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Experimental Study on Combined Effect of Micro Glass Powder and Silica Fume on Mechanical Properties of Standard OPC Concrete

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ABSTRACT:
Ordinary Portland cement is the most common type of cement used in the concrete due to its versatile properties like binding, accepting many waste materials as supplementary or partial replacement materials etc and plays an important role in the production of concrete. The production of OPC causes harmful gases emissions into the atmosphere, One tonne of production of OPC consume about 1.5 tonnes of natural resources apart from abatement of 1.0 tonne of CO_2 to atmosphere. Many supplementary materials have been used in micro form as partial replacement of cement. Recently , the studies on usage of combinations of waste material or supplementary cementing materials in concrete has gained so much of importance for the improvement of the properties of concrete. In the present investigation on attempt is made to find the combined effect of micro glass powder and silica fume as partial replacement of cement in standard OPC concrete. The workability and strength of M_{40} grade of concrete at 0.35 water binder ratio are investigated using super plasticizer. The results reveal that the combination of 15% micro glass powder and 5% silica fume has the greatest effect and improved the compressive and tensile strength of concrete compared to the other combinations.

Keywords:
Glass powder (GP), Silica fume (SF), workability, strength characteristics, microstructure.

INTRODUCTION:
In the process of development the entire world is in a rush to establish more and more number of industries for manufacturing various products, processing of material etc for the ease, need, comfort and benefit of human race. The establishment of new industries in addition to the existing industries, the increased use of fossil fuels, manufacturing of products causing emission of green house gases eventually leading to more global warming effects. Cement industry is one of the major contributors for the emission of CO_2 into the atmosphere. In order to reduce the green house gas as emission, lesser usage of OPC and use of various waste materials into the concrete as supplementary cementious materials or pozzolanic materials as partial replacement to OPC exigated the need for studying the effect of some of the pozzolanic materials such as silica fume, fly ash, ground granulated blast furnace slag, metakaoline etc as partial replacement of cement. In the present study micro glass powder and silica fume combination was used for replacement of cement. It is observed that the workability and strength of concrete have been improved by the use of micro glass powder and silica fume. Presently in India, about 960 million tonnes of solid waste is being generated annually as by-products during industrial, mining, municipal, agricultural and other processes. Of this 350 million tonnes(MT) are organic wastes from agricultural sources, 290 million tonnes are inorganic waste of industrial and mining sectors and out of these

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wastes 4.5 million tonnes are hazardous in nature. Advances in solid waste management resulted in alternative construction materials as substitutes to traditional materials like bricks, tiles, aggregates, ceramics, cement, lime, soil, timber and paint. By the year 2047, municipal solid waste generation in India, is expected to reach 300 MT and land requirement for disposal of this waste would be 169.6km^2 and in 1997 the land used for management of waste was only 20.2 km^2. The urban waste mainly consists of organic matter (46%), paper (6%), glass (0.7%), rags (3.2%), plastic (1%) and the rest is moisture. In India, about 14.5 MT of solid wastes are generated annually from construction industries, which include wasted sand, gravel, bitumen, bricks, and masonry, concrete. However, some quantity of such waste is being recycled and utilised in building materials and share of recycled materials varies from 25% in old buildings to as high as 75% in new buildings [8]. Glass powder is obtained from the grinding of waste flat glasses. About 80% of flat glasses are useful for construction purpose from the production of total flat glass. In the year of 2012-2013 the production of flat glass was 650 MT. From that 10% of waste glass are like broken and damages[1]. Waste glasses are recycled and in recycling process, the production of one ton of glass it produces 0.53 tonnes of CO_2[2], and for one glass bottle recycling it takes 100 watt light bulb of 4 hours energy[3]. Land filling of waste glass causes environment pollution. Waste glass when ground to very fine powder and used in concrete, shows pozzolanic properties as it contains high SiO_2 and therefore, to some extent it can replace cement in concrete and contribute for strength development and it is uncommon throughout the world to have glass products that are made up of nearly 50 % recycled material due to the fact that it is one of the few material that can be recycled many times without altering its chemical properties or composition[4]. Silica fume is also a waste material obtained from the silicon alloys industries. It has high percentage of $Sio_2$and it helps to increase the strength characteristics of concrete. This material usage for concrete preparation is limited. In order to effectively utilize the glass powder and silica fume, an attempt is made to find the optimum combination of glass powder and silica fume which improved both the workability and the mechanical properties of OPC concrete at low water binder ratio. Glass powder when used as a binder with partial replacement of cement which it takes part in hydration reaction and also acts as a filler material. Researchers have been done to fully utilize these wastes as the final products for construction materials such as concrete and mortar. As more emphasis is placed on sustainable construction, the scope of using waste or recycled materials in concrete has become the concern of the construction industry [4].Glass powder milled to micro-scale undergoes pozzolanic reaction and acts as catalyst accelerating the dissolution of clinker phases and forms low basicity calcium silicate hydrate(C-S-H).these reactions give positive effect on mechanical and micro structural properties of concrete[5]. Concrete is the second largest of widely used material, but there are environmental issues related with its use which are needed to be taken under considerations and cannot be ignored. One tone of CO_2 is released into the atmosphere for the production of one tone of cement [7]. Normally in production of glass it produce 1.2 tonnes of CO_2 , in recycling process of glass it produce 0.53 tonnes of CO_2. By using glass powder for production of concrete that will reduce the CO_2 emission into the atmosphere and it makes eco-friendly nature and sustainable material [18].

EXPERIMENTAL INVESTIGATION:

To effectively utilize the glass powder and silica fume in OPC concrete, M_{40} grade concrete was selected. Trial mortars with different combinations of glass powder and silica fume were prepared and tested for compressive strength. Finally it is observed that three parts of glass powder and one part of silica fume combinations give better compressive strength. Hence it was proposed to replace OPC by three parts of glass powder and one part of silica fume in M_{40} grade concrete.

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The water binder ratio of all the mixes was maintained as 0.35. To find out the effect of glass powder on the strength and workability, the percentages of glass powder at increments of 5%, starting from 10% up to 20% super plasticizer at 1.5% of weight of binder is used for improving the workability of all concrete mixtures. To determine the optimum combination of glass powder and silica fume from different combinations of glass powder and silica fume, trial mixes were prepared. Workability tests and viz slump test and compaction factor tests and compressive strength tests were conducted. From the trail tests it was observed that one part of glass powder and 1/3rd of silica fume combination was effective in imparting workability and compressive strength.

Materials Used:

▪ Glass powder

Waste flat glass and broken glass bottles were collected and after breaking them into small pieces, in glass cullet machine, the crushed glass was ground into fine powder. The powder thus obtained was sieved through 45 micron sieve and material passing through 45 micron sieve was used for preparation of concrete.

X-Ray Diffraction Analysis of Glass Powder:

X-ray Diffraction test on glass powder was conducted at Jawaharlal Nehru Technological University, Anantapur.

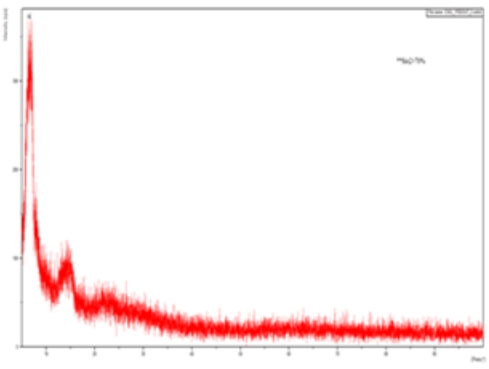

Fig:1 Graph Between Intensity(Counts Per Sec) And 2 Theta(Degrees)

Table1: Properties of Glass Powder

S.no	Properties	Values
1.	Specific gravity	2.58
2.	Fineness of % passing (45 micron)	80%
3.	Density	2538 kg/m^3
4.	SiO_2	72%
5.	CaO	9.43%
6.	MgO	5.64%
7.	Na_2O	13.13%
8.	Al_2O_3	0.08%

▪ Silica Fume

The silica fume used in the present investigation was obtained from Astra chemicals, Chennai. The properties of silica fume are furnished in table no:2.

Table: 2 Properties Of Silica Fume:

S.no	Properties	Values
1.	Specific gravity	2.63
2.	SiO_2	98%
3.	pH	6.9
4.	Density	0.76 /cc

▪ Conplast sp 430(g):

Conplast sp 430(G) manufactured by Fosroc company and procured from Astra chemicals, Chennai having the following properties was used in the study.

Table: 3 Properties Of Conplast Sp 430(G)

S.no	Properties	Values
1.	Specific gravity	1.145
2.	Chloride content	Nil.

• Cement

53 grade Ordinary Portland Cement manufactured by Zuari company was used in the present study.

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- **Fine aggregate**

The sand used in the present investigation was procured from local sand quarry and tested for its size and other properties. The sand confirming to zone-II and the physical properties are tabulated in table no:4.

Table No: 4 Properties Of Fine Aggregate

S. No	Property	Value
1.	Specific gravity	2.6
2.	Fineness modulus	2.8
3.	Bulk density (compact)	1711 kg/cum
4.	Bulk density (loose)	1631 kg/cum
5.	Grading	Zone-II

- **Coarse aggregate:**

The12mm size crushed granite aggregate used in the present investigation was procured from local stone crusher industry and the properties of aggregate are shown in table no:5.

Table No: 5 Properties Of Coarse Aggregate

S. No	Property	Value
		12 mm aggregate
1.	Specific gravity	2.8
2.	Bulk density(compact)	1575 kg/cum
3.	Bulk density (loose)	1356 kg/cum

Mix Design of Standard Concrete:

Mix design is carried out as per IS: 10262-2009 and IS:456-2000.

Table no:6 : Mix proportions:

S. No	Mix designation	Component materials								
		Cementious material (kg)				F.A (kg)	C.A (kg)	Water(lt)	SP (lt)	W/B
		Cement	GP	SF	Total					
1.	P_1	410	-	-	410	673	1252	143.5	6.15	0.35
2.	P_2	356.7	41	12.3	410	670	1245	143.5	6.15	0.35
3.	P_3	328	61.5	20.5	410	668	1241	143.5	6.15	0.35
4.	P_4	299.3	82	28.7	410	667	1239	143.5	6.15	0.35

Experimental program:

M_{40} grade concrete using 410 kgs of cement per cubic meter was designed. The mix proportions are shown in table no: 6. OPC was partially replaced by 10 % , 15% and 20% of glass powder and 1/3rd of above proportions i.e. 3%, 5% and 7% of silica fume in M_{40} grade OPC concrete and 150 x 150 x 150 mm cube specimens were casted for testing compressive strength at 3 days, 7 days, 28 days and 60 days. Standard cylinders of 150 x 300 mm size were casted for testing split tensile strength at 3 days, 7 days, 28 days and 60 days. After casting, the specimens were cured in water and at 3 days, 7 days, 28 days and 60 days. The compressive strength and split tensile strength of P_1, P_2, P_3 and P_4 concrete mixtures were tested. The results obtained are furnished in table no: 8&9.

Results and Discussions:

Workability:

The workability tests such as slump and compaction factor tests were conducted on fresh concrete mixes with different proportions of glass powder and silica fume with w/b ratio 0.35. The slump value and compaction factor values gradually increased with increase in glass powder and silica fume contents in concrete mixtures. The concrete with 15% Glass powder and 5% silica fume has given highest compaction factor and slump values.

Table No: 7 Workability of Different Concrete Mixtures

S. No	Mix designation	Slump value	Compaction factor
1	P_1	60 mm	0.83
2	P_2	72 mm	0.85
3	P_3	90 mm	0.88
4	P_4	80 mm	0.86

Compressive Strength:

The compressive strength test was conducted as per IS: 516-1959. It is estimated by testing concrete cube of standard 150 x 150 x 150 mm size.

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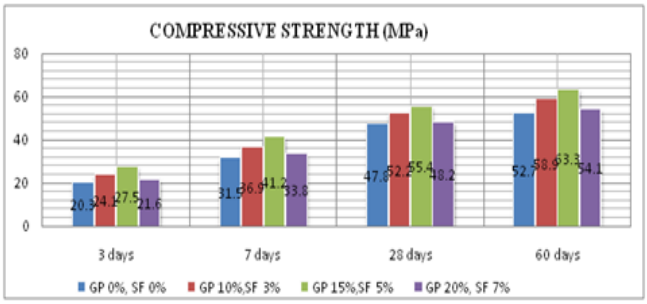
Concrete specimens casted with P_1, P_2, P_3 & P_4 concrete mixtures were cured for 3,7,28 and 60 days in the water. On completion of the curing period the specimens were taken out and weight of the samples recorded. The plates of the compression testing machine were cleaned and the specimen were kept at centre in between the plates. Load was applied gradually on the specimen at a load rate of 5.2 kN/S or 140 kg/m^2/sec up to failure. Once the sample has failed, the failure pattern was recorded and the compressive strength was calculated from the maximum load recorded in the test. The results are represented in table no.8 and also furnished in graph no.1.

Compressive strength = (load/area) = P/A

Table no: 8 compressive strength values with w/b=0.35

S. no	Mix designation	Mix proportions	Compressive strength(MPa)			
			3days	7days	28days	60 days
1.	P_1	0% GP,SF	20.3	31.5	47.8	52.7
2.	P_2	10% GP,3%SF	24.1	36.9	52.2	58.9
3.	P_3	15%GP,5% SF	27.5	41.2	55.4	63.3
4.	P_4	20% GP,7% SF	21.6	33.8	48.2	54.1



Graph: 1 compressive strength values of mix with w/b=0.35

The compressive strength of all the concrete mixtures showed improvement in compressive strength with age. The P_2 concrete mixture with 10% GP and 3% SF showed 18.7%, 17%, 9.2% and 11% increase in compressive strength over the conventional concrete at 3 days, 7 days, 28 days and 60 days respectively.

The P_3 concrete mixture with 15% GP, 5% SF showed 35%, 30.8% 15.9% and 20.1% increase in compressive strength over the conventional concrete at 3 days, 7 days, 28 days and 60 days respectively. The P_4 concrete mixture with 20% GP, 7% SF showed 6.4%, 7.3% 0.8% and 2.6% slight increase in compressive strength over the conventional concrete at 3 days, 7 days, 28 days and 60 days respectively. The results revealed that the M_{40} grade concrete with 410 kg of cement per cubic meter, when part of cement replaced with 15% of glass powder and 5% of silica fume gives heigher compressive strength at all ages compared to conventional concrete.

Split Tensile Strength:

The split tensile strength test was conducted as per IS: 5816-1999 in compressive testing machine. It is estimated by testing cylinders of standard 150mm diameter x 300 mm long size. Concrete specimens cast with combinations of GP and SF mix proportions with w/b ratio 0.35 named as P_1, P_2, P_3, P_4. The specimens were cast with concrete mixes mentioned above table no: 6 and cured for 3,7,28 and 60 days in the laboratory. On completion of the curing period the specimens were taken out and weight of the samples recorded. After noting the weight of the cylinder, diametrical lines are drawn on the two ends, such that they are in the same axial plane. Then the cylinder is placed on the bottom compression plate of the testing machine and is aligned such that the lines marked on the ends of the specimen are vertical. Then the top compression plate is brought into contact at the top of the cylinder. The load is applied at nominal rate within the range 1.2 N/mm^2 to 2.4 N/mm^2 per minute. Until the cylinder fails and the load is recorded. From this load, the splitting tensile strength is calculated from below equation for each specimen and the results are furnished in table no: 9, graphical values furnished in graph no: 2.

$$\text{Split Tensile Strength} = 2P/\pi dl = 0.637\ P/dl$$

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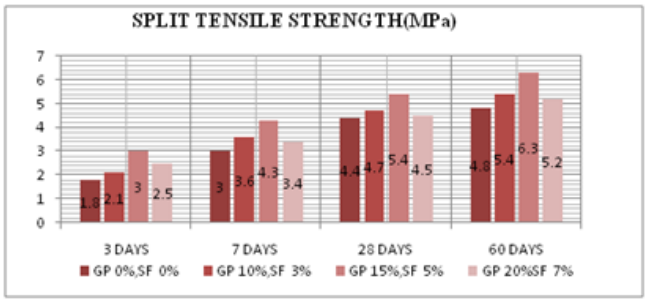
Table no: 9 split tensile strength values of w/b=-0.35

S.no	Mix designation	Mix Proportions	Split tensile strength(MPa)			
			3days	7days	28days	60days
1.	P_1	0% GP,SF	1.8	3.0	4.4	4.8
2.	P_2	10% GP,3% SF	2.1	3.6	4.7	5.4
3.	P_3	15% GP,5%SF	3.0	4.3	5.4	6.3
4.	P_4	20%GP,7% SF	2.3	3.4	4.5	5.2



Graph no.2 split tensile strength values

The tensile strength of all the concrete mixtures showed improvement in tensile strength with age. The P_2 concrete mixture with 10% GP and 3% SF showed 16.6%, 20%, 6.8% and 12.5% increase in tensile strength over the conventional concrete at 3 days, 7 days, 28 days and 60 days respectively. The P_3 concrete mixture with 15% GP, 5% SF showed 66%, 43.3% 22.7% and 31.2% increase in compressive strength over the conventional concrete at 3 days, 7 days, 28 days and 60 days respectively. The P_4 concrete mixture with 20% GP, 7% SF showed 27.7%, 13.3% 2.27% and 8.3% slight increase in tensile strength over the conventional concrete at 3 days, 7 days, 28 days and 60 days respectively. The results revealed that the M_{40} grade concrete with 410 kg of cement per cubic meter, when replaced with 15% of glass powder and 5% of silica fume gives heigher split tensile strength at all ages compared to conventional concrete.

Scanning Electron Microscope Analysis:

This SEM analysis was conducted at physics department in SV University, Tirupathi. Test was conducted for determining morphology of concrete. Difference between the hydrated structure of conventional concrete and OPC concrete with 15% GP and 5% SF are shown with 1.00kx and 2.00kx magnification in plates 1 to 4.

Sem analysis of conventional concrete (P_1):

1.00 kx magnification

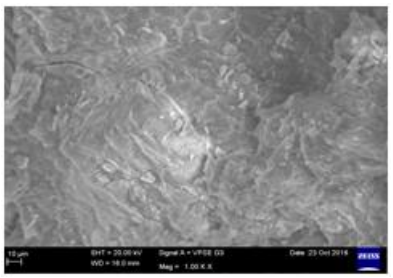


Plate: 1

2.00 kx magnification

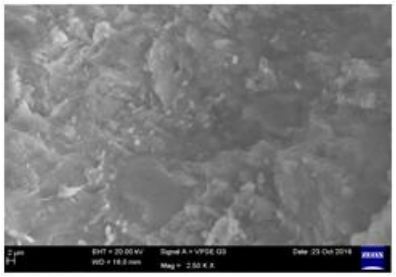


Plate: 2

Sem analysis of 15% GP + 5% SF:

1.00 kx magnification

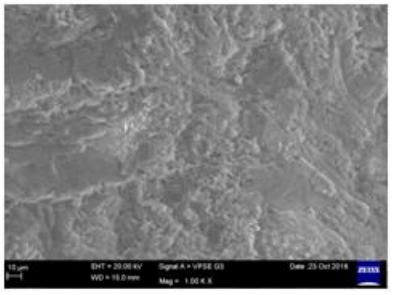


Plate: 3

2.00 kx magnification

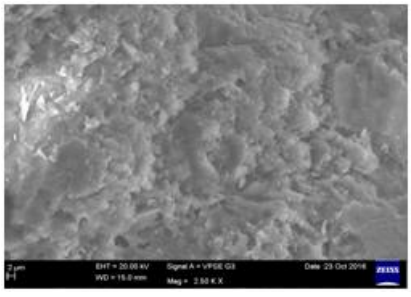


Plate: 4

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CONCLUSIONS:

1. The present investigation results show that the combination of glass powder finner than the 45 micron and silica fume exhibit better pozzolanic effect in M_{40} grade OPC concrete.
2. The compressive strength and tensile strength of M_{40} grade OPC concrete increases at all ages.
3. When OPC is partially replaced by glass powder and silica fume and highest compressive and tensile strengths can be obtained by replacing OPC with 15% of glass powder and 5% by silica fume.
4. The workability of M_{40} grade of OPC concrete can be improved by using micro glass powder and silica fume.

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