Investigating the influence of the NaOH concentration on the properties of the fly ash-basedgeopolymermortars

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تحولت الأبحاث الحديثة في اتجاه تخليق بديلا للاسمنت وهو الجيوبوليمر لأنه يعتبر بديلاً مستدامًا للمواد الأسمنتية الحالية.ويهدف هدا البحث إلى دراسة تأثير تركيز هيدروكسيد الصوديوم على خواص عجينة الجيوبوليمر المصنعة من الرماد المتطاير والتي تعتبر مادة بوزولانية لتقليل انبعاثات ثاني أكسيد الكربون الناتجة عن الإنتاج إلى الأسمنت في تغير المناخ.

تم تحضير ثلاث عينات من عجينة الجيوبوليمر من تركيزات مختلفة من هيدروكسيد الصوديوم 4 و 8 و 10 مول ممزوجة مع محلول سيليكات الصوديوم كمنشط قلوي. تم علاج العينات عند 75درحه مئوية. تم فحص عينات العجينة بواسطة اختبار قوة الضغط في مدد 3 و 7 و 14 و 28 يومًا وتم التأكيد علي النتائج بواسطة تحليل حيود الأشعة السينية. أظهرت النتائج أن العينة الثالثه م3 (10مول) قد حققت مقاومة ضغط في 28 يومًا مقدرها 33.49 ميقا باسكال اعلي من العينات م1و م2 (4مول و8مول) التي قد حققت مقاومة ضغط في 28 يومًا مقدرها 28.62ميقاباسكال و 31.61 ميقا باسكال على التوالي.

يعزى السبب الذي تم العثور عليه إلى تكوين المزيد من رابطات جل غير متبلور (من النوع صوديوم الوميناسيليكات هيدريت) كما هو موضح في العينه 10 مول. والتي حققت اعلي مقاومة ضغط كما هو موضح عبر وتحليل حيود الأشعة السينية.

Abstract;

The recent research shifted towards synthesis geopolymer-based materials as it considered a sustainable alternative to the existing cementitious materials. The ongoing research aimed to investigate the influence of sodium hydroxide (NaOH) concentrations on the properties of alkali-activated mortar-based fly ash considered as a pozzolanic material to decrease the overall CO_2 emission resulted from solid wastes on climate change. Three different mortar specimens prepared from various NaOH concentrations as 4, 8, and 10 moles mixed together with sodium silicate solution (Na_2SiO_3) as an alkaline activator. The specimens were cured at 75 □. The mortar specimens were investigated based on compressive strength (CS) at 3, 7, 14, and 28 days and XRD analysis. The results show that the M3 specimen has achieved with a higher CS at 28-day of33.49MPathan the M1and M2 mortar specimen as 31.61MPa, and 28.62MPa, respectively. The resulting found was attributed to the formation of more amorphous gels binder (N–A–S–H type) as indicated with M3 (10 moles) specimens, which was attributed to the highest CS as indicated via XRD.

Keywords: fly ash, geopolymer, NaOH concentration

1. Introduction

The construction industry is one of the fastest-growing sectors, which consumes an abundant amount of mineralogical and portland cement resources, thus causing serious environmental concerns. Due to the rapid socio-economic growth and consumption of natural resources, there is an urgent need to divert the attention of the construction industry towards sustainable materials and technologies. One of the most consumed material in the construction industry is cement, which proves to be energy consumptive and unsustainabledue to its production process. The amount of cementproduced is estimated to be 4.0 billion tonnes perannum and it is supposed to be growing at 4% eachyear[1,2].The amount of cement is equivalent to 626 kilogram (kg) per capita[3].Due to the enormous demand and production of cement as the raw material for the construction sector; it has raisedserious environmental hazards as 0.66 to 0.82 kg of $CO_2$is liberated in the atmosphere to produce perkg ofcement, contributing to an overall 7% of global CO_2emission [4].Various techniques and materials havebeen tried and tested to reduce theconsumption ofcement by using supplementary cementitiousmaterials such as Fly Ash, Metakaolin, Silica Fume, RiceHusk Ash, etc.Furthermore, to reduce the dependencyon cement researcher has come up with one of thetechniques known as geopolymerizationto providecement less binding material[5].The main advantageof the geopolymer based material is that it does notuse energy consumptive cement as a raw material forits preparation.Geopolymer is one such material which hassustainable traits and it can replace cement as abinder in construction materials. Geopolymerization isthe technique used to form an aluminosilicateinorganic polymeric compound developed by polymerization of materialsrich in silica and alumina with alkaline (NaOH/KOH) solution [5]. Furthermore, Alkaline activated or geopolymer is synthesized by mixing aluminosilicate reactive material with strong alkali solutions such as sodium hydroxide (NaOH) and sodium silicate [6].Fly ash popular source material for product geopolymers or alkali-activated [7] as it’s consists of high levels of amorphous alumina-silica and its highly reactive start to melt when comes into touch with an alkali solution. Fly ash can be utilized as source material in the product of alkali-activated or geopolymers because geopolymerization is basically established onthe alumina-silicate chain. However, the concentration ofthe alkali solution plays a significant role in the solution of the flyash. The solubility of Al^{3+} and Si^{4+}ions in sodium hydroxide solubilityis higher than in potassium hydroxide solution[8,9].All previous studies have completed that Class F and c fly ash is a perfect source for geopolymers or alkali-activated [10].Furthermore, NaOH is superior to otheractivators for the activation of the fly ash in the producer of geopolymers. When NaOH combination with sodium silicate, increasing the compressive strength better than when only NaOH is used. The cause behind this is the reality that in thegeopolymerization process, water glass increases the reactionproduced in which the Si content is higher and provides moremechanical strength[11].When fly ash comes into contact with NaOH, leachingof Si, Al and other minor ions begins. The amount of leaching isdependent on NaOH concentration and leaching time. The mixingof fly ash with 10 M NaOH for 10 min is appropriate for synthesisof geopolymers[12].In this study, geopolymer mortar was fabricated from three mixtures with different concentrations of NaOH(4M,8M, and 10M). Besides, in the current study, NaOH and Na_2SiO_3 solution (water glass) were applied to activate the Class F fly ash in order to determine the mechanical properties of the synthesized geopolymer materials in a short period of time. The changes in the geopolymerization process and the properties of the final product were investigated by curing geopolymer mortars, which were prepared using alkali-activated fly ash and sand, with differing NaOH concentrations. Thus, the changes in the properties of the geopolymer mortars in short periods of time were revealed by detecting the relationships between the alkali solution concentration of NaOH and their compressive strength results.

2. Materials and methods

2.1. The characterization of the fly ash

In this experimental, fly ash materials were obtained from Lafarge Malaysia Berhad (Rawang Plant). The Chemical composition analysis and physical properties are shown in Tables (1) and
(2), respectively.

2.2. The preparation of the geopolymer mortar

In this experimental program, three different molarities (M) of NaOH concentration were used in order to knowledge the influence of NaOH concentration on geopolymer mortars. The designed NaOH pellets were used in order to get concentration. Besides, the prepared alkaline activator solution composes of NaOH concentration and Na_2SiO_3.The source materials are made up of Fly ash. The mixture proportions used inthe preparation of the geopolymer mortar samples are shown inTable (3).

2.3. Preparation geopolymer fly ash mortar and testing

The NaOH solutions were prepared in the planned concentrations and allowedto stand at room temperature for 24 h. Next, using a 4.73-litre Hobart seat mixer. Next, the alkaline activator was fabricated from Na_2SiO_3 and NaOH solutions. The pellets of

NaOH were poured into the tank with distilled water for 4 M, 8 M and 10 M concentrations, the solid material, the alkaline activator and water are weighed. The fly ash and the alkaline activator were added to the water before the slow addition of the fine aggregate. The Hobart N50 paddle mixer is used as described in ASTM C305 (ASTM, 1999b) for blended. Two layers of oil-smeared steel moulds with a dimension of 50 mm x 50 mm x 50 mm were used to pour the mortar specimens. The vibrating table facilitated the vibration of each layer for 15 seconds. The samples were compacted as described in ASTM C109/C109M (ASTM, 1999a). This was followed by an additional vibration of 15 seconds using the vibrating table in the final step. The samples were enveloped in heat-resistant vinyl sacks that prevented moisture loss. This was followed by a 24-hour treatment in an oven at 75 °C (Mijarsh et al., 2015b) More cured samples were maintained in laboratory conditions at 25 °C and 70% RH (RH).

Table 1: Chemical compositions of FA analysed by XRF

Oxides (%)	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	P_2O_5	K_2O	SO_3	TiO_2	Na_2O	LOI
FA	49.053	23.516	6.422	5.080	0.698	1.018	1.309	0.475	1.121	0.2102	2.130

Table 2: Physical properties of FA

Materials	Specific gravity	Median particle size, $d_{50}\mu m$	Surface area m^2/kg	Colour
FA	2.42	9.8	320	grey

Table خطأ! لا يوجد نص من النمط المعين في المستند.: The mixture proportions geopolymer mortars Kg/m^3

Mix	Solid material (kg)	Sand (kg)	Alkaline Activator			
			Na_2SiO_3 (kg)	NaOH 10 M (kg)	Water (kg)	Added Water (kg)
M1 (4M)	Fly ash 0.847	1.270	0.303	0.040	0.08	0.06
M2 (8M)	Fly ash 0.847	1.270	0.303	0.040	0.08	0.06
M3 (10M)	Fly ash 0.847	1.270	0.303	0.040	0.08	0.06

3. Results and Discussion

3.1 Effect of NaOH concentration

Figure (1) shows the results of the compressive strength of the response index increased with the increase NaOHconcentrations from M1 up to M3. It was clear that the highest strength was showed at 28 days for M3 followed by M2 and M1, accordingly. The 28-day strength in M1 was found to be 28.62 MPa, which was increased by 14.03% and 18.97% in M2 and M3 respectively. Nevertheless, this result was attributed to the high number of OH^- to its structure, lowering the total amount of hydroxide groups and allowing the formation of N–A–S–H gel as a secondary reaction product (Rashad, 2013). The highest compressive strength product from a NaOH ratio of 10 M was nearly 33.49 MPa after 28 days.

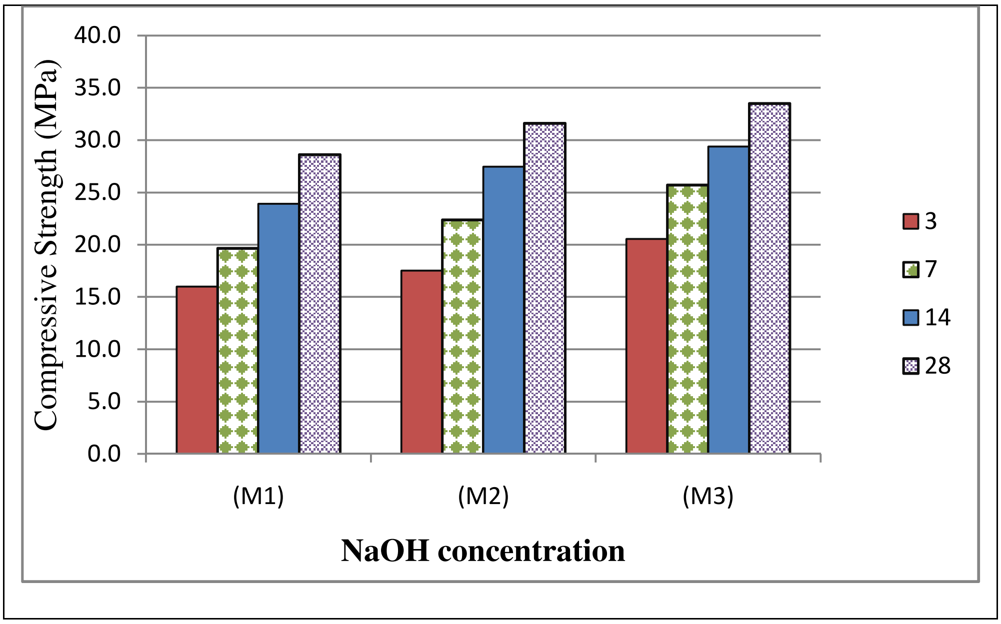

Figure (1) Compressive strength of geopolymer mortar at3, 7, 14, and 28 days

3.2 Mineralogical analysis result

The X-ray diffraction was performed to identify the phases compositions in the geopolymer fly ash (GPMFA). The phase changes were investigated within curing time of 28 day. The results of mixtures (M1-M3) indicated the presence of mullite with chemical composition of ($Al_6Si_2O_{13}$) (ICSD no. 98-006-4581) and quartz (ICSD no. 98-004-6928). The peak at 29.7° 2Θ was attributed to the formation of N-A-S-H type gel with a structure close to mullite. The peak intensity started to increase as the concentration of NaOHwere increased from 4 M to 10 M. The highest peak intensity indicated at mixture of M3 matched with the compressive strength results indicated in this study. This was mainly due to the presence of high soluble SiO_2 derived from alkaline activator solution that would react with dissolved $Al(OH)^{4-}$ to form the gel binder which results in a high rate of reaction. Besides, the high concentration of Na_2O that leads to higher pH values which plays a crucial role in degree of condensation process of main gel binder as the SiO_2 content also would increase [11].

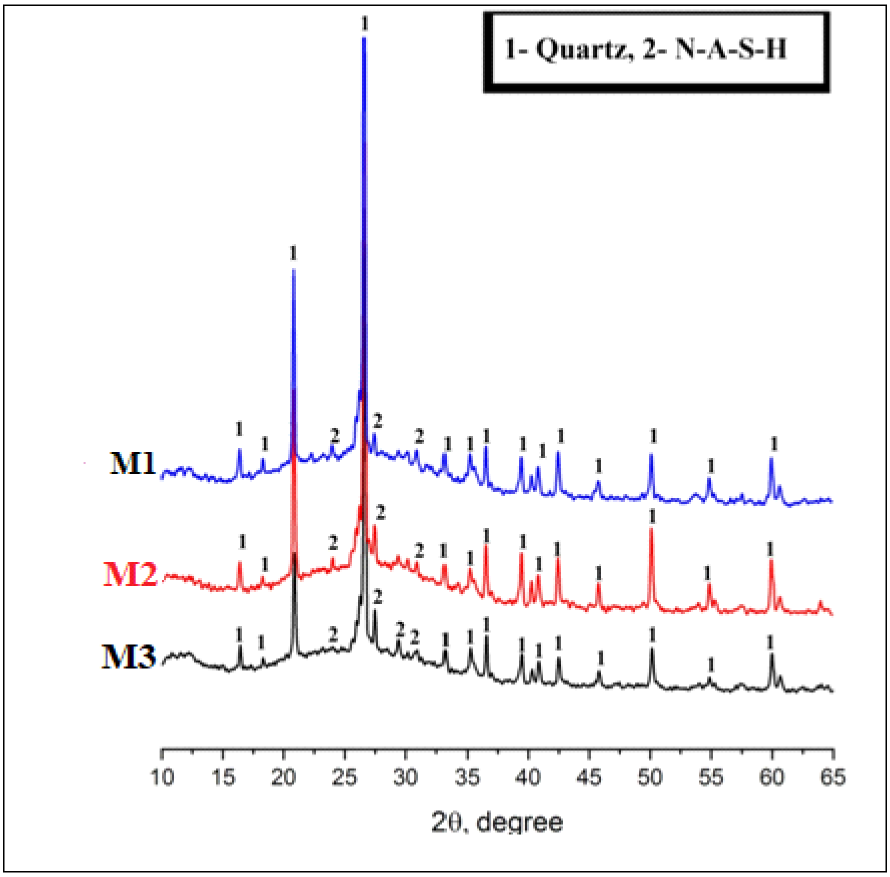

Fig.2 XRD diffractograms of geopolymer mortar mixture (M1, M2, and M3)

4. Conclusion:

The influence of the NaOH concentration on the properties of the fly ash-based alkali-activated mortars was investigated. The results were relevant that the reactivity of fly ash as source material influenced by NaOH concentrations. The highest compressive strength of48 MPa at 28 dayswas obtained with the usage of 10 M NaOH concentration. This was mainly due to the high reactivity and dissolution of fly ash particles when it comes in contact with alkaline activator solution at certain concentration. This was conformed with formation of more gel binder (N-A-S-H) as results of XRD analysis.

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