Processes of forming protective and decorative coatings on concrete at plasma treatment

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Abstract. The development and improvement of technologies for obtaining coatings on various composites using low-temperature plasma is very relevant today. The paper considers the possibility of using broken glass of colored container glasses and other sanitary construction ceramics to obtain protective and decorative coatings on concrete, the selection of the ratio of which will allow getting different tints of the melted layer. To expand the color and decorative characteristics of coatings, mixtures for powder and further compaction were developed. The results of research on plasma treatment of concrete with developed protective and decorative coatings based on broken glass of colored containers, special sanitary construction ceramics and alumina cement are presented. An organoleptic assessment of the quality of coatings after plasma treatment is given. The optimal fractional composition for obtaining protective and decorative coatings on concrete was identified and the optimal speed of plasma treatment of the front layer of the product was established. For practical use, the fraction of colored container glasses and sanitary construction ceramics 0.63–0.8 mm is recommended. By adjusting the speed of the plasma jet passing over the front surface of concrete, they can get a coating with various decorative and relief effects. It was found that at the plasma treatment speed of 10 mm/s a solid coating is formed, and at the plasma treatment speed of 25 mm/s a coating with a bumpy surface is formed.

1. Introduction
Currently, the construction materials industry remains one of the most energy-intensive industries. The use of significant amounts of coal and other organic fuels can lead to even more intense environmental pollution and significantly worsen the given unhealthy environmental situation. In this regard, the development and implementation of environmentally friendly and energy-saving plasma technology in the construction materials industry is very relevant [1–8].

Plasma metallization of concrete and wall ceramics allows obtaining corrosion-resistant coatings, and new types of protective and decorative coatings on glass and ceramics are obtained with plasma spraying [9–11]. On the one hand, plasma and chemical modification increases the chemical stability of the coating and expands the possibilities for obtaining various decorative and color characteristics; on the other hand, it leads to thermal shock and dehydration of hydrosilicates in cement stone and, as a
result, to its softening. This leads to deterioration in the performance of the protective and decorative coating on concrete products, namely, a decrease in strength and frost resistance. Therefore, the use of plasma treatment, which allows developing new technological solutions that improve the technical and operational characteristics of concrete with a protective and decorative coating, is relevant.

2. Materials and methods
Samples of 30×30×30 mm in size from the following raw materials were prepared for research: cement CEM I 42.5 N, quartz sand, water. When forming samples from fine-grained concrete, the mass ratio of Portland cement with quartz sand was 1:3, W/C = 0.4.

For the development of coatings, we used alumina cement of the VGC-1-35 brand, broken sanitary construction ceramics, and broken glass of colored containers. Plasma treatment was performed with an electric arc plasma torch of low-temperature plasma “Gorynych”. The surface texture and color were determined organoleptically.

When developing protective and decorative coatings, the following factors were taken into account: the ratio of alumina cement and filler, filler fractions, and combinations of various types of fillers. Determination of the optimal fractional composition of colored container glasses and other sanitary construction ceramics was carried out experimentally. Fractions of blue and green container glass and sanitary construction ceramics 0.25-0.63 mm; 0.63–0.8 mm; 0.8–1.25 mm were obtained with sieving on laboratory sieves.

Then we prepared samples of fine-grained concrete with protective and decorative coatings. The prepared cement-sand solution was placed on ¼ in metal molds on the ground, which was solidified under usual conditions for 28 days. Then a layer of the developed protective and decorative coatings was placed on the ¼ of top layer and the front surface of the sample was sprinkled with colored container broken glass and sanitary construction ceramics. The powdered layer was compacted with a laboratory roller to obtain a good adhesion of the freshly formed coating to the concrete sample. After hardening for 3 days, plasma treatment of samples with a protective and decorative coating was performed on an electric arc laboratory plasma installation at different speeds of the plasma jet passing over the front surface.

3. Results
The following types of protective and decorative coatings were developed:
– alumina cement: broken glass at a mass ratio of 1:3 with a powder of colored container glass or a mixture of different fractions: 0.25–0.63 mm; 0.63–0.8 mm; 0.8–1.25 mm;
– alumina cement: sanitary construction broken ceramics at a mass ratio of 1:3 with a powder consisting of sanitary construction broken ceramics of various fractions: 0.25–0.63 mm; 0.63–0.8 mm; 0.8–1.25 mm;
– alumina cement: sanitary construction broken ceramics at a mass ratio of 1:3 with a powder mixture of colored container glasses of various fractions: 0.25–0.63 mm; 0.63–0.8 mm; 0.8–1.25 mm.

To expand the decorative and color characteristics, the compositions of mixtures for powdering and further compaction were developed:
– colored container glass and sanitary construction ceramics at the mass ratio of 1:1;
– a mixture of colored container glasses and other sanitary construction broken ceramics at a mass ratio of 2:1.

In order to determine the optimal fractional composition of fillers for protective and decorative coatings, the prepared samples were melted at the optimal speed of the plasma jet passing along the front surface of 10 mm/s. Below there are diagrams of the structure of fine-grained concrete with protective and decorative coating before plasma treatment (Figure 1) and after plasma treatment (Figure 2).
Samples with a fraction of 0.25-0.63 mm made of broken green container glass and sanitary construction ceramics had an uneven color, including black and brown zones due to melting of the surface part of alumina cement. This is because of small fractions of green container glass and sanitary construction ceramics were melted and partially mixed with the resulting melt of alumina cement.

Samples with a fraction of 0.63-0.8 mm from the broken blue container glass had a uniform blue color, from the battle of sanitary construction ceramics – a uniform light beige color.

Samples with a fraction of 0.8-1.25 mm made of broken green container glass and sanitary construction ceramics had a uniform color scheme, but the coating was foamed and bumpy, in some areas of the coating with drips and “melt assembly” (Figure 3).

Thus, for practical use, the fraction of colored container glasses and sanitary construction ceramics 0.63-0.8 mm is recommended. After determining the optimal fraction of the filler for coatings, these samples were subjected to plasma treatment with the regulation of the speed of passing the plasma jet from 2 mm/s to 25 mm/s (Figure 4, 5). Then an organoleptic assessment of the quality of the protective and decorative coating was carried out.

At the plasma treatment speed of 10 mm/s, a solid coating is formed (Figure 4). At a plasma treatment speed of 25 mm/s, the glassy coating is not solid, but similar to the decoration of “mound” glass products (Figure 5). This decor can be used as an independent type for industrial decoration of buildings and structures. The coating on the basis of container glass turned out to be more uniform than on the basis of sanitary construction ceramics, as the chemical composition of sanitary construction ceramics contains more refractory oxides, which do not have time to melt at a plasma treatment speed of more than 20 mm/s.

Figure 1. Structure of fine-grained concrete with protective and decorative coating before plasma treatment: 1 – fine-grained concrete; 2 – quartz sand; 3 – alumina cement; 4 – the broken ceramics or colored container glass.

Figure 2. Structure of fine-grained concrete with protective and decorative coating after plasma treatment: 1 – fine-grained concrete; 2 – quartz sand; 3 – nonablated dehydration zone of protective and decorative coating; 4 – glass-crystal zone; 5 – amorphous zone; 6 – gaseous inclusions.
4. Summary
The fraction of colored container glasses and sanitary construction ceramics 0.63-0.8 mm is recommended for protective and decorative coating compositions. By adjusting the speed of plasma treat-
ment, they can get a coating with various decorative and relief effects. The selection of the ratio of different colors of glass and the composition of sanitary construction broken ceramics makes it possible to obtain different tints of the fritted layer.

5. References

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