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Epoxy resin coatings modified with waste glass powder for sustainable construction

Powłoki z żywic epoksydowych modyfikowane odpadową mączką szklaną dla zrównoważonego budownictwa

Abstract

Due to their numerous advantages, epoxy resin coatings are a common way to finish industrial floors. Obtaining coating strength at the level declared by the manufacturer requires preparation of the cement substrate through mechanical treatment, for example, in the form of sandblasting. The next step is the thorough cleaning and vacuuming of the surface and the application of the adhesives. The aim of this research was to improve the strength parameters of a coating in which no adhesive were used. Materials which have a potentially positive effect on epoxy resins are mineral additives. This paper presents the results of tests aimed at improving the adhesion between a concrete foundation and an epoxy resin coating modified with waste glass powder obtained from the production of glass microspheres.

Keywords: epoxy resin coating, glass powder

Streszczenie

Powłoki na bazie żywicy epoksydowej ze względu na liczne zalety są częstym sposobem wykończenia posadzek przemysłowych. Uzyskanie wytrzymałości powłoki na poziomie deklarowanym przez producenta wymaga przygotowania podłoża cementowego poprzez jego mechaniczną obróbkę w postaci np. piaskowania. Następnym krokiem jest dokładne oczyszczenie i odkurzenie powierzchni oraz naniesienie środka sczepnego. Celem badań było polepszenie parametrów wytrzymałościowych powłoki, w której nie zastosowano środka sczepnego. Materiałem mającym potencjalnie pozytywny wpływ na żywice epoksydowe są dodatki mineralne. W pracy przedstawiono wyniki badań mających na celu poprawę przyczepności pomiędzy podkładem betonowym a powłoką na bazie żywicy epoksydowej modyfikowaną odpadową mączką szklaną pochodzącą z produkcji mikrokulek szklanych.

Słowa kluczowe: powłoka z żywicy epoksydowej, mączka szklana

1. Introduction

Industrial floors are crucial elements of buildings because they constitute a significant part of the investment budget [1]. Improper design or manufacture of these floors can result in the requirement for costly repairs. Therefore, industrial floors should primarily be functional and economical [2]. One of the most important aspects during the design and manufacture of the floors is to obtain properties that will ensure their trouble-free operation for a long time [17]. The durability of industrial floors is influenced by technologies and materials which are mainly intended to finish their surfaces [4].

One of the common ways to finish the floor slab, especially in the pharmaceutical, chemical and food industries, is the application of a resin coating. The main advantage of resin floors is their high resistance to aggressive chemicals and the sealing of the top layer of concrete, reducing the penetration of unfavorable media. The resin coating prohibits concrete to dust contact. An additional advantage is the fact that they are easy to clean and have a very aesthetic appearance [3].

This paper presents the results of research conducted on a floor coating based on epoxy resin modified with waste glass powder. This kind of industrial waste is a popular additive in concrete manufacturing [10]. The waste glass powder has been recently proposed to make overlays in the construction industry [14]. The aim of the research was to improve the mechanical properties of the coating, including its adhesion to the substrate, through the application of waste glass powder.

2. Literature survey

In recent years, numerous studies have been carried out in the construction industry to improve the recipes of building materials used. The aim of the research is not only to improve the strength parameters, but also economic aspects, and to facilitate and speed up the process of their incorporation.

The researchers analyzed the ways of modification of industrial floors, which play a very important role in industrial construction. It is particularly important to ensure continuous use of the floor, because any functional defect and subsequent damage to the structure can cause difficult repairs [12]. An important aspect in floors design is the use of a suitable coating to finish their top layer. These coatings have a decisive influence in ensuring adequate durability of floors. The expected load capacity, durability and individual aesthetic considerations determine the trend in the search for the optimal way to make floors. Only the appropriate materials, the proportion of ingredients together with carefully developed production technology will allow investors and users to meet the requirements [7].

The floors can be modified: plastics, i.e. polymers [18], natural materials such as glass or glass powder [13] or waste materials [5]. One of the first materials used to modify the floors were polymers. These contributions added to the mortar allowed to obtain a very thin (from 5–15 mm) and also very durable coating that is the top layer of the floor [6]. Industrial floors can also be modified by adding rinsed sand to epoxy resins. This component is usually used as a filler for floors and mortars based on epoxy resin. As pointed in [19], the appropriate weight ratio of resin components and rinsed sand additive allow for better mechanical properties of mortars. Another way to modify the properties of the floors is by coating the surface with an epoxy solution with a carbonyl solvent. The application of such a solution on the surface of a concrete floor increases its strength by closing the pores and sealing small cracks [20].

3. Materials

3.1. Basic material – epoxy coating

An industrial coating formed from epoxy resin was chosen for the tests. Epoxy resin consists of two components; the first is base 'A', an epoxy resin based on bisphenol A, and the other is component 'B', which acts as a hardener based on aliphatic polyamines (Fig. 1) [16]. The combined ingredients are easy to apply and are characterised by very good flow and self-venting.

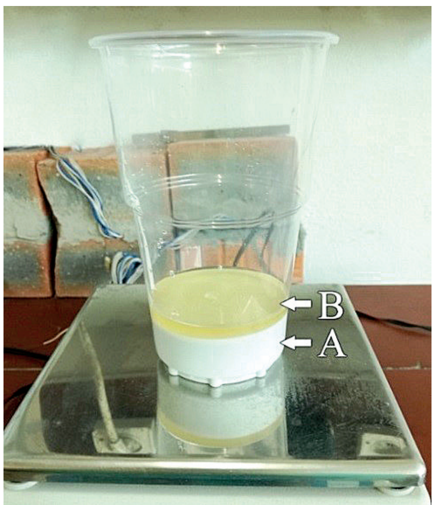

Fig. 1. Coating ingredients – components A and B

This coating is intended for use as a top finishing layer for internal industrial floors subjected to medium and high mechanical loads, e.g. in the automotive industry. This coating makes it possible to finish the floor in a non-slip and smooth form. Its main aesthetic advantage is the possibility of obtaining jointless decorative surfaces with high gloss and different colors.

The epoxy coating is characterised by its high chemical resistance. After hardening, it has high tightness for CO_2 diffusion and creates a surface resistant to impact and damage caused by:

- mineral oils,
- lubricants,
- fuels,

- diluted acids and lyes,
- sea water,
- sewage.

Another advantage is that after curing, the coating becomes neutral to the environment and is very easy to clean. For these reasons, it is recommended for use in rooms with high requirements for cleanliness.

3.2. Additive material – glass powder

The addition of glass powder, silicon dioxide SiO2, was chosen as a positive contribution to the properties of the epoxy-based coating. It is a waste material from the production of glass microspheres. SiO2 is chemically inert; it is stable in water and at elevated temperatures. The SiO2 compound is widely used in industry and is low cost, and glass powder as an additional waste material, the more it generates low costs. Due to its chemical composition, as well as fine graining, silica is typically economical, aesthetic and provides adhesion between the epoxy coating and the concrete substrate.

Fig. 2. Glass powder used in the research

4. Specimen preparation

4.1. Concrete substrate

The tests were performed using concrete foundations taken from existing screed floors. They were previously tested for compressive strength and bending strength [11]. The obtained strength parameters are summarised in Table 1. Eleven foundations were selected and prepared in accordance with the recommendations of the resin coating manufacturer (Fig. 3). In the first step, the top layers of the concrete substrates were mechanically prepared. For this purpose, the surface of the samples was ground using a disc grinder and was then thoroughly cleaned of dust. The surface of the concrete was required to be plain, but at the same time rough, which would guarantee the absorbency of the resin (Figs. 3 and 4). A graft layer was not applied.

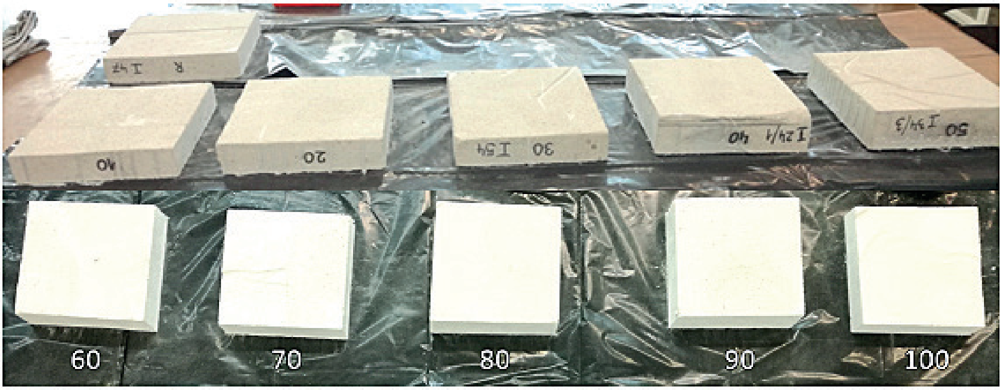

Fig. 3. Concrete substrates used in the research

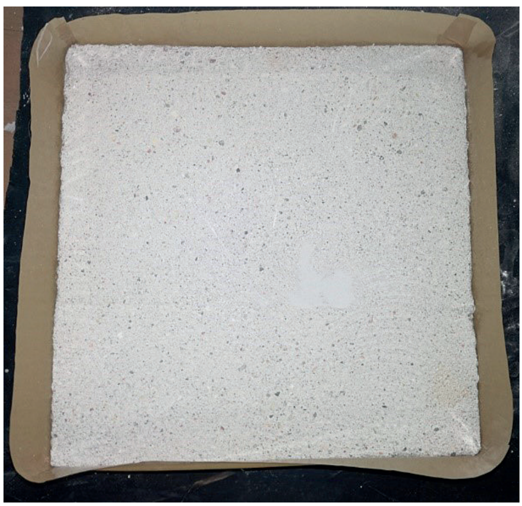

Fig. 4. Concrete substrate after the grinding process

4.2. Preparation and application modified epoxy coating

The components used to make the resin coating have a liquid consistency and a different colour at first. Hardener 'B' was added to the base 'A', then thoroughly mixed until a homogeneous consistency and colour was obtained throughout the entire mass. Mixing the ingredients took three minutes and was performed using a plastic spoon. The ratio (by weight) of component 'A' to component 'B' was 4:1. The glass powder was added in a fixed amount to each sample and mixed again until a homogeneous mixture was obtained (Figs. 5 and 6).

Fig. 5. The stages of preparation of the resin coating (1 – resin, 2 – addition of hardener, 3 – mixing of components, 4 – addition of glass powder)

Fig. 6. Epoxy coating mixed with glass powder

The letter 'R' denotes the control sample (Fig. 3 and Table 1), which was coated with an epoxy coating without the addition of glass powder; numbers 10-100 indicate the weight proportions of the glass powder X content by weight to the coating components (A: B: X). The finished mixture was spread on the surface of the foundations by means of a serrated trowel (Fig. 7a). The coating was then thoroughly vented with a paint roller (Fig 7b). The prepared coating is presented in Fig. 7c. Both activities were performed on the cross, in perpendicular directions. The sample preparation and curing of the resin coating was performed at an air temperature of 21±2°C and a humidity of 50±5%.

a) b)

Fig. 7. Coating application

5. Bond strength tests

Bond strength tests were performed after seven days, in order to obtain the full mechanical load capacity of the epoxy coating used. The test of the adhesion of the coating to the concrete substrate was performed using the pull-off method at three points for each sample (Fig. 8) [15].

The pull-off test is a semi-destructive method and is performed by slight destruction of the top layer of the material. Proper preparation of the concrete surface has a very significant effect on the properties of the coating [8, 9]. A steel disc is glued to the surface to be tested by means of epoxy glue, then an incision is made around the disc to a depth greater than the thickness of the coating. After hardening of the adhesive, the disc is pulled off using a measuring device that displays the measured readings. In this study, detachment of the measuring disc always occurred at a shallow depth in concrete (Fig. 10).

Fig. 8. A view of the test bench for pull-off testing

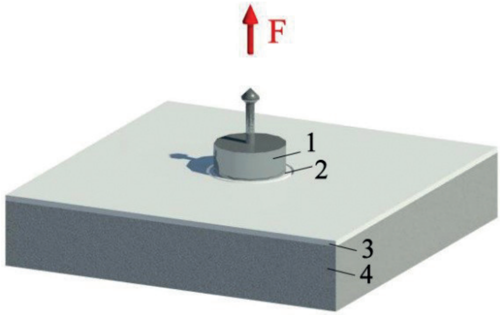

Fig. 9. Peeling off the disc (1 – steel disc, 2 – epoxy adhesive,3 – epoxy resin coating, 4 – concrete substrate)

Fig. 10. View of the sample before (left) and after (right) detachment of the steel discs

6. Results

Table 1 presents the results and the average pull-off strengths for individual concrete substrates.

During the sample preparation, it was observed that by increasing the amount of added glass powder, the density of the mixture, the mixing time, and the precision of mixing process was increased. The mixing force needed to be increased, especially for samples 80, 90 and 100. For samples from 10 to 40, the resin spread very well over the surface of the concrete substrates and self-levelled. Further increases in the content of the glass powder caused a gradual decrease in the self-levelling ability of the coating and the formation of small irregularities. Coverage of the concrete substrates with 80, 90 and 100 coatings was not feasible.

During coating the control sample 'R' with an epoxy resin layer, without the addition of glass powder, the roller absorbed the largest amount of the mixture in comparison to the other samples. According to the manufacturer's recommendations, the average peel strength, tested by the pull-off method, should be min. 1.5 MPa. However, individual results should not be less than 1.0 MPa. All samples obtained results in line with the above requirements.

Table 1. Experimental results

Designation of concrete substrate	Compressive strength of concrete substrate	Bending strength of concrete substrate	The proportions by weight of glass powder content *X*	Measurement from the pull-off method [MPa]			Average pull-off strength	Stan dard deviation
	[MPa]	[MPa]		A	B	C	[MPa]	[MPa]
I 47	14.2	1.7	R-0	2.59	2.70	2.83	**2.71**	0.120
I 50	12.5	1.8	10	2.30	2.40	2.24	**2.31**	0.081
I 53	16.5	1.4	20	2.25	2.54	2.51	**2.43**	0.160
I 54	10.3	1.4	30	1.82	1.87	1.64	**1.78**	0.121
I 24/1	14.0	1.5	40	3.38	3.05	2.77	**3.07**	0.305
I 34/3	15.7	1.6	50	2.69	2.81	2.86	**2.79**	0.087
II 122a	15.5	3.0	60	2.12	2.18	2.30	**2.20**	0.092
II 1.25b	14.9	2.3	70	2.33	2.27	3.00	**2.53**	0.405
II 107	8.7	2.1	80	2.17	2.07	3.08	**2.44**	0.557
II 121/2	10.9	3.0	90	2.76	2.79	2.27	**2.61**	0.292
II 121/3	13.0	2.9	100	2.13	2.37	1.87	**2.12**	0.250

7. Conclusions

This work presents an experimental investigation of coatings from epoxy resin modified with waste glass powder. The main conclusions of the tests are as follows:

- The preliminary tests have indicated that glass powder is a material that affects the adhesion between the coating and the substrate. An additional advantage is the increase in the efficiency of the coating caused by a decrease in the absorptiveness of the roller;
- For some samples, the addition of glass powder improved the adhesion between the epoxy resin coating and the concrete substrate. The highest average peel strength of 3.07 MPa was obtained for sample 40. Values lower than the reference sample (<2.71 MPa) result from inferior strength parameters of the concrete substrates. Therefore, the increase in adhesion is visible only in the graphs of functions of three variables, which also take into account the strength of the underlay concrete;
- Based on the results, it was found that the optimal weight ratio between the epoxy coating components 'A' and 'B', and the content of glass powder 'X' is (A: B: X = 100: 25: 40).

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