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EXPERIMENTAL INVESTIGATION OF PROPERTIES OF CONCRETE ON REPLACING CEMENT PARTIALLY WITH WASTE GLASS POWDER AND FLY ASH

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Abstract: *The cost of constructing a building is increasing day by day as cost of building materials are increasing, the use of any alternative material that has tendency to partially replace the building material may reduce the cost of the construction to certain level. In this research we have selected two materials waste glass powder and Fly Ash for partially replacement with cement. Both the materials are easily available, renewable and also cheap. The grade of concrete on which the investigation will be performed will be M40 grade. The main aim of this research is to check if the two above materials can be used instead of cement up to certain percentage. In this project, the workability, compressive strength, split tensile strength and flexural strength of conventional concrete (CC), concrete made of Glass Powder (GP), concrete made of Fly Ash (FA), and concrete made from mixture of both materials has been studied. The compressive, split tensile and the flexural strength was calculated at 3 days, 7 days and 28 days of normal curing. The percentage replacement for the cement used is 10%. 20% and 30% by weight of cement. For calculating the compressive strength, cubes of size 150 x 150 x 150 mm were casted and were tested using Compression Testing Machine. In this project the distribution of cubes, and beams casted are – 9 are CC, 9 are GP (10%), 9 are GP (20%), 9 are GP (30%), 9 are FA (10%), 9 are FA (20%), 9 are FA 30%), 9 are GP + FA (10%), 9 are GP + FA (20%) and 9 for GP + FA (30%). For calculating the split tensile strength, cylinders of size 300 x 150 mm were casted. The distribution of cylinders casted are – 6 are CC, 6 are GP (10%), 6 are GP (20%), 6 are GP (30%), 6 are FA (10%), 6 are FA (20%), 6 are FA (30%), 6 are GP + FA (10%), 6 are GP + FA (20%) and 6 are of GP + FA (30%).*

Keywords: ***concrete, GP – glass powder, FA – fly ash, M40, workability, compressive strength, flexural strength, split tensile strength***

I. INTRODUCTION

A building material, concrete is an integration of cement, fine and coarse aggregates with water, which on hardening produces solid stone mass. The strength of this solid mass can be enhanced by adding some admixtures during mixing of the ingredients. In simple words concrete production can be defined as the procedure of combining together the various constituents like water, cement, aggregates to produce concrete.

A. Glass Powder

Glass, one of the most inert-material, that could be recycled and put to use numerous times without enhancing its any chemical property. Glass is also an amorphous-material; with high silica-content, thus, making it potentially Pozzolanic, when particle size is less than 75µm. Studies have proved that the fine-ground glass does not lead to an alkali – silica reaction. Recently, numerous attempts and research works have been made to use the ground-glass as the replacement in the conventional ingredients of the concrete production, as a part of green-house management.

B. Fly Ash

The Fly-ash is a cementitious coal combustion by-product that is naturally produced. It is obtained from the precipitators in the smoke-stacks of the coal-burning power plants to diminish the pollution. About 120 coal-based thermal power stations around India produce around 112 Million-Ton fly ash per year. With the rising demand of the power and the coal as the major source of the energy, more in number thermal power stations are expected to commission/augment their capacities in the coming days.

II. NOMINAL MIX DESIGN

Target mean strength of concrete

For a tolerance factor of 1.65 and using table 1 from IS 10262-2000, the standard deviation S = 5 N/mm^2. So, Target mean strength can be given by,

Characteristic cure strength = 40 + (5x1.65) = 48.25 N/mm^2.

Selection of water cement ratio

From table 5 from IS 456-2000, maximum water cement ratio = 0.45
Based on trial, adopt water cement ratio as 0.40
0.40 < 0.45 Hence ok.

Selection of water cement content

From table 2 of IS 10262-2009, maximum water content is 180 liter (for 75-100mm) slump range for 20 mm aggregate.
Estimate water content for (75-100mm) slump = 180 kg/m^3
Required water content = 180 + 5.4 = 185.4 kg/m^3

Calculation of cement content

Water cement ratio = 0.40
Water = 185.4 Kg/m^3
Cement = $\left[\frac{185.4}{0.40}\right]$ = 463.5 kg/m3

From table 5 of IS 456, minimum cement content,
Content for 'Mild' exposure condition = 400 Kg/m^3
400 Kg/m^3 < 463.5 Kg/m^3

Proportion of volume of coarse and fine aggregate

From table 3, of IS 10262 volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate corresponding to zone – II, and water cement ratio of 0.40 = 0.40
Volume of fine coarse aggregate = 1 – 0.40 = 0.60

Mix calculation

The calculations per unit volume of concrete shall be as follows;

a) Volume of concrete = 1 m^3
b) Volume of cement = $\left[\frac{mass\ of\ cement}{specific\ gravity\ of\ cement}\right] \times \left[\frac{1}{1000}\right]$
$= \left[\frac{463.5}{3.15}\right] \times \left[\frac{1}{1000}\right]$ = 0.147 m^3
c) Volume of water = $\left[\frac{mass\ of\ water}{specific\ gravity\ of\ water}\right] \times \left[\frac{1}{1000}\right] = \left[\frac{185.4}{1000}\right]$ = 0.185 m^3
d) Volume of all in aggregate = $[a - [b + c + d]]$ = 1- [0.147 + 0.185]= 0.668 m^3

The proportion of coarse and fine aggregate was calculated on the basis of hit and trail method in which 3 cubes were casted at different proportion for coarse and fine aggregate and that proportion was taken into consideration where the target mean strength was achieved.

e) Volume of coarse aggregate = 0.4435 x 2.60 x 1x 1000 = 1153.13 Kg/m^3
f) Mass of fine aggregate = 0.2117 x 2.42 x1 x 1000 = 512.2 kg/m^3

Table 1: Conventional mix proportion.

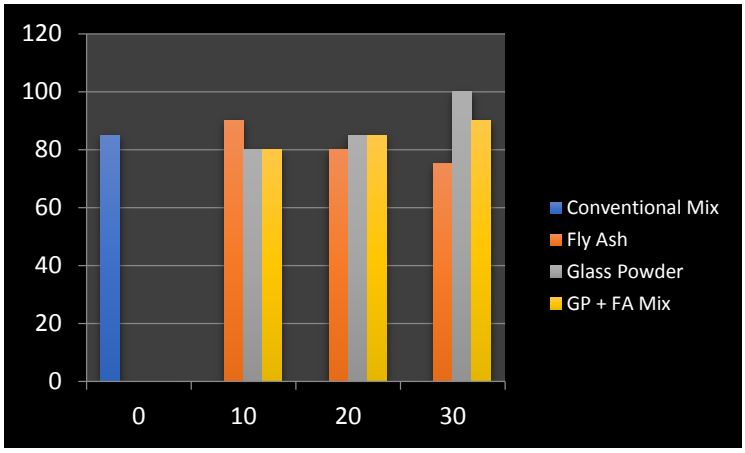
	Cement	Fine aggregate	Coarse aggregate	Water
Weight (kg/m^3)	463.5	512.2	1153.13	185.4 L
Mix Ratio	1	1.11	2.49	0.40

III. RESULTS:

A. Slump Test.

Table 2: Slump Values Obtained.

Replacement %	Fly Ash (mm)	Glass Powder (mm)	Mixture of FA & GP (mm)
0	85	85	85
10	90	80	80
20	80	85	85
30	75	100	90



Graph 1: Slump value obtained

B. Compressive Strength Values.

Table 3: Average Compressive Strength (N/mm²) for cubes of Conventional Concrete

3 Days	7 Days	28 Days
20.29	32.59	48.07

Replacement	3 Days	7 Days	28 Days
Fly Ash	21.73	33.29	53.11
Glass Powder	20.99	32.23	51.03
GP + FA	22.00	33.79	54.95

Table 4: Average Compressive Strength (N/mm²) for cubes of concrete containing 10% replacement.

Replacement	3 Days	7 Days	28 Days
Fly Ash	23.03	35.42	57.32
Glass Powder	22.51	34.95	53.47
GP + FA	22.44	34.31	56.21

Table 5: Average Compressive Strength (N/mm²) for cubes of concrete containing 20% replacement

Replacement	3 Days	7 Days	28 Days
Fly Ash	20.22	30.93	41.99
Glass Powder	18.64	28.47	39.34
GP + FA	19.03	28.88	41.10

Table 6: Average Compressive Strength (N/mm²) for cubes of concrete containing 30% replacement

C. *Flexural Strength Values*.

Table 7: Average Flexural Strength (N/mm²) for beams of Conventional Concrete

3 Days	7 Days	28 Days
3.52	4.52	6.65

Replacement	3 Days	7 Days	28 Days
Fly ash	3.71	4.49	6.92
Glass Powder	3.70	4.44	6.50
GP + FA	3.80	4.58	6.73

Table 8: Average Flexural Strength (N/mm²) for beams of concrete containing 10% replacement.

Replacement	3 Days	7 Days	28 Days
Fly ash	3.86	4.67	7.40
Glass Powder	3.76	4.75	7.13
GP + FA	3.84	4.66	7.16

Table 9: Average Flexural Strength (N/mm²) for beams of concrete containing 20% replacement

Replacement	3 Days	7 Days	28 Days
Fly Ash	3.66	4.36	6.26
Glass Powder	3.40	4.13	6.50
GP + FA	3.48	4.20	6.52

Table 10: Average Flexural Strength (N/mm²) for beams of concrete containing 30% replacement

D. *Split Tensile Strength Values*.

Table 11: Average Split *Tensile Strength* (N/mm²) for cylinder of Conventional Concrete

7 Days	28 Days
3.55	6.48

Replacement	7 Days	28 Days
Fly ash	3.62	6.55
Glass Powder	3.65	6.58
GP + FA	3.77	6.69

Table 12: Average Split Tensile Strength (N/mm²) for cylinder of concrete containing 10% replacement.

Replacement	7 Days	28 Days
Fly Ash	3.72	6.62
Glass Powder	3.79	6.69
GP + FA	3.86	6.76

Table 13: Average Split Tensile Strength (N/mm²) for cylinder of concrete containing 20% replacement

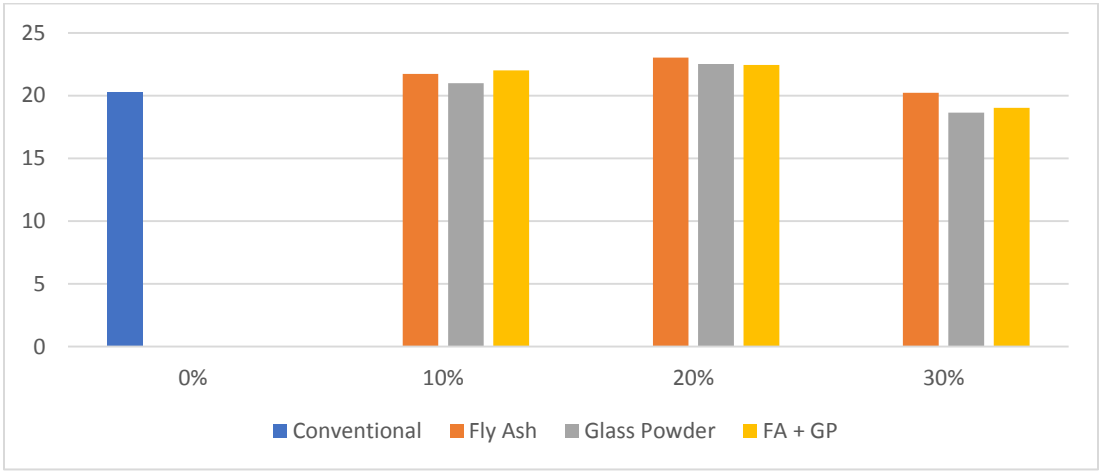
Table 14: Average Split Tensile Strength (N/mm²) for cylinder of concrete containing 30% replacement

Replacement	7 Days	28 Days
Fly Ash	3.53	6.36
Glass Powder	3.46	6.29
GP + FA	3.39	6.22

Fig. 1: Cube and cylinder in Compression Testing Machine

IV. DISCUSSION

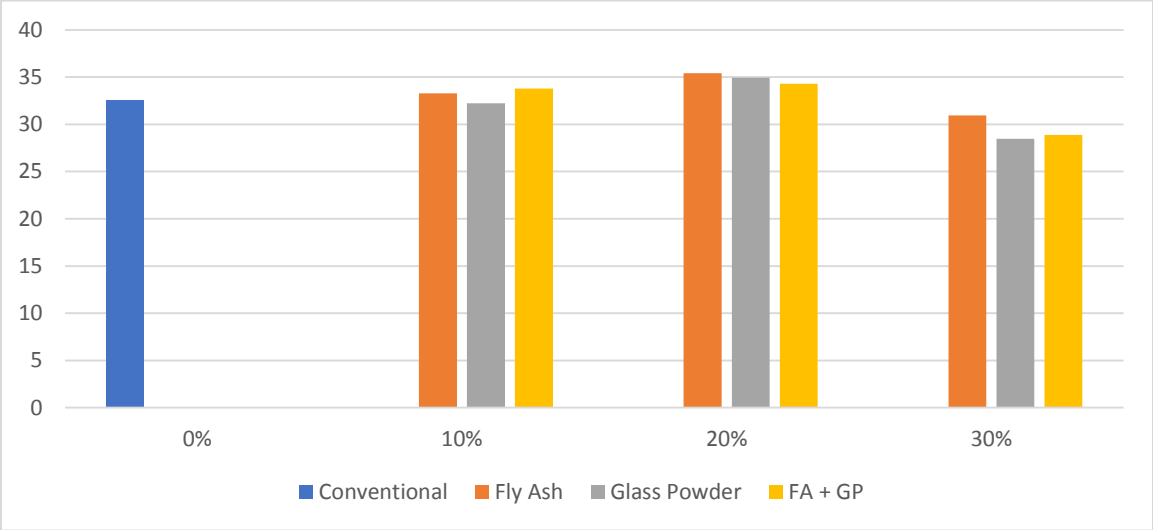
A. Comparison of Compressive Strength for Day 3 of Conventional Concrete with concrete containing replacements for cement.



Graph 1: Comparison of Compressive Strength for Day 3 of Conventional Concrete with: concrete containing replacements for cement.

The above graph shows the comparison between the compressive strength of conventional concrete with other replacement materials of cement. The compressive strength of the conventional concrete after 3 days curing is 20.29 N/mm². On comparing it with fly ash we are observing that there is an increment of 7.09% and 13.50% with respect to CC when cement was replaced by 10% and 20% respectively. On further increasing the FA content to 30%, we observed that there is a decrement of 0.34%. When glass powder was used as a replacement material it was found that increment of 3.44% for 10% replacement and increment of 10.94% for 20% replacement, after increasing the content the compressive strength starts to decrease in percentile of 8.13% for 30% when compared with the CC. When the mixture of FA and GP was used it has been observed that the strength gets increased in percentage of 8.42%, 10.59% for 10% and 20% replacement respectively and decrement of 6.20% for replacement with 30% was noticed.

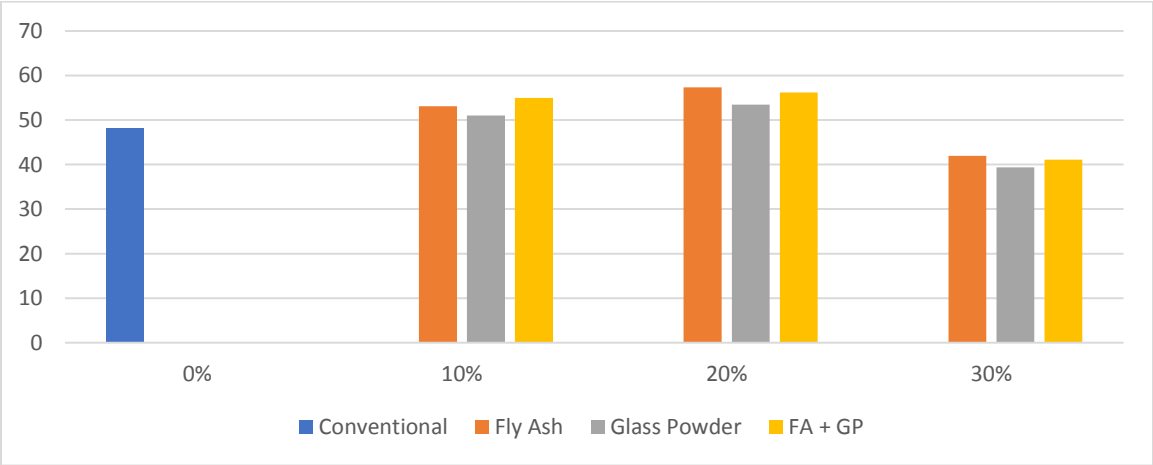
B. Comparison of Compressive Strength for Day 7 of Conventional Concrete with concrete containing replacements for cement.



Graph 2: Comparison of Compressive Strength for Day 7 of Conventional Concrete with concrete containing replacements for cement.

The above graph shows the comparison between the compressive strength of conventional concrete with other replacement materials of cement. The compressive strength of the conventional concrete after 7 days curing is 32.59 N/mm^2. On comparing it with fly ash we are observing that there is an increment of 2.14% and 8.68% with respect to CC when cement was replaced by 10% and 20% respectively. On further increasing the FA content to 30%, we observed that there is a decrement of 5.09%. When glass powder was used as a replacement materials it was found that increment of 0.44% for 10% replacement and increment of 7.24% for 20% replacement, after increasing the content the compressive strength starts to decrease in percentile of 12.64% for 30% when compared with the CC. When the mixture of FA and GP was used it has been observed that the strength gets increased in percentage of 3.68%, 5.27% for 10% and 20% replacement respectively and decrement of 11.38% for replacement with 30% was noticed.

C. Comparison of Compressive Strength for Day 28 of Conventional Concrete with concrete containing replacements for cement.

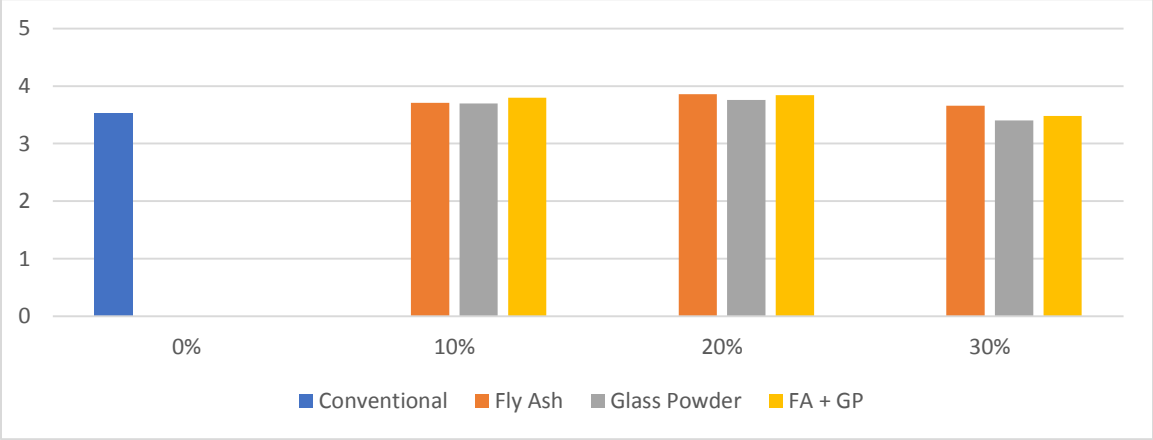


Graph 3: Comparison of Compressive Strength for Day 28 of Conventional Concrete with concrete containing replacements for cement.

The above graph shows the comparison between the compressive strength of conventional concrete with other replacement materials of cement. The compressive strength of the conventional concrete after 28 days curing is 48.07 N/mm^2. On comparing it with fly ash we are observing that there is an increment of 10.48% and 19.24% with respect to CC when cement was replaced by 10% and 20% respectively. On further increasing the FA content to 30%, we observed that there is a

decrement of 12.64%. When glass powder was used as a replacement materials it was found that increment of 6.15% for 10% replacement and increment of 11.23% for 20% replacement, after increasing the content the compressive strength starts to decrease in percentile of 18.16% for 30% when compared with the CC. When the mixture of FA and GP was used it has been observed that the strength gets increased in percentage of 14.31%, 16.93% for 10% and 20% replacement respectively and decrement of 14.49% for replacement with 30% was noticed.

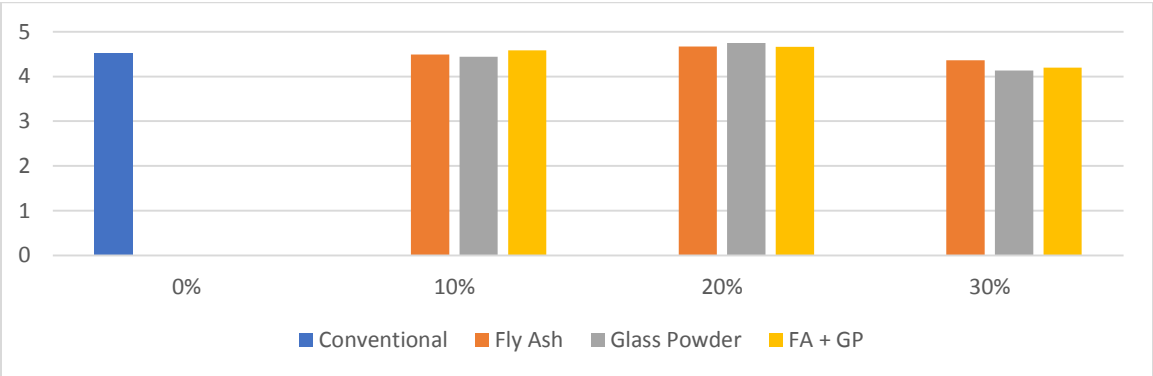
D. Comparison of Flexural Strength for Day 3 of Conventional Concrete with concrete containing replacements for cement.



Graph 4: Comparison of Flexural Strength for Day 3 of Conventional Concrete with concrete containing replacements for cement.

The above graph indicates the comparison made between the flexural strength of conventional concrete with concrete made up of adding replacing materials. The flexural strength of the conventional concrete obtained after 3 days curing is 3.52 N/mm^2. When compared it with fly ash we observed that there is an increment of 5.39% and 9.65% when cement was replaced by 10% and 20% respectively. On further increasing the fly ash content to 30%, we observed that the flexural strength increased by 3.97% to that of conventional concrete. When glass powder was used as a replacement materials it was found that increment of 5.11% and 6.81% for 10% and 20% replacement respectively, after increasing the content the flexural strength starts to decrease in percentile of 3.40% for 30% replacement when compared with the CC. When the mixture of FA and GP was used it has been observed that the strength increased in percentage of 7.95%, 9.09% for 10% and 20% replacement respectively and decrement of 1.13% for replacement with 30%.

E. Comparison of Flexural Strength for Day 7 of Conventional Concrete with concrete containing replacements for cement.

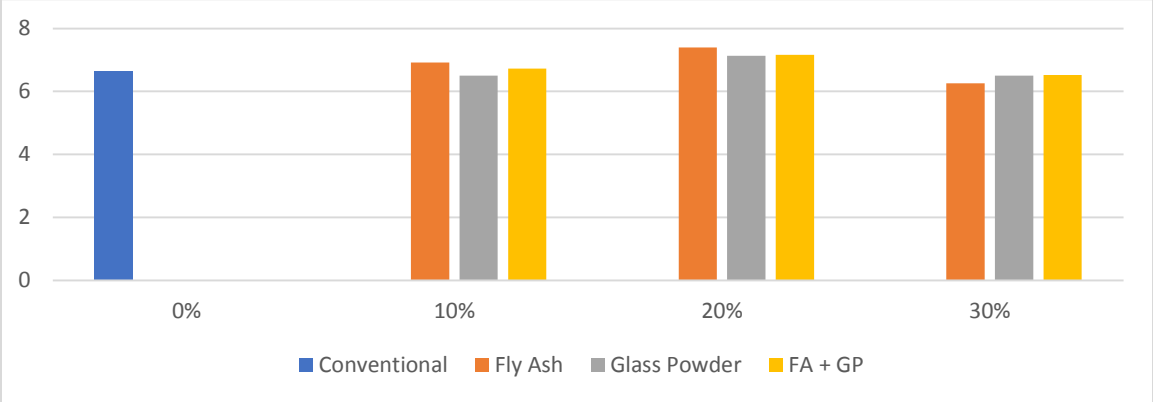


Graph 5: Comparison of Flexural Strength for Day 7 of Conventional Concrete with concrete containing replacements for cement.

The above graph indicates the comparison made between the flexural strength of conventional concrete with concrete made up of adding replacing materials. The flexural strength of the conventional concrete obtained after 7 days curing is 4.52 N/mm^2. When compared it with fly ash we observed that there is an increment of 0.66% and 3.31% when cement was replaced by 10% and 20% respectively. On further increasing the fly ash content to 30%, we observed that the flexural

strength decrease by 3.53% to that of conventional concrete. When glass powder was used as a replacement materials it was found that increment of 0% and 5.08% for 10% and 20% replacement respectively, after increasing the content the flexural strength starts to decrease in percentile of 8.62% for 30% replacement when compared with the CC. When the mixture of FA and GP was used it has been observed that the strength increased in percentage of 1.32%, 3.09% for 10% and 20% replacement respectively and decrement of 7.07% for replacement with 30%.

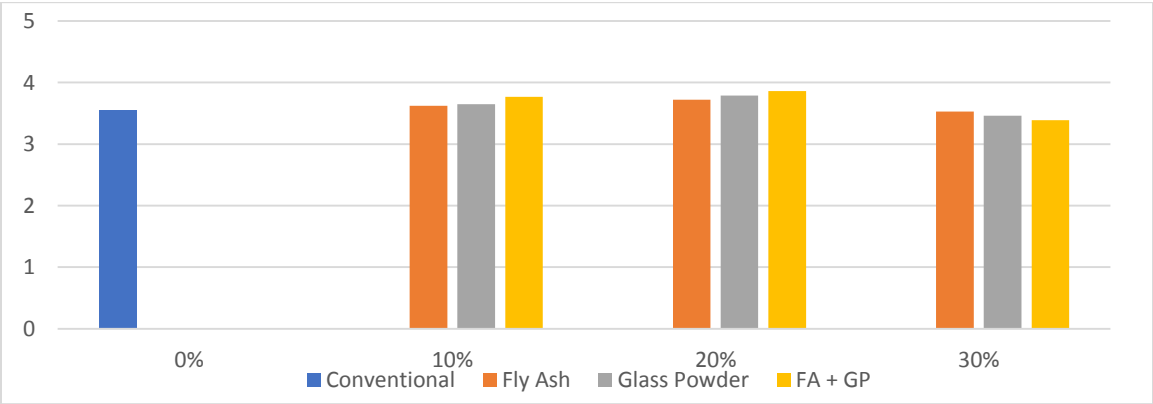
F. Comparison of Flexural Strength for Day 28 of Conventional Concrete with concrete containing replacements for cement.



Graph 6: Comparison of Flexural Strength for Day 28 of Conventional Concrete with concrete containing replacements for cement.

The above graph indicates the comparison made between the flexural strength of conventional concrete with concrete made up of adding replacing materials. The flexural strength of the conventional concrete obtained after 28 days curing is 6.65 N/mm^2. When compared it with fly ash we observed that there is an increment of 4.06% and 11.27% when cement was replaced by 10% and 20% respectively. On further increasing the fly ash content to 30%, we observed that the flexural strength decrease by 5.86% to that of conventional concrete. When glass powder was used as a replacement materials it was found that increment of 0% and 7.21% for 10% and 20% replacement respectively, after increasing the content the flexural strength starts to decrease in percentile of 2.25% for 30% replacement when compared with the CC. When the mixture of FA and GP was used it has been observed that the strength increased in percentage of 1.20%, 7.66% for 10% and 20% replacement respectively and decrement of 1.95% for replacement with 30%.

G. Comparison of Split Tensile Strength for Day 7 of Conventional Concrete with concrete containing replacements for cement.

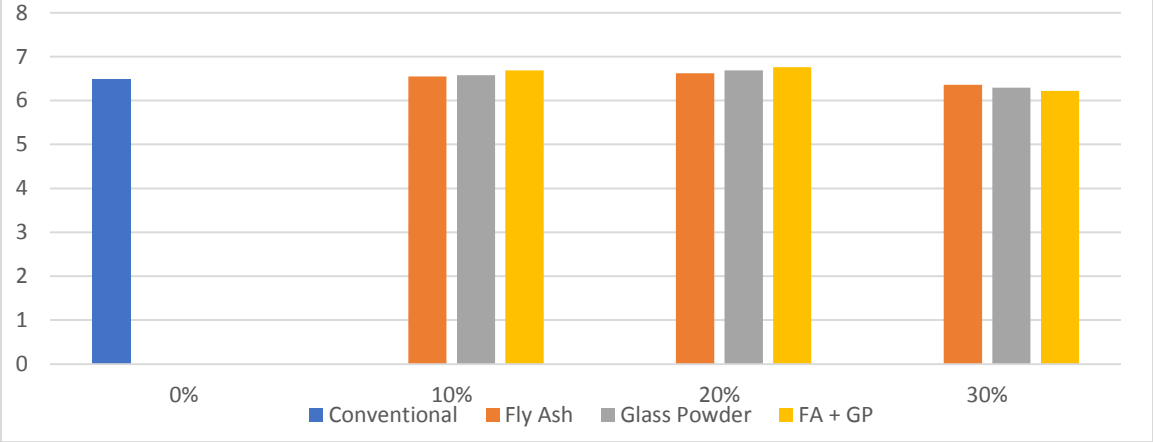


Graph 7: Comparison of Split Tensile Strength for Day 7 of Conventional Concrete with concrete containing replacements for cement.

The above graph indicates the comparison made between the split tensile strength of conventional concrete with concrete made up of adding replacing materials. The split tensile strength of the conventional concrete obtained after 7 days curing is 3.55 N/mm^2. When compared it with fly ash we observed that there is an increment of 1.97% and 4.78% when cement was replaced by 10% and 20% respectively. On further increasing the fly ash content to 30%, we observed that the split tensile

strength decrease by 0.56% to that of conventional concrete. When glass powder was used as a replacement materials it was found that increment of 2.81% and 6.76% for 10% and 20% replacement respectively, after increasing the content the split tensile strength starts to decrease in percentile of 2.53% for 30% replacement when compared with the CC. When the mixture of FA and GP was used it has been observed that the strength increased in percentage of 6.19%, 8.73% for 10% and 20% replacement respectively and decrement of 4.50% for replacement with 30%.

H. Comparison of Split Tensile Strength for Day 28 of Conventional Concrete with concrete containing replacements for cement.



Graph 8: Comparison of Split Tensile Strength for Day 28 of Conventional Concrete with concrete containing replacements for cement.

The above graph indicates the comparison made between the split tensile strength of conventional concrete with concrete made up of adding replacing materials. The split tensile strength of the conventional concrete obtained after 28 days curing is 6.48 N/mm^2. When compared it with fly ash we observed that there is an increment of 1.08% and 2.16% when cement was replaced by 10% and 20% respectively. On further increasing the fly ash content to 30%, we observed that the split tensile strength decrease by 1.85% to that of conventional concrete. When glass powder was used as a replacement materials it was found that increment of 1.54% and 3.24% for 10% and 20% replacement respectively, after increasing the content the split tensile strength starts to decrease in percentile of 2.93% for 30% replacement when compared with the CC. When the mixture of FA and GP was used it has been observed that the strength increased in percentage of 3.24%, 4.32% for 10% and 20% replacement respectively and decrement of 4.01% for replacement with 30%.

V. CONCLUSION

The use of Fly Ash and Glass Powder as partial replacement of Cement should be taken up for acceptable and environmental friendly construction. By using these easily available and the waste material in construction, we can decrease the cost of construction up to certain level and overcoming the environmental hazards. This investigation has also demonstrated that the use of fly ash and glass powder by certain percentage can produce positive results when partially replaced by cement. Thus can be used in construction purpose. It is observed that by replacement the cement with fly ash up to 20% by weight of cement, the compressive strength for the M40 grade concrete gets enhanced. It is seen, that the Compressive Strength for fly ash concrete get increased by about 13.5%, 9.68% and 19.24% for day 3, day 7, day 28 respectively when 20% replacement was made. For Flexural Strength in fly ash concrete, the Flexural Strength also gets improved when replacement was made up to 20%. It has been observed that the increment in the Flexural Strength was in the percentile of 9.65%, 3.31% and 11.7% for day 3, day 7 and day 28 respectively, when compared with the flexural strength for the Conventional Concrete beam. For Split Tensile Strength in fly ash concrete, the strength gets enhanced on replacing the cement with the fly ash by 20%. The increment in the strength is about 4.78% and 2.16% for day 7 and day 28, on replacing the 20% of cement content with fly ash. In case of Glass Powder the strength properties examined gets improved when the replacement is up to 20%, after increasing the content of GP, the strength starts to decrease. The Compressive Strength gets increased by 10.94%, 7.23% and 11.54% for day 3, day 7, and day 28 respectively, when compared with Conventional Concrete. The Flexural Strength also gets enhanced in the percentage of 6.81%, 5.08%, and 7.21% for day 3, day 7 and day 28 respectively. The Split Tensile Strength also gets enhanced in the percentage of 6.76% and 3.24% for day 7 and day 28 respectively. When the mixture of both the replacement materials was used and replaced with the cement, the strengths got intensify up to 20% and on further adding decrement of strengths was noticed. The Compressive Strength increase in the percentile of 10.59%, 5.27%, and 16.93% for day 3, day 7 and day 28 respectively. The Flexural Strength for mixture of the replacing materials get enhanced by 9.09%, 3.09%, and 7.66% for day 3, day 7 and day 28 respectively, when compared with the flexural strength of the Conventional Beam. The Split Tensile Strength increase in the percentile of 8.73% and 4.32% for day 7 and day 28 respectively.

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