

Performance of Concrete Sludge Based Geopolymer with Different Alkaline Activator

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Abstract

As a relatively new material, geopolymer concrete offers the benefits as a construction material for sustainable development. It utilized waste materials such as recycled concrete sludge, fly ash and etc. It has a very low rate of green house gas emission when compared to ordinary Portland cement. In this study, the component of geopolymer is recycled concrete sludge, metakaolin and water glass, NaOH and KOH are used as alkaline activator. To improve the mechanical properties, silica fume is also added as a bonding matrix, and the specimens are cured in the air, after that their mechanical properties like compressive strength and bending strength is measured and the microstructures are investigated by SEM as well.

Keywords: geopolymer, binder, concrete sludge, alkaline activator

1. Introduction

Concrete usage around the globe is second only to water. An important ingredient in the conventional concrete is the Portland cement. The production of one ton of cement emits approximately one ton of carbon dioxide to the atmosphere. Moreover, cement production is not only highly energy-intensive, next to steel and aluminum, but also consumes significant amount of natural resources. Nowadays, more and more researches are focused on environment-friendly construction materials. To reduce CO₂ emission, geopolymer concrete is expected to replace the traditional Portland cement based concrete. It's reported that geopolymer based concrete releases only

1/6 CO₂ compared to those of based Ordinary Portland Cement (OPC). But because of the relative high cost of metakaolin, which is the main component of geopolymer, the application of geopolymer construction material is limited. On the other hand, already huge volumes of concrete sludge are generated around the world, most of that is not effectively used, and a large part of it is disposed in landfills, which also caused construction waste pollution. So the solution of that kind of problem should be regarded.

Geopolymer bonded mortar with full metakaolin as raw material for construction applications can reach a 3-day compressive

strength above 800Kgf/cm² by our previous research. From that point we realized geopolymer can be developed as an excellent binder to replace cement if the cost could be reduced.

This research describes the attempt of using recycled concrete sludge as the raw material to fabricate green geopolymer mortar. To test the effect of different alkaline activator on the properties of this new kind of cement, NaOH, KOH and their mixtures were used as alkaline activator. Also, the silica fume was added to enhance the matrix bonding. And the specimens were cured in the air, then their mechanical properties like compressive strength and bending strength were measured and microstructures were investigated.

2. Experimental procedure

In this study, geopolymer was prepared with metakaolin, recycled concrete sludge powder, silica fume and alkaline activators. Metakaolin was commercially obtained and concrete sludge was supported freely by company. The alkaline activators, sodium hydroxide, potassium hydroxide and soluble glass, were used to activate alumino-silicate oxide.

To test the effect of different alkaline activator on the properties of sludge based geopolymer, the concrete sludge powder and silica sand were well mixed with metakaolin addition from 10%~40% (all the percentage here is wt% of powder matrix) by the aid of vibrating machine. The powder to sand ratio was 30:70 by weight. Sodium hydroxide/potassium hydroxide were dissolved into water respectively to get a caustic activator solution with concentration about 10M. And a group of alkali mixture solution with NaOH/KOH mole ratio about 25/75, 50/50, and 75/25 was also prepared. Then alkali

solution and water glass were mixed together and cooled down to room temperature. After that, the mixture was poured into the vibrating bowl to fabricate castable geopolymer mortar. The mortar was filled into steel mould with dimension of 150x15x15mm and 50x50x50mm for bending and compressive strength test respectively. After cured at room temperature for 24hr, demoulded specimens were taken physical properties test and microstructures were also observed by Scanning Electron Microscope (SEM).

3. Results and discussion

The XRD pattern of recycled concrete sludge was shown as Fig.1. The main phase of concrete is CaCO₃ and quartz, which partially provides SiO₂ for geo-polymerization reaction. The microstructure of sample that contained sludge only was shown in Fig.4 (a). Without metakaolin addition, there's no active alumino-silicate existed, which is the main component for geopolymer formation. And the SiO₂ contained in sludge powder was not active enough to fabricate strong bond. So metakaolin with active alumino-silicate and fine silica fume should be added to enhance the bonding according to our previous works.

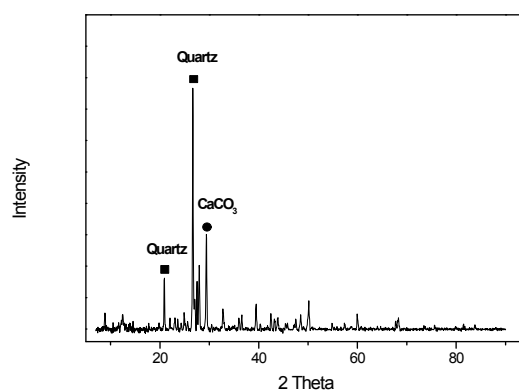


Fig.1: XRD pattern of concrete sludge

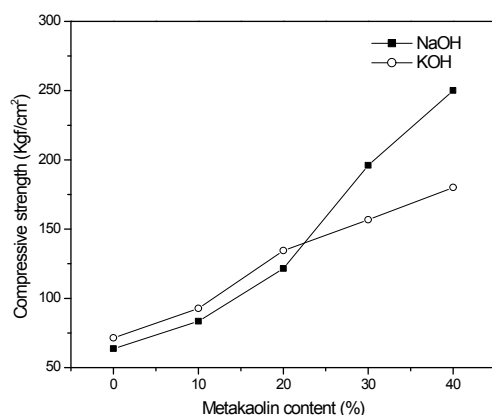


Fig.2: The compressive strength of samples with different alkaline activator

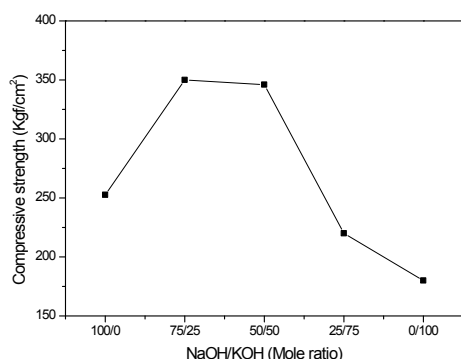


Fig.3: The compressive strength of samples with alkaline mixture

The specimens' bodies became compacter when metakaolin was added. The geopolymer synthesization was much enhanced with the increase of metakaolin content. Sialate bridges (Si-O-Al-O-) formed by the introduction of alumino-silicate. The in-situ formed geopolymer bonded sludge particles and silica sands very well with both activators, lead to a higher compressive strength which was shown as Fig.2. KOH contained samples had a little higher strength when the metakaolin addition was below 20%. And the strength increase was smooth and uniformly. The strength got a sharp increase when over 20% metakaolin added

with NaOH as activator. The microstructures of 40% metakaolin contained sample with NaOH as activator showed a smoother surface and well bonded boundary between sludge matrix and sands grains from Fig 4.(a). There's almost no crack existed and a homogeneous structure was observed compared to the KOH contained sample which showed a crack along the boundary between matrix and sand as indicated by Fig.4 (a).

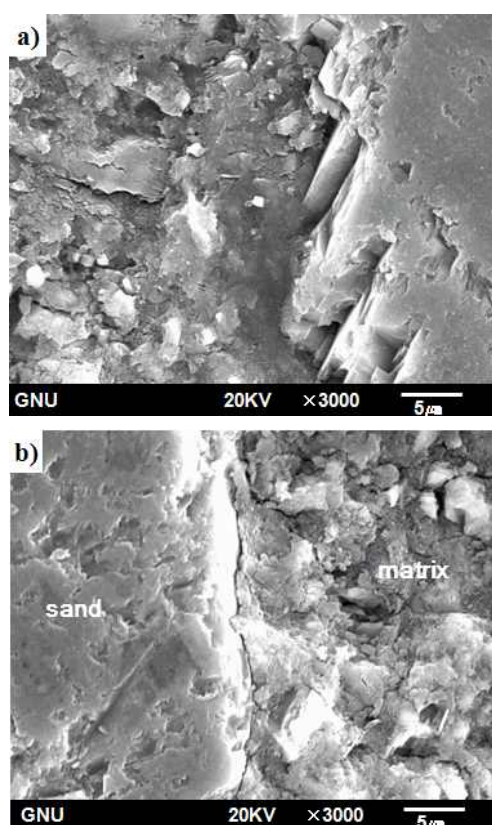


Fig.4: Microstructures of samples with a) NaOH and b) KOH as alkaline activator

When changed the activator to alkaline mixture into 40% metakaolin contained sample, interesting result was obtained. The mixed solution greatly enhanced the strength of mortar when NaOH content was over 50% mole ratio. 50/50 sample showed a little lower strength than 75/25 sample according to the Fig.3. Considered that the pure NaOH

got a better performance than KOH, this phenomenon could be explained by the molecular clearance theory. Because the geopolymer have the empirical formula: $Mn(-(SiO_2)_z-AlO_2)_n, wH_2O$, wherein M is a cation such as potassium, sodium or calcium etc, n is the degree of polycondensation, and z is 1,2,3.... When the minor K^+ diffused into the interspace between bigger Na^+ and OH^- , the polycondensation activating was then enhanced.

4. Conclusion

To fabricate construction applicable geopolymer in a cost-effective manner, recycled concrete sludge was used as raw material, metakaolin powder and different alkaline activators were prepared to optimize the properties.

1. Only concrete sludge contained sample showed poor mechanical properties because of the weak bonding. When adding metakaolin, by introducing alumino-silicate, the in-situ formed geopolymer acted as binder to the raw materials, polymerization bonded particles together well under both NaOH and KOH activator, lead to a better performance. The compressive strength of mortars could meet common construction uses.
2. Pure NaOH activator showed a relatively better effect on the polycondensation compared to that of KOH when metakaolin content was 20% above.
3. The mixture of alkali solutions had superior performance compared with both of its simplex component. It gave a new concept of activator applied to geopolymer fabrication. Due to this research, the other alkaline activator mixtures and optimal ratio could be developed during following studies.

Acknowledgement

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