

Corrosion Resistance of Polyester Powder Coatings Using Fillers of Various Chemical Nature

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Abstract. In the article the effect of fillers of various chemical nature on the corrosion resistance of polyester powder coatings in terms of flaking widths and corrosion expansion widths in accordance with DSTU ISO 4628-8: 2012 was reviewed. According to the results of studies, the effectiveness of the use of fillers to increase the corrosion resistance of the powder coating varies depending on the average particle size and crystalline form of the filler was found. As a rule, in order to receive a powder coating based decorative coating you should apply only one layer of paint, while liquid coatings require applying several layers; this increases the time of coating production. The powder coating can be easily utilized and recycled, thus the economic feasibility of production increases.

Introduction

Choosing a type of corrosion protection for construction metal products and structures considering the technical and economic as well as operating factors is a complex problem [1]. Nowadays the main type of the atmosphere corrosion protection is the application of protective coatings, that is, organic paint coatings; metal coatings (zinc, aluminum and cadmium plating); combined coatings (metalized paint coatings); special protection methods (electrochemical, tread, cathode and anode) [2, 3].

Corrosion construction activities using the organic paint coatings became the most common in practice thanks to the relatively low cost of materials and their availability [4]. Main requirements for the coating are good adhesion, impermeability to the aggressive media, durability, technological effectiveness of the repeated coating, cost-effectiveness subject to the useful life. Despite their variety and comparatively low cost, ordinary organic paint coatings have one substantial defect, namely, short useful life, which requires construction materials to be often recoated; this, in its turn, causes large expenses due to the short overhaul life. However, the 60s of the previous century have brought a new type of paint coatings, that is, powder ones [5, 6].

There are two groups of raw materials for manufacturing powder coatings in chemistry: based on thermoplastic film formers and based on thermosetting film formers [7]. Thermosetting powder coatings became the most common in practice; their production volume is approximately 80 % of the total production of powder paint materials.

The formulation composition of the thermosetting powder coating includes five key components: polymer resin, hardener, pigments, functional additives and filler [8]. In general, the polymer resin and hardener play a key role in ensuring required mechanical characteristics and durability of the powder coating. Introducing pigments to paint materials is a main method to regulate decorative properties of coatings – color and non-transparency (coverage ability). Additives are used to regulate processing properties of the powdered color and operating characteristics of the received coating. Fillers are used to achieve two key goals: the first goal is to reduce the cost of material by replacing the most expensive component, that is, polymer resin; the

second goal is to modify functional properties of the material, such as hardness, gloss, flexing life, impact resistance, elastic modulus; permeability; corrosion, wear resistance; fire resistance [9, 10].

The term “filler” includes a wide spectrum of materials. Most of fillers that are used in powder coating are inorganic and are produced usually from hard rocks or ores and turn into powders by virtue of further processing [11, 12]. Since fillers for manufacturing the powder coating mainly are imported, the research [13, 14] has revealed that the use of Ukrainian-made fillers in composition of the powder coating helps receiving a coating with regulated physical and mechanical characteristics.

Thus, the further research to determine the corrosion resistance of powder coatings using various Ukrainian-made fillers provides the valuable information on their selection.

Purpose and Tasks of the Work.

Purpose and tasks of the work was to study the corrosion resistance of polyester powder coatings using various types of fillers.

Materials and Experimental.

Rationale for choosing raw materials for powder coatings. The formulation composition of the powder coating included the following components: film-forming component, fillers, pigment and functional additives.

As a film-forming component we have used the carboxylated polyester resin Crylcoat 2441-3T manufactured by Alnex, which characteristics are shown in the Table 1. In case of carboxylated polyester resin using a structure-forming hardener is a must. In this paper we have used TGIC manufactured by Huangshan.

Table 1. Characteristics of the film-forming component

Type of the resin	Indexes					
	Appearance	Gloss 200/600, %	Viscosity (cP at 200 °C)	Color Gardnes (10 % in DMF)	Acid Value (mg KoH/g)	Temperature cure and time
Allnex 2441-3T	Opaque granules	67	4000-5200	10	30-35	200°C 10 min

As a white pigment we have used K-2190 titanium dioxide manufactured by Kronos. As a rheology additive the flow control agent Resiflow PV88 manufactured by Estron chemical in the quantity of 1,0 % of the powdered color mass has been used. As a degasser benzoin manufactured by Estron chemical in the quantity of 0.6 % of the powdered color mass has been used.

During the research fillers of varying chemical nature have been used, namely: 1 – salts in the form of *barium sulfate* manufactured by ChangshaLianda, *lime* manufactured by the PrSC ‘Sumyagroprombud’, *calcium carbonate (OMYACARB 1-KA)* manufactured by OMYA; 2 – oxide in the form of *ZnO* manufactured by EverZinc; 3 – silicates in the form of *metakaolin* from Hlukhovetsky deposit, *microsilica No. 1* manufactured by Teravion LLC, *microsilica No. 2* manufactured by the Mining Engineering Company LLC, *wollastonite* manufactured by Minco LTD, *talc* manufactured by IMIFABI; 4 – man-made products in the form of *flue ash* from Ladyzhyn Thermal Power Station, *granulated blast-furnace slag* manufactured by *Ilyich Iron and Steel Works of Mariupol*. The characteristics of fillers are shown in the Table 2.

Research methods. Properties of decorative and protective coatings using various types of fillers have been studied in the following sequence: plates (150x60 mm) made of steel Cr3 have been covered by the powdered color (RAL 9016) using various types of fillers in its composition. The powder coating has been coated electrostatically according to ISO 1514:2016 using the spray gun Start 50. The powder coating on the sample plates has been polymerized in the polymerization oven at 200 °C within 10 minutes.

The corrosion resistance of decorative and protective powder coatings using fillers of varying chemical nature has been studied in the salt spray chamber with the condensation of 5 % water solution of sodium chloride (NaCl) on the surface of samples within 1000 hours at 35 °C according to ASTM B-117. The average flaking of the coating and development of the metal corrosion after test have been defined in accordance with the technique of DSTU ISO 4628-8:2012.

Table 2. Characteristics of the fillers

Fillers	Appearance	pH value	Oil absorption, G/100g	Humidity, %	The average particle size, μm	Crystalline form of the filler
Barium sulfate	white powder	7,86	16,1	0,074	1,87	cubical
Fly ash	grey powder	6,7	19,4	0,042	16,43	spherical
Micro silica No 1	grey powder	6,9	27,3	0,15	15,2	spherical
Micro silica No 2	grey powder	6,8	25,1	0,12	2,9	spherical
Wollastonite	white powder	8,2	38,4	0,1	14,02	needlelike
Lime	white powder	8,6	17,2	0,21	5,47	cubical
Talk	white powder	6,7	36	0,2	7,3	spherical
Calcite Omyacarb 1-KA	white powder	7,9	17,1	0,1	2,9	cubical
Blast-furnace slag	grey powder	6,9	18,2	0,1	28,4	spherical
Metakaolin	white powder	6,1	35,4	0,03	10,03	lamellar
ZnO	white powder	8,4	31,2	0,062	2,32	cubical

Results of study

The experimental research on the influence of fillers of varying chemical nature on the corrosion resistance has been conducted in the laboratory of Lacover LLC. Compositions of powder coatings being studied are shown in the Table 3.

Table 3. Compositions of the powder coating

No	Resin	Fillers	Compositions of the powder coating, %				
			Resin	Hardening agent	Filler	TiO ₂	Additive
1	Crylcoat 2441-3T	Barium sulfate	55,8	4,2	18,4	20,0	1,6
2		Fly ash	55,8	4,2	18,4	20,0	1,6
3		Micro silica No 1	55,8	4,2	18,4	20,0	1,6
4		Micro silica No 2	55,8	4,2	18,4	20,0	1,6
5		Wollastonite	55,8	4,2	18,4	20,0	1,6
6		Lime	55,8	4,2	18,4	20,0	1,6
7		Talk	55,8	4,2	18,4	20,0	1,6
8		Calcite Omyacarb 1-KA	55,8	4,2	18,4	20,0	1,6
9		Blast-furnace slag	55,8	4,2	18,4	20,0	1,6
10		Metakaolin	55,8	4,2	18,4	20,0	1,6
11		ZnO	55,8	4,2	18,4	20,0	1,6

As a result of research it has been established that the change in the chemical nature, average particle size and crystal form of a filler in composition of the powder coating has an influence on the change in the corrosion resistance of coatings.

It has been shown that the use of *barium sulfate* in composition of the powder coating (control composition) causes a coating to be flaked off the plate being studied, which is 8.66 mm in 1000 hours of test of the coating in the salt spray chamber (fig. 1). The average expansion width of the metal corrosion is 6.83 mm (fig. 2).

However, the use of fillers in the form of the man-made waste causes the decrease in the corrosion resistance of the coating. For example, the use of the *granulated blast-furnace slag* results in the increase in the average flaking of the coating from 8.66 to 21.5 mm, which is 148 % more than in the control composition (fig. 1). At the same time, the average corrosion width increases from 6.83 to 12 mm, which is 76 % more than in the control composition. In its turn, the use of the *fly ash* also results in the increase in the average flaking of the coating (by 183 %) and expansion width of the metal corrosion (by 31 %) compared to the control composition (fig. 1, fig. 2). The decrease in the corrosion resistance of the coating using the man-made waste is connected with the change in the density of the received coating by increasing the average particle size in the filler in the form of flue ash and granulated blast-furnace slag compared to barium sulfate (Table 2).

In contrast with the man-made waste, the use of silicates in order to increase the corrosion resistance of the powder coating is effective. For example, the use of *metakaolin* helps increasing the corrosion resistance of the coating compared to the control composition: the average flaking width of the coating decreases by 50 %, which is 4.3 mm (fig. 1), and the average expansion width of the corrosion decreases by 40 %, which is 4.1 mm (fig. 2).

We can see the similar result when using another representative of the silicate group, that is, *microsilica No. 2*, in composition of the powder coating, which helps decreasing the average flaking width of the coating up to 6.1 mm and expansion width of the metal corrosion up to 5.5 mm compared to the control composition (fig. 1, fig. 2). This can be explained by the increase in the system density coefficient by changing the crystal form of the filler from cubic one to spherical one, change in the average particle size in the filler and change in the chemical nature of particles, which defines the increase in the corrosion resistance of the coating.

However, the use of *microsilica No. 1* as a filler results in the increase in the average flaking width of the coating (from 8.2 to 11.5 mm) and average expansion width of the corrosion (from 6.83 to 8.53 mm), which is 132 % and 25 % respectively more than in the control composition (fig. 1, fig. 2). This can be explained by the change in the density of the received coating by increasing the average particle size in the filler in the form of microsilica No. 1 compared to barium sulfate.

The use of silicate in the form of *wollastonite* helps receiving the corrosion resistance at the level of the control composition. The average flaking width of the coating is 7.7 mm (fig. 1), which is 10 % less than in the control composition. At the same time, the average width of the metal corrosion increases by 11 % (fig. 2).

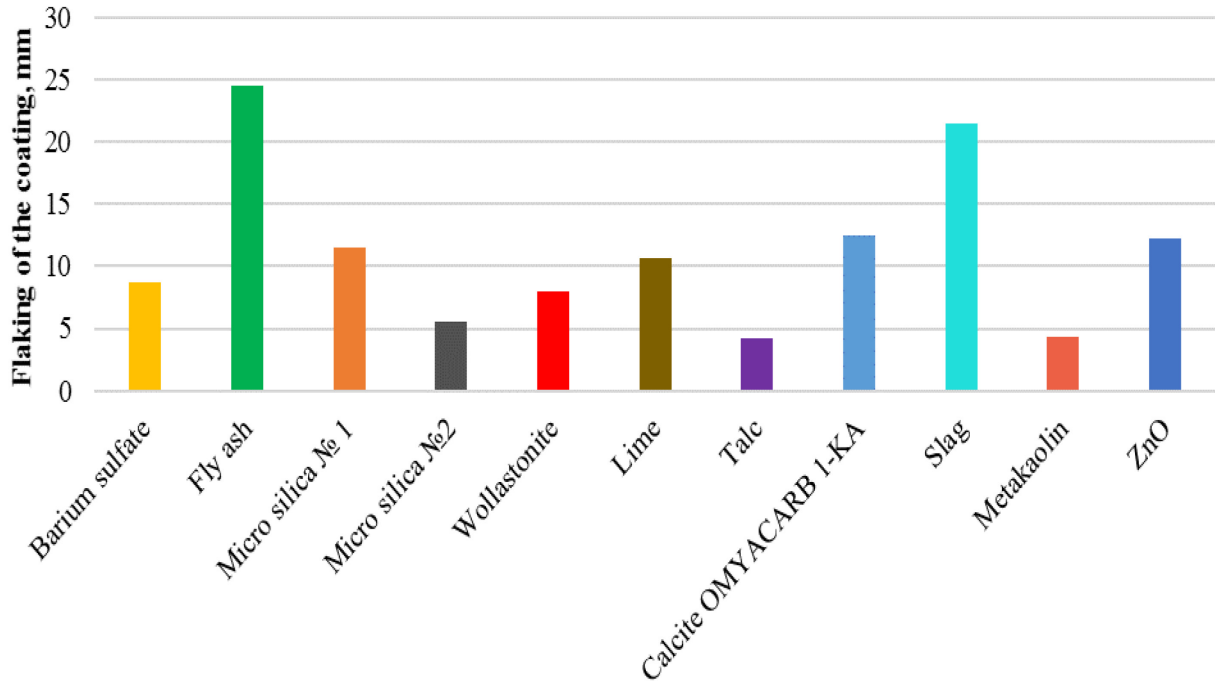


Figure. 1. The average flaking width of the coating.

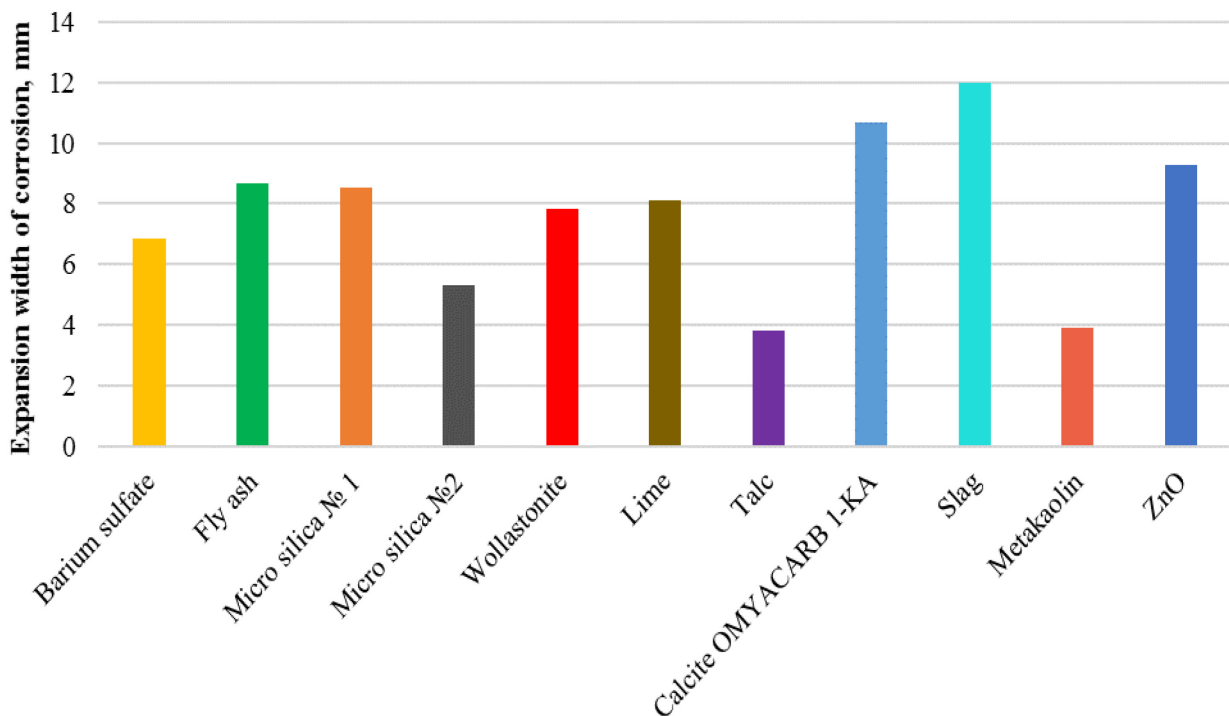


Figure. 2. The average expansion width of the metal corrosion.

The use of the silicate filler in the form of *talc* is the most effective to increase the corrosion resistance of the powder coating, which is marked by the decrease in the average flaking width of the coating from 8.66 (control composition) to 4.2 mm (fig. 1), and decrease in the average expansion width of the corrosion from 6.83 (control composition) to 3.81 mm (fig. 2); this is 52 % and 43 % respectively less than in the control composition.

The introduction of oxide in the form of **ZnO** to the composition of the powder coating causes the increase in the average flaking width of the coating from 8.66 mm (control composition) to 10.2 mm (fig. 1), and average expansion width of the metal corrosion from 6.83 mm (control

composition) to 9.3 mm (fig. 2).

The use of fillers in the form of **lime** and **Omyacarb 1-ka** results in the decrease in the corrosion resistance of the powder coating. For example, when the **lime** is used, the average flaking width of the coating increases by 22 % and is 10.6 mm (fig. 1), and the average expansion width of the metal corrosion increases by 19 % compared to the control composition (fig. 2). The system using **Omyacarb 1-ka** is marked by the increase in the average flaking width of the coating (by 43 %) and average expansion width of the metal corrosion (by 56 %) compared to the control composition (fig. 1, fig. 2). This can be explained by the decrease in the system density by washing calcium compounds away from the powder coating structure during the test, which results in the decrease in the corrosion resistance.

Thus, the replacement of fillers in composition of the powder coating has an influence on the change in the corrosion resistance of the coating. The increase in the average particle size in the filler helps decreasing the corrosion resistance of the powder coating at the expense of change in the system density coefficient. The change in the crystal form of the filler from cubic one to spherical one also helps receiving the more dense system structure with the increase in the corrosion resistance of the coating. The change in the chemical nature of fillers from salts to silicates helps increasing the corrosion resistance of the coating.

Conclusions

During the research we have established that the effectiveness of use of fillers for increasing the corrosion resistance of the coating changes depending on their chemical nature, crystal form and average particle size. According to the corrosion resistance values, the use of silicates in the form of **talc, metakaolin and microsilica No. 1** is the most effective. In addition to that, the analysis of received research results shows that the use of Ukrainian-made fillers being studied in composition of the powdered color helps receiving the coating with regulated corrosion resistance values. The further research is directed to the study of influence of the particle size composition of selected the most effective fillers on the physical and mechanical and operating properties of the powder coating.

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