
Improve the Formation of Geopolymer Concrete Mixed with Seawater and Without Curing

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To cite this article:

Abd Allah R. Abd EL-moatey, Ahmed S. Faried, Waleed H. Soufi, Magdy A. Abd El-Aziz. Improve the Formation of Geopolymer Concrete Mixed with Seawater and Without Curing. *American Journal of Civil Engineering*. Vol. 5, No. 6, 2017, pp. 344-351.

doi: 10.11648/j.ajce.20170506.15

Received: June 27, 2017; **Accepted:** July 6, 2017; **Published:** October 30, 2017

Abstract: Geopolymer is a new trend in cement industry, traditional cement has prompted several problems related to health and environment due to cement dust and carbon dioxide. Geopolymer, however, has attenuated such problems due to the method of manufacturing and low emission of carbon dioxide. This paper examines the ability to form geopolymer cement and the ability to use this cement in the formation of geopolymer concrete in the field. Various papers have been published with concern to the geopolymer cement set the curing in an oven is constraint to the geopolymer cement formation. During this paper are studied in air without any types of curing. Also the improvement of cement by meta koline as a source of aluminium and silica are studied. geopolymer cement based on the slag has been improved as it has been replaced with 10% metakoline. After optimizing the best mix of cement (slag and metakoline). The effect of geopolymer cement content is studied. Results have shown variation in compressive strength related directly to content of geopolymer strength. Water in geopolymer cement is not included in the reaction. So, throughout the paper the sea water is used as an alternative to fresh water. Results have shown an improvement in the compressive strength as compared to the presence of fresh water.

Keywords: Geopolymer Cement, Concrete, Ground-Granulated Blast-Furnace Slag, Metakoline, Compressive Strength

1. Introduction

Concrete is widely used all over the world because of its versatile application. The Portland cement (PC) is not considered a friendly environmental material. The production of PC emits large amounts of CO₂ and other greenhouse gases [1]. It has been reported that the worldwide cement industry contributes around 1.65 billion tons of the greenhouse gas emissions annually [2]. Due to the production of PC, it is estimated that by the year 2020, emissions will rise by about 50% beyond current levels [3]. Research in Cement developed in the direction of low emission and geopolymer cement is present. Geopolymer cement is alkali-activated binder produced by a polymerization reaction [4] (Davidovits, 1999). Geopolymer helps to generate less CO₂ also reuses industrial waste to produce added-value construction material [5] (Malhotra, 2002). Parthiban has

noted no impact of Chemical Admixture on Compressive Strength but has shown considerable increase in the workability of the concrete. 7 days strength has been found to be 70% of its 28 days strength; the 28 days strength is higher as compared to OPC [6]. The ratio of replacement of Fly ash with GGBS (up to 40%), 8M NaOH solution and Na₂SiO₃/NaOH has been 2.5. Results indicate that a high amount of slag is present; the compressive strength of 31.85 at 3 days [7]. The variation in GGBFS and fly ash based geopolymer at ambient temperature has shown backbone accretion slowed down after the age of 28 canicule and continues to access at a slower amount until 180 days [8]. Fly ash Geopolymer with replacement GGBFS 30% of total Binder and treatment is, at ambient Temperature, 55 Mpa compressive strength. The compactness of the Gel increases when Slag Content is higher in the paste [9]. Geopolymers based on alkaline activation have got the highest compressive strength that has been obtained in systems activated with sodium silicate,

which enabled geopolymer synthesis at room temperature. The results obtained in the present study demonstrate the feasibility of using concrete demolition wastes as precursors to obtain geopolymer cements [10].

2. Experimental Procedures

2.1. Materials

The materials used in this investigation are ground granulated water cooled blast Furnace slag (GGBFS) from Iron and Steel Factory- Helwan, Egypt. Meta kaoline

(kaoline fired at 750 two heures) from el esyela, Egypt. It is composed of both GGBFS and MK and represented in Figures (1, and 2). While ground granulated blast furnace slag materials have been composed of amorphous constituents, the alkaline activator used has been formulated from the combination of sodium silicate and sodium hydroxide solution. The author has prepared the activator from the sodium silicate solution ($\text{Na}_2\text{O} = 12\%$, $\text{SiO}_2 = 30\%$, and water = 57% by mass) and sodium hydroxide (NaOH) in flake form with 99% purity. Table (1) shows the chemical composition of MK and SLAG.

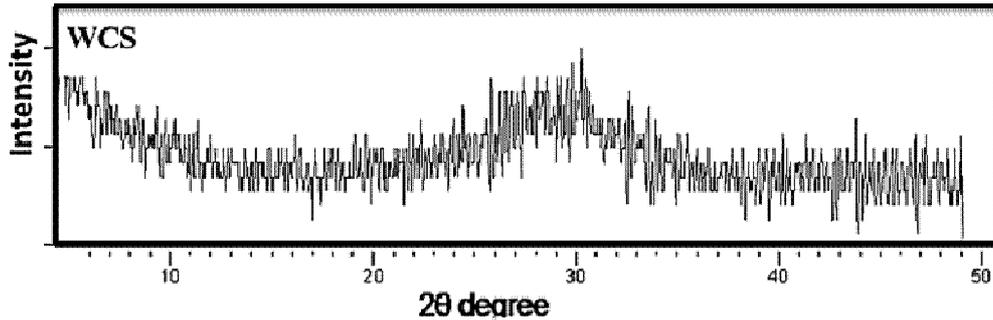


Figure 1. Mineralogical composition of water cooling slag, XRD.

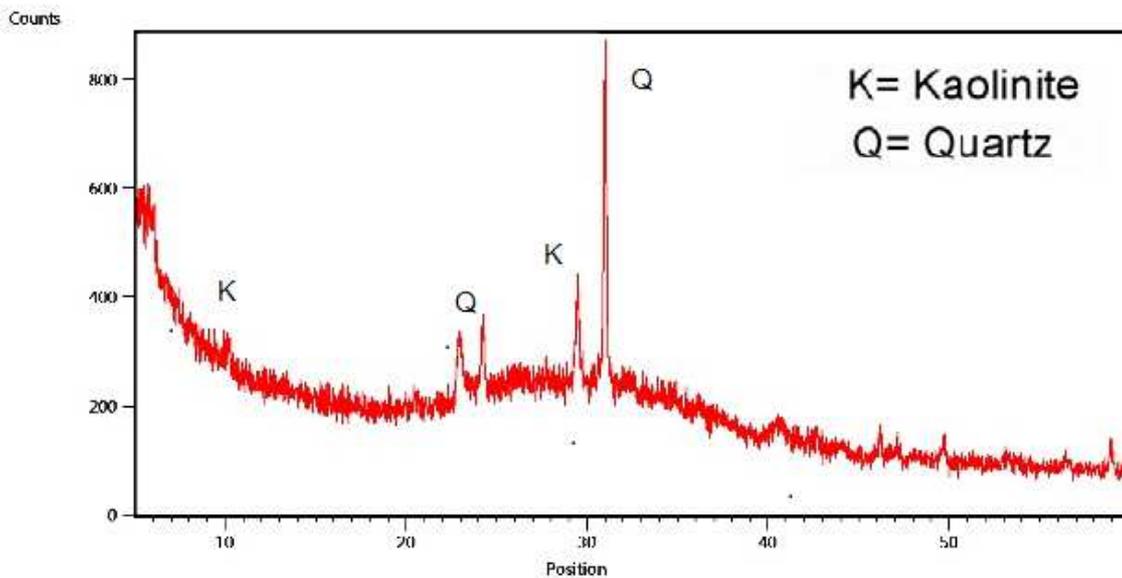


Figure 2. Mineralogical composition of meta kaoline (MK), XRD.

Table 1. XRF analysis of slag, meta-kaolin.

Chemical compounds	CaO	SiO ₂	Al ₂ O ₃	MgO	Na ₂ O	SO ₃	P ₂ O ₅	K ₂ O	TiO ₂	MnO ₂	Fe ₂ O 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
MK	0.14	55.01	40.94	0.34	0.09	0.00	0.00	0.60	0.55	0.00	0.55	0.00	0.00	1.54

Local aggregates comprise 20mm, 14mm and 10mm size. Coarse aggregates C. A of crushed granite-type aggregates have specific gravity of 2.74 and fineness modulus of 2.93. Fine aggregates F. A (sand) in saturated surface dry condition have specific gravity of 2.62 fineness modulus 3.39. The C. A and F. A used in mixing were obtained from Minya quarries. Table (2 and 3) show sieve analysis and physical

properties of C. A and F. A.

Table 2. The sieve analysis of coarse and fine aggregates.

Size	19	16	9.5	4.76	2.8	1.4	0.71	0.355	0.18
%F. A	100	100	100	100	98	85	75	49	23
%C. A	97	84	78	22	0	0	0	0	0

Table 3. The physical properties of coarse and fine aggregates.

	M. E	S. G
F. A	3.39	2.62
C. A	2.93	2.74

2.2. Methods of Investigation

2.2.1. Compressive Strength

The test specimens were cast in steel cubic molds ($50 \times 50 \times 50$ mm) for binder specimens or ($100 \times 100 \times 100$ mm) for

concrete specimens and compacted on a vibrating table. After approximately 24 h, the specimens were removed from the molds. All specimens were put in the air without any types of curing.

For each mix, cubic samples were tested to determine the compressive strengths at 7 and 28 days of mixing. The compressive strength for each mixture was obtained from an average of three cubic specimens. Figure (3) shows the geopolymer concrete cubes during cast and test.



Figure 3. The geopolymer concrete cubes during cast and test.

2.2.2. Instrumental Analyses

Axios (PW4400) WD-XRF Sequential Spectrometer (Panalytical, Netherland) were used for chemical analysis of the starting raw materials. XRD analysis was recorded on a Philips PW 1050/70 Diffractometer using a Cu-K α source with a post sample K α filter. XRD patterns were collected from 0o to 50o 2 Θ (step size 0.02o 2 Θ and speed 0.4o / min).

Bonding characteristics of the specimens were analyzed using a Jasco-6100 Fourier transformed infrared spectrometer FTIR. Test sample was ground and uniformly mixed with KBr at a weight ratio KBr: specimen = 200:1. The mixture, 0.2 g was pressed to a disk of 13 mm in diameter for analysis at 8 t/cm². The wave number was ranging from 400 to 4000cm⁻¹ [11, 12].

3. Results and Discussion

3.1. Optimization of Slag Meta-Koline Mix as Binder in Geopolymer Concrete

3.1.1. Effect of Alkali Activator on Compressive Strength of Binder

Alkaline activator is the second part in geopolymer.

Variations in types of activators and SiO_2 to Na_2O ratio were proved to have great effect on the properties of geopolymer cement. The effect of sodium hydroxide, sodium silicate ratio on slag geopolymer is shown in Figure (4) at different interval times. The best compressive strength is obtained at 30% sodium silicate in both time intervals and recorded 52 N/mm^2 at 28 days.

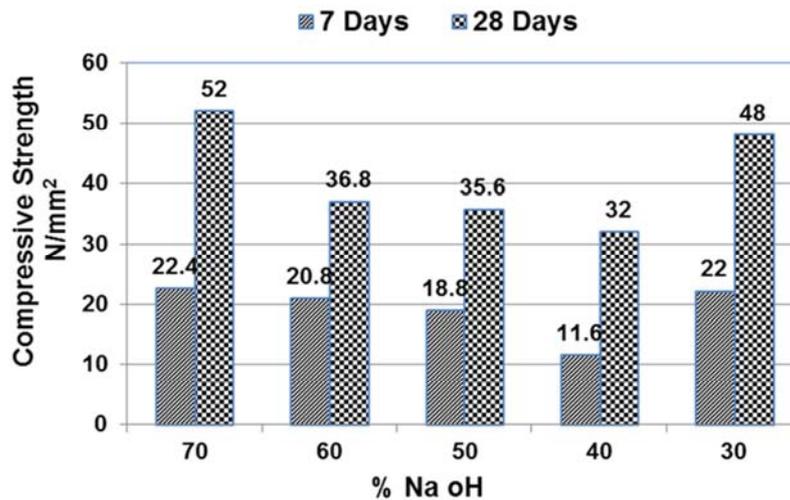


Figure 4. Effect of SiO_2 to Na_2O ratio in compressive strength of slag geopolymer at different interval times.

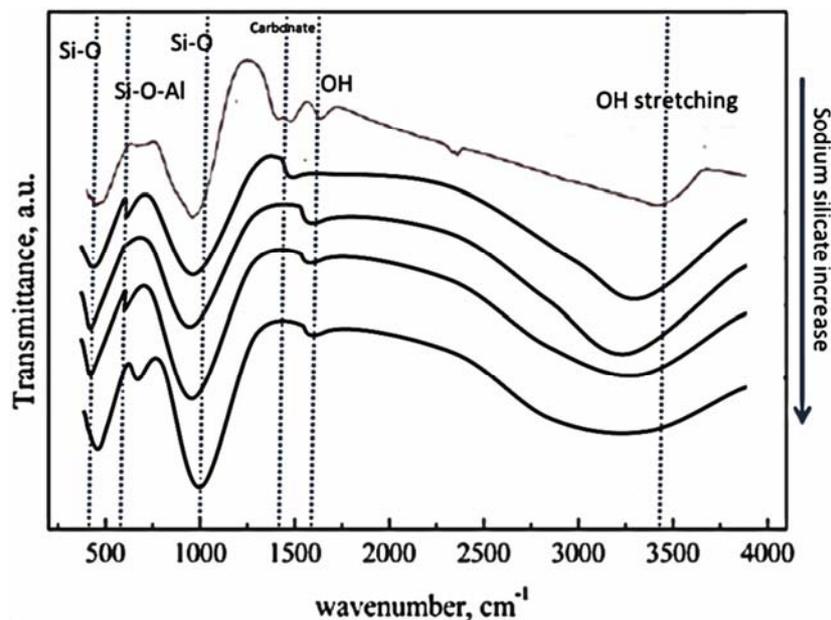


Figure 5. FTIR analysis and identification of cement paste at different concentration at 28 days.

FTIR of sample in figure (4) is determined and identified in figure (5). Variations in FTIR sample have shown a change in wave number and a transmission of the sample. According to that, the increase in sodium silicate gets an increase in wave number as it increases the stability of Si-O bonds and decreases the density of OH group uninformed which appears as 1570cm^{-1} . Si-O-Al density increases with the increase in sodium silicate, but the wave number decreases to indicate less stable form.

3.1.2. Effect of Replacement of Slag by Metakoline

According to the determination of FTIR in the slag geopolymer, the stability of Si-O-Al decreases in correlation with increases in dense structure of geopolymer. This means formation of more geopolymer with low stability. Metakoline have alumina structure with high values. The variation in slag metakoline ratio is studied at certain values of activator ratio according to the above ratio. The effect of slag, the metakoline ratio of geopolymer compressive

strength is shown in Figure (6) at different interval times.

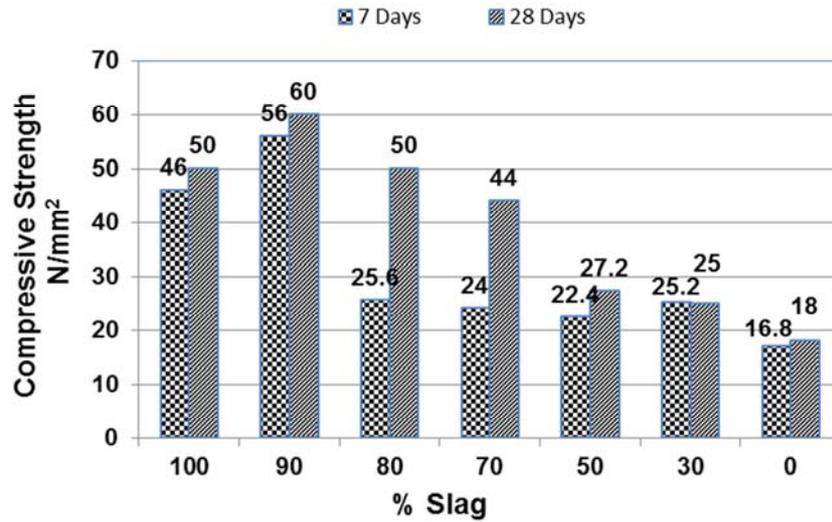


Figure 6. The effect of slag, meta koline ratio of geopolymer compressive strength at different interval times.

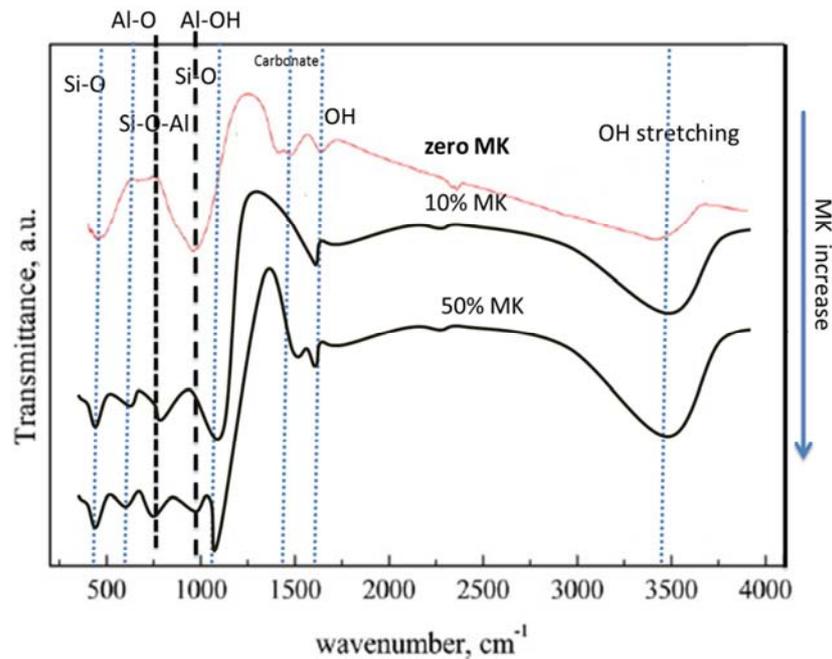


Figure 7. FTIR analysis and identification of cement paste at different concentration at 28 days.

Figure (6) points to increases in compressive strength of geopolymer up to 10% metakoline but this behavior is reflected up to 100% Mk. Compressive strength increases may deal with the formation of more stable geopolymer and decreases in the compressive strength may be due to the less formation of geopolymer structure due to the increases in the Alumina silica ratio. The best compressive strength is obtained at 10% Mk in both time intervals and recorded 60 N/mm² at 28 days.

Figure (7) demonstrates a variation in function group; this variation returns to the high value of aluminum content in Mk. The variation presents two main changes due to the addition of MK. The first change is related to the formation of more concentration of Al-O-Si at 600cm⁻¹. The second change, however, is related to the shift of band to high wave

number which means more stable formation. As well, the increasing percentage in MK causes formation of AL – OH which consequently consumes alkaline activator and aluminum content and form the internal strength which causes a high reduction in compressive strength. These results are matched with the compressive strength.

3.2. Optimization of Concrete

3.2.1. The Effect of Binder Geopolymer Ratio in Geopolymer Concrete

The binder of gaopolymer content directly effects on the characterization of concrete, table (4) present the mix design of geopolymer concrete at different content of geopolymer cement.

Table 4. Mix design of geopolymer at different gopolymer cement using fresh water.

mix	Geo cement Kg/m ³	Na ₂ SiO ₃ Lit.	NaOH Lit.	C. A Kg/m ³	F. A Kg/m ³	Strength for 7 days N/mm ²	Strength for 28 days N/mm ²
1	350	132.5	53	1322.4	661.2	20.5	28.4
2	400	151.43	60.57	1283.7	641.8	23.7	34.3
3	450	170.36	68.14	1216.9	608.4	27.2	38.9
4	500	189.29	75.7	1150.1	575.1	29	41.3
5	550	208.2	83.3	1083.4	541.7	34.1	49.2
6	600	227.14	90.86	1016.5	508.28	38.9	52.8

The effect of binder content at different values of compressive strength of geopolymer concrete at different interval times are shown in Figure (8).

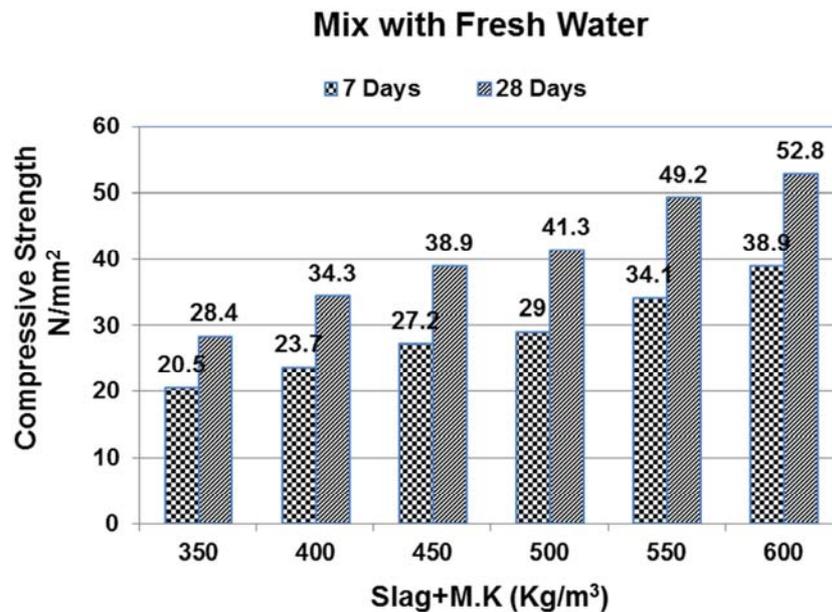
**Figure 8.** The variation in geopolymer cement content with compressive strength of geopolymer concrete at different interval times.

Figure (8) sheds light upon increases in compressive strength attached with increases in geopolymer cement content in both interval times. The variation in the compressive strength is considered an advantage of geopolymer concrete. The compressive strength has changed from 20.5 to 38.9 N/mm² with a change in cement content from 350 to 600 respectively at 7 days. At 28 days compressive strength has been noted to range from 28.4 to 52.8 N/mm².

3.2.2. The Effect of Sea Water as an Alternative of Fresh Water

Different countries suffer the lack water. This is a trial to use seawater as alternative to fresh water in concrete geopolymer. Table (5) presents the mix design of geopolymer concrete at different contents of geopolymer cement by using seawater in concrete.

Table 5. Mix design of geopolymer at different gopolymer cement using sea water.

mix	Geo cement Kg/m ³	Na ₂ SiO ₃ Lit	NaOH Lit.	C. A Kg/m ³	F. A Kg/m ³	Strength for 7 days N/mm ²	Strength for 28 days N/mm ²
1	350	132.5	53	1322.4	661.2	23.5	32.7
2	400	151.43	60.57	1283.7	641.8	27	37.5
3	450	170.36	68.14	1216.9	608.4	30.3	42.1
4	500	189.29	75.7	1150.1	575.1	33.7	46.8
5	550	208.2	83.3	1083.4	541.7	37.2	52.7
6	600	227.14	90.86	1016.5	508.28	40.4	56.1

The effect of binder content at different values and compressive strength of geopolymer concrete at different interval times in seawater are shown in figure (8).

Figure (9) sets forth increases in compressive strength in correlation with increases in geopolymer cement content in

both interval times. The variation in compressive strength is considered an advantage of geopolymer concrete. Concerning the variation in compressive strength in seawater as compared to that in the fresh water, it has been noticed that compressive strength has increased in sea water more than in

fresh water. The compressive strength in sea water has changed from 23.5 to 40.4 N/mm² with a change in cement content from 350 to 600 respectively at 7 days. At 28 days,

compressive strength noted from 32.7 to 56.1 N/mm². This may be related to the stability of geopolymer structure as compared with this formed in fresh water.

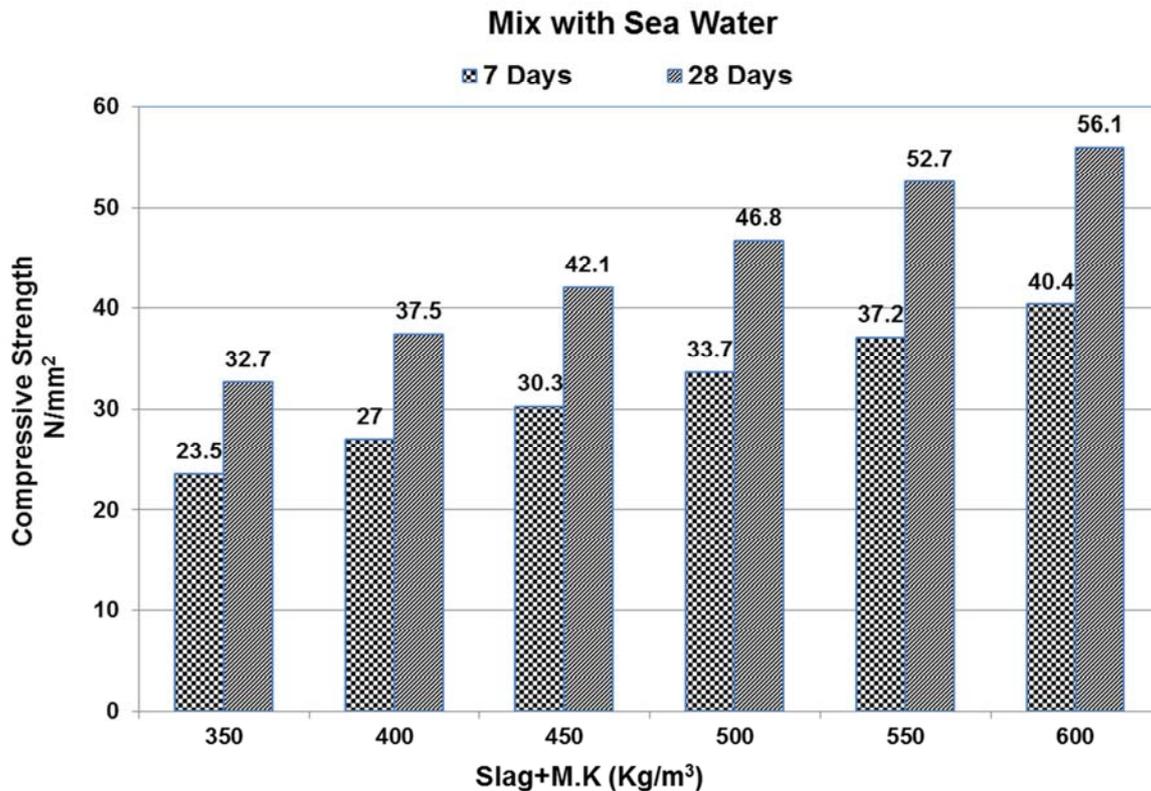


Figure 9. The variation in geopolymer cement content with compressive strength of geopolymer concrete at different interval times in seawater as mixing water.

4. Conclusion

In trying to find the ability to formation of geopolymer cement and the ability to use this cement in the formation of geopolymer concrete in the field. During this paper are studied in air without any types of curing. Also the improvement of cement by meta koline as a source of aluminium and silica are studied. Water in geopolymer cement not included in the reaction so that during this paper the sea water id used as an alternative to fresh water. The following conclusions can be drawn:

- (1) Geopolymer cement is a good alternative to traditional types of cement.
- (2) Slag geopolymer can be improved with the replacement by Metakoline up to 10% of slag content.
- (3) Geopolymer structure gets more stable form in presence of MK.
- (4) Compressive strength of geopolymer concrete increases with the increasing of geopolymer cement content.
- (5) Sea water can be used as a mixing water of geopolymer concrete.
- (6) Seawater, as mixing water, improves concrete geopolymer if compared with geopolymer treated with

fresh water.

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