Fabrication of Green Concrete by Using Recycled Construction Waste

Jian Zhao¹², Peiwei Gao¹ and Zhengxun Yang*³

¹College of Civil Aviation and Flight, Nanjing University of Aeronautics and Astronautics, No.29, Yudao Street, Nanjing, Jiangsu, China, ³Xinjiang Communication Construction Group Co., LTD, No.840, Wuchang Sideroad, Urumqi, Xinjiang, China.

Email: 16709263@qq.com

Abstract. To fabricate a new green building material without higher CO₂ emission and much energy consumption, recycled construction waste was used as a raw material. Metakaolin was introduced as a cementitious binder instead of traditional Portland cement. NaOH and water glass mixture solution played a role of alkaline activator, then the activity of metakaolin would be released to show an excellent performance. The content of metakaolin was varied to obtain an optimal mechanical property and cost ratio. The specimens were fabricated in room, then cured in air after demoulding, robustness properties were measured which consist of compressive strength and bending strength, and their microstructures were investigated finally.

Keywords. Green concrete, recycled construction waste, low CO₂ emission, geopolymer.

1. Introduction

The amount of concrete usage is only inferior to water around the world. The Portland cement is a vital composition in the conventional concrete. Every ton of cement produced will emit as much carbon dioxide into the atmosphere. In addition, significant amount of nature resources will be consumed for cement production, and it is also highly energy-intensive. [1] At present, a number of researchers that interested in new environment-friendly construction materials developments is increasing. Traditional Portland cement-based concrete is expected to be replaced by geopolymer concrete, because of reducing carbon-dioxide emission. It’s said that the produce of Ordinary Portland Cement (OPC) releases approach 6 times CO2 compared to those of geopolymer based concrete. [2]

As the optimal raw material of geopolymer, for comparatively the high cost of metakaolin, the use of geopolymer construction material is restricted. On the other hand, a lot of construction waste is generated every second all over the world, which are not effectively used. A lot of them are disposed for making new land, at the same time, they also cause building waste pollution. Therefore, effective solution of building construction waste treatment should be regarded.

In this study, green geopolymer mortar was prepared by using recycled construction waste. Metakaolin plays a role of geopolymerization binder and sodium hydroxide (NaOH) and sodium silicate solution mixture was used as alkaline activator. To enhance the strength and durability, replacing part of construction waste fines with silica fume as a bonding matrix, its dosage increase from 0% to 10%, and the samples were cured in the air at room temperature, then their robustness properties were measured and the microstructures were observed.
2. Experimental Procedure

In this experiment, geopolymer samples were prepared with metakaolin, recycled construction waste, silica fume and alkaline activators. Construction waste was supported by a construction company for free, which has been crushed and sieved below 50 mm. Industrial grade sodium hydroxide and sodium silicate are commercial obtained. They were dissolved and mixed to activate the alumino-silicate, which was supplied by metakaolin.

Sample 1, to measure the influence of metakaolin addition on the bonding performance of construction waste geopolymer concrete, firstly, the construction waste is fully mixed with metakaolin with different content of 5%-20%. The powder to coarse gravel ratio was 3:7 by weight. Sodium hydroxide was dissolved in water, resulting in a solution with concentration about 8M. NaOH and sodium silicate solution mixture was prepared 1 day before use with a weight ratio of 1:2. Construction waste and metakaolin were dry mixed for 180 seconds, and then pouring the alkaline solution mixture into the vibrating bowl for preparing geopolymer mortar with another 180 seconds mixed. The well mixed geopolymer mortar was filled into steel molds, whose dimensions are 150×15×15 mm and 50×50×50 mm for bending and compressive strength test respectively. The samples were demoulded after cured in the air at room temperature for one day. Then the samples were cured in air at room temperature for 28 days. The 28-day strengths were tested and the do the observation of microstructure were done by Scanning Electron Microscope (SEM).

Sample 2, to investigate the application of silica fume in geopolymer of construction waste, the construction waste particles were well mixed with silica fume, whose content is from 2% to 10% (wt% of fine powder below 0.075). The other processes were the same as sample 1 and the metakaolin content in this group was 10%.

3. Results and Discussions

The XRD pattern of recycled construction waste can be seen in figure 1. The prime pictures of recycled construction waste are quartz and calcium carbonate, which are chemical stable at room temperature. As seen in figure 2a is the microstructure of sample that contained construction only. Without the addition of metakaolin, there would not be active aluminum silicate-the main ingredient in the formation of geopolymers, which leads to a loose and weak structure. The SiO$_2$ contained in construction waste without liveness can not form strong enough bond. The low bending and compressive strength are the consequent of this structure.

![Figure 1. XRD picture of recycled construction waste.](image_url)

The microscopic structures of samples included metakaolin revealed an evener seeming and hard combined with boundary between construction waste small pellets and gravels, it can be seen less cracks and pores in figure 2b. There are hardly no breakings and same more same structure compared to the thick grading without addition by figure 2a. when metakaolin was added, the body of the sample becomes more compact. The geopolymer synthesization was greatly improved with the increment of
rich alumino-silicate content which was support from metakaolin. Sialate bridges (Si-O-Al-O-) were built up by introducing more and more alumino-silicate. [3] New forming geopolymer links construction waste pellets well, which leads to hard link and high number of compressive strength by measuring, as seen in figure 3.

![Microscopic structures](image)

**Figure 2.** Microscopic structures of (a) just construction waste, (b) 20% content of metakaolin and (c) 10% content of silica fume.

![Graphs](image)

**Figure 3.** Variation of (a) breaking strength and (b) compressive strength of geopolymer based construction waste adding metakaolin.

Compressive strength above 23 MPa could be gotten by 10% silica fume addition, which was a applicable value for mortars. When introducing fine silica fume to the samples, it offered high activity SiO$_2$ for the small particle size. That part of SiO$_2$ played an indispensable role in building the siloxo bridges (-Si-O-Si-O-) in geo-polymerization processing [3]. Since these bridges chains formed by silica fume addition can fix granular material stably, robustness strength was improved sequentially that could be seen as figure 4. And figure 1c appeared tighter and more compact structure compared with those test block added no silica fume.

4. Conclusions
To get a new kind building applicable green concrete, recycled construction waste was used as the raw material, to optimize the concrete performance, metakaolin powder and silica fume were prepared as additives.
Figure 4. Variation of (a) breaking strength and (b) compressive strength of geopolymer based construction waste adding silica fume.

(1) Geopolymerization reaction can not be formed with full construction waste included sample. The specimens can not appear fantastic robustness for the weak link. Large fractures and viods between gelled material and gravels are seen from the microstructure investigation.

(2) By introducing soluble alumino-silicate which is contained in metakaolin, the in-situ formed geopolymer plays a role of cementitious binder to bond the construction waste well. Both bending and compressive strength of the green concrete could fulfill the general building demand. The cost could be further reduced if use some other alumino-silicate rich material to replace metakaolin.

(3) The introduction of silica fume offers SiO2 with high activity, which is beneficial to the formation of geopolymer. Therefore, the adding material-silica fume also improves the mechanical performance of construction waste based concrete and makes the structure more dense. But the amount of that should be paid attention because of its high cost.

(4) The recycled construction waste was inexpensive and can be easily obtained, but the alkaline activator such as sodium hydroxide and sodium silicate still cost much money. It is necessary to look for substitutes for those materials to further enhance the performance of these building materials. To obtain a new type of construction applicable green concrete, recycled construction waste was used as the raw material, to optimize the concrete performance, metakaolin powder and silica fume were prepared as additives.

References
[1] Hardjito D, Rangan B V 2005 Development and properties of low-calcium fly ash-based geopolymer concrete Perth
[2] Yang Z X, Hwang K H, Kim M C, et al. 2010 Strength enhancement of geopolymer-based concretes by mixed alkaline activators Materials Science Forum 658 292-295
[3] Davidovits J 1991 Geopolymers: Inorganic polymeric new materials J. Thermal Analysis 37 1633-1656
[4] Davidovits J 1982 Mineral polymers and methods of marking them US Patent 4 p 349 p 386
[5] Davidovits J 1999 Chemistry of Geopolymeric Systems, Terminology in Geopolymer 99 International Conference France
[6] Gourley J T and Johnson G B 2005 Developments in geopolymer precast concrete Proceedings of the World Congress Geopolymer pp 139-143
[7] Li K L, Huang G H, et al. 2005 Early mechanical property and durability of geopolymer, Proceedings of the World Congress Geopolymer pp 117-120