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Research Article

The Comparison of the Properties of Geopolymer Paste and Ordinary Portland Cement Mortar Produced Using Polycarboxylate Based Admixture

Evren Arıöz[1*], Gamze Saraç[2], Ö. Arıöz[3], Ö. Mete KOÇKAR[4]

[1*] Eskisehir Technical University, Faculty of Engineering, Departmant of Chemical Engineering, Eskisehir, Turkey, (ORCID: 0000-0003-4862-5467), evrenbayram@eskisehir.edu.tr
[2] Eskisehir Technical University, Faculty of Engineering, Departmant of Chemical Engineering, Eskisehir, Turkey, (ORCID: 0000-0003-0407-5192), gamzesarac@eskisehir.edu.tr
[3] Toros University, Mersin, Turkey (ORCID: 0000-0002-4070-514X), omer.arioz@toros.edu.tr
[4] Eskisehir Technical University, Faculty of Engineering, Departmant of Chemical Engineering, Eskisehir, Turkey, (ORCID: 0000-0002-8860-9309), mkockar@eskisehir.edu.tr

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Abstract

Chemical admixtures are generally used in ready mixed concrete production to improve and enhance the concrete properties. Polycarboxylate based superplasticizers are classified as third generation plasticizing admixtures which increase fluidity and workability without decreasing compressive strength. Geopolymers having many superior properties are alternative materials to ordinary Portland cement concrete. Geopolymers are environmentally friendly and sustainable materials because they can be synthesized from waste materials such as fly ash. In this experimental study, geopolymer pastes were produced by using fly ash, 10 M sodium hydroxide, sodium silicate solution and plasticizer. Cement mortars were produced according to TS EN 196-1 standard. Polycarboxylate based plasticizers synthesized at laboratory conditions were used at 1% by weight in both ordinary Portland cement mortar and geopolymer paste. Geopolymer samples were aged for 7 and 28 days at laboratory conditions while cement mortars were aged in water bath. The fluidity values of fresh mixtures were determined. The flexural strength and compressive strength tests were conducted at the ages of 7 and 28 days. The plasticizers had positive effects on cement mortars but unfavorable results on geopolymer. The use of plasticizer increased the fluidity and the strength values in mortars, on the contrary, admixtures caused decrease in the values of geopolymer samples. The highest compressive strength was obtained as 38.3 MPa for mortar sample aged for 28 days and was 15.3 MPa for geopolymer samples.

Keywords: Plasticizer, Cement mortar, Geopolymer, Compressive strength, Workability.

Polikarboksilat Esaslı Katkı Kullanılarak Üretilen Geopolimer Macun ve Normal Portland Çimento Harcının Özelliklerinin Karşılaştırılması

Öz

Kimyasal katkılar genellikle beton üretiminde beton özelliklerini iyileştirmek ve geliştirmek için kullanılmaktadırlar. Polikarboksilat esaslı süperakışkanlaştırıcılar, basınç dayanımını düşürmeden akışkanlığı ve işlenebilirliği artıran üçüncü nesil plastikleştirici katkılar olarak sınıflandırılır. Birçok üstün özelliğe sahip olan geopolimerler, geleneksel Portland çimento betonuna alternatif malzemelerdir. Geopolimerler, uçucu kül gibi atık maddelerden sentezlenebildikleri için çevre dostu ve sürdürülebilir malzemelerdir. Bu deneysel çalışmada uçucu kül, 10 M sodyum hidroksit, sodyum silikat çözeltisi ve plastikleştirici kullanılarak geopolimer hamuru üretilmiştir. Çimento harçları TS EN 196-1 standardına göre üretilmiştir. Laboratuvar koşullarında sentezlenen polikarboksilat esaslı akışkanlaştırıcılar hem geleneksel Portland çimentosu harcında hem de geopolimer macununda ağırlıkça %1 oranında kullanılmıştır.

* Corresponding Author: evrenbayram@eskisehir.edu.tr

Geopolimer numuneler laboratuvar koşullarında, çimento harçları ise su banyosunda 7 ve 28 gün yaşlandırılmıştır. Her taze karışımın akışkanlık değerleri belirlenmiştir. Bütün numunelere 7 ve 28. günlerde eğilme dayanımı ve basınç dayanımı testleri uygulanmıştır. Akışkanlaştırıcıların harçlarının özellikleri üzerinde olumlu etkilerinin olduğu ancak geopolimer üzerinde olumsuz etkileri olduğu gözlenmiştir. Akışkanlaştırıcı kullanımı çimento harçlarında akışkanlık ve dayanım değerlerini artırmıştır, ancak geopolimer numunelerinin değerlerinde düşüşe neden olmuştur. En yüksek basınç dayanımı 28 gün yaşlandırılmış beton numunesinde 38,3 MPa, geopolimer numunelerinde ise 15,3 MPa olarak elde edilmiştir.

Anahtar Kelimeler: Akışkanlaştırıcı, Çimento harcı, Geopolimer, İşlenebilirlik.

1. Introduction

Concrete is a composite material consisting of cement, water, aggregate and if required chemcial and mineral admixtures. Approximately 3 tonnes of concrete is consumed per person each year and increasing by 9% annualy [1,2]. Concrete and mortar are used twice– about 35 billion tons – of any other industrial building material, including wood, steel, plastic and aluminium [3]. Cement is the binder that holds the aggregates together [1]. However, cement production poses an environmental threat due to CO_2 emissions [2]. An increased awareness on the depletion and conservation of resources and environmental protection has led many researchers to investigate environmentally friendly and innovative materials alternative to building materials [4,5].

The cement industry does not comply with sustainable development because the raw materials used in the production process are not recycled and non-renewable materials. Waste materials or by-products of numerous industries such as fly ash, bottom ash, blast furnace slag, ground granular blast furnace, rice husk ash, silica fume can be used to reduce carbon dioxide emissions [4,6].

Geopolymer concrete is an alternative material for traditional concrete which can be produced by different raw materials/combinations of various waste materials or by-products [4]. Geopolymeric materials are environmentally friendly building materials because they do not need limestone, do not create pollution and consume less energy [7].

Geopolymers have a three-dimensional network structure containing silicon-oxygen and aluminum-oxygen tetrahedra linked by bridging oxygen atoms and formed by alkali activation of silica-alumina containing raw materials [8]. The rheology of geopolymer is different from ordinary concrete due to the high viscosity of the alkali activator solution. Although the increase in the concentration of the alkali activator solution accelerates the geopolymer reactions, it decreases the workability [9].

Chemical admixtures are widely used in the production of cement-based materials to improve their performance [10].

Superplasticizers which are produced from petrochemicals significantly to improve the workability and to produce flowable cement-based materials and play an important role in the production of high-performance cement-based materials [10,11,12]. The polycarboxylate superplasticizers have become increasingly important for the last 30-40 years as they significantly reduce the amount of water required in the production of high-performance concrete [13].

The addition of polycarboxylate superplasticizers improves the workability of cementitious materials through electrostatic and steric repulsion and affects the hardened cement properties by altering hydration processes [14]. The use of polycarboxylates has positive effect on the workability, mechanical strength and durability of concrete. It has been found by some researchers that changing the structure of polycarboxylate based admixtures such as molecular weight and side chain length affects some properties like workability retention and compressive strength [15].

2. Material and Method

Mortars were produced according to TS EN 196-1 standard. Ordinary Portland cement, CEN-Standard Sand, water and plasticizer were used to produce mortar samples. Cement mortars were produced with a laboratory mixer with a capacity of 50 dm^3 as specified in TS EN 196-1. 450 gr cement, 225 gr water, 1350 gr standard sand were used in each batch.

Geopolymer pastes were synthesized by using flay ash. 10 M sodium hydroxide solution was prepared 24 hours before the experiment. Sodium hydroxide was mixed with sodium silicate to get homogeneous activator solution. Activator solution was added into fly ash and mixed for 5 minutes with cement mixer same as used in cement mortar.

Polycarboxylate based superplasticizer admixtures were prepared at laboratory conditions copolymerization of methacrylic acid and methacrylate. The admixtures were synthesized at 60°C for 1 and 3 hours. The admixtures were added into the both mortars and geopolymer pastes at 1% by weight. The polymerization degree on the fluidity and compressive strength values were investigated.

Cement mortar and geopolymer pastes were cast into 40x40x160 mm moulds. Mortars were aged for 7 and 28 days in water bath while geopolymer pastes were aged at laboratory conditions. The flow values of each sample were measured by flow table. The flexural strength and compressive strength values were measured for all hardened samples.

3. Results and Discussion

The flow values of each fresh mixture were measured by flow table which was set to 15 seconds. After the funnel was filled, the diameter of the mortar was measured in two different directions. The average values of each measurement for both cement mortar and geopolymer paste were given in Figure 1.

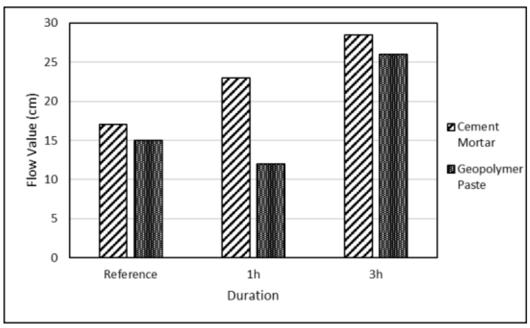

Fig. 1 The flow values of cement mortar and geopolymer paste

The duration of the polymerization of admixtures has positively affected the flow values of cement mortars. The flow values of mortars and geopolymer pastes were increased with the duration. The highest flow value was 28.5 cm for the sample polymerized for 3 hours. The flow value decreased for the geopolymer paste produced with the admixture polymerized for an hour. As the duration of the polymerization of admixtures increased to 3 hours, the flow value increased to about 26 cm that was the highest flow value for geopolymer paste.

The flexural strength of cement mortars aged for 7 days and 28 days are given in Figure 2.

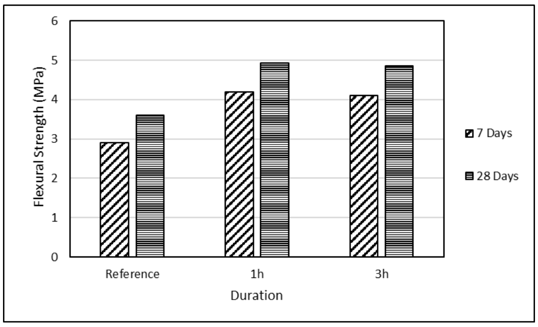

Fig. 2 The flexural strength of cement mortars aged for 7 and 28 days

The flexural strength values of cement mortars produced with admixtures were higher than those of the reference sample. The values of the samples produced with the admixture polymerized for 3 hours were slightly lower than those polymerized for an hour. Test results revealed that the flexural strength values were increased with aging. The highest value was 4.93 MPa for the sample produced with the admixture polymerized an hour and aged for 28 days.

The flexural strength of geopolymer pastes aged for 7 days and 28 days are given in Figure 3.

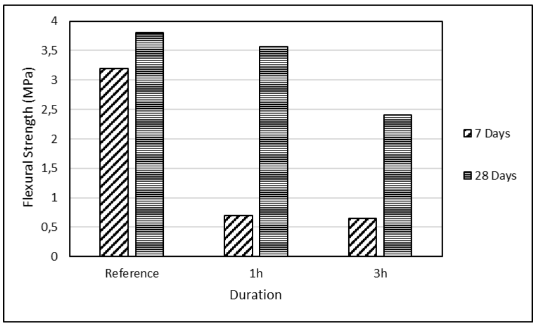

Fig. 3 The flexural strength of geopolymer pastes aged for 7 and 28 days

The flexural strength values of geopolymer pastes for 7 days aging were quite low when compared to those of the reference geopolymer sample. The same decrease was not observed for the samples aged for 28 days. It was observed that the values were decreased with admixture polymerization duration. The highest flexural strengths for the reference sample and geopolymer pastes aged for 28 days were 3.8 MPa and 3.56 MPa, respectively.

The compressive strength of cement mortars aged for 7 days and 28 days are given in Figure 4.

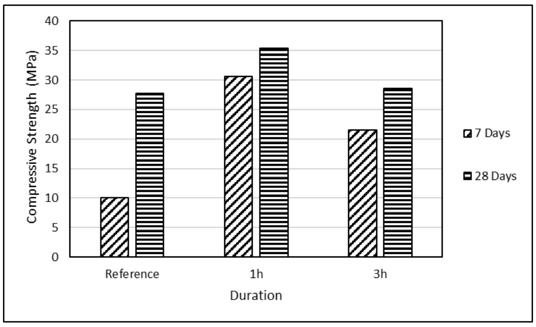

Fig. 4 The compressive strength of cement mortars aged for 7 and 28 days

Test results showed that the compressive strength values of mortars produced with admixtures were higher than those of reference sample. similar to flexural strength values. The highest values were obtained as 30.58 MPa for 7 days and 35.44 MPa for 28 days for samples produced with 1-hour polymerized additive.

The compressive strength of geopolymer pastes aged for 7 days and 28 days are given in Figure 5.

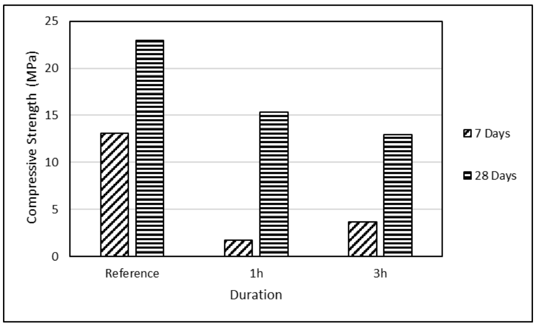

Fig. 5 The compressive strength of geopolymer pastes aged for 7 and 28 days

The compressive strength values of the geopolymer pastes produced with plasticizers were found to be lower than those of the reference sample. The compressive strengths of the reference sample were 13.1 MPa and 22.95 MPa for 7 and 28 days aged samples, respectively. As the polymerization duration of admixtures increased, the compressive strength of the geopolymer pastes aged for 28 days decreased. The compressive strength of the pastes synthesized with the admixture polymerized for 1 hour was 15.3 MPa and 12.96 MPa for the admixture polymerized for 3 hours.

4. Conclusions and Recommendations

The flow value, flexural strength and compressive strength values were compared for cement mortar and geopolymer pastes. The flow values of cement mortars increased with polymerization duration of admixtures. However, the flow values of geopolymer pastes were decreased and increased, respectively with the duration of 1 h and 3h. The flow values of cement mortars were higher than geopolymer pastes. Both flexural strength and compressive strength values of the cement mortar samples were found to be higher than those of the reference sample. However, it was observed that the strength values of the geopolymer samples were lower than those of the reference sample, as opposed to the values of the cement pastes.

The polycarboxylate based admixtures used in this experimental study were synthesized at laboratory conditions. The admixtures affected positively the flowability, flexural strength and compressive strength of the cement mortars but the same results were not obtained with geopolymer pastes. Test results revealed that polycarboxyla based admixture is compatible with cement mortar and resulted in high values, but is not compatible with geopolymer paste. This may be due to the fact that the formation mechanisms of cement mortars and geopolymers are completely different from each other. The synthesis conditions can be changed to enhance the properties of geopolymer pastes.

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