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STUDY ON STRENGTH PROPERTIES OF SHOTCRETE CONCRETE USING MINERAL ADMIXTURES WITH QUARTZ SAND AND QUARTZ POWDER

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Abstract

This article describes experimental investigations into the effects of Quartz sand and Micro Silica on the mechanical properties of Shotcrete concrete. High performance shotcrete, which includes new generations of chemical admixtures, supplementary cementitious materials such as micro silica and fly ash, reinforcement fibres and polymer modifiers, can play an important role in rehabilitation and repair projects. Utilizing these innovative shotcrete materials permits economical, effective, and long-lasting repairs. Numerous investigations are being conducted to identify alternatives to cement, such as fly ash, GGBS, micro silica, etc. [17] describes our current understanding of shotcrete and demonstrates how shotcrete is different from conventional concrete. In this experimental investigation, Cement is partially replaced with 10% of Micro silica and 100% of fine aggregate with Quartz sand and Quartz powder is examined for M40 and M50 grade concrete. Compressive strength, split tensile strength, and flexural strength of High Strength Shotcrete Concrete have been studied. After trials, Partial replacement of cement with Micro silica and full replacement of fine aggregate with Quartz sand and Quartz powder significantly improved the Mechanical Properties of concrete. Micro particles added to concrete improved its mechanical properties by increasing its consistency and reducing its porosity.

Key words: High performance shotcrete, Micro silica, Quartz sand, Quartz powder.

1.0 Introduction

By incorporating pozzolanic materials, the properties of shotcrete concrete, such as workability, durability, strength, crack resistance, and permeability, can be enhanced. Numerous modern concrete mixtures are modified by the addition of admixtures that improve the microstructure and decrease the calcium hydroxide concentration via a pozzolanic reaction. The subsequent modification of the microstructure of cement composites improves their mechanical properties, durability, and service life. When fine pozzolana particles disperse in the paste, they generate a large number of nucleation sites for the precipitation of the hydration products. This mechanism makes paste more homogeneous as a result. This is a result of the reaction between the amorphous silica in the pozzolanic and the calcium hydroxide produced by the cement hydration reactions.

In tunnel construction Shotcrete is using as a support & stabilization of excavated section and also as a lining inner. Shotcrete is a process where concrete is likely to apply under pressure, using a gun onto a surface to form structural shapes including walls, floors, and roofs. This paper highlights shotcrete technology with admixtures effects, strength development control and its importance, spraying & flow processes, proportions of ingredients, mechanical properties, application criteria‘s, advantages and advancement. It also covers a case study of Hong Kong Tunnel works [2].

The experimental investigation of shotcrete concrete by partially replacing pozzolanic admixtures i.e, Quartz powder along with Micro silica and with complete replacement of river sand with Quartz sand [6] for which compressive strength tests were done at w/c of 0.30 and 0.34. It has been demonstrated that the replacement with Micro-Silica, Quartz sand and Quartz powder has improved its mechanical properties and had a positive effect on pore filling. [18] describes about the Micro silica’s property of high reactivity and extreme cohesiveness. [14] emphasises implications of various mineral admixtures

such as fly ash, silica fume, metakaolin, and Ground Granulated Blast Furnace Slag (GGBFS) for the rheological properties of fresh wet-mix shotcrete incorporating crushed aggregates are quantitatively assessed. [20]The experimental investigation of the effect of glass fibres on reinforced high strength self-compacting concrete with alkali-resistant glass fibres was investigated. The presence of fibres contributed to the enhancement of the material's ductility. The presence of steel fibres in concrete slabs reduced the spread of cracks. It led to improved deflection control by enhancing flexural rigidity. [21] An attempt has been made to investigate the Comparative study of Flexural Strength of beams with addition of Steel fiber varying 0 to 1.5 % with two Aspect ratios of M80 grade Mix. The presence of fibers contributed towards improvement in the ductility characteristics. The presence of Steel fibers reduces crack propagation in concrete beams. It enhances the flexural rigidity resulting in better deflection control.

This paper investigates the effects of Micro Silica and Quartz sand & Quartz powder on the mechanical properties of high-performance shotcrete concrete after 28, 90 and 180 days. These characteristics includes the compressive strength, split tensile strength and flexural strength test results.

2.0 MATERIALS USED IN EXPERIMENTATION

2.1 CEMENT

Cement of grade 53 OPC "confirming to IS 12269 - 1987" (Ultra Tech cement) was used. PhysicalProperties are shown in Table No.1.

Table No.1 Physical Properties of OrdinaryPortl and Cement

S.No.	**Property**	TestResults
1	Normal Consistency	32%
2	Initial Setting time	40 min
3	Final Setting time	250 min
4	Specific Gravity of Cement	3.13
5	Compressive Strength at 28days	56.3 N/mm^2

2.2 MICROSILICA

Microsilica confirming to IS 15388-2003(MAC SILICA FUME) is used are obtained from local market and composition is shown in Table No.2.

2.2.1 Composition of Micro Silica

Table No.2- Composition of Micro Silica

S.No	**Constituents**	**Percentage**
1	Silica,Sio_2	92.00
2	Alumina, Al_2O_3	0.46
3	IronOxide,Fe_2O_3	1.60
4	Lime,CaO	0.36
5	Magnesia,MgO	0.74
6	SulphurTrioxide, SO_3	0.35
7	Lossonignition	2.50
8	Na_2O	0.70
9	K_2O	0.90
10	p^H	7.6
11	AcceleratedPozzolonicAcidityindex in7days	104

12	AcceleratedPozzolonicAcidityindex in28days	117
13	Surface Aream^2/kg	18.9
14	MoistureContent	1
15	Bulk Density Kg/m^3	450-650

2.3 QUARTZSAND &QUARTZ POWDER:

In present investigations Quartz sand & Quartz powder used are obtained from local market. Quartz has a hardness of 7 on the Mohs scale, density of 2.65 g/cm³, size of Quartz sand is 0.3 to 0.8 mm and Quartz powder is in order of 0 -10 µm is used as fine aggregate. The Compositionof Quartz sand & Quartz powder is Tabulated in Table No.3 and Physical Properties are shown in Table No.4

Table No.3 Composition of Quartz sand & Quartz powder

Name	Percentage
Sio_2	99.24
Tio_2	Absent
Fe_2o_3	0.04
Al_2o_3	0.12
Cao	0.28
Mgo	Absent
Loss on ignition	0.06

Table No.4 -Physical Properties of Quartz sand

S.No	Property	Test Results
1	Finenessmodulus	2.98
2	Specific gravity	2.66
3	Bulk densitya).Loose b).Compacted	1319kg/m^3 1435kg/m^3

2.4 COARSEAGGREGATE

Machine crushed angular granite metal of 20mm nominal size from the local source is used as coarse aggregate. It is free from impurities such as dust, clay particles and organic matter etc. The course aggregate is also tested for its various properties. The specific gravity, bulk density and fineness modules of coarse aggregate arefoundtobe2.74,1472kg/cumand 6.69respectively. The Physical Properties are tabulated in Table No.5.

Table No.5 Physical Properties of coarse aggregate

S.No	Property	Test Results
1	Finenessmodulus	6.69
2	Specific gravity	2.74
3	Bulk density a) Loose b)Dense	 1319kg/m^3 1472kg/m^3
4	Flakinessindex	2.41%
5	Elongationindex	12.80%

2.5 SUPERPLASTICIZER

Super plasticizer BASF 40 chemical India Ltd. was used as water reducing admixture.

3.0 MIXPROPORTIONINTHELABORATORY

The proportion used in preparation of mix is calculated as per BIS Method. Two high performance series mixes were prepared

$$V = \left\{ \text{Wt. of Water} + \left[\frac{Wt.ofCement}{Sp.grofCement}\right] + \frac{1}{p\left(\frac{Wt.ofFA}{Sp.grofFA}\right)} \right\} X \frac{1}{1000}$$

$$V = \left\{ \text{Wt. of Water} + \left[\frac{Wt.ofCement}{Sp.grofCement}\right] + \frac{1}{(1-p) * \left(\frac{Wt.ofCA}{Sp.grofCA}\right)} \right\} X \frac{1}{1000}$$

The ratio between F.A and C.Ais p:(1-p)

Quantitiesofmaterialrequiredper1 m^3 of Shotcreteconcrete is shown in Table No.6

Table No.6- Quantities of material required per 1 m3 of Shotcrete concrete

S.No	Grade	W/B	Cement (Kgs.)	Micro silica (Kgs.)	F.A. (Kgs.)	C.A. (Kgs.)	Water (Ltrs.)	Super plasticizer (ml/ Cement)
1	M40	0.4	396	44	998	843	176	1980
2	M50	0.36	440	49	975	823	176	3575

4.0 TEST SPECIMENS

As test specimens for compressive, split tensile and flexural strength, 150 mm x 150 mm cubes, 150 x 300 mm cylinders and 100 mm x 100 mm x 500 mm beams are utilised. According to IS:516 compressive and flexural strength, IS: 5816 split tensile tests were performed. Three samples were taken from each test and observed for 28, 90 and 180 days. Each test was performed on three distinct samples, and the mean of these values is provided.

5.0 RESULTS AND DISCUSSIONS :

5.1 COMPRESSIVESTRENGTHOFSHOTCRETE

Compressive strength is conducted on cube specimens for M40 and M50 Grade of concrete. It is found that, the percentage increase in compressive strength of shotcrete concrete of M40 Grade for 90 days & 180 days as 5.33% and 9.34% respectively with respect to 28 days. Percentage increase in compressive strength of shotcrete concrete of M50 Grade for 90 days & 180 days as 7.38% and 11.32% respectively with respect to 28 days is displayed in Fig. 1. The increase in the strength can be attributed to the formation of calcium silicate hydrate (C-S-H) gel which is stronger than the normal C-H gel. This silica-fume gel C-SH forms in the voids of the C-S-H produced by cement hydration, thus producing a very dense structure. So, by using micro-silica, the concrete matrix gets a denser composition filling even the micro-voids thus enhancing the impermeability of concrete. Better impermeability ensures better crack resistance and corrosion resistance as well as less prone to chemical attack.

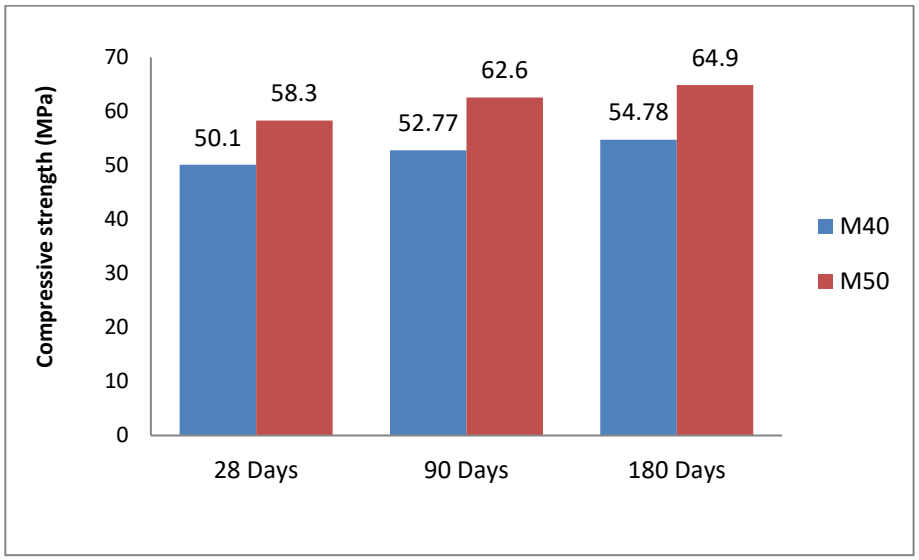

Fig 1 Compressive strength of Shotcrete concrete using Quartz Sand

5.2 SPLIT TENSILE STRENGTH:

It is found that, percentage increase in split tensile strength of shotcrete concrete with respect to concrete of grade M40 for 28days to 90 and 180 days as 1.99% and 11.40% respectively. percentage increase in split tensile strength of shotcrete concrete with respect to concrete of grade M50 for 28 days to 90 and 180 days as 3.41% and 7.32% respectively and results are shown in Fig-2.

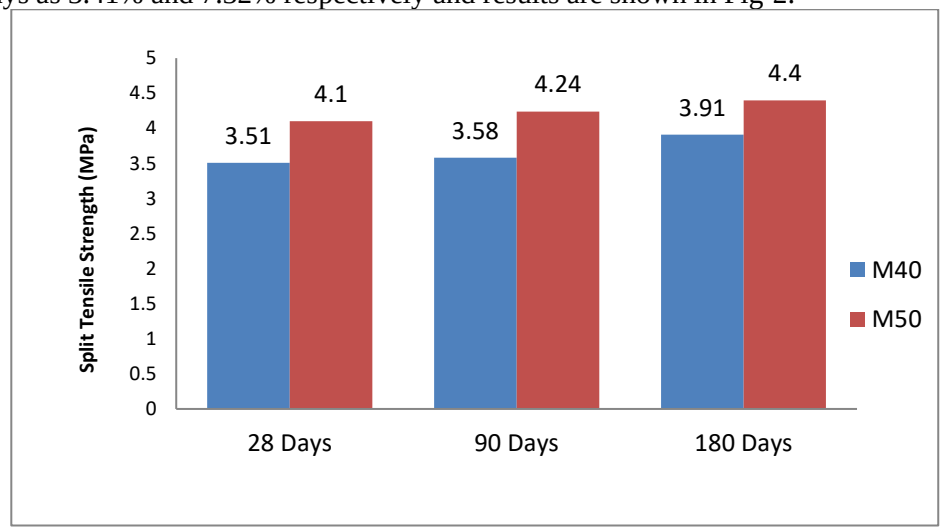

Fig 2. Split tensile strength of Shotcrete concrete using Quartz Sand

5.3 FLEXURAL STRENGTH

Flexural strength of concrete is conducted on Beams of 100 x 100 x 500 mm. It is found that, the percentage increase in flexural strength of shot crete concrete of M40 grade for 90 and 180 days as 7.89% and 11.58% respectively with respect to 28 days. Percentage increase in flexural strength of shotcreteconcreteofM50gradefor90and180daysas3.04%and7.71%respectivelywith respect to 28 days and results are shown in Fig-3.

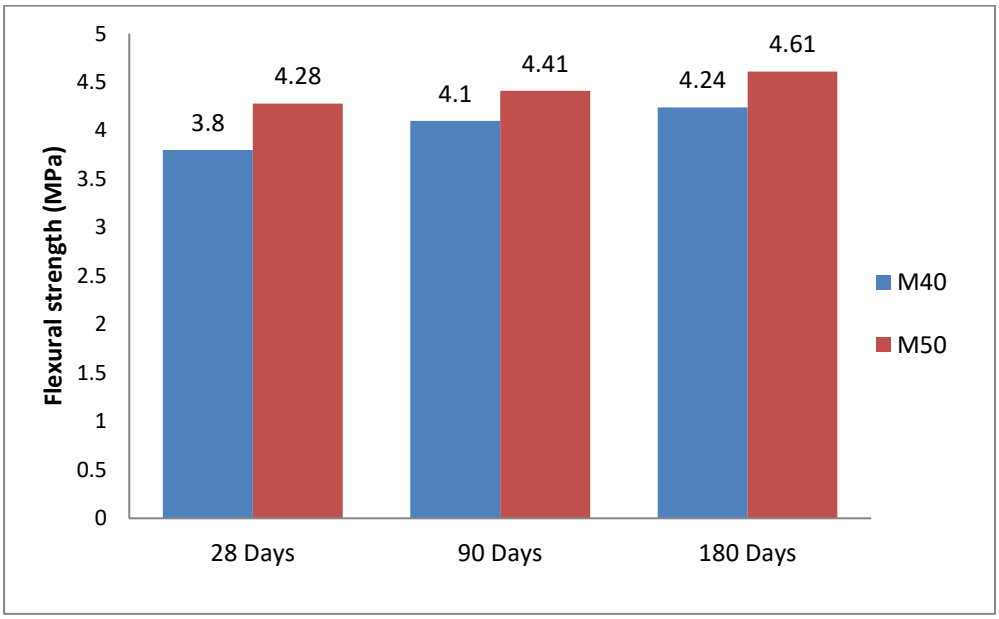

Fig. 3 Flexural strength of Shotcrete concrete using Quartz Sand

6.0 CONCLUSIONS:

- The experimental investigation of shotcrete concrete by partially replacing pozzolanic admixtures i.e, Quartz powder along with Micro silica and with complete replacement of river sand with Quartz sand [6] for which compressive strength tests were done at w/c of 0.30 and 0.34.
- Partial replacement of cement with Microsilica and full replacement of fine aggregate with Quartzs and sand Quartz powder significantly improved the Mechanical Properties of concrete.
- Compressive strength of shotcrete concrete is increased by about 5.33% & 9.34% for M40 and 7.38% & 11.32% for M50 for 90days&180days when compared with respect to 28 days respectively.
- Split Tensile strength of shotcreteconcreteis increased by about 1.99% & 11.40% for M40 and 3.41% & 7.32%for M50 for 90days&180days when compared with respect to 28 days respectively.
- Flexural strength of shotcreteconcrete is increased by about 7.89% and 11.58% for M40 and 3.04% and 7.71% for M50 for 90days&180days when compared with respect to 28 days respectively.
- Results showed that there is an increase in compressive strength, split tensile strength and flexural strength of shotcrete concrete with micro silica and 100%quartzsandandquartzpowderforM40&M50gradesofconcrete.
- The combined action of microsilica, quartzsand and quartz powder improved the dense microstructure and increases compactness which enhances strength properties of shotcrete concrete. The percentage increase in strength is highest for 180days.

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