Evaluation of geopolymer binders biopositivity based on low-calcium fly ash

Natalia Ivanovna Kozhukhova
Belgorod State Technological University

Igor Vladimirovich Zhernovsky
Belgorod State Technological University

V.V. Strokova
Belgorod State Technological University nam…

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Evaluation Of Geopolymer Binders Biopositivity Based On Low-Calcium Fly Ash

N.I. Kozhukhova, I.V. Zhernovsky, V.V. Strokova

Belgorod State Technological University named after V.G. Shukhov, Belgorod, Kostyukova, 46

Abstract
The paper deals with the issues related to the comparative assessment of geopolymer binders biopositivity based on a low-calcium fly ash of TPP and Portland cement according to the procedure of materials phytotesting with the seeds of higher plants.

Keywords: technogenic raw materials, fly ash of TPP, geopolymer binder, phytotoxicity.

1. INTRODUCTION

The increasing disposal role of building materials production caused by the intensification of technogenic mineral raw materials use, which is a waste of metallurgy (blast and steel slag), energetics (fly ash), mining industry and other sectors, contributes to a significant reduction of anthropogenic pressure on the environment and the ecosphere of environment and life process in the "man - material - environment" system [1].

However, the technological waste is the product of natural mineral raw materials deep processing, especially with high thermal stages of their technological history, are able to concentrate low bulk earth (usually heavy) elements in a chemically unbound form. The building materials, made on the basis of such man-made materials, are able to provide various types of adverse effects (carcinogenic, allergenic, etc.) on biological individuals. This factor develops the requirement for biological positivity of technogenic mineral raw materials and the materials on its basis.

This is particularly true for new types of binders - geopolymers obtained at the alkaline activation of aluminosilicate materials. These binders act as a promising class of nano-structured materials with real prospects of application in composite materials, as an alternative material to Portland cement [2]. One type of man-made aluminosilicate raw materials used to produce geopolymer binders is the low-calcium fly ash of thermal power plants, obtained as waste by coal burning [3-6].

The aim of this study is the comparative analysis concerning the degree of environmental safety for geopolymer binder based on the fly ash of thermal power plants and the traditional cement binder. In order to perform the experiment the technique of binders phytotesting was used based on man-made materials produced from the seeds of higher plants. The phytotest used in this paper, is a unified method, according to which, the development of the hazard class and the level of non-hazardous waste according to the phytotoxic action is carried out by certain parameters of phytotoxicity [7].

2. USED RAW MATERIALS

The cement binder (CB) hardening under standard conditions, as well as the geopolymer binder (GB 80) subjected during the process of hardening, to heat treatment at 80 °C and hardening at room temperature (GB 25) were used as the study materials to carry out the comparative analysis. Portland cement TSEM1 42.5 (the manufacturer CJSC "Belgorod cement", Russia) and the fly ash of thermal power plants (Matla, South Africa) were used as initial materials. The examples of binders at the age of 28 days were used as initial testing material.

3. PHYTOTESTING PROCEDURE

The preparation of the studied material samples was carried out in accordance to the guidelines [4]. Prior to testing the binder samples were ground to the coarse dispersed state. In order to determine the range of phytotoxic the working solutions were prepared by serial dilutions of binder native extracts with distilled water 1:10, 1: 100 and 1: 1000.

Distilled water was used as a control environment for the cultivation of test cultures. pH values for the obtained working solutions were determined at different stages of their curing (Table 1).

Table 1 pH values of working solutions depending on the degree of dilution and extract exposure time

Age	CB			GB 80			GB 25			Control
	1:10	1:100	1:1000	1:10	1:100	1:1000	1:10	1:100	1:1000	
1 hour	10,69	9,58	8,72	10,73	9,52	8,63	10,9	9,74	8,78	6,7
7 days	10	–	–	10,95	–		11,1	–	–	6,7

The working solutions were incubated for 2 days, then they were placed in Petri dishes (5 ml of each solution) with the filter paper over the entire surface of the dish bottom, along with the test culture. The intact oat seeds (25 seeds per sample) with a predetermined germination rate making at least 95% were used as the latter one. After the preparation, the samples were placed in an thermostat for 7 days.

During the entire experiment 2 control measurements at the age of 3 and 7 days were performed.

The manifestation of phytoeffect degree on the test culture, depending on the used binder extract is shown by Figure 1.

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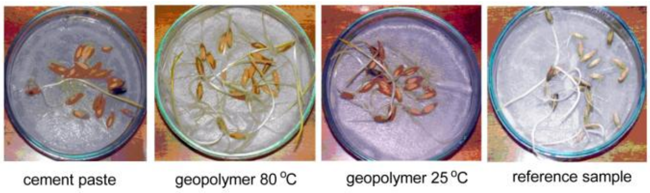

Fig. (1). Intensity of test culture growing in various kinds of extract. Dilution 1:100, 7 days

According to the visual estimation one may assume that the most favorable environment for the germination of test culture grains is the aqueous solution 80 GB.

For the estimation of phytoeffect concerning the studied materials the methodology was used based on experimentally established dependence of the phytotoxic effect on the dilution degree of the aqueous extract. E_T value (braking effect) acts as an output parameter. It is calculated according to the following formula: $E_T = \frac{L_k - L_{on}}{L_k} \cdot 100\%$, where

L_k – the average length of test culture roots in the working solution (mm), and L_{on} – the average length of test culture roots in a test solution (mm).

The dependence of extract type and the degree of dilution influence on the phytoeffect value is shown by the figure 2.

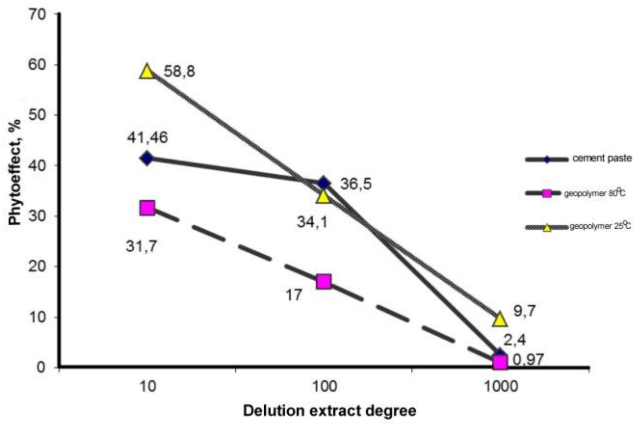

Fig. (2). Phytoeffect dependence on the extract type and concentration

Based on these results we may conclude about the braking effect reduction concerning test culture seed development with an increased degree of dilution. At the same time, the geopolymer binder GB 80, subjected to heat treatment in the process of hardening, has a minimum degree of phytotoxicity. The cement binder and the geopolymer binder (hardened in vivo) values are slightly worse.

It should be noted that the value of phytotoxicity for geopolymer binder GB 80 sample does not exceed the threshold value at the 2nd dilution (1: 100). At that the phytotoxic effect of all studied samples is absent at the 3rd dilution (1: 1000). The latter, according to [4] indicates the minimum degree of toxigenic effects on the environment of biological communities and a man.

4. VISUAL ESTIMATION OF PHYTOTOXICITY

It should be noted that the estimation method of phytotoxicity provides an averaged characteristic of some environment impact, taking into account only the root length of the most active test culture corn. Therefore, regardless of the design data, it is advisable to carry out a visual assessment of phytotoxicity for investigated extracts.

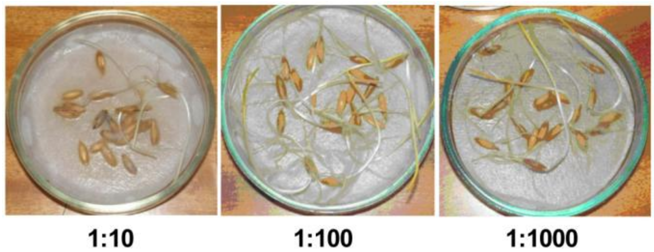

Fig. (3). The intensity of test culture grains growing depending on the concentration of GB 80 aqueous solution

The visual assessment of phytotoxicity level for the geopolymer binder sample GB 80, which has the best values in accordance with the calculated data of phytotoxicity (Figure 2) showed that in spite of the most efficient germination for the extract 1:1000 (Figure 3), the activity of test culture grains is more pronounced with the extract use 1:100.

5. SUMMARY

Thus, the obtained data show that the geopolymer binders based on man-made materials - low-calcium fly ash of thermal power plants do not have higher rates of toxicity. The comparative assessment of phytoeffect showed that the braking effect for the cement binder is higher in comparison to the same value for the geopolymer binder. The environmental feasibility of geopolymer binder heat treatment in the process of its hardening should be noted.

6. CONCLUSION

The obtained results allow us to consider the low-calcium fly ash of thermal power plants as a man-made material with a high level of biopositivity for the production of building materials based on geopolymer binders.

CONFLICT OF INTERESTS

The author confirms that the presented data do not contain any conflict of interests.

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