Experimental Investigation on Silica Fume and Recron 3S fibres aspartial Replacement of Cement in HPC

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ABSTARCT:

One of the main challenges now confronting the concrete industry in India is to meet the demand posed by ever increasing infrastructure needs due to rapid industrialization and urbanization since Concrete is one of the major engineering materials. With the shrinkage of natural resources to produce ordinary Portland cement (OPC), increased use of suitable industrial waste materials having pozzolanic characteristics that can replace cement clinker is one of the ways to meet the challenge. This policy has many-fold advantages such as utilization of industrial wastes in an eco-friendly way, preserving resources, and finally the improvement in properties of concrete which culminates in the sustainable development of the society as a whole.

In this regard a study has been conducted to deal with the high performance concrete(HPC) by replacing and addition of chemical admixtures for obtaining the characteristic target mean strength i.e., by replacing the cement with silica fumes and addition of polyester fiber material for getting maximum compressive strength. The present investigation aims to give design mix for HPC by using silica fume and super plasticizers along with Recron 3s.

Specimens such as cubes, beams and cylinders were cast for various mix proportions and tested at the age of 7,14, 28 and 56 days. The investigation revealed that the partial replacement of cement by silica fume will develop compressive strength, flexure strength and split tensile strength sufficient for construction purposes. The optimum dosage of silica fume found to be 7.5% (by weight), when used as partial replacement of ordinary Portland cement. It can be a suitable alternative to replace the cement quantity required for construction purposes considering the sustainability as well as economic viability.

KEY WORDS: Compressive strength, Flexure strength, High Performance Concrete, Silica fume, Recron 3s

INTRODUCTION:

The challenge for the civil engineering community in the near future will be to realize projects in harmony with the concept of sustainable development, and this involves the use of high-performance materials and products manufactured at reasonable cost with the lowest possible environmental impact. Concrete is the most widely used construction material worldwide. However the production of Portland cement, an essential constituent of concrete, releases large amounts of CO_2 which is a major contributor to the greenhouse effect and the global warming of the planet and the developed countries are considering very severe regulations and limitations on CO_2 emissions.

In this scenario, the use of supplementary cementing materials (SCMs), such as fly ash, slag and silica fume as a replacement for Portland cement in concrete presents one viable solution with multiple benefits for the sustainable development of the concrete industry. Ordinary Portland cement is recognized as a major construction material throughout the world. Researchers all over the world are focusing on the way of utilizing either industrial or agricultural waste, as a source of raw material for industry. This waste utilization would not only be economical, but may also result in foreign exchange earnings and environmental pollution control.

Various researches and experimentation are being conducted day by day to find out new alternatives to improve the properties of concrete[1-8] . Enhancing the structural properties of concrete is one of the major concerns in construction industries now a day.

High Performance Concrete (HPC) has been developed over the last two decades, and was primarily introduced through private sector architectural design and construction such as high rise buildings and parking garages. HPC is used for concrete mixtures, which possess high workability, high strength, high modulus of elasticity, high density, high dimensional stability, low permeability and resistance to chemical attack. According to ACI "High Performance Concrete is defined as concrete whichmeets special performance and uniformity requirements that cannot always be achieved routinely by using conventional materials and normal mixing, placing and curing practices" [1].

The supplementary cementitious materials (SCMs) such as silica fume, fly ash and ground granulated blast furnace slag are more commonly used mineral admixtures in the development of HPC mixes. They generally used to resist compressive forces and also due to its pozzolanic action the properties of High Performance Concrete viz, workability, durability, strength, resistance to cracks and permeability can be improved [2].

Silica fume(SF), which is byproduct of the smelting process in the silicon and ferrosilicon industry. Silica fume is very effective in the design and development of high performance concrete.

It is also known as micro silica,condensed silica fume, volatilized silica or silica dust. Silica fume colour is either premium white or grey. Silica Fume consists of very fine vitreous particles with a surface area between 13,000 and 30,000m2/kg. Its particles are approximately 100 times smaller than the average cement particle. Because of its extreme fineness and high silica content, silica fume is a highly effective pozzolanicmaterial. Silica fume is used in concrete to improve its properties. It has been found that silica fume improves compressive strength, bond strength, and abrasion resistance; reduces permeability; and therefore helps in protecting reinforcing steel from corrosion [3].

High compressive strength is generally the first property associated with silica fume concrete. The addition of silica fume to a concrete mix will increase the strength of that mix by between 30% and 100% depending on the type of mix, type of cement, amount of silica fume, use of plasticizers, aggregate types and curing regimes.[4] Silica fume concrete is very susceptible to temperature variations during the hardening process. The optimum silica fume content to achieve higher strengths seems to range between 15 and 20%.[5]There are three mechanisms namely (i)Strength enhancement by pore sizerefinement and matrix densification, (ii) Strength enhancement by reduction in content of CH and (iii) Strength enhancement by cement paste- aggregateinterfacial refinement are believed to be responsible for the strength development of concrete and mortars containing silica fume.[6].

The main objective of this investigation is to minimize the usage of cement content to some proportion in the High Performance Concrete. This present work focused on various properties viz., compressive strength, Split Tensile Strength and Flexure strength of M60 grade HPC mixes incorporating different percentages silica fume along with Recron 3-S fibres.

II. EXPERIMENTAL INVESTIGATION

In the present experimental investigation silica fume has been used as partial replacement of cement as an additional ingredient in concrete mixes. The effect of adding different percentages of silica fume as additional material along with recron 3s fibers and super plasticizer Conplast SP430 to concrete mixes on their compressive strength is studied. The details of experimental investigations are as follows.

2.1 MATERIALS

2.1.1 CEMENT

Ordinary Portland cement available in the local market of standard brand was used in the investigation. Care has been taken to see that the procurement made from a single batch is stored in airtight containers to prevent it from being affected by the atmospheric and monsoon moisture and humidity.

2.1.2 MICRO SILICA (SILICA FUMED DENSIFIED)

Micro silica or silica fumed is the most commonly used mineral admixture in high strength concrete. It is a good pozzolan, adding to the concrete mix will dramatically enhance the workability, strength & impermeability of concrete mixes while making the concrete durable to chemical attacks, abrasion & reinforcement corrosion, increasing the comprehensive strength.

2.1.3 RECRON 3S (POLYSTER FIBRE MATERIAL)

Recron-3s is a discrete, discontinuous short fiber that can be used in concrete to control and arrest cracks. It arrests shrinkage cracks in concrete and increases resistance to water penetration, abrasion and impact. It makes concrete homogenous and also improves the compressive strength, ductility and flexural strength together with improving the ability to absorb more energy. Use of uniformly dispersed Recron 3s fibers reduces segregation and bleeding and also results in a more homogeneous mix of concrete. Recron3s is meant for secondary reinforcement only.

SPECIFICATIONS OF RECRON 3S

Property	Value
Cut length	6 mm or 12 mm
Shape of fiber	special for improved holding of cement aggregates
Tensile strength	4000-6000 kg/cm2
Melting point	> 250ºC

2.1.4 High performance super plasticizing admixture (Conplast SP430)

Conplast SP430 is a chloride free, superplasticizing admixture based on selected sulphonated naphthalene polymers. It is supplied as a brown solution which instantly disperses in water. Conplast SP430 disperses the fine particles in the concrete mix, enabling the water content of the concrete to perform more effectively. The very high levels of water reduction possible allow major increases in strength to be obtained.

PROPERTIES

Appearance	Brown liquid
Specific gravity (BSEN 934-2)	1.18 @ 22°C + 2°C
Water soluble chloride (BSEN 934-2)	Nil
Alkali content (BSEN 934-2) equivalent/litre of admixture	Typically less than 55gm Na_2O

2.1.5 FINE AGGREGATE

The locally available river sand is used as fine aggregate in the present investigation. The sand is free from clay, silt and organic impurities. The fine aggregate used should conform to the standard specifications as per IS 2386-1963.

2.1.6 COARSE AGGREGATE

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 coarse aggregate is also tested for its various properties. The coarse aggregate should also conform to the standard specifications.

2.1.7 WATER

The locally available potable water accepted for local construction is used in the experimental investigation after testing (p^H value not less than 6).

2.2 PREPARATION OF TESTING SPECIMEN

2.2.1 MIXING

Mixing of ingredients is done in pan mixer of required capacity. The cementitious materials are thoroughly blended and then the aggregate is added and followed by gradual addition of water and mixing. Recron 3s and SP430 are also added carefully. Wet mixing is done until a mixture of uniform colour and consistency is achieved which is then ready for casting.

2.2.2 CASTING OF CONVENTIONAL CONCRETE

A sample of coarse aggregate 20mm and 10mm was taken and mixed by hand batching. Then a sample of fine aggregate and cement was taken and mixed well.

Poured the SP430 liquid and water and mixed the proportion well by hand damping or machine mixing. Every material was taken by 10% extra for a shortage of concrete due to wastage. Then the sample was taken to the slump cone test by pouring the sample in the slump cone and damped well. Later the cone was removed and the value was recorded. If not satisfied with mix, process was repeated by taking a new mix till the satisfied value attained.

After casting the cubes were left for 24 hours of an initial setting time and after 24 hours mould was removed and kept in curing tank for 7 days (or) 28 days (or) 56 days (or) 90 days as per our trails.After 7 or 28 or 56 or 90days a batch of cubes sample was taken and dried by leavingthem in the atmosphere until the absorbed water is exhausted. The cast specimens are tested as per standard procedures, immediately after they are removed from curing period and wiped off the surface water as per IS 516-1969. The test results are tabulated carefully. Thenthesamples tested by U.T.M (or) compressive testing machine and the noted load values for the 3 cubes. Average of load and stress value for 3 cubes were calculated.

Likewise, Recron 3s material was added to the nominal mix concrete to obtain the target mean strength @ 900grms/m3 and the investigation was repeated.

3. RESULTS OF STRENGTH PARAMETERS

The values of compressive strengths of concrete (with 0%, 5%, 10%, 15%, and 20% by weight replacement of cement with silica fume) without addition of recron 3s fibers cured in normal water evaluated at the end of 7 days are plotted in a graph. The graph showed a rise in the value of compressive strength from 0% to 5% replacement of silica fume but then showed a decline from 5% to 20% replacement of silica fume. The maximum value of compressive strength is obtained at 5% replacement of silica fume in cement.

The values of compressive strengths of concrete (with 0%, 5%, 10%, 15%, and 20% by weight replacement of cement with silica fume) with addition of recron 3s fibers cured in normal water evaluated at the end of 7 days are plotted in a graph. The graph showed a rise in the value of compressive strength from 0% to 5% replacement of silica fume but then remained almost uniform from 10% to 20% replacement of silica fume. The maximum value of compressive strength is obtained at 5% replacement of silica fume in cement.

The values of compressive strengths of concrete (with 0%, 5%, 10%, 15%, and 20% by weight replacement of cement with silica fume) without addition of recron 3s fibers cured in normal water evaluated at the end of 28 days are plotted in a graph. The graph showed a rise in the value of compressive strength from 0% to 5% replacement of silica fume but then showed a decline from 5% to 20% replacement ofsilica fume. The maximum value of compressive strength is obtained at 5% replacement of silica fume in cement.

The values of compressive strengths of concrete (with 0%, 5%, 10%, 15%, and 20% by weight replacement of cement with silica fume) with addition of recron 3s fibers cured in normal water evaluated at the end of 28 days are plotted in a graph. The graph showed a rise in the value of compressive strength from 0% to 5% replacement of silica fume but then remained almost uniform from 10% to 20% replacement of silica fume. The maximum value of compressive strength is obtained at 5% replacement of silica fume in cement.

The values of compressive strengths of concrete (with 0%, 5%, 10%, 15%, and 20% by weight replacement of cement with silica fume) without addition of recron 3s fibers cured in normal water evaluated at the end of 56 days are plotted in a graph. The graph showed a rise in the value of compressive strength from 0% to 5% replacement of silica fume but then showed a decline from 5% to 20% replacement of silica fume. The maximum value of compressive strength is obtained at 5% replacement of silica fume in cement.

The values of compressive strengths of concrete (with 0%, 5%, 10%, 15%, and 20% by weight replacement of cement with silica fume) with addition of recron 3s fibers cured in normal water evaluated at the end of 56 days are plotted in a graph. The graph showed a rise in the value of compressive strength from 0% to 5% replacement of silica fume but then remained almost uniform from 10% to 20% replacement of silica fume. The maximum value of compressive strength is obtained at 5% replacement of silica fume in cement.

The values of compressive strengths of concrete (with 0%, 5%, 10%, 15%, and 20% by weight replacement of cement with silica fume) without addition of recron 3s fibers cured in normal water evaluated at the end of 90 days are plotted in a graph

The graph showed a rise in the value of compressive strength from 0% to 5% replacement of silica fume but then showed a decline from 5% to 20% replacement of silica fume. The maximum value of compressive strength is obtained at 5% replacement of silica fume in cement.

The values of compressive strengths of concrete (with 0%, 5%, 10%, 15%, and 20% by weight replacement of cement with silica fume) with addition of recron 3s fibers cured in normal water evaluated at the end of 90 days are plotted in a graph. The graph showed a rise in the value of compressive strength from 0% to 5% replacement of silica fume but then remained almost uniform from 10% to 20% replacement of silica fume. The maximum value of compressive strength is obtained at 5% replacement of silica fume in cement.

IV. CONCLUSION:

When Silica fume are incorporated to concrete, the silica present in these materials react with the calcium hydroxide released during the hydration of cement and forms additional calcium silicate hydrate (C – S – H), which improve durability and the mechanical properties of concrete Based on the observations made in this study it can be concluded that the when compared to the compressive strength of conventional concrete at the end of 90 days, maximum value of compressive strength of concrete is obtained at the end of 90 days at an optimal replacement of 5% by weight of silica fume in cement with the addition of recron 3s fibers and Conplast SP430.

Table-1: Results of strength parameters															
Without Recron 3s															
Silica Fumes	0%			5%			10%			15%			20%		
Recron 3s	0			0			0			0			0		
SP430	1.30%			1.30%			1.30%			1.30%			1.30%		
Load (kg) 7 days	62	71	72	56	80	70	69	58	81	63	70	69	58	71	64
Load (kg) 28 days	88	101	101	80	114	100	98	80	115	90	100	98	82	101	90
Average value of Load for 7 Days(Kg)	69			69			70			68			75		
Average value of Load for 28 Days(Kg)	97			98			98			96			91		
Average value of Stress for 7 Days(N/mm2)	30.084			30.084			30.52			29.64			28.34		
Average value of Stress for 28Days(N/mm2)	42.292			42.72			42.72			41.856			39.676		

Table-2: Results of strength parameters															
With Recron 3s															
Silica Fumes	0%			5%			10%			15%			20%		
Recron 3s(gm/m3)	900			900			900			900			900		
SP430	1.30%			1.30%			1.30%			1.30%			1.30%		
Load (kg) 7 days	80	66	78	88	76	84	70	60	58	64	48	76	56	60	68
Load (kg) 28 days	120	98	116	131	116	125	104	90	87	96	71	114	84	96	101
Average value of Load for 7 Days(Kg)	75.00			82.67			63.00			63.00			62.00		
Average value of Load for 28 Days(Kg)	112.00			125.00			94.00			94.00			94.00		
Average value of Stress for 7 Days(N/mm2)	32.7			36.04			28.00			28.00			28.00		

Average value of Stress for 28Days(N/mm2)	48.83	55.00	40.98	40.98	40.98

Without Recron 3s															
Silica Fumes	0%			5%			10%			15%			20%		
Recron 3s	0			0			0			0			0		
SP430	1.30%			1.30%			1.30%			1.30%			1.30%		
Load (kg) 56 days	102	104	105	103	106	102	105	107	109	99	103	105	89	88	92
Load (kg) 90 days	110	105	109	112	107	110	111	113	109	103	108	106	90	90	93
Average value of Load for 56 Days(Kg)	104			104			107			103			90		
Average value of Load for 90 Days(Kg)	108			110			111			106			91		
Average value of Stress for 56 Days(N/mm2)	45.34			45.34			46.65			44.61			39.24		
Average value of Stress for 90Days(N/mm2)	47.08			47.81			48.396			46.21			39.67		

With Recron 3s															
Silica Fumes	0%			5%			10%			15%			20%		
Recron 3s(gm/m3)	900			900			900			900			900		
SP430	1.30%			1.30%			1.30%			1.30%			1.30%		
Load (kg) 56 days	97	95	92	97	93	104	90	92	96	89	92	93	87	88	89
Load (kg) 90 days	112	103	100	113	106	107	106	100	98	105	102	96	91	90	90
Average value of Load for 56 Days(Kg)	95.00			98.00			93.00			92.00			88.00		
Average value of Load for 28 Days(Kg)	105.00			109.00			102.00			101.00			91.00		
Average value of Stress for 56 Days(N/mm2)	41.42			42.72			40.54			40.11			38.36		

Average value of Stress for 90Days(N/mm2)	45.78	47.52	44.47	44.03	39.67

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