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Green Concrete Geopolymers As A New Concept In Sustainable Green Building "Zero Cement"

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ABSTRACT

Green concrete can be defined as the concrete with the material as a partial or complete replacement for cement or fine or coarse aggregates. The substitution material can be of waste or residual product in the manufacturing process. Green concrete should follow reduce, reuse and recycle technique or any two processes in the concrete technology. The three major objective behind green concept in concrete is to reduce greenhouse gas emission (carbon dioxide emission from cement industry, as one ton of cement manufacturing process emits one ton of carbon dioxide), secondly to reduce the use of natural resources such as limestone, shale, clay, natural river sand, natural rocks that are being consume for the development of human mankind that are not given back to the earth, thirdly use of waste materials in concrete that also prevents the large area of land that is used for the storage of waste materials that results in the air, land and water pollution. Geopolymers cement concretes' (GPCC) are Inorganic polymer composites, which are prospective concretes with the potential to form a substantial element of an environmentally sustainable construction by replacing/supplementing the conventional concretes. GPCC have high strength, with good resistance fire attack, etc. These are commonly formed by alkali activation of industrial aluminosilicate waste materials such as FA and GGBS, and have a very small Greenhouse footprint when compared to traditional concretes. The sustainability of green concrete resulted from the development without destruction natural resources.
Aim of this work mainly explain the preparation of Geopolymers and the different factor that effect on the specifications of concrete. Types of activator, particles size and chemical composition of silica alumina waste materials and setting condition of concrete. Geo polymer concrete gets advantage in the resistivity to change in mechanical and physical characterization at high temperature compared to the traditional concrete.

Keywords : Zero Cement – Geopolymers- Sustainable- Green Building- New Cement And Concrete.

I. INTRODUCTION

One of the problems in building technology today is the environmental pollution produced from cement. In the construction industry mainly the production of ordinary Portland cement (OPC) will cause the emission of pollutants which results in environmental pollution. The emission of carbon dioxide during the production of ordinary Portland cement is tremendous because the production of one ton of Portland cement emits approximately one ton of CO2 into the atmosphere [1, 2] besides causing degradation of earth due to mining activities for limestone [3].

Geopolymer cement is made from aluminium and silicon, instead of calcium and silicon. The sources of aluminium in nature are not present as carbonates and therefore, when made active for use as cement, do not release vast quantities of CO2. Geopolymers are a type of inorganic polymer that can be formed at room temperature by using industrial waste or by-products as source materials to form a solid binder that looks like and performs a similar function to OPC. In recent years, there is an increasing awareness on the quantity and diversity of hazardous solid waste generation and its impact on the human health. Increasing concern about the environmental consequences of waste disposal has led researchers to investigate the utilization of the wastes as potential construction materials. Among the researches, the successful one was through the development of geopolymer concrete to eliminate the use of cement [4].

The geopolymer technology shows considerable promise for application in concrete industry as an alternative binder to the Portland cement [5]. Davidovits (1988; 1994) proposed that an alkaline liquid could be used to react with the Silicon (Si) and Aluminum (Al) in a source material of geological origin or in by product materials such as Ground Granulated Blast Furnace Slag (GGBS) powder, fly ash, meta-kaolin and red mud to produce binders[6-9]. Because the chemical reaction that takes place in this case is a polymerization process, he coined the term geopolymer to represent these binders [10].

Rowles M. reported that alkaline concentration was proportional to the compressive strength of geopolymer paste. Geopolymer has diverse advantages, such as a high mechanical strength after curing at 60–75 °C for 24 h[11]. Bilim and Atis [12] reported that many valuable research results have been reported on alkali activated slag binders which have recently received much attention from the academic field. Blast - furnace-slag geopolymer proved to be more effective sorbent than blast-furnace slag, meta-kaolin, or meta-kaolin geopolymer. The relatively low removal capacities are possibly related to the water matrix, The results indicate that blast-furnace-slag geopolymer could serve as a feasible metal and metalloid sorbent with a specific utilization prospect in the mining industry[13].

Molecular structures are stable at certain temperatures. This stability is affected when the temperature conditions change. The temperature level is the fundamental parameter that affects molecular structure and hence is responsible for material deterioration. Exposure time and heating rates are also important parameters which leading to micro cracks due to incompatible expansion can be the main cause of failure of the material in a fire. The molecular changes and microstructural stresses cause deterioration of compressive strength and other mechanical properties of the material. Portland cement based concrete is a composite material that mainly consists of aggregates, cement and water. It is a reasonably dense and porous material, and it undergoes the damage mechanisms in fire[14].

The previous studies that investigated the thermal properties of the slag geopolymers have reported that these materials possessed low thermal shrinkage and good strength maintenance after exposed to high temperatures[15].

II. EXPERIMENTAL PROGRAMME

2.1. Materials

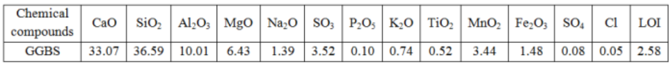
The used materials in the present study were ground granulated blast-furnace slag (GGBFS).

2.1.1. Ground granulated blast furnace slag (GGBFS)

Ground granulated blast-furnace slag was obtained by Iron and Steel factory- Helwan, Egypt. The GGBFS is an industrial by-product resulting from rapid water cooling of molten steel. It is known to have advantageous properties for the concrete industry as it is relatively inexpensive to obtain highly resistant to chemical attack and maintains excellent thermal properties. Major components of the investigated slag are SiO2, CaO, MgO and Al2O3 (Table 1). The Egyptian slag is characterized by its high content of BaO, MgO and MnO than the common international standard one.

It is off-white and grey in colour and substantially lighter than Portland cement. GGBS shall contain at least two-thirds by mass of glassy slag, the sum of CaO, MgO and SiO2. The ratio by mass (CaO + MgO)/ (SiO2) shall exceed 1.0 [16]. GGBS was used as the basic aluminosilicate material to manufacture geopolymers.

Table 1: Chemical composition (wt%) of the raw materials, X-ray Fluorescence (XRF) analysis.



Chemical compounds	CaO	SiO_2	Al_2O_3	MgO	Na_2O	SO_3	P_2O_5	K_2O	TiO_2	MnO_2	Fe_2O_3	SO_4	Cl	LOI
GGBS	33.07	36.59	10.01	6.43	1.39	3.52	0.10	0.74	0.52	3.44	1.48	0.08	0.05	2.58

2.1.2. Chemical Admixtures.

Sodium hydroxide and sodium silicate based alkali activators were used for studying the geopolymerisation process. The NaOH powder had 99% purity. A technical grade waterglass (Na2SiO3) solution was supplied Pacific by Chemicals Industries. Tap water was used throughout the synthesis process. Different types of geopolymer mixes were prepared using sodium hydroxide (12M) and sodium silicate to sodium hydroxide ratios from (0.5:6). Initially, the alkali activator solution was prepared at desired molarity and kept in air for one day prior to mixing in slag for faster initiation of geopolymer reaction. Initially, the calculated activator dosage is added to the slag and mixed by hand for ten minutes and the replacement material.

2.2. Specimen preparation and curing

2.2.1. Activator solution

The alkaline activator used was from the combination of sodium silicate and sodium hydroxide solution. The activator from the sodium silicate solution and sodium hydroxide (NaOH) in flakes or pellets form with 99% purity was prepared according to the reference [18]. The concentration of the sodium hydroxide solution used (12 molar) without additional water.

2.2.2. Preparation of fresh pastes casting and curing:

A total mixtures were prepared by varying the slag, OPC contents. The activators contents were 5:1 Na2SiO3: NaOH chosen and kept constant to investigate the effect of the binders for fire resistance. The proportion of solution to binder (W/G) ratio was 20% in order to obtain better workability of the paste. The mixture proportions for mortar are given in next tables, which curing in air, water and oven. The slag was first mixed together by hand for about 5 min. The alkaline liquid was then added to the dry materials and the mixing was continued for further 10 min to produce the fresh paste. The fresh paste was compacted and vibrated for 2 min to remove entrained air and sealed and the excess paste removed. The moulds were covered by plastic film to avoid evaporation of water. The specimens were cured in water. After the curing period, the test specimens were left in the moulds for at least six hours and demoulded. After demoulding, the specimens were left to air-dry condition in the laboratory with the temperature and humidity of 27°C and 70%, respectively until the day of test [4, 18] and some samples cured in water and other in oven. Curing of these specimens followed the same procedures that were applied to larger specimens of geopolymer pastes especially in oven but not applied to larger in air or water. At the age of 28 days, the sample which cured in air exposed to fire for 2 hours at 200, 400, 500 and 900°c. Half of the geopolymer specimens were left to cool inside the furnace to room temperature and the other half put on water. For each paste mixture, twenty (20) 70*70*70 mm cube specimens were used to determine the compressive strength.

III. RESULTS AND DISSUASION

3.1 Preparation of new geopolymer cement

According this determination the compressive strength of geopolymers cement are determined at different ratio between sodium hydroxide (12 M) and sodium silicate solution. These variations in cement are determined at different curing of sample and at different interval times.

3.1.1 In Air.

The variation in compressive strength in geopolymer cement are determined at different concentration ratio of activator and at different interval times.

Table 2 : The relation between activator ratio and compressive strength at different interval times in air setting at room temperature.

Composition of geopolymer mix				Compressive strength kg/cm^2		
Mix	SiO_2/ NaO	Total solution	Slag (gm)	*3 days*	7 days	28 days
A1	0.5	200	1000	161	335	514
A2	1*	200	1000	170	353	536
A3	2*	200	1000	263	359	546
A4	3*	200	1000	267	365	552
A5	4*	200	1000	273	376	572
A6	5*	200	1000	359	386	603
A7	6*	200	1000	338	383	570

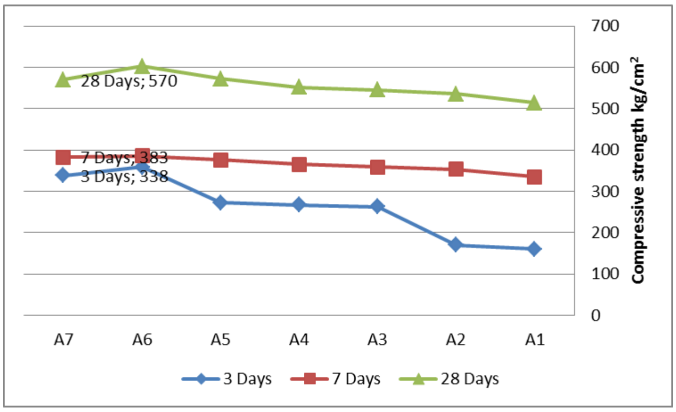


Table 2 shown increases in compressive strength of Geopolymers cement with time and this increases gets highly strength at sample A6 which included SiO_2/NaO ration equal 5. And this behavior change with increasing of ratio as shown in sample A7.

3.1.1 In oven.

The variations in compressive strength in geopolymer cement are determined at different concentration ratio of activator and at different interval times and the settings are occurred in oven champers at 80 C° and humidity 100%.

Table 3: The relation between activator ratio and compressive strength at different interval times in Oven chamber.

Composition of geopolymer mix				Compressive strength kg/cm²		
Mix	SiO_2/NaO	Total solution	Slag (gram)	*3 days*	7 days	28 days
A1	0.5	166	1000	434	587	643
A2	1*	164	1000	498	606	632
A3	2*	162	1000	510	621	663
A4	3*	160	1000	513	650	681
A5	4*	159	1000	551	662	743
A6	5*	157	1000	588	690	780
A7	6*	156	1000	568	659	733

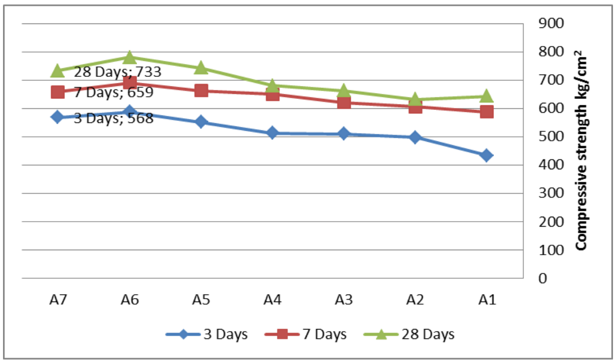


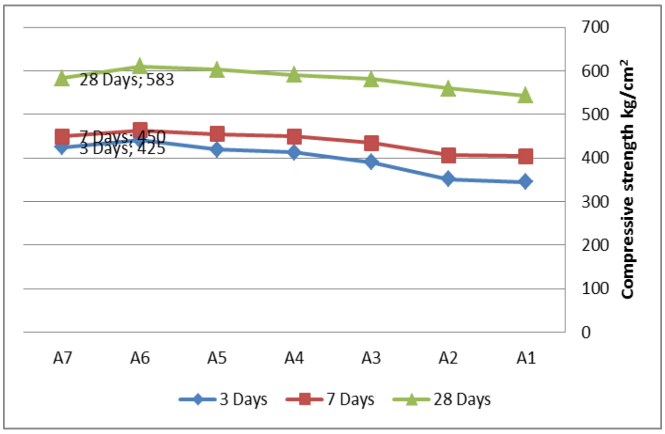
Table 3 shown the same bahaviour of cement geopolymer as shown in air settling of sample but in oven the results get more strength values due to the vaporization of external water in geopolymer cement.

3.1.1 In water.

The variations in compressive strength in geopolymer cement are determined at different concentration ratio of activator and at different interval times and the samples were cured in water along the all intervals time at room temperature.

Table 4: The relation between activator ratio and compressive strength at different interval times in water at room temperature.

Composition of geopolymer mix				Compressive strength kg/cm²		
Mix	SiO_2/NaO	Total solution	Slag (gram)	*3 days*	7 days	28 days
A1	0.5	166	1000	345	404	543
A2	1*	164	1000	351	406	560
A3	2*	162	1000	390	434	581
A4	3*	160	1000	413	449	591
A5	4*	159	1000	419	455	603
A6	5*	157	1000	441	464	610
A7	6*	156	1000	425	450	583



According to Table 4, Compressive strength in all mixes increased with time and with increases in activator ratio up to sample A6 then the compressive strength decreases with ratio increases. These behaviors are matched with above determinations in air and in oven.

3.2 Preparation of geopolymer concrete.

During the preparation of geopolymer concrete, this paper noted the variation in aggregate and sand ratio at new geopolymer cement which produce according to above results.

3.3 Affect the aggregate ratio.

The sample are prepared by cement which produce in above determination and gets the best result in compressive strength (A6) and Bazalt only are used as Coarse Aggregate.

Table 5: The effect of Coarse Aggregate ratio in geopolymer concrete by using new cement A6.

Mix	Slag	Bazalt	SiO_2/NaO=5 Solution, ml	After 7 days		After 28 days	
				air	water	air	water
1	4000	4000	1200	298	375	389	421
2	2670	5330	801	**340**	**402**	**425**	**460**
3	2000	6000	600	221	319	239	358
4	1600	6400	480	118	132	196	206
5	1330	6667	399	27	45	92	110

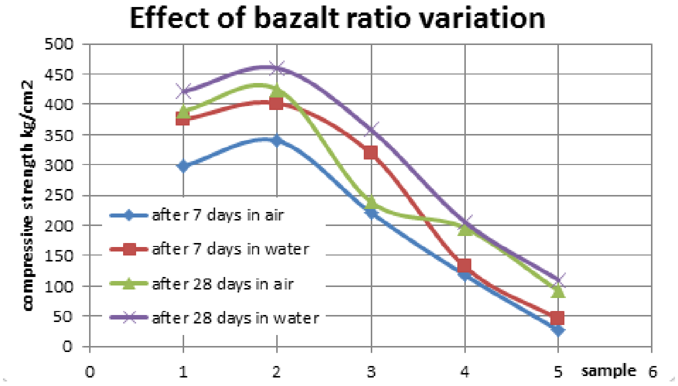


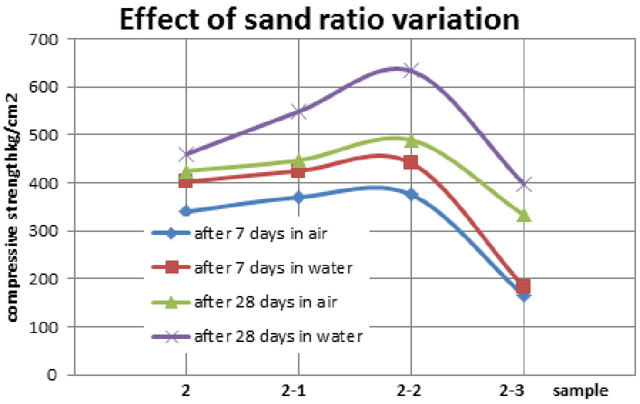
Table 5 shown best mix cement and coarse aggregate are obtained in **mix 2** which get compressive strength 425 kg/cm^2 in air settling and 460 kg/cm^2 in water curing after 28 days.

3.3.1 Affect the coarse aggregate ratio.

According to the effect of basalt ratio and at constant value of geopolymer cement (A6), the effects of sand ratio are studding at mix solution (SiO_2/NaO=5) and volume solution 300 ml.

Table 6: The effect of sand ratio in geopolymer concrete by using new cement A6 and best mix basalt ratio (2).

Mix	Slag	Bazalt	Sand	Fcu at 7 days		Fcu at 28 days	
				air	water	air	water
2	1000	2000	0	**340**	**402**	425	460
2-1	1000	2000	500	370	425	**447**	549
2-2	1000	2000	1000	375	441	489	**653**
2-3	1000	2000	2000	165	183	333	398



According table 6 the best results obtained at 28 days that include sand ratio 0.5 of bazalt weight in concrete and recording 653 kg/cm^2 in water curing. While in air the best result obtained at sand ratio 0.25 of bazalt weight in concrete and recording 447 kg/cm^2 in water curing at 28 days in water curing.

Table 7: Comparison between OPC and geopolymer cement in concrete mix.

Mix	OPC	Bazalt	Sand	Mix Solution	Fcu at 7 days	Fcu at 28 days
					water	water
2-2	zero	2000=2	1000=1	300	441	653
R from Code	1000	2240=2.24	1120=1.12	300	210	355

Table 7 shown the compressive strength of geopolymer concrete compared with the traditional cement concrete prepared by (OPC). Geopolymer concrete recording 653kg /cm^2 while the normal concrete recoded 355 kg /cm^2 .

3.4 Firing behavior of geopolymer cement.

Variations in compressive strength with increasing in firing temperature are determined in both ordinary Portland cement and geopolymer cement.

Table 8: the variation in compressive strength of ordinary Portland cement and geopolymer cement.

Cement types	Compressive strength (kg/cm2). at Firing Temperature.				
	Room temp.	200C^0	400 C^0	500 C^0	900 C^0
OPC	406	352	307	181	168
Geo cement	610	725	762	791	820

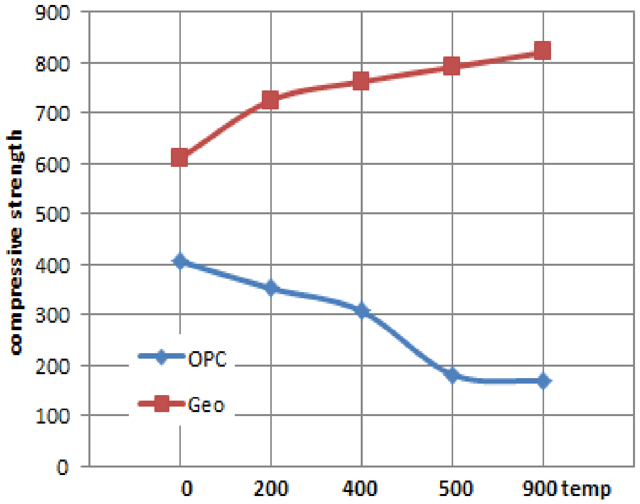
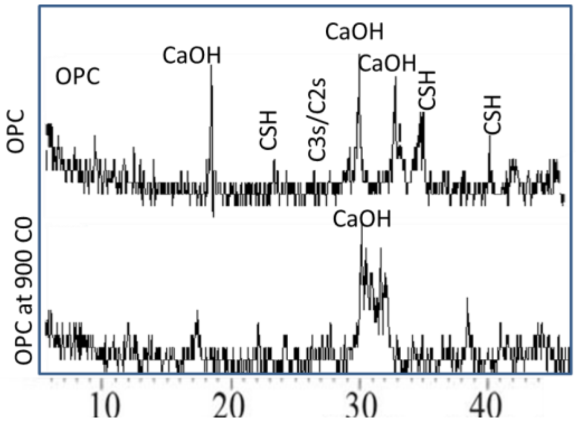


Table 8 shown sharply decrees in compressive strength of OPC with increasing in firing temperature. In case of new geopolymer cement the compressive strength increases up to 900 C^0 and recording 820 kg/cm^2.

3.4.1 X-ray diffraction of firing.

Determinations the variation in crystallinity of different phases are determined by using X-ray diffraction.



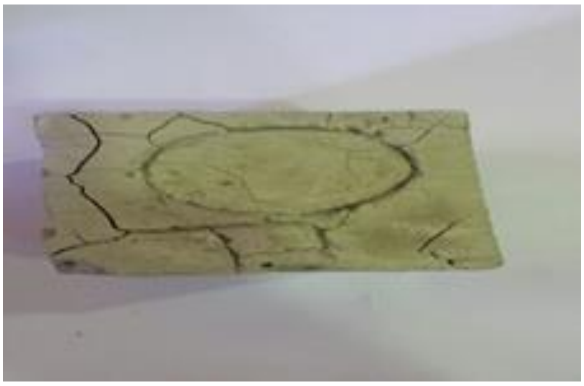


Figure 1. Variation in OPC with firing at 900 C0

Figure 1 shown disinformation in phases of cement specially in SCH which disappears with firing and the reduction of calcium hydroxide sharply in firing. The last reaction may be produce CO_2 gas that increases the external pressure and causing large cracks.

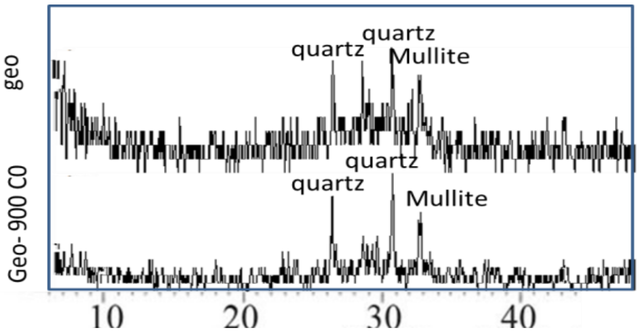


Figure 2. Variation in Geopolymers cement with firing at 900 C0

Figure 2 shown the formation of very stable phases as quartz. These phases highly resistance in firing formation. Furthermore no gas are evaluate during the firing.

IV. CONCLUSION

- Geo polymer gets highly specifications compared with OPC.
- Geopolymer have high strength compared to Ordinary Portland Cement.
- Geopolymer concrete have high strength compared to traditional cement.
- Geopolymers have new still in mixing in concrete.
- Geopolymer concrete can produce by zero cement and zero emission.
- Geopolymer have high resistance to firing.
- Geopolymers have new still in mixing in concrete.

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