Comparative Strength Studies Of Concrete By Using Waste Glass Powder And Fly Ash As Partial Replacement Of OPC.

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Abstract*:* The raw materials used in the manufacturing of cement come from natural resources which are limited. These natural resources are depleting day by day. Also, the manufacturing process of cement releases large quantities of Co_2 in the atmosphere. The Co_2 is considered as a major greenhouse gas and results in global warming. Some of the waste materials produced in the industries have Cementous properties and can be used in concrete thus reducing the cost of construction and also helps in tackling the disposal problem associated with these materials. The purpose of this study is to investigate the strength properties of concrete by partial replacement of cement with fly ash and glass powder. Glass is an inert and amorphous material which can be recycled and used many times without changing its chemical properties. Glass contains high silica content thus making it pozzolonic when particle size is less than 75µm. Fly ash is produced in large quantities from the thermal power plants and has Cementous properties when used in proper proportions with cement in concrete. This study involves partial replacement of cement with fly ash and glass powder in the proportions of 10%, 20%, and 30% by weight in M30 mix. Different strength parameters like compressive strength, flexure strength and split tensile strength of the concrete mixes obtained from the partial replacement of cement with fly ash were compared with those of the glass powder after 7 day and 28 days curing. The results showed that the strength of concrete containing fly ash as partial replacement of cement was more than the concrete containing glass powder.

Key words: Fly Ash, Glass powder, Compressive Strength, Split tensile strength, Flexure strength.

1. INTRODUCTION

Large amounts of Co_2 are released into the atmosphere during the manufacturing process of cement. Co_2 is a greenhouse gas and causes global warming. Among the various greenhouse gases, the contribution of Co_2 to the global warming is about 65%. Out of the total Co_2 emitted globally every year into the atmosphere about 7% is emitted by cement industry alone. In order to address these environmental issues associated with cement manufacturing, there is a need to develop alternative binders to make concrete. Researchers are working to use waste materials and industrial by products in the concrete by partially replacing cement. In this study waste glass powder and fly ash has been used as partial replacement of cement in varying proportions to analyse their mechanical properties.

Glass can be used in different forms in concrete, it can be used either as a coarse aggregate or as a fine aggregate or in the powdered form as a cement replacement. When glass is used as coarse or fine aggregate it has susceptibility to undergo reaction with alkalis called alkali-silicate reactions with deleterious effects on concrete. Studies have shown that finely ground glass does not contribute to alkali -silica reaction. The fine glass powder exhibits pozzolonic properties and could act as a suppressant to the alkali-silicate reactions in the presence of reactive aggregates. On the market price basis, it would be more profitable to use glass in the powder form as a cement replacement then to use as aggregates. In the recent, various attempts and research have been made to use ground glass as a replacement in conventional ingredients in concrete production as a part of greenhouse management.

Fly ash is a cementitious by-product obtained from the combustion of coal. Large quantity of fly ash is generated in thermal industries on daily basis with an adverse impact on the environment and humans. Researchers have established that the use of supplementary cementitious materials (SCMs) like fly ash (FA), silica fume, blast furnace slag, metakaolin(MK), and rice husk ash (RHA), hypo sludge etc. can, not only improve the various properties of concrete - both in its fresh and hardened states, but also can contribute to economy in construction costs.

2. RESERCH OBJECTIVE

The objective of this research is to study the effect of the use of Glass Powder and fly ash as a partial replacement of cement on the strength properties of concrete. The primary objective of this study is to know the extent to which glass powder and fly ash can replace cement. The ordinary Portland cement was replaced by Glass powder and fly ash by 10%,20% and 30% and tested for its compressive, Tensile and flexural strength at 7th day and 28th day of age and the results were compared. The main objectives of this study are:

- The primary objective of this study is to investigate the practicality, versatility and feasibility of utilizing fly ash and recycled glass as a partial replacement to cement.
- To study the effect of addition of different percentages of Fly ash i.e. 10%,20%, & 30% on strength properties such as compressive strength, flexural strength and split tensile strength of concrete.
- To study the effect of addition of different percentages of Waste glass powder i.e. 10%,20%, & 30% on strength properties such as compressive strength, flexural strength and split tensile strength of concrete.
- Determine the optimum fly ash to be added as a partial replacement of cement.
- Determine the optimum waste glass powder to be added as a partial replacement of cement.
- To Compare the results and to find which material is giving best results at different percentages.

3. LITERATURE REVIEW:

Oliveira L.A Pereira de this study focused on using different sizes of waste glass powder (75µm – 150µm,45µm – 75µm and < 4µm) as a Cementitious material and used glass powder as filler or binder in mortar and concrete. This study concluded that the glass powder in the range of 45µm – 75µm give best results and there are no alkali-silicate reactions in this range. The concrete showed best properties at 30% replacement of cement.

Bajad M.N. et.al this study focused on the behaviour of the concrete containing glass powder subjected to sulphate attacks. The peak compressive strength was achieved at 20% replacement of cement by waste glass powder in both cases when concrete is not subjected to sulphate attacks and when concrete is subjected to sulphate attacks. This increment in compressive strength increases upto 25% replacement beyond which it decreases.

Jangid Jitendra B. and Saoji A.C. [2012] workability of the concrete containing waste glass powder as cement replacement was studied. They concluded that workability of concrete decreases with the increase in the percentage of the glass powder in the mix.

Saoji A.C. [2012] compressive strength increases upto 20% when cement is replaced by glass powder upto 40% beyond that compressive strength decreases.

Dali J.S. and Tande S.N. [2012] in this study cement was replaced by waste glass powder and mineral admixtures were added. It was the subjected to alternate wetting and drying and high temperature. They concluded that the strength parameters like compressive strength, flexure strength and split tensile strength of concrete attains peak values when the replacement of cement was at 20%.

Chikhalikar S.M. and Tande S.N. [2012] this paper presented a study conducted on Steel Fibre Reinforced Concrete (SFRC) in which cement was replaced by waste glass powder at different levels. This study concluded compressive strength, flexure strength and split tensile strength all increase with the increase in the percentage of glass powder upto 20% replacement beyond that it decreases. The maximum value of all these parameters were found at 20% dosage of waste glass powder.

Vasudevan Gunalaan and Kanapathy pillay Seri Ganis [2013] they investigated the test results at 7, 14 and 28 days of curing of specimens containing glass powder as partial replacement of cement. The cement was replaced by glass powder by 10%, 15% and 20%.

G.M. Sadiqul Islam [2017] declared fine glass powder as pozzolanic according to ASTM standards. The flow of the concrete was increased slightly with increase in the glass powder content. Considering the mortar and concrete compressive strength the optimum glass content is 20%. The compressive strength was found to be 2% more than the control mix at 90 days.

Hongjian Du And Kiang Hwee Tan unlike previous works, this work focused on using higher percentages of glass powder upto 60%. Some of the conclusions presented in this paper are.

1) The rate and the total amount of heat generated during hydration process continuously decreases with the increase in the glass powder content. As the glass powder show negligible water absorption capability, higher glass powder content shows smaller shear yield stress.
2) The 7-day compressive strength was found to be optimum at 30% replacement. However, with respect to resistance to chloride penetration and water absorption, 60% was found to be the optimum replacement.

Abdullah Anwar et al this study concluded that fly ash is a rich cementitious industrial waste material. The 28-day compressive strength was found maximum at 30% replacement of cement by fly ash.

Md. Moinul Islam and Md. Saiful Islam the test results show that the strength increases with the increase in the fly ash content up to an optimum value beyond which it starts decreasing. The optimum content was found to be 40%. At this replacement, the compressive strength and tensile strength were found 14% and 8% higher than the OPC mortar.

Samaresh Pan concluded that the use of fly ash in concrete results in considerable variation in the properties of fresh concrete. Using fly ash prevented segregation, increased the cohesiveness and reduced the bleeding of the mix. Use of higher percentages of fly ash can cause a change in colour of the mix.

Irshad Ali conducted a comparative study by using two different materials, glass powder and fly ash in different proportions. The strength parameters where studied and compared with the control mix at 7 and 28 days duration of curing. Three different types of mixes were prepared- fly ash, glass powder and fly ash + glass powder. This study concluded that the mixes containing fly ash as replacement gives best results than the other two types of mixes.

4. MATERIALS

4.1 **Cement:** Ordinary Portland cement of grade 53 (Khyber) conforming to IS 12269 from a single lot was used throughout the course of the investigation. It was fresh, grey in colour and dry without any lumps or moisture.

4.2 **Fine Aggregates:** clean river sand whose maximum size was 4.75 mm, conforming to IS 383 (1987) grading zone II was used in this study.

4.3 **Coarse Aggregates**: Machine crushed stones, angular in shape were used as coarse aggregate conforming to IS 383 (1987).

4.4 **Water:** Potable water was used throughout the course of study. This water was free from any detrimental contaminants and was of good quality.

4.5 **Fly Ash:** Fly ash of class F was used in this study and was grey in colour. Size of particle of fly ash was in the range of 0.1µm - 150 µm. the physical and chemical properties of fly ash determined by various laboratory tests are listed below. The specific gravity was found to be 2.30 and bulk density was 400kg/m^3.

TABLE 1. CHEMICAL COMPOSITION OF FLY ASH

Constituents	%age
SiO_2	55.67
Al_2O_3	26.24
Fe_2O_3	2.89
K_2O	1.65
S	1.5
CaO	1.01
MgO	0.36
Na_2O	0.24
Loss on Ignition	10.44

4.6 **Glass Powder**: Glass waste available locally was collected and was turned into glass powder. Glass waste being hard material need to be powdered to desired size before adding it to the concrete. In this study, Waste glass was grinded in ball/ pulveriser for a period of 30 to 60 minutes. It resulted in glass powder having particle sizes less than 150µm and sieved in 75µm. Specific gravity of glass powder was 2.6. Composition of glass as determined by laboratory tests is given below.

TABLE 2. CHEMICAL COMPOSITION OF GLASS POWDER

Oxide contents	%age
SiO_2	67.330
CaO	12.450
Na_2O	12.050
MgO	2.738
Al_2O_3	2.620
K_2O	0.638

4.7 RESULTS OBTAINED VIA MATERIAL TESTING

- Sand is of zone II
- Poorly graded sand.
- Fineness modulus = 2.58, hence fine grained sand.

- Specific gravity = 2.63
- Specific gravity of coarse aggregate = 2.67
- Standard consistency of cement = 30%
- Initial setting time of cement = 3hour 40minutes
- Final setting time of cement = 5hour 20minutes
- Compaction factor of concrete = 0.85

4.8 MIX DESIGN:

The mix is designed keeping in view the required workability and the characteristic strength. The various proportions of the mix are selected either by volume or by mass. In this study M30 was designed with water cement ratio of 4.5. Design mix is obtained as 1: 1.3: 2.8.

TABLE 3. MIX DESIGN

constituent	Quantity Kg/m^3
cement	419.5
Fine aggregate	554
Coarse aggregate	1195

5. CASTING OF SPECIMEN:

In this study Seven types of mixes were prepared; of which One was control mix (i.e. without glass powder and fly ash) and was designed according to Indian Standard Specification IS: 10262(1999). Three mixes were prepared by replacing 10%, 20% and 30% of cement by glass powder and rest three mixes were prepared by replacing 10%, 20% and 30% of cement by fly ash.

5.1 CASTING OF CUBES: 150 x 150x 150 mm steel cube moulds were used to determine the compressive strength. Various constituent materials were weighed and were initially mixed in dry state. Water was added in the required quantity and it was thoroughly mixed manually for 3-5 minutes to get uniform colour of mix. The mix was poured in cubes and the cubes were compacted by a vibrating table. In total 42 specimens were casted from all the 7 mixes (6 from each mix).

5.2 CASTING OF CYLINDERS: 300 mm length and 150mm diameter cylinders were cast according to the mix proportion and cured in water at room temperature in the laboratory for 7 and 28 days. Various constituent materials were weighed and were initially mixed in dry state. Water was added in the required quantity and it was thoroughly mixed manually for 3-5 minutes to get uniform colour of mix. then the mix was poured in the cylinder layer by layer and each layer was thoroughly compacted. In this case, total 42 specimens were casted from all the 7 mixes (6 from each mix).

5.3 CASTING OF BEAMS: The concrete mixes were filled in the Beam moulds. Forty-two number standard specimens of 500× 100× 100mm were casted from the mixes.

6. CURING:

After 24 hours, all the specimens were removed from their moulds and were stored in clean water at normal temperature. All Cubes, Cylinders and Beams were de-moulded and were kept in water for curing at normal temperature. The concrete specimens were taken out of the curing tank after 7days & 28 days of curing for testing.

7. TESTING METHODOLOGY

7.1 COMPRESSIVE STRENGTH TEST: The compressive strength tests were performed on standard compression testing machine of 3000kN capacity, as per IS: 516-1959 on both glass and fly ash added concrete. The tests were performed on standard specimens of dimensions 150 × 150 × 150 mm as per the IS code 10086 – 1982. During the compression test load is applied slowly without any shock and increased continuously at a rate of approximately 140 kg/cm^2/min until the specimen breaks down and no further load is sustained. the load at failure is noted down and the compression strength is calculated by the formula;

Compressive strength = P/A (1)

P = Maximum applied load just before the failure, A = Plan area of cube mould in mm^2

7.2 SPLIT TENSILE STRENGTH TEST: The test is carried out by universal testing machine. The cylindrical specimen is placed horizontally between the loading surfaces and the load is applied until failure of cylinder along the vertical diameter takes place. Split tensile strength is calculated by the formula;

Split tensile strength, $f_{sp} = 2P/\pi DL$ (2)

Where P = Load at failure in N, L = Length of the Specimen in mm, D = Diameter of the Specimen in mm

7.3 FLEXURAL STRENGTH: It is also known as known as modulus of rupture. It is defined as the ability of a material to resist deformations under loads. The value of flexural strength of a beam depends on the type of loading and the dimensions of the beam. The loading is generally applied centrally or third-point loading. In this case third-point loading is applied. The critical crack can appear at any section, where bending moment is maximum or the resistance is minimum. Flexural strength is calculated by formula,

The flexural strength when a >133 mm for 100 mm specimen,

$f_b = Pa / bD2$ (3)

The flexural strength when a < 133 mm for 100 mm specimen,

$f_b = 3Pa / bD2$ (4)

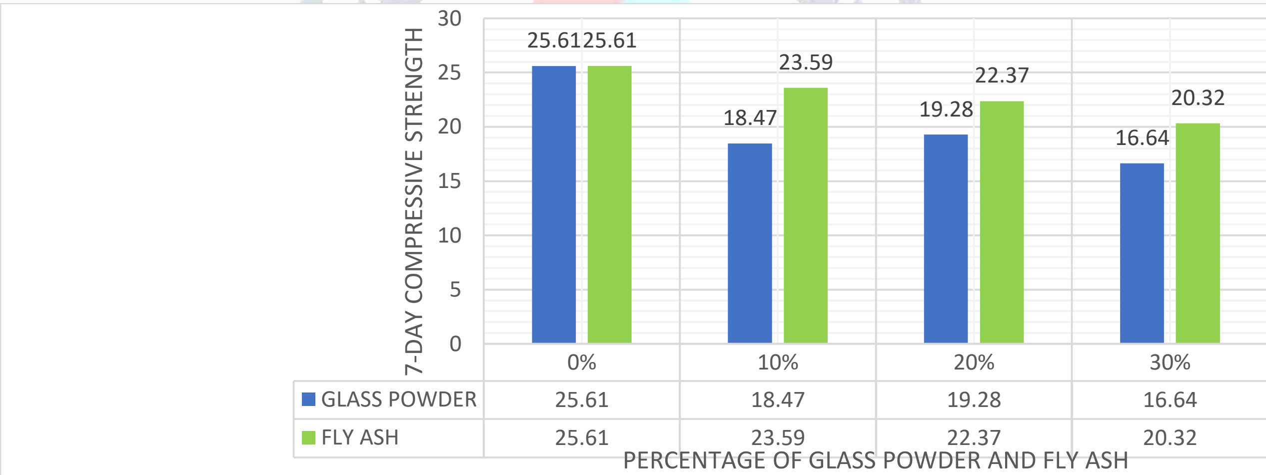
where b = measured width of specimen in mm, D = measured depth in mm of the specimen at the point of failure, a = distance of the crack from the nearer support in mm, P = maximum load in N applied to the specimen.

8. RESULTS AND DISCUSSIONS:

The following tables and graphs give the details of the experimental results of concrete mixed with Glass powder and fly ash.

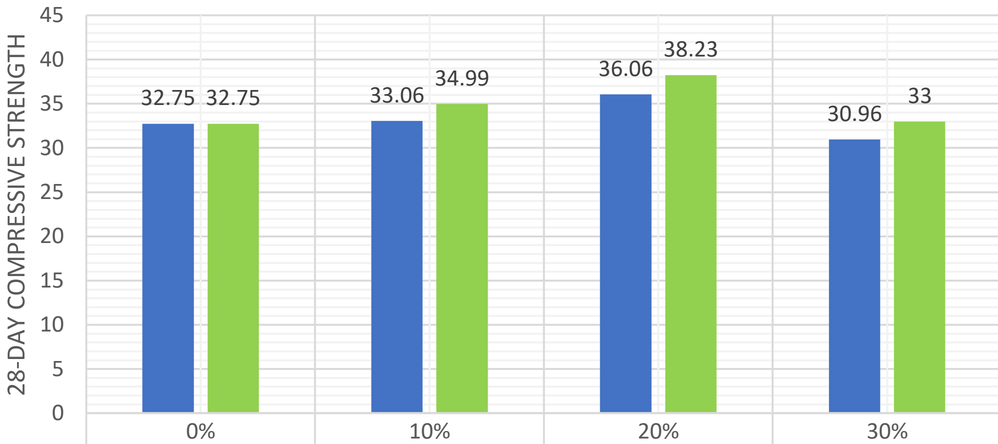
8.1 COMPRESSIVE STRENGTH: One of most important property of the hardened concrete is compressive strength. The concrete cubes were tested in accordance with the IS standards after 7 and 28 days. Three cubes were tested from each mix both at 7th and 28th day. The table below shows the test results of compressive strength at the 7th day.

FIGURE 1. 7- DAY COMPRESSIVE STRENGTH



The compressive strength at the 28th day of curing for different replacement of cement by glass powder and fly ash in the proportions of 0%, 10%, 20% and 30% are shown below.

FIGURE 2. 28-DAY COMPRESSIVE STRENGTH

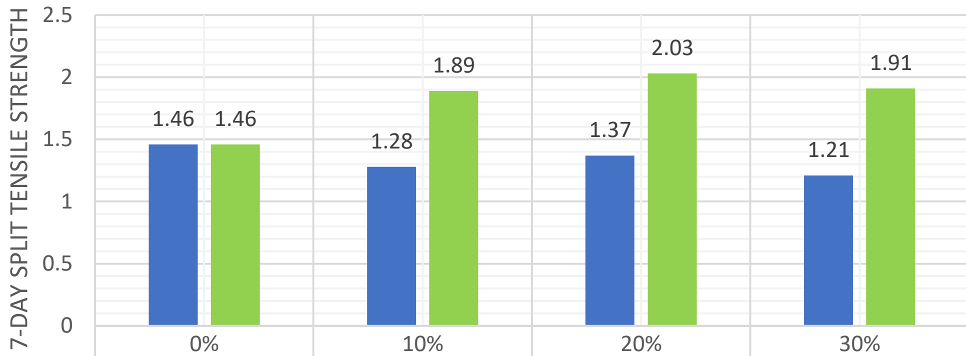


	0%	10%	20%	30%
GLASS POWDER	32.75	33.06	36.06	30.96
FLY ASH	32.75	34.99	38.23	33

PERCENTAGE OF GLASS POWDER AND FLY ASH

8.2 SPLIT TENSILE STRENGTH: The specimens were cured and tested at 7th and 28th days. Cylinder specimens were placed in testing machine and the load were applied. Split tensile strength is one of the most important properties of hardened concrete. The table below shows the results of the split tensile strength of various mixes at 7-day curing.

FIGURE 3. 7- DAY SPLIT TENSILE STRENGTH

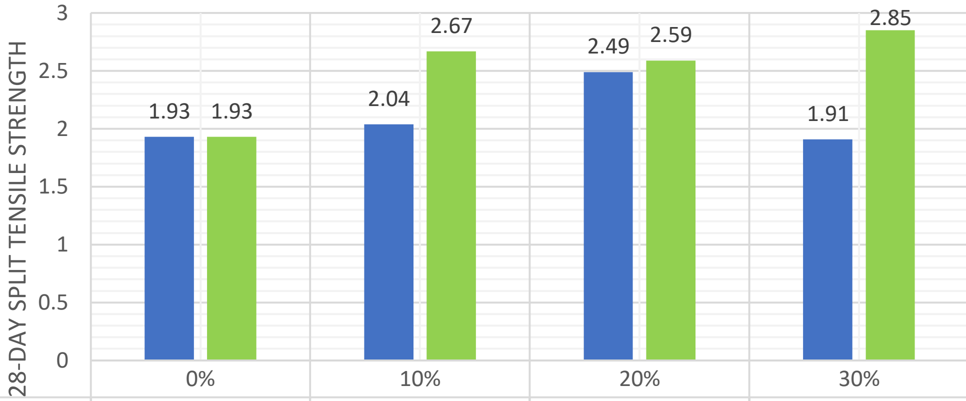


	0%	10%	20%	30%
GLASS POWDER	1.46	1.28	1.37	1.21
FLY ASH	1.46	1.89	2.03	1.91

PERCENTAGE OF GLASS POWDER AND FLY ASH

The split tensile strength at the 28th day of curing for different replacement of cement by glass powder and fly ash in the proportions of 0%, 10%, 20% and 30% are shown below.

FIGURE 4. 28- DAY SPLIT TENSILE STRENGTH

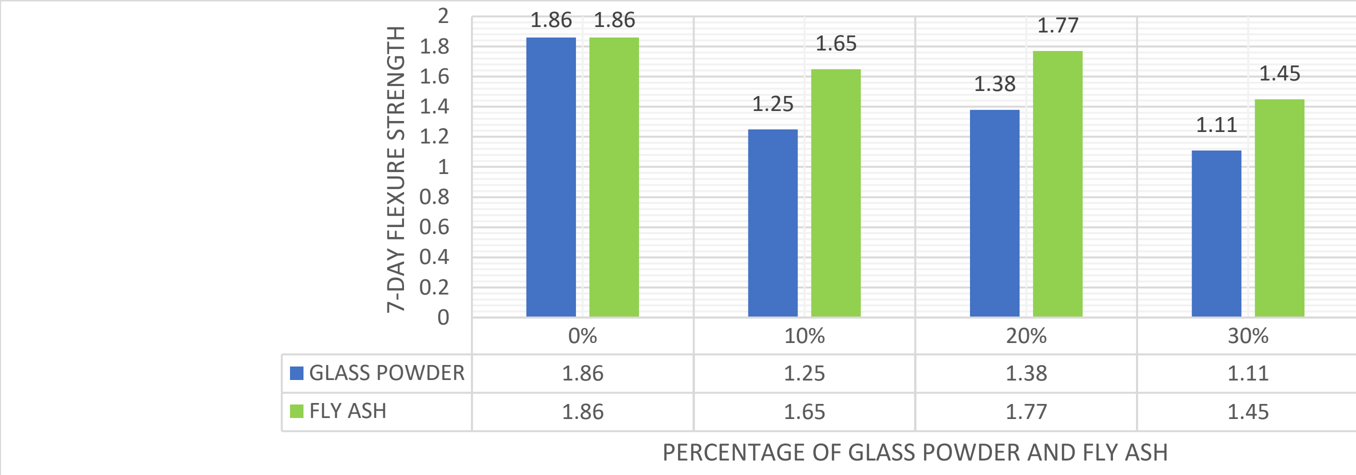


	0%	10%	20%	30%
GLASS POWDER	1.93	2.04	2.49	1.91
FLY ASH	1.93	2.67	2.59	2.85

PERCENTAGE OF GLASS POWDER AND FLY ASH

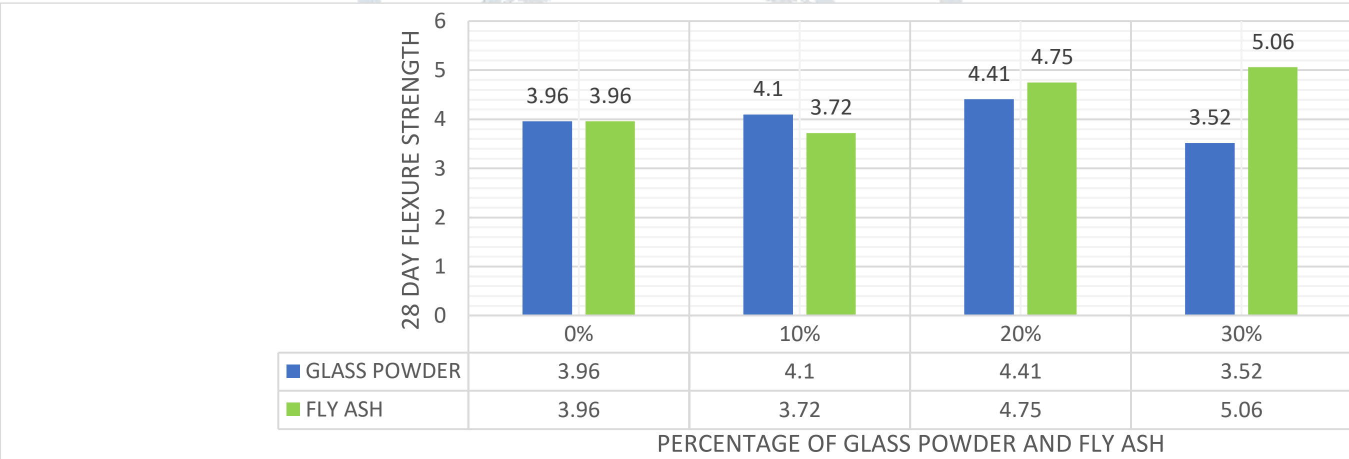
8.3 FLEXURE STRENGTH: the flexure strength is an important property of hardened concrete. The beam specimens 500× 100× 100mm were used for testing the flexural strength after 7 and 28 days for an M30 grade of concrete as per IS: 516-1959. Specimens were casted from the control mix and from different mixes containing different percentages of fly ash and glass powder respectively. The flexural strength at 7th day of curing is shown below;

FIGURE 5. 7- DAY FLEXURE STRENGTH



The flexure strength at the 28th day of curing for different replacement of cement by glass powder and fly ash in the proportions of 0%, 10%, 20% and 30% are shown below.

FIGURE 6. 28- DAY FLEXURE STRENGTH



9. CONCLUSION:

- On addition of Glass Powder, initial rate of gain of strength is low but at 28th day strength is more than the design strength. The initial compressive strength decreases with the addition of fly ash and glass powder but there is an increase in the ultimate strength of the concrete.
- The 7-day strength of concrete with different percentages of fly ash is more than the concrete with different percentages of glass powder.
- At 7th day the compressive strength decreases from 25.61N/mm^2 at 0% addition of glass powder to 16.64N/mm^2 at 30% addition of glass powder.
- At 10% addition of glass powder there is a decrease of 28% in compressive strength. Similarly, the decrease is 25% & 35% at 20% and 30% replacement of cement by glass powder respectively.
- At 10% addition of fly ash there is a decrease of 8% in compressive strength. Similarly, the decrease is 13% & 20% at 20% and 30% replacement of cement by fly ash respectively. 7-day compressive strength decreases from 25.61N/mm^2 at 0% addition of fly ash to 20.37 N/mm^2 at 30% addition of fly ash.
- The decrease in compressive strength of concrete with the addition of fly ash is less than the glass powder.

- The 28-day strength is more than the desired strength in both cases. The strength increases from 32.75N/mm^2 at 0% addition of glass powder to36.06 N/mm^2 at 20% addition. However, there is a decrease in strength beyond 20% addition. At 30% addition, the strength is only 30.96 N/mm^2.
- In case of fly ash, the strength increases from 32.75 N/mm^2 at 0% addition to 38.23 N/mm^2 at 20% addition. There is also a decrease in strength if addition is more than 20%.
- The optimum percentage in both the cases is 20% replacement because it gives desirable results.
- As the percentage of replacement of cement with glass powder increases strength increases up to 20% and beyond that it decreases.
- At 7th day the flexure strength gradually decreases with both fly ash and glass powder addition.
- After 7th day, flexure strength reduces by 10 to 40% for various percentages of glass powder.
- The decrease in strength in case of fly ash is less than the glass powder. There is a reduction by 5 to 25% for various percentages of fly ash.
- The 28-day flexure strength is more in both the cases then the normal concrete.
- The 28-day flexure strength increases gradually with the increase in percentage of glass powder upto 20%. After that there is a decrease in flexure strength. The maximum strength in case of glass powder is 4.41N/mm^2 at 20% replacement. There is an 11% increase in flexure strength at 20%.
- In case of fly ash, the flexure strength increases continuously with the increase in fly ash percentage. The maximum flexure strength is 5.06N/mm^2 at 30%.
- However, with the addition of fly ash there is a decrease of strength at 10% replacement and strength decreases by 7%. After that strength increases again.
- 7-day split strength decreases gradually with the increase in the percentage of glass powder addition. The strength decreases by 7 to 12% with the increase in percentage of glass powder from 10 to30%.
- In case of fly ash 7-day split strength gradually increases. The strength is maximum at 20% (2.03N/mm^2) with an increase of 28%.
- 28-day split tensile strength in case of glass powder increases gradually from 1.93N/mm^2 of normal concrete to 2.49N/mm^2 at 20% addition. The split strength decreases at 30% addition.
- In case of fly ash there is rapid increase in the flexure strength with the increase in fly ash percentage. The flexure strength increases by 28% at 10% replacement, 26% at 20% replacement and 32% at 30% replacement by fly ash.

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