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Ultra-high Strength Concrete with Reduced Carbon Footprints

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***Abstract*— In today's scenario, the availability of land is much less than its requirement, so there is need of constructing massive structures but demands high cement usage. This paper aims to achieve ultra-high strength of concrete by replacing cement with waste materials like alccofine and iron dust. This will reduce usage of cement, which can save energy and reduce pollution. The ultra-high strength is achieved by partial replacement of cement with micro-silica and alccofine. Further, if cement is partially replaced by micro silica and sand is replaced by iron dust, ultra-high strength is achieved, but not appreciable.**

Keywords: Alccofine, Iron-dust, Micro Silica, Supercon-100.

I. INTRODUCTION

In the past several years, improvements have been occurring in Concrete Technology. revolutionary developments in super-plasticizing admixtures and sustainable use of supplementary materials have facilitated improvements in the mechanical properties and durability of concrete. For example, researchers are using micro silica and high range water reducing admixtures to produce high density concrete. Along with micro silica, various environmental friendly materials can also be used as a replacement of cement and sand to fill the voids and increase the compressive strength of concrete. Production of Ultra-High Strength Concrete has been carried out since years. The project is focused on strength as well as on reducing the use of natural materials. We are aware that production of cement generates large amount of carbon-dioxide which leads to pollution in the environment. The amount of carbon-dioxide emitted in the atmosphere can be decreased by reducing the usage of cement in concrete. So, instead of using cement, it has been partially replaced by the eco-friendly materials like micro-silica and alccofine. On the other hand for the improvement of compression and flexural strength, sand has been be partially replaced by iron-dust in small quantity. A great effort has been made on reducing water-cement ratio and achieving good workability by using a melamine based superplasticizer i.e.supercon100.

II. BACKGROUND

The Ultra- High Strength Concrete (UHSC) is composed of cement, coarse aggregate, fine aggregate, grit, micro silica and water reducing admixture. When used in optimum dosages, this admixture reduces the water-cement ratio while improving the workability of concrete. The mechanical properties of paste are enhanced by addition of micro silica which contributes in filling voids, producing secondary hydrates and enhancing rheology. The porosity of cement paste is reduced by lowering water-cement ratio and improves durability.

Saurabh Gupta, Dr.Sanjay Sharma, Er. Devinder Sharma [1] studied "A Study on Alccofine a supplementary cementitious material" Due to its ultra-fine size and high content of calcium oxide (CaO), Alccofine 1203 can be used as SCM. It is essential in terms of reducing heat of hydration and strength at all stages. Alccofine 1101 can be used as a grouting purpose. To determine the effect of Alccofine 1203 on workability water requirement and HRWR dosages, 3 trials of concrete mixes were prepared, based on following mix designs methodology- Results are taken from study carried out by Counto Micro fine Products PVT. LTD.

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From the research it was concluded that as Alccofine is a mineral admixture in a concrete mix, it can increase the initial strength of concrete than the ordinary concrete. It has property which helps the concrete to possess and retain workability for sufficient time. Alccofine can be added directly with cement which makes it easy to use. The Ultrafine Particles of Alccofine provides smooth and better surface finish. For High Strength Concrete the cost of concrete mix with Alccofine is lesser than the concrete without Alccofine.

Dr. Prema Kumar W. P., Mr. Ananthayya M. B., Mr. Vijay K. [2] Studied "Effect of replacing sand by Iron Ore Tailings on the compressive strength of concrete and flexural strength of reinforced concrete beams. In their experimental work, they studied the effect of replacing sand partially or completely in cement concrete by Iron Ore tailing. Iron Ore Tailing is a waste material from the Iron Ore industry. They have investigated the disposal problem of iron Ore tailing leading to environmental pollution. Compressive strength and flexural strength of cement concrete cubes and reinforced concrete beams respectively were tested by varying percentages of sand replacement by Iron Ore tailing. From the results, it was concluded that the compressive strength of cement concrete and flexural strength of reinforced concrete beams were not impaired by sand replacement. On the contrary, there was an enhancement in the strength for all the percentages of sand replacement.

Richard P and Cheyrezy M. (1995) [3] studied "Composition of Reactive Powder Concrete" recommended the following principles to develop UHSC:

- Concrete can be made homogenous by removal of coarse aggregate.
- To carry out pozzolanic reaction in concrete, micro silica should be used.
- Optimization of the granular mixture for enhancement of compacted density.
- Application of presetting pressure for better compaction.
- Post-setting heat treatment to enhance the mechanical properties of the microstructure.
- Ductility can be achieved by adding steel fibers to the concrete.

III. MATERIALS

A. ALCCOFINE:

Alccofine is a new generation ultrafine product whose basic raw material is slag of high glass content with high reactivity obtained through the process of controlled granulation. Its particle size much finer than other hydraulic materials like cement, fly ash, silica etc. being manufactured in India. Alccofine has unique characteristics to enhance, performance of concrete in fresh and hardened stages due to its optimized particle size distribution.

I. Benefits of Alccofine-1101:

Alccofine penetrates better in tight joints, fissures & pore spaces. This penetration imparts greater water tightness. Ultrafine particle size allows the grout to penetrate fine sands and finely cracked rock. By using Alccofine 1101 initial and final setting time faster than normal grade cements which increases the productivity in tunnel grouting operation and reduce the waiting time for the next activity to start. It has no hazardous components, better working environment and excellent durability. Alccofine 1101-s is a hydraulic binder which can be used as an additive for complex mix design. It is also cost effective.

The Physical and Chemical Properties of Alccofine-1101 is as follows:

Table 1: Chemical Properties of Alccofine-1101

Chemical Analysis	S	IR	SO_3	MgO	CL	LOI
Mass(%)	1.5	5	4	3	8	0.1

Table 2: Physical Properties of Alccofine-1101

Physical Analysis	**Range**
Bulk Density	600-700 kg/m^3
Surface Area	>8000 cm^2/gm
Specific Gravity	2.9-3.0
Particle Size, d_{10}	<2.5 µ
d_{50}	<6 µ
d_{90}	<12µ
Initial Setting Time (min)	1 hr
Final Setting Time (max)	10 hr

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II. Compressive Strength

As per IS 4031 (Part 6):1988

Table 3: Compressive Strength

DAY	MPa
7	>20
14	>30
28	>40

B. IRON-DUST

Iron-Dust is an industrial by product generated from miling industry in powdered form. It is left largely unused and is hazardous to human health because it is airborne and can be inhaled. The chemical properties of the iron- dust used in the study is as follows:

Table 4: Chemical Composition of Iron-Dust

Chemical Compound	Weight (%)
SiO_2	2.41
TiO_2	0.72
Al_2O_3	1.81
Fe_2O_3	89.0
MgO	0.23
MnO	2.16
CaO	0.45
Na_2O	0.66
K_2O	1.64
P_2O_5	0.34
Ni	0.002
Cu	0.003

C. MICRO SILICA

Micro Silica (MS), also called condensed silica fume (CSF), is mineral admixture, mostly composed of submicron particles of amorphous silicon dioxide. When added to concrete, micro silica acts in two ways. As filler it improves the physical structure, occupying the space between hydrated cement particles, and as a pozzolan, it reacts chemically with the calcium hydroxide released during the hydration on cement, forming strength giving compounds to impart greater strength and durability to concrete. Bridge construction, marine structures, parking structure, water supply and sewage facilities, all benefit from the use of micro silica. MS is always used with a chemical admixture in concrete.

Physical Characteristics:

MS is essentially amorphous silicon dioxide and is dark grey in color. Besides its amorphous nature, the reactivity of MS in concrete depends upon the size of particles, size distribution and how well the particle gets dispersed in concrete after mixing. The sand present in concrete is also silicon dioxide, chemical similar to MS but crystalline in nature, hence does not react with hydrated cement. The physical characteristics of MS are given below:

Table 5: Physical characteristics of Micro-Silica

Particle Size (typical):	Bulk Density: (as-produced): (densified):	Specific Gravity:	Specific Surface
<1µm	130 to 430 kg/m^3 480 to 720 kg/m^3	2.2	15,000 to 30,000 m^2/kg

Chemical Characteristics:

The typical chemical composition of Micro Silica obtained from various sources is as follows:

Table 6: Chemical Composition of Micro-Silica

CONSTITUENT	SOURCE AND COMPOSITION (%)		
	SILICON	FERRO-SILICON	SILICON QUARRY
SiO_2	97.5	96	92.48
C	0.40	0.50	-
Fe_2O_3	0.03	0.50	0.09
Al_2O_3	0.29	0.20	2.60
CaO	0.20	0.20	0.31
MgO	0.10	0.50	0.00
K_2O	0.20	0.50	0.04
Na_2O	0.10	0.20	1.08
Cl	0.01	0.01	-
SO_3	0.10	0.15	0.09
Moisture	0.20	0.50	-
Loss of ignition	0.70	0.70	1.85

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IV. MIX DESIGN

Mix design 1:0.62:1.64
(Cementitious material: Fine aggregate: Coarse aggregate)
Replacement of Micro-silica with varying percentages by cement:

Table 7: Materials for 1m3 of concrete (Keeping 20% constant of micro-silica rest 80% of cement was again partially replaced by Alccofine.)

Cement (kg)	Water (kg)	Sand (kg)	Coarse aggregate (kg)	Grit (kg)	Micro-silica (kg)	Replacement (%)
940.7	234.6	580.2	619.8	928.4	0.0	0%
846.9	234.6	580.2	619.8	928.4	93.8	10%
753.1	234.6	580.2	619.8	928.4	187.7	20%
659.3	234.6	580.2	619.8	928.4	281.5	30%

Keeping 20% constant of micro-silica rest 80% of cement was again partially replaced by Alccofine.

Table 8: Results of compression test.

N/mm^2	7th day cubes	Average Strength of 7days	28th day cubes	Average Strength of 28days	90th day cubes	Average Strength of 90days
0%	67.00	70.77	88.88	89.63	95.88	95.59
	71.14		86.67		97.90	
	74.22		93.33		95.59	
10 %	67.11	67.19	75.55	73.33	93.63	89.49
	67.33		73.33		87.33	
	67.12		71.11		87.51	
20 %	65.33	66.56	80.00	79.11	79.51	80.80
	65.44		73.77		82.67	
	68.88		83.55		80.22	
30 %	64.44	65.97	65.44	68.33	76.00	74.55
	67.82		69.33		74.98	
	65.66		70.23		72.66	

Table 9: Materials for 1m^3 of concrete (Keeping 20% constant of micro-silica, sand was partially replaced by waste material Alccofine).

Cement (kg)	738.45	729.04	719.63	710.23
Water (liter)	235.17	235.17	235.17	235.17
Sand (kg)	580.20	580.20	580.20	580.20
Coarse Aggregate (kg)	619.80	619.80	619.80	619.80
Grit (kg)	928.40	928.40	928.40	928.40
Micro-silica (kg)	188.14	188.14	188.14	188.14
Alccofine (kg)	14.11	23.52	32.92	42.33
Super-plasticizer (liter)	4.70	4.70	4.70	4.70
Replacement (%)	1.5%	2.5%	3.5%	4.5%

Table 10: Result of Compression Test

N/mm2	7th day cubes	Average strength of 7th day	28th day cubes	Average strength of 28th day
1.5%	51.11	52.31	77.78	77.96
	52.89		77.78	
	52.92		78.32	
2.5%	48.00	51.04	76.55	77.01
	54.22		76.69	
	52.67		77.78	
3.5%	55.55	57.43	82.00	56.48
	57.78		83.90	
	58.97		84.78	
4.5%	55.56	83.56	86.45	89.07
	56.89		88.56	

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Table 11: Materials for 1m3 of concrete (Keeping 20% constant of micro-silica, sand was partially replaced by waste material Alccofine).

Cement (kg)	940.70	940.70	940.70	940.70
Water (litre)	282.21	282.21	282.21	282.21
Sand (kg)	557.00	533.78	510.58	487.37
Iron-dust (kg)	23.21	46.42	69.62	92.83
Coarse Aggregate (kg)	619.80	619.80	619.80	619.80
Grit (kg)	928.40	928.40	928.40	928.40
Micro-silica (kg)	188.14	188.14	188.14	188.14
Super-plasticizer (liter)	5.64	5.64	5.64	5.64
Replacement (%)	4%	8%	12%	16%

Table 12: Result of Compression Test

N/mm^2	**4%**	**8%**	**12%**	**16%**
7th day cubes	47.56	52.44	49.78	56.89
	48.48	52.54	52.44	56.92
	48.68	52.98	52.57	57.00
Average strength of 7days	48.24	52.65	51.59	56.93
28th day cubes	75.08	75.0	77.22	82.45
	75.98	77.98	77.65	86.78
	76.32	79.33	81.02	87.97
Average strength of 28days	75.79	77.44	78.63	85.73

Comparison Graph of Materials:

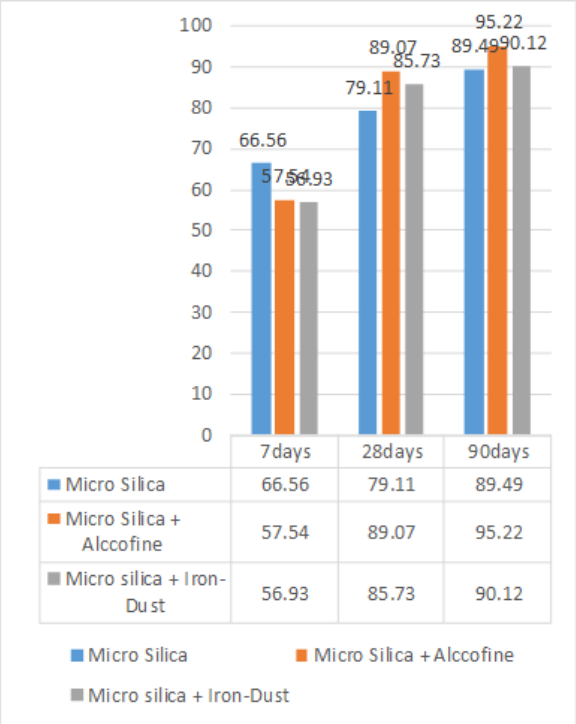

Figure 1. Comparison

V. CONCLUSION

This project was conducted to obtain ultra-high strength concrete with reduction in usage of cement and partially replacing it with eco-friendly and waste materials. Thus, the eco-friendly material alccofine and micro silica are partially replaced with 4.5% and 20% of cement respectively. The waste material iron-dust is replaced by 16% of sand. Further, to obtain true slump and proper workability, 1.5% melamine based super plasticizer supercon-100 is used. Thus, partial replacement of natural materials can result in member

size reduction which decreases the dead load of the building. Further application of this can be extended as a shock absorbing material due to less voids. Moreover, it can be used as a construction material for barracks.

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