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PII: S1342-937X(16)30411-7
DOI: doi:10.1016/j.gr.2016.11.001
Reference: GR 1702

To appear in: *Gondwana Research*

Received date: 19 July 2016
Revised date: 10 November 2016
Accepted date: 23 November 2016

Please cite this article as: Wang, Kai-tuo, Lemougna, Patrick N, Tang, Qing, Li, Wei, Cui, Xue-min, Lunar regolith can allow the synthesis of cement materials with near-zero water consumption, *Gondwana Research* (2016), doi:10.1016/j.gr.2016.11.001

Lunar regolith can allow the synthesis of cement materials with near-zero water consumption

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Abstract: With the continuous development of science and technology and the human understanding of the moon, many scientists have planned the creation of a space station on the moon using lunar building materials. Environmental factors mainly include large temperature differentials, and the presence of a hard vacuum on the surface of the moon is a huge challenge for the performance of lunar building materials. Geopolymer materials have the following properties: approximately zero water consumption, resistance to high- and low-temperature cycling, vacuum stability and good mechanical properties. Additionally, they meet most of the requirements for use in the lunar environment. Here, we present a potential lunar cement material that was fabricated using volcanic ash and sodium hydroxide solution as activator, based on geopolymer technology. The compressive strengths of the volcanic ash geopolymer specimens processed for 24 hours under vacuum conditions and 30 freeze-thaw cycles in liquid nitrogen are 45.53 and 44.95 MPa, respectively. Additionally, 98.61% of water could be recycled, in consistence with the water recycling-simulated lunar environment in the lab. Although volcanic ash is not equivalent to the lunar soil, we speculate that the alkali activation of lunar soil could be very close to that of volcanic ash because of their similar chemical and mineralogical composition. In summary, this study provides a feasible approach for the development of near-zero water consumption lunar cement materials based on geopolymer technology.

Keywords：lunar regolith; volcanic ash; geopolymerization; cement materials; near-zero water consumption

1. Introduction

The human exploration of the moon consists of three stages: “unmanned lunar probe”, “manned lunar-landing” and “establishing a base on the moon”. At present, the first two stages have been achieved; returning to the moon, development of the moon resources and establishing a moon base have become the competitive focus in the world’s space activities. Considering the growing interest for space exploration, the moon will play a crucial role as a staging post for the next generation of human space exploration missions. The Chinese lunar exploration project has the same vision. The project is now in the manned landing stage, with a plan to establish a lunar base by 2030 (Ouyang, 2005). However, the surface environments of the moon and of the Earth are quite different; hence, establishing a lunar base is very challenging (Taylor, 2014; Wang et al., 2016). These lunar building materials will be designed and prepared based on the following primary considerations (Benaroya and Bernold, 2008): [1] resistance to severe lunar temperature cycles (102.4 K to 387.1 K), [2] stability in a vacuum environment, and [3] minimal water requirements.