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An Experimental Investigation on the Strength Properties of Concrete by Partial Replacement of Cement with Glass Powder and Silica Fume

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ABSTRACT: The purpose of this research is to find the suitability of Glass powder as a partial replacement of cement for new concrete with mineral admixture as silica fume. The experimental investigation is carried out in two phases in order to find the proportions. The PHASE-I consists of varying proportions of glass powder and silica fume. The PHASE-II consists of fixed proportion of glass powder with varying proportion of silica fume. In the Phase-I, M20 grade of concrete is chosen to perform the effective replacement of glass powder with cement by replacement levels of 0%, 8%, 16%, 24%, 32% and 40%, Silica fume with cement by replacement levels of 0%, 2%, 4%, 6%, 8%, 10% and the behavior of fresh and hardened properties of concrete was carried out. In Phase-II, glass powder is kept constant with cement by replacement level as 32%, Silica fume with cement by replacement levels of 0%, 2%, 4%, 6%, 8%, 10% and the behavior of fresh and hardened properties of concrete was carried out. The compressive strength shows an average of 30% more strength than the conventional concrete for an optimal percentage of 40% which consist of 32% of glass powder and 8% of silica fume. The flexural strength has an increase of 100% when compared to conventional concrete for 28 days and 27% more for 56 days. The split tensile strength has an increase of 35% when compared to conventional concrete for 56 days.

KEYWORDS: Micro-Silica, Glass powder, Partial Replacement, Particle Packing and Strength of Concrete, Combination and Strength of Concrete.

I. INTRODUCTION

To reduce the consumption of cement, the application of Pozzolana materials is increasing day-by-day in the form of partial cement replacement for concrete preparation. Previous studies indicated that the use of micro-silica leads to the reduction in cement consumption and also helps to increase the strength and durability of concrete. Since the demand in the concrete manufacturing is increasing day by day, the utilization of river sand as fine aggregate leads to exploitation of natural resources, lowering of water table, sinking of the bridge piers, etc as a common threat. Attempts has been made in using crushed glass as fine aggregate in the replacement of river sand. The crushed glass was also used as coarse aggregate in concrete production but due to its flat and elongated nature which enhances the decrease in the workability and attributed the drop in compressive strength.

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II. OBJECTIVE

The main objective of the present experimental investigation is to obtain the influence of the combined application of Silica Fume and Glass Powder on various strength properties of M20 grades of concrete. 10%, 20%,30%, 40% & 50% of glass powder and 2%, 4%, 6%, 8% and 10% of silica fume. Compressive strength, split tensile strength, Flexural strength, Modulus of Elasticity & water absorption tests of the concrete prepared using different proportions of silica fume from 0 to 10 % at 2 % variation and keeping glass powder as 32 % are to be obtained and the results are to be compared with that of controlled concrete.

III. EXPERIMENTAL INVESTIGATION

3.10 PROPERTIES OF MATERIALS

3.11 CEMENT

In the present investigation Ordinary Portland Cement (OPC) of 53 Grade confirming to IS specifications was used. The properties of cement are shown in Table.1.

Table 1. Properties of Cement

S. No	Characteristics	Test results	Requirements as per IS 12269 – 1987
1	Fineness (retained on 90- μ m sieve)	7.6%	<10%
2	Normal Consistency	30%	--
3	Initial setting time of cement	65 min's	30 minutes (minimum)
4	Final setting time of cement	300 min's	600 minutes (maximum)
5	Expansion in Le-chatelier's method	4 mm	10 mm (maximum)
6	Specific gravity	3.15	3.10 – 3.25

3.12 FINE AGGREGATE

Locally available river sand confirming to IS specifications was used as the fine aggregate in the concrete preparation. The properties of fine aggregate are shown in Table.2.

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Table 2. Properties of Fine Aggregate

S.No	Property	Value
1	Specific Gravity	2.76
2	Fineness Modulus	2.77
3	Bulk Density (Loose)	14.50 kN/m ³
4	Grading of Sand	Zone – II

3.13 COARSE AGGREGATE

Crushed granite metal of nominal size 20 mm and 10 mm obtained from the local quarry and confirming to IS specifications were used. The properties of coarse aggregate are shown in Table.3. The coarse aggregate used for the preparation of concrete is a combination of 20 mm and 10 mm size aggregates in ratio 1.5: 1.0.

Table3. Properties of Coarse Aggregate

S.No	Property	Result
1	Specific Gravity	2.83
2	Bulk Density (Loose)	14.80 kN/m ³
3	Water Absorption	1.2 %
4	Fineness Modulus	7.1

3.14 GLASS POWDER

Waste glass powder which is produced form the glass manufacturing industry is been collected and made into glass powder. The physical and chemical properties are presented in the table. The properties of glass powder are shown in Table 4 & Table 5.

Table 4. Physical Properties of Glass Powder

S.No.	Property	Value
1	Specific gravity	2.6
2	Fineness Passing 150µm	99.5 %
3	Fineness Passing 90µm	4%

Table 5. Chemical Properties of Glass Powder

S.No.	Property	Value
1	pH	10.25
2	Colour	Grayish white

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3.15 SILICA FUME:

Silica Fume is highly pozzolanic mineral admixture, which is mainly utilized to improve concrete strength and durability of concrete. Silica Fume reacts with calcium hydroxide formed during hydration of cement results in the increase in strength and also the Silica Fume fills the voids between cement particles leads to increase in the durability. Silica Fume is procured from ASTRRA CHEMICALS, Thousand Lights and Chennai. The properties of Silica Fume are shown in Table 6 and Table 7.

Table 6. Physical Properties of Silica Fume

S.No.	Physical Properties	Results
1	Physical State	Micronised Powder
2	Odour	Odourless
3	Appearance	White Colour Powder
4	Colour	White
5	Pack Density	0.76 gm/cc
6	PH of 5% SOLUTION	6.90
7	Specific Gravity	2.63
8	Moisture	.058%
9	Oil Absorption	55 ml / 100 gms

Table 7. Chemical Properties of Silica Fume

S.No.	Chemical Properties	Results
1	Silica (SiO ₂)	99.886%
2	Alumina (Al ₂ O ₃)	0.043%
3	Ferric Oxide (Fe ₂ O ₃)	0.040%
4	Titanium Oxide (TiO ₂)	0.001%
5	Calcium Oxide (CaO)	0.001%
6	Magnesium Oxide (MgO)	0.000%
7	Pottassium Oxide (K ₂ O)	0.001%
8	Sodium Oxide (Na ₂ O)	0.003%

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3.16 WATER

Water used for casting and curing of concrete test specimens is free from impurities which when present can adversely influence the various properties of concrete.

3.17 CONCRETE MIX PROPORTION

The concrete mix design was proposed by using Indian Standard for control concrete. The grade was M20. The mixture will be prepared with the cement content of 310 kg/m³ and water to cement ratio of 0.5. The mix proportion of materials is 1:2.36:4.02 as per IS 10262-2009.

3.20 TEST SPECIMENS

Concrete test specimens consist of 150 mm × 150 mm × 150 mm cubes, cylinders of 150 mm diameter and 300 mm height and 100 mm × 100 mm × 500 mm prisms. Concrete cube specimens were tested at 3, 7, 28, 56 & 90 days of curing to obtain the compressive strength of concrete. Cylindrical specimens were tested at the age of 28 days to obtain the compressive strength, split tensile strength and Modulus of Elasticity of concrete. The prisms were tested at the age of 28 days to obtain the flexural strength of concrete. The rate of loading is as per the Indian Standard specifications. Water absorption test is also performed for durability.

IV. RESULTS AND DISCUSSIONS

4.10 COMPRESSIVE STRENGTH

The variation of the cube compressive strength with the age of M20 grade concrete prepared using the various proportions of Silica Fume & Glass Powder is shown in Fig.1. Each value of the cube compressive strength indicates the average of three test results. It can be observed that the compressive strength of 8% Silica Fume and 32% Glass Powder concrete exhibits more than the control concrete in Phase I & Phase II and with further increase in Silica Fume the strength decreases for the given Glass Powder content.

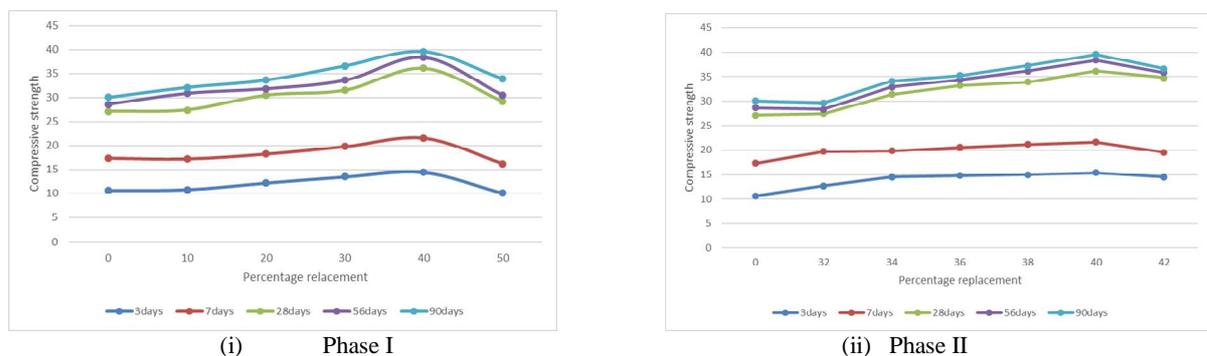


Fig. 1. Variation of Cube Compressive Strength of M20 Grade Concrete with age for different percentages of Glass Powder & Silica Fume.

4.20 SPLIT TENSILE STRENGTH

The variation of the Split Tensile strength with the age of both 28 Days and 56 Days of M20 grade concrete prepared using the various proportions of Silica Fume & Glass Powder is shown in Fig.2. It can be observed that the Split Tensile strength of 8% Silica

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Fume and 32% Glass Powder concrete exhibits more than the control concrete in Phase I & Phase II and with further increase in Silica Fume the strength decreases for the given Glass Powder content.

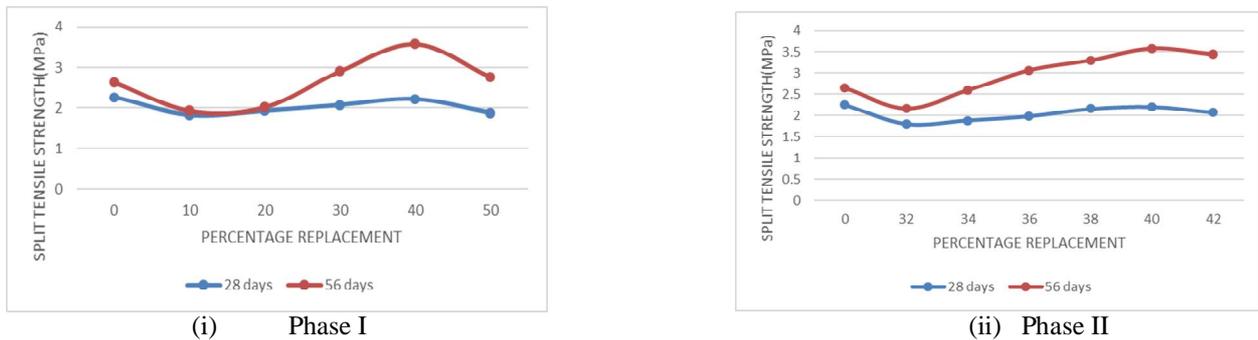


Fig. 2. Variation of Split Tensile Strength of M20 Grade Concrete with age for different percentages of Glass Powder & Silica Fume.

4.30 FLEXURAL STRENGTH

The variation of the Flexural strength with the age of both 28 Days and 56 Days of M20 grade concrete prepared using the various proportions of Silica Fume & Glass Powder is shown in Fig.3. It can be observed that the Flexural strength of 8% Silica Fume and 32% Glass Powder concrete exhibits more than the control concrete in Phase I & Phase II and with further increase in Silica Fume the strength decreases for the given Glass Powder content.

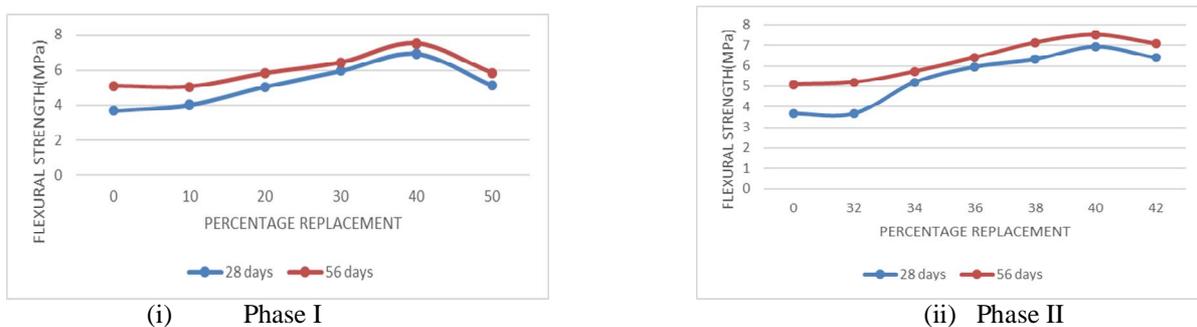


Fig. 3. Variation of Flexural Strength of M20 Grade Concrete with age for different percentages of Glass Powder & Silica Fume.

4.40 MODULUS OF ELASTICITY

The variation of the Modulus of Elasticity with the age of both 28 Days of M20 grade concrete prepared using the various proportions of Silica Fume & Glass Powder is shown in Fig.4. It can be observed that the Flexural strength of 8% Silica Fume and 32% Glass Powder concrete exhibits more than the Modulus of Elasticity in Phase I & Phase II and with further increase in Silica Fume the strength decreases for the given Glass Powder content.

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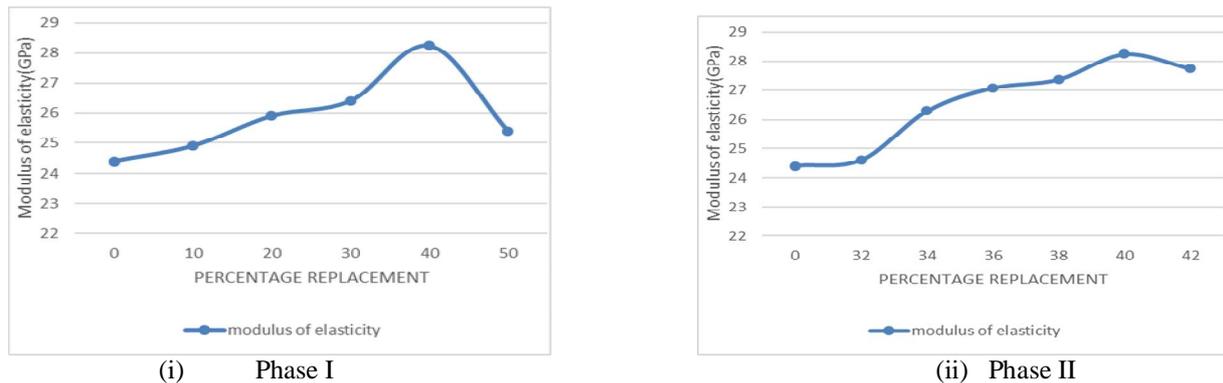


Fig. 4. Variation of Modulus of Elasticity of M20 Grade Concrete with age for different percentages of Glass Powder & Silica Fume.

4.50 WATER ABSORPTION AND DESORPTION

The variation of the Water Absorption & Desorption of M20 grade concrete prepared using the various proportions of Silica Fume & Glass Powder is shown in Fig.5. It can be observed that the Water Absorption & Desorption of 8% Silica Fume and 32% Glass Powder concrete is higher in Phase I & Phase II.

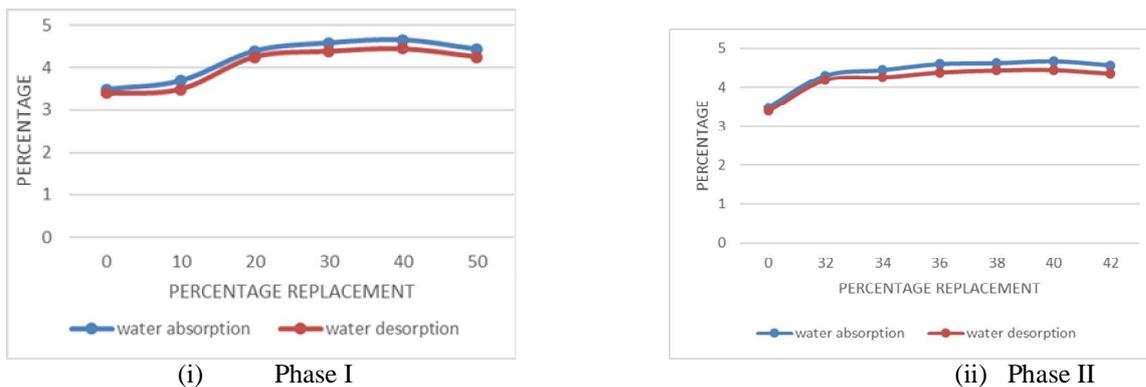


Fig. 5. Variation of Water Absorption & Desorption of M20 Grade Concrete with age for different percentages of Glass Powder & Silica Fume.

V. CONCLUSIONS

The compressive strength shows an average of 30% more strength than the conventional concrete for an optimal percentage of 40% which consist of 32% of glass powder and 8 % of silica fume. Flexural strength has an increase of 100% when compared to conventional concrete for 28 days and 27% more for 56 days. The split tensile strength has an increase of 35% when compared to conventional concrete for 56 days. The main reason for the mineral admixture used here because of the particle size of the glass powder which is more than the 75µm which causes alkali-silica reaction. To avoid the usage of the mineral admixture the glass powder should be finely grounded to less than 75µm. Glass powder increases the compressive strength, split tensile strength and flexural strength effectively when

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compared to conventional concrete. Hence glass powder can be used as partial replacement of cement, with satisfactory results.

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