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Anıl Niş
ISTANBUL GELISIM UNIVERSITY

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Compressive strength variation of alkali activated fly ash/slag concrete with different NaOH concentrations and sodium silicate to sodium hydroxide ratios

Anıl Niş^{a,*}

^a Department of Civil Engineering, Istanbul Gelisim University, TURKEY

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Abstract

Waste disposal becomes a crucial issue for both the environment and the economy. One of the solutions for waste disposal is to utilize waste materials in concrete production. Nowadays, alkali activated concrete takes attention since waste materials (fly ash and ground granulated blast furnace slag) are utilized instead of ordinary Portland cement as binder materials. In this study, alkali activated fly ash/slag concrete is produced using 50% F-type fly ash and 50% ground granulated blast furnace slag and the compressive strength of the alkali activated fly ash/slag concrete is evaluated. The sodium silicate (Na_2SiO_3) and sodium hydroxide (NaOH) solutions were utilized with four different sodium silicate to sodium hydroxide ratios (1, 1.5, 2, and 2.5) and three different molarities were utilized (6M, 10M, and 14M) for alkali activation to determine the effect of these parameters on the compressive strength of the alkali activated fly ash/slag concrete. In addition to ambient-curing (AC), the influence of the delayed oven-curing (OC) was also studied to determine the effect of curing regime on the compressive strength of the alkali activated fly ash/slag concrete. The results indicated that both the alkali activator ratio and NaOH concentration significantly affected the compressive strength of the alkali activated fly ash/slag concrete. In addition, the delayed oven-curing was also found as an important parameter for the compressive strength of the alkali activated fly ash/slag concrete.

Keywords: Alkali activated fly ash/slag concrete; sodium hydroxide concentration; molarity; fly ash and slag; sodium silicate to sodium hydroxide ratio.

1. Introduction

The utilization of the industrial waste materials (fly ash, ground granulated blast furnace slag) instead of ordinary Portland cement becomes significant in terms of environment and economy. The cost of the waste disposal increases per year due to increasing labor cost and environmental pollution is also a crucial problem during waste disposal as well as cost. Therefore, the utilization of industrial waste materials takes great attention and it may be necessary in the upcoming years for the sustainable environment and economic growth. The concrete industry can be one of the areas for the utilization of these waste materials since fly ash and slag materials have already been used partially instead of cement. The ordinary Portland cement (OPC) production releases a significant amount of CO_2 and it is responsible for approximately 7% of all greenhouse gases released worldwide [1]. Therefore, the utilization of alternative binder materials

Corresponding author. Tel.: 0212 422 70 00
E-mail address: anis@gelisim.edu.tr (Nis, A.)

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instead of OPC becomes necessary for a sustainable environment. Recently, geopolymer concrete or cement-free concrete becomes as an alternative concrete due to its environmental friendliness nature [2]. Considerable research has been conducted in order to use geopolymer concrete instead of ordinary Portland cement concrete in the structural applications [3-5]. The geopolymer concrete (GPC) or alkali activated concrete includes alkali activators and alumino-silicate materials for mechanical strength. The sodium hydroxide or potassium hydroxide, sodium silicate and their combination can be utilized for the alkali activators [6, 7] and fly ash, ground granulated blast furnace slag and silica fume can be used as alumino-silicate materials [8].

The fly ash based alkali activated concrete takes great attention due to its easy accessibility, rich alumina and silica amounts and low water requirement [9-13]. However, the fly ash based alkali activated concretes require high temperature curing around 60°C for geopolymerization as fly ash shows low reactivity at ambient environment [14]. Therefore, 100% fly ash utilization for the production of alkali activated concrete is prevented from structural use since ambient-curing condition is required for the practical applications. Instead of totally fly ash use, ground granulated blast furnace slag is added to the fly ash based alkali activated concretes in order to eliminate the elevated temperature curing since slag includes CaO that responsible for the strength improvement by forming N-A-S-H type structure to N-(C)-A-S-H type structure without elevated temperature curing. In addition, compressive strength enhancement was also reported with slag addition into fly ash based alkali activated concrete [15, 16]. Therefore, 50% fly ash and 50% ground granulated blast furnace slag materials were utilized in the scope of the research to investigate the ambient curing and elevated temperature curing conditions on the alkali activated fly ash/slag based concrete.

In addition to curing conditions, sodium silicate to sodium hydroxide ratio, sodium hydroxide molarity, $\text{SiO}_2/\text{Na}_2\text{O}$ ratio in the alkaline solutions, and fly ash and slag content determine the compressive strength development of the alkali activated concretes [17]. However, the effect of these parameters on the resulting performance on the alkali activated materials has been unclear. In an earlier investigation, it was reported that sodium silicate to sodium hydroxide ratio of 2.5 was found as the optimum ratio for the fly ash based geopolymer concretes [18]. In another study, the optimum sodium silicate to sodium hydroxide ratios of 1 and 0.67 were found when sodium hydroxide concentrations were utilized in the range of 10M and 20M [19]. In the other study, the superior compressive strength was obtained on fly ash based GPC specimens using sodium silicate to sodium hydroxide ratio of 2 [20]. In addition to this, it was also reported that compressive strength was found to increase with an increase in the total sodium content with respect to total silica content and the researcher also added that increasing the sodium amount after a certain limit does not improve the compressive strength of the specimens [21]. For the standardization process of the alkali activated concrete for the structural applications, further studies are required related to the different alkali activator ratios, various sodium hydroxide concentrations, curing type and regime. Therefore, compressive strengths of the alkali activated fly ash/slag concrete specimens were investigated considering different sodium silicate to sodium hydroxide ratios (1, 1.5, 2 and 2.5), various sodium hydroxide molarity concentrations (6M, 10M and 14M) and different curing conditions (ambient curing and delayed oven-curing). The obtained results can be useful for the standardization process of the alkali activated fly ash/slag concretes for structural utilization.

2. Materials and Methods

2.1. Materials

F-type fly ash (50%) and ground granulated blast furnace slag (50%) binder materials were utilized for the alkali activated fly ash/slag concrete production. F-type fly ash was taken from the Çatalağzı thermal power plant and ground granulated blast furnace slag (GGBS) was obtained from the Iskenderun iron and steel plant. For the alkali activation of the fly ash/slag concrete, a combination of sodium silicate (Na_2SiO_3) and sodium hydroxide (NaOH) solutions was used with different silicate to hydroxide ratios. The silicate solution with an alkaline modulus of 2 and the hydroxide pellets were taken from a local market. The commercially available sodium hydroxide pellets with 98% purity was obtained and melted in water to achieve NaOH solution with various concentrations. In the scope of the research, three NaOH molarities (14 M, 10 M and 6 M) and four sodium silicate to sodium hydroxide ratios (2.5, 2, 1.5 and 1) were used in order to investigate the effects of different molarities and sodium silicate to sodium hydroxide ratios on the compressive strength of the alkali activated fly ash/slag concretes. A naphthalene based superplasticizer was used in order to have an S4 slump class concrete. Table 1 shows the chemical composition and physical properties of the F-type fly ash (FA) and ground granulated blast furnace (GGBS) materials.

Table 1. Physical properties and chemical composition of the FA and GGBS

Chemical Composition	GGBS	FA
CaO (%)	37.92	1.79
Al ₂ O ₃ (%)	13.27	26.37
SiO ₂ (%)	37.97	56.15
Fe ₂ O ₃ (%)	1.16	6.44
MgO (%)	5.64	2.35
SO ₃ (%)	0.23	0.056
Na ₂ O (%)	0.84	1.1
K ₂ O (%)	0.56	3.8
Cl (%)	0.015	0.09
Loss on ignition (%)	0.01	2.2
Specific Gravity (g/cm ³)	2.95	2.05
Specific Surface (cm ² /g)	5131	3870

For coarse aggregates, coarse No I (5-12 mm) aggregate with a specific gravity of 2.71 g/cm³ and coarse No II (12-22 mm) aggregate with a specific gravity of 2.72 g/cm³ were used. For fine aggregates, crushed sand with a specific gravity of 2.70 g/cm³ and natural sand with a specific gravity of 2.65 g/cm³ were utilized. Fig. 1 indicates the aggregate sieve analysis of the used aggregates in the alkali activated fly ash/slag concretes.

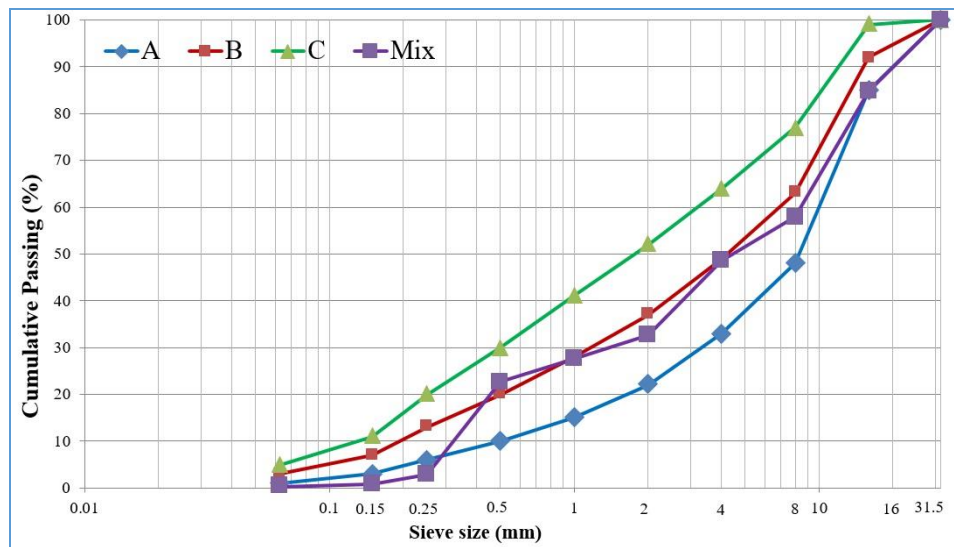


Fig. 1. Aggregate sieve analysis

2.2. Mixture Composition

Table 2 shows the mixture compositions of the alkali activated fly ash/slag concretes with different NaOH molarities and sodium silicate to hydroxide ratios. For the concrete production, 360 kg/m³ binder material was utilized and alkaline activator to binder ratio was chosen as 0.45. The additional water amount kept constant for all mixes, while the superplasticizer amount was changed with different molarities and sodium silicate to sodium hydroxide ratios (Na₂SiO₃/NaOH) as can be seen in Table 2.

Table 2. Mixture composition of the alkali activated fly ash/slag concrete with various molarities and Na₂SiO₃/NaOH ratios (kg/m³)

Materials	14M 2.5	14M 2	14M 1.5	14M 1	10M 2.5	10M 2	10M 1.5	10M 1	6M 2.5	6M 2	6M 1.5	6M 1
NaOH	46.3	54	64.8	81	46.3	54	64.8	81	46.3	54	64.8	81
Na ₂ SiO ₃	115.7	108	97.2	81	115.7	108	97.2	81	115.7	108	97.2	81
FA	180	180	180	180	180	180	180	180	180	180	180	180
Slag	180	180	180	180	180	180	180	180	180	180	180	180
No I	560	560	560	560	560	560	560	560	560	560	560	560
No II	560	560	560	560	560	560	560	560	560	560	560	560
Crushed Sand	373	373	373	373	373	373	373	373	373	373	373	373
Sand	373	373	373	373	373	373	373	373	373	373	373	373
Superplasticizer	6.88	6.88	8.44	10.00	6.88	8.44	8.44	11.56	6.88	8.44	10.00	11.56
Additional Water*	43.75	43.75	43.75	43.75	43.75	43.75	43.75	43.75	43.75	43.75	43.75	43.75

* Water amount in order to obtain S4 slump class

During mixing procedure, coarse and fine aggregates, fly ash and ground granulated blast furnace slag (dry materials) were added in the mixer and mixed for 2 min. Then, sodium silicate, sodium hydroxide and half of the superplasticizer were mixed together in a container and the obtained liquid solution was included into the mixer and mixed for 2 min. Finally, additional water and remaining half of the superplasticizer were mixed together in a container and then added into the mixer for an additional 2 min. The overall mixing procedure was completed in 6 min. For the further alkali activation and the enhanced workability, water addition into the alkali activated materials was also reported in the earlier investigations [22, 23].

2.3. Curing Process and Compressive Strength Test Method

After the casting procedure, alkali activated fly ash/slag concretes were cast into the 150x150x150 mm cube molds and required compaction was applied to eliminate air voids in the concrete specimens. The cubic specimens were left in the ambient environment for 3 days in order to achieve the required compressive strength prior to demolding. Meanwhile, top surfaces of the cubic specimens were covered with plastic sheets to prevent alkaline solution from evaporation. After demolding, half of the specimens were left in the laboratory environment at 6°C ± 4 for 28 days to represent ambient cured (AC) specimens in winter conditions. The delayed oven-curing (OC) was also applied to the remaining half of the specimens in order to observe the influence of the delayed curing on the compressive strengths of the alkali activated fly ash/slag specimens with different molarities and SS/SH ratios. It was reported in the previous study that elevated temperature around 70°C is needed in order to have adequate compressive strength for the fly ash based geopolymer concrete specimens [24] and compressive strength increase was found insignificant after 48 h. [11]. Therefore, the specimens were cured in an oven-curing at 70°C for 48 hours in the scope of the research. However, the delayed oven-curing that first specimens were cured in ambient-curing conditions at 6°C ± 4 for 26 days and then oven-curing applied at 70°C for 48 hours (2 days) applied to the specimens. That is, the delayed oven-curing was applied to the specimens after the 26 days of ambient-curing condition (first 26 days for ambient curing condition + 2 days for oven curing condition).

The compressive strength tests were realized on 150x150x150 mm cubic specimens using ASTM C39 standard at the age of 28.day for both ambient and delayed oven-cured specimens. Three identical specimens were utilized to obtain average compressive strength values for each alkali activated fly ash/slag concrete types. The influence of delayed oven-curing on the compressive strength performance of the different alkali activated fly ash/slag concrete specimens was examined.

3. Results and Discussion

3.1. The effect of 14M NaOH concentration

The compressive strength test results of the alkali activated fly ash/slag specimens with different molarities

and sodium silicate to sodium hydroxide ratios ($\text{Na}_2\text{SiO}_3/\text{NaOH}$) were given in Figs. 2-4. Fig. 2 indicates the compressive strength test results of the alkali activated fly ash/slag specimens with 14 M NaOH concentration and $\text{Na}_2\text{SiO}_3/\text{NaOH}$ ratios of 1, 1.5, 2 and 2.5 in the ambient curing (AC) and delayed oven-curing condition (OC). The compressive strength values of the specimens with 14 M concentrations were found to be 18.28 MPa (AC) and 27.08 MPa (OC), 12.08 MPa (AC) and 25.10 MPa (OC), 10.04 MPa (AC) and 12.99 MPa (OC), and 5.64 MPa (AC) and 10.16 MPa (OC) for the $\text{Na}_2\text{SiO}_3/\text{NaOH}$ ratios of 1, 1.5, 2, and 2.5, respectively. For the 14M NaOH concentrations, the highest compressive strength (~27 MPa) was obtained in the specimens with a $\text{Na}_2\text{SiO}_3/\text{NaOH}$ ratio of 1, while the least compressive strength (~6 MPa) was achieved in the specimens with a $\text{Na}_2\text{SiO}_3/\text{NaOH}$ ratio of 2.5. The results pointed out that for the high amount of NaOH concentration (14M), compressive strength was found to be decreased with an increase in the $\text{Na}_2\text{SiO}_3/\text{NaOH}$ ratios in both ambient-cured and oven-cured environments.

In addition, the effect of delayed oven-curing was found significant for the 14 M NaOH concentrations since the compressive strength improvements due to oven-curing were 48%, 108%, 29%, and 80% for the specimens with $\text{Na}_2\text{SiO}_3/\text{NaOH}$ ratios 1, 1.5, 2 and 2.5, respectively. The lowest and the highest compressive strength improvements due to oven-curing were obtained in the specimens with $\text{Na}_2\text{SiO}_3/\text{NaOH}$ of 2 and 1.5, respectively.

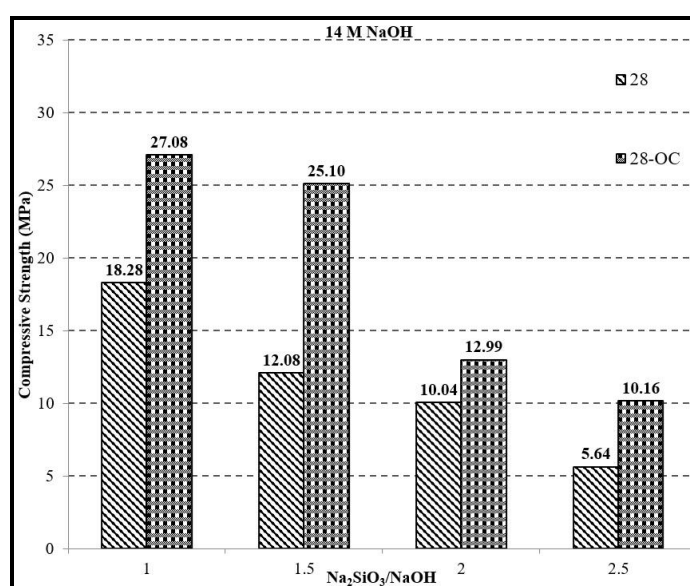


Fig. 2. Compressive strength test results of the alkali activated fly ash/slag specimens with 14 M NaOH

3.2. The effect of 10M NaOH concentration

Figure 3 shows the compressive strength test results of the alkali activated fly ash/slag specimens with 10 M NaOH concentration and $\text{Na}_2\text{SiO}_3/\text{NaOH}$ ratios of 1, 1.5, 2 and 2.5. The compressive strengths of the specimens with 10M NaOH concentration were 2.59 MPa (AC) and 15.04 MPa (OC), 8.27 MPa (AC) and 16.43 MPa (OC), 16.91 MPa (AC) and 32.42 MPa (OC), and 3.51 MPa (AC) and 5.09 MPa (OC) for the $\text{Na}_2\text{SiO}_3/\text{NaOH}$ ratios of 1, 1.5, 2, and 2.5, respectively. For the 10M NaOH concentrations, the maximum compressive strength (~32 MPa) was obtained in the specimens with a $\text{Na}_2\text{SiO}_3/\text{NaOH}$ ratio of 2, while the minimum compressive strength (~5 MPa) was achieved in the specimens with a $\text{Na}_2\text{SiO}_3/\text{NaOH}$ ratio of 2.5. The results pointed out that the compressive strengths of the specimens with 10 M concentrations were found to be increased with an increase in the alkali activator ratio up to a certain $\text{Na}_2\text{SiO}_3/\text{NaOH}$ value of 2, then the compressive strength was found to be decreased for the higher alkali activator ratio of 2.5.

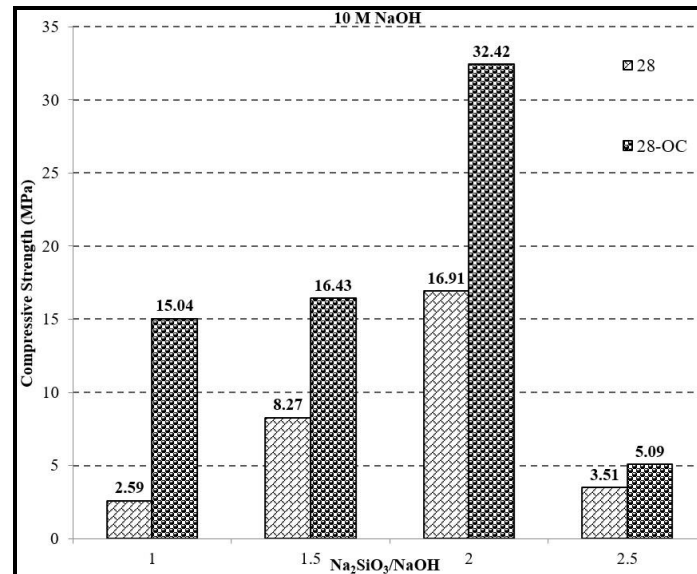


Fig. 3. Compressive strength test results of the alkali activated fly ash/slag specimens with 10 M NaOH

Meanwhile, the influence of delayed oven-curing was also found important for the specimens with 10 M NaOH concentrations. The enhancements in the compressive strength due to the oven-curing were 481%, 99%, 92%, and 45% for the specimens with Na₂SiO₃/NaOH ratios 1, 1.5, 2 and 2.5, respectively. The effect of delayed oven-curing was found to be decreased with an increase in the alkali activator ratio in the following order: Na₂SiO₃/NaOH=1 > Na₂SiO₃/NaOH=1.5 > Na₂SiO₃/NaOH=2 > Na₂SiO₃/NaOH=2.5.

3.3. The effect of 6M NaOH concentration

Figure 4 indicates the compressive strength variations of the alkali activated specimens with 6M NaOH concentration and Na₂SiO₃/NaOH ratios of 1, 1.5, 2 and 2.5. The compressive strengths of the specimens with 6M NaOH concentration were 0.55 MPa (AC) and 0.96 MPa (OC), 2.48 MPa (AC) and 9.08 MPa (OC), 9.18 MPa (AC) and 13.16 MPa (OC), and 7.43 MPa (AC) and 8.43 MPa (OC) for the Na₂SiO₃/NaOH ratios of 1, 1.5, 2, and 2.5, respectively. For the 6M NaOH concentrations, the highest compressive strength (~13 MPa) was obtained in the specimens with a Na₂SiO₃/NaOH ratio of 2, while the least compressive strength (~1 MPa) was achieved in the specimens with a Na₂SiO₃/NaOH ratio of 1. The compressive strength enhancement of specimens with 6M NaOH concentration was found similar to specimens with 10M NaOH concentration since the compressive strength of the specimens with 6M concentrations were also increased with an increase in the alkali activator ratio up to a certain Na₂SiO₃/NaOH value of 2, then the compressive strength was found to be decreased for the higher alkali activator ratio of 2.5.

The improvements in the compressive strengths of the specimens with 6M NaOH concentration were 75%, 266%, 42%, and 13% for the specimens with alkaline activator ratios of 1, 1.5, 2, and 2.5, respectively. The results also indicated that the effect of delayed oven-curing decreased with an increase in the alkali activator ratio, except for the specimens with a Na₂SiO₃/NaOH ratio of 1. For this specimen (6M concentration and Na₂SiO₃/NaOH=1), there is almost no compressive strength was obtained probably due to the low sodium silicate content and sodium hydroxide concentration (low alkali content).

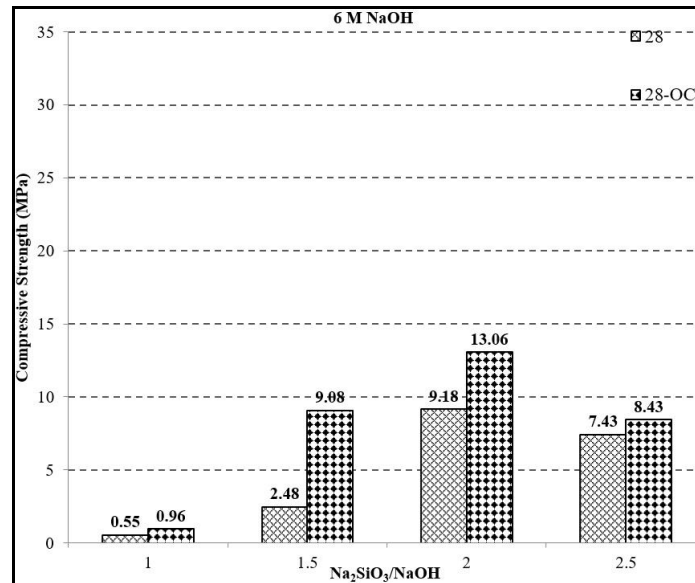


Fig. 4. Compressive strength test results of the alkali activated fly ash/slag specimens with 6M NaOH

3.4. The effect of alkali activator ratio

Figure 5 shows the influence of alkaline activator ratios on the compressive strength of the alkali activated fly ash/slag concretes under the ambient-curing (AC) and delayed oven-curing (OC) conditions with different NaOH molarities. For the lowest sodium silicate content and the highest sodium hydroxide amount ($\text{Na}_2\text{SiO}_3/\text{NaOH}=1$), the compressive strengths of the specimens decreased in the order of: 14M (OC) > 14M (AC) > 10M (OC) > 10M (AC) > 6M (OC) > 6M (AC). The results pointed out that the compressive strengths of the specimens significantly affected by the molarity concentration, and the highest compressive strength was obtained in the specimens with the highest NaOH molarity (14M) concentration. In addition, the effect of NaOH molarity was found to be also significant than the effect of delayed oven-curing conditions.

For the specimens with an alkali activator ratio of 1.5, the compressive strengths of the specimens decreased in the order of: 14M (OC) > 10M (OC) > 14M (AC) > 6M (OC) > 10M (AC) > 6M (AC). The results showed that the compressive strength also significantly influenced by the NaOH concentration and the highest and lowest compressive strength was achieved in the specimens with 14M and 6M concentrations, respectively. However, some of the oven-cured specimens with low NaOH molarity yielded higher compressive strength values than the specimens with high molarity cured in the ambient environment (10M (OC) > 14M and 6M (OC) > 10M). The results indicated that the effect of delayed oven-curing was started to be a dominant factor in the compressive strength of the specimens with a $\text{Na}_2\text{SiO}_3/\text{NaOH}$ ratio of 1.5.

For the higher alkaline activator ratio of 2, the compressive strengths of the specimens reduced in the order of: 10M (OC) > 10M (AC) > 6M (OC) > 14M (OC) > 14M (AC) > 6M (AC). The results pointed out that for the sodium silicate content of 2, the highest compressive strength of the specimens was achieved in the specimens with moderate NaOH concentrations (10 M). The compressive strength of the specimens was found less for the high (14M) and low (6M) NaOH molarity concentrations than the moderate (10M) NaOH concentration.

For the alkali activator ratio of 2.5, the compressive strength values were found to be close to each other and the compressive strengths were found to be reduced in the order of: 14M (OC) > 6M (OC) > 6M (AC) > 14M (AC) > 10M (OC) > 10M (AC). It was interesting to note that the specimens with 6 M NaOH concentrations (highest sodium silicate and lowest sodium hydroxide) yielded higher compressive strength values for the 10 M NaOH concentrations (both AC and OC condition) and 14M (AC) conditions. It should be pointed out that for the higher sodium silicate solutions, the higher compressive strengths yielded with the low sodium hydroxide concentrations, except for the 14M (OC) specimens.

The overall compressive strength test results indicated that the highest compressive strengths were obtained for the specimens with 14M NaOH concentrations for the various alkaline activator ratios, except only for a $\text{Na}_2\text{SiO}_3/\text{NaOH}$ ratio of 2. Meanwhile, the lowest compressive strength values were obtained in the specimens with 6 M NaOH for the different alkaline activator ratios, except for a $\text{Na}_2\text{SiO}_3/\text{NaOH}$ ratio of 2.5. It can be

concluded that the highest compressive strength was obtained in the alkali activated fly ash/slag concretes with 14 M NaOH concentrations, while the lowest compressive strength was achieved in the specimens with 6 M NaOH concentrations.

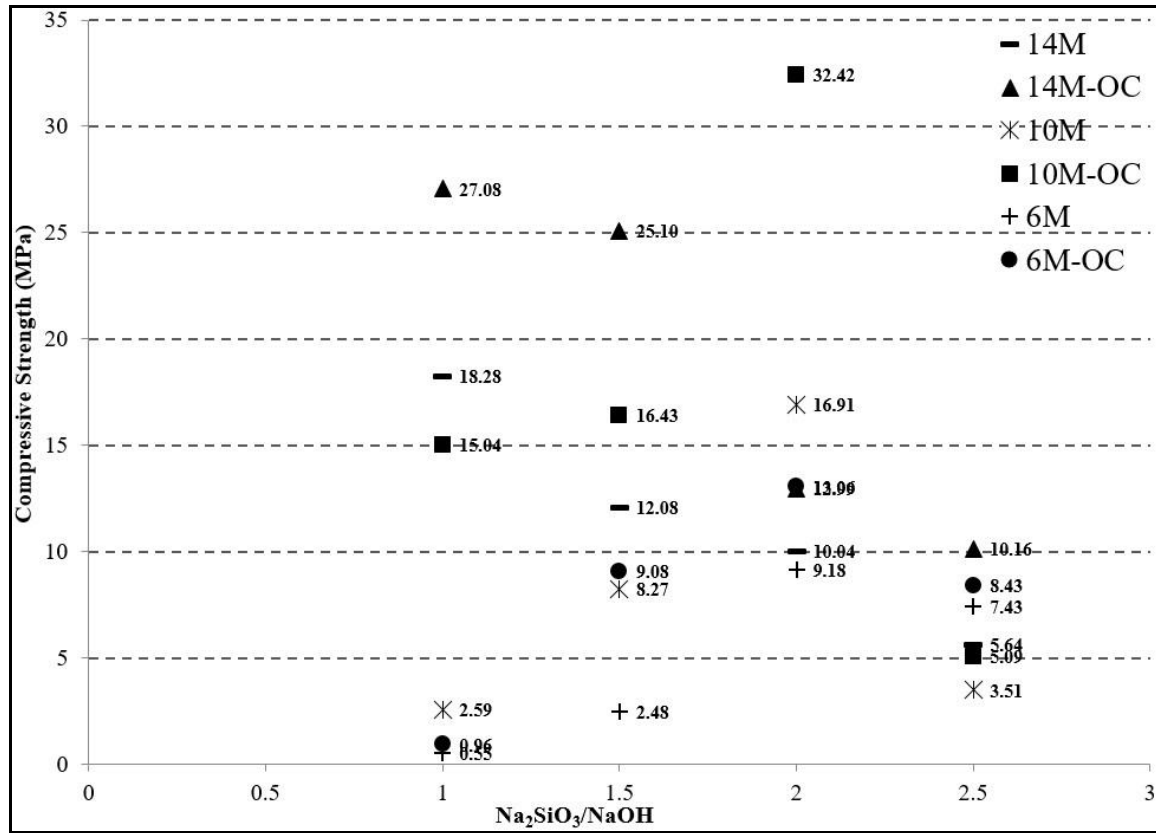


Fig. 5. Compressive strengths of the alkali activated fly ash/slag specimens with various alkaline activator ratios

For the comparison of the used alkali activator ratios, the average compressive strengths of the specimens with each alkaline activator ratios were calculated for the ambient-cured specimens, oven-cured specimens and average of the ambient and oven-cured specimens and given in Table 3.

Table 3. The average compressive strength values (MPa) of the specimens with various sodium silicate to sodium hydroxide ratios

$\text{Na}_2\text{SiO}_3/\text{NaOH}$ ratio	Ambient-curing (AC)	Oven-curing (OC)	Average
1	7.14	14.36	10.75
1.5	7.61	16.87	12.24
2	12.04	19.49	15.76
2.5	5.52	7.89	6.71

The results pointed out that the highest average compressive strength was obtained in the specimens with a $\text{Na}_2\text{SiO}_3/\text{NaOH}$ ratio of 2, while the lowest compressive strength was achieved on the specimens with a $\text{Na}_2\text{SiO}_3/\text{NaOH}$ ratio of 2.5. The highest compressive strength of the specimens with a $\text{Na}_2\text{SiO}_3/\text{NaOH}$ ratio of 2 was also obtained in the earlier investigation [20]. In addition, the maximum average compressive strength improvement (~122%) due to the oven-curing was obtained in the specimens with an alkali activator ratio of 1.5, while the least compressive strength improvement (~43%) was found in the specimens with an alkaline activator ratio of 2.5.

4. Conclusions

In this study, the effect of different NaOH concentrations (6M, 10M, and 14M) and various sodium silicate to sodium hydroxide ratios (1, 1.5, 2, and 2.5) on the compressive strength of alkali activated fly ash/slag concrete

was investigated under ambient-curing conditions (AC) and delayed oven-curing (OC) conditions. The findings were summarized below:

- The compressive strength of the alkali activated fly ash/slag concrete was significantly influenced by the alkali activator ratio, NaOH concentrations and delayed oven-curing condition. For the specimens with 14M NaOH concentrations, the compressive strength of the specimens decreased with an increase in the alkali activator ratio. In addition, the maximum and minimum compressive strength enhancements due to OC were obtained in the specimens with an alkali activator ratio of 1.5 and 2, respectively.
- The compressive strengths of the specimens with 10M and 6M NaOH concentrations increased with an increase in the alkali activator ratio up to $\text{Na}_2\text{SiO}_3/\text{NaOH}$ value of 2, then compressive strength of the specimens started to decrease for the higher alkali activator ratio of 2.5. For the specimens with 10M and 6M NaOH concentrations, compressive strength improvement due to OC was generally reduced for the increased alkali activator ratios.
- For the specimens with an alkali activator ratio of 1.5, the influence of the delayed oven-curing was started to be a dominant factor on the compressive strength of the alkali activated fly ash/slag concretes. The highest and lowest compressive strength was achieved in the specimens with 14M and 6M concentrations, respectively.
- For the alkali activator ratios of 2, the highest compressive strength was achieved in the specimens with moderate NaOH concentrations (10M) and the relatively lower compressive strength values were obtained with the 6M and 14M NaOH concentrations.
- For the alkali activator ratio of 2.5, the compressive strengths were found to be close to each other. The superior compressive strength was obtained in the specimens with 14M NaOH concentrations; however, specimens with 6M concentrations yielded higher compressive strength values than the 10M concentrations under both ambient and oven-cured conditions.
- The highest compressive strength was achieved generally in the alkali activated fly ash/slag concretes with 14 M NaOH concentrations, while the lowest compressive strength was achieved in the specimens with 6M NaOH concentrations.
- The highest average compressive strength of the alkali activated fly ash/slag concrete was obtained in the specimens with an alkali activator ratio of 2, while the lowest average compressive strength was achieved in the specimens with an alkali activator ratio of 2.5. It can be concluded that the high alkali activator content can be detrimental to the mechanical strength of the alkali activated fly ash/slag concretes.
- The delayed oven-curing significantly improved the compressive strength of the alkali activated fly ash/slag concrete specimens. The average compressive strength enhancement (~122%) was obtained in the specimens with an alkali activator ratio of 1.5, while the minimum average compressive strength enhancement (~43%) was achieved in the specimens with an alkaline activator ratio of 2.5.

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