

Experimental Study on Mechanical Properties of Silica Fume Coated Aggregates

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ABSTRACT: The Strength and performance of concrete plays a vital for construction of heavy structures like bridges, power stations, tall buildings, etc. Concrete that meets special performance and uniformity requirements are produced by using different mix proportions, different curing practices, using different admixtures and by using low water cement ratio. These concretes contain new type of Superplastiser which responsible for obtaining high strength and high durability. In addition to High Performance Concrete which has become relatively common, some High Strength Concrete, which is of interest for the Indian market. For high strength concrete the characteristic compressive strength varies between 40MPa and 100MPa. The alternate materials available to increase the strength of concrete are silica fume, metakaolin, alccofine, Ground Granulated Blast furnace Slag (GGBS), etc. All these materials are added as partial replacement for cement content to obtain high strength. So in this study instead of adding silica fume as partial replacement of cement, the coarse aggregates are coated with silica fume and used in the concrete mix by varying the proportions of size of aggregates as 4-8mm, 8-12mm and 12-16mm.

KEYWORDS: High strength concrete, silica fume, silica fume coated aggregates

I. INTRODUCTION

The main difference between high strength concrete and normal strength concrete relates is the compressive strength that refers to the maximum resistance of a concrete sample to applied pressure. Even though there is no accurate point of separation between high strength concrete and normal strength concrete, the American Concrete Institute (ACI) defines concrete having strength more than 40MPa as high strength concrete. The high strength concrete does require some special ingredients and needs to be carefully designed and produced. Manufacture of high strength concrete involves making proper use of the ingredients that constitute normal strength concrete. The high strength concrete is achieved by lowering the water cement ratio below 0.30. In addition to this adding silica fume as adding silica fume as admixture will prevent formation of calcium hydroxide crystals which in turn reduces the cement aggregate bonding. Selection of good Portland cement and other required aggregates is also one of the major process involved in making high strength concrete. High strength concrete are mainly used in high rise buildings, bridges, shear walls and large footings. High Strength concrete has several advantages like improved durability characteristics and much lesser micro cracking than normal strength concrete.

II. LITERATURE REVIEW

A.Wetzel, B.Middendorf (2019) This paper is based on the principles of ultra-high performance concrete (UHPC) a Portland cement free, alkali-activated material was optimized in order to enhance strength and durability. The formulation is based on ground granulated blast furnace slag and as an activator a combination of potassium water-glass and potassium hydroxide was used. Further, silica fume and metakaolin as inorganic fines were used to increase the packing density of the mixture. A w/b ratio of less than 0.25 was found using a certain mixing procedure with a high intensity mixer.

PiotrSmazewski (2019) The main aim of this study is to determine the fracture energy of high performance concrete (HPC) containing silica fume (SF). This paper presents the investigation on changes of the mechanical properties



including compressive strength, splitting tensile strength, modulus of elasticity, fracture energy, and characteristic length of six HPC caused by the addition of SF. Additions of SF into the HPC were 0%, 5%, 10%, 15%, 20% and 25% by weight of cement content. The water/binder ratio was 0.25. A 10% content of silica fume resulted in a 26% increase in tensile splitting strength, a 13% increase in compression strength and a 5% increase in the static modulus of elasticity.

B Varalaxmi Y Sai Krishna (2019)In this investigation M100 grade concrete mix is designed by adding fibers. The specimens are tested for compressive strength, split tensile strength, flexural strength at 7, 28, 56,90 days and the obtained results are compared with that of the normal concretes.Among this the mix of concrete that was added by alccofine with robo sand combination is has got 22% higher values than the target mean strength at the age of 28 days.

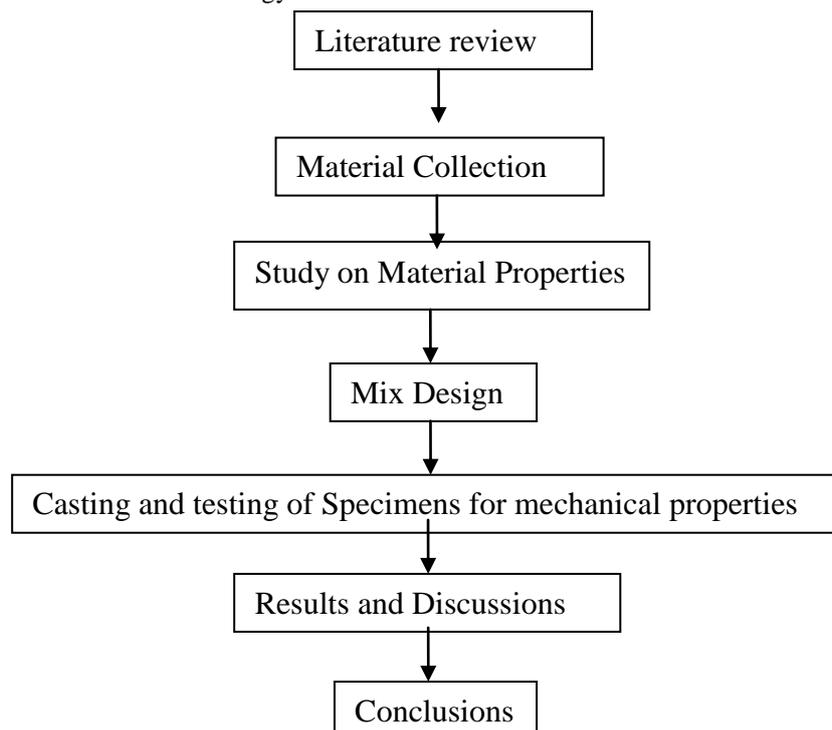
KarumanchiMeeravali, AvulaGopikrishna(2018)In this paper they design M100 or more than 100Mpa by using silica fume and super plasticizers in the proportions of 4-10 percentage and 4-8 percentage by its dry weight respectively. Design and analysis of buildings by using M100 checking with Indian standards. We propose the mix proportion of M100 in terms of cement, fine aggregates and coarse aggregates including silica fume percentage by replacing of cement and super plasticize percentage by replacing of water.

A Sreenivasulu (2018)In this investigation, Silica fume is used as mineral admixture and 920SH is used as chemical admixture. The w/c ratio for M150 concrete is considered as 0.25. By following the design procedure given by ACI Method, the mix Proportion for M150 grade concrete is derived as 1:0.454: 1.527. The compressive and split tensile strengths are identified for the concrete after exposed to elevated temperature ranging from 50 to 250°C with the exposure duration of 1 to 4 hours. The results for w/c ratio as 0.25, the respective 28 days compressive strength of the concrete is achieved as 152.06 N/mm² at 15% replacement of silica fume.

V Umamaheswaran, C Sudha, PT Ravichandran (2015)In this study M100 grade concrete mix was designed with replacement of OPC by different types of mineral admixtures using river sand and manufactured sand along with Polycarboxylate Ether (PCE) based superplasticizer. The Compressive strength, flexural strength and split tensile strength at various curing periods such as 28 and 56 days. Among these the Alccofine with Manufactured sand combination has achieved 21% higher than the target strength at age of 56 days and other strength parameters such as split tensile and flexural strength also slightly increased in this combination comparatively.

III. METHODOLOGY

The following chart describes the methodology:



IV. MATERIALS

Cement (IS 1489 PART I 1991)- Portland cement is the basic ingredient of concrete. It was developed from other types of hydraulic lime in England in the mid-19th century. Portland cement consists essentially of compounds of lime (calcium oxide, CaO) mixed with silica (silicon dioxide, SiO₂) and alumina (aluminum oxide, Al₂O₃). The lime is obtained from a calcareous (lime-containing) raw material, and the other oxides are derived from an argillaceous (clayey) material. Additional raw materials such as silica sand, iron oxide (Fe₂O₃), and bauxite containing hydrated aluminum, Al (OH)₃ may be used in smaller quantities to get the desired composition. OPC is used as cement material for obtaining high strength.

Fine aggregates (IS 383-1970)- Fine aggregate is one of the main ingredient in making cement concrete and mortar. Manufactured sand (Msand), which is obtained by from crushed rock, is emerging as a valuable alternative to river sand. The use of this Msand (also called artificial sand) is nowadays widely used in almost all major cities in India. Production process generally involves crushing of the rock or stone, screening the particles and finally washing it. Separation these particles into discrete fractions, recombining and blending are also necessary. Manufactured Sand falling within Zone II as specified by IS 383 and passing through IS 4.75mm sieve is used in this experiment.

Coarse aggregates (IS 383-1970)- Crushed granite aggregate is used as coarse aggregate. By carefully grading the material and selecting an optimal particle size distribution, a maximum packing density can be achieved, where the smaller particles fill the void spaces between the larger particles. Such dense packing minimizes the amount of cement paste needed and generally leads to improved mechanical and durability properties of the concrete. The aggregate constitutes typically 75% of the concrete volume, or more, and therefore its properties largely determine the properties of the concrete. In this investigation aggregate conforming to zone II passing through 20 mm and retained on 12mm sieve is used as natural coarse aggregate.

Silica fume (IS 15388-2003)- When silica fume is added to concrete, initially it remains inert. Once Portland cement and water in the mix start reacting with each other (hydrating), primary chemical reactions produce two chemical compounds: Calcium Silicate Hydrate (CSH), which is the strength producing crystallization, and Calcium Hydroxide (CH), a byproduct also called free lime which is also responsible for lining the available pores within concrete as a filler and leaching out of inferior concrete. Silica fume contains 80% of silica content and hence it is a excellent use as a Portland cement supplement. Silica fume provides high workability and imparts strength to the concrete and hence rightly used as a high performing admixture.

Water- Water is one of the most important component of concrete as it takes part in the chemical reactions with cement. The strength of cement concrete mainly comes from the binding action of the hydrated cement gel. The requirement of water should be limited so that the chemical reaction of unhydrated cement takes place and the excess water would end up in only formation of undesirable voids in the hardened cement paste in concrete. From High Performance Concrete mix design considerations, it is important to have the compatibility between the given cement and the chemical/mineral admixtures along with the water used for mixing.

Silica fume coated aggregates-The normal aggregates are first sieved into various sizes using IS sieve equipment. They are classified into sizes ranging from 4-8mm, 8-12mm and 12-16mm sizes. Then they are coated with high condense silica fume using advanced coating instruments. This process is done and given by SATHYA ENVIROTECH LLP, Coimbatore.

V. MATERIAL PROPERTIES

Specific gravity test - In concrete mix design, the specific gravity of materials is used in mix design calculation of concrete mixes. The specific gravity of each material known and its weight can be converted in to solid volume and hence a theoretical yield of concrete per unit volume can be calculated. Specific gravity of materials is also required in calculating the compaction factor in connection with the workability measurements and similarly the specific gravity of materials is required to be considered when we deal with high strength concrete.



Table 1: Result of Specific Gravity of Materials

S.NO	MATERIAL	SPECIFIC GRAVITY	LIMITATIONS FROM CODE	CODE
1	Cement	3.15	3-3.25	IS 2720 Part -3
2	Fine Aggregate	2.6	2.5-3	IS 2386 Part 3
3	Coarse Aggregate	2.74	2.5-3	IS 2386 Part 3

Table 2: Specific gravity test on coated aggregates:

S.NO	COATED AGGREGATES SIZES	SPECIFIC GRAVITY VALUE	REQUIREMENTS AS PER CODE	LIMITATIONS
1	4-8 mm	2.7	IS:2386 part-3	2.5-3
2	8-12mm	2.76		
3	12-16mm	2.8		

Water absorption test (IS 2386 part 3)-For this test a sample of 2kg of oven dried aggregates is taken and immersed in water for 24 hours. After 24 hours the sample is taken out from water and wiped with cloth and then weighed. . The difference in the weight of aggregates before immersion and after immersion denotes the amount of water absorbed. Water absorption test on aggregates generally gives an idea of strength of the aggregate. Aggregates having more absorption are more porous in nature and generally considered unsuitable unless they are found to be acceptable based strength, impact and hardness test. Porosity and absorption will affect the workability of the concrete. The porosity of the aggregate will also affect the durability of concrete when it is subjected to freezing and thawing and also when the concrete is subjected to chemically aggressive liquids. Let **A**=Weight of wet aggregate **B**=Weight of dry aggregate

Table 3: Result of Water Absorption on Aggregates

S.NO	MATERIAL	WATER ABSORPTION
1	Fine Aggregate	0.45
2	Coarse Aggregate	0.6

Table 4: Water absorption test on coated aggregates:

S.NO	COATED AGGREGATES SIZES	WATER ABSORPTION VALUE	REQUIREMENTS AS PER CODE	LIMITATIONS
1	4-8 mm	0.8%	IS:2386 part-3	0.2-2%
2	8-12mm	0.65%		
3	12-16mm	0.7%		

Impact test on aggregates- The property of a material to resist impact is known as toughness. Due to movement of vehicles on the road the aggregates are subjected to impact resulting in their breaking down into smaller pieces. The aggregates should therefore have sufficient toughness to resist their disintegration due to impact. This characteristic is measured by impact value test. The aggregate impact value is a measure of resistance to sudden impact or shock, which may differ from its resistance to gradually applied compressive load.



Table 5-Result of Impact Test on Aggregates

S.NO	COATED AGGREGATES SIZES	AGGREGATE IMPACT VALUE	REQUIREMENTS AS PER CODE	LIMITATIONS
1	4-8 mm	22.33%	IS:2386 part-4	Not more than 45%
2	8-12mm	18.55%		
3	12-16mm	15.62%		

Crushing value test on aggregates- Aggregate crushing value test on coarse aggregates gives a relative measure of the resistance of an aggregate crushing under gradually applied compressive load. Coarse aggregate crushing value is the percentage by weight of the crushed material obtained when test aggregates are subjected to a specified load under standardized conditions. Aggregate crushing value is a numerical index of the strength of the aggregate and it is used in construction of roads and pavements. Crushing value of aggregates indicates its strength. Lower crushing value is recommended for roads and pavements as it indicates a lower crushed fraction under load and would give a longer service life and a more economical performance.

Table 6-Result of Crushing Value Test on Aggregates

S.NO	COATED AGGREGATES SIZES	AGGREGATE CRUSHING VALUE	REQUIREMENTS AS PER CODE	LIMITATIONS
1	4-8 mm	25.66%	IS:2386 part-4	Not more than 30%
2	8-12mm	23.16%		
3	12-16mm	20%		

VI. MIX DESIGN

Grade of concrete: M100

Size of aggregate: 12.5 mm -6mm, Degree of workability: 0.76 (compaction factor), Degree of quality control: good, Type of exposure: moderate Cement: Ordinary Portland Cement (OPC 53 grade)

Test Data for Materials Specific gravity of cement: 3.15, Specific gravity of fine aggregate: 2.68, Specific gravity of coarse aggregate: 2.72, Water absorption of fine aggregate: 0.45% , Water absorption of coarse aggregate: 0.6%, Bulk Density of coarse aggregate: 1600 kg/m³

Step-1: Target Strength f_{cr} = Trial Mix Strength, f_{ck} = Specified Compressive Characteristics Strength=100 N/mm² S = Standard deviation (from ACI 211.4) =10

- 1) $f_{cr} = f_{ck} + 1.34 * S = 100 + 1.34 * 10 = 113.4 \text{ N/mm}^2$
(Or)
- 2) $f_{cr} = 0.9 * f_{ck} + 2.33 * S = 0.9 * 100 + 2.33 * 10 = 113.3 \text{ N/mm}^2$

Larger Value out of these two is taken as f_{cr} , Therefore, the Value of $f_{cr} = 113.4 \text{ N/mm}^2$

Step-2: Choice of slump The value of slump height is taken from the table 6.1 of ACI 211.4R based on the type of work. Slump Height is considered as 50 mm.

Step-3: Choice of maximum size of aggregate The ACI method is based on the principle that the Maximum size of aggregate should be the largest available so long it is consistent with the dimensions of the structure. When high



strength concrete is desired, best results may be obtained with reduced maximum sizes of aggregate as they produce higher strengths at a given w/c ratio. The maximum size of Coarse aggregate is taken as 12 mm from the Table 6.2 of ACI 211.4R code.

Step-4: Estimation of mixing water and air content From the Table 6.4 of ACI 211.4R, the quantity of water required (for 50 mm Slump and 12 mm aggregates) = 175 kg/m³

Step-5: Selection of water/cement ratio Let the water/cement ratio = 0.25

Step-6: Calculation of cement content Water/cement ratio = 0.25 Water content = 175 kg/m³ Specific gravity = 3.15
Cement content = 175 / 0.25 = 700 kg

Step-7: Estimation of coarse aggregate content From the Table 6.3 of ACI 211.4R, the volume of oven dry rodded coarse aggregate per unit of volume of concrete = 0.68 for 12 mm aggregate with fineness modulus of fine aggregate as 2.6. Bulk Density of Coarse aggregate = 1600 kg/m³ per 1m³ of Concrete, The Volume of C.A = 0.68 m³, the quantity of C.A = 1600*0.68 = 1088 kg

Step-8: Estimation of Fine Aggregate Content Volume based calculation Volume of water = 175/1000 = 0.175 m³ ,Volume of Cement = 700/ (3.15*1000) = 0.224 m³ ,Volume of Coarse aggregate= 1088 / (2.74*1000) = 0.372 m³ ,Volume of entrapped air = 0.05 m³ ,Volume of Fine aggregate = 1 - 0.175 - 0.224 - 0.372 - 0.05 =0.179 m³ , Fine Aggregate Content=0.179x2.6x1000= 465.4 kg

Step-9: Adjustments for Aggregate Moisture Aggregate quantities actually to be weighed out for the concrete must allow for moisture in the aggregates. Usually the air-dry condition for the coarse aggregate is close enough for use in laboratory, but the fine aggregate is often 2% or 3% above or below SSD. This means that a correction must be made before a laboratory batch of concrete is made.

Step-10: Trial Batch Adjustments The ACI method is written on the basis that a trial batch of concrete will be prepared in the laboratory, and adjusted to give the desired slump, freedom from segregation, finish ability, unit weight, air content and strength

Table 7: Mix ratio

Cement	Fine Aggregate	Coarse Aggregate	Water
700 kg/m ³	465.4 kg/m ³	1088 kg/m ³	175 kg/m ³
1	0.66	1.55	0.25

VII. Results and discussion

Table 8: Compressive strength of cube for 7days (4-8mm Aggregates)

Mixes	Weight(kg)	Load(KN)	Compressive strength(N/mm ²)	Average strength(N/mm ²)
Nominal Mix	2.510	402.5	40.25	39.19
	2.340	391.2	39.12	
	2.250	382.2	38.22	
Coated Aggregate Mix	2.315	682.5	68.25	69.05
	2.335	712.5	71.25	
	2.465	676.5	67.65	

Table 9: Compressive strength of cube for 7days (8-12mm Aggregates)

Mixes	Weight(kg)	Load(KN)	Compressive strength(N/mm ²)	Average strength(N/mm ²)
Nominal Mix	2.665	356.6	35.66	35.73
	2.750	349.8	34.98	
	2.550	365.5	36.55	
Coated Aggregate Mix	2.235	652.5	65.25	66.61
	2.295	682.4	68.24	
	2.455	663.5	66.35	



Table 10: Compressive strength of cube for 7days (12-16mm Aggregates)

Mixes	Weight(kg)	Load(KN)	Compressive strength(N/mm ²)	Average strength(N/mm ²)
Nominal Mix	2.450	323.6	32.36	33.38
	2.575	354.7	35.47	
	2.655	323.3	32.33	
Coated Aggregate Mix	2.350	602.5	60.25	62.75
	2.455	648.7	64.87	
	2.410	631.4	63.14	

Table 11: Compressive strength of cube for 28days (4-8mm Aggregates)

Mixes	Weight(kg)	Load(KN)	Compressive strength(N/mm ²)	Average strength(N/mm ²)
Nominal Mix	2.315	685.4	68.54	67.88
	2.335	652.5	65.25	
	2.465	698.7	69.87	
Coated Aggregate Mix	2.510	1026.4	102.64	101.79
	2.340	1005.1	100.51	
	2.250	1021.3	102.13	

Table 12: Compressive strength of cube for 28days (8-12mm Aggregates)

Mixes	Weight(kg)	Load(KN)	Compressive strength(N/mm ²)	Average strength(N/mm ²)
Nominal Mix	2.450	642.3	64.23	63.18
	2.575	617.8	61.78	
	2.655	635.5	63.55	
Coated Aggregate Mix	2.350	1005.8	100.58	99.42
	2.455	986.5	98.65	
	2.410	990.3	99.03	

Table 13: Compressive strength of cube for 28days (12-16mm Aggregates):

Mixes	Weight(kg)	Load(KN)	Compressive strength(N/mm ²)	Average strength(N/mm ²)
Nominal Mix	2.665	603.1	60.31	61.10
	2.750	594.5	59.45	
	2.550	635.6	63.56	
Coated Aggregate Mix	2.235	943.7	94.37	92.12
	2.295	901.1	90.11	
	2.455	918.9	91.89	

DISCUSSION OF RESULTS

- Based on the compression results obtained from the 28days strength shows that silica fume coated aggregates with 4-8mm achieves the target strength of 101.79 N/mm².
- The results also show that lesser the aggregate size the strength of the concrete is more; this is because of the bonding strength between the aggregates is more.
- The results also shows that the silica fume coated aggregates show a very high strength compared the nominal mix.



VIII. CONCLUSION

Thus from the above conducted experimental analysis we can conclude that silica fume coated aggregates with smaller size have achieved the maximum strength.

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