Upcycling of natural volcanic resources for geopolymer: Comparative study on synthesis, reaction mechanism and rheological behavior

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Introduction

Background
• Volcanic ash has several negative impacts on the environment: air pollution, acid rain, water pollution. More sustainable methods are needed to upcycle the volcanic ash. Synthesis of geopolymer is considered an environmentally friendly way to make extensive use of volcanic ash.

Research gaps
• Different geopolymerization reactivity of volcanic ash.
• Rheology of fresh geopolymer mixtures.

Research aims
• The purpose of this paper was to study the reactivity of two different volcanic ash and the effects of different alkali activator concentrations on the mechanical strength, setting time, and rheological parameters of geopolymers based on two kinds of volcanic ash by the comparative method.

Materials and methods
• Two kinds of volcanic ash used in this study were extracted from Shanxi Province (central China) and Jinlin Province (northeast-China), respectively. The former volcanic ash from Shanxi was named as S1, and the latter one from Jinlin was named as S2.
• The sodium hydroxide solution with different concentrations (6, 8, and 10 mol/L) were prepared by mixing analyze pure granular sodium with distilled water.
• Test method: setting time(GBT 1346-2011); Dynamic rheological measurements (Anton Paar MCR 702); Flexural and compressive strength; SEM-EDS.

Results and discussion

The two materials’ XRD curves have a broad hump at about 20 to 30 degrees, which indicates that both of them contain a large number of amorphous components. It can be observed that S2 contains 51.24% amorphous phase, which is higher than 34.56% in S1. The mineral composition of the two types of volcanic ash is significantly different. The crystalline phases detected in the S1 are Augite, Fassaite, Diopside, Diopside ferroan, and Calcium Magnesium Silicate, while S2 consists mainly of feldspar minerals including Albite-high, Sandinina (Na-exchange), Andesine, Labradorite, and Bytownite.

Both the flexural strength and compressive strength of geopolymer prepared with S2 are higher than that prepared with S1 at both 24 h and 72 h curing age and at any concentration level of alkaline activator. The difference in mechanical strength of the resulting geopolymer can be attributed to the higher content of amorphous phase in S2 than that in S1.

Conclusion

Although the volcanic ash S1 and the volcanic ash S2 are very similar in chemical composition, the rheological behavior and geopolymer reactivity of the two kinds of volcanic ash are considerably different under the same conditions. Therefore, it is not possible to evaluate the geopolymerization activity of volcanic ash from chemical composition alone. The optimal alkaline amount of S2 volcanic ash is 8 mol/L, and the 72-hour compressive strength can reach 44.8MPa. The present study has confirmed the potential synergy between utilization of volcanic ash waste and geopolymer industry.