = 4669 gm. Or 4.82 Kg

Unit Weight = 8.82-4/0.002832

= **1700 kg/m^3**

DATA SHEET

Table 4.6: Unit Weight of Fine (sand) Aggregate

Type of Test	Type of Aggregate	Wt. of Bucket (kg)	Wt. of Bucket+Material (kg)	Wt. to Material (kg)	Volume Of Bucket V (m^3)	Unit Weight, M (kg/m^3)
Shoveling Procedure	Fine (sand)	4	8.26	4.26	0.002832	1505
Rodding Procedure	Fine (sand)	4	8.67	4.67	0.002832	1649
Jiggling Procedure	Fine (sand)	4	8.82	4.82	0.002832	1700

Unit wt. of Aggregate, M (kg/m^3)	Bulk Sp.Gr., S (O-D basis)	Density of water W (kg/m^3)	% Void = [(s*w)-M/s*w]*100
1505	2.5	998	39.6
1649	2.5	998	33.9
1700	2.5	998	31.8

4.4.2 Unit Weight of Coarse Aggregates

Bucket Weight = 4000 gm

Bucket Dia. = 6 in.

Bucket Height = 6 in.

Volume of Measure = $(3.1416/4)*0.5^2*0.5$

$= 0.1\ ft^3$

$= 0.002832\ m^3$

Temping Rod Dia = 16mm

Temping Rod Height = 240mm

Temping Rod Weight = 100gm

(d) Shoveling Procedure:

Bucket Weight = 4000 gm or 4 Kg

Bucket + Aggregate Weight = 8033 gm or 8.03 Kg

So Aggregate Weight = 8033 - 4000 = 4033 gm. Or 4.03 Kg

Unit Weight = 8.03-4/0.002832

= **1424 kg/m³**

(e) Rodding Procedure:

Bucket Weight = 4000 gm or 4 Kg

Bucket + Aggregate Weight = 8348 gm or 8.35 Kg

So Aggregate Weight = 8348 - 4000 = 4348 gm. Or 4.35 Kg

Unit Weight = 8.35-4/0.002832

= **1535 kg/m³**

(f) Jiggling Procedure:

Bucket Weight = 4000 gm or 4 Kg

Bucket + Aggregate Weight = 8447 gm or 8.45 Kg

So Aggregate Weight = 8447 - 4000 = 4669 gm. Or 4.45 Kg

Unit Weight = 8.45-4/0.002832

= **1570 kg/m³**

DATA SHEET

Table 4.7: Unit Weight of Coarse Aggregate

Type of Test	Type of Aggregate	Wt. of Bucket (kg)	Wt. of Bucket+Material (kg)	Wt. to Material (kg)	Volume Of Bucket V (m^3)	Unit Weight, M (kg/m^3)
Shoveling Procedure	Coarse	4	8.03	4.03	0.002832	1424
Rodding Procedure	Coarse	4	8.35	4.35	0.002832	1535
Jiggling Procedure	Coarse	4	8.45	4.45	0.002832	1570

Unit wt. of Aggregate, M (kg/m^3)	Bulk Sp.Gr., S (O-D basis)	Density of water W (kg/m^3)	% Void = [(s*w)-M/s*w]*100
1424	2.7	998	47.1
1535	2.7	998	43
1570	2.7	998	41.7

4.5 14 Day Compressive Strength Test

The average value recorded from compressive strength tests carried out on specimens cured for 14 days can be seen below in Figure 4.1. Only one sample (15% glass replacement) has found to be have increased compressive strength than the control mix. Sample with 15% glass replacement has gained 0.4% more compressive strength (3216.5 psi) than the original control mix (3203.4 psi). Sample with 20% glass replacement has gained 1.5% more strength (3251.8psi) than the control mix. Addition of 25% glass replacement has found to be have gained 12.8% less compressive strength (2794.6 psi) than the original mix.

Table 4.8: 14 days Compressive strength between control and the glass replaced concrete

Test Title	0% Glass Replacement	15% Glass Replacement	20% Glass Replacement	25% Glass Replacement
14 Days Compressive Strength (Psi)	3203.43	3216.47	3251.78	2794.63

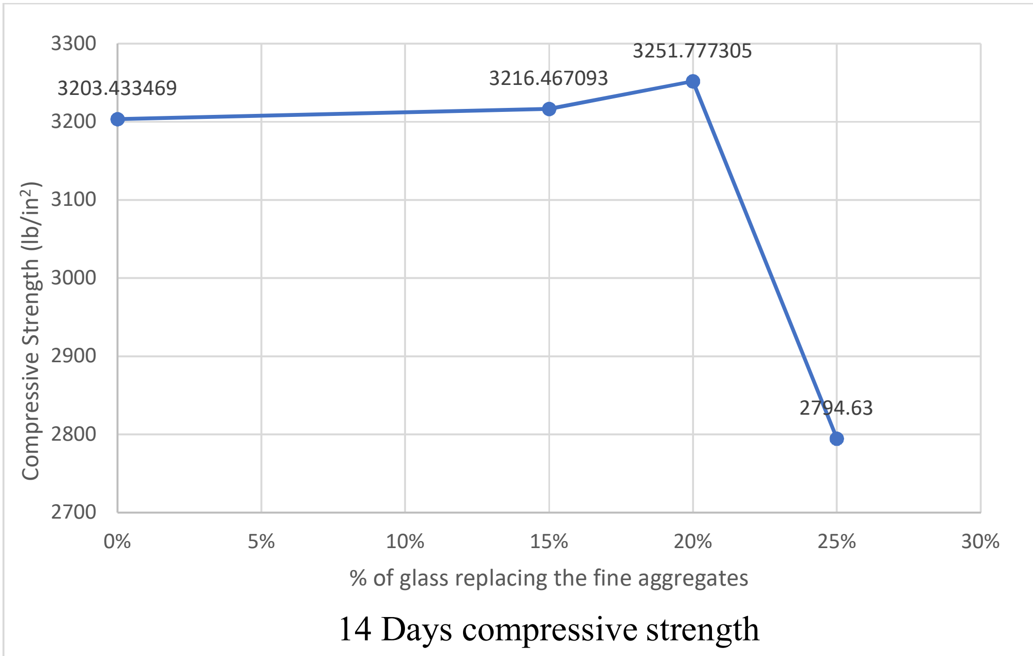

Fig 4.1: Comparison of the 14 day compressive strength between the control and glass aggregate concrete.

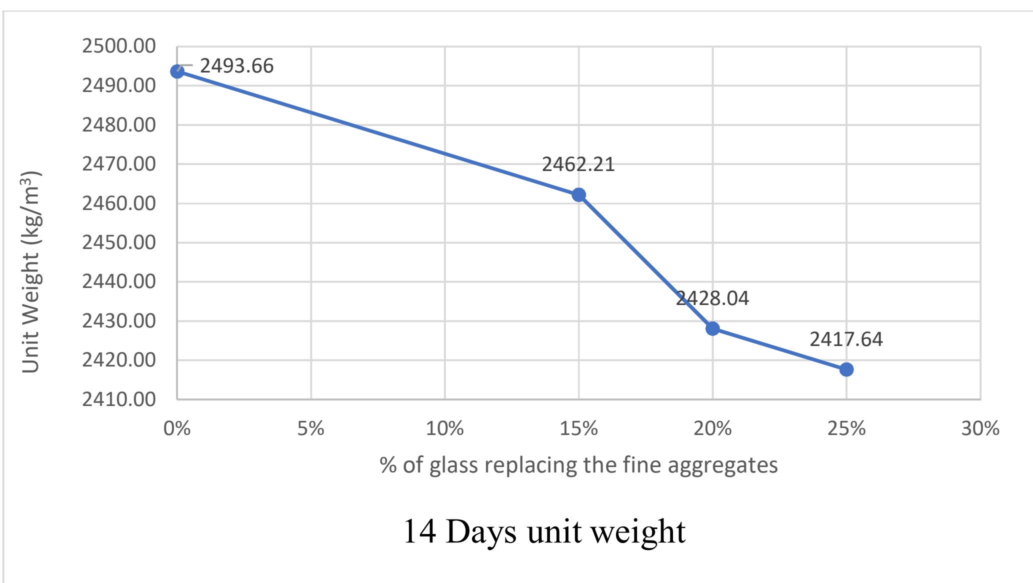

Fig 4.2: Comparison of Unit Weight in 14 days between the control and glass aggregate concrete.

4.6 28 Day Compressive Strength Test

The result of 28 days compressive strength can be seen on Fig 4.2. In 14 days compressive strength test we saw increase in strength only at 15% glass replacement, but in 28 days test, there is increase in strength till 20% glass replacement. The control mix gained a strength of 3545.77 psi (24.45 Mpa). Concrete sample with 15% glass replacement gained 3592.1 psi (24.77 Mpa), which is 1.31% more than the control mix. Sample with 20% replacement has gained 3634 psi (25.06 Mpa), which is 2.5% more than the original control mix. And the last sample of 25% replacement gained 3105 psi (21.41 Mpa), which is 12.43% less strength than the control mix.

Table 4.9: 28 days Compressive strength between control and the glass replaced concrete

Test Title	0% glass replacement	15% glass replacement	20% glass replacement	25% glass replacement
28 days compressive strength (psi)	3545.77	3592.1	3633.95	3105.37

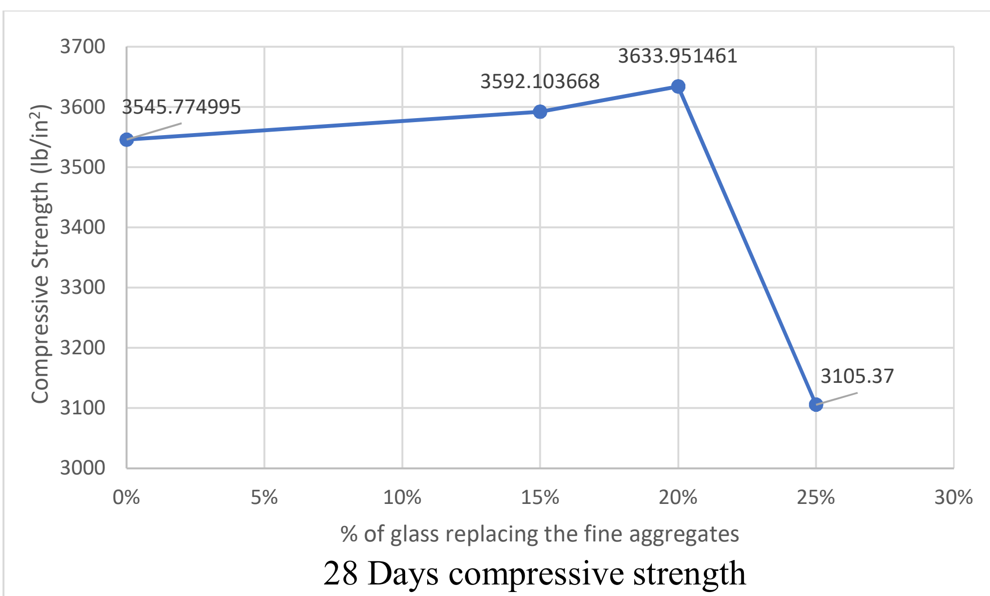

Fig 4.3: Comparison of the 28 day compressive strength between the control and glass aggregate concrete.

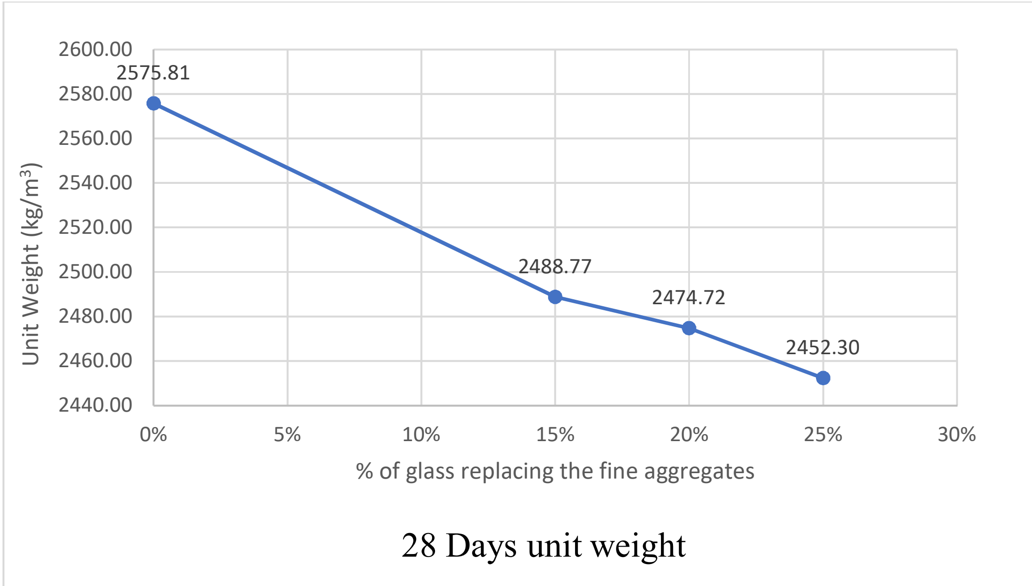

Fig 4.4: Comparison of Unit Weight in 28 days between the control and glass aggregate concrete.

4.7 Summary

The material tests that are conducted were sieve analysis, specific gravity, unit weight and absorption capacity. All the test result were conforming to the ACI and BNBC codes. In 14 days compressive test only 15% replacement got more strength than the original mix. But in 28 days test 20% replacement got the highest strength, 2.5% more strength than the control mix.

CHAPTER 5

Conclusions and Future Works

5.1 Conclusions

The current investigation was conducted with the aim of observing the efficacy of assessing crushed waste glass as a partial replacement of fine aggregate. A concrete grade M20 was adopted as per IS 456: 2000 for this concrete mix. The water cement ratio 0.45 was adopted. Crushed waste glass having fineness modulus (FM) of 3.38 was used in this test. The main goal of this study is to find the improvement in compressive strength of a given mix by replacement of fine aggregate with crushed waste glass at proportion 15%, 20% and 25%. In this research we found that-

1) For M20 grade of concrete using crushed waste glass as fine aggregate replacement at proportion 15%, 20% and 25%. It was found that compressive strength at 14 days were increased at 15% replacement of fine aggregate with crushed waste glass about 1.33% as compared to the original concrete mix.
2) In 28 days compressive strength test, it was found that at proportion 15% and 20% replacement of fine aggregate with crushed waste glass the strength were increased by 1.31% and 2.5% as compared to the conventional mix respectively.
3) The optimum percentage replacement of sand with fine glass aggregate was determined to be 20%.
4) The incorporation of waste glass into the mixture resulted in an increment in the compressive strength up to the point of optimal replacement. This outcome can be ascribed to the angular characteristics of the glass particles, which facilitated an enhanced bonding interaction with the cement paste.
5) From the above results discussion it is concluded that replacement of fine aggregates with glass powder at proportion 20% gives better result of compressive strength and it can be more economical and environmentally

friendly and have the potential to be used as a replacement of the conventional concrete.

5.2 Limitations and Recommendations for Future Works

5.2.1 Limitations

- Only compressive strength of the concrete is determined in this study.
- Only 14 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 days test can be done too determine the early strength.
- 60 days and other long period compressive test can do to see the behavior of concrete.

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