

Kompozisyon Değişiminin Geopolimer Köpük Beton Temel Özelliklerine Etkisi

M. Serhat BAŞPINAR¹, Cansu KURTULUŞ²

¹Afyon Kocatepe Üniversitesi, Teknoloji Fakültesi, Metalurji ve Malzeme Mühendisliği Bölümü, Afyonkarahisar.

²Afyon Kocatepe Üniversitesi, Mühendislik Fakültesi, Malzeme Bilimi ve Mühendisliği Bölümü, Afyonkarahisar.

e-posta: sbaspinar@aku.edu.tr

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Özet

Geopolimer teknolojisi, uçucu külün kullanımında çevre ve ekoloji üzerindeki olumsuz etkilerinden kaçınarak yeni ve iyi bir çözüm sunmaktadır. Doğal mineraller ve uçucu kül, yüksek fırın cürufu gibi endüstriyel alüminosilikat minerallerinin genellikle NaOH ve sodyum silikatin oluşturduğu alkali ortamda reaksiyona girmesi sonucu üretilebilen inorganik polimerlerdir. Bu çalışmada uçucu kül temel Jeopolimer malzemesi olarak kullanılmıştır. Köpükleştirme maddesi olarak hidrojen peroksit kullanılmıştır. Uçucu kül ve yüksek fırın cürufunun karışım oranlarını değiştirerek farklı örnek serileri hazırlanmıştır. Fiziksel ve mekanik özellikler test edilmiştir. Mineralojik ve mikroyapısal karakterizasyonlar XRD ve SEM teknikleri ile yapılmıştır. Artan yüksek fırın cürufu ilavesi çatlak oluşumuna neden olmuştur. İri agrega ilavesi, kuruma büzülmesini önemli ölçüde azaltmış ve çatlak oluşumunu önlemiştir. Aynı zamanda iri agrega katkısının geopolimer köpük beton bloklarının yoğunluğunun düşmesine yardımcı olduğu gözlenmiştir.

Anahtar kelimeler

Geopolimer;
Köpük Beton; H₂O₂;
Uçucu Kül; Perlit.

Effect of Composition on Geopolymer Foam Concrete Basic Properties

Abstract

Geopolymer technology provides a new and good solution for avoiding the negative effects of environment and ecology on the use of fly ash. Natural minerals and inorganic polymers which can be produced by reaction of aluminosilicate minerals such as fly ash, blast furnace slag, etc. in the alkaline environment were usually formed by NaOH and sodium silicate. In this study, fly ash was used as basic Geopolymer material. Hydrogen peroxide was used as the foaming agent. Different sample series were prepared by changing the mixing ratios of fly ash and blast furnace slag. Physical and mechanical properties were tested. Mineralogical and micro structural characterizations were carried out by XRD and SEM techniques. Increasing blast furnace slag addition caused crack formation. The addition of large aggregates significantly reduced drying shrinkage and prevented crack formation. Likely, it was observed that the coarse aggregate addition contributed to reduce the density of geopolymer foam concrete blocks.

Keywords

Geopolymer; Foam
Concrete; H₂O₂; Fly
ash; Perlite.

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1. Introduction

The development of new binders, as an alternative to traditional cement and concretes, by the alkaline activation of industrial by-products (i.e. amorphous ground slag and fly ash) is a relatively new area and

research topic for the scientific community (Puertas et al. 2003). Use of alkali activated materials in concrete manufacturing has environmental benefits because its production requires less energy than ordinary Portland cement (OPC) and utilises industrial by-products. They have

superior durability in aggressive environments compared to OPC (Tatiana Bakharev, Sanjayan, and Cheng 1999b). On the other hand, Ordinary Portland cement (OPC) contributes significantly to the global CO₂ emissions. Approximately 50–60% of OPC-production-related CO₂ emissions are released from the calcination (decarbonation) of limestone at 1400–1450 °C (Damtoft et al. 2008)(Davidovits 2015). It is worth pointing out that the reduction of anthropogenic CO₂ is now an urgent goal because many scientists estimate that the concentrations of CO₂ and other climate forcing substances in the atmosphere already exceed the safe level (Van Deventer, Provis, and Duxson 2012). Consequently, the development of alternative low carbon binders is recognized as one option to reduce CO₂ emissions (Gartner and Hirao 2015).

The innovation of geopolymers relates to the possibility to harden at room temperature without high treatment temperature and consequently reduced CO₂ emissions, representing an eco-friendly innovative alternative to cement. The term “geopolymer” describes a family of mineral binders that have a polymeric silicon–oxygen–aluminium framework structure. The formation of geopolymers requires reactive precursor materials and a high concentration of the reagents (especially of OH⁻) (Provis and Van Deventer 2009). Geopolymer chemistry generally involves mechanisms such as dissolution of silicates and aluminates in a strongly basic medium, followed by polymerization of surface active groups of particles with the dissolved species to form a solid geopolymer structure. This consists of a network of more or less amorphous SiO₄ and AlO₄, where silicon and aluminum are in IV-fold coordination with oxygen. The presence of alkaline ions such as Na⁺, K⁺, Li⁺ in the network is necessary to compensate the negative charge of Al³⁺ in IV-fold coordination (Ph. Davidovits 2008)(Phair and Van Deventer 2001)(T. Bakharev, Sanjayan, and Cheng 1999). Geopolymers give the potential possibilities to prepare inorganic bonds and building materials from the waste as blast furnace slag, fly ash, kaolinitic substances, etc (Davidovits J. 2008). Geopolymers are important materials which could

be used to replace concrete and some other industrial materials. They possess many favourable properties such as rapid setting and hardening, good long-term properties and durability (T. Bakharev 2005). Thanks to these attractive properties this technology is receiving increasing attention in different application fields like refractory filters, lightweight panels for thermal and acoustic isolation, low cost ceramics and fire protection structures (Toniolo and Boccaccini 2017). Fly ash (FA) is the most used and suitable waste material in geopolymerization due to the huge amount produced worldwide, estimated to be around 780 million tons annually and its great workability (Duan, Yan, and Zhou 2016). The geopolymer technology provides a new good and green solution to the utilization of fly ash, avoiding its negative impact on environment and ecology. Fly ash is generally regarded as a good source material because it is the residue from burning coal in a thermal power plant and consists mainly of silica and alumina. Fly ash has a complex microstructure comprising a mixture of amorphous and crystalline components. The structure and physical properties of fly ash geopolymer are dependent upon a variety of parameters including water content, thermal history, particle size, and the degree of amorphicity (van Jaarsveld, van Deventer, and Lukey 2003).

Shrinkage of concrete at early age is generally considered as a critical parameter for durability design of concrete structures (Tatiana Bakharev, Sanjayan, and Cheng 1999a). Drying shrinkage is a major reason for the deterioration of geopolymer structure and it is interested to discuss (Wongkeo, Thongsanitgarn, and Chaipanich 2012). Most studies of alkali-activated fly ash/ slag have focused on microstructure and mechanical properties whereas shrinkage characteristics of alkali-activated fly ash/slag blended mortar and concrete have been investigated very little. Slag addition to a fly ash affects the shrinkage of a fly ash/slag binder. The lack of research on shrinkage may actually result in some problems for practical applications (Lee, Jang, and Lee 2014). It is well known that drying shrinkage is an everlasting process when

concrete is subjected to drying conditions; this can be explained by the loss of water held in capillary pores of cement paste. It was revealed that the drying shrinkage of concrete progresses with the increase of its unit water content or water/dry mix ratio, which has been referred to as the major factor affecting the drying shrinkage properties (Zwang, Zakita and Hama 2013). In addition that Hansen reported that the coarse aggregate has an influence on the long-term drying shrinkage of concrete. The aggregates play an important role in restraining the shrinkage of the matrix, which could reduce the shrinkage of concrete (Hansen 1987).

The aim of this study was to develop geopolymer by preventing drying shrinkage in view of potential applications in the field of thermal insulation. The geopolymeric matrices were prepared using different proportions perlite as a coarse aggregate.

2. Material and Method

Fly ash (FA) was obtained from the Seyitömer Thermal Power Station Turkey and XRD analysis is given in Figure 1. Blast furnace slag (BFS) was also used in the geopolymer mix. It was taken from Karabük Iron and Steel plant Turkey. In order to examine the effect of perlite addition samples were prepared. The composition of the samples was given in Table 1. Additive amount was given as wt percentage amount of fly ash and blast furnace slag. Alkali activator solution was prepared by mixing 10 M NaOH solution with sodium silicate solution. H₂O₂ (50% concentration) was used in experiments as foaming agent. Foam stabilizer (FS) was used in order to obtain foam stabilization and prevent collapsing of the samples.

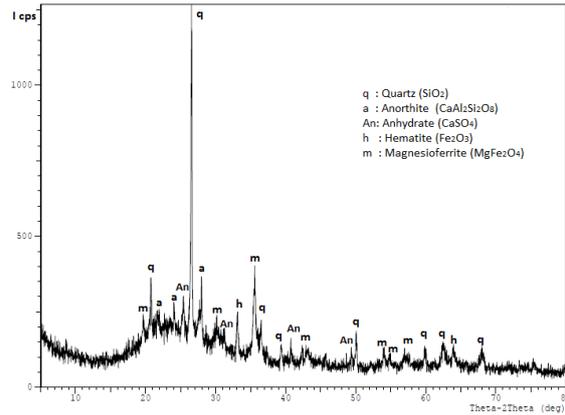


Figure 1. XRD pattern of fly ash.

Chopped short polypropylene fibres were used to prevent early shrinkage of the cast sample. First liquid part of the mixture was prepared and then solid part of the mixture was added. The sodium hydroxide flakes were dissolved in water to make a solution. The sodium hydroxide and the sodium silicate solutions were mixed together and then added to dry materials and mixed for about five minutes. After mixing in shear type mixer, samples were casted into the 100x100x100 mm plastic moulds. Samples were cured at 60 °C for 24 hour to obtain faster geopolymerization.

Two types of sample were produced based on low and high FS content. Mix design of the samples is given at Table 1. Additive amounts were given as percent weight of total weight of FA+BFS. Bulk density of the samples was calculated by simply dividing weight of the samples to volume. Compressive strength measured along the foaming direction.

Table 1. Mix design of the samples and measured properties.

Main Components	% wt
FA	90
BFS	10
Total	100
Additives	Wt % of Main Components
FS	0-0,70
Sodium silicate sol.	50
10 M NaOH	63
Polypropylene fiber	0,2
Perlite (expanded)	0-2,5

Super plasticizer	5,5
H ₂ O ₂	0,85
Bulk density Kg/m ³	520-560
Compressive strength MPa	1,55-2,00

3. Results and Discussions

Drying cracks are the main problem for cellular concrete structures. Fiber and larger aggregate addition usually prevent the cracking problems. Figure 2a. shows the high shrinkage amount at samples which has no expanded perlite content. When expanded perlite was added to the mixture, shrinkage was prevented and better foaming was observed (Figure 2b.)

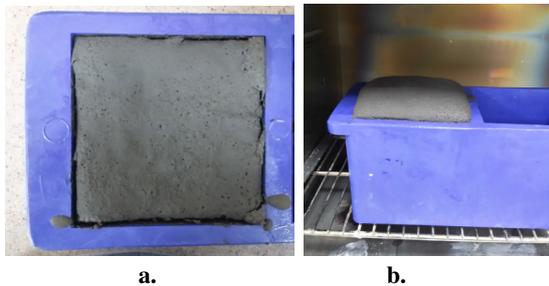


Figure 2. High shrinkage without perlite addition (a.) and lower shrinkage at perlite addition (b.)

All samples were dried at the laboratory conditions. Every day weight of the samples was measured. Calculated density vs. time graphic was drawn (Figure 3). Perlite containing samples reached the constant weight after eleven days. Samples which do not have perlite showed similar drying curve.

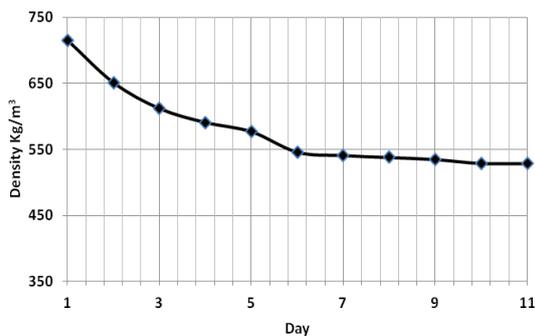


Figure 3. Drying rate of the perlite containing samples.

Figure 4. shows the SEM pictures of fractured surface of the samples. When the foam stabilizer amount was decreased (Figure 4b.), pore size of the geopolymer foam increased. Polypropylene fibers almost save their shape during the preparation steps. It preserved their shape even raising temperature of 50 °C during the mixing of geopolymer mix. Very good binding between perlite particles and geopolymer matrix was observed (Figure 4a.).

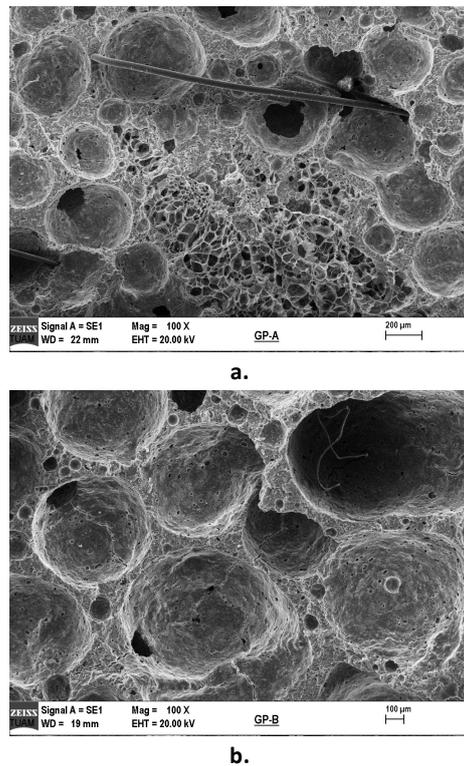


Figure 4. SEM picture of samples (a. high FS, with perlite addition, b. low FS, without perlite)

Bulk density of the samples strongly depends on the foam stabilizer and perlite amount. Bulk density decreased with increased expanded perlite addition. Porous nature of expanded perlite results in decrease in the bulk density. The study shows that, bulk density of the foam samples strongly depends on the FS to H₂O₂ ratio. Addition of larger perlite particles and PP fibers together is very successful for the prevention of drying cracks of the geopolymer foam concrete. Porous structure of the expanded perlite particles also decreased the bulk density of the geopolymer foam. Correct

selection of FS to H₂O₂ ratio is also important for the defect free sample production. Improper ratio selection resulted in collapsing of the foam samples.

Geopolymerization temperature was also important factor for the production of defect free geopolymer foam samples. Geopolymerization temperature higher than 60 °C increased the risk of drying crack formation and resulted in higher shrinkage. On the other hand lower geopolymerization temperatures decreased the foaming ability of the mixtures and lower geopolymerization rate. It is well known that the foam generation ability of the H₂O₂ increases with increased temperature.

According to TSE 13655 standards, geopolymer foam concrete masonry units must have minimum compressive strength of 1,5 MPa. Measured compressive strength of the geopolymer foam samples conform to the standard values. Foam structure and bulk density are the main factors that affect the compressive strength of the geopolymer foam samples. Expanded perlite addition decreased the strength of the geopolymer foam samples. Porous nature of the expanded perlite is the main reason for strength reduction. Figure 4 shows the compressive testing of samples and the resulted cracking patterns. Geopolymer foam samples did not collapse completely after the compressive testing. Although polypropylene fiber addition was useful for the early shrinkage reduction, its addition also affects the strength behavior of the geopolymer foam samples.



Figure 4. Compressive testing of foam concrete and

deformation pattern.

4. Conclusion

Geopolymer foam concrete blocks were successfully produced from fly ash and blast furnace slag without any cracks. Effect of different amount of foam stabilizer and expanded perlite addition was investigated. Expanded perlite addition decreased the cracking tendency of the geopolymer foam concrete.

Excellent bonding was observed between expanded perlite particles and geopolymer foam matrix. Foam stabilizer to H₂O₂ ratio is very important for pore size and bulk density. When foam stabilizer amount increased, pore size of the geopolymer foam was decreased.

Geopolymerization temperature must be correctly chosen for crack free samples. High geopolymerization temperatures resulted in cracks. On the other hand, low geopolymerization temperatures resulted in weak foaming and higher bulk density.

All samples reached to constant weight after 11-12 day drying under laboratory conditions. Compressive strength of the geopolymer foam concrete samples conforms to minimum strength requirements according to the TSE 13655.

Polypropylene fiber addition was successful for the elimination of the shrinkage cracks, but at the same time its addition increased the compressive strength by simple fiber strengthening effect.

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