International Journal of Civil Engineering and Technology (IJCIET)
Volume 9, Issue 7, July 2018, pp. 112–122, Article ID: IJCIET_09_07_011
Available online at http://www.iaeme.com/ijciet/issues.asp?JType=IJCIET&VType=9&IType=7
ISSN Print: 0976-6308 and ISSN Online: 0976-6316

STUDIES ON ROLE OF SILICA FUME IN GEOPOLYMER CONCRETE AND ITS PROPERTIES

Ahmed Mohmed Ahmed Blash
Scholar, Department of Civil Engineering, & Technology,
Acharya Nagarjuna University India

Dr. T.V.S. Vara Lakshmi
Assistant Professor, Department of Civil Engineering, & Technology,
Acharya Nagarjuna University India

ABSTRACT

Geopolymer Concrete (GPC) is the new type of concretes based on alumina-silicat (an inorganic) binder order if compared with calcium-silicate hydrate order mode of concrete. It possesses the advantage of speedy strength gaining, elimination of the water treatment perfect mechanical and the durability properties. It also the eco-friendly and sustainable alternative to Ordinary Portland Cement (OPC) based concrete. In the construction manufacture, the main production of PC issues is the emission of air-pollutants which increase the effects of environmental pollution. This paper presents the details of the studies carried out on the development of strength for various mixes of geopolymer concrete made with (silica fume) SF. The sodium hydroxide (NaOH) and sodium silicate (Na) have used in the study as alkaline-liquids for geopolymerization process. The GPC samples have tested for the compressive strength after the ages 7, 14 and 28 days water curing and room curing also for HCL attack.

The GPCs mixes with normal concrete grade 45 (M45) compared with the effect of these treatments. These results are used for development of GPC with other materials like SF.

Key words: Silica Fume, Geopolymer, Alkaline, Slump, SEMA.

Cite this Article: Ahmed Mohmed Ahmed Blash and Dr. T.V.S. Vara Lakshmi, Studies on Role of Silica Fume in Geopolymer Concrete and its Properties, International Journal of Civil Engineering and Technology, 9(7), 2018, pp. 112–122.
http://www.iaeme.com/IJCIET/issues.asp?JType=IJCIET&VType=9&IType=7

1. INTRODUCTION

Last years the concrete plays a very important role in construction fields such as in the infrastructure of cities and dams and roads of various kinds etc. It is produced with the cement and aggregates or another more additives. These additions may be natural or industrial, but in general concrete works, have focused on the use of natural ones and with continued use will lead to the depletion or lack of important sources. Thus using the alternative aggregate mean a natural step toward resolving good part of the depletion reduction of natural aggregate, and the alternative aggregate processed from waste materials would appear to be an even greater good solution [1, 2 and 3]. The investigation of alternative materials for concrete-process started much before more than half a century.

The most important objective of the re-use of materials is to decrease the effectiveness of the human activities on an environment and the planet. The using of an inorganic made-up by-product in the field of concrete-making then will lead to the sustainable concrete design. An industrial and another waste like fly ash (FA), wood waste ash, rice husk ash (RHA), slag, copper, oil palm shells, granite sludge, cement kilns dust; steel chips, SF, etc. were used to improve the property of the concrete and to minimize the cost [5, 6].

The manufacture of PC worldwide is increasing by 9% annually. The PC industry is a process of concern and needs to be reviewed because of the large quantities of gases produced and continuously rising to the upper atmosphere. Moreover, PC is considered to be one of the majorities of building materials that consume large amounts of energy in manufacturing processes [17]. Currently, the amount of gases emitted into the atmosphere produced by the cement industry is about 1.5 billion tons yearly or about 7% of the total gases emitted from the earth into the atmosphere. Most of the problems facing the world today are environmental pollution. In other words, the production of PC means the product of rising gases due to the rise in CO_2. During cement production has two various sources of CO_2 $3SiO_3$. On the opposite aspect, day by day the requirement for concrete is increasing for its easy making ready and fabricating altogether kinds of convenient shapes. So to resolve this problem, the concrete must be environmental friendly [2]. In order to be able to obtain useful and very friendly concrete for the environment, cement in concrete should be replaced by secondary materials. These secondary materials are an industrial neglected waste, for example, FA, SF, GGBS etc. Currently, FA disposal is an increasing problem in growing as nearly 15% of FA is used in applications of high importance such as construction and concrete work, while others are used for landfill and burial. SF increased the strength of the concrete in the state of hardened concrete. In recent years there has been emerged a high interest rate of SF in concrete works, including GPC [3, 4]. All types and grades of SF can be used in the geopolymer technology applications and therefore there a great possibility of reducing the stocks of neglected SF materials. In the current study, the use of SF in geopolymerous concrete applications is to accommodate large quantities of SF produced and neglected [7, 8].

GPCs are kind of inorganic polymer composites, for producing an essential element in the friendly environmentally sustainable construction by replacing the conventional concretes.

The three-dimensional alumino-silicates material has given the term geopolymer by Davidovits at 1970, which is the binder produced by a reaction of the source material abundant in aluminum (Al) and silicon (Si) with the concentrated alkaline solution [5]. The industrial waste is used as source materials such as red mud, FA, RHA and GGBS in the synthesis of geological polymers. And the alkaline liquids concentrated in the aqueous alkali hydroxide or /silicate solution, together with dissolvable alkali metals which customarily Sodium- (Na) or Potassium- (K) based. High concentration of the alkaline liquids is utilized to encourage the atoms of the silicon and aluminum in the raw source materials to shape and dissolve the geopolymeric binder.

2. MATERIALS USED

2.1. Silica Fume (SF): The SF is specified by ASTM C 1240-93 (1993) [14]

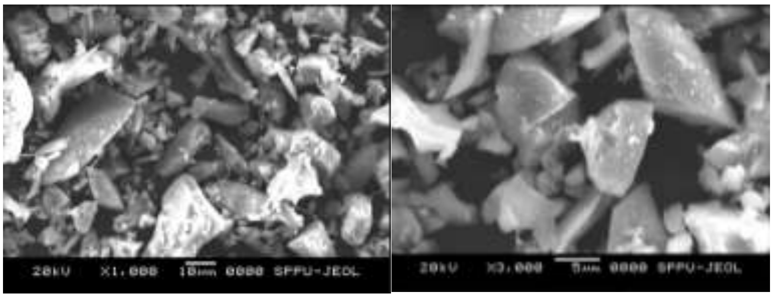


Figure 1 SEMA of SF by two different zooms (X1000 and X3000).

Table 1 XRF analysis data of Silica Fume Composition.

Chemical Composition	Percentage (%)
SiO_2	92.26
$Al2O_3$	0.79
Fe_2O_3	1.57
CaO	0.43
MgO	0.40
Na_2O	0.38
K_2O	1.31
SO_3	0.33
Specific gravity	2.62
Color	Grey

2.2. Portland cement (OPC): To make of the normal concrete with grade 45 (M45).

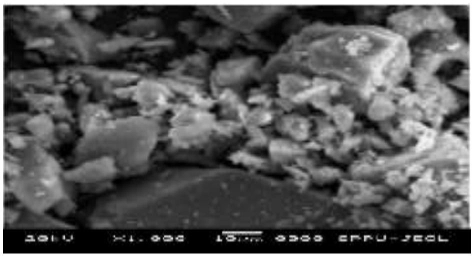


Figure 2 SEMA of OPC by zoom X1000.

Table 2 XRF analysis data of OPC.

Chemical Composition	Percentage (%)
SiO_2	20.10
Al_2O_3	4.90
Fe_2O_3	2.50
TiO_2	0.20
CaO	65
MgO	3.10
Na_2O	0.20
K_2O	0.40
P_2O_5	0.82
SO_3	2.30
Specific gravity	3.20
Color	Grey

2.3. Alkaline Liquids

Table 3 Alkaline Liquids as used.

Alkaline Liquids	Properties
sodium silicate solution(A53)	water = 55.9% by mass and Na_2O to SiO_2 = 0.5
sodium hydroxide	8M
Super plasticizer (SP)	4% by mass of SF

2.4. Aggregates

Table 4 Various aggregates used

Aggregates	Requirement COD	Size (mm)
coarse aggregate	IS 2386-1997	7,14 and 20
Fine Aggregate	IS code 383-1970	River sand

3. PREPARING OF THE MATERIALS

The weight and processing of raw materials of the most important processes in the test before the mixing process. The materials were weighed and processed as required to the test.

3.1. Alkaline Liquids

Sodium silicate solution (A53) and sodium hydroxide (NaOH) solution both together utilized as the AL. It is recommended prepare the alkaline liquid with blending both the solutions together at least a day before use.

4. MIX PROPORTION

In this study, the mix proportion is the same way of making the OPC concrete. So, the aggregates occupy about 70% to 80% and the water content is 0.19 of the total weight of the mixture with a compressive strength designed around 45 MPa [18].

The paste of geopolymer concrete based on SF/GGBS produced by increasing percentage of SF in mixes with double-sizing system, which started from 0%, 20% to 100%. The dosage of (SiO_2/Na_2O =2) is 9.4kg, SP is 0.54kg and the fine sand is 50.49kg for making 27 cubes.

Table 4 Mix properties for 27 cube (kg).

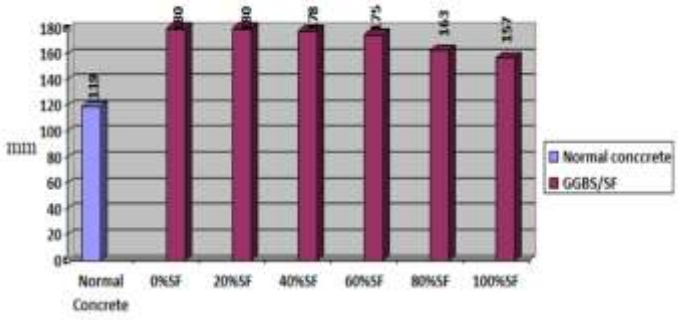
Coarse aggregate (mm)			SF	GGBS	NaOH
20	14	7			
58.97	33.72	25.25	37.18	0	3.73
58.97	33.72	25.25	29.74	7.44	3.73
58.97	33.72	25.25	22.31	14.87	3.73
58.97	33.72	25.25	14.87	22.31	3.73
58.97	33.72	25.25	7.44	29.74	3.73
58.97	33.72	25.25	0	37.18	3.73

5. RESULTS AND DISCUSSION

5.1. The Slump Results

The average result of the three samples for each mixture of the SF/GGBS based of geopolymer concrete were compared with normal concrete (M45) slump values were shown by Graph 1.

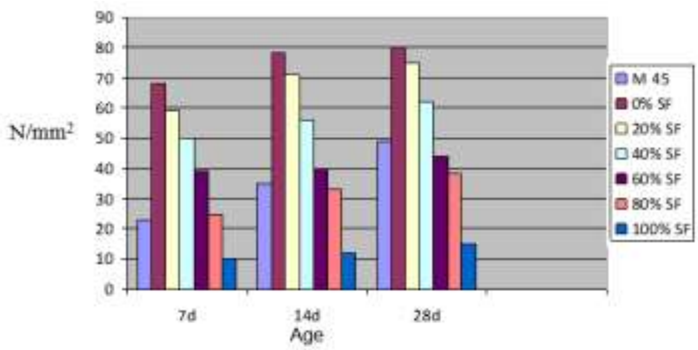
Graph 1shows that, with continued increased of SF dosage the workability of geopolymer concrete and setting time is less than with continued increased of GGBS in the mixtures. The reducing workability with increasing dosage of SF might relate to the finer size of SF that required of mixing. P. lakshmaiah and Kumcham in 2017[19], have reported that, SF in geopolymer samples absorbs water less than GGBS in geopolymer samples. In general, if compared fresh concretes of M45 with geopolymer concrete based on SF/GGBS; M45 mixture exhibited less cohesiveness than geopolymer concrete.



Graph 1 Slump values between M45 and geopolymer concrete based on SF/GGBS ratios.

5.2. The Compressive Strength under Effect of Room Curing

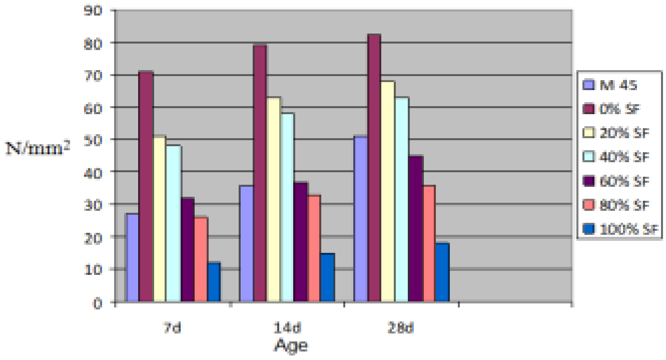
Graph 2 shown the compressive strength values with the effect of room temperature conditions. From the Graph 2, it is clear that concrete M45 obtained an early strength less than geopolymer concrete with SF/GGBS content. As the SF content continues to increase, the value of the compressive strength decreases and the amount of GGBS for the geopolymer concrete increases. When the geopolymerial concrete mixtures contained 60% SF, the compressive strength values started decreases if compared with the M45 at same ages.



Graph 2 Effect of room curing on strength of M45 and SF/GGBS based on geopolymer concrete.

5.3. The Compressive Strength under Effect of Water Curing

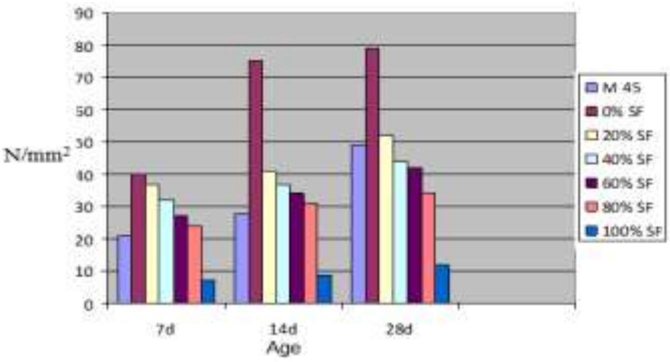
In Graph 3, M45 samples have got strength with increasing the treatment age. Geopolymer concrete with decrease of SF amounts has gained early strength more than M45 strength, but some mixes of geopolymer with 80% SF and 100% SF the compressive strength was less than M45 at same ages of curing. Also, geopolymer concrete blended with 60% SF and 40% GGBS at ages 7 and 14 days obtained strength higher than M45. While at age 28days water curing the strength of M45 was higher than geopolymer concrete blended with 60% SF and 40% GGBS.



Graph 3 Effect of water curing on strength of M45 and SF/GGBS based on geopolymer concrete.

5.4. The Compressive Strength under Attack of HCL

Graph 4 shown the variation of the compressive strength results of geopolymer concrete mixes contain different amounts of SF/GGBS and M45 under effect of 5%HCL attack. From the Graph 4 it is very clear that the geopolymer concrete mixes blended with 100% GGBS shown the maximum strength values than M45 and all geopolymes mixes at all different ages of HCL curing. On the other hand, also geopolymer concrete with 100% GGBS at ages 14 and 28 obtained high strength values and overly. With prepared using of 20%SF and 80%GGBS the geopolymer mixes gained earlier strength than M45 if compared at same ages of treatment. While geopolymer mixes contained (40%SFand 60%GGBS), (60%SF and 40%GGBS) and(80%SF and 20%GGBS) have got early strength higher than M45 mixes at 7 and 14 days of HCL curing, but at 28days of curing the strength were less than M45.

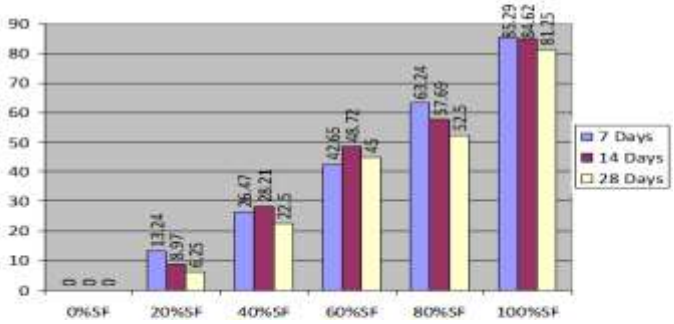


Graph 4 Effect of HCL attack on strength of M45 and SF/GGBS based on geopolymer concrete.

5.5. Effect of the Room Curing on the Compressive Strength

Table 6 The compressive strength according to the percentage of GGBS to SF in each mixture under room temperature treatment.

Materials %		Compressive strength (MPa)			Average Temperature ^{0}C
GGBS	SF	7days	14days	28days	
100	0	68	78	80	22-32
80	20	59	71	75	22-33
60	40	50	56	62	22-32
40	60	39	40	44	22-32
20	80	25	33	38	22-32
0	100	10	12	15	21-30

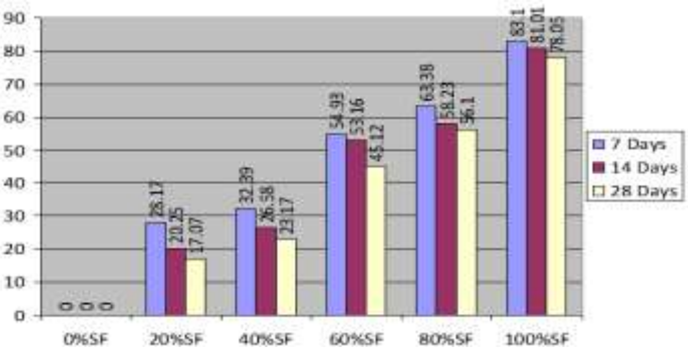


Graph 5 Ratio of compressive strength of all mixes (SF+GGBS)/100%GGBS mix under ambient temperature treatment.

5.6. Effect of the Water curing on the Compressive Strength

Table 7 The geopolymer concrete compressive strength according to the percentage of GGBS to SF in each mixture under Water Curing.

Materials %		Compressive strength (MPa)			Average Temperature ^{0}C
GGBS	SF	7days	14days	28days	
100	0	71	79	82	20-31
80	20	51	63	68	24-34
60	40	48	58	63	24-34
40	60	32	37	45	24-34
20	80	26	33	36	24-34
0	100	12	15	18	24-35

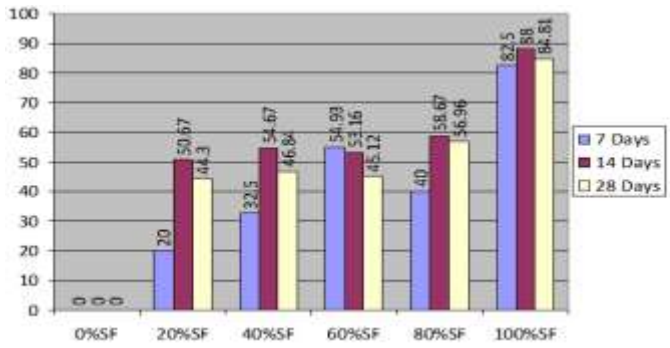


Graph 6 Ratio of compressive strength of all mixes (SF+GGBS)/100%GGBS mix under Water Curing.

5.7. Effect of the HCL Attack on the Compressive Strength.

Table 8 Strength of GGBS and SF based geopolymer after attacked by HCL.

Materials %		Compressive strength (MPa)		
GGBS	SF	7days	14days	28days
100	0	40	75	79
80	20	37	41	52
60	40	32	37	44
40	60	27	34	42
20	80	24	31	34
0	100	7	9	12



Graph 7 Ratio of compressive strength of all mixes (SF+GGBS)/100%GGBS mix under 5%HCL Curing.

5.8. Microstructer of SF/GGBS based Geopolymer Concrete

Figure 4 shown the SEMA for geopolymer concrete based on 100%GGBS and synthesized with 2.72 ratio of GGBS/Alkaline activator.

According to the SEMA result shown in Figure 4, the microscopic structure of the geopolymers powder based on 100%GGBS has contained some spongy or partly grain reaction. The particles of GGBS have experienced geological polymerization because of reaction products generated and effect of the alkali activator.

GGBS particles have shown example model in form the actual bonds within matrix. It has been reported by Xu. H and Van [20] the non-reacting particles cannot act as probes only, but can support to increase the strength of matrix with increasing of the age by bonding power which that can provide by the complex interactions between particle surface.

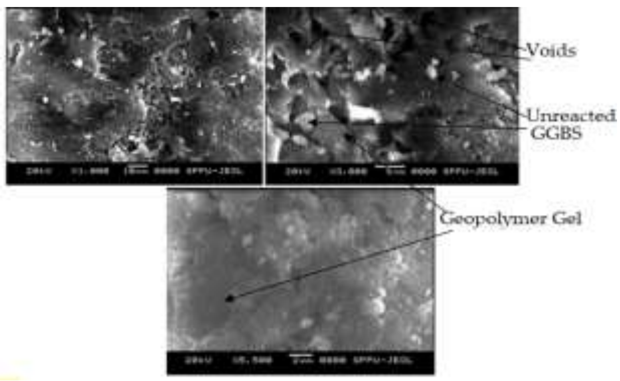


Figure 4 SEMA of geopolymer contains 100%GGBS with attack of HCL.

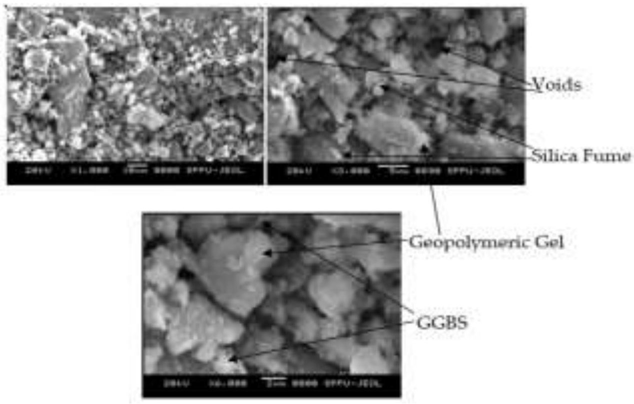


Figure 5 SEMA of geopolymer contains 20%GGBS+80%SF with attack of HCL.

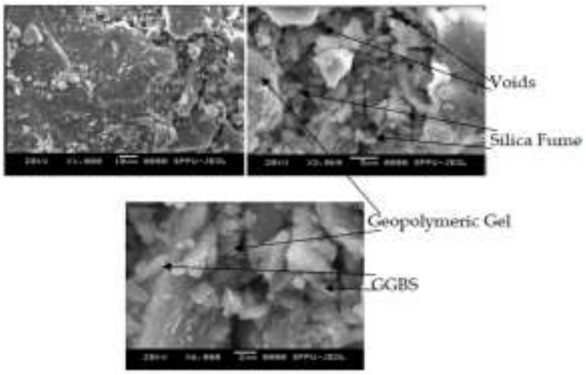


Figure 6 SEMA of geopolymer contains 40%GGBS+60%SF with attack of HCL.

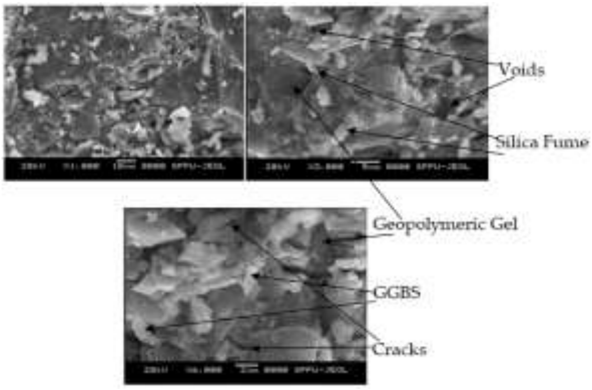


Figure 7 SEMA of geopolymer contains 60%GGBS+40%SF with attack of HCL.

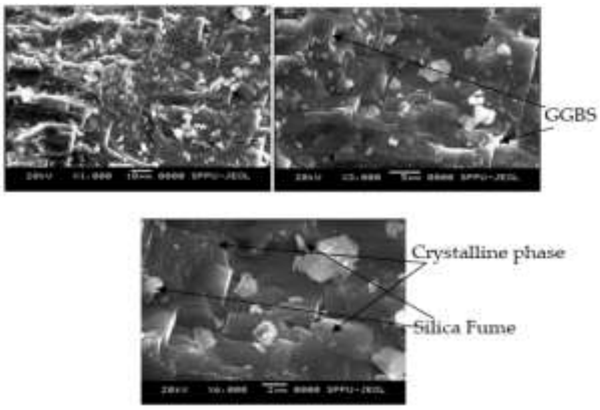


Figure 8 SEMA of geopolymer contains 80%GGBS+20%SF with attack of HCL.

As result of the SEMA shown in Figures 5, 6, 7 and 8 the matrix of the sample appears to be rough, rough terrain and contains many blanks. This indicates the inability of the sample to withstand the strength of the compressor as well as the weakness of its mechanical properties. With the non-reacting particles of the sample powders with attack of HCL. The acid solution works to dissolve the reaction products (alumino-silicate and zeolite). At the same time, the powders particles do not react very much with the acid solution [21].

The degree of overall reaction and the system reaction rate is a formed product permeability function and the alkali diffusion through the layer crust wall and over the remaining powders particles.

It depicts the microscopy of some non-interacting and partially non-interacting particles embedded in the gelopolymer gel. The matrix was very small and exhibited surface coherence, whereas microscopy had exhibited a greater number of individual particles having a random deposition (irregular dispersion) but the morphology of the product reaction was maintained with pores of different sizes and open pores that appeared in sufficient case to obtain a structure with a low density and from which increases the rate of water absorption and reduce the resistance of the forces of the pressure.

As well as results show a number of deflation cracks or as a result of the abandonment of liquid substances and solutions to them and also there is a greater number of reaction is not reaction and partially given to them irregular and rough form.

With increase amount of GGBS, it is possible to observe many features, small cracks and spaces that are not clearly present same as in the samples with the highest ratios of SF content. The spaces become smaller, so the distances have significantly reduced pores and a more dense structure is obtained. There are also large and dense materials such as gel that are likely to be the biopolymer binder with inactive padding, therefore, it is reasonable to conclude that the continuous area like a gel with no blanks made of a pure geopolymer binder, reveals microscopic mostly a crystallized phase.

6. CONCLUSIONS

- The fresh geopolymer concrete workability got clear effect with increasing SF dosage; which the slump values decreased with increase of SF.
- Fresh normal concrete grade 45 (M45) has got slump value less than geopolymer concrete values.
- Geopolymer concrete with increasing of GGBS gained a strong and coherent matrix.
- An early strength had gained for all geopolymer samples at the age 7days under different conditions with increase of GGBS in mixes, while a slight increasing in strength at 14 and 28days at same conditions.
- M45 samples gained strength with increasing the curing time.
- Geopolymer concrete obtained strength higher than M45 at the high content of GGBS under different treatments.
- Using 5%HCL as attack, geopolymer had a non-strong effect when compared to water and room curing. On the contrary, M45 had a significant effect compared to water and room curing.
- Through the results of concrete resistance to acid attack, it became clear that it is possible to use concrete in applications resistant to acid environment.

REFERENCES

[1] M.D.A. Thomasa, M.H. Shehataa, S.G. Shashiprakasha, D.S. Hopkinsb, K. Cail. “Use of ternary cementitious systems containing silica fume and fly ash in concrete‖” Cement and Concrete Research, Vol. 29, 1999, pp. 1207–1214.

[2] G. Prokopski , B. Langier. “Effect of water/cement ratio and silica fume addition on the fracture toughness and morphology of fractured surfaces of gravel concretes”, Cement and Concrete Research, vol. 30, 2000, pp. 1427- 1433.

[3] Jian-Tong Ding and Zongjin Li. “Effects of Metakaolin and Silica Fume on Properties of Concrete”,ACI materials journals,A V. 99, 2002,pp. 393 – 398.

[4] C.D. Atis, F. O¨ zcan, A. Kilic , O. Karahan, C. Bilim, M.H. Severcan. “Influence of dry and wet curing conditions on compressive strength of silica fume concrete”, Building and Environment, vol. 40, 2005, pp. 1678–1683.

[5] H.S. Wong, H. Abdul Razak. “Efficiency of calcined kaolin and silica fume as cement replacement material for strength performance”, Cement and Concrete Research, vol. 35, 2005, pp.696– 702.

[6] Terence C. Holland, 2005. “Silica user‘s manual”, report no.FHWA- 1F-05.

[7] Amarendranath Deshini. “Fineness of Densified Microsilica and Dispersion in Concrete Mixes‖ Concrete-General”, ODOT Item 499.03, 2006.

[8] Friede and Bernd. “Microsilica– characterization of an unique additive”, IIBCC 10th intern. Inorganic bonded fiber composites conference, 2006, pp. 135- 144.

[9] S. R. Shadizadeh,, M. Kholghi, M. H. Salehi Kassaei. “Experimental Investigation of Silica Fume as a Cement Extender for Liner Cementing in Iranian Oil/Gas Wells”, Iranian Journal of Chemical Engineering Vol. 7, 2006, pp.42- 66.

[10] I.K. Cisse, M. Laquerbe. “Mechanical characterisation of filler sandcretes with rice husk ash additionsStudy applied to Senegal”, Cement and Concrete Research, vol. 30, 2000, pp. 13–18.

[11] K. Ganesan, K. Rajagopal, K. Thangavel. “Rice husk ash blended cement: Assessment of optimal level of replacement for strength and permeability properties of concrete”, Construction and Building Materials, vol. 22, 2008, pp. 1675–1683.

[12] Thanongsak Nochaiya, Watcharapong Wongkeo, Arnon Chaipanich. “Utilization of fly ash with silica fume and properties of Portland cement–fly ash–silica fume concrete”, Fuel, vol. 89, 2010, pp. 768–774.

[13] Sammy Y.N. Chan and Xihuang Ji. “Comparative study of the initial surface absorption and chloride difusion of high performance zeolite, silica fume and PFA concretes”, Cement & Concrete Composites, vol. 21, 1999, pp. 293-300.

[14] ASTM C 33 Aggregates are classified (fine or course) Annual Book of ASTM Standards: Concrete and Aggregates. 04.02 philadelphia: American Society for Testing and Materials.

[15] BS 812: Part 102: (1984): Methods for sampling. Testing Aggregates.

[16] BS 1881: Part 102: (1983) Method of normal curing of test specimens (20^{o} C method).

[17] McCaffrey, R., 2002. “Climate Change and the Cement Industry”, Global Cement and Lime Magazine (Environmental Special Issue), 15-19.

[18] Hardjito, Djwantoro, and B. Vijaya Rangan."Development and properties of low-calcium fly ash-based geopolymer concrete." Curtin University of Technology, Perth, Australia, 2005.

[19] P Lakshmaiah Chowdary and Kumcham Venkata Siva Reddy. "Study on Mechanical Properties of Geopolymer Concrete Using GGBS and Silica Fume." International Journal of Innovative Research in Science, Engineering and Technology, Vol. 6, Issue 5, May, 2017, pp 9873- 9894.

[20] Xu H, Van Deventer JSJ. The geopolymerisation of aluminosilicates minerals. Int J Miner, 2000, Process;59:247–66.

[21] Rashad, Alaa M., Hosam El-Din H. Seleem, and Amr F. Shaheen. "Effect of silica fume and slag on compressive strength and abrasion resistance of HVFA concrete." International Journal of Concrete Structures and Materials 8.1, 2014, .pp 69-81.

[22] Purushotham, P., M. Hari Prasad, and P. Naveen."A study on green concrete.", 2017 pp 601-607.

[23] Khater, Hisham M. "Effect of silica fume on the characterization of the geopolymer materials." International Journal of Advanced Structural Engineering, 2013, 5.1: 12.