Partially Replacement of Cement using Silica fume and Metakaolin for Geopoymer concrete

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Abstract—**In construction field, geopolymer concrete is the new one type of concrete based on alumina-silicate binder order is compared with calcium-silicate hydrate mode of concrete. it possesses advantage of rapid strength gaining, elimination of water curing of mechanical and durability properties. It is an ecofriendly concetre and alternative to ordinary Portland cement(OPC) based concrete. This paper present to investigate the compressive strength of geopolymer produced by partially replacement of cement with silica fume and metakaolin. Here OPC is replaced with 5%, 10%, 15%, 20% combination of both silica fume and metakaolin. In geopolymer concrete the sodium hydroxide(NaoH) and sodium silicate(Na) used for study as alkaline liquid for geopolymerization process. the geopolymer concrete specimens tested for compressive strength at the ages of 7, 14, 28 days.** ***The GPC concrete mixes with normal grade M25.***

Keywords— geopolymer, Silica fume, Metakaolin, alkaline liquids, Compressive strength.

I. INTRODUCTION

In the modern world, a role of concrete in construction is an important for dams, buildings, roads etc,. It is made with cement and other additives or aggregate are mixed.these additives are natural or artificial, the use of natural additives are very important source. The search of alternative material for concrete making started much before more than half a century. The main objectives of reuse of materials would be minimize the impact of human activities on the environment in order to manufacture of PC is increasing worldwide by 9% annually.OPC is considered to to be one of the majority of building materials that consume large amounts of energy in manufacturing processes. the world is facing the environmental pollution as a major problem due to emission of CO_2 during its production of cement.on the other hand demand of concrete is increasing day by day. to produce environmental friendly concrete to produce geopolymer concrete. Silica fume (SF) is one of several types of industrial by-products generated. Silica fume is very effective in the design and development of high strength concrete. The natural kaolin clay is heated to 650 – 900^{o}c to obtain.Metakaolin is the anhydrous calcined form of the clay mineral kaolinite. Minerals that are rich in kaolinite are known as china clay or kaolin, traditionally used in the manufacture of porcelain. The addition of silica fume and metakaolin as a partial replacement for cement of 5%, 10%, 15% and 20% and it is very advantageous. The alkaline liquids are concentrated aqueous alkali hydroxide or silicate solution, with soluble alkali metals usually sodium or potassium based. High alkaline liquids are used to induce the silicon and aluminium atoms in the source materials to dissolve and forms the geopolymeric binder.

II. LITERETURE REVIEW

A. **Amudhavalli& Mathew (2012)** studied the Effect of silica fume on the strength and durability characteristics of concrete.The main parameter investigated in this study is M35 grade concrete with partial replacement of cement by silica fume by 0, 5, 10,15and by 20%. a detailed experimental study in Compressive strength, split tensile strength, flexural strength at age of 7 and28 day was carried out.Results Shows that Silica fume in concrete has improved the performance of concrete in strength as well as in durability aspect Badogiannis(1) et.al (2014)

B. **Pradhan and Dutta (2013)** investigated the effects of silica fume on conventional concrete The optimum compressive strength was obtained at 20% cement replacement by silica fume at 24 hours, 7days and 28 days higher compressive strength resembles that the concrete incorporated with silca fume was high strength concrete

C. **Nova John [9] (2013)** in her paper "Strength Properties of Metakaolin Admixed Concrete" studies the effect of Metakaolin as mineral admixture in the concrete on its performance. The replacement was done in a pattern of 0, 5, 10, 15 and 20% to cement by Metakaolin. Concrete mix of M30 grade was used for the experimental investigation.. The tests are performed after 7 days and 28 days curing of the specimens. The results indicate that the use of Metakaolin in concrete has improved the strength characteristics of concrete.From the results of considered parameters, it is observed that 15% replacement of cement with Metakaolin showed better performance in case of strength parameters such as compressive, flexural and split tensile strength.

D. **Duxson et al (2005)** Compressivestrength. Metakaolin. Sodium silicate and sodium hydroxide solution. Hot air oven curing at 80°C. This demonstrates that the characteristics of geopolymers can be tailored for applications with requirements for specific microstructural, chemical, mechanical, and thermal properties.

III. MATERIALS

Cement

Cement is a binder, a substance used in construction that sets and hardens and can bind other materials together. The most important types of cement are used in the components in the production of mortar in masonry and of concrete, which is a combination of cement and an aggregate to form strong building materials available in the world.

Silica Fume

Silica Fume also known as condensed silica fume or micro silica is very fine, non-crystalline produced in electric arc furnaces as a by-product of the production of elemental silicon o silicon allows. The specific gravity ranges from 2.2 to 2.3. Silica fume is added to Portland cement concrete to improve its properties, in particular compressive strength, bond strength and abrasion resistance.

Physical Properties of Silica fume

Physical State	Solid- Non-Hazardous
Specific Gravity	2.23
Mean grain size (μm)	0.15
Colour	White
Odour	Odourless

Chemical Compostion of Silica Fume

Chemical Name	**Ingredients percentage**
Silicon dioxide (Sio_2)	85
Aluminium Oxide ($Al_2 O_3$)	1.12
Iron Oxide ($Fe_2 O_3$)	1.46
Calcium Oxide (CaO)	0.2-0.8
Magnesium Oxide (MgO)	0.2-0.8
Sodium Oxide ($Na_2 O$)	0.5-1.2
Potassium Oxide ($K_2 O$)	0.5-1.2

Metakaolin

Metakaolin is the anhydrous calcined form of the clay mineral kaolinite. Minerals that are rich in kaolinite are known as china clay or kaolin, traditionally used in the manufacture of porcelain. It is a product that is manufactured for use rather than a by-product and is formed when china clay, the mineral kaolin, is heated to a temperature between 600 and 800ºC.

Its quality is controlled during manufacture, resulting in a much less variable material than industrial pozzolans that are by-products The particle size of metakaolin is smaller than cement particles, but not as fine as silica fume usually 8% - 20% (by weight) of Portland replaced by metakaolin. Such a concrete exhibits favorable engineering properties.

Alkaline liquid

Sodium Silicate Solution-The sodium silicate solution is commercially available in different grades. The sodium silicate solution A53 with SiO_2-to-Na_2O ratio by mass of approximately 2 ,SiO_2=29.4%, Na_2O = 14.7%, and water = 55.9 %by mass. **Sodium Hydroxide** The sodium hydroxide with97-98% purity. The solids must be dissolved in water to make a solution with the required concentration. The concentration of sodium hydroxide

Physical Properties of Metakaolin

Physical State	Solid- Non-Hazardous
Specific Gravity	2.30
Mean grain size (μm)	1-2
Colour	Light Creamy White
Odour	Odourless

Chemical Composition of Metakaolin

Chemical Name	**Ingredients percentage**
Silicon dioxide (Sio_2)	53
Aluminium Oxide ($Al_2 O_3$)	43
Iron Oxide ($Fe_2 O_3$)	1.2
Calcium Oxide (CaO)	0.5
Magnesium Oxide (MgO)	0.4
Sodium Oxide ($Na_2 O$)	-
Potassium Oxide ($K_2 O$)	-

Fine Aggregates

The fine aggregates used in natural sand. The sand is sieved to remove all pebbles. The sieve size used is 4.75mm. The grading should be uniform throughout the work. The moisture content or absorption characteristics must be closely monitored as quality of SCC will be sensitive to such changes.

Coarse Aggregates

Crushed gravel stones obtained by crushing of gavel or hard stone are used as coarse aggregate. The maximum size of aggregates is generally limited to 20 mm. the aggregates serves as reinforcement to add strength to the overall composition. Aggregates are formed due to natural disintegration of rock hence they derived many gravity, hardness strength, physical and chemical stability.

Water

Water is one of the important elements in construction. It is required for preparation of mortar, is utilized in the hydration of cement to form the binding matrix in which the inert aggregates are held in suspension until the matrix is hardened and the remaining water serves as a lubricant between the fine and coarse aggregates and make concrete workable. The pH in surface water is 6.5 to 8.5 and the pH range for ground water is 6 - 8.5.

Control Mix Design

The mix design properties were designed as per IS 10262 code book guide lines, 1:1.88:2.82 (Cement: Fine Aggregate(FA): Coarse Aggregate(CA))

From the mix percentage the weight of silica fume and metakaolin required is tabulated and calculated.

Weight of material used

CEMENT (Kg/m^3)	FINE AGGREGATE (Kg/m^3)	COARSE AGGREGATE (Kg/m^3)	WATER (lit/m^3)
394	743.08	1114.63	197

Weights of cement, silica fume and metakaolin required

	Replacement % of cement by Silica Fume and Metakaolin (SF + MK)	(SF + MK) (2.5 + 2.5) = 5%	(SF + MK) (5 + 5) =10%	(SF + MK) (7.5 + 7.5) =15%	(SF + MK) (10 + 10) =20%
CEMENT	Silica Fume (Kg/m^3)	9.85	19.7	29.55	39.4
	Metakaolin (Kg/m^3)	9.85	19.7	29.55	39.4
	Cement (Kg/m^3)	374.3	354.6	334.9	315.2

RESULT AND DISCUSSION

Compressive strength

Aa test result is the average of at-least three standard cured strength specimens made from the same concrete sample and tested at the same age. The dimensions of the cube are 150mm X 150 mm X 150 mm. At first, the cube mould is prepared by connecting it properly with nuts and bolts. Then, it is thoroughly applied with grease in all nuke and corner of the mould. Now the prepared concrete is kept in three layers then the compaction or vibration are ignored. Finally leveling is done in the mould. It is allowed to set for 24 hours and then demoulded. The load was applied without shock and increased continuously at a rate of approximately 140 Kg/cm^2/min until the resistance of the specimen to the increased load broke down and no greater load could be sustained. It is done on curing of cubes after 7, 14 and 28 days. This process is repeated for the percentages 5%, 10%, 15% and 20%.

Compressive Strength Test

Compressive Strength (fc) = P/A

Where,

P – Load at Failure in Kg and

A – Surface area of bearing cube in mm^2

Figure 1:Cube Casting

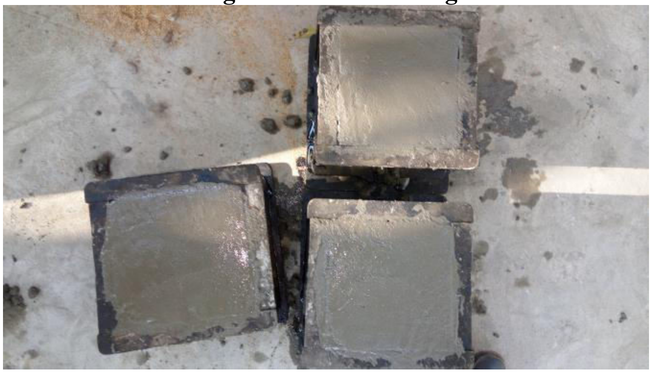
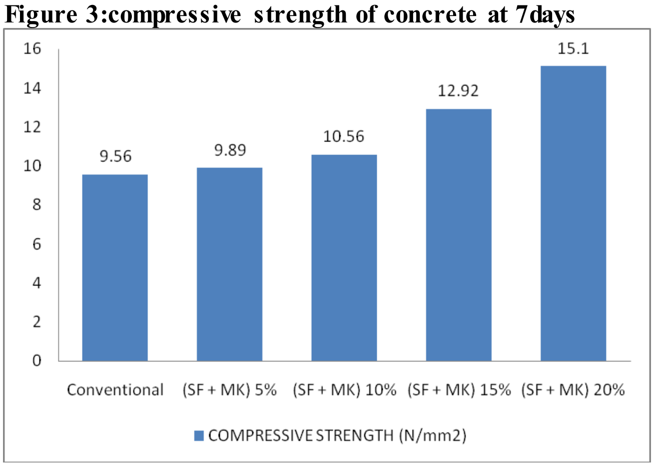


Figure 2:Cube Testing

Compressive strength of concrete (7 days)

S.NO	SPECIMEN	COMPRESSIVE STRENGTH (N/mm^2)
1	Conventional	9.56
2	(SF + MK) 5%	9.89
3	(SF + MK) 10%	10.56
4	(SF + MK) 15%	12.92
5	(SF + MK) 20%	15.100

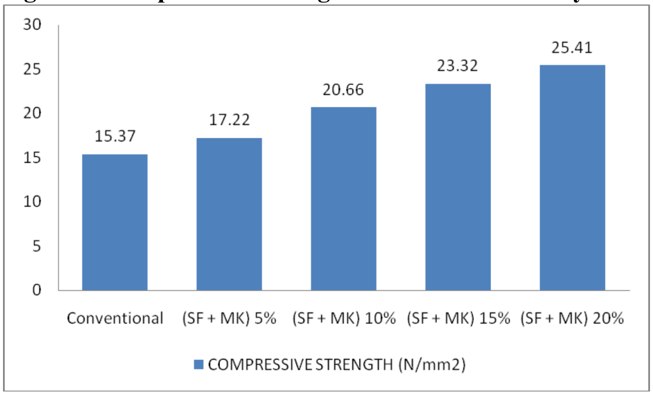
Figure 3:compressive strength of concrete at 7days



Compressive strength of concrete (14 days)

S.NO	SPECIMEN	COMPRESSIVE STRENGTH (N/mm^2)
1	Conventional	15.37
2	(SF + MK) 5%	17.22
3	(SF + MK) 10%	20.66
4	(SF + MK) 15%	23.32
5	(SF + MK) 20%	25.41

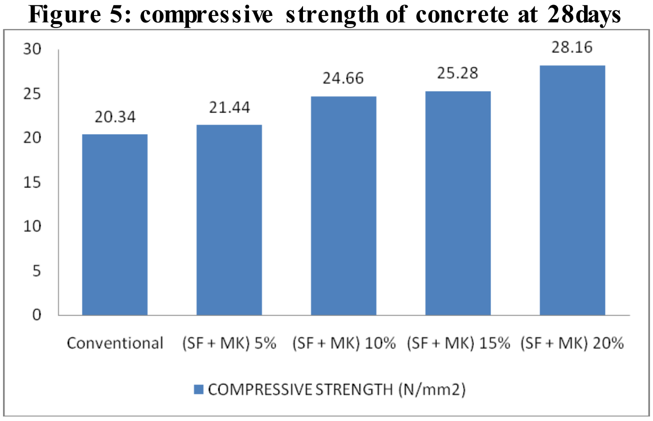
Figure 4: compressive strength of concrete at 14days



Compressive strength of concrete (28 days)

S.NO	SPECIMEN	COMPRESSIVE STRENGTH (N/mm^2)
1	Conventional	20.34
2	(SF + MK) 5%	21.44
3	(SF + MK) 10%	24.66
4	(SF + MK) 15%	25.28
5	(SF + MK) 20%	28.16

Figure 5: compressive strength of concrete at 28days



From the graph of result above, the mixture of gopolymer concrete has several results and different replacement of cement by silica fume and metakaolin. The compressive strength has gives the results at ages 7, 14, 28 days.further the strength of geopolymer concrete increases with curing age and replacement of cement by silica fume and metakaolin

- **conclusion**

Based on the experimental investigations carried out on geopolymer concretes, it can be concluded that: 1)The incorporation of SF and metakaolin in the geopolymer concrete mixes resulted in finer pore structure thus produce low permeability concrete. 2)The geopolymer concretes produced with different combination of SF and metakaolin are able to produce structural concretes of high grades (much more than 25MPa) by self curing mechanisms only 3)The GPC mixes were produced easily using equipment similar to those used for production of conventional cement concretes. 4)The influences of SF and metakaolin on strength of geopolymer concrete mixes were studied. It has been observed that the decreasing the quantity of SF and metakaolin increase of Compressive strength of geopolymer . 5)Apart from less energy intensiveness, the GPCs utilize the industrial wastes for producing the binding system in concrete. There are both environmental and economical benefits of using SF,metakaolin

- **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,pp.1207–1214(1999).

[2] G. Prokopski , B. Langier, ―Effect of water/cement ratio and silica fume addition on the fracture toughnes sand morphology of fractured surfaces of gravel concretes‖, Cement and Concrete Research ,vol.30 pp.1427± 1433 (2000).

[3] Jian-Tong Ding and Zongjin Li, ― Effects of Metakaolin and Silica Fume on Properties of Concrete,‖ACI materials journals ,V. 99,pp. 393 – 398\(2002).

[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 Use either SI (MKS) or CGS as primary units. (SI units are encouraged.) English units may be used as secondary units (in parentheses). An exception would be the use of English units as identifiers in trade, such as "3.5-inch disk drive".sconcrete‖, Building and Environment, vol. 40,pp. 1678–1683,(2005).

[5] H.S. Wong, H. Abdul Razak, ―Efficiency of calcined kaolin and silica fume as cement replacement materialfor strength performance,‖ Cement and Concrete Research ,vol. 35,pp.696– 702, (2005).

[6] Terence C. Holland ―Silica user‘s manual‖ ,reportno.FHWA-1F-05.(2005),‖

[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 ,pp. 135-144,(2006).

[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,pp.42- 66,(2006).
[10] I.K. Cisse, M. Laquerbe, ―Mechanical characterisatio nof filler sandcretes with rice husk ash additions Study applied to Senegal‖ Cement and Concrete Research, vol.30 ,pp. 13–18 (2000).
[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,pp. 1675–1683 (2008).
[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,pp. 768–774 (2010).
[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,pp.293±300(1999).
[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. TestingAggregates.
[16] BS 1881: Part 102: (1983) Method of normal curing of test specimens (20o C method).
[17] McCaffrey, R. (2002). Climate Change and the Cement Industry, Global Cement and Lime Magazine (Environmental Special Issue), 15-19.
[18] van Oss Hendrick, G., 2012. Minerals Yearbook 2010, Slag, Iron and Steel, United States Geological Survey.