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Review

Synthesis reaction and compressive strength behavior of loess-fly ash based geopolymers for the development of sustainable green materials

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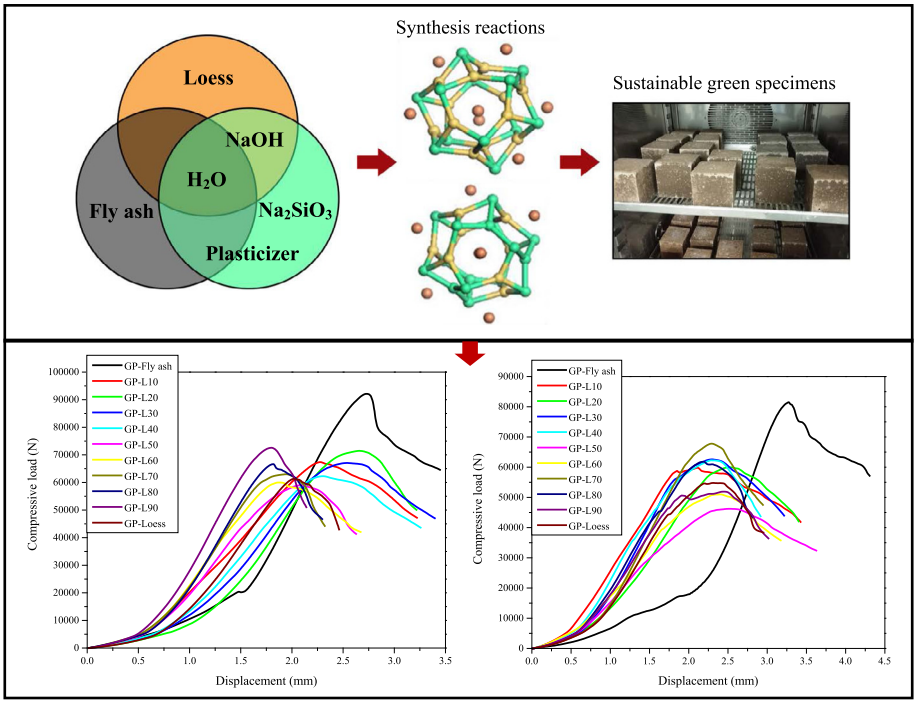
HIGHLIGHTS

- The synthesis reaction and the compressive strength behavior of loess-fly ash based geopolymers for the development of sustainable green materials were investigated.
- The interaction between the two materials was discussed and the desired short-term and long-term properties were achieved.
- The ratios of 20% and 90% loess were identified as the most significant and efficient for the mix design preparation; and the ratio of 50% loess and fly ash reduces suitably the compressive strength.
- Excessive quantities of loess provides a greener alternative to Portland cement.

GRAPHICAL ABSTRACT



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ABSTRACT

This study investigated the potential use of natural loess to activate a geopolymerization reaction, and also to identify the efficient fly ash ratios that is to be combined with loess for the development of a new geopolymer material. A combination of two chemical solutions, sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3) as well as a plasticizer were used to investigate the synthesis reaction and the compressive performance on loess-fly ash based geopolymer pastes. A consecutive addition ratio of 10% of L/FA is added within the range of 10–100% was adopted and the specimen's mass loss measurement, relative density variation and compressive strength comparison were performed at different time frames. The test results showed that the presence of high porosity in the geopolymer specimen makes it a light weight material with limited compressive strength and density directly proportional to its strength

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Mass loss
Density
Compressive strength

factor. It was found that the geopolymer pastes derived from 90% loess and 10% fly ash ratios represent the most significant ratio with compressive strength value of up to 14.54 MPa at 7 days curing period. It was also found that when appropriate proportions of loess and fly ash were used, the interaction between the two materials provided the desired short-term and long-term geopolymer properties. This indicated that a very high quantity of loess at a given lowest fly ash proportion gave high strength and provided a greener alternative to Portland cement with maximum economic solution.

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Contents

1. Introduction

Over the last decades, considerable research has been undertaken to develop energy efficient and sustainable materials. The principle of eco-friendly construction is based on structural design optimization which results in use of raw materials and lower life-cycle costs. The use of industrial waste byproduct materials can produce aluminosilicate reactions such as fly ash, kaolin clay and blast. Also, metallurgical slags can be activated using alkaline solutions at controlled temperatures to synthesize binders that have comparable or superior properties to those of Ordinary Portland Cement (OPC)-based binders [1–3]. However, the production of Ordinary Portland Cement (OPC) concrete produces a large amount of carbon dioxide CO_2. It is reported that, the production of Ordinary Portland Cement is responsible for around 6% of all man-made global carbon emissions [4]. In general, the choice of geopolymer as a binder is increasing due to its low or no CO_2 emission, high compressive strength in record time, and its long-term durability. In this dynamism, a wide range of different geopolymer source materials have been reported and discussed. However, most of them focused merely on the materials such as fly ash, metakaolin, clay, blast furnace, slag, red mud, and recently Completely Decomposed granite (CDG) [5]; and few researches were done on the use of natural loess, as a geopolymer source material.

By definition, loess is an eolian light-coloured fine grained accumulation that is mainly composed of silt mineral and clay particles and has been deposited by the wind. It is very often found around the world, including central Asia, central Europe, northwestern and central USA, South America, northern Russia, and interior Alaska [6–9]. Loess is characterized by an open structure, in which the primary quartz particles are agglomerated with one another by bonding [10]. It has been studied since many years by renowned authors [11–15] and its known as one of the problematic soils with catastrophic failures in geotechnical engineering [16,17]. According to the research by Stevens et al. [18,19], the most complete and thickest loess deposits are found in China, in the provinces of Shanxi, Shaanxi, and Gansu; and the dust deposition and the formation of continuous loess in China's loess plateau began 22 years ago [20].

Most of the previous research was focused on loess stabilization. For instance, Zhen Liu et al. [21] studied the feasibility of loess stabilization with fly ash by using two different activators such as potassium hydroxide and sodium hydroxide; White et al. [22] also investigated the use of fly ash to improve Iowa loess. It was deduced that the stability is partially improved and the long term strength durability of loess are not desirable. In addition, Kim et al. [23] successfully developed a loess paste by geopolymerization process with natural loess and alkali activator, which implies that the use of loess-based geopolymer can be used as a stabilization material in road and pavement construction to consolidate the subgrade, sub-base or the base.

In view of that, we investigated a green source material that can be used, in terms of efficiency and durability, to form high strength geopolymer material. That is why this research work was carried out to study the synthesis and compressive strength performance of natural loess combined with fly ash. The key parameters in this study were to investigate the potential use of loess in order to activate a geopolymerization reaction and to identify efficient fly ash ratios by keeping fixed the activator solution value for the development of sustainable geopolymer green materials.

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