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A Laboratory Study on Use of Waste Glass Powder as Partial Replacement of Cement in Concrete Production

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Abstract— The Role of Concrete Industry in India is significant in the economic development of the country. The concrete industry in India is one of the oldest sectors in India. The industry is driven by the immense growth in the housing sector, the infrastructure development, and construction of transportation systems.

This study was conducted to investigate the effect of using waste glass powder in concrete. Laboratory work was conducted to determine the performance of control sample and concrete with used waste glass powder. The performance of these types of concrete was determined by the workability test, density test and compressive strength test. The workability of concrete is determined using slump test. Meanwhile, compressive strength test is done to determine the strength of concrete. For each type of concrete sample, a total of six 150mm x 150mm x 150mm cubes were cast. The cubes were tested at the ages of 7 and 28 days to study the development of compressive strength. The results indicate that the concrete with using waste glass powder were able to increase the workability of concrete and also the compressive strength. However, the density is reduced compare to standard mixture of concrete.

Keywords— Concrete, Glass Powder, Unit Weight of cube, Water Absorption, Compressive strength, PH Value.

I. INTRODUCTION

Concrete is one of the world's most used construction material due to its versatility, durability and economy. India uses about 7.3 million cubic meters of ready-mixed concrete each year. It finds application in highways, streets, bridges, high rise buildings, dams etc. Green house gas like CO2 leads to global warming and it contributes to about 65% of global Warming. The global cement industry emits about 7% of green house gas to the atmosphere. To reduce this environmental impact alternative binders are introduced to make concrete.

Glass is an amorphous material with high silica content making it potentially pozzolanic when particle size is less than 75µm. The main problem in using crushed glass as aggregate in Portland cement concrete are expansion and cracking caused by the glass aggregate due to alkali silica reaction. Due to its silica content ground glass is considered a pozzolanic material and as such can exhibit properties similar to other pozzolanic material. In this study, finely powdered waste glasses are used as a partial replacement of cement in concrete and compared it with conventional concrete. Concrete mixtures were prepared with different proportions of glass powder ranging from 5 to 20% with an increment of 5% and tested for compressive strength after 7 and 28 days of curing and other properties.

II. LITERATURE REVIEW

2.1 Literature Review

Many works have been done to explore the benefits of using pozzolanic materials in making and enhancing the properties of concrete. Waste Samtur H.R, 1974, have studied that the use of recycled glass as aggregate greatly enhances the aesthetic appeal of the concrete. Research findings have shown that concrete made with recycled glass aggregate have shown better long term strength and better thermal insulation due to its better thermal properties of the glass aggregates. When tested for the compressive strength values at the 10 %, 40%, and 60 % aggregate replacement by waste glass with 0 – 10mm particle size were 3%, 8% and 5% above the value of conventional concrete.

Basically waste glass powders are made from the waste glass material that cannot be reused due to the high cost of manufacturing. Therefore the manufacture will disposed in the waste landfill.

TABLE 1 CHEMICAL COMPOSITION OF GLASS POWDER

Composition	Amount
SiO2	98.01
Al2O3	0.33
TiO2	0.02
Cr2O3	0.002
Fe2O3	0.10
CaO	0.61
MgO	0.35
Na2O	0.316
K2O	0.05
SO3	0.21

Due to environmental problem, researcher tries to use the waste glass in to concrete, to create a new material to use in construction field. Researcher found that, the main material composition of glass is silica that also contain in cement production and other compound that also similarly contain in cement production. The chemical composition of these products is similar for a given type of glass, and typical chemical compositions of the glass powder have been presented in Table 1 above.

III. EXPERIMENTAL WORK

3.1 Concrete Mix Design

The concrete mix design is done by systematic analysis and knowledge to choose and proportion the ingredient used in a concrete mix produce economical concrete which will have the desired properties both when fresh and when hardened. The variables which can be controlled are water cement ratio, maximum aggregate size and aggregate grading. This concrete mix design is done without addition of admixture. The concrete mix without glass powder was proportioned as per Indian Standard Specifications. Mix design was done for M20 grade of concrete.

3.2 The concrete mix design

Grade:	M20 grade of concrete without chemical admixture
Exposure condition:	Mild
Workability:	120-150mm slump
Maximum W/C ratio:	As per IS: 456
Cement:	PPC (Jaypee)
Minimum cement content:	As per IS: 456

The recommendations for M20 grade of concrete for the target average 28-day compressive strength of 26.60 N/mm2 are given below:

TABLE: 2 COMPOSITIONS OF MATERIALS IN CONCRETE

Mix Constituents (Kg)	For One Cubic Meter
Cement (PPC)	380
Water	205
Fine Aggregate	653
Coarse Aggregate 10-20mm (50%)	543
Coarse Aggregate <10mm (50%)	543
Water Cement ratio	0.54

3.3 Tests on concrete with partial replacement of waste glass powder

Tests on concrete with glass powder as an additive in various percentages are:

1) Unit Weight of the Concrete Cube test
2) Water Absorption test
3) Compressive strength test
4) PH value test

Five Samples of 0, 5, 10, 15 and 20% of glass powder is used as partial replacement of cement is prepared.

In this research, the concrete will mixed using concrete mixer and for each mixes, total of eight of 150x150x150mm cubes will cast. The sample will be cured until the day of testing. The cubes will be tested at ages of 7 day and 28 day to study the development of the compressive strength. The detail of samples that to be tested are shown in table below as per mix design and Mix design composition is taken from table 2.

TABLE: 3 COMPOSITIONS OF MATERIALS IN CONCRETE FOR 1 CUBIC METER

Sr. No.	Sample Name	% weight of glass powder by weight of cement in sample	Cement (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)	Glass Powder (kg)	Water (l)
1	Sample A	0	380	653	1086	0	205
2	Sample B	5	361	653	1086	19	205
3	Sample C	10	342	653	1086	38	205
4	Sample D	15	323	653	1086	57	205
5	Sample E	20	304	653	1086	76	205

3.4 Moisture Correction Application

TABLE: 4 MOISTURE CONTENT IN AGGREGATES

Sr. no.	Moisture Content	Fine Aggregates	Coarse Aggregates (10mm)	Coarse Aggregates (20mm)
1	Weight of wet aggregate sample (A), g	500	500	500
2	Weight of oven dry aggregate sample (B), g	495	498.5	498.5
3	Weight of Moisture (A-B), g	05	1.5	1.5
4	Moisture Content = {(A-B)*100/B}, %	1.01	0.30	0.30

Absorption of Fine Aggregate = 0.8%

% Moisture Content of Fine Aggregate = 1.01%

% Correction of Fine Aggregate = 1.01 – 0.8 = 0.21 %

TABLE: 5 MOISTURE CORRECTIONS FOR CONCRETE PRODUCTION

Sr. no.	Ingredients	Weight of ingredients for 1 m3 (Kg)	Correction Applied (Calculation)	Corrected Batch Weight (Kg)
1	Fine Aggregates	653	+1.371	654.371
2	Coarse Aggregates (10mm)	543	0.00	543
3	Coarse Aggregates (20mm)	543	0.00	543
4	Water	205	-1.371	203.629

TABLE: 6 CORRECTED COMPOSITION OF MATERIALS IN CONCRETE FOR 1 CUBIC METER

Sr. No.	Sample Name	% weight of glass powder by weight of cement in sample	Cement (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)	Glass Powder (kg)	Water (l)
1	Sample A	0	380	654.371	1086	0	203.629
2	Sample B	5	361	654.371	1086	19	203.629
3	Sample C	10	342	654.371	1086	38	203.629
4	Sample D	15	323	654.371	1086	57	203.629
5	Sample E	20	304	654.371	1086	76	203.629

3.5 Unit Weight of the Concrete Cube Specimen

Test to study the variation of concrete samples with the addition of different percentages of glass powder, the unit weight test for the cube was conducted. The table and bar chart in next result and analysis chapter shows the details about the unit weight of the cube after with the increase in the percentage of the glass powder in concrete 28 days curing.

TABLE: 7 UNIT WEIGHT OF CONCRETE

Sr. No.	Sample Name	Glass Powder %	Weight of the Cube (Kg)	Unit Weight of the Cube (Kg/m3)
1	Sample A	0%	8.350	2474.074
2	Sample B	5%	8.210	2432.592
3	Sample C	10%	8.185	2425.185
4	Sample D	15%	8.162	2418.370
5	Sample E	20%	8.138	2411.259

The graph shown in figure below illustrates the variation of the unit weight of the cube with different percentage replacement of cement by glass powder.

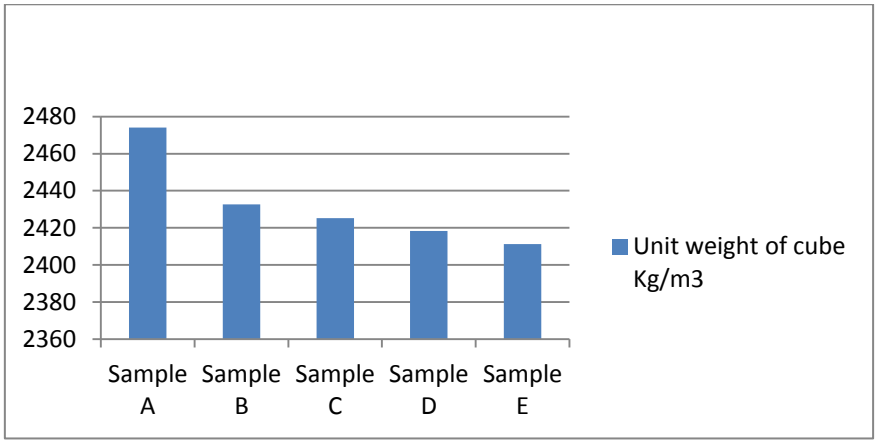

Figure: 1 Unit Weight of Concrete Cube

3.6 Porosity test

Water absorption test or the porosity test was carried out to calculate the amount of water absorbed by cube. Out of eight standard cubes of each sample, two cubes were retained to measure water absorption after 28 days curing. This test is conducted to measure the capillary absorption which indirectly measures the durability.

Procedure is as follows:

The sample was dried in oven at 105ºC until constant mass was obtained. Sample was cool down to room temperature for 6hr. The side of the sample was coated with bitumen or paraffin to attain unidirectional flow. The sample was exposed to water on one side by placing it on a pan filled with the water. The water in the pan was kept about 5mm above the base of the specimen as shown in the figure below. The weight of the sample was measured after 30 minutes.

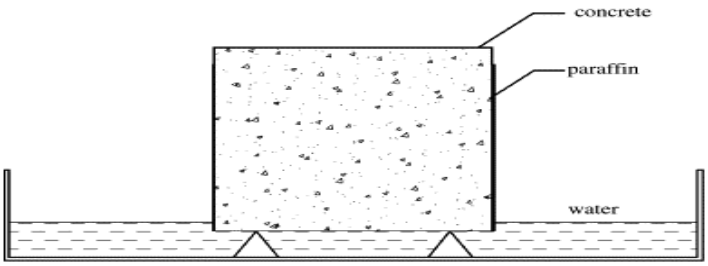

Figure: 2 Concrete Cube Position in Water Absorption Test

TABLE: 8 WATER ABSORPTION OF CONCRETE CUBE

Sr. no.	Waste Glass Powder Content in %	Average Dry Weight (gm)	Average Wet Weight (gm) after 30 minutes	Water Absorbed (gm)	Percentage Water Absorption (%)
1	0%	8324	8416	92	1.105
2	5%	8147	8223	76	0.933
3	10%	8112	8172	60	0.740
4	15%	8084	8139	55	0.680
5	20%	8042	8075	33	0.410

3.7 Compression Test on Concrete Cubes

The compressive strength test is the most common test which is conducted on the hardened concrete, partly because it is easy to perform and partly because of desirable characteristic properties is qualitatively related to compressive strength. For compressive strength testing 150mm X 150mm X 150mm cubes are casted from the reference mix and kept in a curing pound up to 28-days. The specimens are tested after 7-days and 28-days, using a calibrated compressive strength testing machine of 2000KN capacity as per IS: 516-1959.

Compressive strength of concrete = P/A

Where,

P= load at failure of cube,

A= cross-section area of cube

Figure: 3 Concrete Cubes

Figure: 4 Compressive Strength Test Machine

TABLE: 9 COMPRESSIVE STRENGTH OF CONCRETE SAMPLE A

Sr. No.	Age in Days	Cube no.	Load in KN	Strength in N/mm2	Average Strength
1	7 Days	1	426	18.933	19.052
2		2	442	19.644	
3		3	418	18.578	
4	28 Days	1	689	30.622	29.644
5		2	645	28.667	
6		3	667	29.644	

TABLE: 10 COMPRESSIVE STRENGTH OF CONCRETE SAMPLE B

Sr. No.	Age in Days	Cube no.	Load in KN	Strength in N/mm2	Average Strength
1	7 Days	1	449	19.956	19.304
2		2	416	18.489	
3		3	438	19.467	
4	28 Days	1	662	29.422	29.896
5		2	654	29.067	
6		3	702	31.20	

TABLE: 11 COMPRESSIVE STRENGTH OF CONCRETE SAMPLE C

Sr. No.	Age in Days	Cube no.	Load in KN	Strength in N/mm2	Average Strength
1	7 Days	1	446	19.822	19.659
2		2	423	18.800	
3		3	458	20.356	
4	28 Days	1	659	29.289	30.237
5		2	671	29.822	
6		3	711	31.600	

TABLE: 12 COMPRESSIVE STRENGTH OF CONCRETE SAMPLE D

Sr. No.	Age in Days	Cube no.	Load in KN	Strength in N/mm2	Average Strength
1	7 Days	1	432	19.2	19.956
2		2	448	19.911	
3		3	467	20.756	
4	28 Days	1	678	30.133	30.474
5		2	661	29.378	
6		3	718	31.911	

TABLE: 13 COMPRESSIVE STRENGTH OF CONCRETE SAMPLE E

Sr. No.	Age in Days	Cube no.	Load in KN	Strength in N/mm2	Average Strength
1	7 Days	1	445	19.778	19.778
2		2	429	19.067	
3		3	461	20.489	
4	28 Days	1	714	31.733	30.222
5		2	668	29.689	
6		3	658	29.244	

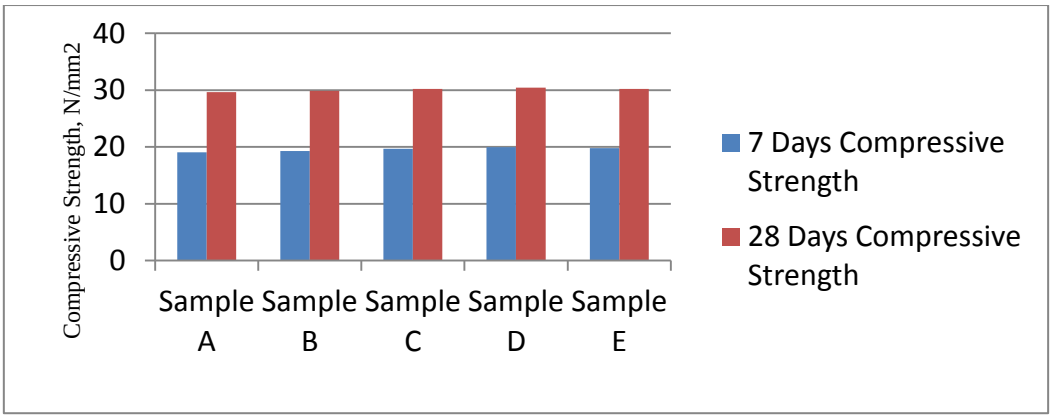

Figure: 5: 7 & 28 Days Compressive Strength of Concrete Samples

3.8 Alkalinity test

For conducting the alkalinity test, after 28 days curing the specimen are taken out from curing tank. Specimens are dried in oven at 105°C for 24 hours. The dry specimens are cooled to room temperature. Dry specimens are broken and separated the mortar from the concrete. Then the mortar is grinded into powder form. The powdered mortar is sieved in 150µ. 10gm of mortar is taken and it is diluted in 50ml distilled water and completely stirred it.

Figure: 6 Digital PH Meter

Then the pH meter immerse into the solution and pH value of the solution is noted. The general pH value of the solution and the level of inducing corrosion in the concrete are noted and the results are shown in next result and analysis chapter. Then immerse the pH meter into the solution and pH value of the solution is noted.

TABLE: 14 THE ALKALINITY TEST VALUES FOR VARIOUS SAMPLES OF CONCRETE

Sr. No.	Sample Name	% Replacement of Cement by Glass Powder in Concrete	PH value
1	Sample A	0%	12.3
2	Sample B	5%	12.52
3	Sample C	10%	12.48
4	Sample D	15%	12.61
5	Sample E	20%	12.73

IV. ANALYSIS & CONCLUSIONS

4.1 Plotting Curves for analysis of above results

Following curves are plotted for the analysis of above test results. i.e.

i. Unit Weight of the Concrete Cube Specimen
ii. Porosity test of Concrete Specimens
iii. Compression Test on Concrete Cubes Specimens
iv. Alkalinity test

TABLE: 15 DATA FOR PLOTTING CURVES OF CONCRETE SPECIMENS

Sr. no.	**Sample Name**	**% Replacement of Cement by Glass Powder in Concrete**	**Unit Weight of the Concrete Cube (Kg/m3)**	**Percentage Water Absorption (%)**	**Compressive strength, 7 days (N/mm2)**	**Compressive strength, 28 days (N/mm2)**	**Alkalinity, PH value**
1	Sample A	0%	2474.074	1.105	19.052	29.644	12.3
2	Sample B	5%	2432.592	0.933	19.304	29.896	12.52
3	Sample C	10%	2425.185	0.740	19.659	30.237	12.48
4	Sample D	15%	2418.370	0.680	19.956	30.474	12.61
5	Sample E	20%	2411.259	0.410	19.778	30.222	12.73

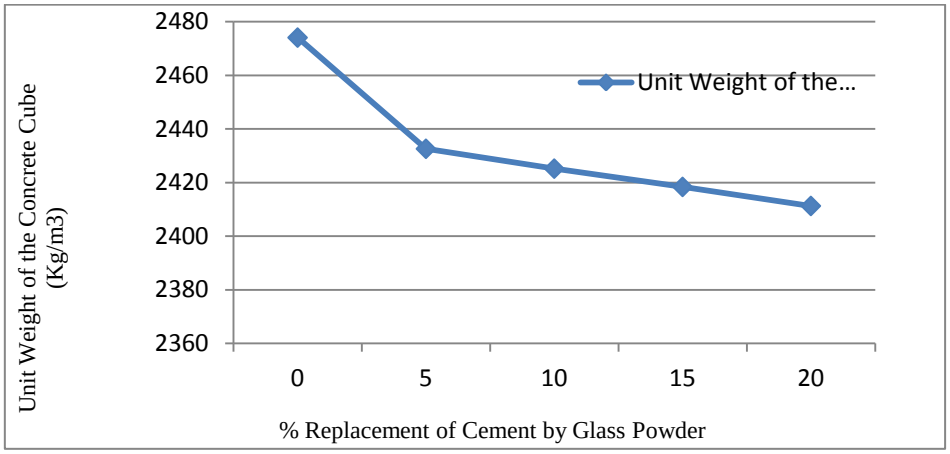

Figure: 7 Unit Weight Curves of Specimens

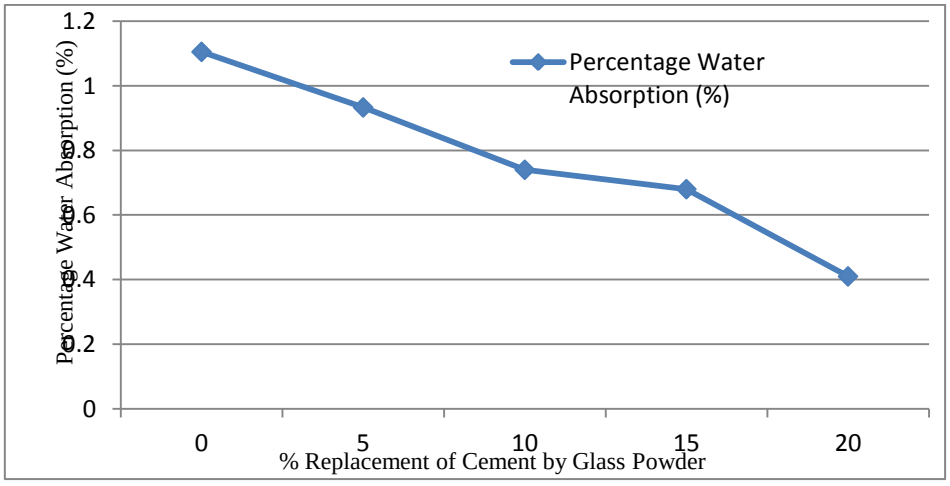

Figure: 8 Water Absorption Curves of Samples

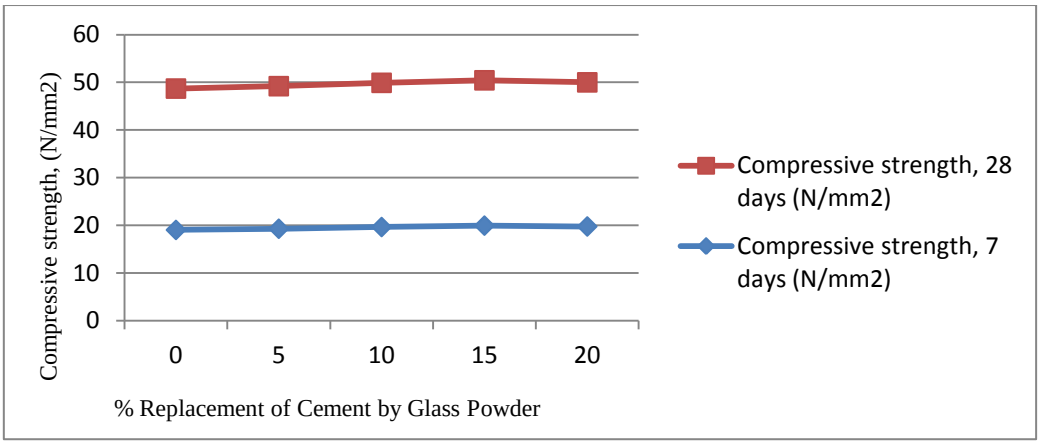

Figure: 9: 7 & 28 Days Compressive Strength Curve Of Concrete Specimens

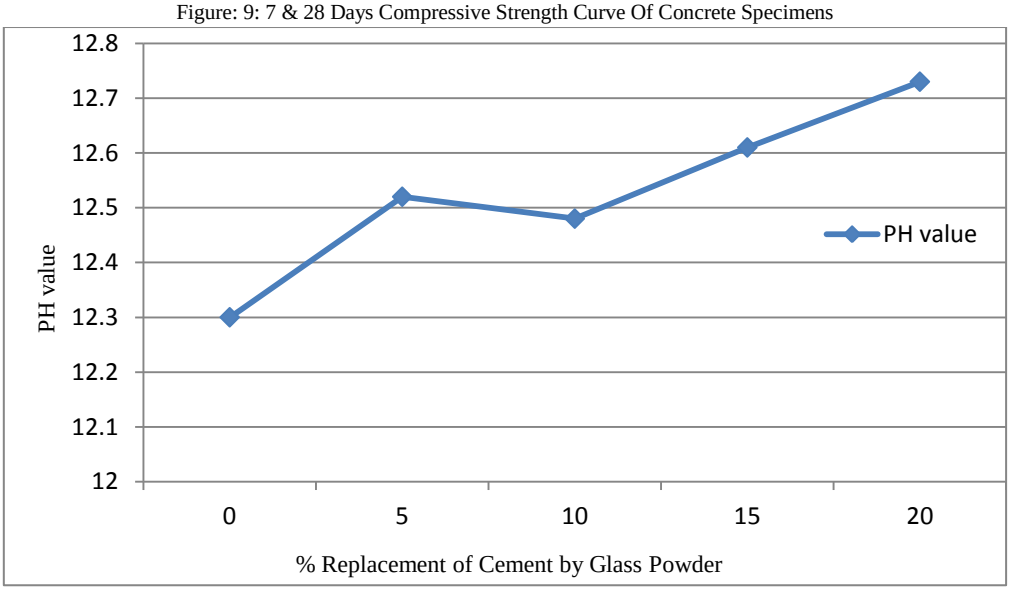

Figure: 10 Alkalinity Curves of Specimens

Conclusion

The value of glass powder content at which the sample has maximum Compressive Strength Value of concrete samples. The concrete samples should also have minimum water absorption percentage is called as Optimum Glass Powder Content. From the Figure – 7, 8, 9 & 10 we get the Optimum Glass Powder Content as 15%. Referring from the table 15 above in Figure 9, it shows that the overall average compressive strength value at 7 days , which by using 15% of waste glass powder in my specimen is giving very high value were about 19.956 N/mm2 compared to standard mixture that only give 19.052 N/mm2.

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