The influence of biomass fly-ash and asphalt emulsion on cement composites properties – a statistical study

Jakub Popławski[1, a)] Małgorzata Lelusz[1, b)]

[1]*Department of Construction and Road Engineering, Bialystok University of Technology*

[a)]Corresponding author: j.poplawski@doktoranci.pb.edu.pl
[b)]m.lelusz@pb.edu.pl

Abstract. The usage of biomass for energy production in Poland has been growing since its accession to the European Union. Largely unutilized, the fly ash derived from its combustion is a growing environmental concern. Considering their similarity and differences from coal fly ashes, a suitable application in concrete technology can be proposed. The aim of this study is to assess the influence of biomass fly ash and anion asphalt emulsion on density of concrete mixture, compressive strength and water absorption of hardened concrete. Statistical methods were used and presented to validate the results.

INTRODUCTION

The entrance of Poland's accession to the European Union changed its energy industry. Since 2004 the government has been following the EU directives that promote renewable energy sources. As a result the percentage of energy supplied from them soared from 0,0% in 2004 to 13,1% in 2015. A prominent source of renewable energy, considering the amount of energy created, is biomass [1]. The strategies that were recently created at the Department of Energy involve further development of green energy. Ecological solutions in cement industry could as well reduce carbon foot-print of the economy. Up to 8% of global CO_2 emissions come from cement industry [2].

Fly ashes are also generated by combustion of biomass. In some European countries this type of fly-ash is utilized in agricultural and forestry industry. Currently, this route of application is prohibited in Poland with heavy metal leaching as the main concern [3, 4].

Utilization of siliceous and calcareous fly-ashes are allowed by PN-EN 197-1 in cement production. The PN-EN 450-1 permits the use of "fine powder of mainly spherical, glassy particles, derived from burning of pulverized coal with or without co-combustion materials, which has pozzolanic properties and consists essentially of SiO_2 and Al_2O_3" as an addition to concrete [5].

The properties of biomass fly ashes exhibit higher variability than those of coal fly ash. The chemical composition and physical properties are highly dependent on type of fuel and the conditions in which combustion takes place. The fly ash derived from wood firing usually contains elevated amounts of calcium oxide, the fly ash obtained from straw combustion contains more alkali metal oxides. Significant differences are also observed in one group of biomass fly ashes. The amount of silica in woody fly ash can be as low as 1,9% and as high as 68,2%. The specific surface can fluctuate in the range of 7,9-40,3 m^2/g [3].

This variability is also observed in the influence of woody fly ash on cement composites' properties. Its 20% binder's mass (b.m.) addition can diminish and retard the maximum hydration heat values of cement binder [6]. In another research identical addition of fly ash had no influence on hydration heat emission [7]. The 20% b.m. addition of woody fly ash can retard the initial setting time by 38% [8]. The influence of biomass fly ash on mechanical properties may vary due to inconsistent pozzolanic properties of those fly ashes [2, 3, 9].

The aim of this study was to assess the influence of biomass fly ash and anion asphalt emulsion on density of fresh mixture, compressive strength and water absorption of hardened concrete. Statistical analysis was performed.

MATERIALS AND TEST METHODS

As a binder material a commercial CEM I 42,5R cement was used. The material conformed the requirements of the PN-EN 197-1 standard. The biomass fly-ash was taken from fluidized bed combustion. Natural sand and aggregate with maximum diameter of 16 mm were used. The tap water was used in the mixing and curing.

The percentage of fly-ash in the binders mass was 20%, 40% or 60%. The amount of anion asphalt emulsion was 0%, 1,5% or 3% of binder's mass. The concrete specimens were cast in 10x10x10 cm molds and completely compacted by vibration. They were tested for compressive test after 7, 28, and 90 days. The density, water absorption tests were performed after 28 days. Cochran's C test and two-factor analysis of variance (ANOVA) with replication where utilized for statistical validation. Cochran's C test compares the highest value of variance for a single series of results with mean value of variances of all series. The ANOVA compares the influence of two factors on response variable, the method estimates the probability with which each of the factors may be the reason for the observed mean results. Additional analysis was done using surface graphs in Statistica 13 software.

TEST RESULTS AND DISCUSSION

The values of Cochran's C test for fresh mix density, water absorption, compressive strengths and hardened concrete density results enabled further statistical analysis of those properties. The ANOVA results showed that the dosage of both emulsion and fly ash had influenced the results of all aforementioned properties. The interaction of both variables was found significant only in the case of water absorption results.

Addition of emulsion caused noticeable decrease in 90-days compressive strength. For example, the addition of 3% b.m. of emulsion resulted in 19% decrease of concrete samples' compressive strength, comparing mean results of series with 20% b.m. addition of fly ash. The increase of fly ash dosage caused observable differences in compressive strength results of samples with 1,5% and 3% b.m. admixture of emulsion. Water absorption of concrete samples with 3% b.m. of emulsion decreased by 35% for samples with 20% b.m. fly ash addition.

CONCLUSIONS

Significant influence of asphalt emulsion and fly ash dosages on physical and mechanical properties of concrete was found. Most noticeably, the 3% b.m. dosage of emulsion diminished water absorption of concrete samples while decreasing their compressive strength. The decrease in water absorption was up to 35% with collateral 19% decrease in 90-days compressive strength in the case of samples with 20% b.m. addition of fly ash.

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