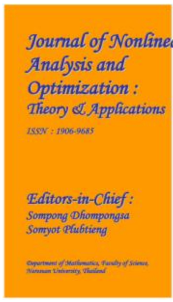
Journal of **N**onlinear **A**nalysis and **O**ptimization
Vol. 15, Issue. 1 : 2024
ISSN : **1906-9685**



CONCRETE USING GLASS POWDER AS A PARTIAL REPLACEMENT OF CEMENT

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ABSTRACT:
Other than the combustion of fossil fuels and deforestation, the cement manufacturing business is one of the sources of carbon dioxide emissions. Global warming is mostly caused by greenhouse gases like CO2 that are released into the atmosphere. One of the greenhouse gases responsible for about 65% of global warming is CO2. Global cement production accounts for about 7% of greenhouse gas emissions into the environment. The creation of concrete substitute binders is required to mitigate the impact of cement manufacturing on the environment. As a result, there is a lot of research being done on cement alternatives that employ different waste products and industrial wastes. The purpose of the study is to evaluate the effects of substituting glass waste powder for cement.
while calculating the concrete's weight, density, and compressive strength. Durability studies, such as Concrete's Resistance to Acid Attack, are also studied. To produce the concrete composites, ordinary Portland cement (Opc) of grade 53 was substituted with 43%,45%, 47%, glass powder . For this project, a mix design of M50 and 0.44 W/C ratio was used. Slump test was conducted on the concrete, and 52 cubes of 150 x 150 x 150 mm were casted and cured for 7, 14, and 28 days, respectively. The compression strength , Acid attacked specimen strength were determined. The strength is maximum for M50 concrete for 47% replaced concrete at 28 days.

Keywords:
Ordinary Portland cement, compressive strength. Durability, coarse aggregate , fine aggregate, Glass powder

1. INTRODUCTION

It is noteworthy that the primary ingredient in concrete is cement; yet, the process of assembling Portland concrete has a fundamentally detrimental effect, as one ton of Portland cement clinker produces approximately one ton of carbon dioxide and other ozone depleting compounds (GHGs). Greenhouse Gases Thus, a sensible development plan inside the cement and concrete business should minimize the emission of this noteworthy amount of carbon dioxide. Generally speaking, glass has no negative effects on the climate because it emits no pollutants. However, if handled carelessly, it can harm humans and other animals as well as the environment because it is not biodegradable. Thus, the development of fresh innovations has been necessary.

A few different substance types are included in the phrase "glass," such as borosilicate, alkali-silicate, and soda lime silicate glass. These types of glass powder have up till now been widely used as pozzolana in cement and aggregate blends for civil works. The presence of leftover glass in concrete will increase the cement's alkali content. It also aids in the production of ceramics and blocks,

conserves raw resources, uses less energy, and reduces the amount of trash that is dumped in landfills. Glasses and glass powder are valuable recycled resources that are mostly used in structural design-related fields. For example, they are used in cement as coarse aggregate and pozzolana (supplemental cementitious materials).
The second most common material is concrete. 7 percent of greenhouse gas emissions come from the cement industry. In the industrial setting, one ton of cement requires the release of one ton of carbon dioxide into the environment. Concrete must be made with the substitute materials in order to lower this emission. There are numerous substitutes, including glass powder, eggshell, fly ash, and rice husk ash. When choosing an alternative in building, it should be affordable and accessible. Glass is an amorphous substance made by heating a mixture of silica, soda ash, and calcium carbonate to a high temperature, then chilling the mixture to allow for solidification without the need for crystallization. River sand is used as fine aggregate in concrete since the need for concrete is growing daily.
Around the world, tons of waste glass are produced each year. Glass refuse is still an unsustainable product that is dumped in landfills since it doesn't break down naturally. (An approximate survey indicates that more than 200 million tonnes of glass garbage are dumped in landfills each year.) We are all aware that silica makes up the majority of glass.
As a result, the grinding and partial replacement of cement in concrete with glass waste represents a significant advancement in the creation of cost-effective, environmentally friendly, and energy-efficient infrastructure systems.
Concrete that contains up to 60% more waste glass powder exhibits greater dense characteristics in the interfacial transition zone. The outcomes also demonstrate that all concrete exhibits increased strength and compactness when combined with glass powder. It has also been noted that, technically, high volume transfer of water and chloride is impeded in glass powder concrete.
Thus, the results of the investigation indicate that replacing cement-based concrete with finely crushed glass powder can increase durability attributes by up to 60%. The concrete with the best strength and lowest porosity was made with glass powder instead of cement.

2. REVIEWS OF LITERATURES STUDIES

1. **S.P Kanniyappan & T. Muthukumaran** et al [1] studied the effect of glass powder on compression strength and tensile strength of concrete and it is partially replaced with some proportions. a detailed evaluation is done at ages of 7,14,28 days of curing. results showed that higher replacement ratios increases in higher strength.
2. **G.M Sadiqullasm , M.H Rahman** et al (2017) [2] studied the sustainable concrete practice by replacing waste glass with cement and evaluated the chemical analysis of both colored & clear glass using X-ray Fluorescence technique (XRF). Results show that flow diameter increase in percentages of replacement, the compression results showed that they increased with higher replacements.
3. **Gaurav chand, Mithila Achintha** et al (2023) [3]investigated replacing glass powder with cement at various percentages and assessed the chemical reactions that occur when cement hydrates on chemical compounds. The ideal percentage of cement replacement, glass powder reactions, and the hydration mechanism of Portland cement were all studied in the experimental investigation. In the study, they substituted cement compounds of C3S and C2S for 0–40% of the glass powder. The content of primary and secondary C-S-H generated in concrete with waste glass powder can be determined by analyzing the hydration reactions of C3S and C2S as well as the reaction of CH with the silica contained in the glass powder. The maximum amount of total C-S-H generated determined the ideal cement replacement percentage waste termination.
4. **Daban.A.Muheddin &Rahel K.Ibrahim** et al (2023) [4] examined the effects of replacing some of the cement and sand with glass powder. Their research looks on the properties of concrete that has waste glass powder (WGP) mixed in with some sand and cement. After 7, 28, 60, and 90 days of moist curing, laboratory experiments were conducted to assess the compressive strength and split tensile strength of concrete with 0%, 5%, 10%, 15%, and 20% partial substitution of cement and sand individually by WGP. The findings indicate that the use of WGP can significantly increase the compressive strength of concrete at 7, 28, 60, and 90 days.

5. **Al-jburi Najad &A. Hasan Kareem,** et al (2023) [5] investigated the novel applications of leftover glass in cement and concrete, the effects of pozzolanic and thermal activity on the waste glass's properties, and the influence of the glass's qualities on the toughness and functionality of the resulting cement and concrete. The study's parameters include waste glass's thermal behavior. The best use of waste glass as a partial replacement in cement is approximately 15%, 16%, 17.5%, or 20% for aggregate and fine; the best use for waste glass sludge is approximately 10%.
6. **K.I.M. Ibrahim** et al (2021) [6] conducted an experimental investigation on the use of recycled waste glass powder in concrete containing fly ash and silica fume as a partial replacement for cement. Both the fresh and hardened stages of the concrete's qualities are examined in that experimental investigation. When the complete degree of curing was reached in 7, 14, 28, and 96 days, waste glass powder was substituted with cement ratios of 0%, 5%, 10%, 15%, and 20%. The results demonstrated that using waste glass powder (WGP) as cement in concrete is appropriate. Using an optimal WGP proportion increases the compressive and tensile strengths declined after replacements.
7. **Hosana. S, Snega. S** et al (2019) [7] investigated the analysis of using glass powder in place of some cement. This study investigates the viability of replacing some of the cement in fresh concrete with glass powder. In order to create cubes, glass powder was substituted in portions of 0%, 25%, 35%, and 50%. The cubes were then evaluated for compressive, tensile, and flexural strength at different ages and the results were compared to those of standard concrete. The findings shown that, in comparison to traditional concrete, glass powder concrete efficiently boosts compressive, tensile, and flexural strength. Compressive strength and split tensile strength dropped .
8. **Aniket sharma et al (2021) [7]** composes a research report on the substitution of glass powder for cement. In this investigation, new concrete formulations included glass waste powder (GWP) in place of some cement. For this objective, two concrete mixes with corresponding compressive strengths of 25 MPa and 32 MPa were developed, with cement being partially replaced by 0%, 10%, 15%, 20%, and 25% waste glass powder. The results indicated that replacing concrete improves the workability of concrete while having no appreciable effect on the air content material in sparkling concrete.
9. **Mohammad ShoebSayeeduddin et al (2016) [7]** carried out a study on the partial substitution of cement in fiber-reinforced concrete with glass powder. In this work, waste glass powder was used in place of cement, with increments of 5% in M20 from 0% to 40%. At 7, 28, 60, 90, and 180 days of age, the concrete specimens underwent tests for workability, splitting tensile strength, flexural strength, and compressive strength. The investigation was completed. The Increased and split tensile strength gains with greater replacement levels exhibited the highest percentage increases in compressive strength.
10. **Shanmuguanathan ,Gokila.R** et al (**2017**) [8] conducted an experimental investigation on the partial replacement of cement with glass powder. Porosity, water absorption, the alkali-silica reaction, workability, and compressive strength were determined when cementitious material was partially replaced in concrete in ratios of 10%, 15%, and 20%. The findings indicate that adding more glass powder causes the slump value and flexural strength of the concrete to decline more than that of regular concrete, the workability decreased and the flexural strength increased.

3. Material Collection

Cement:

In building, a cement is a binder—a chemical that binds other materials together by setting, hardening, and adhering to them. Cement is primarily used to bond materials, like as sand, together. It is rarely used alone. Masonry mortar is made from cement combined with fine aggregate, and concrete is made from cement combined with sand and gravel. When regular Portland cement of grade 53 was utilized, IS 269-1969 requirements were met.

Because of its excellent compressive strength, OPC 53 grade cement is the recommended variety. The phrase "53 Grade" refers to the cement's minimum compressive strength, which it reaches after 28 days of curing, of 53 MPa.

Composition and Properties of OPC 53 Grade :

Materials containing silica, alumina, iron oxide, calcareous and argillaceous particles make up the majority of OPC 53 grade cement. After the components are heated to high temperatures, a nodule known as clinker is produced, which is subsequently crushed into a fine powder. We call this fine powder cement. One of the most popular types of cement is Portland cement. Ordinary Portland Cement is created by grinding Portland clinker with gypsum. The particular ratio and combination of these ingredients affect the cement's characteristics.
According to a procedure carried out using Pycnometer equipment that complies with IS12269-1987, the specific gravity of cement is 3.15 .
Glass Powder:
A byproduct of making glass is waste glass powder. Glass becomes a fine powder once it is crushed and milled. Generally speaking, this powder is regarded as a waste product. The leftover glass is ground into tiny particles and used in place of cement. The results of the compressive strength test indicate that the combination of recycled glass and concrete produced samples with greater strength and durability than the other samples. It saves the environment in addition to controlling costs.
Description of glass powder utilized in this project:
Glass powder is a waste product that is milled and crushed in a breaker before being sieved through sieves to create granules. It is utilized for blasting surfaces, reinforcing synthetic polymers.
Glass powder specification:

Compound	Value (%)
SiO2	71.1
CaO	9.2
Fe2O3	0.16
AI2O3	0.95
MgO	4.4
Na2O	12.6

Water:
Water is the key ingredient, which when mixed with cement, forms a paste that binds the aggregate together. The water causes the hardening of concrete through a process called hydration. The quality of water has great influence on strength and durability of concrete. pH value of water should be between 6 and 8. Water should be free from organic and other impurities. Locally available potable water free from impurities is used in the present study.
Fine aggregate:
The term "fine aggregate" in concrete refers to the tiny, inert particles that are essential in defining the final concrete's characteristics. According to IS 383, the specific gravity of fine aggregate is 2.64.
Coarse aggregate:
Coarse aggregate consists of granular materials that are larger in size compared to fine aggregates. These materials can include crushed stone, gravel, or even recycled concrete. the particles are retained on 4.75mm sieve. The specific gravity of coarse aggregate is 2.74 as per IS 383 (part 3):1963.
Hydrochloric acid :
Hydrochloric acid is an aqueous solution of hydrogen chloride (HCl), sometimes referred to as spirits of salt or muriatic acid. The solution is colourless and has a strong, odorous fragrance. It is under the strong acid category. It is a part of the stomach acid found in most animal digestive systems, including human digestive systems. An essential industrial chemical and laboratory reagent is hydrochloric acid. A volume of approximately 5 litres is required for submerging the cube specimen in hydrochloric acid.
Mix design :

Cement	447 kg/m^3
Water	197 litres
Fine aggregate	752 kg/m^3
Coarse aggregate 20mm	1028 kg/m^3

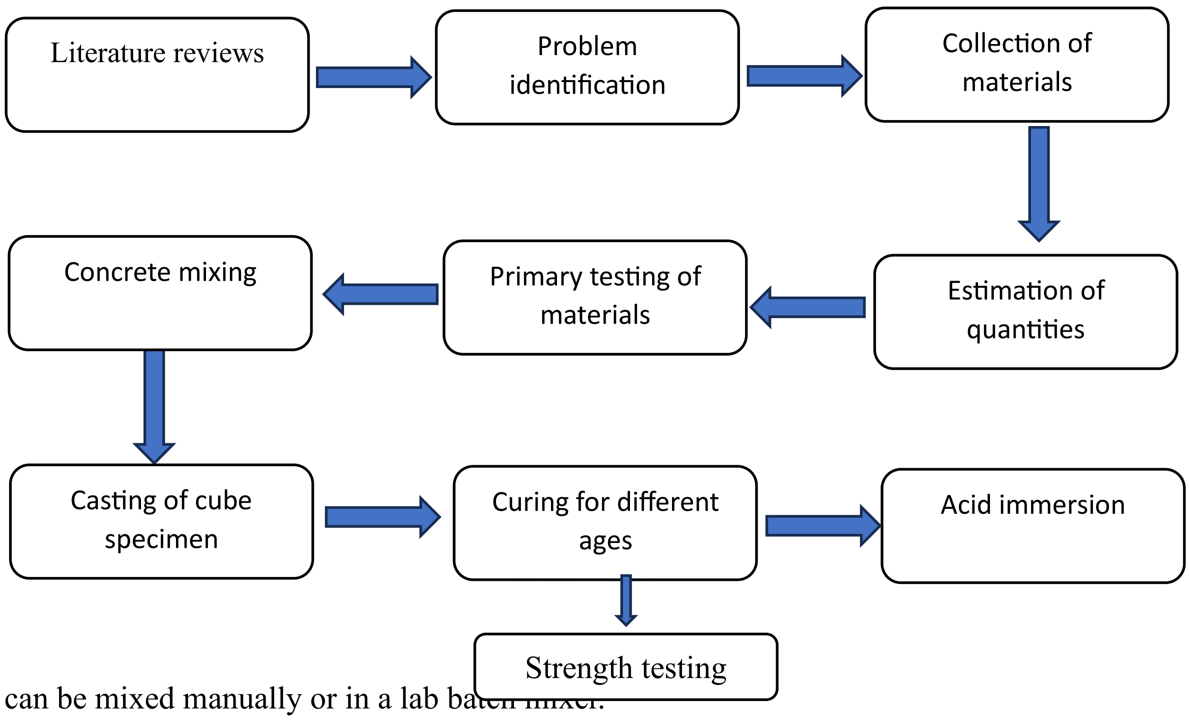
Water-cement ratio	0.44
Mix Proportion By weight	**1:1.68:2.29**

4. METHODOLOGY

The proposed methodology involves stages to full fill the objectives of the present research work.

1. The first step involves the identification of the research problem and reviewing the previous literature to fix the objectives of the research.
2. The second step involves collecting materials, designing mix patterns for commencing the work.
3. The third step involves calculating the quantities required for casting cube specimens.
4. The fourth step involves testing materials for workability, weight proportions i,e slump cone test, specific gravity test as per requirements of the IS codes.
5. The fifth step consists of mixing concrete (hand mixing) , glass powder by weight proportions, fine & coarse aggregate with Suitable W/c ratio as per the requirements of Indian standard code.
6. The mortar is filled in the cubes after lubrication and allowed to settle for hardening for 24 hours.
7. In the seventh step the cube specimens are cured for respective ages.
8. The strength tests are conducted on compression testing machine (Ctm) and and the other cube specimens are immersed in acid (Hcl) for 28 days age.
9. The acid attacked specimens are tested for weight loss proportion & strength.

Flow chart for methodology :



Mixing :
Concrete can be mixed manually or in a lab batch mixer.

Hand mixing:

(i) Add the coarse aggregate and mix with the cement and fine aggregate until the coarse aggregate is evenly distributed throughout the batch.
(ii) Add water and mix the mixture until it looks homogeneous and has the desired consistency.
(iii) Mix the mixture on a watertight, non-absorbent platform until it is completely blended and uniform in colour.

Procedure of Slump test :

i) A thin layer of oil is applied after the interior surface of the mould has been properly cleaned.
(ii) A horizontal, smooth, firm, and non absorbent surface is used to set the mould.
(iii) After that, the mould is filled with freshly mixed concrete in four levels, each about one-fourth of the mould height.
(iv) The rounded end of the tamping rod tamps each layer 25 times, distributing the strokes uniformly across the cross section.

(v) A trowel is used to knock the concrete off the level after the top layer has been rodded.
(vi) The concrete is promptly cleared of the mould by gradually elevating it vertically.
(vii) It is measured how much the highest point of the subsiding concrete differs from the height of the mould. The concrete slump is shown by this variation in height in millimetres.

Casting & Curing:

i) Oil the mounds and clean them.
(ii) Use a tamping rod (a steel bar with a 16mm diameter and 60cm length, with a bullet tip at the bottom end) to compact each layer of concrete in the moulds with a minimum of 35 strokes.
(iii) Fill the moulds with concrete in layers that are about 5 cm thick.
(iv) Use a trowel to level and smooth the upper surface.
(v) The cube Specimens are cured in curing tank for different ages.

Casting of Cubes Curing of Cubes

Compression strength test :

Objective :To find out the compressive strength of 24 test specimens.
Apparatus: Compression testing machine
Specimen:52 cubes of 15*15*15 cm size mix of M50 (design mix)
Procedure:
(i) Remove the specimen from water after specified curing time and wipe out excess water from the surface.
(ii) Take the dimension of the specimen.
(iii) Clean the bearing surface of the testing machine
(iv) Place the specimen in the machine in such a manner that the load shall be applied to the opposite sides of the cube cast.
(v) Align the specimen centrally on the base plate of the machine.
(vi) Rotate the movable portion gently by hand so that it touches the top surface of the specimen.
(vii) Apply the load gradually without shock and continuously at the rate of 140KG/cm2/minute till the specimen fails
(viii) Record the maximum load and note any unusual features in the type of failure.

Cube testing

Acid attack :

Objective :To find out the compressive strength of Acid soaked 24 test specimens.
Apparatus :Compression testing machine, Acid (HCL) of 5L
Specimen: 52 cubes of 15*15*15 cm size mix. M50 (design mix)
Procedure :

1. The initial weight of cube is taken as w1.
2. The cube specimens are immersed in 5L acid and left out for 28 days for complete soaking and absorption of acid.
3. The weight of immersed cube after 28 days taken out is w2.
4. The weight loss percent and compression test is determined for acid attacked specimen.

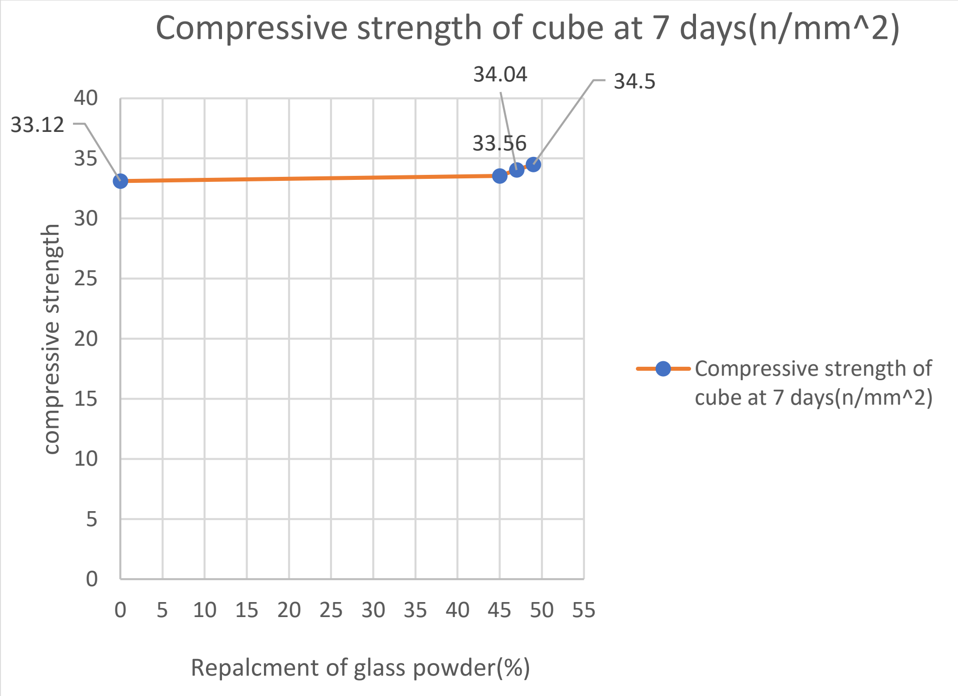
Analysis and Evaluation of Strength Properties :

Grade designation :- M50
Type of Cement:- OPC 53 Grade Conforming to IS 12269-1987
Size of Aggregate :- 20 MM
Minimum Cement content:- 320 kg/m^3
(Table 5 of IS 456-2000 exposure condition)
Exposure Condition:- Severe
Type of material used for replacement : Glass powder
weight of proportions to be replaced : 43%, 45%, 47%
Maximum Water cement Ratio:- 0.45 (Table 5 of IS 456-2000 for Exposure Condition)
Method of Concrete Placing:- Pumping
Type of Aggregate:- Crushed Angular Aggregates
Maximum Cement Content:- 450 kg/m^3
Mix design : **1:1.68:2.29**
Specimen (cubes) casted : 52 no's

Test Results :

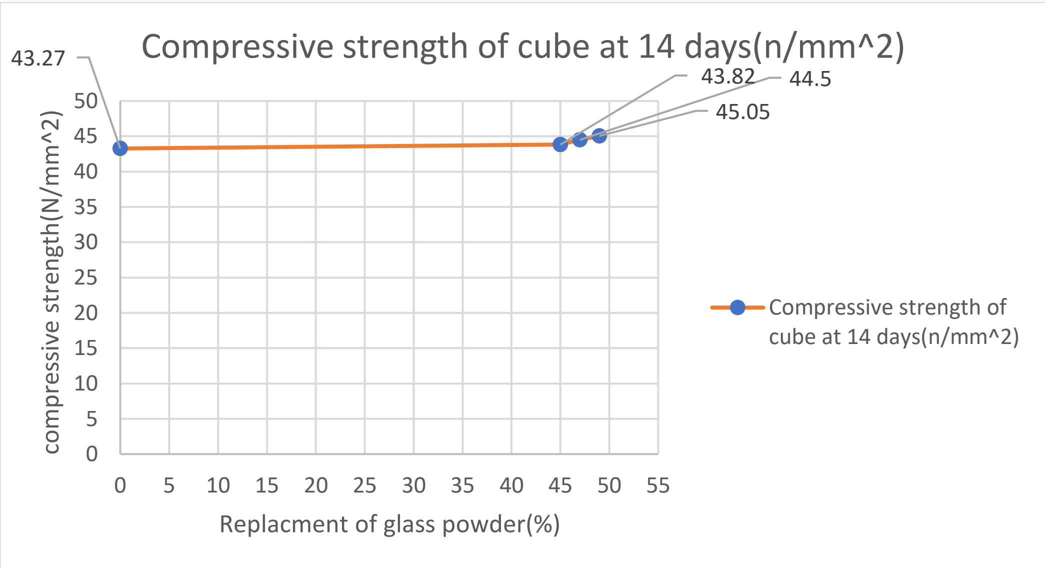
7th day load & compression Strength calculations and Graph:

Sample	Percentage		Load (P) N	Area A mm^2 (150*150mm)	Avg Compressive strength of 3 specimens P/A (N/mm^2)
	Cement	Glass powder			
Normal cube	100	0	745.2	22500	33.12
43% replaced	55	45	755.10	22500	33.56
45% replaced	53	47	765.9	22500	34.04
47% replaced	51	49	778.05	22500	34.58



14th day load & compression Strength calculations and Graph:

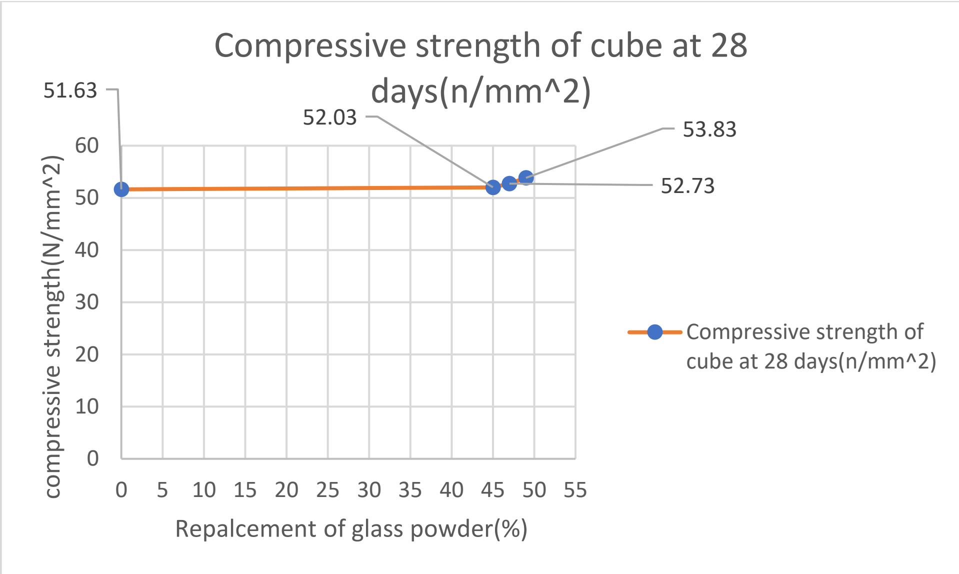
Sample	Percentage		Load (P) N	Area A mm^2 (150*150mm)	Avg Compressive strength of 3 specimens P/A (N/mm^2)
	Cement	Glass powder			
Normal cube	100	0	973.57	22500	43.27
43% replaced	55	45	985.95	22500	43.82
45% replaced	53	47	1001.25	22500	44.50
47% replaced	51	49	1013.625	22500	45.05



28th day load & compression Strength calculations and Graph:

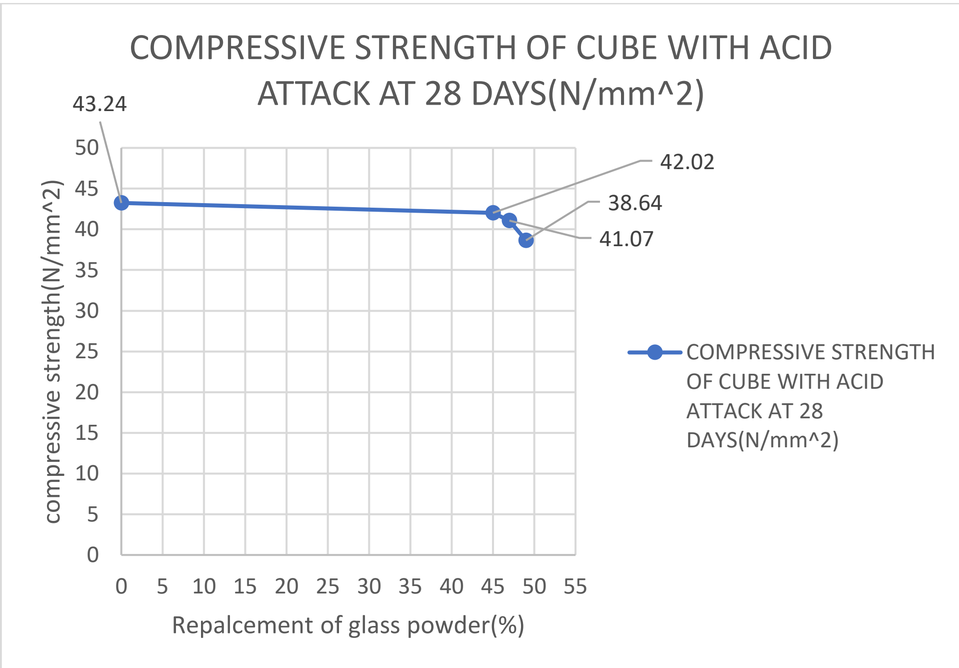
Sample	Percentage		Load (P) N	Area A mm^2 (150*150mm)	Avg Compressive strength of 3 specimens P/A (N/mm^2)
	Cement	Glass powder			

Normal cube	100	0	1161.67	22500	51.63
43% replaced	55	45	1170.67	22500	52.03
45% replaced	53	47	1211.17	22500	52.73
47% replaced	51	49	1229.40	22500	53.83

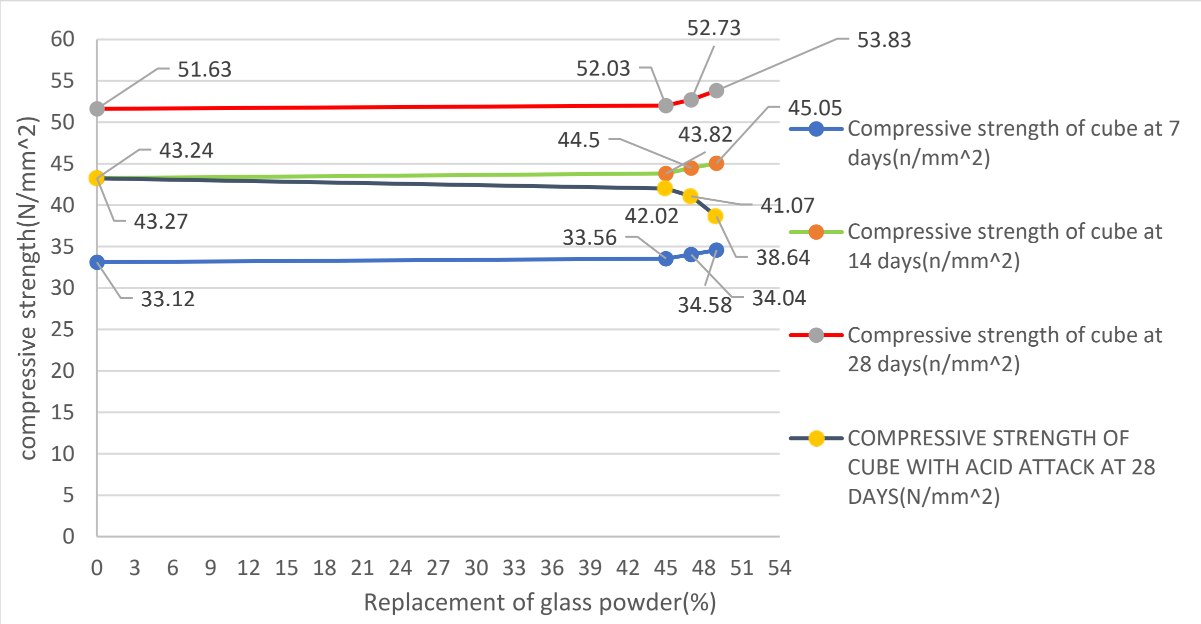


28th day load & compression Strength calculations of Acid attacked specimen and Graph :

Sample	Percentage		Load (P) N	Area A mm^2 (150*150mm)	Avg Compressive strength of 3 specimens P/A (N/mm^2)
	Cement	Glass powder			
Normal cube	100	0	972.90	22500	43.24
43% replaced	55	45	945.45	22500	42.02
45% replaced	53	47	924.07	22500	41.07
47% replaced	51	49	869.40	22500	38.64



Comparison of all ages cubes :



5. CONCLUSIONS

1. In this project, some of the cement in the concrete is swapped out for glass powder. The test findings unequivocally demonstrate that, in all proportions and at all ages of curing, the conventional concrete's compressive strength is higher than that of the concrete that was replaced with glass powder.
2. It is discovered that at 28 days of age, the compressive strength of the glass-replaced concrete reaches its maximum at 47% replacement. At levels of replacement and age, the compression strength is marginally higher than for regular cubes.
3. The degree of hydration is increased by adding waste glass powder, which results in a denser microstructure and better cure. An increase in cement replacement proportion resulted in a deterioration in concrete's workability. This is a result of glass's water absorption.
4. The specimen strength that was attacked by acid dropped as replacement percentages increased and was lower than that of a regular cube.
5. In comparison to a typical specimen, the strength characteristics marginally rise with an increase in glass powder in the concrete. The strength attained is still less than the desired strength, though. Furthermore, pozzolanic processes cause the strength to increase with age. As a result, the addition of glass powder to concrete helps to turn it from a resource that poses a threat to the environment to one that can be used to produce a highly efficient substitute cement.

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