# A COMPARATIVE ANALYSIS OF THE COMPRESSIVE STRENGTH OF CONCRETE BY REPLACING FINE AGGREGATE WITH GLASS POWDER

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

Section: (23B+23D)

Semester-Year(FALL-2024)

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***Dedicated***

*To*

*"OUR PARENTS & TEACHERS"*

## ACKNOWLEDGEMENTS

We would like to thank all the people who contributed in some way to the work described in this thesis. First and foremost, we thank our academic advisor (HEMLITA MONDAL), for her unwavering patience, enthusiastic encouragement, and her valuable feedback. During our tenure, she contributed to a rewarding graduate school experience by giving us intellectual freedom in our work, supporting us at various conferences, engaging us in new ideas, and demanding a high quality of work in all our endeavors. Additionally, we are profoundly appreciative of the contributions of our team members, whose insightful suggestions and advice played a crucial role in this endeavor. We also wish to acknowledge (MD ROBIULLAH's) instrumental help in locating pertinent materials, who patiently taught us his method for synthesizing a number of other laboratory techniques, and who worked closely with us to present this thesis. The successful completion of this work was made possible only through the collective effort and support of our team. We are deeply thankful for their hard work, commitment, and creativity.

Finally, we would like to acknowledge friends and family who supported us throughout this entire process & in every moment of the hard times of our life.

# ABSTRACT

The thesis explores the use of Glass powder as a partial replacement for conventional aggregates in sand. The objective is to determine if we can increase the strength by using waste glass powder and the effects of these eco-friendly materials on compressive strength, particularly in lightweight concrete applications. The study involves mixing different proportions of Glass Powder (5%, 10%, 15% & 20%) into the sand and testing their performance after curing for 7 and 28 days. In the 7-day result, there was no significant result showing against normal sand but in the 28-day result, it showed huge changes in strength and the strength had increased a lot than the normal sand. Compressive strength up to 28 days respectively will be compared with those of the control mix created with natural sand. However, higher glass powder content slightly affects workability. This research demonstrates the potential of Glass Powder in producing lightweight, strong, and sustainable concrete, suitable for concrete casting. Glass powder utilized in concrete creation ends up in a greener setting. It highlights the environmental benefits of using alternative materials in construction, aligning with global sustainability trends. The work is done using M20-grade concrete.

**Keywords:** Lightweight concrete, Glass Powder, Compressive strength

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# CHAPTER 1

# Introduction

## 1.1 Background

In order to form concrete business property, the utilization of waste materials in situ of natural resources is one in every of the simplest approaches. A massive amount of waste glass is generated all around the world. In Bangladesh, the generation rate of waste varies throughout the cities ranging from 0.25 to 0.70kg/capita/day, where the city, Chittagong (0.56 kg/capita/day) and Dhaka, the capital city (0.70kg/capita/day) producing the largest amount of waste.

The utilization of watercourse sand as a fine mixture ends up in the exploitation of natural resources, lowering of formation, sinking of bridge piers, and erosion of watercourse bed. If fine mixture is replaced by waste glass by specific share and in specific size vary, it'll decrease fine mixture content and thereby reducing the sick effects of watercourse dredging and so creating concrete producing business property. The number of waste glass created has bit by bit redoubled over the recent years because of associating ever growing use of glass product. Most waste glass has and is being drop into lowland sites

We will go over the elements that impact the compressive strength of typical concrete in this brief article. The significance of compressive strength in concrete design and construction will also be covered. The results of current studies on the compressive strength of typical concrete will be shown before we conclude.

## 1.2 The definition of compressive strength and its importance in concrete design and construction.

Compressive strength is a material's ability to withstand compressive loads without breaking or deforming. It's a key parameter in concrete design and construction because it measures the resilience of hardened concrete. Megapascals (MPa) are used to measure it. Concrete has compressive strengths that typically range from 20 to 40 MPa, making it a powerful material. Importance in the design and construction of concrete o Compressive strength is one of the most crucial characteristics of concrete since it determines the ability of concrete structures to

support loads.

Concrete constructions are made to resist the loads they are expected to sustain. The maximum load that a structure can support before failing is calculated using the concrete's compressive strength. Concrete's compressive strength is crucial in building. The concrete needs to be strong enough to handle the loads and the weight of the construction.

### 1.3 Organization of the Thesis

1. The layout of the thesis is written through five chapters in the following sequence.

2. Chapter one deals with the background and the definition of compressive strength and its importance in concrete design and construction.

3. Chapter Two is a literature review that includes the definition of the compressive strength of Glass Powder.

4. Chapter Three contains the Methodology and Experimental Program the Material, the Procedure of Making the cylinder, the methodology Overview, and a Summary.

5. Chapter Four contains the experimental results along with the data, figures, and graphs obtained from the laboratory tests, discussions on the test results, specific aims, and a summary.

6. Chapter Five describes the conclusion of the research work and recommendations for further research.

### 1.4 Objective

- To find out the maximum compressive strength of concrete using Glass Powder at varying contents and to compare it with that of conventional concrete.

# CHAPTER 2

# Literature Review

## 2.1 General.

Rakesh Sakale (2015) investigated the effects of replacing fine aggregate with waste glass powder by volume of cement in steps of 10%, 20%, 30%, and 40%, and the effects on compressive strength, split tensile strength, workability, and flexural strength. The compressive, flexural, and split tensile strengths of concrete are found to increase initially as glass powder increases, peaking at around 20%, and then decreasing. [1]

S.M. Chikhalikar and S.N. Tande (2012) there is a need to replace a portion of fine aggregate with waste glass powder to reduce fine aggregate consumption and to reduce environmental pollution to some extent. Recently, research has revealed that waste glass can be used as fine aggregate in concrete. Because of its high silica content, waste glass has cementitious properties when ground to a fine powder. [2]

Moriconi and Naik (2005) Concrete is the world's second most widely used material. However, the production of Portland cement results in a significant amount of $CO_2$, a greenhouse gas, being released into the atmosphere. It is estimated that one ton of Portland cement clinker produces one ton of $CO_2$ and other greenhouse gases (GHGs). [3]

VeenaV. Bhat, N.BhavanishankarRao (2014) Glass is an indeterminate material with high silica content ($SiO_2$) i.e.72% of waste glass when grounded to very fine powder (600 micron) reacts with alkali in cement & cementations product that help to contribute to the strength development. [4]

Idir R (2009) Demand for recycled glass has Considerably decreasing in recent years. Glass is cheaper to store than to recycle, as it is expensive for the recycling process. There are several alternatives for the reuse of waste glass. In order to provide a sustainable solution to glass storage, a potential and incentive way would be to reuse this type of glass in concrete. [5]

## 2.2 Summary

The literature highlights the potential of expanded Glass powder to enhance concrete properties. Glass powder reduces concrete density, making it lightweight while maintaining adequate strength, and is effective for improving thermal insulation. Glass powder, known for its durability and toughness, reinforces concrete, increasing compressive strength. However, excessive Glass powder can reduce workability.

Overall, the combination of Glass powder and Sand offers promise for producing lightweight, strong concrete, with optimal proportions being key to balancing strength and workability. This study further explores their combined effects on concrete performance.

# CHAPTER 3
# Methodology

## 3.1 Introduction

The methodology employed in this study focuses on analyzing the compressive strength of concrete through the partial replacement of coarse aggregate with expanded Glass powder. The experimental process is designed to evaluate the potential of these materials to enhance the properties of lightweight concrete, specifically its compressive strength.

The study involves the preparation of concrete cylinders using different proportions of Glass Powder, ranging from 0% to 20% by volume of coarse aggregate. The concrete mix is prepared with standard materials such as cement, fine and coarse aggregates, and water. After casting the specimens, they are cured for specified periods (7, and 28 days), followed by compressive strength testing using a Universal Testing Machine. This methodology aims to provide a comparative analysis of how these eco-friendly materials affect the structural performance of concrete, offering potential applications in lightweight and sustainable construction practices.

## 3.2 Methodology Overview:

The methodology employed for investigating the compressive strength of concrete using Glass Powder involves a systematic approach that encompasses various experimental and analytical steps. This section provides a concise overview of the key methodologies utilized in the research process.

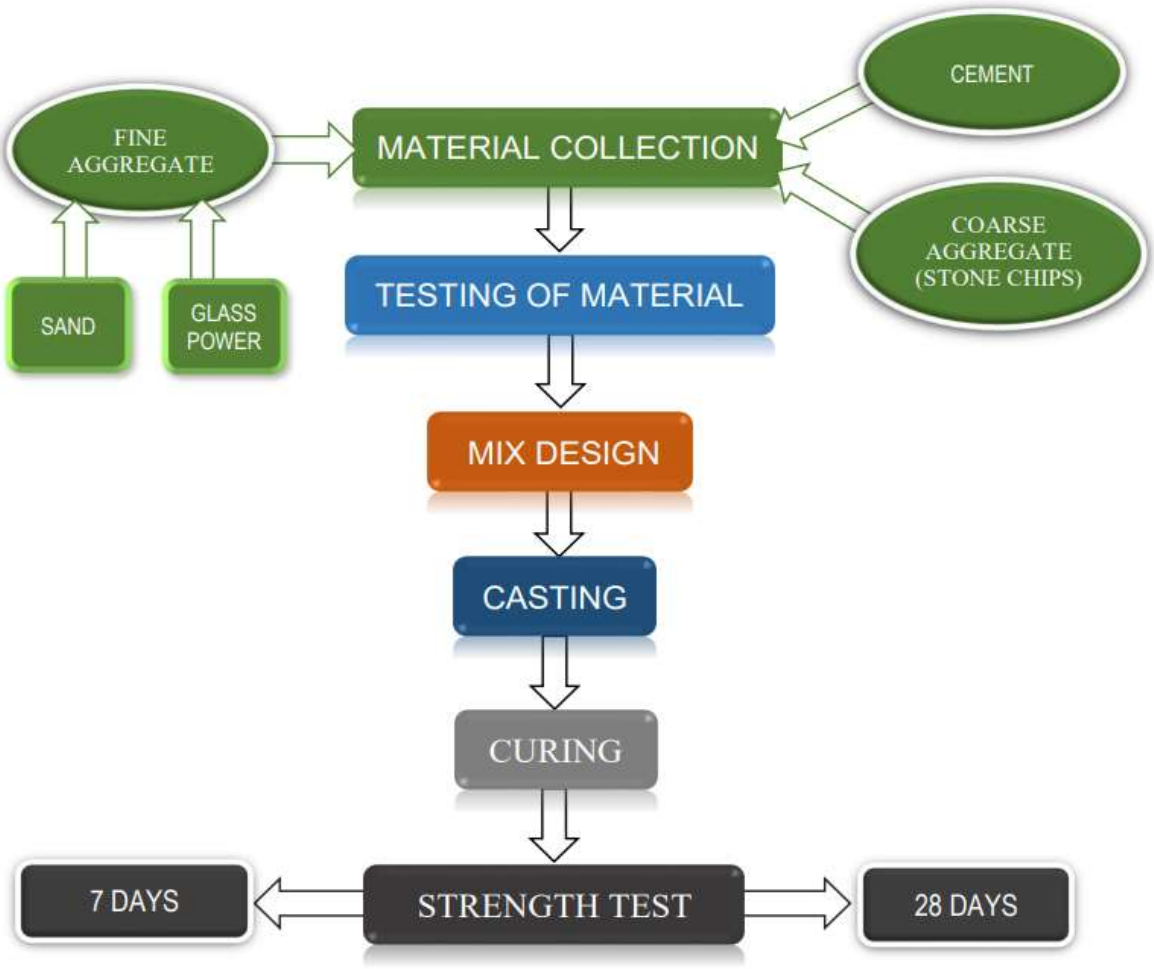



**Figure 3.1 Overview of the Glass Powder methodology**

**3.2.1Cement**:

One of the problems faced in the manufacture of high-strength concrete is the difficulty of workability and the rising price of OPC and PCC cement. To overcome these problems, a self-compacting system is needed in concrete to make the workability easier to work with and the use of other types of cement besides OPC and PCC.But We have used PCC in our test.

Plain Cement Concrete is referred to as PCC. Cement, sand-like fine aggregate, and coarse aggregate are the three main components of PCC. It is also known as cement concrete or blinding concrete (CC). Concrete is poured on top of the soil's surface before pouring the foundation to keep the reinforcing from coming into direct contact with the soil and water. Concrete made with only cement, sand, and coarse aggregates devoid of steel is known as plain cement concrete. PCC, an essential building element, is positioned on the earth's surface to prevent the reinforcing of the

concrete from coming into direct touch with dirt and water.

The process of producing concrete involves mixing a variety of ingredients, including water, aggregate, cement, and any additions. Concrete manufacturing must be completed quickly. Concrete must be placed as soon as it is mixed to avoid hardening. A concrete plant, usually referred to as a batch plant, is a sizable industrial structure where the majority of concrete is manufactured in the modern world.




**Figure: 3.2 Cement**

**3.2.3 Fine Aggregates**: Fine aggregates are essentially any natural sand particles won from the land through the mining process. Fine aggregates consist of natural sand or any crushed tone particles that are ¼" or smaller.




**Figure: 3.3 Fine Aggregates**

This product is often referred to as 1/4"' minus as it refers to the size, or grading, of this particular aggregate. They are granular materials, typically smaller than 5mm in diameter, that play a crucial role in enhancing the workability, strength, and durability of construction mixes. Here's an in-depth overview of fine aggregates. Sylhet sand was used for producing lightweight cylinders for performing compressive strength tests.

**3.2.3 Coarse Aggregates**:

Coarse aggregate is a construction material used to make concrete that is made from rock that is larger than a standard No. 4 sieve (3/16 inches) and less than 2 inches. Coarse aggregates are typically irregular and granular in nature and can be found in the form of sand, gravel, or crushed stone. The size of coarse aggregate is important because it affects the strength, workability, and amount of water needed for the concrete mix. Larger coarse aggregates have a smaller bondable surface area for cement, sand, and water, so less water and fine aggregate is needed. Here's an in-depth exploration of coarse aggregates. Natural gravel from the West Bengal region

with a nominal aggregate size of 9.5-20mm, shown in Figure 3.3, was used as coarse aggregates in all mixes. The physical and chemical parameters of the coarse aggregates comply with the Indian standard [17].




**Figure: 3.4 Coarse Aggregates**

### 3.2.4 Water:

According to IS 456: 2000, water used for mixing and curing shall be clean and free from injurious amounts of oils, acids, alkalis, salts, sugar, organic materials, or other substances that may be deleterious to concrete or steel. Potable water is generally considered satisfactory for mixing concrete. The pH value of water shall be not less than 6. Water is a fundamental and essential element in the construction industry, playing a critical role in various construction processes and materials. It serves as a mixing and curing agent, a component of construction materials, and a medium for cleaning and hydration. Here's an exploration of the significance and functions of water in construction.



**Figure: 3.5 Water**

### 3.2.5. GLASS:

Glass, an inorganic solid material that is usually transparent or translucent as well as hard, brittle, and impervious to the natural elements. Glass has been made into practical and decorative objects since ancient times, and it is still very important in applications as disparate as building construction, housewares, and telecommunications. It is made by cooling molten ingredients such as silica sand with sufficient rapidity to prevent the formation of visible crystals. Commercial glasses may be divided into soda–lime–silica glasses and special glasses, most of the tonnage produced being of the former class. Such glasses are made from three main materials—sand (silicon dioxide, or $SiO_2$), limestone (calcium carbonate, or $CaCO_3$), and sodium carbonate ($Na2CO_3$). Fused silica itself is an excellent glass, but, as the melting point of sand (crystalline silica) is above 1,700 °C (3,092 °F) and as it is very expensive to attain such high temperatures, its uses are restricted to those in which its superior properties—chemical inertness and the ability to withstand sudden changes of temperature—are so important that the cost is justified. Nevertheless, the production of fused silica glass is quite a large industry; it is manufactured in various qualities, and, when intended for optical purposes, the raw material used is rock crystal rather than quartz sand.

To reduce the melting point of silica, it is necessary to add a flux; this is the purpose of the sodium carbonate (soda ash), which makes available the fluxing agent sodium oxide. By adding about 25 percent of the sodium oxide to silica, the melting point is reduced from 1,723 to 850 °C (3,133 to 1,562 °F). But such glasses are easily soluble in water (their solutions are called water glass). The addition of lime (calcium oxide, or CaO ), supplied by the limestone, renders the glass insoluble again, but too much makes a glass prone to devitrification—i.e., the precipitation of

crystalline phases in certain ranges of temperature. The optimum composition is about 75 percent silica, 10 percent lime, and 15 percent soda, but even this is too liable to devitrification during certain mechanical forming operations to be satisfactory.



**Figure: 3.6 Glass Sheet**




**Figure: 3.7 Glass Powder**

### 3.2.6 **Procedure of Making the Cylinder:**

The mixture composition paving cylinder used the ratio of 1:1.5:3 which is 1kg cement, 1.5kg sand, and 3kg Coarse Aggregates, Expanded Glass Powder with the addition of 450ml of water (not too much water should be added in order to get maximum water-cement ratio). Glass Powder by 0%, 5%, 10% 15% and 20% of all Aggregates weight were added. The mixture compositions were mold. The mold was hit 9 times in order to even up the mixture so there were no air voids. The finished mixture was taken out from the mold into plywood




**Figure: 3.8 Concrete mixing with Glass Powder**



**Figure: 3.9 Concrete mixing with Glass Powder**

### 3.2.7Materials Selection and Preparation:

These substances for concrete components have been:

- Plain Cement Concrete (PCC)
- Fine aggregate
- Coarse aggregate
- Glass powder
- Water

High-quality materials will be selected to ensure accurate and repeatable results. The Glass Powder will be of uniform size and be properly processed to remove impurities.

### 3.2.7 Mix Proportioning:

A series of concrete mixtures will be designed with varying proportions of Glass Powder. The mix design will be based on established guidelines for achieving the desired compressive strength. The control mixtures without any additives will also be prepared for comparison.



**Figure: 3.10 Mix Proportioning**

### 3.2.16 Concrete Mixing:

The concrete mixtures will be batched using a concrete mixer, following standard mixing procedures.



**Figure: 3.11 Concrete Mixing**

The sequence of adding materials, mixing duration, and water-cement ratio will be consistent for all batches to ensure consistency.

### 3.2.16 Specimen Casting:

The freshly mixed concrete will be cast into standard cylindrical or cubic molds, adhering to relevant testing standards. Special care will be taken to prevent segregation during casting. The molds will be properly vibrated to eliminate air void.



**Figure: 3.12 Specimens Casting**

### 3.2.16 Curing Regime:

The cast specimens will undergo a controlled curing process to simulate real-world conditions. This process will involve both moist curing and air curing, as per established concrete curing practices. The curing duration will be chosen to ensure proper hydration and development of strength.



**Figure: 3.13 Curing Regime**

### 3.2.16 Compressive Strength Testing:

After the curing period, the specimens will be carefully demoded and tested for compressive strength using a universal testing machine.



**Figure: 3.14 Preparing For Compressive Strength**



**Figure: 3.15 Compressive Strength Testing**

The load will be applied gradually and uniformly until failure occurs. The maximum load at failure and the corresponding stress will be recorded to calculate the compressive strength.

### 3.2.17 Data Collection and Analysis:

The obtained compressive strength values from different mixtures will be compiled and analyzed statistically. The effects of varying proportions of Glass Powder on the compressive strength will be studied. Comparative analysis will be conducted between the modified concrete mixes and the control mixes.

**Unit Weight of**

a. Shoveling Condition – 8.413 kg (Bucket + Material)

b. Roding Condition – 8.587 kg

c. Jigging Condition – 8.818 kg

Volume of Bucket = 0.00278 $m^3$

| Types of Procedure | WT of Bucket kg (T) | WT of Bucket+Material kg (G) | WT of Material (G-T) | Volume of Bucket (V) $m^3$ | Unit WT Material $kg/m^3$ | Average Unit WT Material |
|---|---|---|---|---|---|---|
| Shoveling | 4.000 | 8.413 | 4.413 | 0.00278 | 1588 | 1658 |
| Roding | 4.000 | 8.587 | 4.587 | 0.00278 | 1650 | |
| Jigging | 4.000 | 8.818 | 4.818 | 0.00278 | 1734 | |

| Unit WT Material $kg/m^3$ | Bulk SP Gs (0-0) Basis | Density of Water Weight $kg/m^3$ | Percentage Void |
|---|---|---|---|
| 1658 | 3.579 | 998 | 53.58 |
| M | S.S.D (Basic) | W | Percentage Void |
| 1616 | 3.66 | 998 | 55.75 |

**Specific Gravity of Stone**

1922 gm = A

1433 gm = C

1970 gm = B

**Apparent Specific Gravity**

A/(A-C) = 1922/(1922-1433) = 3.93

**Bulk Specific Gravity (S.S.D Basis)**

B/B-C = 1922/1970-1433 = 3.579

**Absorption Capacity, 0%**

(B-A) x 100/A = (1970-1922) x 100/1922 = 2.49

**Unit Weight of (Sand)**

a) Shoveling Condition – 8213 gm (Bucket + Sample)

b) Rodding Condition – 8488 gm (Bucket + Sample)

c) Jiggling Condition – 8706 gm (Bucket + Sample)

*Bucket → H=6" Bucket Weight = 4000gm

D=6"

Volume of Bucket = 0.002779 $m^3$, of 0.09817 $ft^3$

| Types of Aggregate | WT of Bucket gm (T) | WT of Bucket+Material gm (G) | WT of Material (G-T) | Volume of Bucket V $m^3$ | Unit Weight kg/$m^3$ | Average kg/$m^3$ |
|---|---|---|---|---|---|---|
| Shoveling | 4000 | 8213 | 4213 | 0.00278 | 1516 | 1608 |
| Rodding | 4000 | 8488 | 4488 | 0.00278 | 1615 | |
| Jiggling | 4000 | 8706 | 4706 | 0.00278 | 1693 | |

Percentage of Void = ((SxW)-M)/ SxW x100 = (2.42x998)-1608/2.42x998 = 33.42

| Unit Weight of M kg/$m^3$ | Bulk Sp.Ga (0-0) Basis | Density of Water Weight kg/$m^3$ | Percentage of Void |
|---|---|---|---|
| 1608 | 2.42 | 998 | 33.42 % |
| M/M(1+A/100) | (S.S.D) Basis | W | |
| 1613 | 2.5 | 998 | 35.4 % |

### 3.3 Summary

The methodology of this study focuses on evaluating the compressive strength of concrete with partial replacement of coarse aggregate using expanded Glass Powder. Ordinary Plain Cement Concrete (PCC), fine aggregates, and natural coarse aggregates were used alongside varying percentages of Glass Powder (5%, 10%, 15% and 20%).

Concrete cylinders were cast following a standard mix ratio and water-cement ratio. The specimens were cured in controlled environments for 7 and 28 days. Compressive strength tests were conducted using a Universal Testing Machine to assess the performance of the different concrete mixes. The methodology also included data analysis to compare the performance of modified concrete mixes with normal concrete. This experimental approach aims to provide insights into the viability of Glass Powder as sustainable alternatives to traditional coarse aggregates in concrete.

# CHAPTER 4

## Results and Discussion

### 4.1 Introduction

This pivotal section delves into the empirical outcomes and insightful interpretations derived from the experimental investigation on the utilization of Glass Powder as additives in concrete. The primary focus centers on the compressive strength characteristics of the modified concrete mixes.

### 4.2 Results

#### 4.2.1 Density

The quantity and density of lightweight aggregates are two of the most crucial elements in regulating a variety of physical properties in LWC. Due to the low density of powder, the density of LWC falls as Glass powder volume increases.

#### 4.2.2 Compressive Strength

This rise is the result of the cement hydration process becoming more advanced with time. and both provide a comparison of the compressive strengths of several specimens at 7 days and 28 days of age.

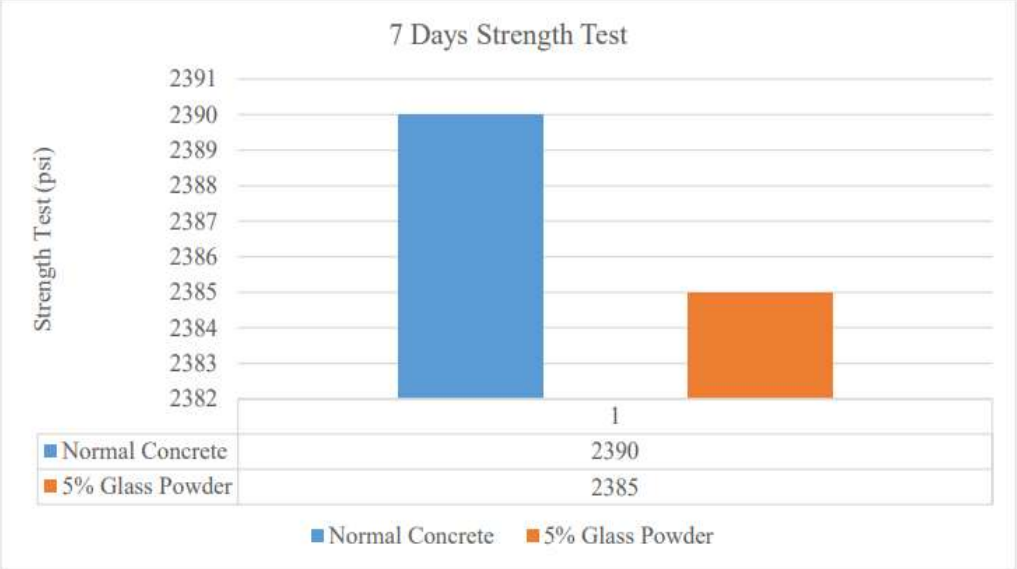


**Figure 4.1: Compare Compressive Strength with Normal Concrete, 5% Glass powder**

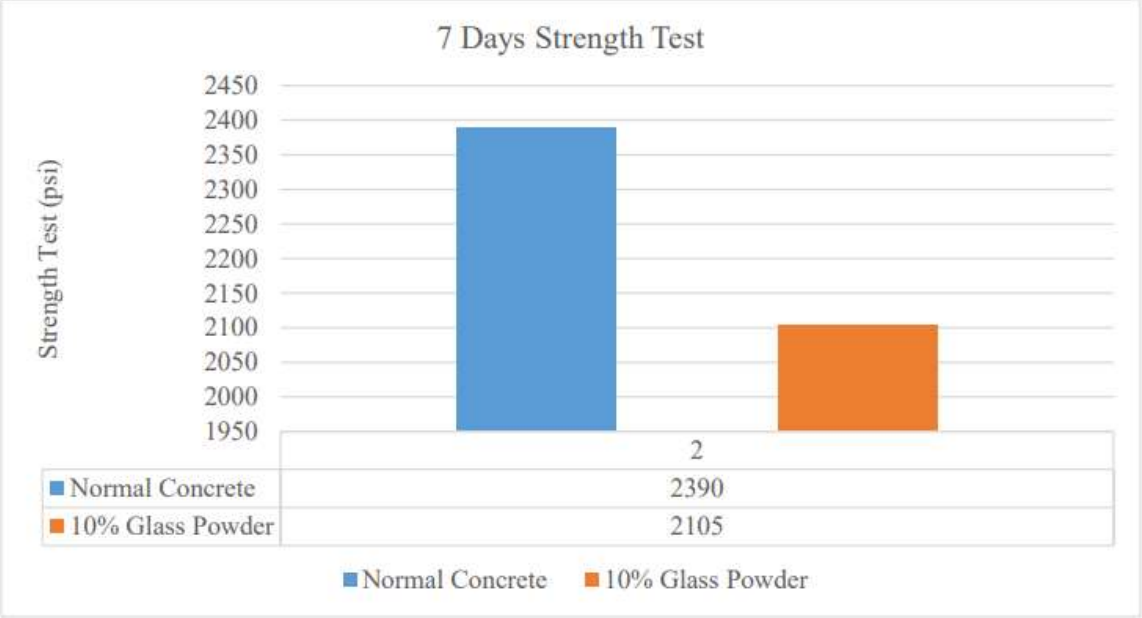



**Figure 4.2: Compare Compressive Strength with Normal Concrete, 10% Glass powder**

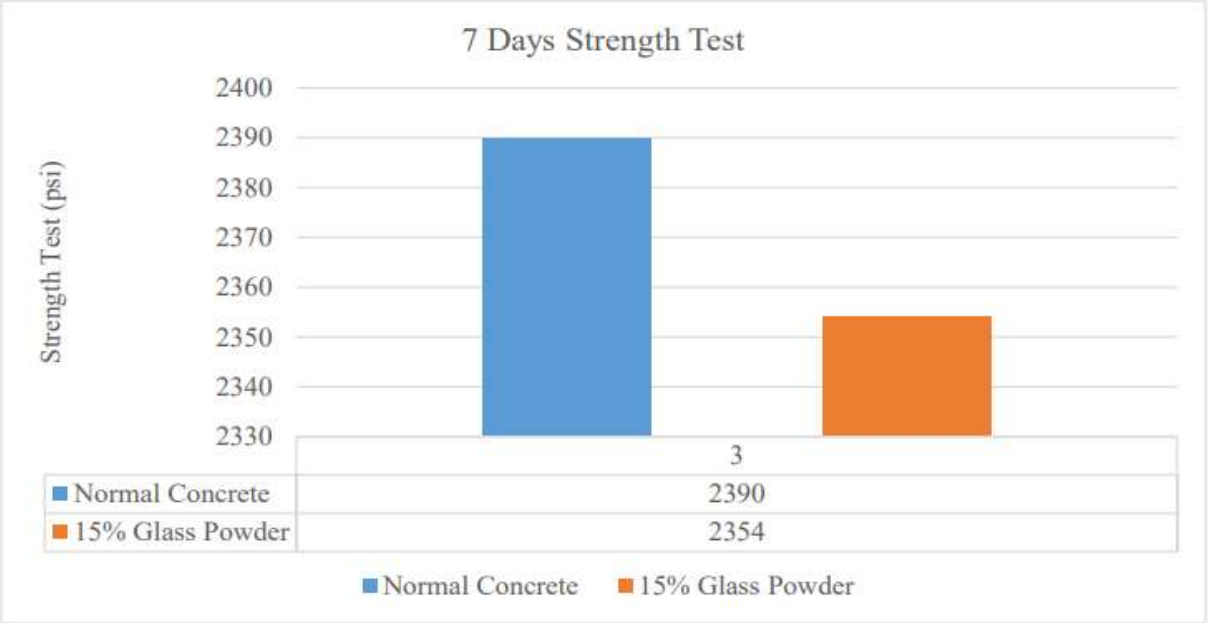



**Figure 4.3: Compare Compressive Strength with Normal Concrete, 15% Glass powder**

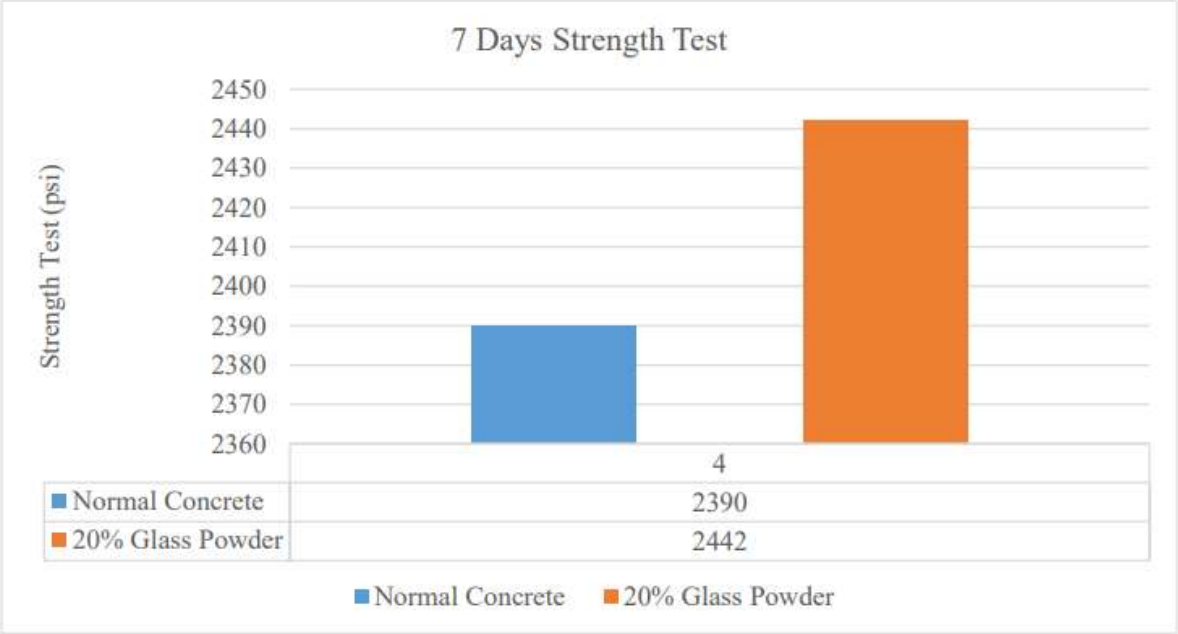



**Figure 4.4: Compare Compressive Strength with Normal Concrete, 20% Glass powder**

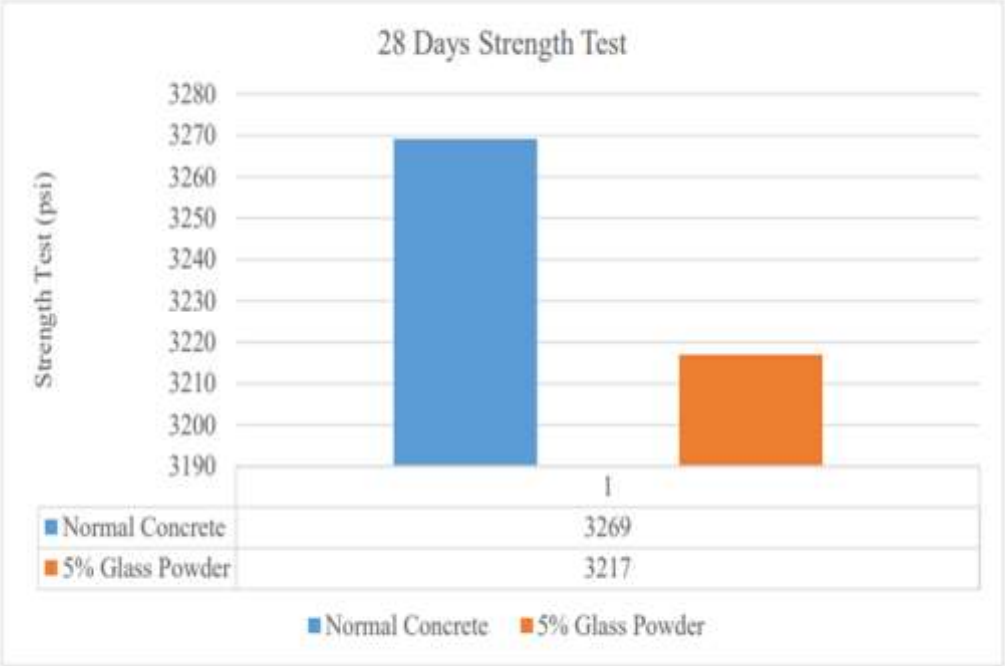



**Figure 4.5: Compare Compressive Strength with Normal Concrete, 20% Glass powder**

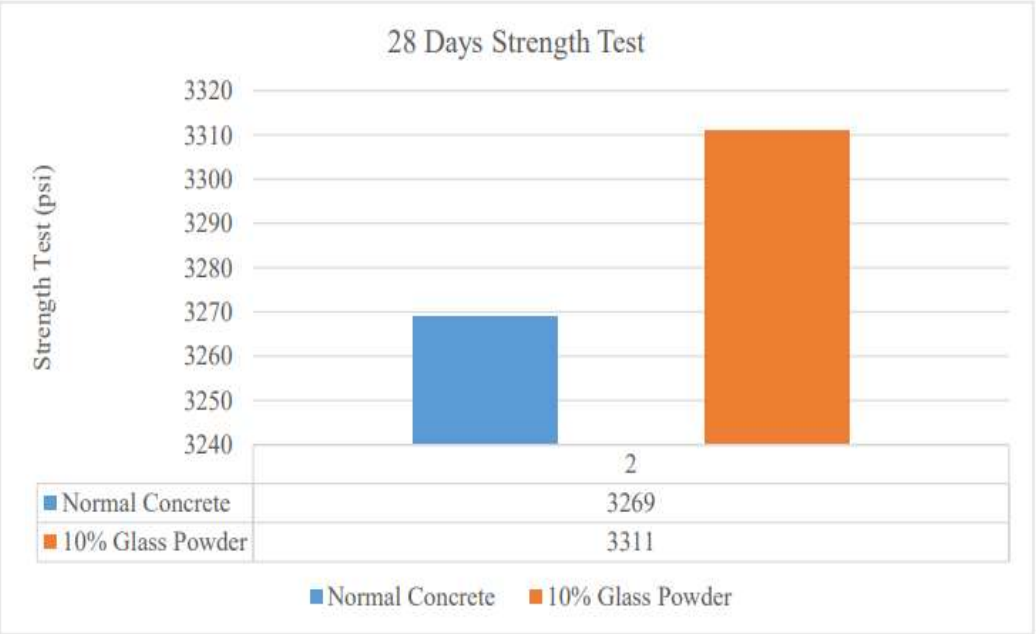



**Figure 4.6 Compare Compressive Strength with Normal Concrete, 10% Glass Powder**

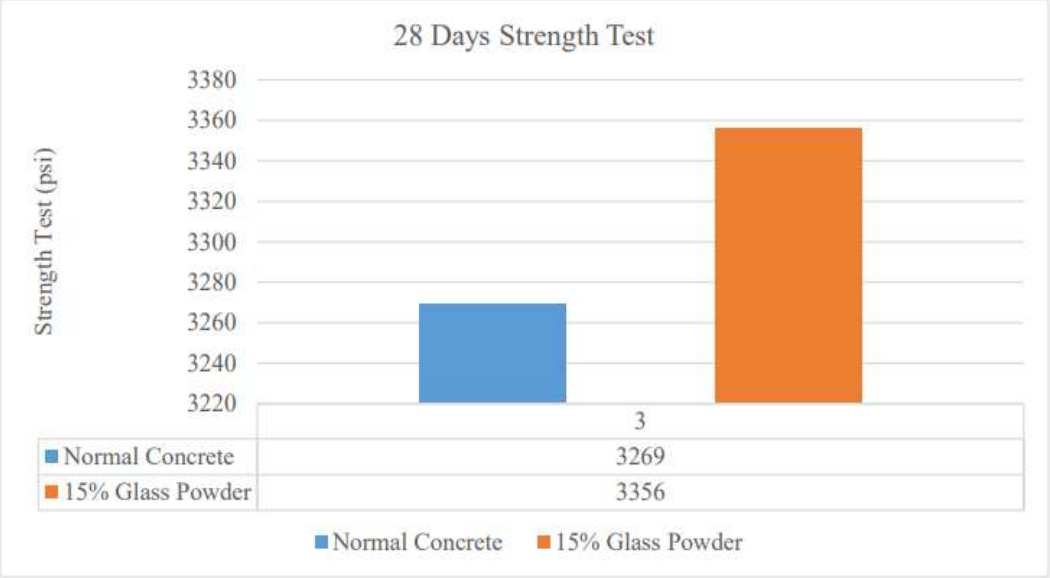



**Figure 4.7 Compare Compressive Strength with Normal Concrete, 15% Glass Powder**

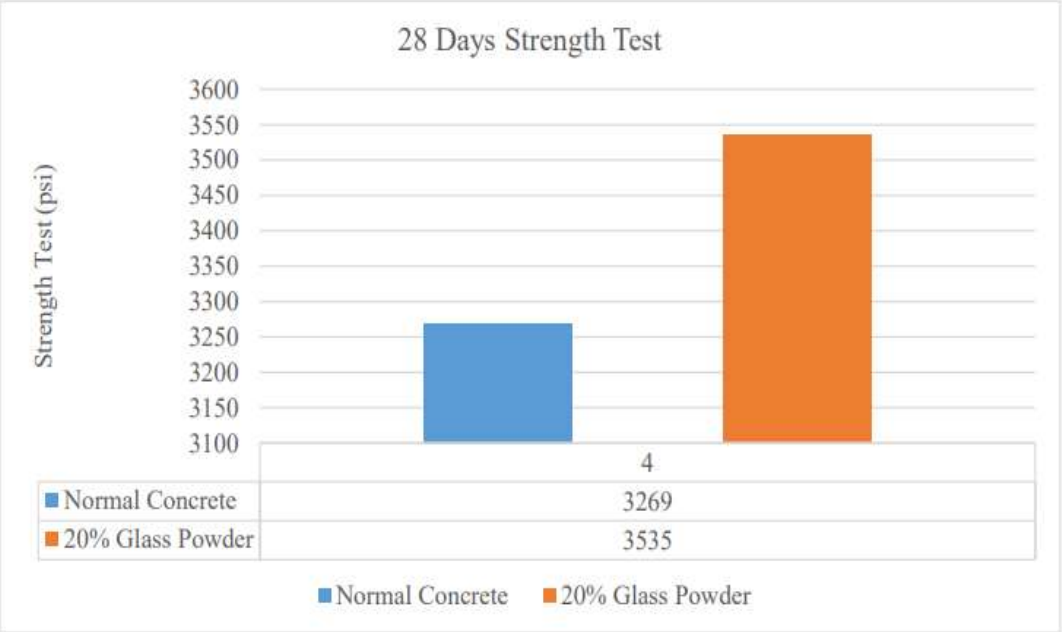



**Figure 4.8 Compare Compressive Strength with Normal Concrete, 20% Glass Powder**

**Table 4-9. Summary of the goodness-of-fit of the prediction models.**

| For 28 Days | | | | | | |
|---|---|---|---|---|---|---|
| SL No. | Dia (mm) | Height (mm) | Weight (gm) | Load (KN) | Average Crushing Strength (KN) | PSI |
| Normal Concrete | | | | | | |
| 1 | 102.62 | 206.5 | 4045 | 190 | 185 | 3269 |
| 2 | 103.11 | 205 | 4079 | 180 | | |
| 5% Glass Powder | | | | | | |
| 1 | 102.96 | 204 | 4073 | 188 | 182 | 3217 |
| 2 | 102.75 | 206 | 4068 | 176 | | |
| 10% Glass Powder | | | | | | |
| 1 | 102.67 | 206.5 | 4141 | 184 | 187 | 3311 |
| 2 | 102.76 | 206.5 | 4113 | 190 | | |
| 15% Glass Powder | | | | | | |
| 1 | 101.63 | 206 | 3891 | 185 | 183.5 | 3356 |
| 2 | 103.6 | 206.5 | 4058 | 194 | | |
| 20% Glass Powder | | | | | | |
| 1 | 102.55 | 207.5 | 3990 | 202 | 198.5 | 3535 |
| 2 | 101.61 | 205 | 3969 | 195 | | |

**Table 4-10: Summary of the goodness-of-fit of the prediction models.**

| For 7 Days | | | | | | |
|---|---|---|---|---|---|---|
| SL No. | Dia (mm) | Height (mm) | Weight (gm) | Load (KN) | Average Crushing Strength (KN) | PSI |
| Normal Concrete | | | | | | |
| 1 | 102.2 | 204.5 | 3950 | 124 | 134.3 | 2390 |
| 2 | 102.29 | 200 | 3836 | 145 | | |
| 5% Glass Powder | | | | | | |
| 1 | 101.11 | 205 | 3970 | 142 | 133 | 2385 |
| 2 | 101.63 | 205 | 4016 | 124 | | |
| 10% Glass Powder | | | | | | |
| 1 | 101.09 | 205.5 | 3963 | 130 | 117.5 | 2105 |
| 2 | 101.86 | 205.5 | 3932 | 105 | | |
| 15% Glass Powder | | | | | | |
| 1 | 102.07 | 204.5 | 4042 | 135 | 131 | 2354 |
| 2 | 100.2 | 205 | 3808 | 127 | | |
| 20% Glass Powder | | | | | | |
| 1 | 102.39 | 206 | 3952 | 145 | 137.5 | 2442 |
| 2 | 102.33 | 205 | 4041 | 130 | | |

### 4.3 Summary:

The "Results and Discussion" section stands as the culmination of empirical data and interpretative insights, driving the narrative towards a more profound understanding of the application of Glass Powder in enhancing concrete's compressive strength and broader performance attributes.

# CHAPTER 5
## Conclusions

### 5.1 Conclusions

- The research successfully demonstrates that integrating Glass Powder into concrete mixtures enhances properties while offering improved compressive strength under optimal conditions.
- Specifically, concrete with 15-20% Glass Powder significantly increases compressive strength, particularly at 28 days of curing.
- These modifications make the concrete suitable and sustainable building applications, aligning with modern needs for green construction practices.

### 5.2 Limitation

- It was somewhat difficult to accurately extract the FM from glass powder due to its brittle nature.
- If there was some more time, the test results could have been seen by curing for 90 days.
- The same work can be carried out by blending glass powder from one or more sources.
- Super plasticizer of different type can be used and water reduction can be determined.

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