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TESTS OF SELECTED PROPERTIES OF CONSTRUCTION MORTARS MODIFIED WITH WASTE GYPSUM BINDER OBTAINED IN THE FLUE GAS DESULPHURIZATION PROCESS

BADANIA WYBRANYCH WŁAŚCIWOŚCI ZAPRAW BUDOWLANYCH, W ASPEKCIE ICH TRWAŁOŚCI, Z ODPADOWYM SPOIWEM GIPSOWYM OTRZYMANYM W PROCESIE ODSIARCZANIA SPALIN

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Abstract

The article presents the results of tests of selected properties of plastering mortars that are based on natural gypsum binder, as well as on synthetic gypsum binder from the flue gas desulphurization process. The mortars were analyzed with regards to their durability. For the purpose of the publication, the recipe (quantitative) compositions of the plastering mortars, which differed in terms of the type of used setting retarder (PlastRetard PE and tartaric acid A200), were designed. The mortar recipes were determined experimentally, assuming that the beginning of the setting time was 120 min (the average beginning of the setting time for currently available building mortars), and that the content of the binder was 70%. The assumed research program included tests of flexural and compressive strength, surface hardness, and the adhesion to the substrate. The results of the research confirmed the possibility of modifying the recipe compositions of gypsum plastering mortars.

Keywords: plastering mortars, flue gas desulphurization gypsum, retarders

Streszczenie

W artykule przedstawiono wyniki badań wybranych właściwości zapraw tynkarskich na spoiwie gipsowym budowlanym i syntetycznym pochodzącym z procesu odsiarczania spalin, w aspekcie ich trwałości. Na potrzeby publikacji zaprojektowano składy recepturowe zapraw tynkarskich różniących się rodzajem użytego opóźniacza wiązania (PlastRetard PE i kwas winowy A200). Receptury zapraw zaprojektowano metodą doświadczalną przy założeniu początku czasu wiązania wynoszącym 120 min (średni początek czasu wiązania dla dostępnych zapraw budowlanych) i zawartości spoiwa na poziomie 70%. Założony program badawczy obejmował wykonanie badań wytrzymałości na zginanie i ściskanie, twardości powierzchniowej oraz przyczepności do podłoża. Otrzymane w toku badań wyniki potwierdziły możliwość modyfikowania składu gipsowych zapraw tynkarskich spoiwem syntetycznym pochodzącym z procesu odsiarczania spalin.

Słowa kluczowe: zaprawy tynkarskie, gips z odsiarczania spalin, opóźniacze wiązania

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1. INTRODUCTION

Taking into account the pace of development of innovative technologies, there is a growing demand for combining various industrial branches. A particularly desirable phenomenon is the possibility of using materials that are seen as waste in one industry, but in another fit perfectly into the process of creating "something new". The chemical industry provides many by-products (waste) that pose a significant problem for a sustainable economy. One of them is synthetic gypsum, which is derived from the flue gas desulphurization process. This gypsum, and the products made from it, seem to be one of the most interesting examples of combining the chemical industry with the construction industry. The paper deals with the problem of the possibility of using gypsum from flue gas desulphurization as a full-value binder in plastering mortars. The storage and recycling of such waste is now a subject that is worth considering, and this is reflected in numerous publications [1-7]. The authors' experience to date confirms that this type of binder can be a full-value substitute for natural building binders in the recipes of building mortar. The strength parameters of such mortars are similar, or sometimes even exceed the parameters of mortars that are developed based on natural binders.

The scope of the undertaken research activities included the designing of quantitative and qualitative compositions of gypsum plastering mortars that meet the standard requirements for these materials. Moreover, the conducted studies involved the testing of selected properties of plastering mortars that were prepared based on building and synthetic gypsum. Flexural and compressive strength, surface hardness, and the adhesion to the substrate were analyzed during the testing.

2. THE RECIPE COMPOSITIONS OF THE DESIGNED MORTARS

The compositions of the designed plastering mortars included: gypsum binder (synthetic gypsum from the flue gas desulphurization process and building gypsum), setting retarders, lime powder, methylcellulose, perlite, and hydrated lime. The proportions of the individual components were determined experimentally, assuming that the beginning of the setting time was 120 min (the average beginning of the setting time for currently available building mortars), and that the binder content was at the level of 70%.

The synthetic gypsum that was used in the recipes came from a petrochemical plant located in Poland. In order to obtain a full-value binder, it was calcined at a specific temperature and for a specific time. After the calcination process, the synthetic binder lost, on average, approximately 25% of its weight. Figure 1 shows the synthetic gypsum before and after the calcination process.

Fig. 1. The synthetic gypsum before and after the calcination process

In order to reach the assumed beginning of the setting time (approx. 120 min), it was necessary to use setting retarders. For this purpose, two retarders were used: PlastRetard PE and A200 tartaric acid. Unfortunately, the correct dosage of retarders during the execution of mortars poses a problem. The amounts of retarders, which were declared by the manufacturers with regards to extending the setting time, did not coincide with the actual extension that was obtained in the study. Additionally, the matter was complicated by the fact that e.g. a difference of only 0.0002% of PlastRetard PE retarder per 1 kg of mortar could delay the setting time by even 10 ÷ 15 minutes. A similar relationship was observed in the case of the A200 tartaric acid.

A list of the prepared mortars (with the adopted designations) is presented in Table 1, while the recipe compositions are shown in Table 2.

Table 1. List of the made plastering mortars

Type of mortar	Adopted designation	Used retarder
Plastering mortars based on building gypsum (reference mortars)	AK.GB.TR	PlastRetard PE
	AK.GB.TK	Tartaric acid A200
Plastering mortars based on synthetic gypsum (experimental mortars)	AK.GS.TR	PlastRetard PE
	AK.GS.TK	Tartaric acid A200

Table 2. Recipes of the made plastering mortars

Mortar designation	The content of ingredients of the gypsum plastering mortars [g]						
	binder	lime powder	methyl cellulose	perlite	hydrated lime	retarder	water
Plastering mortars based on the building gypsum							
AK.GB.TR	700.00	245.95	3.00	29.00	50.00	1.03	620.00
AK.GB.TK		245.93				0.40	
Plastering mortars based on the synthetic gypsum							
AK.GS.TR	700.00	245.95	3.00	29.00	50.00	1.05	620.00
AK.GS.TK		245.91				0.41	

3. RESEARCH ON THE PROPERTIES OF THE GYPSUM PLASTERING MORTARS

The adopted research program included testing of plastering mortars with regards to flexural strength, compressive strength, surface hardness, and the adhesion to the substrate. The mortars were prepared on the basis of building and synthetic gypsums, and with the addition of different setting retarders: PlastRetard PE and A200 tartaric acid. The research was carried out in the Laboratory of the Institute of Building Engineering of Warsaw University of Technology (Branch in Płock).

3.1. Flexural strength

The test was carried out in accordance with PN-EN 13279-2 [8] on 6 bar samples with dimensions of 40x40x160 mm. The samples were subjected to standard treatment – 7 days at a temperature of 23°C ±2°C and a relative air humidity of 50% ±5%, followed by drying to a constant weight in a temperature of 40°C ±2°C (Fig. 2).

Fig. 2. A sample during the flexural strength test

During the study, it was noticed that the samples containing the PlastRetard PE binding retarder achieved a constant mass in a faster time. The average results of the flexural strength test for the mortars based on the building gypsum, as well as those based on the synthetic gypsum that was obtained in the flue gas desulphurization process, are shown in Figure 3.

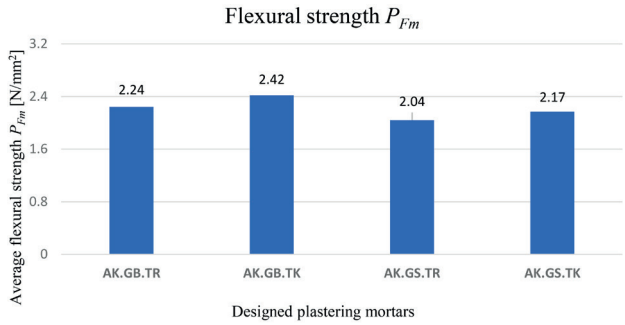

Fig. 3. Results of the average flexural strength of the plastering mortars

The study of the flexural strength of the gypsum plaster mortars that were modified with setting retarders showed slight differences in terms of results – ranging from 2.04 to 2.42 N/mm^2. The use of the synthetic gypsum in the designed mortars allowed for the obtaining of results similar to those based on the building gypsum. Importantly, for all the recipes, the achieved results were not lower than the standard value, which is equal to 2 N/mm^2.

3.2. Compressive strength

The test was carried out in accordance with PN-EN 13279-2 [8] on 12 halves of bars, which were obtained

after the flexural strength test. After the samples were dried to a constant weight, they were placed into a testing machine and examined (Fig. 4).

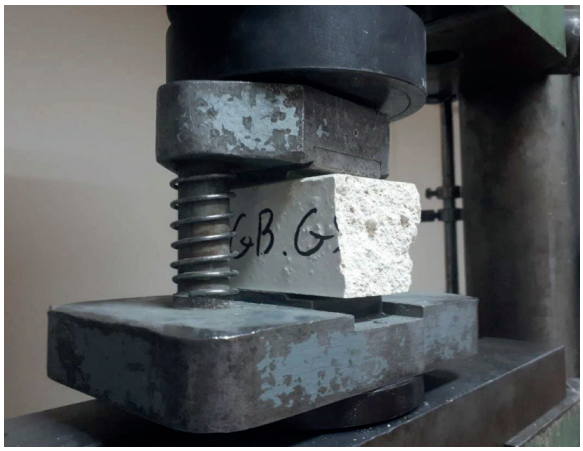

Fig. 4. A sample during the compressive strength test

The average results of the compressive strength test for the mortars that were prepared based on the building gypsum, as well as those based on the synthetic gypsum obtained in the flue gas desulphurization process, are shown in Figure 5.

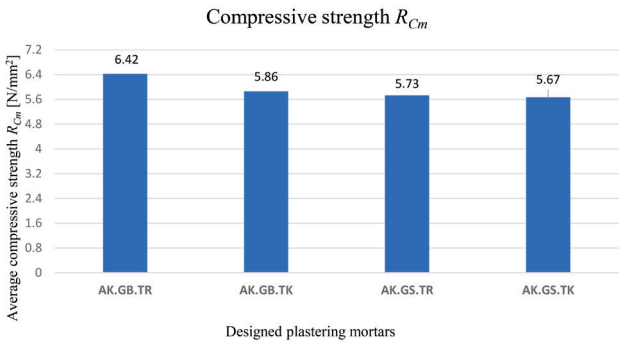

Fig. 5. Results of the average compressive strength of the plastering mortars

After the samples were destroyed, the obtained type of damage was compared and the results were recorded. The sample destruction patterns were very similar. The distinguishing of the mortars based on the building gypsum binder from the mortars based on the synthetic gypsum binder after damage was only possible thanks to the color of the binder. As in the case of the flexural strength test, the obtained results did not differ from each other. The best results were obtained for the samples with the use of the building gypsum as the binder, and the most durable samples were those with the PlastRetard PE retarder – the average compressive strength was equal to 6.42 N/mm^2.

3.3. Surface hardness

Surface hardness was tested in accordance with PN-EN 13279-2 [8]. Its determination involved the measuring of the depth of the indentation made using a hardened steel ball (with a diameter of 10 mm) on rectangular specimens with dimensions of 40x40x160 mm (3 samples, 6 indentations each) (Fig. 6). The results of the average surface hardness are shown in Figure 7.

Fig. 6. A sample during and after the surface hardness test

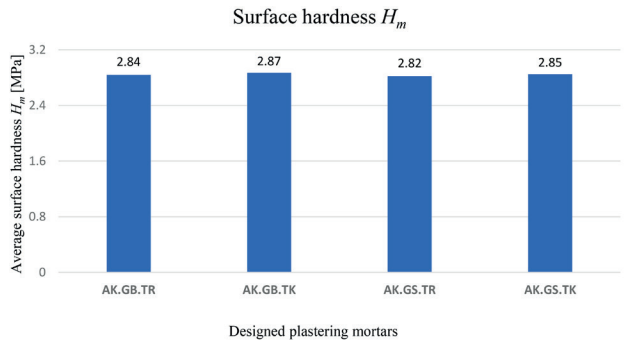

Fig. 7. Results of the average surface hardness of the plastering mortars

In terms of the durability of the plastering mortars, this test is very important due to the nature of their use. The results of the determination of the surface hardness for all the recipes were similar. The difference in the test results was only equal to 0.05 MPa. When studying literature concerning the subject [9], it can be noticed that the variable firing temperature of synthetic binder affects the results of the surface hardness test. Due to the fact that the tested samples contained a binder fired at a constant temperature, the test results did not differ from each other.

3.4. Pull-of adhesion to the substrate

The interlayer adhesion test was carried out in accordance with PN-EN 13279-2 [8]. For this purpose, concrete slabs with dimensions of 50 x 25 cm and a thickness of 50 mm were used. They were seasoned for at least two months. In the first stage, mortar (5 mm) was spread on the entire surface of the slabs. Afterwards, incisions were made in the plaster in order to separate the measuring areas, onto which metal discs (with a surface corresponding to these

areas) were glued using epoxy resin. The sample's pull-off force in relation to the contact surface was taken as a measure of the adhesion of the mortar to the substrate (Fig. 8). After testing the samples, the nature of their destruction was compared (cohesive – in the binder, adhesive – between the mortar and the concrete substrate).

Fig. 8. A sample during the pull-off tests

The results of the average value of pull-off adhesion are shown in Figure 9.

The obtained nature of the destruction – cohesive (in the binder) – for all the tested mortars indicates that their pull-off adhesion is greater than the tensile strength of the mortars. The mortars prepared on the basis of the synthetic binder with the PlastRetard PE retarder obtained the best results. This confirms that their addition has a positive effect on the pull-off adhesion between the mortars and the substrate.

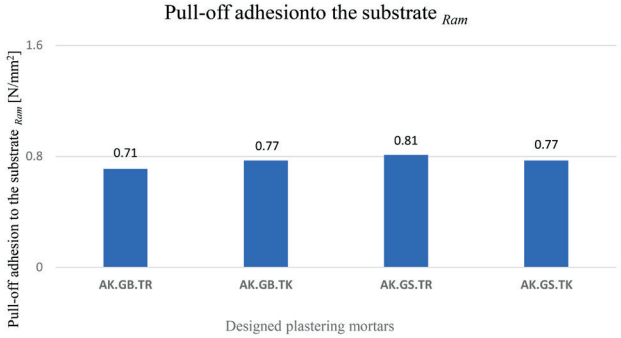

Fig. 9. Results of the average value of the pull-off adhesion between the substrate and the plastering mortars

4. CONCLUSIONS

The obtained test results confirmed the possibility of modifying the composition of gypsum plastering mortars with different setting retarders and with the addition of a synthetic binder derived from the flue gas desulphurization process.

Regarding the conducted research, it seems advisable to carry out further tests of gypsum plaster mortars (with e.g. different contents of gypsum binder in the mixtures, or with the addition of other retarders or admixtures) in order to especially improve the tensile strength of mortars. Such an extension of the research program will significantly improve the pull-off adhesion between the plaster and the substrate, and will also contribute to the achievement of a change in the nature of damage from cohesive to adhesive.

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