"THE STUDY ON STRENGTH PARAMETER OF M35 GRADE CONCRETE MADE WITH PARTIAL REPLACEMENT OF GLASS POWDER"

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Abstract: **In a growing country like India a huge amount of industrial waste are polluting the Environment. 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 waste glass powder was tested with concrete. Cement was replaced by the waste glass powder in the proportion of 0%, 5%, 10%, 15%, 20%, 25% and 30% for concrete with 0.45 and 0.5 water cement ratio. The compressive strength, split tensile strength and flexural strength characteristics 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 waste glass powder is economically cheap as well as a superior concrete can be made.**

***IndexTerms*– Glass powder, Conplast SP430, Compressive Strength, Flexural Strength, Split Tensile Strength.**

1. INTRODUCTION

Concrete is the most vital material in modern construction. It has versatile properties like easy mouldability, high compressive strength, and long lasting durability. These properties of concrete have made it most popular construction material for all types of civil engineering works. The latest developments in concrete technology have made it possible to use it in intricate and architecturally complex structures, requiring high degree of performance, and aesthetic appearance. It is obtained by mixing cement, water, and aggregates in required proportion. The hardening is caused by chemical action between water and cement, it continues for a long time and consequently the concrete grows stronger with age. Waste reduction and reusing are imperative components in a waste administration system since they help to moderate common assets, decrease interest for important landfill space, lessen the need of crude materials to make new item, diminish air and water contamination, decrease vitality and make new employments. It worth saying that in European zero waste program it is evaluated that asset productivity enhancements up and down the chains could lessen material sources of info needs by 17– 24% by 2030 and a superior utilization of assets could speak to a general sparing capability of €630 billion/year for European industry.Moreover, in excess of 180,000 direct employments in the EU by 2020, not withstanding the evaluated 400,000 occupations that will be made by the execution of the waste enactment in drive. They will prompt fulfilling in the vicinity of 10% and 40% of the crude material request in the EU, while adding to accomplishing the EU focus to diminish ozone harming substance emanations by 40% – 62 Mt of CO_2/year would be maintained a strategic distance from in 2030. Anyway, the utilization of reused glass in the assembling of new glass decreases vitality utilization, crude materials utilize, and wear and tear on hardware. Be that as it may, not all utilized glass can be reused into new glass as a result of polluting influences, cost, or blended hues.For sure, there is a need to set up new alternatives for reusing waste glass. One vital alternative is to utilize squander glass in building materials. Since 1963, the primary examination had been done on the utilization of glass chips to create structural uncovered total for concrete. Afterward, inferable from the amazing hardness of glass, broad looks into have been done to use reused glass as coarse or fine total in cement and mortar. Squashed glass particles that were utilized as total are by and large rakish fit as a fiddle and may contain some stretched and level particles. The level of precision and the amount of level and stretched particles relies upon the level of pounding. Littler particles, came about because of additional devastating, displayed to some degree less rakishness and decreased amounts of level and stretched particles. Different examinations contemplated the plausibility of processing the glass cullet into powder frame and utilized it to supplant bond in cement and mortar. As of late, Glasses and its powder has been utilized as a development material to diminish ecological issues. The coarse and fine glass totals could cause ASR (antacid silica response) in concrete, yet the glass powder could smother their ASR propensity, an impact like supplementary cementations materials (SCMs). In this way, glass is utilized as a substitution of supplementary cementitious materials.Glass is amorphous material with high silica content, thus making it potentially pozzolanic when particle size is less than 75µm. Studies have shown that finely ground glass does not contribute to alkali – silica reaction. 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. A major concern regarding the use of glass in concrete is the chemical reaction that takes place between the silica – rich glass particle and the alkali in pore solution of concrete, which is called Alkali – Silicate reaction can be very detrimental to the stability of concrete, unless appropriate precautions are taken to minimize its effects. ASR can be prevented or reduced by adding mineral admixtures in the concrete mixture, common mineral admixtures used to minimize ASR are pulverized fuel ash (PFA), silica fume(SF) and metkaolin (MK).A number of studies have proven the suppressing ability of these materials on ASR. A high amount of waste glass as aggregate is known to decrease the concrete unit weight.

2.OBJECTIVES

The main objectives of this project are as follows:

- To investigate the effect of variable percentage of powdered glass content on workability of M35 grade concrete.
- To investigate the effect of varying percentage of powdered glass content on compressive strength of M35 grade concrete.
- To investigate the effect of variable proportion of powdered glass on split tensile forte of M35 grade concrete.
- To examine the effect of variable percentage of powdered glass content on flexural strength of M35 grade concrete.

3.LITERATUREREVIEW

Numerous works have researched endeavoring to anticipate the profit of using waste glass powder material in making and improving the properties of concrete.

Literature survey:

Ahmad Shayan et.al [2004]: studied use of waste glass in concrete in a few structures, including fine aggregates, coarse aggregates and glass powder. It is viewed as that the last frame would give significantly more noteworthy chances to esteem including and cost recuperation, as it could be utilized as a substitution for costly materials, for example, SF, fly fiery remains and bond. The utilization of glass powder in cement would anticipate broad ASR within the sight of powerless total. Arrival of soluble base from GLP did not give off an impression of being adequate to cause malicious ASR development. Quality pick up of glass powder-bearing mortar and cement was acceptable. Microstructural examination has additionally demonstrated that glass powder would deliver a thick lattice and enhance the sturdiness properties of cement fusing it. It has been reasoned that 30% glass powder could be joined as bond or total substitution in concrete with no long haul impeding impacts. Up to half of both fine and coarse totals could likewise be supplanted in cement of 32-MPa quality review with adequate quality improvement properties.

Lavanya et.al [2016]: tentatively examined glass powder to decide the attributes of different evaluations of cement, for example, M20, M30 and M40 by supplanting of bond with Glass Powder (GLP) and fine total with Granite powder (GRP) for a curing time of 7, 14 and 28 days. Solid examples were threw and tried for decide the Compressive quality, Split elasticity and Flexural quality. Compressive quality increments as for the review of solid, greatest compressive quality happened at 20% Glass powder and 25% Granite powder traded for bond and fine total separately in all evaluations of cement. Greatest Compressive quality of solid shape is observed to be 42.06 Mpa for M40 and it is expanded by 12% than the regular cement. Most extreme split rigidity of chamber is observed to be 6.99 Mpa for M40 and it is expanded by 18% than the regular cement. Most extreme flexural quality of crystal is observed to be 9.26 Mpa for M40 Balanced segment and it expanded by 7% than the regular cement. From the above test comes about, it is demonstrated that Glass powder and Granite powder can be utilized as elective materials in solid, diminishing concrete utilization and lessening the cost of development.

Ibrahim [2017]: examined squander glass impact as Partial sand substitution on concrete. In their investigation, sand was supplanted by WG powder as 0%, 5%, 10%, 15%, 20%, 25%, 30%, 35% and 40% by weight. A steady water/bond =0.45 and a consistent concrete substance 400kg/m3 are utilized. The examples of cement were tried at age = 28 days to indicate elasticity, compressive quality, water assimilation and dry thickness. The examination comes about outlined that admissibility of utilizing WG as incomplete sand substitution until 40% by weight without diminishment in tractable and compressive qualities with correlation of control concrete. The best substitution dose of WG is 15% which appeared around 37% and 25% expanding in elastic and compressive qualities of cement individually. greenhouse gases by the cement industry.

Harshad G Patel et.al [2017]: considered the possibility of supplanting fine aggregates with blend of poly vinyl carbonate powder and glass powder in M25 review concrete. The fine totals were supplanted at measurements of 0%, 5%, 10%, 15%, 20%, 25% and 30%.The physical properties that is thickness, workability and water retention and mechanical properties, for example, flexural and compressive quality and strength viewpoints (alkalinity and corrosive assaults) were learned at various doses. The outcomes show that the execution of cement regarding above parameters as inside worthy limits as indicated by IS codes. Encourage minuscule investigations uncovers that glass and PVC particles have shaped great and even conveyance crosswise over cement.

4.WORKABILITY TEST ON FRESH CONCRETE

General

The following table shows the slump values which are observed or obtained from our project work. The slump test is conducted on a different water cement ratio with different mix proportions of glass powder.

Fig 4.1 Slump Test

Fig 4.2 For 0.45 w/c ratio

Fig 4.3 For 0.5 w/c ratio

Table 4.1 Slump results of fresh concrete, w/c=0.5

% glass powder	Slump (mm)
0.0 (Normal concrete)	110
5	100
10	94
15	90
20	88
25	86
30	83

Table 4.2 Slump results of fresh concrete, w/c= 0.45

% glass powder	Slump (mm)
0.0 (Normal concrete)	110
5	100
10	94
15	90
20	88
25	86
30	83

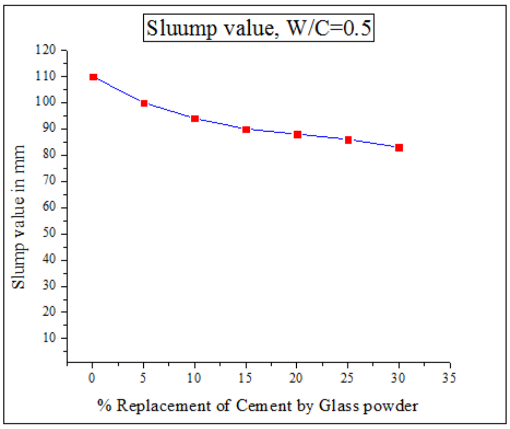


Fig. 4.3 Slump results of fresh concrete, w/c=0.5

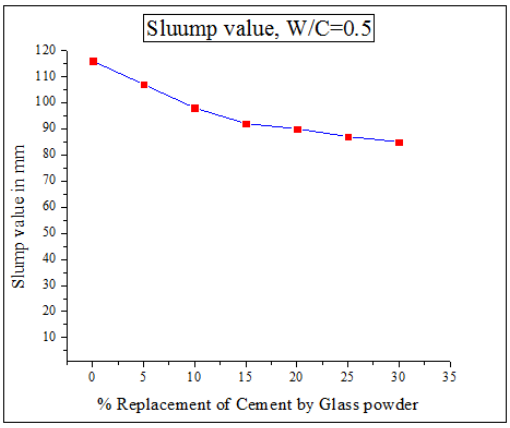


fig. 4.4 Slump results of fresh concrete, w/c= 0.45

- From the table 4.1 and 4.2 it is observed that the workability has been increased along with increasing w/c ratio.
- Above fig 4.3 and 4.4 shows the graph of slump value against different W/C ratio for different mix.
- From Figures 4.3 and 4.4 , it can be observed that workability measured in terms of slump reduces with increase in percentage of replacement of cement by glass powder and as the water cement ratio is reduced the workability will increase.

5.RESULTS AND DISCUSSION

5.1Compressivestrength:-

Fig 5.1.1 Compressive test on GPC

Fig 5.1.2Compression Failure of GPC

Table 5.1.1 compressive strength results, For 7 days w/c=0.45

% glass powder	Compressive strength (MPa) for 7 days,w/c=0.45
0.0 (Normal concrete)	28.38
5	30.23
10	33.56
15	35.89
20	31.1
25	28.87
30	23.79

Table 5.1.2 compressive strength results, For 14 days w/c=0.45

% glass powder	Compressive strength (MPa) for 14 days,w/c=0.45
0.0 (Normal concrete)	38.61
5	41.34
10	43.63
15	47.01
20	42.08
25	38.39
30	34.78

Table 5.1.3: compressive strength results, For 28 days, w/c=0.45

% glass powder	Compressive strength (MPa) for 28 days,w/c=0.45
0.0 (Normal concrete)	42.48
5	45.46
10	46.6
15	48.89
20	43.96
25	42.8
30	39.11

Table 5.1.4: compressive strength results, for 7 days, w/c=0.5

% glass powder	Compressive strength (MPa) for 7 days,w/c=0.5
0.0 (Normal concrete)	24.67
5	27.23
10	30.76
15	32.87
20	28.5
25	25.56
30	21.23

Table 5.1.5: compressive strength results, For 14 days, w/c=0.45

% glass powder	Compressive strength (MPa) for 14 days,w/c=0.5
0.0 (Normal concrete)	34.23
5	37.32
10	39.37
15	43.14
20	37.76
25	35.32
30	31.7

Table 5.1.6: compressive strength results, for 28 days, w/c=0.5

% glass powder	Compressive strength (MPa) for 28 days,w/c=0.5
0.0 (Normal concrete)	36.62
5	39.46
10	44.47
15	46.65
20	41.54
25	37.79
30	34.76

Fig 5.1.3: 7days Compressive Strength, W/C=0.45

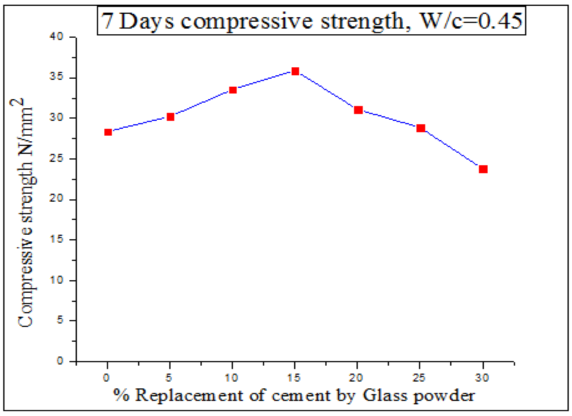


Fig 5.1.4: 14days Compressive Strength, W/C=0.45

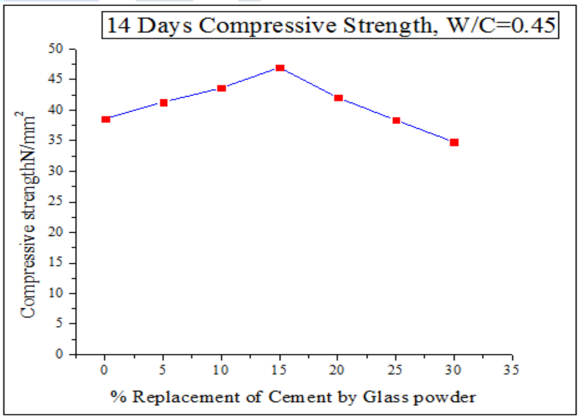


Fig 5.1.5: 28days Compressive Strength, W/C=0.45

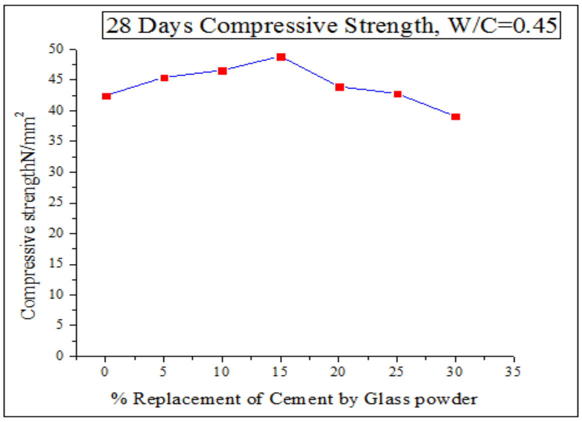


Fig 5.1.6: 7days Compressive Strength, W/C=0.45

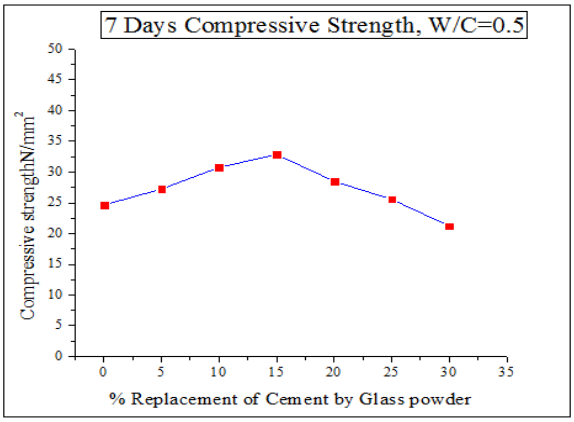


Fig 5.1.7: 14days Compressive Strength, W/C=0.5

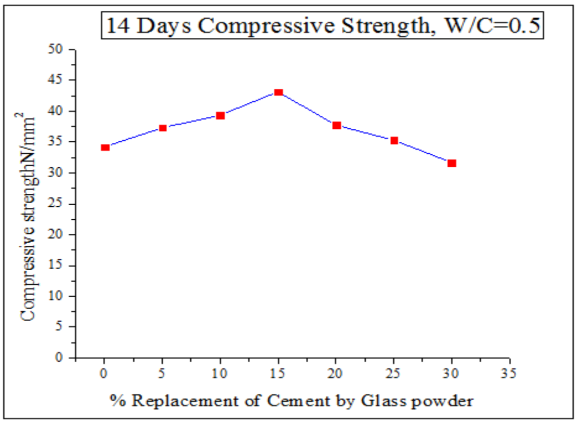
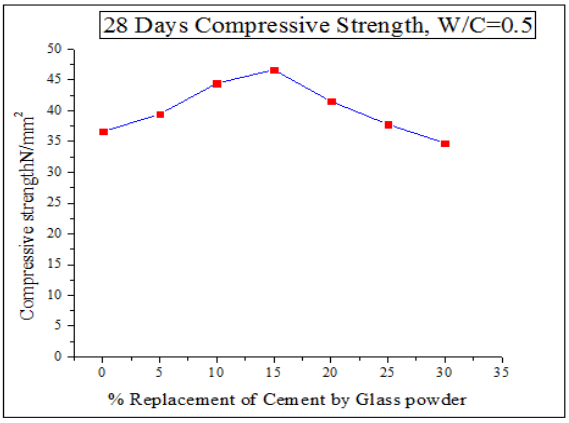


Fig 5.1.8: 28days Compressive Strength, W/C=0.5



- The comparison of a compressive strength of plain concrete cubes with glass powder concrete cubes with respect to the change of the water cement ratio for different glass powder proportion.
- From table 5.1.1 it can be observed that, 15 % glass power volume of concrete of 0.45 W/C ratio for 7 days having a maximum strength that is 35.89 Mpa, and as the percentage of the glass powder increase the compressive strength decreases.
- From table 5.1.2 it can be observed that, 15 % glass power volume of concrete of 0.45 W/C ratio for 14 days having a maximum strength that is 47.01 Mpa, and as the percentage of the glass powder increase the compressive strength decreases.
- From table 5.1.3 it can be observed that, 15 % glass power volume of concrete of 0.45 W/C ratio for 28 days having a maximum strength that is48.89 Mpa, and as the percentage of the glass powder increase the compressive strength decreases.
- From table 5.1.4 it can be observed that, 15 % glass power volume of concrete of 0.5 W/C ratio for 7 days having a maximum strength that is 32.87 Mpa, and as the percentage of the glass powder increase the compressive strength decreases.
- From table 5.1.5 it can be observed that, 15 % glass power volume of concrete of 0.5 W/C ratio for 14 days having a maximum strength that is 43.14 Mpa, and as the percentage of the glass powder increase the compressive strength decreases.
- From table 5.1.6 it can be observed that, 15 % glass power volume of concrete of 0.5 W/C ratio for 28 days having a maximum strength that is 46.65 Mpa, and as the percentage of the glass powder increase the compressive strength decreases.

5.2 Flexuralstrength:-

Fig 5.2.1 Flexural test on GPC

Fig 5.2.2Flexural Failure of GPC

Table 5.2.1: 7 days flexural strength results, W/C=0.45

`% glass powder	Flexural strength (MPa) for 7 days, w/c=0.45
0.0 (Normal concrete)	3.63
5	3.86
10	4.12
15	4.21
20	3.85
25	3.74
30	3.42

Table 5.2.2: 14 days flexural strength results, W/C=0.45

% glass powder	Flexural strength (MPa) for 14 days,w/c=0.45
0.0 (Normal concrete)	4.35
5	4.54
10	4.65
15	4.8
20	4.59
25	4.37
30	4.23

Table 5.2.3: 28 days flexural strength results, W/C=0.45

% glass powder	Flexural strength (MPa) for 28 days,w/c=0.45
0.0 (Normal concrete)	4.45
5	4.67
10	4.78
15	5.18
20	4.65
25	4.27
30	4.12

Table 5.2.4: 7 days flexural strength results, W/C=0.5

% glass powder	Flexural strength (MPa) for 7 days, w/c=0.5
0.0 (Normal concrete)	3.54
5	3.67
10	3.75
15	4.12
20	3.73
25	3.4
30	3.3

Table 5.2.5: 14 days flexural strength results, W/C=0.5

% glass powder	Flexural strength (MPa) for 14 days, w/c=0.45
0.0 (Normal concrete)	4.11
5	4.2
10	4.48
15	4.61
20	4.28
25	4.13
30	3.84

Table 5.2.6: 28 days flexural strength results, W/C=0.5

% glass powder	Flexural strength (MPa) for 28 days, w/c=0.45
0.0 (Normal concrete)	4.32
5	4.49
10	4.52
15	4.78
20	4.51
25	4.41
30	4.23

Fig 5.2.3: 7 days flexural strength, W/C=0.45

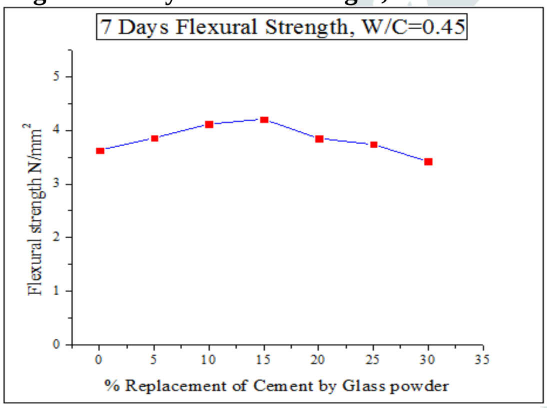


Fig 5.2.4: 14 days flexural strength, W/C=0.45

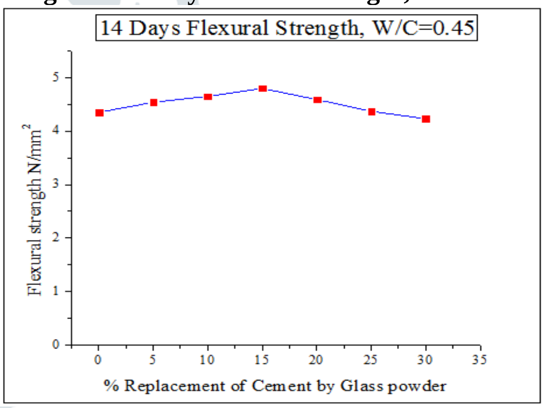


Fig 5.2.5: 28 days flexural strength, W/C=0.45

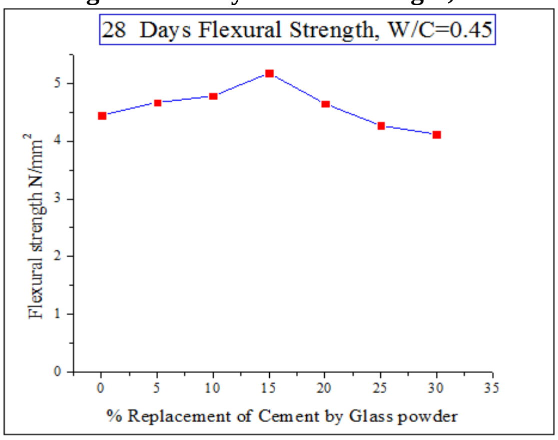


Fig 5.2.6: 7 days flexural strength, W/C=0.5

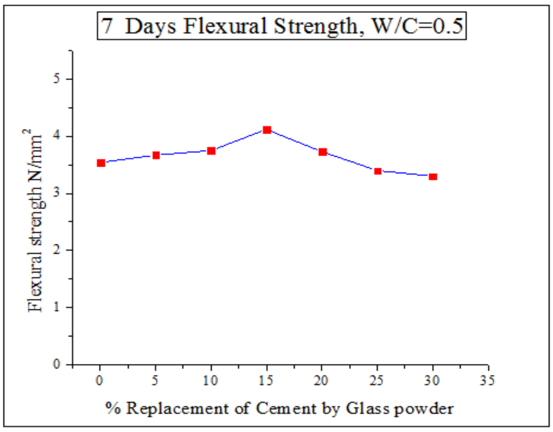


Fig 5.2.7: 14 days flexural strength, W/C=0.5

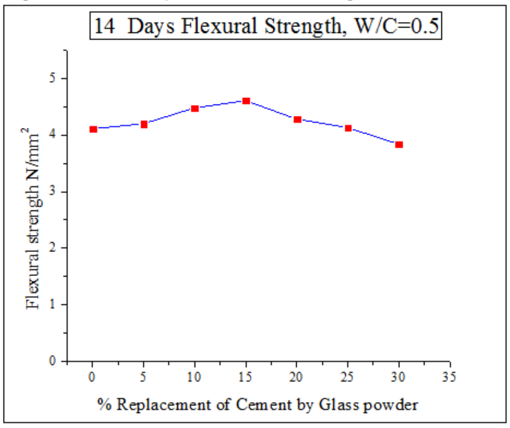
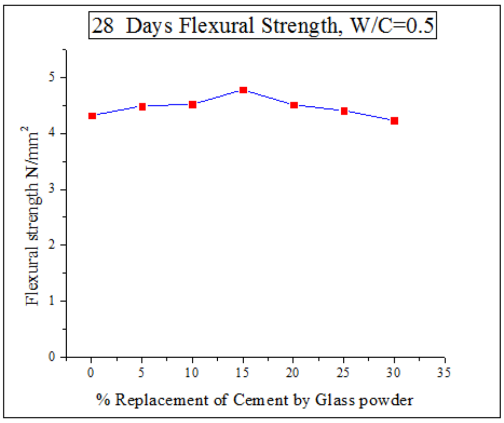


Fig 5.2.8: 28 days flexural strength, W/C=0.5



- The comparison of flexural strength of plain concrete cubes with glass powder concrete cubes with respect to the change of the water cement ratio for different glass powder proportion.
- From table 5.2.1 it can be observed that, 15 % glass power volume of concrete of 0.45 W/C ratio for 7 days having a maximum strength that is 4.21 Mpa, and as the percentage of the glass powder increase the flexural strength decreases.
- From table 5.2.2 it can be observed that, 15 % glass power volume of concrete of 0.45 W/C ratio for 14 days having a maximum strength that is 4.8 Mpa, and as the percentage of the glass powder increase the flexural strength decreases.
- From table 5.2.3 it can be observed that, 15 % glass power volume of concrete of 0.45 W/C ratio for 28 days having a maximum strength that is 5.18 Mpa, and as the percentage of the glass powder increase the flexural strength decreases.
- From table 5.2.4 it can be observed that, 15 % glass power volume of concrete of 0.5 W/C ratio for 7 days having a maximum strength that is 4.12 Mpa, and as the percentage of the glass powder increase the flexural strength decreases.
- From table 5.2.5 it can be observed that, 15 % glass power volume of concrete of 0.5 W/C ratio for 14 days having a maximum strength that is 4.61 Mpa, and as the percentage of the glass powder increase the flexural strength decreases.
- From table 5.2.6 it can be observed that, 15 % glass power volume of concrete of 0.5 W/C ratio for 28 days having a maximum strength that is 4.78 Mpa, and as the percentage of the glass powder increase the flexural strength decreases.

5.3 Split Tensile strength:-

Fig 5.3.1 Split tensile test on GPC

Fig 5.3.2Split Tensile Failure of GPC

Table 5.3.1: 7 days split tensile strength results, W/C=0.45

% glass powder	Split tensile strength (MPa) for 7 days, w/c=0.45
0.0 (Normal concrete)	1.86
5	2.01
10	2.12
15	2.18
20	1.95
25	1.87
30	1.71

Table 5.3.2: 14 days split tensile strength results, W/C=0.45

% glass powder	Split tensile strength (MPa) for 14 days, w/c=0.45
0.0 (Normal concrete)	2.1
5	2.26
10	2.49
15	2.62
20	2.25
25	2.16
30	2.06

Table 5.3.3: 28 days split tensile strength results, W/C=0.45

% glass powder	Split tensile strength (MPa) for 28 days, w/c=0.45
0.0 (Normal concrete)	2.28
5	2.52
10	3.13
15	3.26
20	2.32
25	2.27
30	2.21

Table 5.3.4: 7 days split tensile strength results, W/C=0.5

% glass powder	Split tensile strength (MPa) for 7 days, w/c=0.5
0.0 (Normal concrete)	1.76
5	1.86
10	1.88
15	2
20	1.86
25	1.68
30	1.64

Table 5.3.5: 14 days split tensile strength results, W/C=0.5

% glass powder	Split tensile strength (MPa) for 14 days, w/c=0.5
0.0 (Normal concrete)	1.95
5	2.12
10	2.18
15	2.28
20	2.23
25	2.06
30	1.88

Table 5.3.6: 28 days split tensile strength results, W/C=0.5

% glass powder	Split tensile strength (MPa) for 28 days, w/c=0.5
0.0 (Normal concrete)	2.12
5	2.17
10	2.39
15	2.52
20	2.27
25	2.12
30	2.06

Fig 5.3.1: 7 days split tensile strength, W/C=0.45

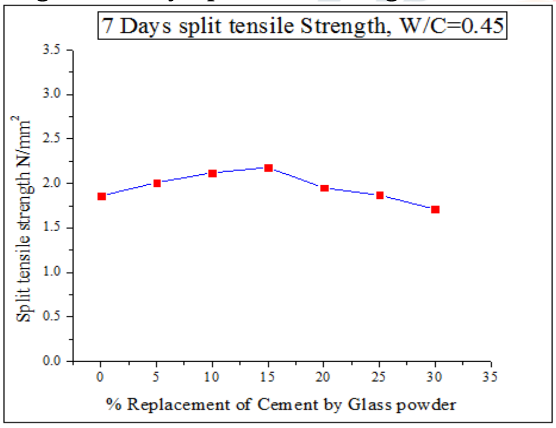


Fig 5.3.2: 14 days split tensile strength, W/C=0.45

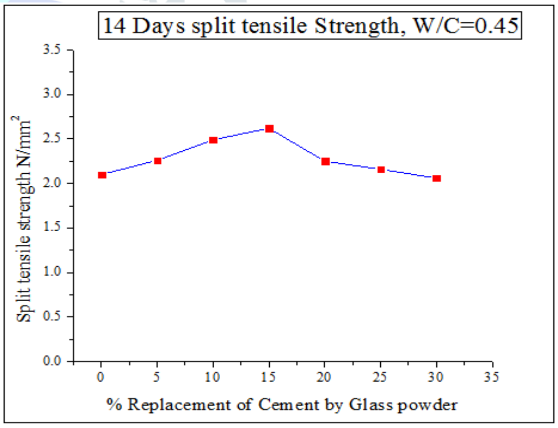


Fig 5.3.3: 28 days split tensile strength, W/C=0.45

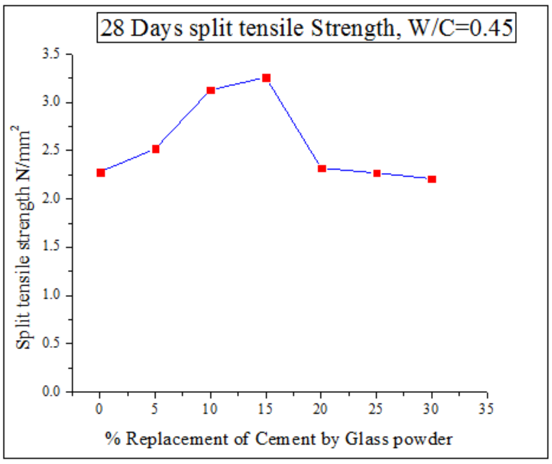


Fig 5.3.4: 7 days split tensile strength, W/C=0.5

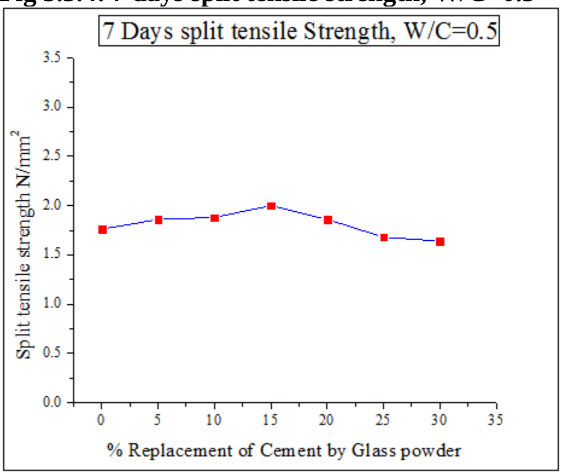


Fig 5.3.5: 14 days split tensile strength, W/C=0.5

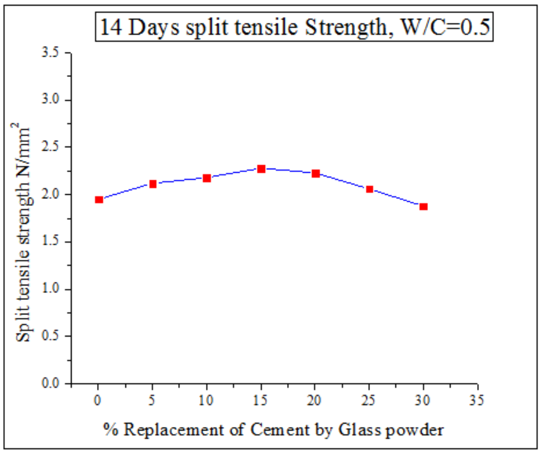
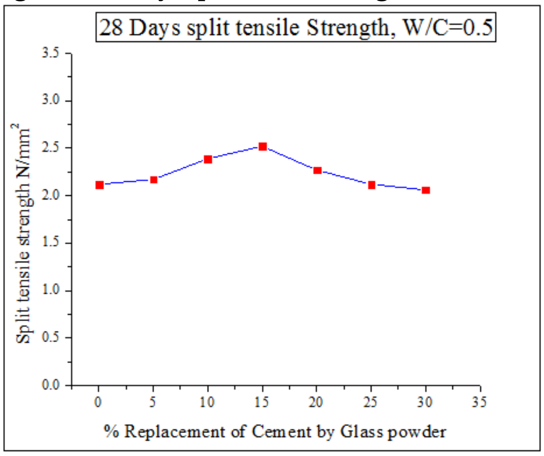


Fig 5.3.6: 28 days split tensile strength, W/C=0.5



- The comparison of flexural strength of plain concrete cubes with glass powder concrete cubes with respect to the change of the water cement ratio for different glass powder proportion.
- From table 5.3.1 it can be observed that, 15 % glass power volume of concrete of 0.45 W/C ratio for 7 days having a maximum strength that is 2.18 Mpa, and as the percentage of the glass powder increase the split tensile strength decreases.
- From table 5.3.2 it can be observed that, 15 % glass power volume of concrete of 0.45 W/C ratio for 14 days having a maximum strength that is 2.62 Mpa, and as the percentage of the glass powder increase the split tensile strength decreases.
- From table 5.3.3 it can be observed that, 15 % glass power volume of concrete of 0.45 W/C ratio for 28 days having a maximum strength that is 3.26. Mpa, and as the percentage of the glass powder increase the split tensile strength decreases.
- From table 5.3.4 it can be observed that, 15 % glass power volume of concrete of 0.5 W/C ratio for 7 days having a maximum strength that is 2 Mpa, and as the percentage of the glass powder increase the split tensile strength decreases.
- From table 5.3.5 it can be observed that, 15 % glass power volume of concrete of 0.5 W/C ratio for 14 days having a maximum strength that is 2.28 Mpa, and as the percentage of the glass powder increase the split tensile strength decreases.
- From table 5.3.6 it can be observed that, 15 % glass power volume of concrete of 0.5 W/C ratio for 28 days having a maximum strength that is 2.52 Mpa, and as the percentage of the glass powder increase the split tensile strength decreases.

6.CONCLUSION

In In the present study on "The Study on Strength parameters of M35 grade Concrete Made with partial replacement of Glass Powder ", the following important conclusions are drawn.

1.It can be observed that workability measured in terms of slump reduces with increase in percentage of replacement of cement by glass powder.

2.For 7, 14 and 28 days, compressive strength of concrete increases with increase in replacement of cement by glass powder content up to 15%, with further increase in glass powder content decrease, in compressive strength is observed and compressive strength of concrete decreases with increase in water cement ratio is observed.

3.For 7, 14 and 28 days, split tensile strength of concrete increases with increase in replacement of cement by glass powder content up to 15%, with further increase in glass powder content decrease, in split tensile strength is observed and split tensile strength of concrete decreases with increase in water cement ratio is observed.

4.For 7, 14 and 28 days, flexural strength of concrete increases with increase in replacement of cement by glass powder content up to 15%, with further increase in glass powder content decrease, in flexural strength is observed and flexural strength of concrete decreases with increase in water cement ratio is observed.

7. REFERENCES

1. Ahmad Shayan, Aimin Xu. "**Performance of glass powder as a pozzolanic material in concrete:A field trial on concrete slabs**". Cement and Concrete Research 36, 457–468, 2004.
2. EsraaEmam Ali, Sherif H. Al-Tersawy. "**Recycled glass as a partial replacement for fine aggregate in self-compacting concrete**".Construction and Building Materials 35, 785–791, 2012.
3. G.Lavanya, R.Karuppasamy. "**Experimental Study on Concrete Using Glass Powder and Granite Powder**". International Journal of Advanced Engineering Research and Technology (IJAERT) Volume 4 Issue 4, ISSN No.: 2348 – 8190, 2016.
4. Aseel B.AL-Zubaid, KadumMuttarShabeeb. "**Study The Effect of Recycled Glass on the Mechanical Properties of Green Concrete**". International conference on Technologies and Materials for renewable energy, environment and sustainability, TMRESS17, 21-24, 2017.

5. K. I. M. Ibrahim. "**The Effect of Using Waste Glass [WG] as Partial Replacement of sand on Concrete**".IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684, P-ISSN: 2320-334X, Volume 14, Issue 2 Ver. II, PP 41-45, 2017.
6. Harshad G Patel, Sejal P Dalal. "**An experimental investigation on physical and mechanical properties of concrete with the replacement of fine aggregates by Polyvinyl chloride and Glass waste**". Procedia Engineering 173, 1666-1671, 2017.
7. Gambhir M.L, ***"Concrete Manual"***, Dhanpat Rai & Co. (Pvt) Ltd., Educational and Technical Publishers, 1710, NaiSarak, New Delh –110 006.
8. Shetty M.S, ***"Concrete Technology"***, S. Chand & Company Ltd., Ram Nagar, New Delhi -110 055.
9. IS 383 (2016), "Coarse and Fine Aggregate for Concrete–Specification", Bureau of Indian Standards, New Delhi, India.
10. IS 456 (2000), "Plain and Reinforced Concrete–Code of Practice", Bureau of Indian Standards, New Delhi, India.
11. IS 516 (1959), "Methods of Tests for Strength of Concrete", Bureau of Indian Standards, New Delhi, India.
12. IS 1199 (1959), "Methods of Sampling and Analysis of Concrete", Bureau of Indian Standards, New Delhi, India.
13. IS 1786 (2008), "High Strength Deformed Steel Bars and Wires for Concrete Reinforcement–Specification", Bureau of Indian Standards, New Delhi, India.
14. IS 2386–Part I (1963), "Methods of Test for Aggregates for Concrete, Part I: Particle Size and Shape", Bureau of Indian Standards, New Delhi, India.
15. IS 2386–Part III (1963), "Methods of Test for Aggregates for Concrete, Part III: Specific gravity, Density, Voids, Absorption and Bulking", Bureau of Indian Standards, New Delhi, India.
16. IS 2386–Part IV (1963), "Methods of Test for Aggregates for Concrete, Part IV: Mechanical Properties", Bureau of Indian Standards, New Delhi, India.
17. IS 4031–Part 2 (1999), "Methods of Physical Tests for Hydraulic Cement, Part 2: Determination of Fineness by Blaine Air Permeability Method", Bureau of Indian Standards, New Delhi, India.
18. IS 4031–Part 3 (1988), "Methods of Physical Tests for Hydraulic Cement,Part 3: Determination of Soundness", Bureau of Indian Standards, New Delhi, India.
19. IS 4031–Part 4 (1988), "Methods of Physical Tests for Hydraulic Cement, Part 4: Determination of Consistency of Standard Cement Paste", Bureau of Indian Standards, New Delhi, India.
20. IS 4031–Part 5 (1988), "Methods of Physical Tests for Hydraulic Cement, Part 5: Determination of Initial and Final Setting Times", Bureau of Indian Standards, New Delhi, India.
21. IS 4031–Part 6 (1988), "Methods of Physical Tests for Hydraulic Cement, Part 6: Determination of Compressive Strength of Hydraulic Cement other than Masonry Cement", Bureau of Indian Standards, New Delhi, India.
22. IS 4031–Part 11 (1988), "Methods of Physical Tests for Hydraulic Cement, Part 11: Determination of Density", Bureau of Indian Standards, New Delhi, India.
23. IS 10262 (2009), "Concrete Mix Proportioning–Guidelines", Bureau of Indian Standards, New Delhi, India.
24. IS 8112 (2013), "Ordinary Portland Cement, 43 Grade–Specification", Bureau of Indian Standards, New Delhi, India.
25. I.S 456 (2000), ***"Indian standard code of practice for plain and reinforced concrete"***, Fourth revision, Bureau of Indian standards, ManakBhavan, 9 Bahadur Shah Zafar Marg, New Delhi-110 002, India.
26. I.S 10262 (1982), ***"Recommended guidelines for concrete mix design"***, First revision, Bureau of Indian standards, ManakBhavan, 9 Bahadur Shah Zafar Marg, New Delhi- 110 002, India.
27. I.S 10262 (2009), ***"Concrete mix proportioning-Guidelines"***, First revision, Bureau of Indian standards, ManakBhavan, 9 Bahadur Shah Zafar Marg, New Delhi-110 002, India.