Effect of Pb^{+2} ion on physico chemical properties of fly ash -slag geopolymer pastes

Sara H. Abdallah*, Doaa A. Ahmed, Sheren M. Ragei

Chemistry Department, Faculty of Women for Arts, Science and Education, Ain-Shams University, Cairo, Egypt.

Abstract

The aim of this work is to examine the stabilization or immobilization of heavy metals such as Pb $(NO_3)_2$ in a various paste of slag and slag-FA based and on geopolymer pastes. Geopolymer prepared by 100% slag and partially substitution of slag by 15% Fly ash (FA) [85% slag+15%FA]. The alkaline activator is (1:1) liquid sodium silicate (Na_2SiO_3) and sodium hydroxide (NaOH) solution (the concentration of sodium hydroxide is 5 Molar). Different percentages of Pb $(NO_3)_2$ were added to the alkali activation mixture, 0.5%, and 1% by mass% of the solid binder. The obtained geopolymer specimens are cured in water for 90 days. The compressive strength test, combined water content, X-ray diffraction (XRD), Atomic absorption, and Transform infrared spectrometry (FTIR) are examined. The results showed that the used lead nitrate caused a retarding effect for the hydration of the investigated geopolymer mixes.The best mix for immobilization were 99.98% in mix SF1[85%slag+15%Fly ash +0.5%Pb^{+2}].

Keywords

Geopolymer Slag, Fly ash, Immobilization, Leaching.

1. Introduction

A great advancement in recent years in a new kind of inorganic cementitious Geopolymerar is required to substitute portland cement (OPC) for improved environmental and durability performance. The fabrication of Portland Cement is

---

***Corresponding author**: Sara H. Abdallah, Chemistry Department, Faculty of Women for Arts, Science and Education, Ain-Shams University, Cairo, Egypt.

E-mail: sara_science@yahoo.com

most important global warming is produced by carbon dioxide emission. The manufacture of Portland cement produced high CO_2 arising 7% of all CO_2 generated attached to calcination of limestone which led to the formation and release of CO_2 and high energy consumption during manufacturing at a temperature higher than 1550C°. Each 1- ton of OPC produced results in loading about 1- ton of CO_2 into the environment. More research carried out on the development of alkali-activated binders shows that this new binder is likely to have a massive potential to become an alternative to Portland cement. These binders are still at an early stage of development and therefore require further research to become technically and economically viable construction materials [1]. The aluminum silicate network "polysialates" consists of tetrahedral anions $[SiO_4]^{4-}$ and $[AlO4]^{5-}$ that need positive ions such as (Na^+, K^+, Li^+, Ca^{2+}, Ba^{2+}, NH^{4+}, H_3O^+) to compensate for the electrical charge of Al^{3+} in tetrahedral coordination (after dehydroxylation, the aluminum changes from coordination 6 (octahedral) to coordination 4 (tetrahedral)). The polysialate has the following empirical formulae:

Mn {-(SiO_2) z-AlO_2} n, wH_2O

Geopolymer and alkali activation technology has received a lot of attention in recent years as a sustainable alternative for conventional cement due to its superior strength, durability, and environment-friendly characteristics [2]. The largest savings of carbon dioxide from the industry affect gaseous pollution to have a major negative influence on health, the low production of carbon dioxide achieved by the adding of supplemental cementitious materials, such as fly ash or ground granulated blast-furnace slag [3]. The geopolymerization process converts a variety of waste aluminosilicate materials into useful binders that can be used in construction materials. A large number of naturally occurring and industrially produced aluminosilicates are used for the synthesis of geopolymers [4].Numerous studies have demonstrated that the formation of extra calcium due to the inclusion of GBFS in the FA geopolymer is responsible for improving the mechanical and microstructure properties of the system[5–7]. The durability of fly ash-based geopolymer pastes in the marine environment and also showed that geopolymer fly ash-based pastes and alkaline sodium hydroxide and sodium silicate solutions can play a substantial role in environmental control of the greenhouse effect [8]. The pollution of heavy metal has

become a very dangerous global environmental and it's very serious in time. In a recent field, it makes great demolish to human beings and the environment. The concentration of heavy metals produced from soil, water, and air may cause bioaccumulation of heavy metals in humans and animals [9]. Various investigations confirmed that geopolymers comprising of metal or waste, such as fly ash, slag, and tailing, could solidify some heavy metals. Investigations have indicated that heavy metal ions have been implicated in the geopolymer response process. The blast furnace slag and MK as raw material to get a geopolymer. The solidifying performance of the geopolymer to Cu, Pb revealed the largest compressive strength in the case of 50 percent slag and the solidification rate of Cu, Pb above 98.5 [10]. The evaluation of geopolymeric binder by alkali activation of fly ash by sodium silicate solution offered a possible means of treating heavy metal waste. The effect of Cr (VI), Cd (II), and Pb (II) in the form of nitrate and chromate salt on geopolymer structure contamination of geopolymers was investigated. They also discovered that it is possible to see the addition of relatively low levels of heavy metal salts [11].During the research of a series of geopolymeric matrices mostly including Cu and Pb, it has been stated that many factors can affect the immobilization behavior of heavy metals such as the difference in composition and the nature of heavy metals[12].Our study aims to examine the immobilization of different Lead ions concentrations (0.5% and 1%) in geopolymer pastes containing 15% of Fly ash +85% slag activated by the alkaline solution of (1:1) NaOH (5Molar)/ Na_2SiO_3. The impact of various lead ions concentrations in the hydration product of geopolymer pastes was also reviewed.

2. Experimental

2.1. Materials:

From the Egyptian iron and steel company Helwan taken granulated blast furnace slag (GGBFS). Fly ash (FA) was provided from Sika Egypt company obour, Egypt, for construction chemicals. The chemical composition of starting raw materials obtained from X-ray fluorescence (XRF) analysis was presented in Table (1). The X-ray diffraction (XRD) analysis pattern of Ground granulated blast furnace slag (GGBFS) is demonstrated in Fig. (1) . Fly ash is demonstrated in Fig. (2). A mixture of sodium hydroxide (NaOH) and liquid sodium silicate (Na2SiO3) was utilized as an alkali activator solution. The NaOH pellets were supplied from the EL-Goumhoria

chemical company, Cairo, Egypt with a purity of 99%. Liquid Sodium silicate (LSS) was supplied from silica Egypt Company, Burg Al-Arab, Alexandria, Egypt. The chemical analysis of sodium silicate liquid is 32.8 wt % $SiO2$, 11.7 wt %Na_2O and H_2O mass%, and silicate modulus SiO/Na_2O equal 2.80.
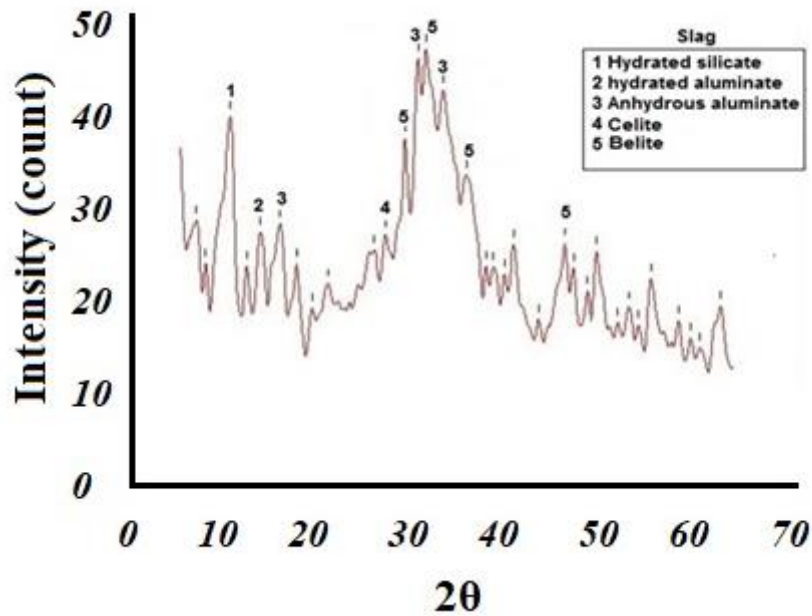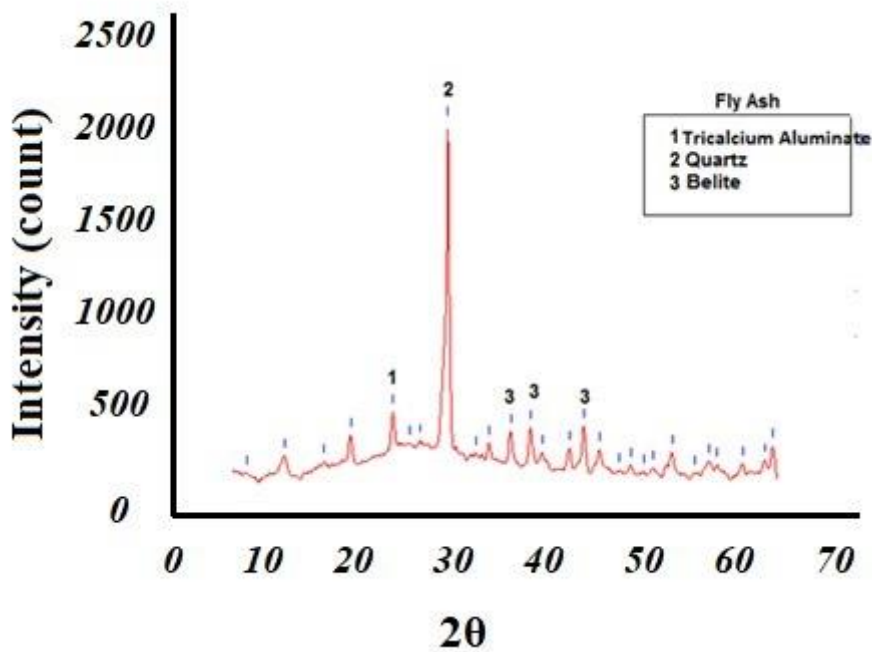
Fig. (1): XRD pattern of Slag.

Fig. (2) XRD pattern of Fly ash (FA).

Table (1): The chemical composition of starting raw materials.

Oxides	Slag	Fly ash
SiO$_2$	34.10	63.20
Al2O$_3$	12.40	26.34
Fe2O$_3$	0.77	5.10
Cao	42.30	2.20
MgO	6.50	0.10
SO$_3$	0.90	0.15
K$_2$O	0.35	0.76
Na$_2$O	0.26	0.44
Cl $^-$	0.08	0
L.O. I	1.50	2.3
Total	99.08	100.59

2.2 Geopolymer synthesis

2.2.1. Preparation of alkaline activator (AA)

Alkaline activator solution was a mixture of sodium hydroxide and liquid sodium silicate necessary for geopolymerization. The concentration of NaOH is 5 M prepared by dissolving NaOH pellets into distilled water and allowed to cool at room temperature. Liquid sodium silicate and Sodium hydroxide solution were mixed by a fixed proportion of (1:1) until a clear gel was observed.

2.2.2. Preparation of specimens

The mixture proportions of prepared samples are signified in Table (2). The paste specimens are prepared by adding the prepared activator to dry mixes and mixed

for 3 min. Two proportions of Pb $(NO_3)_2$ were used: 0.5 and 1.0% by mass %of solid. After mixing the pastes were rapidly placed into a cubic mold cube with a dimension of 25x25x25mm^3. The mould was vibrated to eliminate the air bubbles and then left in a humidifier (100%R.H.) under room temperature for 24hours. After this period, the cubes are demolded and divided into two sets one of them cured under tap water in a plastic container until the required time of testing 3, 7, 28and 90, days of curing, and the other was used for leaching measurement in a static mode at the time intervals 28and 90 days. To determine leachability taking 3 cubes of each mixture have been separately cured in 100 ml distilled water in a sealed plastic bottle. At the end of curing, the cubes were removed from their curing condition and conformed to the compressive strength, combined water content, bulk density, and total porosity measurements. The hydration reaction was stopped by taking the resulted crushed specimens and stirred with a stopping solution of alcohol/acetone (1:1) to avoid further hydration followed by drying of the crushed specimens for 24 h at 100C°, then kept in a desiccator for analysis.

Table (2): Description and composition of the various mixtures.

Mix Abb.	Ground granulated blast furnace slag (GGBFS)	Fly ash(FA)	Metal% Pb^{+2}	W/S Ratio (%)
S	100 %	----	----	22.000
S1	100 %	----	0.5%	24.00
S2	100 %	-----	1%	32.50
SF	85 %	15 %	----	22.60
SF1	85%	15 %	0.5 %	30.00
SF2	85%	15 %	1 %	31.25

2.3. Methods of investigation

1. X-ray diffraction (XRD) analysis is used to explore the phases of hydration products formed at different ages of the different mixes. The using X-ray diffractometer (PW 1390) Cu Kα radiation of wavelength (λ= 1.54178 Å) at voltage 40 kV and current 40 mA, at the National Institute of Standards NIS Giza, Egypt.

2. The Fourier Transform Infrared Spectroscopy (FTIR) measurement is carried out on a unicame mastton 1000 infrared spectroscopy using potassium bromide (KBr)pellets, at the central laboratory, Ain Shams University, Egypt. The wavenumber of infrared spectra was ranging from 400 to 4000 cm^{-1}. At the end of each interval time, the leachate solution is used to evaluate the concentration of the leached metal ions by the Atomic Absorption Spectrophotometer Savant AA-GBC Scientific Equipment at the central laboratory, Ain Shams University, Egypt.

3. Determining the immobilization percent of the different heavy metal's ions in the used hardened geopolymer pastes as follows,

   x (grams in 100 ml) =Concentration (ppm)X10^{-4}

   Original Wt. of metal ion = wt. of cube X percent used of the ions/ 100

   Leaching %= (x/original wt. of metal ion) 100

   Immobilization=100 –Leaching %

4. The water for normal consistency was determined according to ASTM C187[13]. The compressive strength of all set pastes was measured. A manual compression testing machine (D550-control type, Milano Italy) with a measuring range of 0 to 55 KN. The average compressive strength of the three cubes is considered as the result in Kg /cm^2 unit.

5. chemical combined water content [Wn] is calculated from the relation:

   Wn% = [($w_1 - w_2$) / (w_2)] x 100

   Were, w_1: The weight of the sample before ignition,

   w_2: The weight of the sample after ignition at 900C˚.

6. Total porosity and bulk density tests are carried out by determining the weight of samples of hardened pastes suspended in water, W_2, and those in air, W_1 then dried at 100C^o for about 24 hours and weight in the air, W_3. The total porosity percentage of (P %) calculated according to the following equation:

P %= [(W_1-W_3)/ (W_1-W_2)] x100, While the bulk density is calculated using the following equation:

Bulk density = [W_1/ (W_1-W_2)]

3. Result and discussion:

3.1. Compressive strength:

The compressive strength values of hardened activated slag pastes in presence of different percentages of Pb (NO_3)$_2$ are graphically represented in Fig. (3). The result shows a continual rise in the compressive strength attributed to the formation and collection of hydration products, mainly sodium and calcium aluminosilicate hydrate (CASH). It can be observed that an increase in the concentration of lead nitrate at all curing ages, causes a decrease in the compressive strength of the hardened activated slag paste. This is attributed to the limited diffusion of the dissolved species of lead hydroxide through a network of hardened paste matrix pores and the formation of some structural defect [14]. The addition of NaOH /Na_2SiO_3 has a positive effect on the compressive strength values, this can be attributed to providing an activated system by silicate group enhance the strength [15].According to Fig. (3)., we can be seen that the addendum of Fly ash to hardened activated slag increases the value of compressive strength for all pastes in the absence and presence of Pb+2 ions compared to alkali-activated slag (AAS)specimens. Highest value of strength shows in case 15%FA +85% slag and the lowest value in the case of alkali slag with 1%Pb+2.The compressive strength of all mixes lower than the control mix which resulted in a delaying effect with the addition of lead ions, as the concentration of lead ion increase the compressive strength decrease in geopolymer [16], [17].
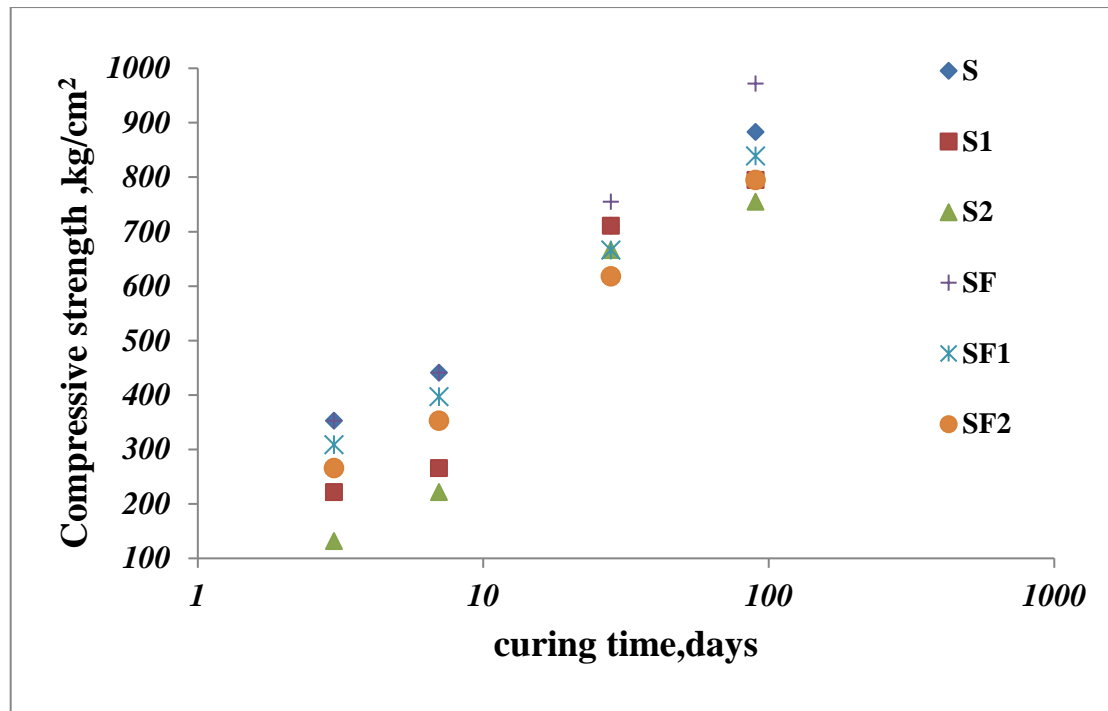
Fig. (3): Compressive strength of Alkali activated slag pastes and Alkali activated slag/FA containing various ratios of lead nitrate at different hydration ages.

3.2. Total porosity (P %):

The total porosity of hardened activated slag and slag/ fly ash specimens containing different lead nitrate contents equivalent to Pb^{+2} concentration of 0, 0.5, and 1% are represented in Table (3). It can be observed that the porosity decreases with curing time up to 90 days for all of the hardened pastes due to the continual activation and formation of hydration products which precipitated in some of the open pores [18]. As the concentration of Pb^{+2} ions increases the porosity increase due to Pb+2 retard the consistence of geopolymer gel, increasing the total pore volume, and therefore matrix permeability [19]. The addition of Fly ash to the system in the absence and presence of Pb^{+2} ions decrease the value of porosity for all pastes, this attributed to an increase in both alkali content and FA, which improve the activation of GGBFS, therefore the formation of more hydration products that decrease the total porosity, such results agree with those of the compressive strength. The porosity increases as the concentration of Pb^{+2} increases that attributed to lead ions precipitate as insoluble hydroxide salt makes pores in the geopolymer network.

Table (3): Total porosity of activated slag pastes and activated slag /Fly pastes containing various ratios of lead nitrate at different hydration ages.

Mixes / Curing time	Porosity%					
	S	S1	S2	SF	SF1	SF2
3	29.70	30.40	31.00	29.71	30.10	30.21
7	27.01	28.09	29.44	26.86	29.10	29.44
28	24.50	26.21	28.00	24.00	26.50	27.50
90	20.00	23.30	23.50	19.80	23.50	23.61

3.3. Bulk density:

The bulk density of alkali-activated slag and slag/fly ash pastes containing different lead nitrate contents equivalent to Pb^{+2} concentrations of 0, 0.5, and 1 are represented in table (4). The bulk density of alkali-activated slag increases through immersed time up to to 90 days. It is attached to the continual activation and growth of the hydration product, which makes the microstructure more homogeneous and denser, showing an increase in mass density. As the concentration of Pb^{+2} ions increases the porosity increase and the bulk density decreases, which is due to Pb^{+2} retard the formation of calcium silicate hydrate (CSH)and calcium aluminosilicate hydrate (CASH), increasing total pore volume [12]. The bulk density is increased by the addition Fly ash up to 90 days, this is due to the continual activation and formation of hydration products that make denser microstructure results in an increase in the bulk density. The presence of lead ions has a delaying effect on the hydration reaction of all mixes which is reflected as a decrease in bulk density values. These results agree with the compressive strength values, such that as the bulk density increases the compressive strength increase.

Table (4): Bulk density of activated slag and slag/Fly ash pastes in presence and absence lead nitrate at different hydration ages.

Mixes\Curing time	Bulk density					
	S	S1	S2	SF	SF1	SF2
3	2.60	2.55	2.45	2.61	2.58	2.57
7	2.86	2.80	2.74	2.88	2.85	2.83
28	2.95	2.90	2.80	2.97	2.86	2.85
90	3.00	2.95	2.84	3.20	2.98	2.96

3.4. Combined water content (Wn %):

Chemically combined water contents of activated slag and 85%alkali activated slag +15% Flyash containing different Pb^{+2} concentrations of 0,0.5 and 1 wt % are graphically represented in Fig. (4). It is noticed that the chemically combined water content increase for all mixes with the curing time, due to the progress of hydration of constituents to form the corresponding hydration products. The main hydration product for all mixes is calcium silicate hydrate (CSH) and calcium aluminate silicate hydrate (CASH). The combined water content decreases with an increase in the concentration of Pb^{+2}, insoluble Pb salt retard the hydration of the silicates phase. The lead ion concentrated on the surface of slag and precipitated into salt like hydroxide, because lead salt had extremely low solubility, it was likely to work as a barrier between slag particle and water, due to this reason, lead ion retarded the initial hydration of slag [20]. It is found that chemically combined water contents increased with adding FA, this is due to the high pozzolanic reactivity of Fly ash results in the formation of additional CSH. The combined water content decreases with the addition of lead ions due to the retardation effect.
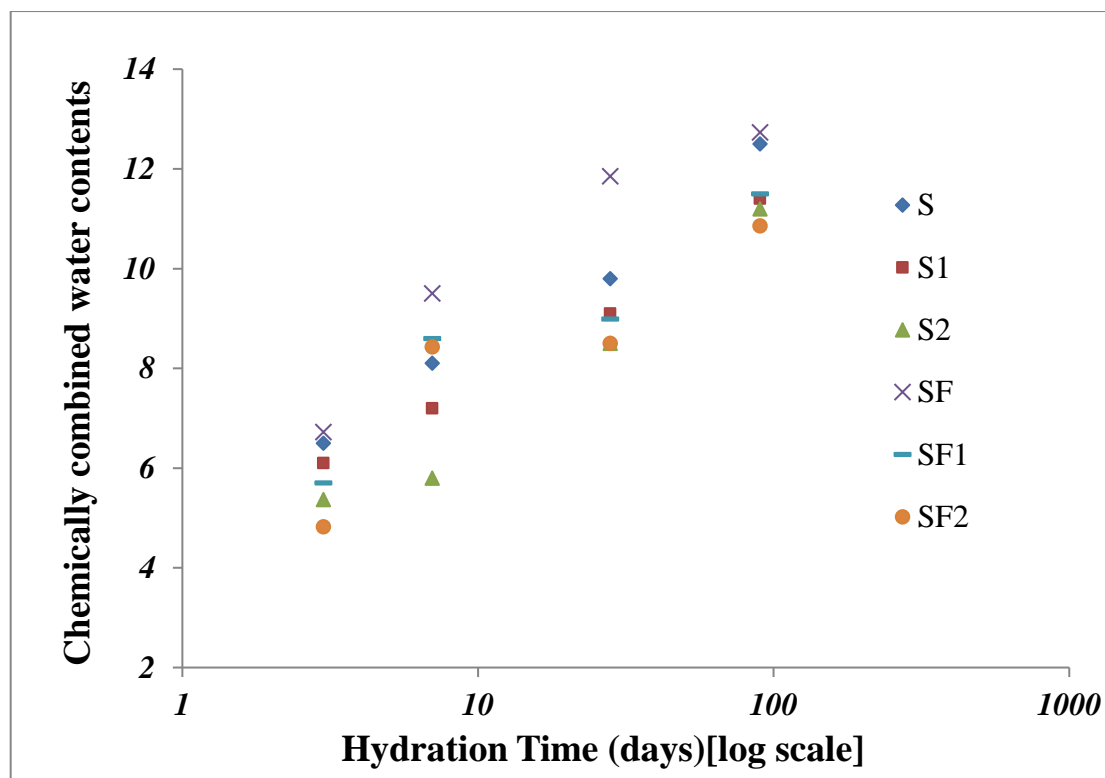
Fig. (4): Chemical combined water content of Alkali activated slag pastes and Alkali activated slag/FA containing various ratios of lead nitrate at different hydration ages.

3.5. Leaching percent %:

The results of the leaching percent of activated slag and slag/fly ash containing 0.5 and 1 % Pb $(NO_3)_2$ are shown in Table (5). It is shown that there is a slight increase in the leaching percent up to 90 days and a decrease in the immobilization, S1(99.98% and 99.87%), and S2(99.89% and 99.78%) at 28 -90 days. Heavy metals precipitate created in geopolymeric matrices might be either metal hydroxide or metal silicate types in the alkali silicate environment [12]. The lead ion concentration [mg/l]in leachate showed even more than the maximum toxicity in the whole hardened activated slag mixture. In the presence of FA, a significant reduction in lead ion concentration has been detected for all alkali-activated mixes., there is a slight increase in the leaching percent for all mixes up to 90 days and a decrease in the immobilization, SF1(99.98 and 99.98) and SF2(99.97 and 99.94) at 28 -90 days. The presence of $NaOH/Na_2SiO_3$ increased the efficiency of metal immobilization due to the providing of silicate group improving hydration product formation. Nevertheless, Pb concentration is still more than the toxicity limit (0.001 mg/l).

Table (5): Leaching percent of activated slag containing various ratios of lead nitrate at different hydration ages (28 and 90 days).

| Mixes	S1			S2		
Time (days)	Leaching percent %	Leaching mg/l	Immobilization %	Leaching percent %	Leaching mg/l	Immobilization %
28	0.0186	0.34	99.98	0.1037	3.95	99.89
90	0.1260	2.35	99.87	0.2170	7.61	99.78

Table (6): Leaching percent of activated slag /Fly ash pastes containing various ratios of   lead nitrate at different hydration ages (28 and 90 days).

Mixes	SF1			SF2		
Time (days)	Leaching percent %	Leaching mg/l	Immobilization %	Leaching percent %	Leaching mg/l	Immobilization %
28	0.018	0.22	99.98	0.0235	0.85	99.97
90	0.038	0.32	99.98	0.0501	1.74	99.94

3.6. The XRD analysis:

The X-ray diffraction patterns of alkali-activated slag are shown in Fig. (5) (a), (b) The X-ray of alkali-activated slag containing 0.5%, and (c) 1% of $Pb(NO_3)_2$ at different hydration ages (7,28 and 90 days). The XRD patterns of specimens of alkali-activated slag pastes indicate the presence of calcium silicate hydrates gel that has resulted in increasing compressive strength, the peak at $2\Theta=25-35$ appears after 7 days. The calcite phase is observed that overlapping with CSH as a hydration product.

Calcite formation is caused by the interaction of (OH$^-$) for alkaline activator through mixing and Ca^{+2} for the source material of specimen to produce calcium hydroxide (Ca (OH)$_2$ who later reacts with CO$_2$ in the environment. The crystalline peaks of Quartz due to unreacted species collapse into pores as a filler. Pastes sintering observed in the creation of a good resolved crystalline peak attached to Gehlenite (Ca$_2$Al$_2$SiO$_7$), Zoisite Ca$_2$Al$_3$(SiO$_4$)(Si$_2$O$_7$)O(OH), and wollastonite (CaSiO$_3$). In (AAS) mixes, a new-found crystalline peak linked to the creation of the Pb$_3$SiO$_5$ was detected. These phases are dehydrating types of force donating as calcium silicate hydrate (CSH) and calcium aluminum silicate hydrate (CASH). As the hydration ages increase, the intensity of phases increases; while the intensity considerably decreased with the addition of Pb^{+2} which the variation of hydrates with heavy metal addition. this could be due to the retardation effect of Pb^{+2}. The X-ray diffraction patterns of alkali-activated slag /FA are shown in Fig. (6) (d), (e) the X-ray of alkali-activated slag /FA containing 0.5 and (f) 1% of Pb (NO$_3$)$_2$ at different hydration ages (7,28 and 90 days). The crystalline reaction products are calcium silicate hydrate and calcium carbonate. The figure represents that unreacted phases Quartz and mullite peaks are remarked in the whole specimens, attached for fly ash. It can be noticed that the peak of calcite decreases gradually up to 90 days due to the reaction of calcium hydroxide released with silica from FA is responsible for the reduction of calcite peak. The sintering of specimens caused the creation of good-resolved crystalline peaks linked to gehlenite (Ca$_2$Al$_2$SiO$_7$), Zoisite Ca$_2$Al$_3$(SiO$_4$)(Si$_2$O$_7$)O(OH), and wollastonite (CaSiO$_3$). A crystalline peak related to the creation of the Pb$_3$SiO$_5$ detected mostly signifies the rise in performing alkali-activated-GGBFS/FA in the solidification and stabilization of Pb^{+2} by its transformation to insoluble phase. The intensity of wollastonite phases disappears which enhances the formation of hydration products. These phases are dehydrating sorts of force donating as Calcium silicate hydrate (CSH) and Calcium aluminum silicate hydrate (CASH). As the hydration ages increase, the intensity increase, and with the addition of NaOH/Na$_2$SiO$_3$- activator which verifies the positive impact of silicate alkali activator at mechanical assets of alkali-activated -GGBFS/FA.
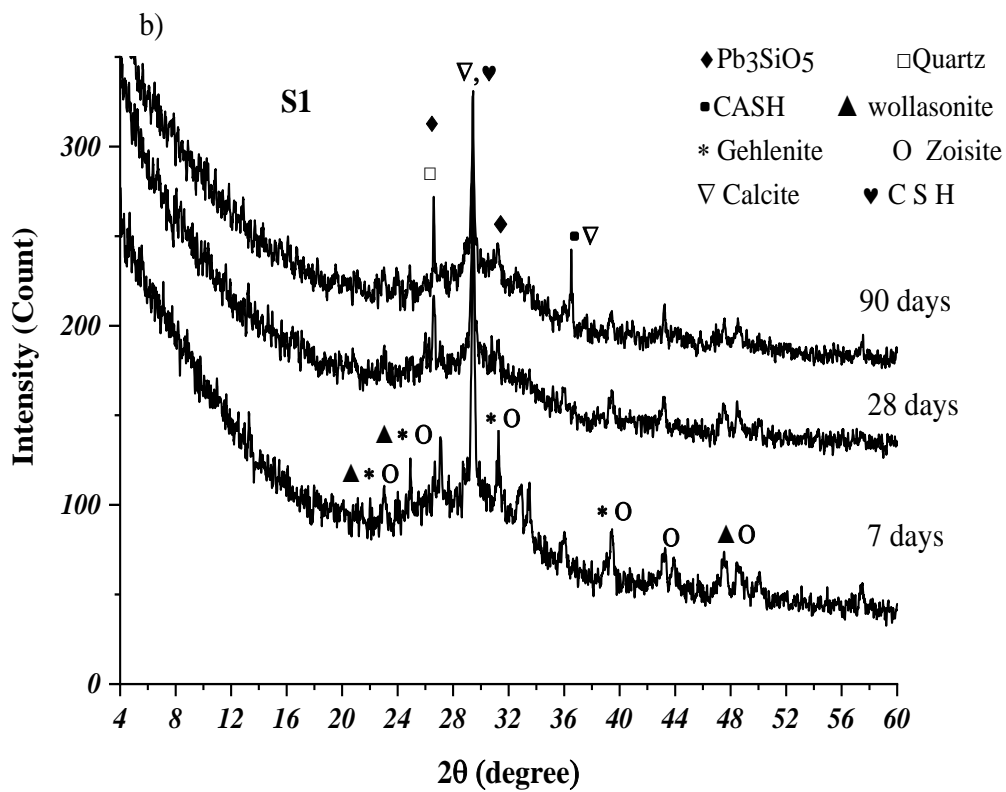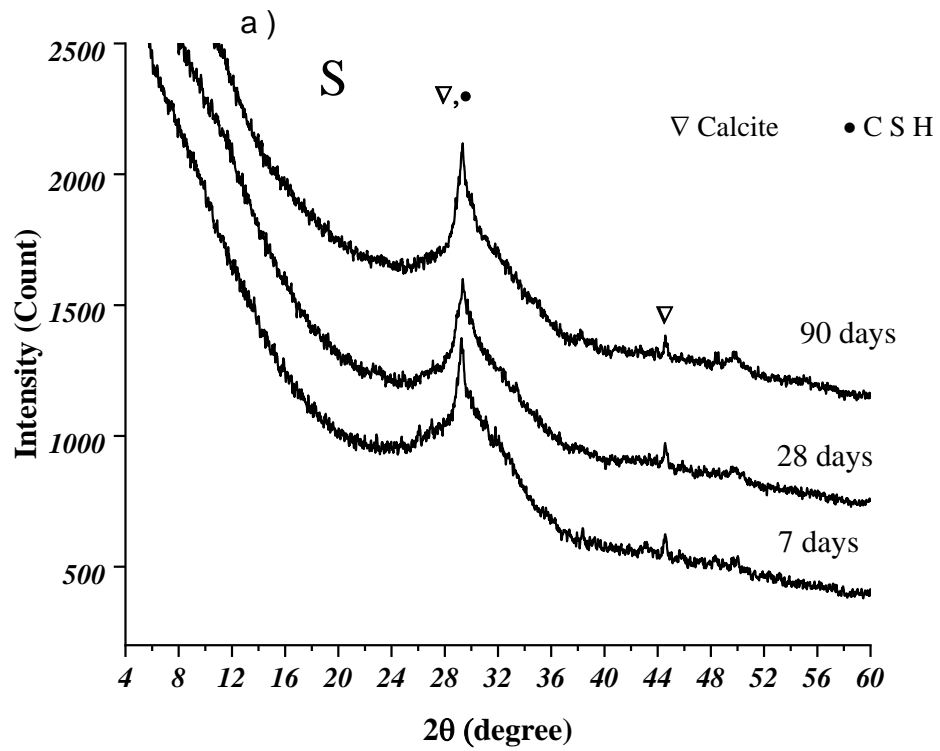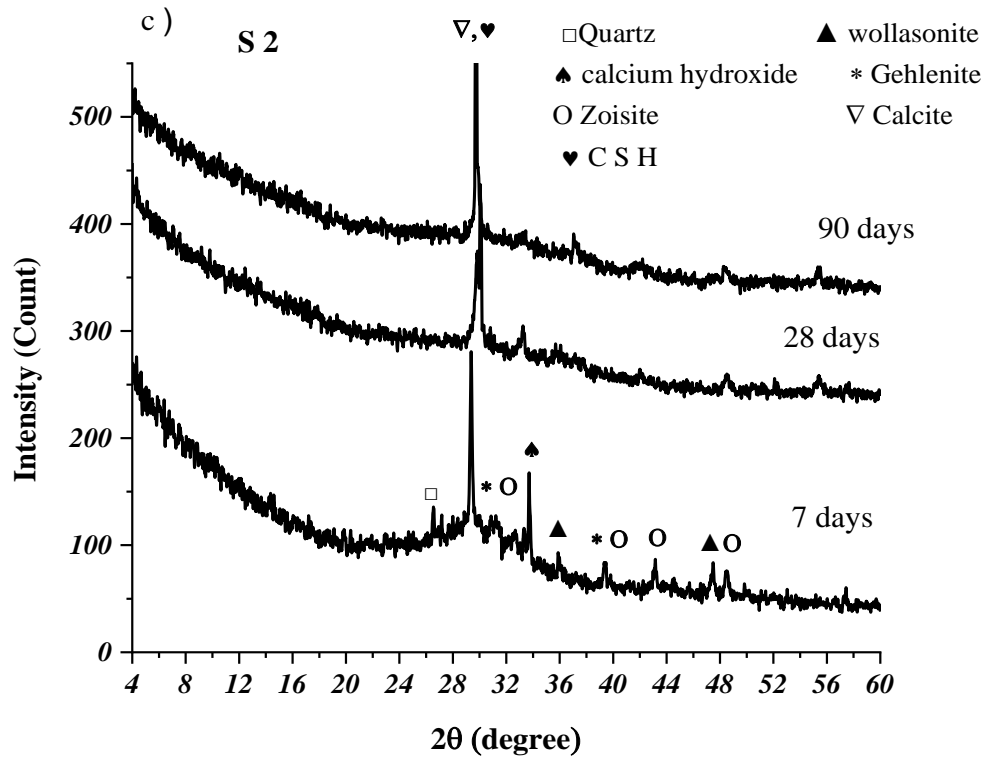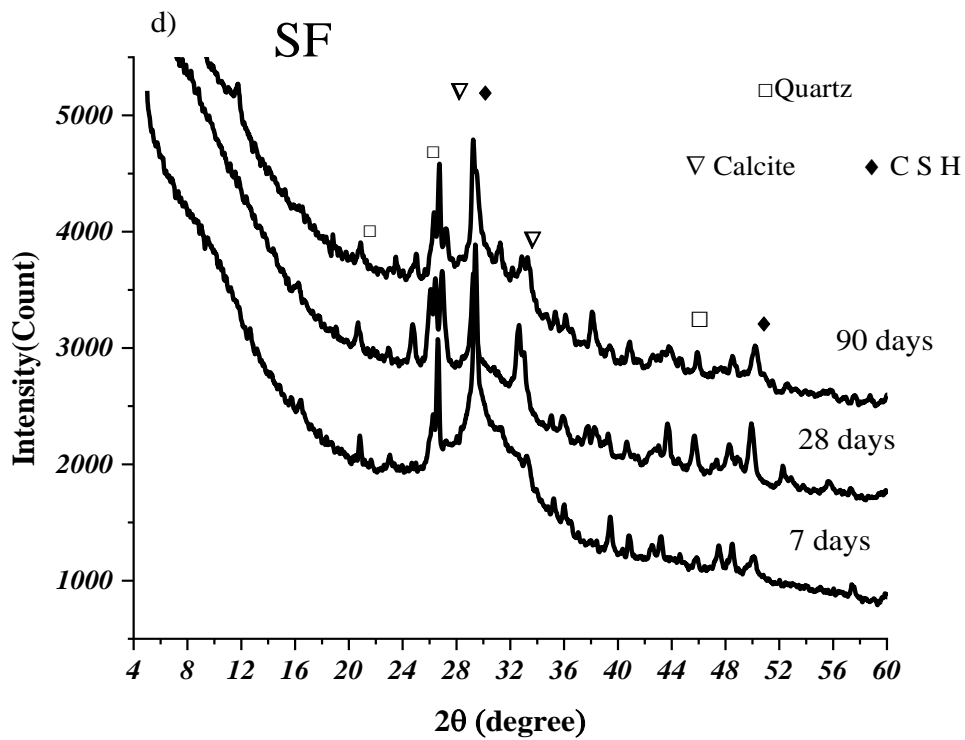
Fig. (5): a) X.R.D of hardened activated slag, b) X.R.D of hardened activated slag containing 0.5 %Pb^{+2} and, c) 1% Pb $(NO_3)_2$ at different hydration ages.
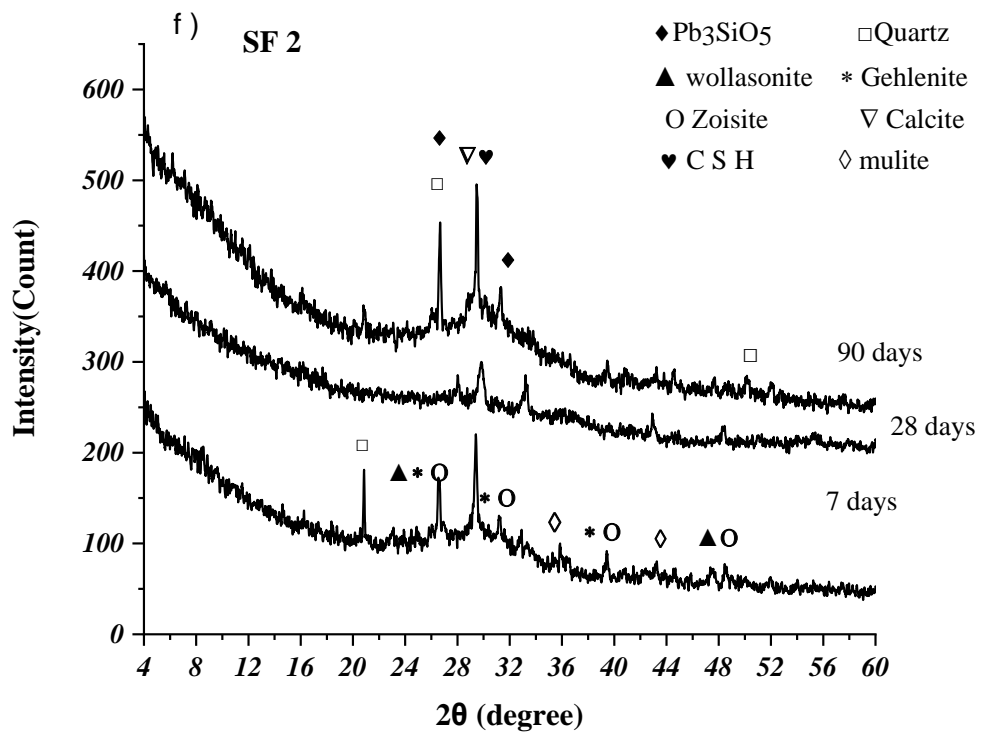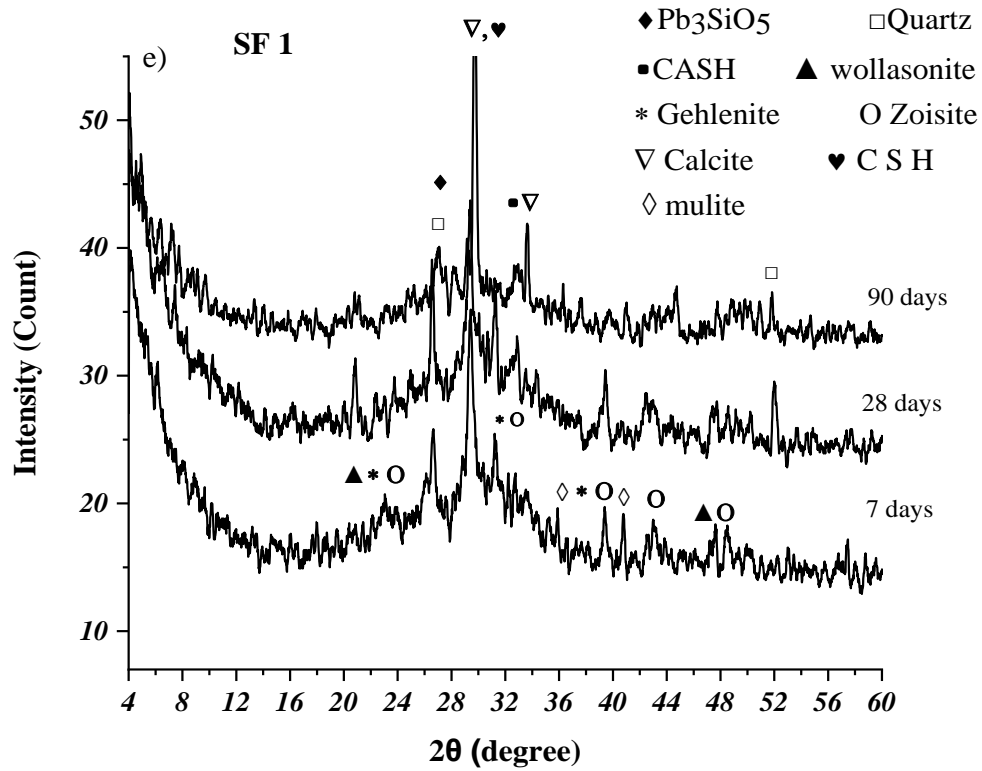
Fig. (6): d) XRD of alkali activated slag /Fly ash e) XRD of alkali activated slag /Flyash including 0.5 Pb^{+2} and, f) 1% Pb (NO$_3$)$_2$ at different hydration ages.

3.7. Fourier transform infrared spectroscopy (FTIR)

The FTIR of geopolymer specimen containing alkali-activated slag and slag /Fly ash in presence of Pb (NO$_3$)$_2$ in ratios 0.5 and 1% for 90 days (S1, S2, SF1, and SF2) are shown in Fig. (7). The spectrum shows the intensity of the absorption band related to stretching vibration mode of the O-H group at 3453 cm^{-1} and bending vibration mode of H-O-H at 1643 cm^{-1}. The peak at 1007 cm^{-1} related to the asymmetric stretching vibration of Si-O- T (Si or Al), shifted around 1000 cm^{-1} for geopolymer mixes. This shift can result from geopolymerization process and formation of aluminosilicates gels CSH and CASH in geopolymer. The shift toward the low wavenumber may be attributed to the partial replacement of SiO$_4$ tetrahedron by AlO$_4$ tetrahedron, resulting in a change in the local chemical environment of the Si-O bond. This agreement with the lower in shift band at about 711cm^{-1} and 673 cm^{-1} which related to the symmetric stretching vibration of (Si-O-Si) and Si-O-Al) and bending vibration mode of Si-O-Si at about 456 cm^{-1}related to Quartz.
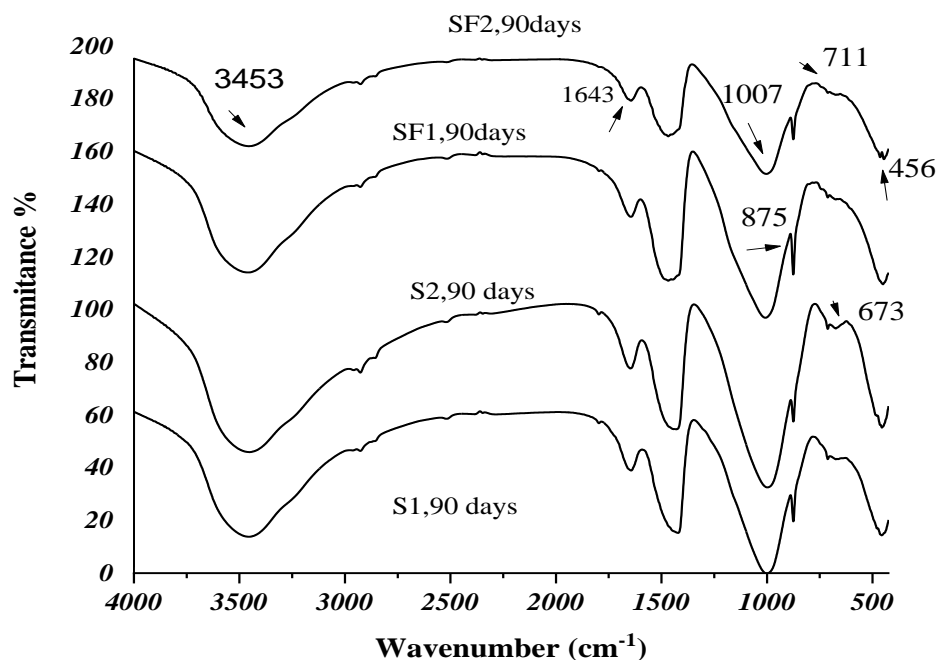

Fig. (7): IR spectra of mixes containing slag and slag/Fly ash in presence of lead nitrate at 90 days.

CONCLUSIONS

The main observation that could be evaluated from this paper can be summarized as follow:

The compressive strength increases up to 90 days for all alkali-activated pastes due to the progress of the formation of hydration products.The combined water content up to 90 days increase for all alkali-activated slag and slag+fly ash mixture due to the formation of hydration products.The total porosity and bulk density are in good agreement with the compressive strength, as the compressive strength value increase, the bulk density increase, and total porosity reduces.The addition of Pb^{+2} as lead nitrate to alkali-activated slag has negative action, due to the retardation effect for the hydration of investigated geopolymer pastes.All the investigated mixed showed a high degree of immobilization, but the mixes containing fly ash in addition to AAS have a high degree of immobilization than alkali-activated slag pastes.The best mix for immobilization SF1 (85% slag+15%Fly ash +0.5% Pb $(NO_3)_2$.

References

[1] F. Pacheco-Torgal, J. Castro-Gomes, and S. Jalali, "alkali-activated binders: A review. Part 2. About materials and binders manufacture. " Constr. Build. Mater., 22:(2008) 1315–1322.

[2] S. F. A. Shah, B. Chen, M. R. Ahmad, and M. A. Haque, "Development of Cleaner One-part geopolymer from lithium slag."J. Clean. Prod.,(291) :(2021) 125241.

[3] M. N. Qureshi and S. Ghosh, "Alkali-activated blast furnace slag as a green construction material. " J. Mech. Civ. Eng., 2:(2013) 24–28.

[4] S. K. John, Y. Nadir, and K. Girija, "Effect of source materials, additives on the mechanical properties and durability of fly ash and fly ash-slag geopolymer mortar: A review. " Constr. Build. Mater., 280:(2021)122443.

[5] S. Kumar, R. Kumar, and S. P. Mehrotra, "Influence of granulated blast furnace slag on the reaction, structure, and properties of fly ash-based geopolymer. " J. Mater. Sci., 45:(2010) 607–615.

[6] F. Puertas, S. Martínez-Ramírez, S. Alonso, and T. Vazquez, "Alkali-activated fly ash/slag cements: strength behavior and hydration products."Cem. Concr. Res., 30:(2000) 1625–1632.

[7] A. Rajerajeswari, G. Dhinakaran, and M. Ershad, "Compressive strength of silica fume based geopolymer concrete. " Asian J. Appl. Sci., 7:(2013) 240-247.

[8] D. V Reddy, J.-B. Edouard, and K. Sobhan, "Durability of fly ash–based geopolymer structural concrete in the marine environment." J. Mater. Civ. Eng., 25:(2013) 781–787.

[9] Y. Wang, F. Han, and J. Mu, "Solidification/stabilization mechanism of Pb (II), Cd (II), Mn (II) and Cr (III) in fly ash based geopolymers ." Constr. Build. Mater., 160:(2018) 818–827.

[10] Z. Yunsheng, S. Wei, C. Qianli, and C. Lin, "Synthesis and heavy metal immobilization behaviors of slag based geopolymer. " J. Hazard. Mater., 143:(2007) 206–213.

[11] J. Zhang, J. L. Provis, D. Feng, and J. S. J. van Deventer, "Geopolymers for immobilization of Cr^{6+}, Cd^{2+}, and Pb^{2+} ." J. Hazard. Mater., 157:(2008) 587–598.

[12] J. W. Phair and J. S. J. Van Deventer, "Effect of silicate activator pH on the leaching and material characteristics of waste-based inorganic polymers. " Miner. Eng., 14:(2001) 289–304.

[13] ASTM ,C. "Standard test method for amount of water required for normal consistency of hydraulic cement paste."(2011)

[14] V. Nikolić, M. Komljenović, N. Džunuzović, and Z. Miladinović, "The influence of Pb addition on the properties of fly ash-based geopolymers. " J. Hazard. Mater., 350:(2018) 98–107.

[15] M. J. Nadoushan and A. A. Ramezanianpour, "The effect of type and concentration of activators on flowability and compressive strength of natural pozzolan and slag-based geopolymers. " Constr. Build. Mater., v 111:(2016) 337–347.

[16] B. Guo, B. Liu, A. A. Volinsky, M. Fincan, J. Du, and S. Zhang, "Immobilization mechanism of Pb in fly ash-based geopolymer. " Constr. Build. Mater., 134:(2017) 123–130.

[17] Y. Zhang, J. Jiang, and C. Maozhe, "MINTEQ modeling for evaluating the leaching behavior of heavy metals in MSWI fly ash. " J. Environ. Sci., 20:(2008) 1398–1402.

[18] J. Singh and S. P. Singh, "Development of alkali-activated cementitious material using copper slag. " Constr. Build. Mater., 211:(2019) 73–79.

[19] P. J. Davis, R. Deshpande, D. M. Smith, C. J. Brinker, and R. A. Assink, "Pore structure evolution in silica gel during aging/drying. IV. Varying pore fluid pH, " J. Non. Cryst. Solids., 167:(1994) 295–306.

[20] C. Y. Rha, S. K. Kang, and C. E. Kim, "Investigation of the stability of hardened slag paste for the stabilization/solidification of wastes containing heavy metal ions. " J. Hazard. Mater., 73:(2000) 255–267.

الملخص العربي

تأثير أيون الرصاص في الخواص الفيزيائية الكيميائية باستخدام الجيوبوليمر المحتوي علي الرماد المتطاير

ساره هلال عبدالله ,دعاء عبد المنعم ,شيرين محمد رجائي

كليه البنات جامعة عين شمس, كليه البنات جامعة عين شمس, كليه البنات جامعة عين شمس

يهدف هذه البحث الي دراسة تاثير اضافه ايون الرصاص (نترات الرصاص) لتركيزات مختلفه من الرصاص 0.5 ،1% بالوزن علي الاداء والخصائص الفيزيائيه والميكانيكيه لعجائن مختلفه بديلة للاسمنت من خبث افران الحديد المنصهر الحبيبي (GGBFS)وخليط من الخبث مع الرماد المتطاير الناتج من حرق وقود الفحم (FA) ، GGBFS/FAوجميع هذه العجائن بديله للاسمنت كانت منشطه قلويا باستخدام $NaOH/Na_2SiO_3$ بنسبة (1:1). وتم ايضا قياس درجه تثبيت عنصر الرصاص في هذه العجائن. تم دراسه كل خليط من العجائن بديله للاسمنت بعد عمليه التأدرت في الماء عند ازمنة التأدرت 3،7،28،90 يوم في وجود وعدم وجود عنصر الرصاص .وقد تم ذلك بقياس قوه التحمل للضغط الميكانيكي ،تعيين حجم الفراغات (المسامية) الموجوده داخل المخاليط المختلفه ،تعيين محتوي الماء المتحد كيميائيا ،دراسه التركيب الدقيق لنواتج التأدرت باستخدام حيود الاشعة السينية والاشعه تحت الحمراء وكذلك قياس التسرب الايوني لايونات الرصاص وتشمل قياس :

ا) كميه الايونات المترسبة (مللي /لتر)

ب) حساب درجة التثبيت عند ازمنة مختلفه 28،90 يوم

ومن هذه الدراسه نستنتج بشكل عام كل خلطات العجائن المستخدمه اوضحت درجة عالية من التثبيت للرصاص ولكن تعتبر افضل الخلطات لتثبيت عنصر الرصاص هي (Pb^{+2} 0.5+ FA15%+85% Slag)SF1 حيث وصلت درجه التثبيت بعد 90 يوم من الغمر في الماء الي 99.98% من القيمه الاصليه المضافه الي الخلطه.