International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2015): 6.391

Significance of Silica Fume on the Mechanical Properties of Recycled Aggregate Concrete

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Abstract: ***The various studies related to sustainable concrete construction have encouraged recycled aggregate which is a partial replacement of natural aggregate in concrete mixes. The significance of silica fume (SF) in concrete mix will improve the quality of recycled aggregates in concrete. The Portland cement was replaced with Silica Fume at 0%, 5% and 10%. The coarse aggregate in concrete mix is replaced by 0%, 25%, 50%, 75%, and 100% of recycled coarse aggregates (RCA). The compressive strength and split tensile strength of concrete made with recycled aggregates are evaluated. Manufacturing of recycled aggregate concrete with silica fume consists of different methods to increase the strength of RCA such as surface treatments, three stage mixing and pozzolanic material. In this paper, the method of using pozzolanic material is studied. In this silica fume is used as pozzolanic material. In this study, the mixing of concrete is done by triple mix method. With silica fume as an admixture recycled aggregate concrete of M35 grade will be manufactured and tested for physical and mechanical properties. These strength results obtained is compared with conventional concrete results. The target strength is achieved at 5% replacement of silica fume.***

Keywords: Recycled aggregate, Recycled coarse aggregate concrete, Silica fume, Compressive strength, Split tensile strength.

1. Introduction

Concrete is considered as the basic material for every type of construction and is mostly used. With the increase in the population and the fast development in industrialization and infrastructures causes huge construction activities. Very large quantities of demolished concrete waste materials are increased due to the collapsing of reinforced concrete buildings. The solid waste generated due to the demolition of construction activities is more. Generally recycled aggregates contains high absorption, rough texture and angular than natural aggregates. So, to increase the strength of recycled aggregates, pozzolanic materials are used. In this study silica fume is used as pozzolanic material.

Researchers like N.Siva kumar et al., (2014)[1] studied the effect of micro silica and the strength of concrete with ordinary Portland cement. N.K.Amudhavalli et al., (2012)[2] studied the influence of silica fume on concrete. Ozgur Cakir et al., (2014)[3] studied the influence of silica fume on mechanical and chemical properties of recycled aggregate concrete. I.R. Isan Raj at al., (2015)[4] studied on the effect of silica fume on the properties of recycled aggregate concrete. Kalaiarasu et al., (2006)[5] have studied on the properties of high performance concrete with micro silica and in combination with recycled coarse aggregate.

In this study the various percentages of recycled aggregate were added to coarse aggregates and 5% and 10 % of silica fume is replaced with cement. The compressive strength and split tensile strength are observed.

2. Materials

The usage of natural aggregate is getting more and more intense with the advanced development in infrastructure area. In order to reduce the usage of natural aggregate, recycled aggregate can be used as the replacement materials. These recycled coarse aggregates are obtained by crushing and chipping of the cubes that are casted with M35 grade mix design.

2.1 Recycled Coarse Aggregates (RCA):

Recycled coarse aggregates are comprised of crushed, graded inorganic particles processed from the materials that have been used in the constructions and demolition debris. Recycled concrete aggregates mainly differ from natural aggregates in that they are composed of two different materials:

1) Natural aggregate and
2) Cement mortar attached.

Recycled coarse aggregate are obtained from concrete waste. Recycled aggregates contains high absorption, rough texture and angular than natural aggregates that affect the concrete mix proportion. The environmental benefits increase by using these recycled coarse aggregates in the preparation of new concrete. Hence, recycling of the concrete waste can be considered as an excellent source of coarse aggregate for the production of new concrete.

The recycled coarse aggregates are highly heterogeneous and have high porosity and also have high impurity content. The characteristics of recycled aggregates are influenced by heterogeneity and the compressive strength, tensile strength reduces due to the increase of porosity in concrete and have a weak aggregate- matrix interfacial bonding. To increase the properties of recycled aggregate concrete there are methods such as surface treatments, mixing methods and pozzolanic materials. In surface treatment, collected recycled coarse aggregate is cleaned with different acids to increase the strength of recycled coarse aggregate. There are three methods of mixing. They are normal mixing method (NM), double mixing method (DM) and triple mixing method (TM)[8] as shown in fig.1. Pozzolanic materials

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improves the strength of recycled coarse aggregate by filling air voids which were occurred in recycled coarse aggregate and also by using pozzolanic material it increases the bond strength between motor and cement paste.

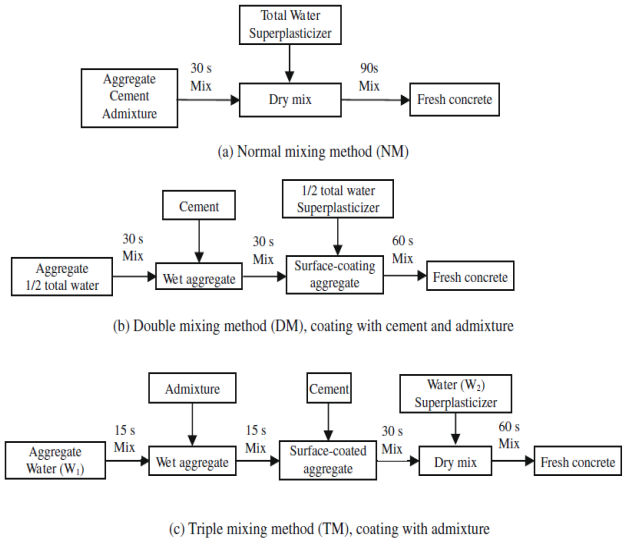

Figure 1: Types of mixing methods

In this study, the pozzolanic material is used to improve the strength of the recycled aggregate concrete. Silica Fume or micro silica is used as the pozzolanic material. The details of replacement of recycled coarse aggregates in natural coarse aggregates are shown in Table 1.

Table 1: The details of replacement of recycled coarse aggregates in natural coarse aggregates

	Mix (0.43 W/C ratio)				
NCA	100%	75%	50%	25 %	0%
RCA	0%	25%	50%	75%	100%

For this study, two different types of coarse aggregates were used in the preparation of concrete i.e. Natural coarse aggregate (NCA) and Recycled coarse aggregate (RCA). Both NCA and RCA aggregates were screened into two different size fractions (i.e. 70% of 20mm to 16mm sized and 30% of 12mm to 10mm sized) and combined to form NCA & RCA.

2.2 Silica Fume

Silica fume, also known as micro silica, is a by-product material that is used as a pozzolan. This by-product is a result of the reduction of high-purity quartz with coal in an electric arc furnace in the manufacture of silicon or ferrosilicon alloy. Silica fume rises as an oxidized vapour from the 2000°C furnaces. When it cools it condenses and is collected in huge cloth bags. The condensed silica fume is then processed to remove impurities and to control particle size. Condensed silica fume is essentially silicon dioxide (usually more than 85%) in noncrystalline form. Since it is an airborne material like fly ash, it has a spherical shape. Since it is an extremely with fine particles, the diameter is 1 µm with an average diameter of 0.1 µm. This is 100 times smaller than cement particles.

Figure 2: silica fume

The Silica fume is used as a partial replacement of cement. The chemical composition and physical properties of silica fume are as follows:

Table 2: The chemical composition of silica fume

Components	*Silica fume*
Silica (SIO_2)	99.886%
Alumina (AI_2O_3)	0.043%
Ferric Oxide (Fe_2O_3)	0.040%
Titanium Oxide (TiO_2)	0.001%
Calcium Oxide (CaO)	0.001%
Magnesium Oxide (MgO)	0.000%
Pottasium Oxide (K_2O)	0.001%
Sodium Oxide (Na_2O)	0.003%
Loss On Ignition	0.015%

Table 3: The physical properties of silica fume

Physical Properties	*Results*
Physical State	Micronized powder
Odour	Odorless
Appearance	White colour powder
Colour	White
Pack Density	0.76 gm/cc
pH of 5% Solution	6.90
Specific Gravity	2.63
Moisture	0.058%
Oil Absorption	55ml/100 gms

3. Mix Design

Concrete mix proportions were designed as per IS 10262:2009 code. A super plasticizer of SP430 was used for high degree of workability. The content of super plasticizer was 0.9% of cement used. The resulting concrete is proportioned for M35 grade as per nominal mix design. The natural coarse aggregate is replaced by recycled coarse aggregate in percentages i.e., 0%, 25%, 50%, 100% and these specimens were tested for compression and split tensile strengths. The variations of compressive strength and split tensile strength with fly ash and without fly ash are discussed in the result section.

3.1 Mix Proportions

Here three mixes of concrete were prepared i.e., without replacement of silica fume, with the replacement of silica fume by 5% and 10% respectively. The water-cement ratio is 0.43. And when super plasticizer (SP430) is used the water-cement ratio is 0.42. The crushed aggregates are used for the replacement of natural aggregates in different

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proportions such as 0%, 25%, 50%, 75%, and 100%. The tables 3 show the mix proportions of recycled aggregate concrete without silica fume. Tables 4 and 5 shows the mix proportions of recycled aggregate concrete with 5% and 10% silica fume.

Table 3: Without replacement of silica fume

RAC Mix	Source of RCA (Parent concrete)	% RCA	Mix proportions(Kg/m^3)				
			Cement	FA (Sand)	NCA	RCA	Water
M35	M35 (RAC 35)	25	385.185	808.157	888.043	296.01	171.852
		50	385.185	808.157	592.029	592.029	171.852
		75	385.185	808.157	296.01	888.043	171.852
		100	385.185	808.157	0	1184.05	171.852

Table 4: With 5% replacement of silica fume

RAC Mix	Source of RCA (Parent concrete)	% RCA	Mix proportions(Kg/m3)					
			Cement	Silica fume (10%)	FA (Sand)	NCA	RCA	Water
M35	M35 (RAC 35)	25	346.67	38.52	808.157	888.04	296.01	167.86
		50	346.67	38.52	808.157	592.03	592.03	167.86
		75	346.67	38.52	808.157	296.01	888.04	167.86
		100	346.67	38.52	808.157	0	1184.058	167.86

Table 5: With 10% replacement of silica fume

RAC Mix	Source of RCA (Parent concrete)	% RCA	Mix proportions(Kg/m3)					
			Cement	Silica fume (5%)	FA (Sand)	NCA	RCA	Water
M35	M35 (RAC 35)	25	365.93	19.26	808.157	888.04	296.01	167.86
		50	365.93	19.26	808.157	592.03	592.03	167.86
		75	365.93	19.26	808.157	296.01	888.04	167.86
		100	365.93	19.26	808.157	0	1184.058	167.86

4. Results and Discussions

4.1 Compressive Strength

The experimental results obtained after the curing of 7 days and 28 days are shown in the table 6. The compressive strength of the two sets is decreased with the increase in percentage of recycled aggregates. At 28 days 100% replacement of RCA with addition of silica fume achieves strength of 32.63 MPa. In a long period of time this strength can the equal or exceed to the strength of natural aggregate concrete.

Table 6: Compressive strength for 7 and 28 days with and without silica fume

% of RA	Compressive strength (MPa)					
	Without S.F		With S.F (5 %)		With S.F (10 %)	
	7 days	28 days	7 days	28 days	7days	28 days
0	30.68	45.58	31.54	46.78	29.47	44.54
25	29.76	44.68	30.01	45.69	27.54	42.37
50	28.37	43.66	29.12	44.76	26.61	40.28
75	25.02	39.91	27.32	41.53	23.11	35.56
100	23.87	35.84	25.63	38.59	21.26	32.63

4.2 Split Tensile Strength

The split tensile strength results obtained after 7 days and 28 days of curing are shown in table 7. The split tensile strength of the two sets is also decreased with increase in the percentage of recycled aggregates.

Table 7: Split tensile strength for 7 and 28 days with and without silica fume

% of RA	Split tensile strength (MPa)					
	Without S.F		With S.F (5 %)		With S.F (10 %)	
	7 days	28 days	7 days	28 days	7days	28 days
0	3.77	4.82	3.64	4.58	3.39	4.33
25	3.41	4.65	3.27	4.29	3.20	4.07
50	3.21	4.42	2.97	3.91	3.07	3.71
75	2.93	4.01	2.76	3.72	2.87	3.45
100	2.73	3.67	2.57	3.51	2.64	3.26

Figure 3 and figure 4 shows the variation of compressive strength for 7 days and 28 days. And figure 5 and figure 6 shows the variation of split tensile strength for 7 days and 28 days.

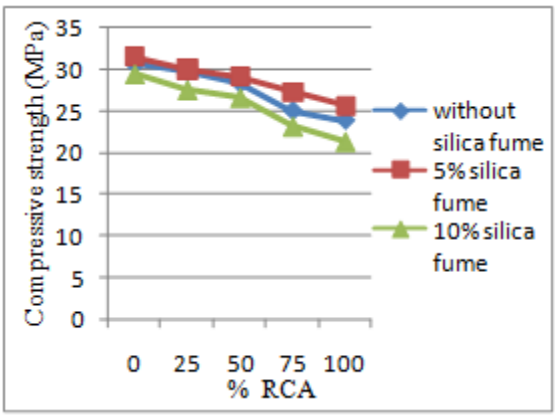

Figure 3: Compressive strength for 7 days without silica fume and 5%, 10% silica fume

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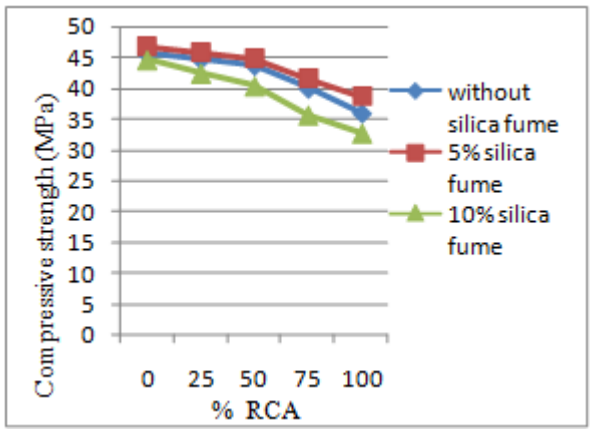

Figure 4: Compressive strength for 28 days without silica fume and 5%, 10% silica fume

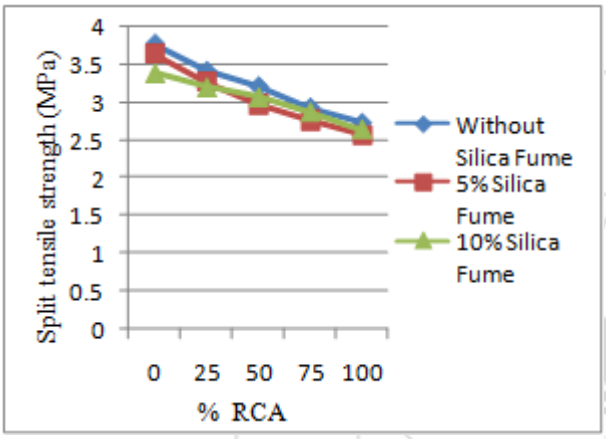

Figure 5: Split tensile strength at 7 days without silica fume and 5%, 10% silica fume

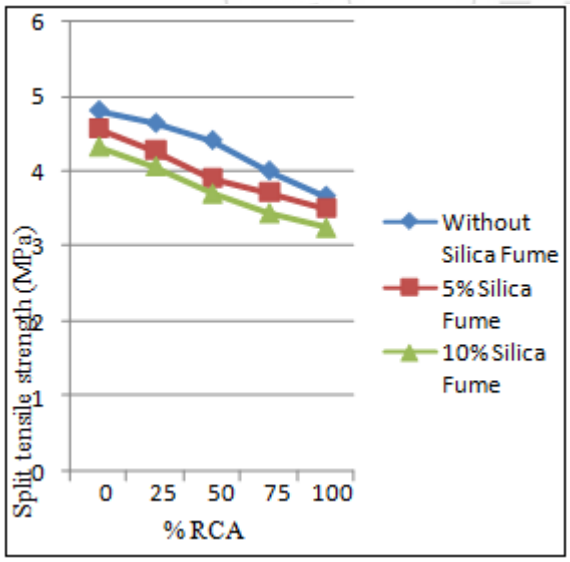

Figure 6: Split tensile strength at 28 days without silica fume and 5%, 10% silica

5. Conclusion

From the study following conclusion are made:

1) The reduction in compressive strength of recycled concrete is observed when the natural aggregates are replaced with recycled coarse aggregate by 25, 50, 75 and 100% respectively. This may be because of the loose mortar around the recycle aggregate which do not allow the proper bonding between the cement paste and aggregate.
2) For 10% replacement of silica fume in cement the strength value decreases when compared to5% of silica fume.
3) At 28 days 100% replacement of RCA with addition of silica fume achieves strength of 32.63 MPa. In a long period of time this strength can the equal or exceed to the strength of natural aggregate concrete.
4) The split tensile strength is less for pozzolanic materials and increases with long period of time

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