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THE EFFECT OF DIFFERENT FACTORS ON FRESH AND HARDEN PROPERTIES OF GEOPOLYMER CONCRETE

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الملخص:
أثناء صناعه الأسمنت البورتلاندى تخرج كميات كبيرة من غاز ثاني أكسيد الكربون في الغلاف الجوي مما يؤدي الي حدوث كثير من الأضرار .ولتقليل الأضرار الناتجه عن الأسمنت البورتلاندي تم استخدام بديل للخرسانه التقليديه وهي خرسانه الجيوبوليمر وهي مكونه من مخلفات الصناعه مثل خبث الحديد بالاضافه الي محلول مكون من(هيدروكسيد الصوديوم وصوديوم سيليكات) بدلا من الاسمنت والماء في الخرسانه العاديه . ونحن في هذا البحث تم عمل خلطات بنسب مختلفه للحصول علي أفضل النتائج لعجينه جيوبوليمريه. ومن اهم مميزاتها تعمل علي تحسين الخصائص في صناعة البناء والتوفير في التكاليف وتقليل الآثار البيئية الضاره . وقد تبين من الدراسات السابقه ان هذا النوع من الخرسانات تتحسن خواصها في الاوساط المائيه المالحه أو المياه المحتويه علي كلوريدات وكبريتات. عن طريق اختبار أربعة خلطات من عجينة الجيوبوليمر مختلفة في تركيزات هيدروكسيد الصوديوم (8-10-12-14) . خمس خلطات عن طريق استخدام نسب مختلفه بين هيدروكسيد الصوديوم وصوديوم سيليكات. خمس خلطات للحصول علي أفضل نسبه محلول مع خبث الحديد وأفضل نسبه بين وكانت نتيجه البحث هي أفضل نسبه لهيدروكسيد الصوديوم هي 12 وسجلت قوه ضغط 460 كيلو جرام/سنتيمتر2 هيدروكسيد الصوديوم الي صوديوم سيليكات هي (2.33:1) وسجلت قوه ضغط 530 كيلو جرام/سنتيمتر2 وأفضل كميه محلول بالنسبه لخبث الحديد هي 24. وسجلت قوه ضغط 591 كيلو جرام/سنتيمتر2 ,. وبالنسبه لطرق المعالجه أفضل طريقه هي الفرن.

ABSTRACT

Manufacturing of Portland cement (OPC) is releases large amounts of gas CO_2 into the atmosphere Hence, reduce this ill effect, the search for alternative result is geopolymer concrete utilizing slag as source material. Slag is receiving more attention now since their uses generally improve the properties in construction industry, cost saving and reduction of negative environmental effects. This paper presents an experimental study on the strength and Consistency properties of Geopolymer concrete. Four different mixes of paste has been tested to determine the effect of concentration of sodium hydroxide (8-10-12-14M) and sodium silicate : sodium hydroxide ratio to setting time and compressive strength .The second sets study Effect of solution activator to slag ratios on properties of geopolymer concrete with different curing .The result showed that the geopolymer paste with NaOH concentration of 12 M produced maximum strength, 24%form the mix solution by weight of slag gives the highest compressive strength. The compressive strength of samples increases with the Increasing of Sodium Silicate: Sodium hydroxide ratio(Na_2SiO_3: NaOH) This peaks at ratio of (2.33:1) by mass.the results descripts that the best curing method is oven curing

Keywords: Geopolymer concrete; Slag; Sodium hydroxide; Sodium Silicate

1-INTRODUCTION

Ordinary Portland cement(OPC) manufacturing process is known as one of the main participators which consume intensive energy and releases a large amount of greenhouse gas to atmosphere during its production as Maholtra (2002). Around seven percent of the worldwide carbon dioxide (co_2) emission is accounted for this clinker process which seriously contributes to the global climate change as Shi (2011). Nearly 40% of the cost of production of cement is energy related as Marei AR (1990). The alternative low-carbon cementing binders have been, therefore, extensively studied to reduce that amount of greenhouse gas. One of the efforts is to promote alternative binders by utilizing abundant of alumina-silicate pozzolanic) wastes from industrial sector, e.g. fly ash as Chindaprasirt (2007), bottom ash as Hardjito and Fung (2010), cement kiln dust as Khater (2012), silica fume as Nuruddin (2011b) and GBFS as Nath and Sarker, (2012) .

Geopolymer concrete is concrete which does not utilize any Portland cement in its production Rather, the binder is produced by the reaction of an alkaline liquid with a source material that is rich in silica and alumina as Davidovits, J (1991).

Geopolymer is being studied extensively and shows promise as a greener alternative to Portland cement concrete. Research is shifting from the chemistry domain to engineering applications and commercial production of geopolymer. It has been found that geopolymer concrete has good engineering properties as Rangan,B.V. (2008), Sumajouw, M. D. J. and Rangan, B.V. (2006).

Consumption of slag in the manufacture of geopolymers is an important strategy in making concrete more environmentally friendly. For this reason, slag has been chosen as a base material for this project in order to better utilize this industrial waste

2- RAW MATERIALS

2.1- COARSE AGGREGATE (C.A)

The used coarse aggregate in this paper is Natural aggregate (Basalt). Its have specific gravity 2.63, Volume Weight (t\m3) 1.61 and Absorption 0.9%

2.2 -FINE AGGREGATE (F.A)

The used fine aggregate in this research were natural sand from 6 October quarries, it's have Specific gravity is 2.55, Volume weight (t/m3) 1.52 and Fineness modulus 2.57

2.3- THE GROUND GRANULATED BLAST FURNACE SLAG (GGBS)

GGBFS is an industrial by-product resulting from rapid water cooling of molten steel with specific gravity 3.52 available in Iron and Steel Factory, Helwan Governate. The main components of blast furnace slag are CaO (30-50%), SiO_2 (28-38%), Al_2O_3 (8-24%), and MgO (1-18%) as shown table (2-1).

Table (2-1) : XRF analysis of ground granulated blast furnace slag (GGBFS)

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

2.4 -ACTIVATOR SOLUTION

The alkaline activator used was from the combination of sodium silicate and sodium hydroxide solution. The activator from the sodium silicate solution (Na_2O = 12%, SiO_2 = 30%, and water = 57% by mass) and sodium hydroxide (NaOH) in flakes or pellets form with 99% purity was
prepared according to the reference.

3 .EXPERIMENTAL INVESTIGATIONS

In order to overcome the high evolution of heat during the preparation of NaOH solution, this has been prepared a day before the casting. Then the Na_2SiO_3solution was mixed the NaOH solution for the required ratio of AAS. In order to achieve the required workability of GPC and chemical admixture .
The Geopolymer mixes were prepared by taking Sodium Hydroxide solution with concentration of 8M, 10M, 12M and 14M. The ratio of alkaline solution was varied as 1.0, 2.33 and varying the liquid binder ratio to get an acceptable workability of concrete. The detailed mix proportioning is listed in Table (3-1**) .** The mixtures were casted in 50 size cube specimens and vibrated using table vibration technique. The curing of the specimens was done at ambient ,water and temperature condition as there is no significant increase in the strength at elevated temperature.

Table (4-1) effect concentration of NaoH on setting time

Mix	Slag (gram)	NaOH molarity	Total solution (gram)	Initial setting time	Final setting time
M1-1	1000	8	260	12mintue	42 minute
M1-2	1000	10	260	9 minute	37 minute
M1-3	1000	12	260	6 minute	30 minute
M1-4	1000	14	260	4 minute	24 minute

Table 4-1, Figure 4-1 shown that the effect concentration of NaoH on setting time.It can be too notice by increasing concentration of NaoH decrease setting time of all samples up to concentration of 14 ml the samples not given workability.In work laboratory notices With the increase in sodium hydroxide concentration, the workability of fresh concrete was slightly reduced, When the concentration of sodium hydroxide is increased, the reaction is faster than low concentration .

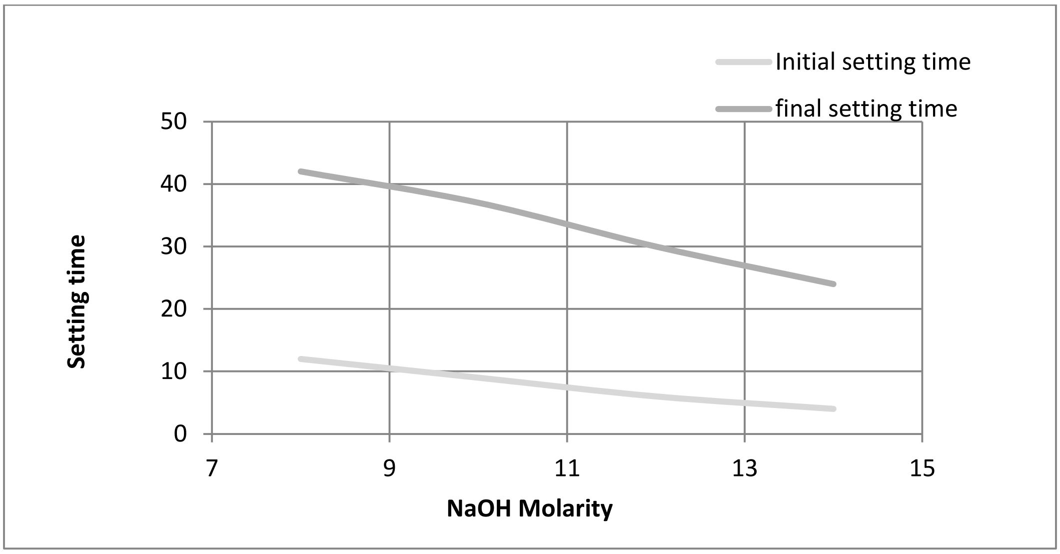


Figure (3-1) effect concentration of NaoH on setting time

4.2. Effect of concentration of sodium hydroxide on compressive strength

This part study effect of molarity on hard properties of geopolymer concrete , where using sample compote of 100% slag, different concentration of sodium hydroxide and w/c ratio is 0.26 as shown in **Table 4-2** then tested this sample after 7and 28 days to evaluate compressive strength of geopolymer concrete.

The results infer that the strength of the Geopolymer mixes increases with the increase in the concentration of NaOH solution. attains more than 20% of the strength for .There was no such significant increase in the strength for 14M NaOH solution. By plotting these results **Figure 4-2**, an interesting phenomenon can be noticed; the early gain of compressive strength (7 days) reaches a ratio of about 80 to 90% of the compressive strength at 28 days . Its notice with high concentration of sodium hydroxide occure large craks of samples ,so that we preferable to use a concentration of 12 NaOH solution.

Table 4-2: Effect of sodium hydroxide molarity on compressive strength

Mix	Slag (gram)	NaOH molarity	Total solution (gram)	Fc7 (kg/cm^2)	Fc28 (kg/cm^2)
M1	1000	8	260	180	210
M2	1000	10	260	295	330
M3	1000	12	260	400	460
M4	1000	14	260	410	465

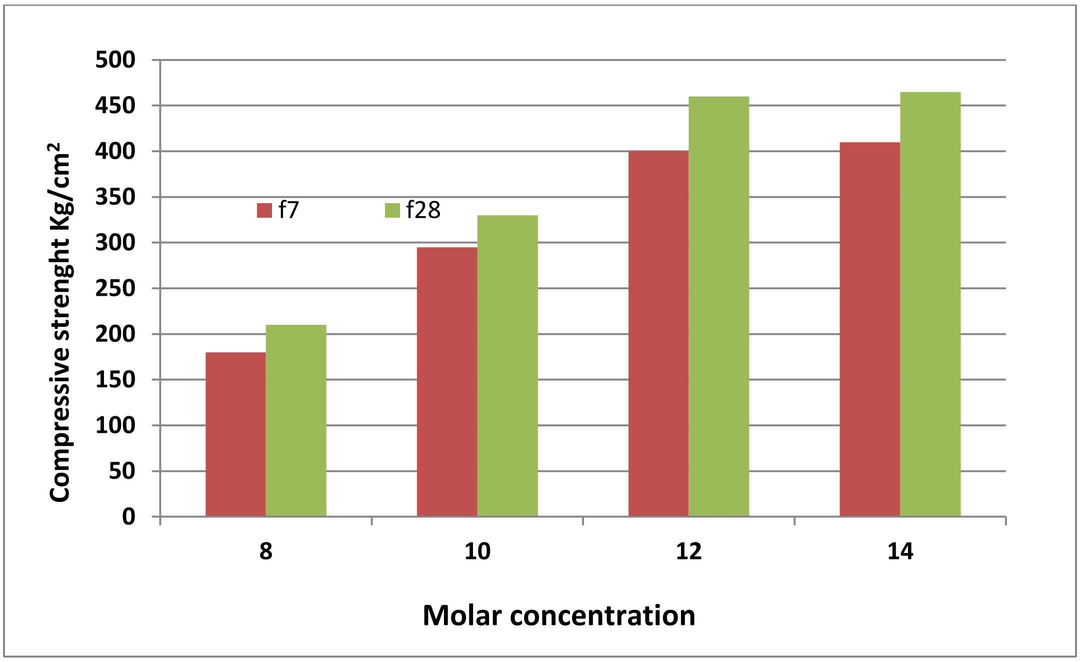


Figure (4-2) effect concentration of NaoH on compressive strength

4.3. Effect of naoh :Na_2SiO_3 ratio on Consistency and compressive strength

For setting time tests, different slag samples were prepared as shown in table (4-3) **shows** the setting time of slag paste samples with various activator ratios and with constant activator solution quantity of ($NaOH+Na_2SiO_3$) is 0.26 from slag (S/B=0.26) and use the different of sodium hydroxide to sodium silicate. As determined from **table (4-3)** and **figure (4-3**). Additionally, OPC sample was used as a reference sample with water cement ratio=0.26.

Table (4-3): Effect of Na_2SiO_3: NaoH on setting time

Mix	Slag	Na_2SiO_3% by volume	NaoH% By volume	Na_2SiO_3:NaOH	Initial setting time	Final setting time
OPC	0	0	0	0	65 min	270 min
S1	1000	100	0	1:0	90min	720 min
S2	1000	70	30	2,33	40min	75 min
S3	1000	50	50	1	37min	70 min
S4	1000	30	70	0,43	26min	62 min
S5	1000	0	100	0	5 min	30 min

It can be concluded from **table (4-3**)that either initial or final setting time gets increase with increasing the Na_2SiO_3:NaOH ratio as shown also in **figure (4-3)** The initial setting time of S4 is 26 minutes which complies with the limits of special rapid-hardening Portland cement (less than 30 minutes). with increasing amount of sodium silicate increase workability.

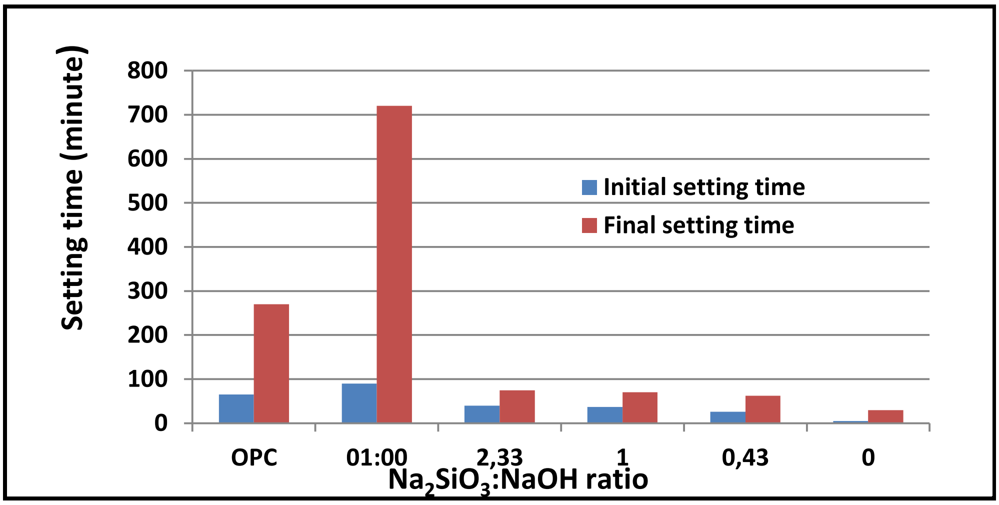


Figure (4-3): Effect of Na_2SiO_3: NaOH on setting time

This part study the effect of NaOH :Na_2SiO_3 ratio on compressive strength of G.P.C. **Table (4-4)** shows the compressive strength of slag samples with various sodium silicate to sodium hydroxide ratios curing in ambient. By inspecting the values in **Table (4-4)**, it can be Concluded that sample S_2 gives the highest compressive strength over the other samples. **Figure(4-4)** Show that The compressive strength of samples increases with the Increasing of Sodium Silicate: Sodium hydroxide ratio(Na_2SiO_3: NaOH). This peaks at ratio of (2.33:1) by volumes then it reverses its pace.

.Table(4-4): effect of Na_2SiO_3: NaoH on compressive strength

Mix	Slag	Na_2SiO_3% by volume	NaoH% By volume	Na_2SiO_3:NaOH	FC_7	FC_{28}
OPC	0	0	0	0	220	408
S1	1000	100	0	1:0	80	125
S2	1000	70	30	2,33	330	530
S3	1000	50	50	1	267	451
S4	1000	30	70	0,43	250	420
S5	1000	0	100	0	212	283

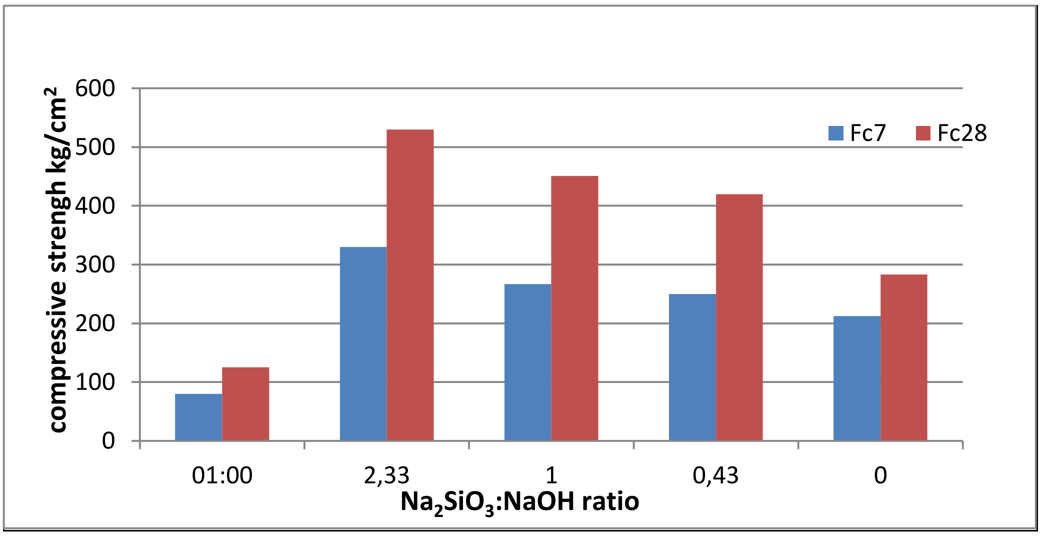


Figure (4-4): effect of Na_2SiO_3: NaoH on compressive strength

4. 4- Effect of solution activator to binder ratios on setting time and compressive strength

This is the term used to describe the stiffening (change from liquid to rigid state) of the slag paste and the ability of it to flow. It can be measured by water to slag ratio. **Table (4-5),** shows the consistency of slag samples (water / slag) with alkali solution activator (Na_2SiO_3: NaOH)= 2.33:1 at 12 molar NaOH in ambient conditions.

.Table(4-5) : effect of solution activator to binder ratios on setting time

MIX	Slag	Mix solution	Water/ slag ratio	Initial setting time	Final setting time
1	1000	150	0,15	20 min	55
2	1000	180	0,18	27 min	61
3	1000	210	0,12	32 min	66
4	1000	240	0,24	37 min	72
5	1000	270	0,27	46 min	79

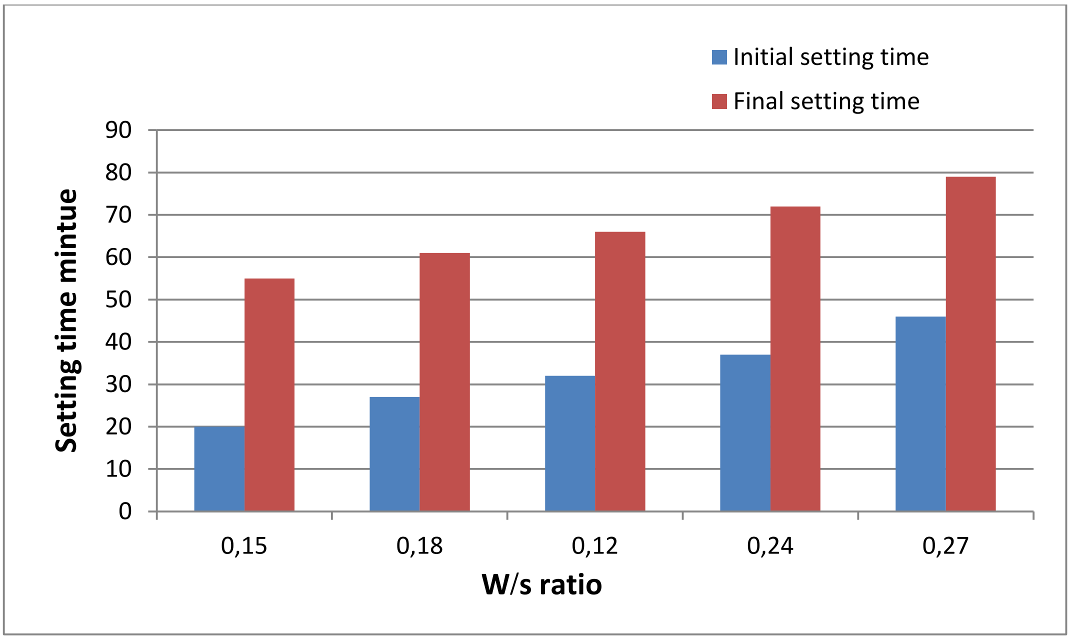


Figure (4-5): effect of of solution activator to binder ratios on setting time

By inspecting the values in Table (4-5) It can be concluded that the ratio of about 24% form the mix solution by weight of slag gives the required consistency within the limits of E.C.P. as shown also in Figure (4-5)

Table (4-5) , shows the compressive strength of slag samples with various alkali solution activator (Na_2SiO_3 molar NaOH in ambient conditions from slag by weight. By inspecting the values in Table (4-5), it can be concluded that the ratio of 24 %form the mix solution by weight of slag gives the highest compressive strength at (Na_2SiO_3: NaOH) =2.33:1 at 12 ml of NaOH in Figure (4-6).

Table(4-5) effect of solution activator to binder ratios on compressive strength

MIX	Slag	Mix solution	Water/ slag ratio	FC7	FC28
1	1000	150	0,15	280	397
2	1000	180	0,18	312	478
3	1000	210	0,12	363	554
4	1000	240	0,24	384	591
5	1000	270	0,27	350	543

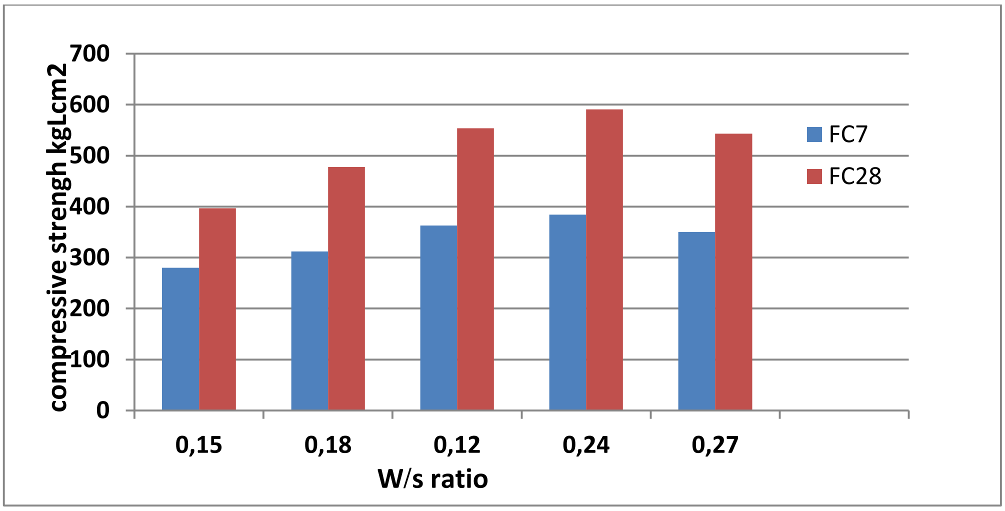


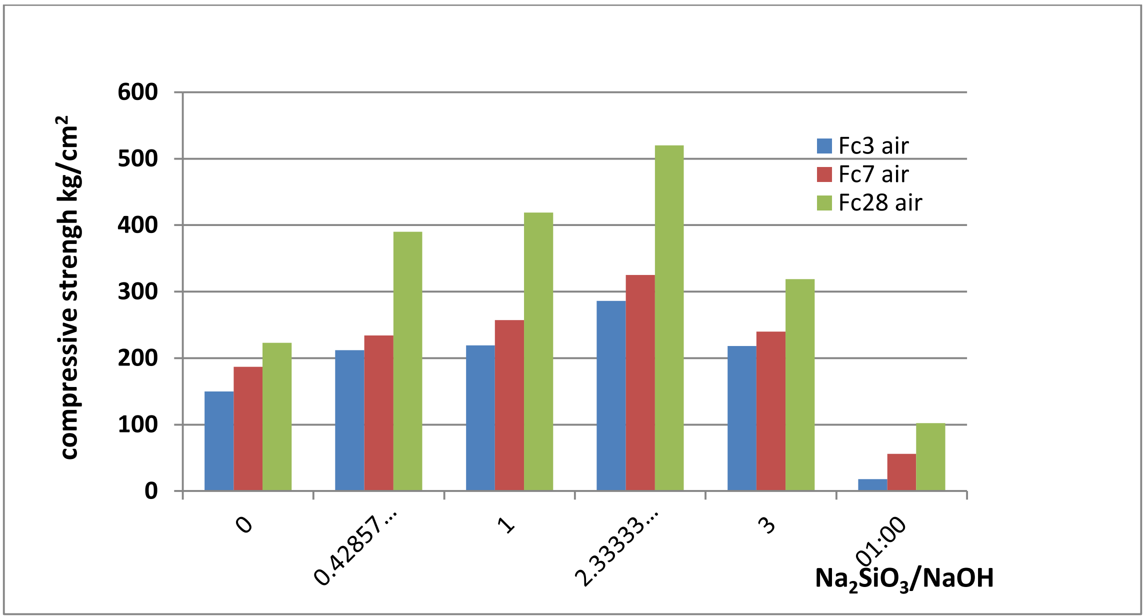
Figure (4-6): effect of of solution activator to binder ratios on compressive strength

Effect of activator ratio on compressive strength in different 4-5 .conditions curing

Table (4-6) shows the compressive strength of slag "SN" samples with various activator ratios in ambient, water and oven curing for 24 hours (80^{C}) conditions , 12M Concentration of (NaoH) By inspecting the values in table (4-6), it can be concluded that sample SN4 gives the highest compressive strength over the other samples for all curing conditions. Regardless of the curing method ,the compressive strength of samples increases with the increase in Sodium Silicate: Sodium hydroxide ratio (Na_2SiO_3: NaOH). This increase peaks at ratio of 2.33:1 then it reverses its pace**.**

Table 4-6: Effect of activator ratio on compressive strength in different conditions

MIX	slag (gram)	sand (gram)	%Na_2sio_3	%NaoH	Na_2SiO_3/NaOH	FC3			FC 7			curing		
						air	water	oven	air	water	oven	air	water	oven
SN1	1000	3000	0	400	0	150	156	298	187	196	315	223	231	322
SN2	1000	3000	120	280	0.43	212	223	434	234	258	490	390	472	509
SN3	1000	3000	200	200	1	219	234	503	257	314	514	419	488	524
SN4	1000	3000	280	120	2.33	286	311	530	325	330	580	520	499	610
SN5	1000	3000	300	100	3	218	225	445	240	243	498	319	331	560
SN6	1000	3000	400	0	01:00	18	24	150	56	64	162	102	113	186



Figurer (3-6) : Effect of activator ratio on compressive strength of “S”Samples in air curing

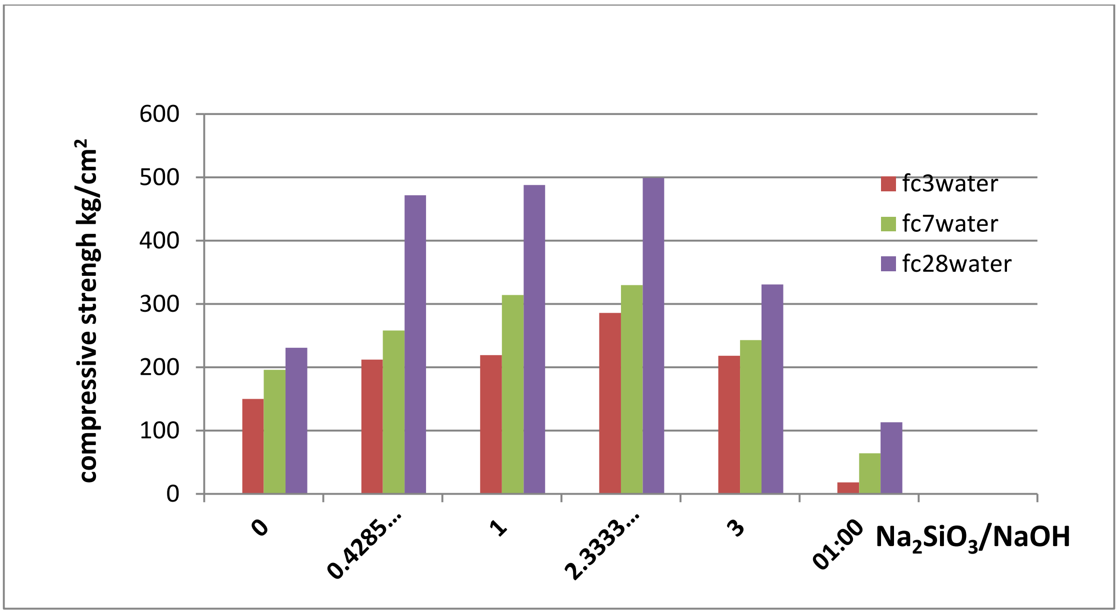


Figure (3-7): Effect of activator ratio on compressive strength of “S”samples in water curing.

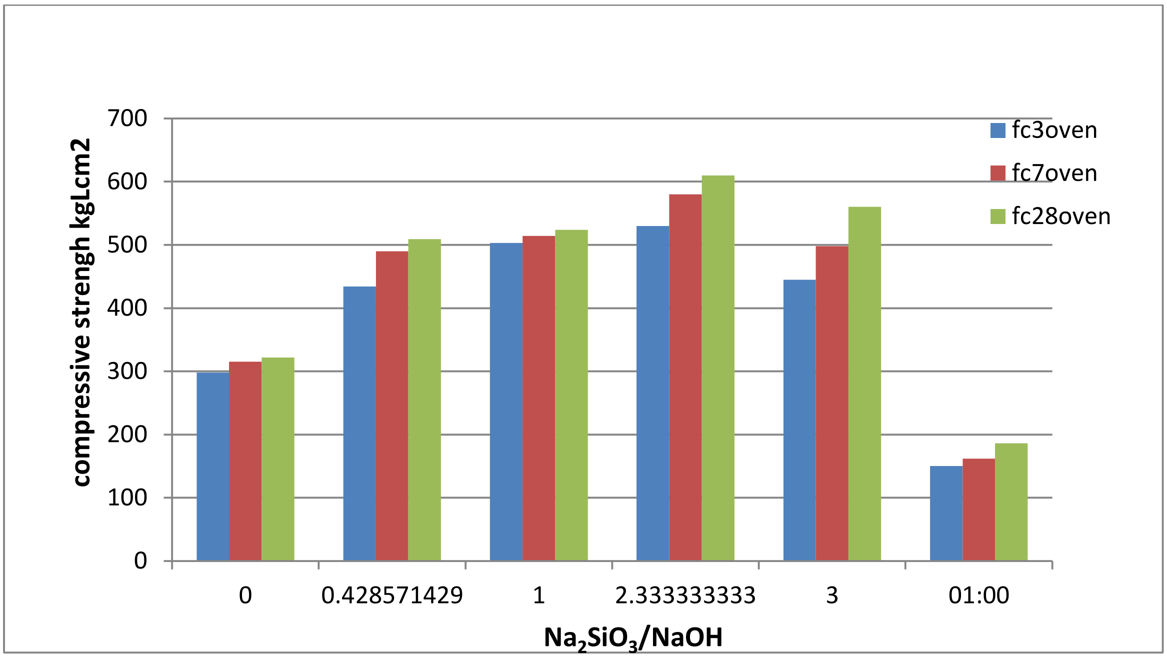


Figure (3-8) : Effect of activator ratio on compressive strength of "S" samples in oven curing

Also, it can be noticed that oven curing leads to the highest compressive strength for all samples, then water curing and the least values are related to air curing.

5. CONCLUSION

From the test results, the following conclusions were made:

1- The use of Portland cement has been completely eliminated; thereby reduce the emission of $CO_2$to the atmosphere which results in the reduction of Green House Gases.

2- By increasing concentration of NaoH decrease setting time of all samples up to concentration of 14 ml the samples not given workability.

3- Geopolymer Concrete shows superior results in compressive strength compared with the Ordinary. Portland Cement Concrete.

4- The compressive strength of the Geopolymer mixes increases significantly with the increase in the NaOH concentration and found be more than (80%-90%0 than the results obtained for the mix with 8M NaOH solution and there is no such significant increase for the mix with 14M NaOH solution.

5- The compressive strength of the Geopolymer mixes increases with the increase in the alkaline ratio and the result with an alkaline ratio of 2.33 were found to be in the range of 21% to 25% than that of the mix with the alkaline ratio of 1.0

6- The initial or final setting time gets increase with increasing the Na_2SiO_3: NaOH ratio.

7- It can concluded that the ratio of 24 % form the mix solution by weight of slag gives the highest to compressive strength.

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