Strength Parameters of Concrete Replacing Cement by Glass Powder with Different Dosages for M25 and M30 Grade Concrete

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***Abstract*—In a growing country like India a huge amount of industrial waste are polluting the environmental. With a view to the above, this study aims at utilization of such industrial by product for value added application. In addition the waste can improve the properties of construction materials. The recycled glass has been used in the form of powder. The glass powder was tested with concrete and mortar. Cement was replaced by the glass powder in the proportion of 0%, 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, 50%, 55% and 60% for M25 grade and M30 grade of concrete with 0.5 and 0.44 water-cement ratios respectively. The compressive strength, split tensile strength, consistency and flexural strength were conducted for the above replacements. The result showed glass powder improves the mechanical properties. The advantages of this project are that the replacement of glass powder is economically cheap as well as a superior concrete can be made.**

***Index Terms*— Concrete, Cement, Glass Powder, M25, M30, Strength Parameters**

I. INTRODUCTION

There are shifting trends in construction materials from being natural to becoming more [1] man-made artificial and combined; biodegradable to imperishable; indigenous (local) to being transported globally; repairable to disposable; and chosen for increased levels of fire-safety. [2] These trends are liable to increase the initial and protracted terms: economic, ecological, energy, and social costs of construction materials.

Building materials can be categorized into two sources, natural and synthetic. Several naturally occurring substances such as clay, sand, wood and rocks and even twigs and leaves have been used to construct buildings. In the naturally occurring materials, many man-made products are in use, some more and some less synthetic. Natural construction materials are those that are untreated or minimally treated by industry such as lumber or glass. Synthetic materials are made in industrial settings by undergoing many human manipulations like plastics and petroleum-based paints. Both have their own applications. Mud, Stone, tents made of flexible materials such as cloth or skins and fibrous plants are the essential basic construction materials. [3] Human beings all over the world have used these three materials together to create homes to suit their local weather conditions. In general, stones are used as primary structural components in these buildings, while mud is used to fill in space between, acting as a type of concrete and insulation.

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Many researchers have thus come forward and have investigated usage of this waste glass into something of productive value. One such group of research scholars has highlighted the usage of glass in powdered form as a partial replacement of cement [4] in concrete. In relation, the recycling of waste glass as a component in concrete gives waste glass a sustainable alternative to land filling and therefore makes it economically viable. A variety of public and private research was investigated to understand the limitations of glass concrete and its properties. Results found were promising as strength tests showed the glass concrete mixtures in question to have moderate to high strengths which shows that a concrete derived from recycled glass could be effectively applied to a multitude of services including structural applications. There is considerable interest in the use of recycled glass with port land cement in making a variety of different types of cement products. This interest has been motivated by the large quantity of recycled glass available through municipal recycling programs--which far exceeds the demand for such glass from conventional markets like container manufacturers. If glass could be incorporated in cement products, it would greatly reduce the disposal of recycled glass and/or its use in lower valued markets such as fill and road base material.

The waste glass [5] is one of the issues of environmental problem. Glass is used in a variety of applications right from construction, automobiles, nose-diving submarines, doors and windows, utensils, waste containers, windscreen, medicinal bottles, soft-drink bottles, tube lights, bulbs, electronic equipments, etc. Hence, the usage of glass has increased considerably, which has in essence, contributed to the increase of waste disposal. In addition, glass waste is considered as non-decaying material that pollutes the surrounding environment.

In this paper, the aim is to study the usage of glass in powdered form as a partial replacement of cement in fiber reinforced concrete and its impact on compressive strength of concrete. A considerable amount of research work is carried around the world on fiber reinforced concrete. However, most of the studies are related predominantly to the investigation of basic properties of fibrous concrete.

II. LITERATURE REVIEW

This part summarizes the pioneer works on glass replacing cement. **Hau-yan Leung et al (2003)** studied the effects polypropylene fibers on workability. And the effects of Quality Assured processed Fly Ash also known as Pulverised Fuel Ash (PFA) and silica fume (SF) on the properties of polypropylene fiber reinforced concrete (FRC) in the fresh state were investigated experimentally under the same conditions. According to the experimental investigation, the Vebe time test is a more appropriate method than tire slump test to measure the low workability of FRC and the workability of FRC with pozzolan. 10 % substitution of cement with PF A in the fiber concrete mixes generally had positive effects on the workability of fresh mix as represented by the Vebe time test.

The study by **Jagannadha Rao K et al (2009)** aimed to determine the suitability of glass fibers for use in structural RAC of high strength. The fresh and hardened state properties of partially replaced recycled aggregate concrete, with varying percentages of glass fibers, were compared with the corresponding conventional aggregate concrete. The compressive, split tensile and flexural strengths of M50 grade concrete with 0% RCA and 50% RCA increased as the fiber content increased. The maximum values of all these strengths were obtained at 0.03% of fiber content for both the concretes of 0% RCA and 50% RCA. Large deflections of beams before failure indicated improved ductility with the addition of fibers.

Shakor & Pimplikar et al (2011) Concluded that 7 days average compressive strength of concrete is maximum when 1.5 % of glass fibres by weight of cementitious material are used. At lower 0.11% of glass fibers or higher 2 *%* of glass fibers, about 15% to 20% reduction in strength was observed nevertheless at 28 days, the reduction in strength approaches to 5% to 10%. Percentage of glass fiber of 2% gave a flexural strength of 6.15 MPa, which is 10% more than that obtained at 1.5%.

P. Sangeetha et al (2011) reported that increase in the percentage of glass fiber by weight of concrete (0.1%, 0.2%& 0.3%) increases the compressive and impact strength. The percentage increase in compressive strength was reported to be up to 23%.

H. Sudarsana Rao, M. Safari Tabalvandani, Krishan Rao MV et al (2011) Stated that workability of glass fiber reinforced high performance concrete mixes decreases with increase in the percentage of glass fibers. The work of different researchers on GFRC has been found on concretes cast by using foreign ingredients only. The trend of locally branded concretes manufactured by using indigenous materials found in Pakistan was still demanding a lot of research work. The current investigation was planned to explore the effects of using different percentages of glass fibers on properties of flesh and hardened concrete like workability, compressive strength, tensile strength, flexural strength and ultra-sonic pulse velocity.

Pshtiwan et al (2011) Studied on glass fiber reinforced concrete used in construction. They concluded that by using 20 mm of coarse| aggregate more air entraining is increased in the concrete which reduces the compressive strength of the concrete, only 10 mm coarse aggregate should be used to solve the problem of reduced flexural strength. Glass fiber helps concrete to increase compressive strength until indicated limit. A limit exists to a particular percentage from glass fiber mixed with concrete because increasing its effects on the bond of materials as is seen in the result. For 1.5% of cementations weight gained best results were obtained as compared to other results.

Ferrira et al., Bhuvaneshwari and Murali (2011, 2013) studied on Glass Fiber Reinforced Concrete (GFRC) mechanical properties for structural applications. The results showed that the presence of fibers may imply a loss of compressive strength of the material. However the presence of finer glass fibers in the matrix improved the strain hardening and crack arresting properties.

Vijaia K et al. (2011) studied on properties of glass fiber reinforced geo-polymer concrete composites. Compressive strength, split tensile strength and flexural strength of glass fiber reinforced geo polymer concrete composites decreases for the addition of 0.01 and 0.02% volume fraction of glass fiber resulted in the reduced mechanical properties.

Deshmukh S.H. et al. (2012) studied the effect of addition of glass fibers in ordinary Portland cement concrete. In the experimental investigation the effect of glass fibers in different percentage 0 to 0.1% on mechanical properties of concrete by carrying compressive strength test, flexural strength test and splitting tensile strength test were studied. The results show improvement in mechanical and durability properties with the addition of glass fibers.

III. Materials

Manufacturing Basically concrete is a versatile engineering material which can be mould in to wide verities of shapes when in wet condition. Concrete is a mixture of cement, fine aggregates, coarse aggregates, water, and admixture (if any). The red mud concrete is a mixture of cement, fine aggregates, coarse aggregates, water. In this project work we used waste glass powder as a partial replacement of cement. The ingredients are used in proper proportion. Also the cement is replaced at 15%, 20%, and 25% by glass powder.

A) Cement

Cement is one of the binding materials in this project. Cement is the important building material in today's construction world 53 grade Ordinary Portland Cement (OPC) conforming to ([17] IS: 8112-1989). Table 1 gives the properties of cement used.

Cement is a binder, a substance used in construction that sets and hardens and can bind other materials together. The most important types of cement are used as a component in the production of mortar in masonry, and of concrete, which is a combination of cement and an aggregate to form a strong building material. Cements used in construction can be characterized as being either hydraulic or non-hydraulic, depending upon the ability of the cement to set in the presence of water. [5]

- Non-hydraulic cement will not set in wet conditions or underwater; rather, it sets as it dries and reacts with carbon dioxide in the air. It can be attacked by some aggressive chemicals after setting.
- The chemical reaction results in mineral hydrates that are not very water-soluble and so are quite durable in water and safe from chemical attack. This allows setting in wet condition or underwater and further protects the hardened material from chemical attack.

Table 1: Properties of Portland Pozzolona Cement [9]

Parameter	Value
Specific gravity	2.92
Bulk density	1400kg/m^3
Loss on ignition	4.2%
Magnesium oxide (MgO)	5.1%
Sulphuric anhydride	2.2%
Insoluble material	25.12%

Figure 1: Raw Cement

B) Fine Aggregates

It is the aggregate [6] most of which passes 4.75 mm IS sieve and contains only so much coarser as is permitted by specification. According to source fine aggregate may be described as:

1. **Natural Sand**– it is the aggregate resulting from the natural disintegration of rock and which has been deposited by streams or glacial agencies
2. **Crushed Stone Sand**– it is the fine aggregate produced by crushing hard stone.
3. **Crushed Gravel Sand**– it is the fine aggregate produced by crushing natural gravel.

According to size the fine aggregate may be described as coarse sand, medium sand and fine sand. IS specifications classify the fine aggregate into four types according to its grading as fine aggregate of grading Zone-1 to grading Zone-4.

The four grading zones Crushed aggregate is a maximum size of 20 mm and normal grading. The specific gravity of the coarse aggregates of 2.73 was used. The sieve analysis of coarse and fine aggregates is confirmed to IS10262.

Become progressively finer from grading Zone-1 to grading Zone-4. 90% to 100% of the fine aggregate passes 4.75 mm IS sieve and 0 to 15% passes 150 micron IS sieve depending upon its grading zone.

Figure 2: Fine Aggregates

C) Coarse Aggregate

It is the aggregate [22] most of which is retained on 4.75 mm IS sieve and contains only so much finer material as is permitted by specification. According to source, coarse aggregate may be described as:

1. **Uncrushed Gravel or Stone**– it results from natural disintegration of rock
2. **Crushed Gravel or Stone**– it results from crushing of gravel or hard stone.
3. **Partially Crushed Gravel or Stone**– it is a product of the blending of the above two aggregate.

According to size coarse aggregate is described as graded aggregate of its nominal size i.e. 40 mm, 20 mm, 16 mm and 12.5 mm etc. for example a graded aggregate of nominal size 20 mm means an aggregate most of which passes 20 mm IS sieve.

Figure 3: Coarse Aggregates

A coarse aggregate which has the sizes of particles mainly belonging to a single sieve size is known as single size aggregate. For example 20 mm single size aggregate mean an aggregate most of which passes 20 mm IS sieve and its major portion is retained on 10 mm IS sieve.

D) Glass Power

Glass is an amorphous & transparent material, which are super-cooled liquid and not a solid. Glass can be made verity of forms and sizes from small fiber to meter-sizes pieces. Primarily glass is produced by melting a mixture of materials such as silica, CaCO3, and soda ash at high temperature followed by cooling during which solidification occurs without crystallization. Glass has been used as aggregates in road construction, masonry and building materials. Before adding glass powder in the concrete it has to be powdered to wanted size. Glass powder is obtained from Crushing of glass Pieces. A Glass powder [13] can be used as cement replacement material upto particle size less than 90µm.

Figure 4: Glass Powder

Glass powder is an extremely fine powder made from ground glass. It can be used in a number of industrial and craft applications and is often available through supplier of glass and industrial supplies. High precision machining equipment is necessary to prepare it, as it needs to be very uniform, with an even consistency. Costs vary, depending on the level of grind and the applications.

The mixing process was done using an electrically operated concrete mixer of 0.04 m^3 capacity. The concrete making and mixing in the laboratory was done with accordance to ASTMC-192. The batching procedure was as follows:

- Add coarse, fine aggregate mixing for about 2-3 minutes.
- Add cement than mixing for about 1-2 minutes.
- Add approximately two-thirds of water slowly and mix for 2-3minutes.
- Add fiber with water than mixing for 2-3 minutes.

IV. Compressive Strength Test of Concrete

Twenty four number standard specimens of dimensions 150 × 150 × 150 mm were cast according to the mix proportion and cured in water at room temperature in the laboratory for 7 and 28 days. At the end of each curing period, three specimens for each mixes were tested for compressive strength and the average strength was recorded. The size of the specimen is as per the IS code 10086 – 1982. The compressive strength test on both conventional and glass added concrete was performed on standard compression testing machine of 3000kN capacity, as per IS: 516-1959.

Figure 5: Compressive strength testing using UTM

The compressive strength of concrete cubes was tested under Universal Testing Machine. The load was applied gradually without shock till the failure of the specimen occur and thus the compressive strength of concrete cubes was found.

V. Results and Analysis

Tests on Raw Materials

- **Cement**

Table 1: Test result for Cement

S.No.	Test	Results	IS Code Used	Acceptable Limit
1	Specific gravity of cement	3.150	IS:2386:1963	3 to 3.2
2	Standard consistency of Cement	6mm at 34% w/c	IS:4031:1996	w/c ratio 28%-35%
3	Initial and Final Setting Time	50mins and 10 hours	IS:4031:1988	Minimum 30mins and should not more than 10 hours
4	Fitness of Cement	3.48	IS:4031:1988	<10%

- **Coarse Aggregates**

Table 2: Test result for Coarse Aggregates

Sl. No	Test	Results	Is code used	Acceptable limit
1	Fineness modulus	6.5	IS:2386:1963	6.0 to 8.0mm
2	Specific gravity	2.90	IS:2386:1963	2 to 3.1mm
3	Porosity	46.83%	IS:2386:1963	Not greater than 100%
4	Voids ratio	0.8855	IS:2386:1963	Any value
5	Bulk density	1.50g/cc	IS:2386:1963	-
6	Aggregate impact value	37.5	IS:2386:1963	Less than 45%
7	Aggregate crushing	26.6%	IS:2386:1963	Less than 45%

- **Fine Aggregates**

Table 3: Test result for Fine Aggregates

Sl. No	Test	Result	Is code used	Acceptable limits
1	Fineness modulus	4.305	IS:2386:1963	Not more than 3.2 mm
2	Specific gravity	2.43	IS:2386:1963	2.0 to 3.1
3	Porosity	36.6%	IS:2386:1963	Not greater than 100%
4	Voids ratio	0.577	IS:2386:1963	Any value
5	Bulk density	1.5424	IS:2386:1963	-
6	Bulking of sand	3.0%	IS:2386:1963	Less than 10%

The testing of raw materials is cement, Coarse Aggregates and Fine Aggregates in different parameter showed in above tables. Some test is depends on physical properties of materials.

Tests on Concrete

- **First concrete tests**

Table 4: Slump cone test

Sl. No	% of replacement of glass powder	Slump value for M25 grade concrete	Slump value for M30 grade concrete
1	0%	33	25
2	5%	36	25
3	10%	50	25
4	15%	55	40
5	20%	60	50
6	25%	65	50
7	30%	70	65
8	35%	75	65
9	40%	75	75
10	45%	75	75
11	50%	80	75
12	55%	100	100
13	60%	100	100

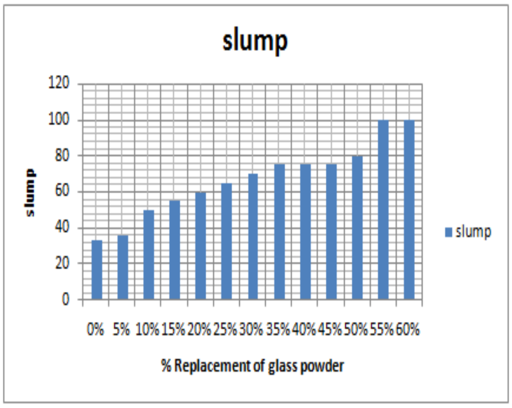

Figure 6: Graph: For M25 grade concrete

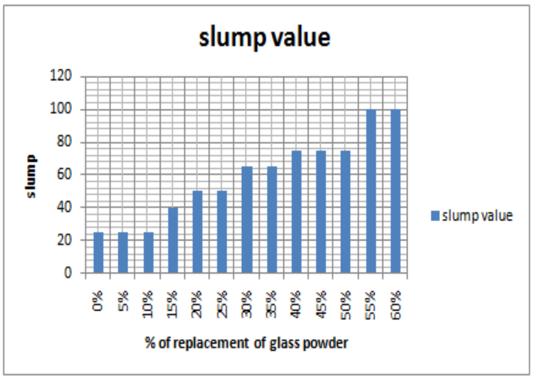

Figure 7: Graph: For M30 grade concrete

At first concrete test, Slump cone test to show as percentage replacement of glass powder in mixture. As per M25 and M30 mixture grade concrete to show different slump values of percentage of replacement of glass powder.

The result is variation of compressive strength of concrete produced by replacing cement with glass powder with glass fiber for 7 and 28 days. The results also show the variation of compressive strength of concrete replacement of glass powder for 7 and 28 days.

Table 5: Compaction factor test

s. no	% of replacement of glass powder	Compaction factor test for M25 grade concrete	Compaction factor test for M30 grade concrete
1	0%	0.932	0.862
2	5%	0.940	0.874
3	10%	0.948	0.896
4	15%	0.950	0.920
5	20%	0.965	0.90
6	25%	0.968	0.94
7	30%	0.968	0.960
8	35%	0.97	0.972
9	40%	0.972	0.986
10	45%	0.972	0.976
11	50%	0.980	0.980
12	55%	0.982	0.984
13	60%	0.988	0.99

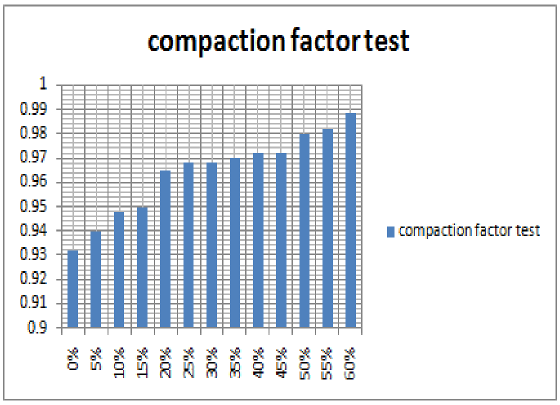

Figure 8: Graph: For M25 grade concrete

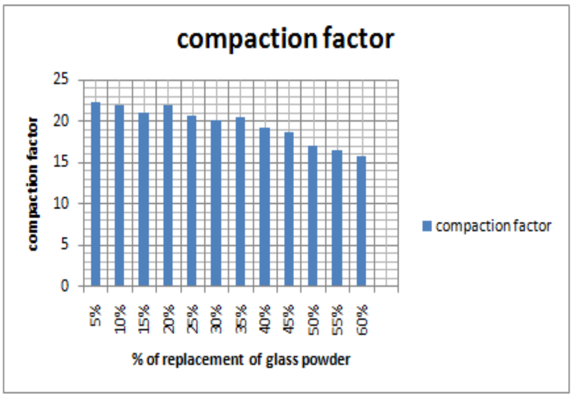

Figure 9: Graph: For M30 grade concrete

At first concrete test, Compaction factor test to show as percentage replacement of glass powder in mixture. As per M25 and M30 mixture grade concrete are show different Compaction factor of percentage of replacement of glass powder.

- **Tests on Hardened Concrete**

Table 6: Compressive Strength of Concrete

Sl. No	% replacement	Compressive strength of concrete for M25 grade concrete		Compressive strength of concrete for M30 grade concrete	
		7days	28days	7 days	28days
1	0%	24.30	24.98	29.40	29.96
2	5%	22.36	23.24	27.46	28.34
3	10%	21.98	22.40	26.84	27.60
4	15%	21.00	21.80	26	26.40
5	20%	21.90	22.20	26.20	26.90
6	25%	20.60	21.80	24.80	25.60
7	30%	20.10	20.60	24.20	25.20
8	35%	20.48	20.40	24.60	24.80
9	40%	19.20	20.10	23.10	24.20
10	45%	18.60	19.10	22.80	23.10
11	50%	16.98	18.60	21.00	22.50
12	55%	16.40	17.00	20.60	21.20
13	60%	15.80	16.20	20.20	20.30

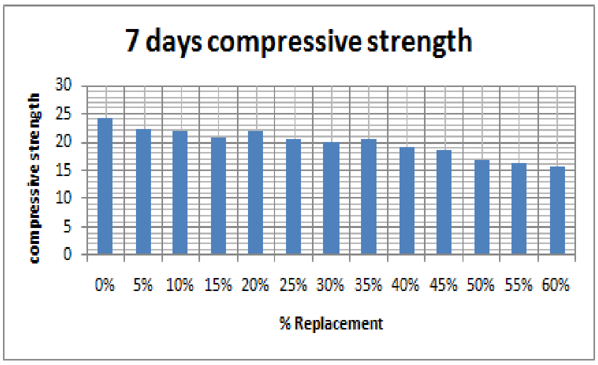

Figure 10: Graph: 7 days compressive strength of concrete for M25 grade concrete

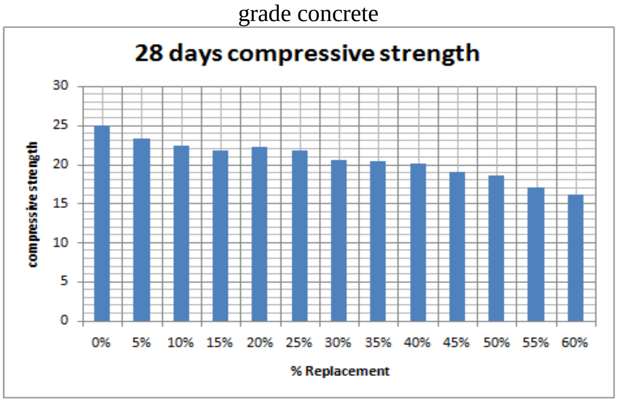

Figure 11: Graph: 28 days compressive strength of concrete for M25 grade concrete

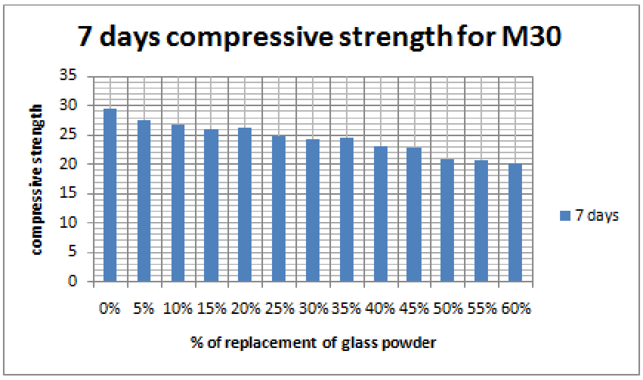

Figure 12: Graph: 7 days compressive strength of concrete for M30 grade concrete

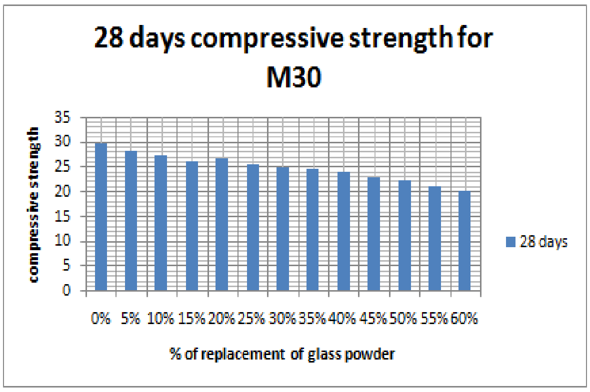

Figure 13: Graph: 28 days compressive strength of concrete for M30 grade concrete

At **Tests on Hardened Concrete**, Compressive Strength of Concrete test to show as percentage replacement of glass powder in mixture. As per M25 and M30 mixture grade concrete are show different Compressive Strength of Concrete of percentage of replacement of glass powder in 7 and 28 days.

VI. Conclusion

The following conclusions are made based on the above work:

i. The material properties of the cement, coarse aggregates, and fine aggregates are within the acceptable limits hence theses materials are suitable for the research.

ii. The optimum value of compressive split tensile and flexural strength of concrete was observed at 20% replacement of cement by glass powder.

iii. The slump of concrete increases monotonically as the replacement cement with glass powder increases. The workability decreases when cement is replaced partially with glass powder.

iv. The present study shows that there is a great potential for the utilization of glass powdering concrete as partial replacement of cement. About 20% of cement may be replaced with glass powder without any sacrifice on the compressive strength.

v. Further investigation can be done by using plasticizers to improve the workability and strength. Also durability investigations can be done in sees the long term effect of glass powder replacement.

vi. From the analysis and discussion, we are clearly understood that the objectives of this study are achieved. The objectives of the research are:

   a. The main purpose of this research is to check the compressive strength of the concrete using the waste glass powder.

   b. To check the workability of the concrete using the waste glass powder.

vii. Considering the strength criteria, the replacement of cement by glass powder is feasible. Therefore we can conclude that the utilization of waste glass powder in concrete as cement replacement is possible.

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