Global Journal of researches in engineering
Civil And Structural engineering
Volume 12 Issue 1 Version 1.0 January 2012
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

Investigations on Microsilica (Silica Fume) As Partial Cement Replacement in Concrete

By Faseyemi Victor Ajileye
UNIVERSITY OF IBADAN

Abstract - Now a day, we need to look at a way to reduce the cost of building materials, particularly cement is currently so high that only rich people and governments can afford meaningful construction. Studies have been carried out to investigate the possibility of utilizing a broad range of materials as partial replacement materials for cement in the production of concrete. This study investigated the strength properties of Silica fume concrete.

Keywords : Concrete, Silica Fume/Micro Silica, Compressive Strength, Density.

GJRE-E Classification : FOR Code: 090503

INVESTIGATIONS ON MICROSILICA SILICA FUME AS PARTIAL CEMENT REPLACEMENT IN CONCRETE

Strictly as per the compliance and regulations of:

Investigations on Microsilica (Silica Fume) As Partial Cement Replacement in Concrete

Faseyemi Victor Ajileye

Abstract - Now a day, we need to look at a way to reduce the cost of building materials, particularly cement is currently so high that only rich people and governments can afford meaningful construction. Studies have been carried out to investigate the possibility of utilizing a broad range of materials as partial replacement materials for cement in the production of concrete. This study investigated the strength properties of Silica fume concrete.

The specific gravity and chemical composition of silica fume and cement were replaced with micro silica from 0 to **25%** in steps of **5%** by weight, mix proportioning was based on **1:2:4** mix ratio. Cubes **(150 x 150 x 150 mm)** were produced and cured in a curing tank for **3, 7, 14** and **28** days. The cubes were subjected to compressive strength tests after density determination at **3,7,14** and **28** days respectively. The chemical composition and physical composition of micro silica and cement were determined. Ordinary Portland cement was replaced with silica fume. The total amount of Tricalcium aluminate in the cement was **7.7%** and this was above the requirement. (Table **3.1** shows **3.5** max, Specified by **BS12/EN196:1996**),others chemical compositions for silica fume such as SiO_2, moisture content, loss of ignition, carbon, > 45 micron, bulk density. Tables 3.1 were within the specified limit. Also % chemical composition and physical properties for SiO_2, Al_2O_3, Fe_2O_3,CaO, MgO, SO_3, Alkalis (Na_2O + $0.658K_2O$), loss of ignition (Lo1), insoluble residue (IR), Tricalcium, silicate, Dicalcium silicate, CaO / SiO_2, chloride, fineness (Blaine air permeability test) in Cm^2/g, soundness (mm) table 3.1 were in compliance with BS Standard. The density of the concrete decreased with increased in percentage of micro silica replacement up to **10%**. Increase in the level of micro silica fume replacement between 15% to **25%** led to a reduction in the compressive strength of hardened concrete (table 3.3)

This study has shown that between **5** to **10%** replacement levels, silica fume concrete will develop strength sufficient for construction purposes. Its use will lead to a reduction in cement quantity required for construction purposes and hence sustainability in the construction industry as well as aid economic construction.

Keywords :Concrete, Silica Fume/Micro Silica, Compressive Strength, Density.

I. Introduction

It was observed and noted that since decade of years that the cost of building materials is currently so high that only corporate organizations, individual, and government can afford to do meaningful construction. Waste can be used as filler material in concrete, admixtures in cement and raw material in cement clinker, or as aggregates in concrete (Olutoge, 2009).

Ordinary Portland cement (OPC) is acknowledged as the major construction material throughout the world. The production rate is approximately 2.1 billion tons per year and is expected to grow to about 3.5 billion tons per year by 2015 (Coulinho, 2003). According to Adepegba (1989), the annual cement requirement in Nigeria is about 8.2 million tones and only 4.6 million tones of Portland cement are produced locally. The balance of 3.6 million tonnnnes or more is imported. If aiternative cheap cement can be produced locally, the demand for Portland cement will reduce. The search for suitable local materials to manufacture pozzolana cement was therefore intensified (Adepegba, 1989). Most of the increase in cement demand could be met by the use of supplementary cementing materials, in order to reduce the green gas emission (Bentur, 2002). Industrial wastes, such as silica fume, blast furnance slag, fly ash are being used as supplementary cement replacement materials and recently, agricultural wastes are also being used as pozzolanic materials in concrete (Sensale, 2006). When pozzolanic materials 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

(Igarashi et al, 2005). High strength concrete refers to concrete that has a uniaxial compressive strength greater than the normal strength concrete obtained in a particular region. High strength and high performance concrete are being widely used throughout the world and to produce them, it is necessary to reduce the water binder ratio and increase the binder content. High strength concrete means good abrasion, impact and cavitations resistance. Using high strength concrete in structures today would result in economical advantages.

In future, high range water reducing admixtures (Super plasticizer) will open up new possibilities for use of these materials as a part of cementing materials in concrete to produce very high strengths, as some of them are make finer than cement. The brief literature on the study has been presented in following text.

(Hooten RDC, 1993) investigated on influence of silica fume replacement of cement on physical properties and resistance to sulphate attack, freezing

Author : Technical Manager, Al Andalus Factory For Cement Products, Street 37, Gate 154 Doha- Qatar

and thawing, and alkali silica reactivity. He reported that the maximum 28 days compressive strength was obtained at 15% silica fume replacement level, at a W/C ratio of 0.35 with variable dosages of HRWRA. (Prasad et al, 2003), has undertaken an investigation to study the effect of cement replacement with micro silica in the production of high – strength concrete.

(Yogendran et al, 1987), investigated on silica fume in high – strength concrete at a constant water binder ratio (w/b) of 0.34 and replacement percentages of 0 to 25, with varying dosages of HRWRA. The maximum 28 day compressive strength was obtained at 15% replacement level. (Lewis et al, 2001) presented a broad overview on the production of micro silica effect of standardization of micro silica concrete both in the fresh and hardened state.

(Bhanja et al, 2003) reported and directed towards developing a better understanding of the isolated contributions of silica fume concrete and determining its optimum content. Their study intended to determine the contribution of silica fume on concrete over a wide range of w/c ratio ranging from 0.26 to 0.42 and cement replacement percentages from 0 to 30.

(Tiwari et al, 2000) presented a research study carried out to improve the early age compressive strength of Portland slag cement (PSC) with the help of silica fume. Silica fume from three sources: one imported, two indigenous were used in various proportions to study their effect on various properties of PSC.

II. Methodology

The methodology adopted comprised of both preliminary and experimental investigations carried out using the study material and these are presented as follows:

a) Preliminary Investigations

For the preliminary investigations, micro silica and cement was subjected to physical and chemical analyses to determine whether they are in compliance with the standard used.

The experimental program was designed to investigate silica fume as partial cement replacement in concrete. The replacement levels of cement by silica fume are selected as 5%, 10%, 15%, 20%, and 25% for standard size of cubes for the C30 grade of concrete. The specimens of standard cubes (150 x 150 x 150 mm), was casted with silica fume. Compressive machine was used to test all the specimens. The specimens were casted with C30 grade concrete with different replacement levels of cement from 0 to 25% with silica fume. Seventy two samples was casted and the cubes were put in curing tank for 3, 7, 14, and 28 days and density of the cube, and compressive strength were determined and recorded down accordingly. The other materials used are listed as follow:

- Cement

Ordinary Portland cement produced by QNCC was used in this study. The cement conformed to the requirements of BS 12 (1996).

- Aggregates

There are the inert filler in the concrete mixture which constitute between 70 – 75% by volume of the whole mixture. The sand used was collected within Ibadan metropolis, Nigeria. It was clean and free from organic material and clay. The coarse aggregate used were mainly material retained on a 4.7mm BS 410 test sieve and contained only so much fine materials as was permitted for various sizes in the specification.

- Water

The water used for the study was free of acids, organic matter, suspended solids, alkalis and impurities which when present may have adverse effect on the strength of concrete.

Figure 2.1 : Showing Micro Silica in a sample Pan.

b) Preparation of Specimens

In this study, a total number of 12 cubes for the control and cement replacement levels of 5%, 10%, 15%, 20% and 25% were produced respectively. For the compressive strength, 150mm x 150mm x 150mm cubes mould were used to cast the cubes and 3 specimens were tested for each age in a particular mix (i.e. the cubes were crushed at 3, 7 ,14 and 28 days respectively). All freshly cast specimens were left in the moulds for 24 hours before being de – moulded and then submerged in water for curing until the time of testing. Table 2.1 shows the number of specimens cast and the testing arrangement.

Table 2.1 : Number of Specimens and Ages for each Test.

Specimens	Testing Age (Days)			
	3	7	14	28
MS (0%)	3	3	3	3
MS (5%)	3	3	3	3
MS (10%)	3	3	3	3
MS (15%)	3	3	3	3
MS (20%)	3	3	3	3
MS (25%)	3	3	3	3

Mix Proportioning

Mix Proportioning by weight was used and the cement/ dried total aggregates ratio was 1: 2: 4. Micro silica were used to replace OPC at dosage levels of 5%, 10%, 15%, 20% and 25% by weight of the binder. The mix proportions were calculated and presented in table 2.2

Table 2.2 : Mix proportion for 30Mpa Concrete

Materials	Mix Proportion (Kg)					
	Control	MS 5%	MS 10%	MS 15%	MS 20%	MS 25%
Cement(Kg)	370.0	351.5	333.0	314.5	296.0	277.5
Micro silica (Kg)	0	18.5	37.0	55.5	74.0	92.5
Total Water (Ltr)	140	140	140	140	140	140
Fine Aggregate (Kg)	780	780	780	780	780	780
Coarse Aggregate (Kg)	1180	1180	1180	1180	1180	1180
MS432 (ltr)	4	4	4	4	4	4
W/C	0.38	0.38	0.38	0.38	0.38	0.38

c) Testing of Specimens

Compressive strength test were carried out at specified ages on the cubes. The consisted of the application of uniaxial compressive load on the cube until failure at which point the load require for failure of each cube was noted (Fig 2.2), prior to testing, the density of each cube was determined using standard procedures for density determinations.

Figure 2.2 : Compression machine

III. Results and Discussion

The results of the chemical analysis of cement and micro silica are shown in Table 3.1.

Table 3.1: Chemical Properties of Cement and Micro Silica

Chemical Composition (%)	Cementitious Materials (%)				
	OPC	Requirement	MS Characteristics	Specification Requirement	Result by % by Mass
SiO_2	20.31	-	SiO_2	% Min 85.0	89.5
Al_2O_3	4.81	-	Moisture Content	% Max 3.0	0.8
Fe_2O_3	2.98	-	Loss of Ignition 975C	% Max 6.0	2.0
			Carbon		
CaO	62.73	-	45 Micron	% Max 2.5	0.7
MgO	2.97	5.0 Max	45 Micron	% Max 10	0.3
SO_3	2.78	3.5 Max		% Max 10	0.3
Alkalis (Na_2O + 0.658K_2O)	0.69				
Loss of Ignition (LOI)			Bulk Density		
Insoluble Residue (IR)	1.75	3.0 Max		500 – 700	675
Tricalcium silicate (C_3S)	0.62	1.5 Max		(Kg/m^3)	
Dicalcium silicate (C_2S)	70.79	66.7 Min			
Tricalcium aluminate (C_3A)	70.79	66.7 Min			
CaO/SiO_2	7.70	3.5 Max			
Chloride					
	3.09	2.0 Min			
	0.048	0.10 Max			
Physical Properties					
Fineness (Blaine Air Permeability Test Cm^2/g)	3290	No Limit			
Soundness (mm)	1.0	10 Max			

Density of Cubes

Table 3.1 shows the average densities of cured cubes before they were subjected to compressive strength tests.

Table 3.2 : Density of Cubes at testing Ages

% MS Replacement	Density (g/cm3)			
	Control	3 Days	7 Days	28 Days
0	2.55	2.57	2.59	2.64
5	2.46	2.47	2.50	2.60
10	2.40	2.45	2.47	2.52
15	2.41	2.43	2.48	2.50
20	2.39	2.44	2.46	2.49
25	2.37	2.43	2.45	2.46

Table 3.3 : Compressive strength Test Result for varying Micro Silica Replacement Levels in Concrete

%MS Replacement	Average Concrete Strength Mpa			
	3 Days	7 Days	14 Days	28 Days
0	26.32	30.55	36.07	40.55
5	28.11	33.11	40.77	44.44
10	30.57	38.26	44.72	48.75
15	29.19	34.59	42.58	45.17
20	28.02	31.40	36.25	41.53
25	26.39	30.85	36.20	40.90
% Increased	16.15%	29.24%	23.98%	20.22%

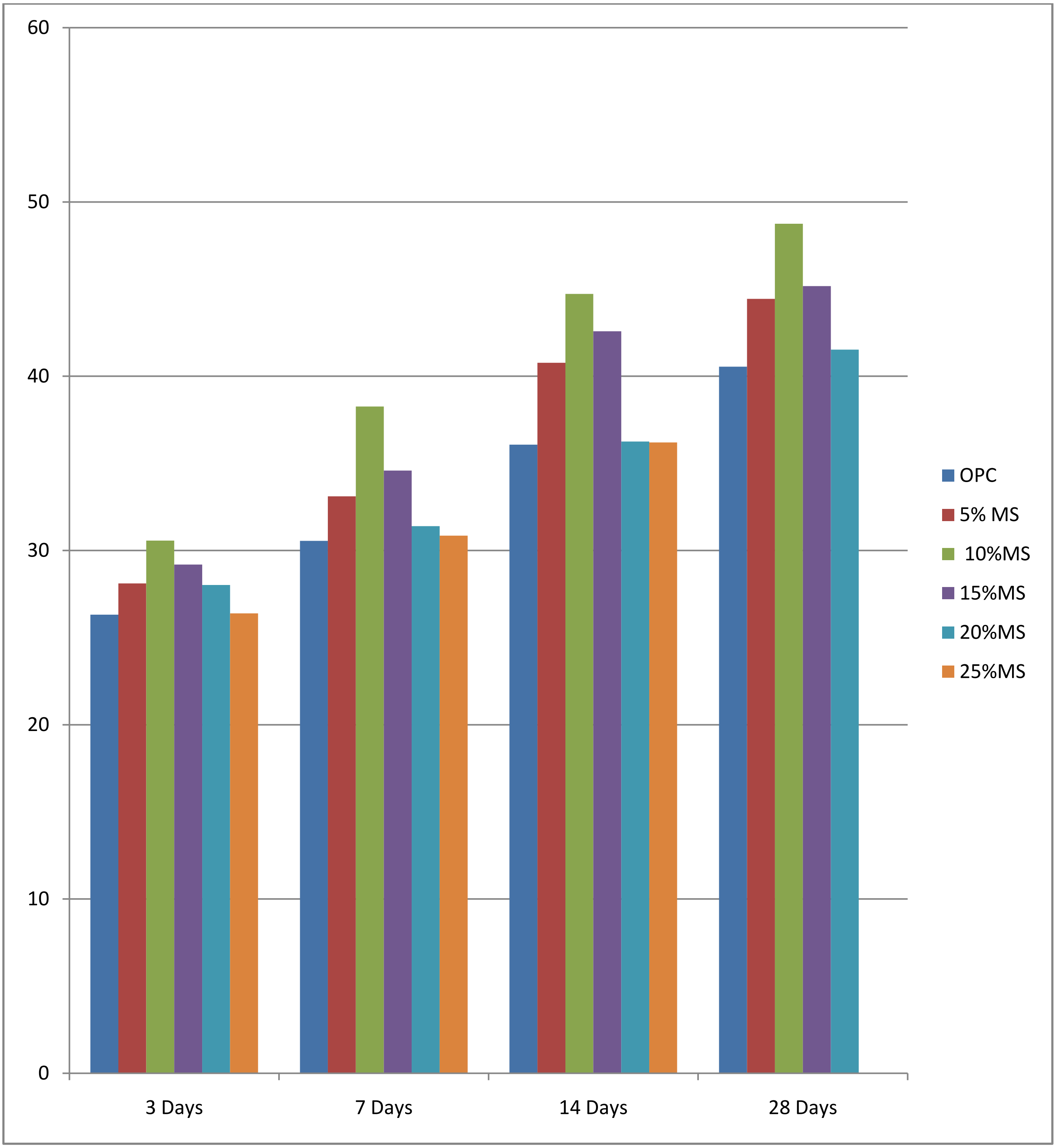

Figure 3.1 : Relationship between compressive strength of varying MS replacement levels.

a) Compressive Strength of Concrete

The test was carried out conforming to BS EN: 12390 – 3: 2009 to obtain compressive strength of C30 grade of concrete. The compressive strength of high strength concrete with OPC and silica fume concrete at the age of 3, 7, 14 and 28 days are presented in table 3.3.

There is a significant improvement in the strength of concrete because of the high pozzolanic nature of the micro silica and its void filling ability. The compressive strength of the mix C30 at 3, 7,14 and 28 days age, with replacement of cement by micro silica was increased gradually up to an optimum replacement level of 10% and then decreased. The maximum 3, 7, 14 and 28 days cube compressive strength of C30 grade with 10% of silica fume was 30.35, 38.26, 44.51, and 48.22 mpa respectively.

The compressive strength of C30 grade concrete with partial replacement of 10% cement by silica fume shows 15.31% greater than the controlled concrete. The maximum compressive strength of concrete with silica fume depends on three parameters, namely the replacement level, water cement ratio and chemical admixture. The superplasticiser admixture dosage plays a vital role in concrete to achieve the given workability at lower w/c ratio. Cement replacement up to 10% with micro silica leads to increase in compressive strength and beyond 10% to 25% there is a decrease in compressive strength for 3, 7, 14 and 28 days curing period.

It was observed that the percentage of micro silica replacement from average concrete strength (mpa) in table 3.3 were 16.15%, 29.24%, 23.98% and 20.22% for 3, 7, 14 and 28 days. The percentage given above shown that the compressive strength increased from 3 days to 7 days and decreased from 14 days to 28 days i.e. (23.98% to 20.22%). The maximum replacement level of silica fume is 10% for C30 grade

IV. Conclusions and Recommendations

- Cement replacement up to 10% with silica fume leads to increase in compressive strength, for C30 grade of concrete. From 15% there is a decrease in compressive strength for 3, 7, 14 and 28 days curing period.
- It was observed that the compressive strength of C30 grade of concrete is increased from 16.15% to 29.24% and decrease from 23.98% to 20.22%.
- The maximum replacement level of silica fume is 10% for C30 grade of concrete.
- Both the physical and chemical properties of micro silica and cement are in compliance with the standard except SO3 analyzed from cement.

Based on the conclusions arrived at, the following recommendations are made for future work:

- It is recommended that testing of concrete produced with micro silica concrete be extended to 56 or possibly 90 days to further determine the pozzolanic ability of the micro silica.
- Volume replacement methods are recommended to investigate the possibility of producing high strength concrete with micro silica.
- Detailed cost analysis should be carried out to determine the level of savings from the use of micro silica in concrete.

References Références Referencias

1. **Abdullah K. M, Hussin W, Zakaria F, Muhamad R, Abdul Hamid Z. (2006)** "POFA: A Pontential Partial Cement Replacement in Aerated Concrete" Proceedings of the 6th Asia- Pacific Structural Engineering and Construction Conference (APSEC 2006), 5-6 September 2006, Kuala Lumpur, Malaysia.
2. **Adepegba D. (1989)** " Pozzolanin Activity of Palm Bunch Wastes, Materials and Structures" Riaux et Constructions, 1989, 22,220-224.
3. **Bentur A. (2002),** Cementitious Materials – Nine Millennia and A New Century: Past, Present and future. Journal of Materials in Civil Engineering 2002: 14(1): 1-22.
4. **Bhanja S, Sengupta B.** Optimum silica fume content and its mode of action on concrete, ACI Materials Journal, September – October 2003, pp. 407 – 712.
5. **Coutinho SJ. (2003),** The combine benefit of CPF and RHA in improving the durability of concrete structures. Cement and Concrete Composites 2003: 25(1):5159. Gastaldine ALG, Isaia GC, Gomes NS, Sperb JEK.
6. **Hooten RD.** Influence of silica fume replacement of cement on physical properties and resistance to Sulphate attack, Freezing and Thawing, and alkli silica reactivity, ACI Material Journal, No. 2, 90(1993) 143 – 51.
7. **Igarashi S, Watanabe A, Kawamura M. (2005),** Evaluation of capillary pore size characteristics in high-strength concrete at early ages. Cement and Concrete Research 2005: 35(3): 513- 519.
8. **Olutoge FA. (2009):** Effect of Rice Husk Ash in the Production of Hollow Sandcrete Block. LAUTECH Journal of Engineering and Technology 5(1) 2009: 58-63.
9. **Sensale GR. (2006),** Strength development of concrete with rice husk ash. Cement and Concrete Composites 2006:28(2):158-160.
10. **Tiwari A, Momin I.** Improving early age strength of PSC with indigenous silica fume, The Indian Concrete Journal, October 2000, pp. 595 – 98
11. **Yogendran V, Langan BW, Haque MN, Ward MA.** Silica on high strength concrete, ACI Material Journal, No. 2, 84(1987) 124 – 9.