IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Experimental Investigation on Strength of Glass Powder Replacement by Cement in Concrete with Different Dosages

Rajeev Singh Parihar, Abhay Kumar Jha
Professor
Department of Civil Engineering
LNCT Bhopal

Mranal Agrawal
M. Tech Scholar
Department of Civil Engineering
LNCT Bhopal

ABSTRACT:

The properties of concrete by partial replacement of cement with waste glass powder (10%, 20%, 30% and 40 %) are being studied in the present work. The different properties of concrete, compressive strength, tensile strength, workability, and flexural strength are determined using experimental testing. It was found that the compressive, flexural and tensile strength of concrete improve initially as the replacement percentage of cement by glass powder increases and peak was reached at 20% replacement. Finally, it was concluded that the replacement of cement as much as about 20% of glass powder can be accomplished without sacrificing the compressive strength.

Keywords: Cement, Concrete, Glass Powder, Compressive Strength Workability, M-25

I. Introduction

The interest of the construction community in using waste or recycled materials in concrete is growing because of the emphasis placed on sustainable production, the waste glass from in and across the various sources is disposed as waste in landfills. Glass is an inert material which could be recycled and used many times without losing its chemical properties. Besides the use of waste glass as cullet in glass production, waste glass is beaten into unique sizes for use as mixture in diverse packages inclusive of water filtration, grit plastering, sand cover for game turf and sand alternative in concretes [Babu and Jayaram (2017)].

The utilization of river sand as fine combination leads to exploitation of natural resources, reduced water level, sinking of the bridge piers etc. Many research have been conducted by replacing river sand by crushed glass as a substitute. The crushed glass is also used as coarse aggregate in concrete manufacturing however because of its flat and elongated shape, it causes considerable decrease in the workability and compressive strength.

Some of the studies indicates the suppressing ability of those substances on alkali–silica reaction. A high amount of waste glass as mixture is considered to lower the unit weight of concrete. The use of finely divided glass powder as a cement replacement has yielded high quality concrete. The aim of this work is to check the performance of concrete containing glass powder and compare it with the overall performance of conventional concrete.

II. GLASS POWDER REINFORCED CONCRETE

High-overall performance concrete is described as a concrete assembly special mixture of performance and uniformity requirements that cannot continually be finished robotically the use of conventional parts and everyday mixing, setting, and curing practices. High-overall performance concrete (HPC) exceeds the houses and constructability of regular concrete. Every day and unique materials are used to make those mainly designed concrete that have to meet a aggregate of performance requirements. Special mixing, placing, and curing practices can be had to produce and deal with high-performance concrete. Excessive-performance concrete almost continually has a better electricity than everyday concrete. But, strength is not always the number one required property. For example, a ordinary power concrete with very high durability and very low permeability is taken into consideration to have high overall performance houses. By means of using through-merchandise which include silica fume with high-quality plasticizer we can reap excessive overall performance concrete, which own excessive workability, high power, and excessive modulus of elasticity, high density, high dimensional balance, low permeability and resistance to chemical assault. HPC is often known as “long lasting” concrete because its energy and permeability to chloride penetration makes it last tons longer than traditional concrete.

III. LITERATURE REVIEW

Babu and Jayaram (2017) studied the replacement of waste glass in concrete grades M25 and M30, with water-cement ratios of 0.5 and 0.44 respectively, by replacement percentage of 0%, 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, 50%, and 60%. They studied the different properties of concrete. For the aforementioned replacements, tests on consistency, flexural strength, split tensile strength, and compressive strength were done. According to their findings, glass powder enhances mechanical qualities. This concept has the benefits of being economically inexpensive to replace the glass powder and producing excellent concrete.

Hosanna et al. (2018) investigates the potential for using glass powder to replace cement in concrete. The compressive, tensile, and flexural strengths of the glass powder-replaced concrete were evaluated at 0%, 25%, 35%, and 50% respectively. The results showed that glass powder can be employed as a cement replacement material suitably.

Kumar and Yadav (2019) For concrete grades M25 and M30 with water-cement ratios of 0.5 and 0.44, respectively, glass powder was substituted in the following amounts: 0%, 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, 50%, and 60%. For the aforementioned replacements, tests on consistency, flexural strength, split tensile strength, and compressive strength were done.

Khan et al. (2020) investigated the use of waste glass powder (WGP) as an additional cementitious material in concrete. WGP was used to replace Portland cement in concrete in amounts ranging from 0% to 35% by weight, in 5% increments. Based on the study's findings, it was determined that a replacement ratio of 25% WGP for cement is the most optimum.

Ibrahim (2021) conducted his study to investigate the suitability and impact of using waste glass powder (WGP) as a partial replacement for cement weight in three different types of concrete. 0%, 5%, 10%, 15%, and 20% were the WGP replacement percentages based on cement weight. Ordinary concrete (group 1) has compressive and tensile strengths that are increased by 5% WGP when compared to the control mix by around 8% and 13%, respectively. For all the concrete types used in this investigation, increasing the WGP concentration improved workability.

Kannan and Sophia (2021) evaluated the mechanical and long-term durability performance of reactive powder concrete (RPC), which uses waste glass powder (GP) in place of quartz sand and granite powder (GrP) in place of cement. According to their results, GrP and GP substitution at 15% and 30% of their optimal levels, respectively, improves RPC performance with the achievement of satisfiable workability at a 0.35 w/b ratio. With advancing age, a considerable rise in electrical resistivity and resistance to chloride penetration was also seen. They concluded that it is possible to use granite and glass powder as alternative building materials that are both inexpensive and environmentally friendly.

IV. BEHAVIOUR OF GLASS POWDER REINFORCED CONCRETE UNDER CONVENTIONAL LOADING

Preceding studied of glass fiber suggests with addition of E-glass powder composition of 2% of glass powder and 6% of e-glass powder had been fabricated by way of liquid metallurgy (stir solid) method. The casted composite specimens were machined as in line with check requirements. The specimens had been tested to realize the common casting defects using ultra-sonic flaw detector testing machine. Some of the mechanical homes were evaluated and comparison with E-Glass powder. Extensive improvement in tensile strength, compressive strength and hardness are great as the weight % of the glass powder increases. The microstructures of the composites had been studied to realize the dispersion of the E-glass fiber in matrix. It has been determined that addition of E-glass powder drastically improves ultimate tensile strength in conjunction with compressive strength and hardness as compared with that of unreinforced matrix. The specimens had been organized by way of machining from the cylindrical, cube and beam castings.

V. EXPERIMENTAL SETUP

In order to achieve the stated objectives, this study was carried out in few stages. On the initial stage, all the materials and equipment's needed must be gathered or checked for availability. Then, the concrete mixes according to the predefined proportions. Concrete samples were tested through concrete tests such as cube test.

A. Experimental Program

In order to study effect of replacement of cement in various ratio of industrial waste glass powder compression, flexure, split tension. The experimental program was divided into four groups.

Each group consists of 3 cubes, 1 cylinder and 1 beam, of (15x15x15)cm, 15cm x30cm and (15x15x70)cm respectively.

The first group is the control (Plain) concrete with 0% glass powder (PPC)

The second group consisted of 10% glass powder, with aspect ratio by replacement of cement.

The third group consisted of 20% glass powder, with aspect ratio by replacement of cement.

The fourth group consisted of 30% glass powder, with aspect ratio by replacement of cement.

The fifth group consisted of 40%glass powder, with aspect ratio by replacement of cement.

B. Materials And Tests

1. Cement

Cement acts as a binding agent for materials. Cement as applied in Civil Engineering Industry is produced by claiming at high temperature. It is admixture of calcareous, siliceous, aluminous substances and crushing the clinkers to a fine powder. Cement is the most expensive materials in concrete and it is available in different forms. When cement is mixed with water, a chemical reaction takes place as a result of which the cement paste sets and hardens to a stone mass.

- **Tests On Cement**

Standard Consistency and Initial Setting Time

Standard consistency of cement is defined as that water content at which the needle of the apparatus fails to penetrate the specimen by 5mm from bottom of the mould.

Standard Consistency of the cement paste = 30%.Initial Setting Time of Cement = 45min.

Weight of cement taken in the mould = 300 grams

2. Glass Powder

Table 1: Physical properties of Glass powder

1	Specific gravity	2.6
2	Fineness passing 150µm	99.5
3	Fineness passing 90 µm	98
Chemical Properties		
1	Ph	10.25
2	Color	Grayish white
Chemical composition		% by mass
1	SiO_2	67.33
2	Al_2O_3	2.620
3	Fe_2O_3	1.420
4	TiO_2	0.157
5	CaO	12.450
6	MgO	2.738

7	Na_2O	12.050
8	K_2O	0.638
9	ZrO_2	0.019
10	ZnO_2	0.008
11	SrO	0.016
12	P_2O_5	0.051
13	NiO	0.014
14	CuO	0.009
15	Cr_2O_3	0.022

C. Workability of Concrete

Table 2: Workability test for M-25 grade

S.No	**Grade of concrete**	**Slump Values**				
		0%	10%	20%	30%	40%
1	M-25	29	45	60	70	75

D. Curing

Curing is the process of preventing the loss of moisture from concrete while maintaining a satisfactory temperature. After casting the molded specimens are stored in the laboratory and at a room temperature for 24 hours from the time at addition of water to dry ingredients. After this period the specimens are removed from the moulds immediately submerged in clean and fresh water. The specimens are cured for 28days in the present work.

E. COMPRESSIVE STRENGTH

The results of compressive strength were presented in table 3. the test was carried out conforming to **IS:516-1959** to obtain compressive strength of concrete at the age of 7,14,21 and 28 days. the cubes were tested using UTM. The compressive strength of the concrete with partial replacement of glass powder increases with the percentage of glass powder at some extent. concrete mix with 10 percent GP as replacement of cement is the optimum level as it has been observed to show a significant increase in compressive strength at 28 days when compared with control mix.

F. FLEXURAL TEST

SFRC beams of size (150x150x700)mm are tested using a flexure testing machine. The specimen is simply supported on the two rollers of the machine which are 600mm apart, with a bearing of 50mm from each support. The load shall be applied on the beam from two rollers which are placed above the beam with a spacing of 200mm. The load is applied at a uniform rate such that the extreme fibers stress increases at 0.7 N/mm^2/min i.e., the rate of loading shall be 4 KN/min. The load is increased till the specimen fails. The maximum value of the load applied is noted down. The appearance of the fracture faces of concrete and any unique features are noted.

G. SPLIT TENSILE TEST

SFRC cylinders of size 15cm (Dia) x 30cm (height) are casted. The test is carried out by placing a cylindrical specimen horizontally between the loading surface of a compression testing machine and the load is applied until the failure of the cylinder, along the vertical diameter. When the load is applied along the generatrix, an element on the vertical diameter of the cylinder is subjected to a horizontal stress of $2P/\pi ld$.

VI. RESULT

Table3: Result of compressive strength for M-10 to M-25 grade of concrete on cube specimen with 0%,10 %, 20%, 30 %, 40% glass powder mixes

% of glass powder	M-10 Average compressive strength in N/mm^2				M-15 Average compressive strength in N/mm^2				M-20 Average compressive strength in N/mm^2				M-25 Average compressive strength in N/mm^2			
	7 days	14 days	21 days	28 days	7 days	14 days	21 days	28 days	7 days	14 days	21 days	28 days	7 days	14 days	21 days	28 da
0%	3.44	10.55	11.96	13.37	9.97	15.22	16.63	18.04	14.97	20.22	21.63	23.04	18.44	25.55	26.96	28
10%	5.60	11.53	13.12	14.70	11.07	16.56	18.15	19.73	16.07	21.56	23.15	24.73	20.60	28.53	30.12	31
20%	7.30	12.87	14.09	15.30	11.32	16.69	18.41	20.12	16.32	21.69	23.41	25.12	22.30	30.87	32.59	34
30%	4.73	10.32	11.84	13.36	10.07	15.37	16.89	18.41	15.07	20.37	21.89	23.41	19.73	27.32	28.84	30
40%	2.63	9.41	10.76	12.12	9.95	15.30	16.65	18.01	14.95	20.30	21.65	23.01	17.63	24.41	25.76	27

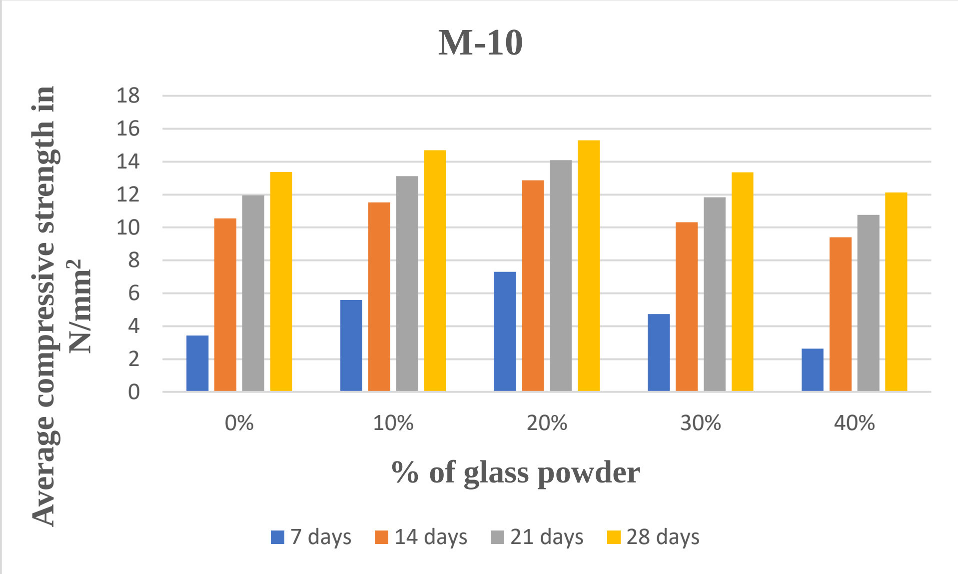

Fig-01: compressive strength of concrete for M-10 grade

Result of compressive strength for M-10 grade of concrete on cube specimen with 0%,10 %, 20%, 30 %, 40% glass powder mixes are shown in table-3 and fig01. Table-3 and fig01 show the compressive strength values of M-10 to M-25 grade concrete and glass powder mixes and their values are observed to be varied from 3.44 to 13.37 N/mm^2 with 0% glass powder 5.60 to 14.70 N/mm^2 with 10%, 7.30 to 15.30 N/mm^2 with 20%, 4.73 to 13.36 N/mm^2 with 30 %, and 2.63 to 12.12 N/mm^2 with 40% of glass powder. the 7,14,21 and 28 days compressive strength of concrete increases initially as the replacement percentage of cement with glass powder increases and become maximum at about 20% and later decreases.

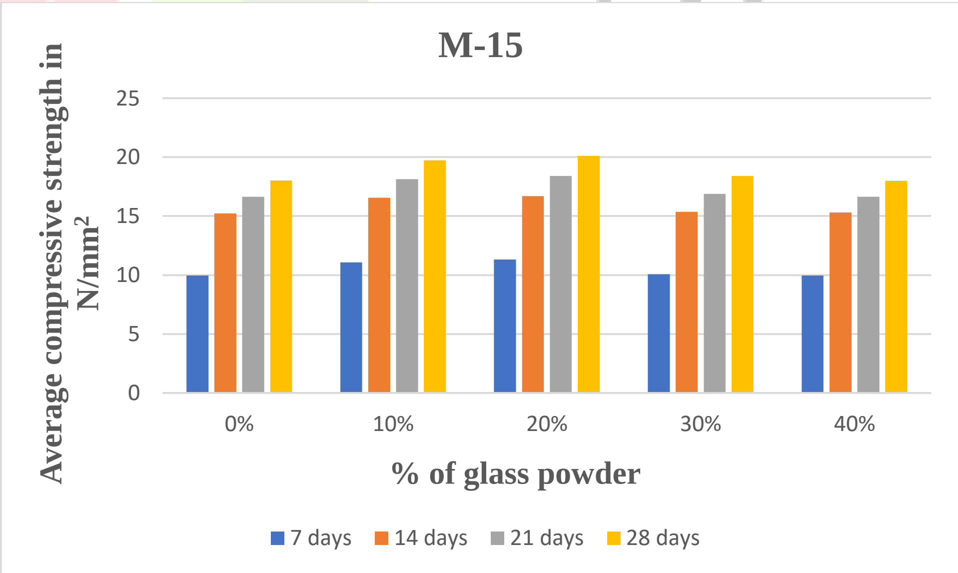

Fig-02: 28 days compressive strength of concrete for M-15 grade

Result of compressive strength for M-15 grade of concrete on cube specimen with 0%,10 %, 20%, 30 %, 40% glass powder mixes are shown in table-3and Fig2. Table-3 and Fig2 show the compressive strength values of M-10 to M-25 grade concrete and glass powder mixes and their values are observed to be varied from9.97 to 18.04 N/mm^2 with 0% glass powder, 11.07 to 19.73 N/mm^2 with 10%, 11.32 to 20.12 N/mm^2 with 20%, 10.07 to 18.41 N/mm^2 with 30 %, and 9.95 to 18.01 N/mm2 with 40%of glass powder. the 7,14,21 and 28 days compressive strength of concrete increases initially as the replacement percentage of cement with glass powder increases and become maximum at about 20% and later decreases.

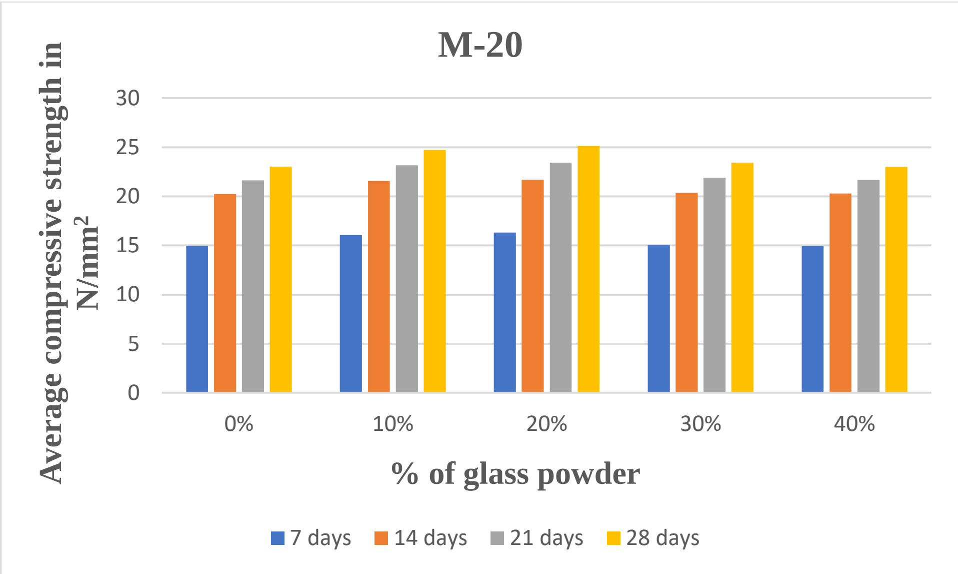

Fig-03: compressive strength of concrete for M-20 grade

Result of compressive strength for M-20 grade of concrete on cube specimen with 0%,10 %, 20%, 30 %, 40% glass powder mixes are shown in table-3 and fig3. Table-3 and Fig3 show the compressive strength values of M-10 to M-25 grade concrete and glass powder mixes and their values are observed to be varied From14.97 to 23.04 N/mm^2 with 0% glass powder, 16.07 to 24.73 N/mm^2 with 10%, 16.32 to 25.12 N/mm^2 with 20%, 15.07 to 23.41 N/mm^2 with 30 %, and 14.95 to 23.01N/mm^2 with 40% of glass powder. the 7,14,21 and 28 days compressive strength of concrete increases initially as the replacment percentage of cement with glass powder increases and become maximum at about 20% and later decreases.

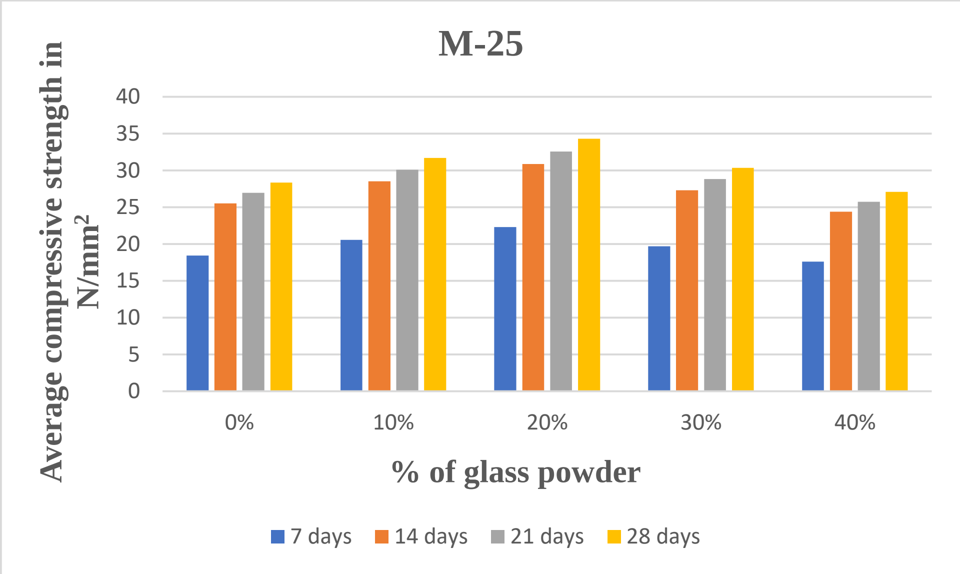

Fig-04: compressive strength of concrete for M-25 grade

Result of compressive strength for M-25 grade of concrete on cube specimen with 0%,10 %, 20%, 30 %, 40% glass powder mixes are shown in table-3and fig4. Table-3 and Fig4 show the compressive strength values of M-10 to M-25 grade concrete and glass powder mixes and their values are observed to be varied From18.44 to 28.37 N/mm^2 with 0% glass powder, 20.6 to 31.7 N/mm^2 with 10%, 22.3 to 34.3 N/mm^2 with 20%, 19.734 to 30.36 N/mm^2 with 30 %, and 17.628 to 27.12 N/mm^2 with 40% of glass powder. the 7,14,21 and 28 days compressive strength of concrete increases initially as the replacement percentage of cement with glass powder increases and become maximum at about 20% and later decreases.

Table 4: Result of Flexural Strength of Concrete for M-10 to M-25 grade of age After 28 Days

Percentage Replacement of Glass Powder	M-10	M-15	M-20	M-25
0 % GP	2.10	2.45	2.80	3.15
10 % GP	2.01	2.47	2.93	3.39
20 % GP	2.24	2.83	3.42	4.01
30 % GP	0.74	1.58	2.42	3.26
40 % GP	0.46	1.32	2.18	3.04

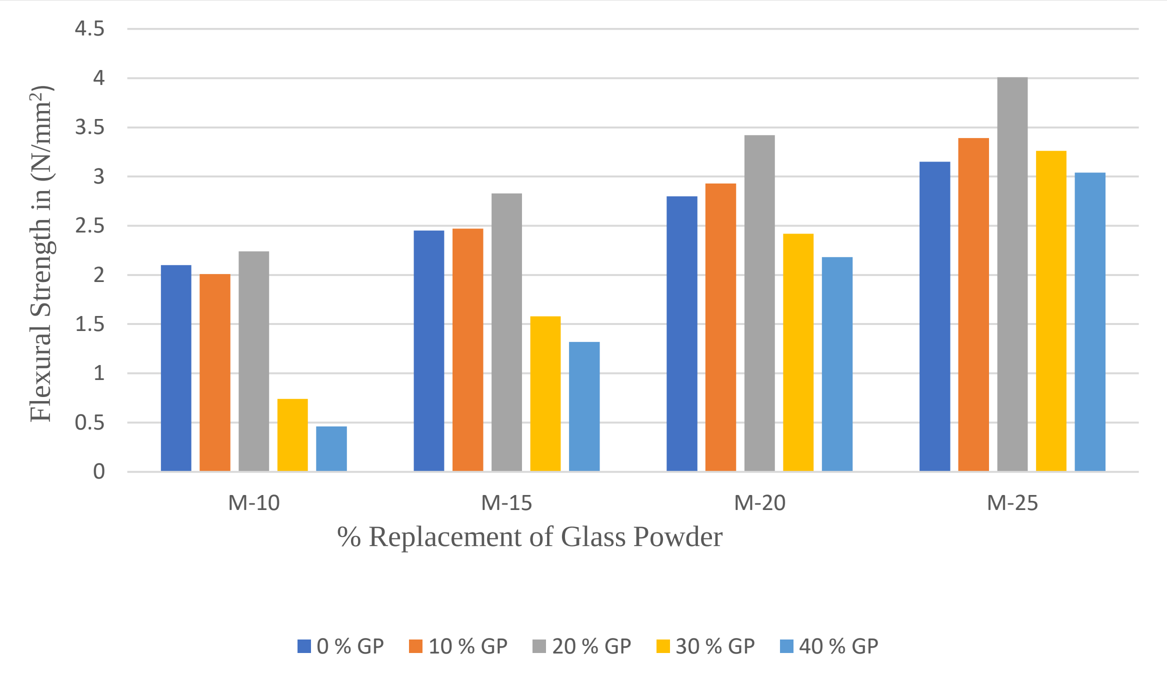

Fig5: 28 days Flexural Strength of concrete

Table – 5: Result of Split Tensile Strength of Concrete for M-10 to M-25 grade of age After 28 Days

Percentage Replacement of Glass Powder	M-10	M-15	M-20	M-25
0 % GP	2.52	2.99	3.46	3.93
10 % GP	3.65	3.78	3.91	4.04
20 % GP	4.16	4.27	4.38	4.49
30 % GP	3.54	3.65	3.76	3.87
40 % GP	3.34	3.46	3.58	3.70

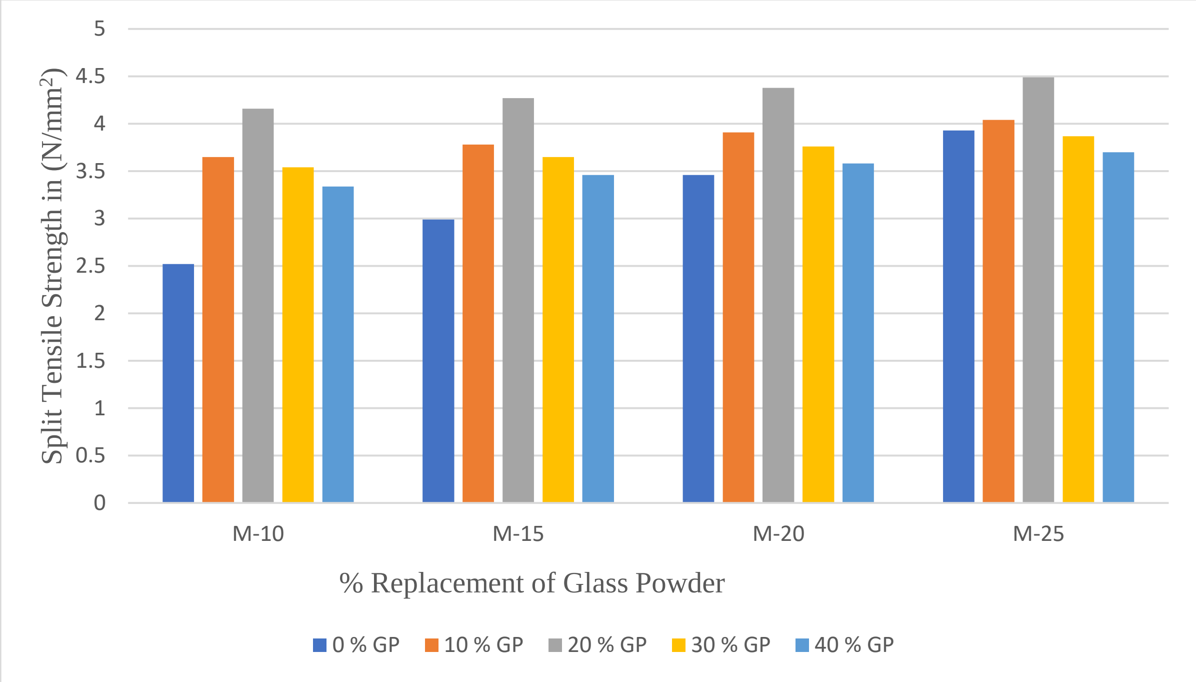

Fig6: 28 days Split Tensile Strength of concrete

VII. CONCLUSION

The following conclusions are made based on the above study:

1. The 7days, 14days, 2days and 28days compressive strengths of concrete increase initially as the replacement percentage of cement with glass powder increases and become maximum at about 20% and later decreases. For (M-10 5.92 N/mm^2, M-15 2.07 N/mm^2, M-20 2.07 N/mm^2, M-25 5.93 N/mm^2)
2. The flexural strength of concrete increases initially as the replacement percentage of cement with glass powder increases and becomes maximum at about 20% and later decrease.
3. The split tensile strength of concrete increases initially as the replacement percentage of cement with glass powder increases and becomes maximum at about 20% and later decrease.
4. The slump of concrete decrease monotonically as the replacement Percentage of cement with glass powder increases. The workability decreases when cement is replaced partially with glass powder.
5. The present study shows that there is a great potential for the utilization of glass powdering concrete as partial replacement of cement. About 20% of cement may be replaced with glass powder without any sacrifice on the compressive strength.
6. Using of waste glass powder in local construction Bhopal area its reducing cost significantly in casting of one m^3 for grade concrete M-25 save in Rs 348 approximately.

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