The protective-decorative coatings on concrete products, obtained by the method of plasma treatment

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Abstract

The article deals with the peculiarities of producing the protective-decorative coatings on concrete products by means of fusing the face surface with plasma torch. The concrete products with protective-decorative coatings, obtained by means of plasma spraying, have the high aesthetic, performance and application properties. There was designed an efficient formula of the intermediate layer, preventing dehydration of the concrete face surface during the plasma fusing. The intermediate layer includes chamotte with the strictly defined grain size composition and white portland cement. There were researched such basic functional characteristics of protective-decorative coatings, as density of the coating, frost-resistance, porosity, micro hardness, acid-resistance and alkali-resistance.

Key words: concrete products, protective-decorative coatings, glazing, bond strength, plasma treatment.

Introduction

Today, the necessity to provide the population with affordable housing leads to the substantial increase of demand for high-quality and available building materials, including concrete and ferroconcrete products [1]. This requires the manufacturing application of up-to-date technologies [6]. Plasma technologies are widely used both in our country and abroad for producing and treating glass, ceramics and concrete with high performance and aesthetic characteristics [9]. The high temperatures of plasma induce the intensive melting of the material and formation of products with high performance criteria [4,10]. The plasma technologies allow obtaining protective-decorative coatings, both by fusion method and by spraying method [2,7].

The building materials industry is rather an energy-intensive branch of industry, where energy expenditures amount to 10-40% of the overall cost of the product. So the development of using non-conventional energy sources, including low-temperature plasma, in the building materials industry is an important factor of improving performance and aesthetic properties of concrete products, reduction of finishing works costs and raising the products competitiveness [3].

Materials and methods

To improve the aesthetic and performance properties of concrete products, there are used various materials and technologies of laying them on the face surface.

To make the protective-decorative coatings on the concrete products nowadays, there are used such materials as polymer-cement and gypsum-polymer-cement pastes, epoxide-compound-based decorative coatings, finishing coatings on the base of waterborne paints, organo silicone polymer decorative coatings, organo silicone enamels, and decorative coatings of paste compositions with crushed material sprinkling. The main drawback of these protective-decorative coatings is their small service durability.

The protective-decorative coatings, obtained by methods of local thermal action on the face surface of concrete products, are more durable and of high quality.

Producing the protective-decorative coatings on the base of glazes, metals and alloys is a promising way of improving the aesthetic and performance properties of concrete products. For this purpose different methods of heat treatment of the concrete products face surface can be used. Thus for glazing, the concrete is covered with an additional protective layer, which is then fused with screen furnace at temperature 800-900^{0}C. The open flame of gas-burner is used for fusing a glazing slip, preliminarily laid onto the surface.

The most promising is the application of low-temperature plasma for fusing the concrete products face surface and spraying it with enamels, glazes, metals and their alloys, metal oxides and different mining industry waste. By the method of plasma spraying, the non-ferrous metals, glazes, metal oxides were laid on the face surface of concretes with a protective ceramsite layer, 4-5 mm thick, obtained at the "facedown" forming.

There is also known a method of producing decorative concrete products by the method of fusing the prepared face surface with plasma torch and the subsequent curing and hardening within 28 days.

The drawback of these methods is the low bond strength of the coating with the under layer due to partial dehydration and softening of the concrete products face surface as a result of thermal shock [2].

Results and Discussion

The goal of the research is developing the technology of producing protective-decorative coatings on concrete products, which would allow mitigating the effect of thermal shock and preventing dehydration processes in the surface layer.

In order to achieve the desired goal, the following tasks were being solved:

– designing the composition and technology of preparing the intermediate layer;
– designing the optimum modes of producing protective-decorative coatings by the method of plasma spraying; and
– researching the properties of protective-decorative coatings, obtained by method of plasma spraying.

As model sample there was taken concrete prepared of the following raw materials:

– portland cement M-400 by GOST 10178-85;
– mortar sand by GOST 8736-85; and
– water by GOST 23732-79.

The cement-sand ratio amounted to 1:3 and the water-cement ratio was CB (C) – 0,43.

Table 1: The chemical composition of glass, used for glazing concrete products

Type of glass	Weight content, %								
	SiO_2	Al_2O_3	CaO	MgO	Na_2O	K_2O	SO_3	B_2O_3	Fe_2O_3
Domestic glass, green, dyed with chrome *	72.7		6.8	2.0	15.0	2.0	0.5	1.0	0.05
Domestic glass, blue, dyed with cobalt **	68.6	6.3	9.3	-	14.8	1.0		-	0.05
Window glass	71.8-72.4	1.8-2.2	6.4-6.8	-	14.5-14.9	14.5-4.9	0.3-0.4	-	0.2
Show-window glass, unpolished	73.0	1.0	8.6	-	14.8	1.0	0.4	-	0.5
Domestic colorless glass	72.5	1.0	9.0	3.0	14.0	4.0	0.5	-	0. 05

*-content of Cr_2O_3 in domestic green glass – 0.5%

**-content of CoO - in domestic blue glass – 0.002%

As a mixture for forming the intermediate layer of heat-resistant concrete, there was used aluminous cement, defined in the standard GOST 969 and chamotte powder by GOST 23037.

As objects of research, there were used concrete bars 50x50x200mm. The arc-jet plasmotron UPU-8 M was used as a high-temperature thermal source. The acid-resistance and alkali-resistance was determined by GOST 473.1-81 and by GOST 473.2-81 within the accuracy of 0.02 %; the thermal resistance – by method of temperature shock by GOST 17773-72; density – by picnometer method within the accuracy of 0,1 kg/m^3 in the vacuum desiccator, according to GOST 9553-74.

The laying of coatings on the face surface of concrete products was done with a modified plasma burner GN-5p of the arc-jet plasmotron UPU-8M. To obtain protective-decorative coatings on concrete products, there was used colored and colorless broken glass (Table 1). The broken glass was ground in ball mills, sieved and sorted to grading fractions, corresponding to the conditions of plasma spraying. The distance from the snout of plasma burner to the surface of the concrete was 100 mm. The velocity of plasma burner GN-5P passage along the face surface of the concrete amounted to 1.5-2.0 cm/s. The operating conditions of the plasmotron were: operating voltage 30V; current force 450 A. Argon was used as plasma-supporting gas, its consumption amounted to 1.5 m^3/h at pressure 0.25 Pa. The temperature of plasma torch was determined by Sag equation amounting to 8780 K. The bond strength of coating with the under layer was determined by pull test. The porosity of the coating was determined by spot test.

The statistical processing of measured data with calculating mean-square deviation, variation coefficient, confidence interval, accuracy of experience and misses was carried out by standardized procedures, using computer technologies.

During the plasma treatment of concrete products, the structure and properties of the surface layer of concrete are altered [5]. This considerably reduces the concrete products performance characteristics, including the bond strength of coating with the under layer.

It is prescribed that, before the plasma treatment, the intermediate layer consisting of heat-resistant concrete and chamotte powder is formed on the face surface.

The intermediate layer is intended to prevent dehydration of the concrete products surface layer and to reduce the effect of thermal shock, during the plasma spraying of glass powder. In order to increase the bond strength of coating with the under layer, the surface of the intermediate layer must be micro indented [8]. To obtain the micro indented surface, different ratios of coarse and fine fractions of chamotte powder were included into the mixture, the ground glass was sprayed onto the face surface of concrete products and the bond strength of the coating with the surface was determined. The findings of the research are presented in Table 2.

As it is seen from Table 2, at 20% of aluminous cement in the mixture, the best result was obtained for makeup #4 and for mixture with 30 % of aluminous cement makeup #10 is optimal.

The technology of obtaining the intermediate layer have been developed. To prepare the mixture chamotte was ground in a ball mill during 4 hours. The obtained powder was sieved and sorted to fractions, using screens with standard mesh sizes: 1.14; 0.315; 0,63; 1.25 and 2.5 mm.

Table 2: Formulas of the intermediate layer

# of mixtures	Makeup's, mas. %				The bond strength of coating and under layer
	Chamotte, grading fractions, mm			aluminous	
	1,25-2,5	0,63-1,25	0,63-0,315		
1.	10	35	35	20	3,3
2.	15	30	35	20	3,4
3.	20	25	35	20	3,6
4.	25*	20*	35*	20*	3,7*
5.	30	15	35	20	3,6
6.	35	10	35	20	3,5
7.	10	35	25	30	3,5
8.	15	30	25	30	3,6
9.	20	25	25	30	3,6
10.	25**	20**	25	30	3,8**
11.	30	15	25	30	3,3
12.	35	10	25	30	2,8

*, ** - optimum makeup's

The fractions were mixed in a blending tank, and then the necessary amount of aluminous cement was added. The ready mixture was mixed with water. Then the mixture was laid on the face surface of concrete products.
The technology of obtaining the intermediate layer for concrete products is presented in Figure 1 and decorative coatings are presented in Table 3.

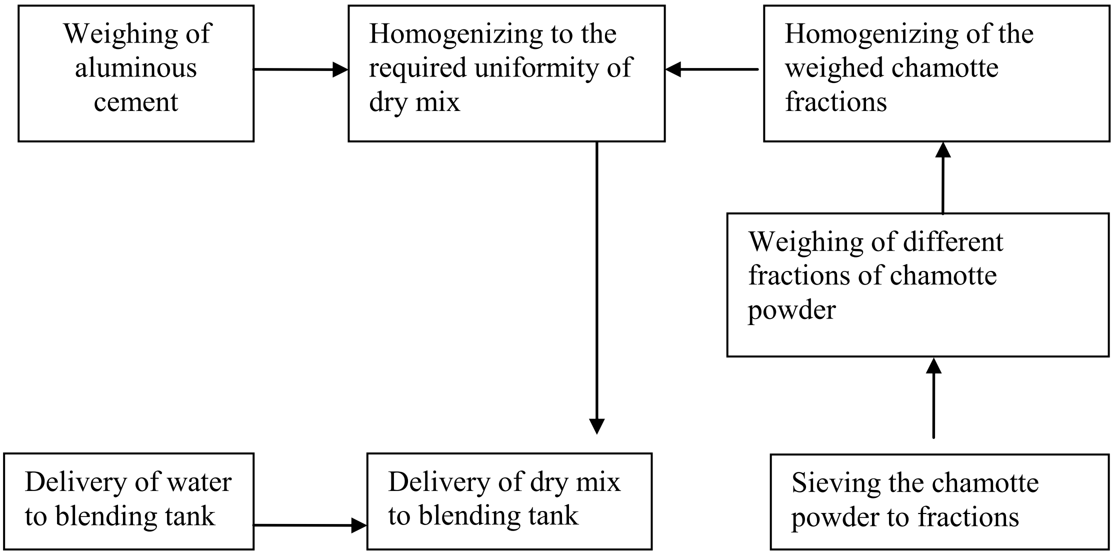

Fig. 1. Technology of intermediate layer producing
The performance criteria of concrete products with protective- decorative coatings

Table 3: The performance criteria of concrete products with protective-decorative coatings

The property	**Dimension**	**Numerical value of the index**
Thermal coefficient of linear expansion of the coating	grad $^{-1}$	$(98.7\text{-}109.1)*10^{-7}$
Density of the coating	kg/m^3	1499-1519
Frost-resistance	Cycles	over 100
Porosity	Mpa	no
Water resistance of the coating	Hydrolytic class	III
Thickness of the coating	µm	250-350
Bond strength of coating with the under layer	Mpa	3.7-3.8
Microhardness	Mpa	5532-5671
Velocity of plasma torch passage	m/s	0,015-0,020
Acid-resistance of the coating	% of mass	98.18
Alkali-resistance of the coating	% of mass	91.73

Conclusion

The carried-out research allowed us making the conclusion that the protective-decorative coating on the base of broken glass is characterized by rather high chemical stability and micro hardness. At the coating thickness 250-350 µm its bond strength with the under layer amounts to 3.7-3.8 MPa. As a result, the coating is more durable.

There is designed a technology of producing protective-decorative coatings on concrete products by method of plasma treatment.

The research also allows us making the conclusion about the opportunity of wide industrial implementation of the developed technology at the enterprises producing concrete products.

References

1. Bazhenov Yu. M.(2005) The high temperature finishing of concrete with vitreous coatings / Bazhenov Yu. M. [and others]. - M.: ASV publishing house,. – 128p.
2. Bessmertny V.S. (2012). Producing the protective-decorative coatings on concrete products /V.S. Bessmertny, P.S. Dyumina., N.I. Bondarenko.- M.: The Belgorod University of Cooperation, Economy and Law publishing office,– 119p.
3. Bessmertny V.S. (2011). Producing the protective-decorative coatings on concrete products by method of plasma spraying / V.S. Bessmertny, N.I. Bondarenko, V.I. Stadnichuk, S.Yu. Vdovina // The Bulletin of Belgorod Shukhov State Technological University. №2. P.121-123.
4. Bolelli G., Lusvarghi L., Manfredini T., Siligardi C., (2007). Devitrification behavior of Plasma – sprayed glass coatings. Journal of the European Ceramic Society, 2(3): 623 – 628.
5. Bolelli G., Cannillo V., Lusvarghi L., Manfredini T., Siligardi C., Bartuli C., Loreto A., Valente T., 2005. Plasma-sprayed glass-ceramic coatings on ceramic tiles: microstructure, chemical resistance and mechanical properties. Journal of the European Ceramic Society. 11: 1835-1853.
6. Nartsev V.M.(2012) Research of the properties of TIOX-coatings formed by means of vacuum-plasma technologies / V.M. Nartsev, Prokhorenkov D.S., Osipenkov N.V., Zaytsev S.V., Yevtushenko E.I. // Fundamental research.-. №11. P.1195-1200.
7. Puchka O.V.(2010) Designing a heat-insulating glass composite with protective-decorative coating on the face surface/ O.V. Puchka, N.I. Minko, M.N. Stepanova, Ya.G. Naumova// Ceramics and refractories.-.- P.181-185.
8. Puchka O.V. (2009) Designing the inorganic decorative-protective coatings for heat-insulating foam glass / O.V. Puchka, N. I. Minko, M.N. Stepanova // Technics and technology of silicates.-. №2. P.9-10.
9. Saucedo E.M., Perera Y.M., Robles D., 2012. Plasma assisted novel production process of glass-ceramic spheres in the quaternary system $CAO\text{-}SIO_2\text{-}AL_2O_3\text{-}MGO$ Ceramics International. 4: 3161-3165.
10. Yao Y., Mofazzal Hossain M., Watanabe T., Tsujimura T., Funabiki F., Yano T., 2008. Effects of feed rate and particle size on the in-flight melting behavior of granulated powders in induction thermal plasmas. Thin Solid Films. 19: 6622-6627.

الطلاء الوقائي التزييني للمنتجات الخرسانية بواسطة طريقة مصباح البلازما

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الملخص

تناقش هذه الورقة خواص إنتاج الطلاء الوقائي التزييني (الزخرفي) للمنتجات الخرسانية بواسطة دمج الوجه بمصباح البلازما. المنتجات الخرسانية بالطلاءات الوقائية التزيينية ممكن الحصول عليها بواسطة رش البلازما بصورة جمالية عالية التطبيق والأداء. حيث تكون كفاءة الطبقة المتوسطة بمنع جفاف سطح الوجه الخرساني أثناء دمج البلازما متظمنة الطبقة المتوسطة (شاموت)، حيث تم بحث الخاصية الوظيفية الأساسية للطلاء الوقائي التزييني (الزخرفي)، كثافة الطلاء، مقاومة الصقيع، المسامية، الصلابة الدقيقة، مقاومة الحامضية، ومقاومة القلوية.

الكلمات المفتاحية: المنتجات الخرسانية، طلاءات وقائية تزيينية، تزجيج، قوة رابطة، معالجة بلازما.