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Review about the effect of chemical activation of industrials waste which is rich by SiO_2 and CaO

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ABSTRACT

Most previous research on the term of alkaline and thermal activation, applied in the presence of cement as a main constituent, mixed with industrial waste like (fly ash, slag, glass...) by certain percentages to give a geopolymers or alkali-activated materials for studying the chemical and physical, as well as mechanical behaviour. These methods carried out by chemical solutions such as (NaOH, KOH, Na_2CO_3...) by different concentrations to facilitate the solubility of the aluminates-silicates, it's depending on the nature of (CaO-SiO_2-Al_2O_3) system in mineral residues, also there is the thermal method cured at a differents temperature between (20 °C and 100 °C) for 24 h that according to studies and researchers, all these methods to protect the environment from the emission of gaseous pollutants into the atmosphere.

Selection and peer-review under responsibility of the scientific committee of the International Symposium on Materials Chemistry.

1. Introduction

Usually, the Portland Cement (OPC) is the first one used binder in the construction sector being its basic component of building materials; However, OPC production contributes to, approximately, 6% of the total anthropogenic global dioxide emissions [1]. Because the production of one ton of cement allows to give about one ton of CO_2 [2,3,4], relied on this problem, the idea of researching industry materials was launched on how to create an eco-friendly material and protect the environment by new ways. Among the methods discovered in recent and previous research, we find chemical activation and thermal activation, or both at the same time, as well as mechanical activation it's the principal one for crushing the raw materials with varying fineness, and it's adopted in the cement industry as a best example.

Among the most widely used methods in recent years, we find the chemical activation method, which allows the development and provision of alternative binders that reduce carbon dioxide emissions and are a recognized option for the environmental situation [5,6]. This type of activation allows two classes of substances to be given the first one is geopolymers; it's manufactured by combined natural and amorphous pozzolanic materials aluminosilicates such as (coal ash and metakaolin, ceramic....) [7,8] and the second one is alkaline activated materials (AAM); we can obtain it by using synthetic materials with an unnatural mineral source like (slag, glass,.... .) and the most importantly, it should be rich by SiO_2 and CaO. In addition the geopolymers, it is considered from sub-group of alkaline-activated materials and gives an encouraging substance in this regard [9]. As well as the geopolymers are inorganic binders that are kept in the room temperature or less temperature, and is formed by alkaline activators, such as water glass (Na_2SiO_3), sodium hydroxide (NaOH), or KOH [7,8]. The structure of the geopolymer is characterized by disorderly connected tetrahedral composed with the silicon cations being replaced by aluminum cations and the charge imbalance resulting from the replacement of cations is compensated by the metals present in the alkaline activators [10]. When compared to cement, we find that geopolymers show good mechanical, thermal, as well as chemical properties that are much better, especially against acid resistance and toxic elements [7,11,12]. Also, its manufacture does not require a high temperature and thus allows the generation of the lowest percentage of generation of carbon gas. In addition to the geopolymer reaction process, it is allowed to be treated by

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polymerization of aluminates and silicate compared to cement is formed by the hydration reaction [7].

On the other hand, we have alkaline activated materials (AAM), it is alternative system mostly elaborated by mixing amorphous materials containing mainly Ca, Si and Al with effective quality alkaline activators, these solid components can increasingly be found in the industrial waste [13,14]. AAM production it provides an opportunity to divert this type of waste into useful and valuable materials [15]. Many factors contribute and intervene in the activation of the mechanism and properties of the materials obtained for the final [16], the type of activators solutions [17], the most widely used waste is glass, slag, fly ash, silica fume….with different percentage mixed with Portland cement or without. Those materials are well known to modify the macro performances of mixtures, the fresh properties and reduce the cement consumption.

The objective of this study is to know the extent of the effect of alkaline activation process on the internal structure of the materials constituting industrial waste, according to the nature of alkaline activators used and the degree of their concentration, as well as the extent to which they are affected by external factors after their manufacture, (e.g. high temperature and others). By summarizing the latest research and developments, the previous research in this field and confirming it as an official launch in preserving the environment and the international economy.

2. Influence of Na_2O content and ratio (Si_2O/Na_2O) of alkaline activator

In general, the effect of the concentration of alkaline activator doping is mainly on the fresh and viscous properties of mixtures (e.g. pastes, mortars), thereof the setting time, on the physical and mechanical properties (e.g. density, water absorption, porosity, shrinkage and strength) in the solid state after the occurrence of chemical and thermal treatment that starts from room temperature is 20 °C and above, and also on the microstructure that differs from one substance to another, according to the type of industrial waste, the proportions of its components, the shape and size of the particles. All of these factors can change with the change of Na_2O content from one mixture to another.

2.1. Effect of Na_2O content on setting time

Usually, for measured the setting time of pastes in the cement we used the Vicat test (per ASTM C 191-18a [18]) placed in room temperature between (20 °C and 25 °C), in order to determine the initial and final setting tine. So we can use the same principle with alkaline activated materials (AAM) in order to know a specific time to maintain their consistence.

Research says, the Alkali-activated slag (AAS) materials, which is prepared by using a chemical activator mixed with granulated slag (GGBFS), is a standard zero cement binder. Because the slag (GGBFS) is calcium aluminosilicate vitreous, it has sturdy latent hydraulic properties. However, the GGBFS needs alkaline activators in order to eluted, Si^{4+}, Al^{3+}, Ca^{2+}, Mg^{2+}, and Na ions from slag and conserved the proceeds reaction [19]. Chang, studied the setting properties of silica-activated pastes it is related to the type of alkaline activator used, and it was concluded that the determination of the setting time is closely related to the increase in the amount of alkaline activator [20]. Today, the effects of the alkaline activator on the fresh properties such as workability and setting of AAM especially when we use the granulated slag, and knowing how to activate mechanism it until it has not been clearly identified [19].

2.2. Effect of Na_2O content on physical and mechanical behavior

Krizan and al. [21] informed that high strength could be expected when the Ms (SiO_2/Na_2O) within approx **of 0.6**–1.5. With further research on inorganic cementitious components which are rich in aluminates and silicates proposed them to use as binders. These binders can be activated by alkaline solution gives them cementitious properties by the process of poly-condensation reaction [22]. Properties of Geo-polymer concrete GPC depend on several parameters such as chemical and physical properties of binders like alkaline solution to binder ratio, pH of alkaline solution, percentage of compounds like SiO_2, Na_2O, CaO, Al_2O_3 etc., molarity of NaOH each has their own significance [23].

The mechanical, physical, and chemical changes due to oxides molar ratios (SiO_2/Al_2O_3 and SiO_2/CaO), and various Na_2O concentrations of treated palm oil fuel ash (TPOFA)-based alkali-activated mortar (AAM) after being exposed to different elevated temperatures up to 1,000 °C were investigated by Mustafa Juma et al [24]. The results indicated that the relative compressive strength (CS) improved significantly from 9.20 to 34.62% after being exposed to 800 °C. This was mainly due to the decrease in the total oxide's ratio of SiO_2/Al_2O_3 and SiO_2/CaO from 14.84 and 6.98% to 4.27 and 2.03%, respectively. The relative CS has increased from 0.0 to 101.38% after exposed to 1,000 °C when Na_2O concentration reduced from 7.1 to 5.5%. This was due to the formation of more N–A–S–H and C–A–S–H gel binders as indicated at 28 days, which were transformed to nepheline ($NaAl(SiO_4)$) and wollastonite ($CaSiO_3$) phases after exposure to 800 °C and 1,000 °C, respectively. However, there are few publications in literature that have focused on the influence of activator on the AAS performance when subjected to elevated temperatures. Chi, M.C. [25] studied durability in high temperate alkali activated slag (AAS) res environment to 800 °C of AAS concrete while using alkaline activator with different concentrations of 4%, 5%, and 6% of Na_2O by slag weight. The results exhibited high temperatures resistance of concrete was improved when increasing the Na_2O concentration. Rashad, A.M. et al. [26] studied the effect of elevated temperatures on the AAS paste activated by Na_2SO_4 with concentrations 1%, 3% of Na_2O equivalent by slag mass. The sample compressive strength was observed to increase slightly with an increase Na_2O concentration after exposure to temperatures from 600 to 800 °C.

3. Effect of high temperature on alkaline activation waste

Most of the research confirmed the tests of temperature effects carried out by various teams have approved the geopolymers and alkaline activated materials have best behavior on the strength in high temperature [27]. Davidovits affirmed that properly produced geopolymer and AAM binders can indicate fire resistance up to 1200 °C [28]. On the other hand, Barbosa and Mackenzie treated the behaviour of a metakaolin geopolymer with an activator that provided sodium silicate and sodium hydroxide. At 100–200 °C, the material shrank only hardly due to water loss. Between the 250–800 °C, the samples conserved dimensional stability [29].

Also the shrinkage was noted due to increasing density and changes in volume resulted by the crystallization and formulation of new phases, at temperature variety from 880 °C to 900 °C, this process was detained and the samples maintained dimensional stability (depending on differences in their composition) up to 1000–1300 °C, and after that they ultimately melted. When Bakharev [30] examined fly ash-based geopolymer with an activator containing Na, she observed shrinkage cracks and a sudden decrease in resistance at 800 °C [27].

4. Conclusion

After all the research and studies we have done, we conclude in the end:

The alkaline activation process contributes significantly to reducing the proportion of industrial waste such as (slag, glass, brick....) by manufacturing it and converting it into high quality building materials. In addition to thermal activation, it also helps in improving the properties of chemically activated materials by increasing the rate of interaction between used materials and chemical activators.

Most researchers have concluded that changing the concentration of sodium hydroxide affects mainly the mechanical and physical aspects. However, there are still unclear matters that are still being studied.

In the end, we can say that there is a way we can rely on the exploitation of materials and reduce their size in the environment and to preserve the raw material.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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