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The influence of micronized rubber powder on the properties of deformable tile adhesives

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Abstract: The article examines the possibility of using micronized rubber powder from recycled used car tires in a deformable tiles adhesive. For this purpose, part of the sand was replaced with the tested material. The effect of modification on the key properties of deformable tile adhesives was examined – initial adhesion, adhesion after water immersion, thermal ageing, freeze-thaw cycles and deformability. A very beneficial effect of the analyzed powders on the deformability of mortars was demonstrated. A small share of additives had a beneficial effect on the adhesion of adhesive mortars to the substrate.

Keywords: micronized rubber powders, deformable tile adhesives, deformability, adhesion to the substrate

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Introduction

The largest group of rubber waste are used car tires, which, due to their composite structure (they contain fiber and steel bars), pose a major challenge for their reuse (Ołdakowska, 2006). Recognizing the problem of the significant amount of waste generated, the current policy of European authorities aims to reduce the amount of landfilled waste and its recycling. An example of such actions in the aspect of car tires is the Directive 1999/31/EC of the European Parliament of 26 April 1999

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(Landfill Directive) prohibiting the landfilling of whole used tires and shredded tires. One of the directions of actions aimed at adapting to the current regulations is attempts to use purified shredded rubber from tires withdrawn from use in the cement industry. The micronized rubber powders (MRP) obtained in this way are defined by the manufacturer as dry, powdered elastomeric mixtures that are easy to disperse and to apply in many systems and applications (Rosenmayer et al., 2012). Their addition is used in acrylic coatings, cement plasters and mortars, asphalt cements, asphalt roof coatings, waterproof membranes, and many other purposes.

Ołdakowska demonstrated the effect of the additive on improving water resistance and fatigue strength of concrete (Ołdakowska, 2014; 2015). Research has proven the positive effect of the MRP addition on the flexibility of composite pine particleboards (Cole & Street, 2019). In other studies on the use of MRP in concrete, the effect of the additive on the rheology of the concrete mixture and the deterioration of the mechanical resistance were observed (Silva et al., 2019).

According to the manufacturer, micronized rubber powders, depending on the application, enable: cost reduction (replacement for primary materials and black dyes), anti-slip properties, giving the appropriate surface texture, eliminating scratches and cracks, damping vibrations and sounds, and thermal insulation.

The described properties mean that the MRP additive has the potential to be used in cement mortars, where the deformability (flexibility) of the finished product is of great importance. Deformable adhesive mortars are among these types of materials.

According to the standard PN-EN 12004-1, adhesive mortars can be classified as deformable if the conditions of the standard deformability test are met:

- S1 type mortars: transverse deformation at three-point bending of 2.5-5.0 mm,
- S2 type mortars: transverse deformation at three-point bending of at least 5.0 mm.

These mortars are used primarily due to the susceptibility of cement mortars to cracking in the case of thin layers spread over a large surface (Kulesza et al., 2020).

1. Purpose of the work

The aim of the study was to check the effect of micronized rubber powder with a maximum fraction of 180 micrometers declared by the manufacturer on the deformable properties of cement-based adhesive mortars. For this purpose, part of the sand with a grain size of 0.0-0.5 mm was replaced with MRP in the mortar composition. The mortar samples were subjected to tests of initial adhesion, adhesion after immersion in water, adhesion after freeze-thaw cycles, deformability and their working properties were determined. All tests were performed in accordance with the standards PN-EN 12004-1 and PN-EN 12004-2.

2. Experimental material and testing method

A tile adhesive with a formula determined during preliminary tests, meeting the requirements of class C2TES1 according to PN-EN 12004-1, was used for the tests.

The adhesive mortar was mixed with water in accordance with the EN 1015-2:2000 standard. Based on preliminary tests, it was determined that the mortar achieves the most advantageous application properties with an amount of water of 230 g per 1 kg of dry mortar. After mixing all the ingredients, consistency tests were carried out using a flow table in accordance with the procedure described in the PN-EN 1015-3 standard. The consistency of the samples was regulated by using a superplasticizer. The superplasticizer was dosed without reducing the mass of the dry ingredients of a given sample, and the appropriate amount of the added superplasticizer was determined on the flow table until the desired consistency was obtained. Along with the use of additives in the form of micronized rubber powder, the mass fraction of quartz sand was reduced so that the mass of the sum of the ingredients was constant. The maximum share of MRP was 10 %.

After performing the consistency tests and determining the required amount of superplasticizer, samples were prepared for determining the adhesion and deformation of the tested cement tile adhesives. Tests were carried out according to PN-EN 12004-2.

3. Materials

Portland cement CEM I 42.5 R was used. The formulation also consisted of: dried quartz sand with a fraction of 0.0-0.5 mm, cellulose thickener – hydroxymethylpropylcellulose with a viscosity of 12,000-18,000 mPas (Brookfield, 2 % solution, 20 °C), EVA redispersible powder – polyvinyl acetate modified with ethylene with an average particle size of 90 μm and an MFFT temperature of 0 °C. The recipe also included the addition of metakaolin and the addition of a superplasticizer – sulfonated melamine formaldehyde polycondensate (SMF).

Micronized rubber powder (MRP) with maximum fraction declared by the manufacturer of 180 μm was used. According to the manufacturer's declaration, this material consists of hardened natural rubber, styrene-butadiene (SBR) and carbon black (30 %). Its specific gravity is 1.14 g/cm^3, and the glass transition temperature (Tg) is –70 °C. 1 %, 3 %, 5 % and 10 % by mass of sand were replaced by MRP, respectively.

The compositions of the tested samples are listed in Table 1. The reference sample is marked as sample "0". Additionally, for each sample, an appropriate amount of superplasticizer was added to obtain the appropriate consistency.

Table 1. Compositions of samples with micronized rubber powder (*own research*)

	"0"	K 180/1	K 180/3	K 180/5	K 180/10
Cement CEM I 42.5 R [% mas.]	40	40	40	40	40
Quartz sand 0.0-0.5 mm [% mas.]	54.7	53.7	51.7	49.7	44.7
Cellulose ether [% mas.]	0.3	0.3	0.3	0.3	0.3
Redispersible powder [% mas.]	4	4	4	4	4
Metakaolin [% mas.]	1	1	1	1	1
MRP 180 [% mas.]	0	1	3	5	10
Superplasticizer [% mas.]	0	0	0	0	1

4. Results and discussion

4.1. The influence of MRP on the adhesion of the tile adhesive

The adhesion of the adhesive mortar to the substrate was measured using a pull-off type apparatus. For each adhesion test, at least 5 measurements were performed for each recipe. The average results of the initial adhesion test are presented in Figure 1. As shown in Figure 1, partial replacement of sand with MRP had a beneficial effect on initial adhesion with a small additive dosage. After increasing the share of MRP with to over 3 % by mass, the initial adhesion deteriorated significantly.

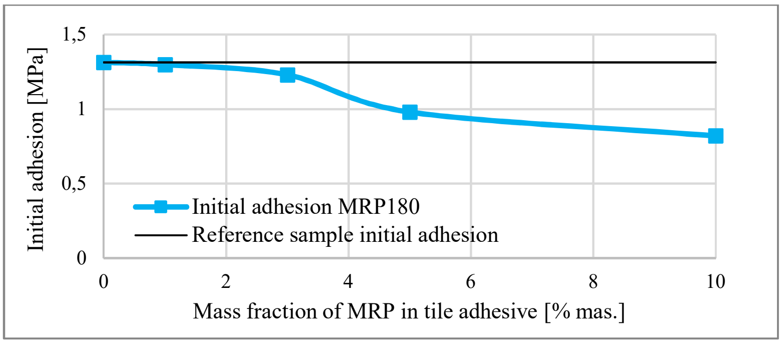

Fig. 1. The influence of MRP on the initial adhesion of the mortar determined in accordance with PN-EN 12004-1:2017-03 (*own research*)

Averaged results of the study of the effect of MRP additive on the adhesion of adhesive mortar after water immersion are shown in Figure 2. The most favourable adhesion test results after water immersion were obtained for the sample containing up to 3 % by mass of MRP additives. The highest adhesion was observed for the adhesive mortar containing 1 % by mass of MRP. It was 5 % higher than the adhesion after water immersion of the sample not containing MRP. Similarly to the initial adhesion test, increasing the share of MRP additives to over 3 % by mass resulted in a decrease in adhesion after water immersion.

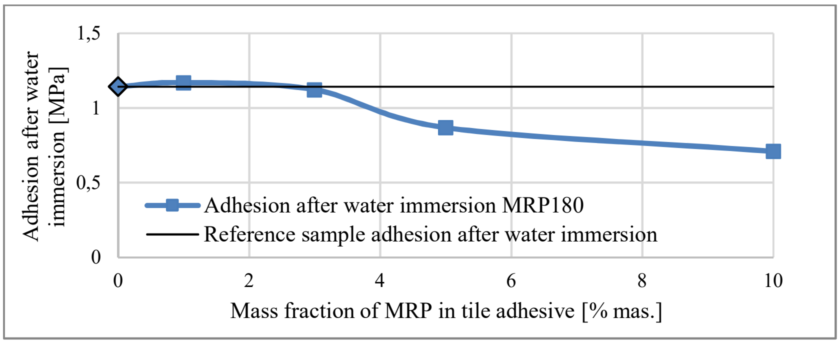

Fig. 2. The influence of MRP on the adhesion of the tile adhesive after water immersion determined in accordance with PN-EN 12004-1:2017-03 (*own research*)

Figure 3 graphically presents the results of testing the influence of MRP additives on the adhesion after thermal ageing of the adhesive mortar.

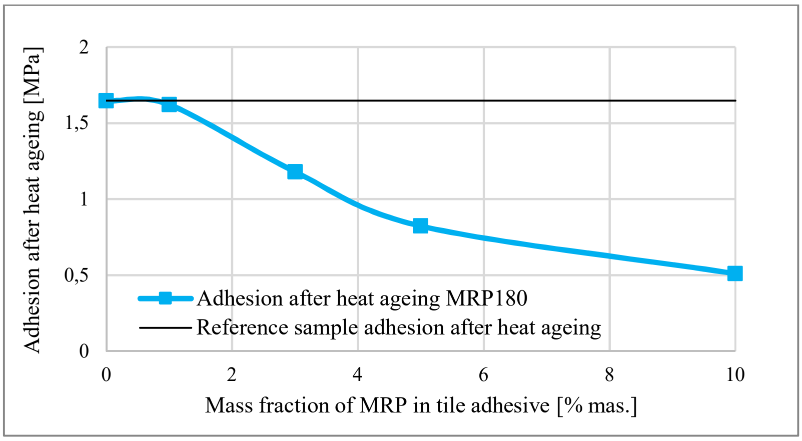

Fig. 3. The influence of MRP on the adhesion of the tile adhesive after thermal ageing determined in accordance with PN-EN 12004-1:2017-03 (*own research*)

In Figure 3 a small beneficial effect of MRP in case of its small dosage can be observed. Increasing the mass fraction of MRP additive above 1 % by mass caused a significant deterioration of the joint strength. Mortar containing 3 % by mass of additive still met the standard requirements for adhesion after thermal ageing.

The effect of MRP additive on the adhesion of the tile adhesive to the substrate after freeze-thaw cycles was also tested. The test results are presented in Figure 4.

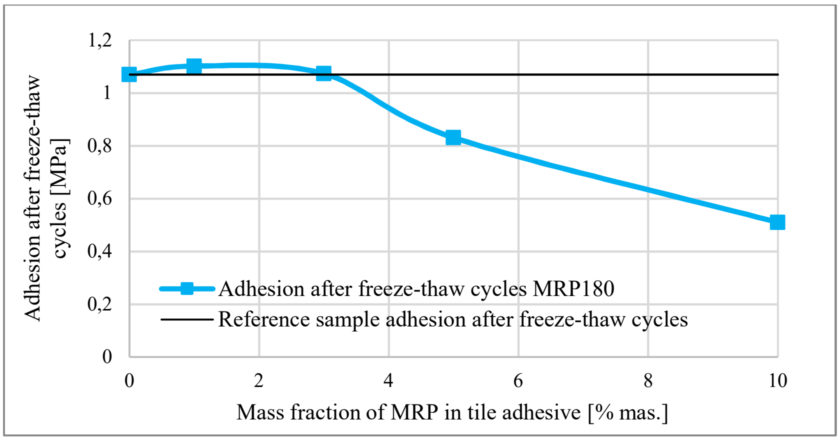

Fig. 4. The influence of MRP on the adhesion of tile adhesive after freeze-thaw cycles determined in accordance with PN-EN 12004-1:2017-03 (*own research*)

As in the case of other adhesion tests, the most beneficial effect on adhesion after freeze-thaw cycles was noted in the case of a small dosage of MRP. The addition of MRP not exceeding 3 % by mass of the mortar improved the strength of the joint compared to the reference sample by 3 %. Further increase in the share of additive was associated with a significant deterioration in adhesion after freeze-thaw cycles.

4.2. The influence of MRP on the elasticity of the tile adhesive

In order to determine the effect of the MRP additive on the elasticity of the material, a standard test of the deformability of tile adhesives containing MRP was carried out. The test results are presented in Figure 5.

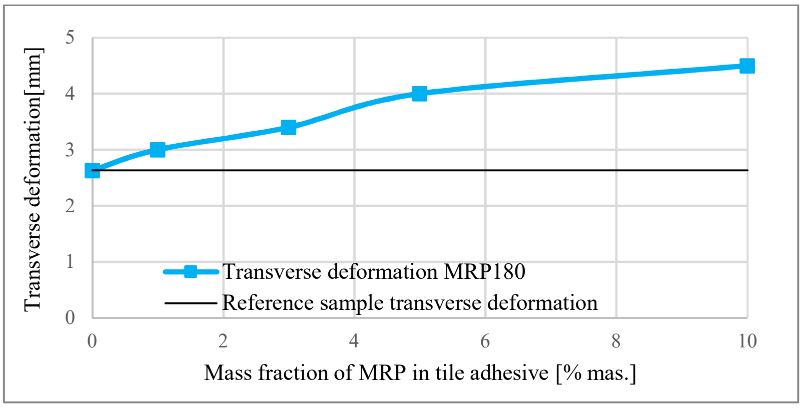

Fig. 5. The influence of MRP additive on the deformability of the tile adhesive according to PN-EN 12004-1:2017-03 (*own research*)

In Figure 5, it can be seen that the addition of MRP had a beneficial effect on deformability. The highest result was recorded for the sample containing 10 % by mass of this additive – this sample showed almost twice as high deformability as the reference sample. In the entire analyzed range, increasing the share of MRP had a positive effect on the transverse deformability of the mortar.

Conclusions

The studies have shown a beneficial effect of the MRP additive on the properties of deformable tile adhesive mortars. In the case of adhesion tests, the most beneficial effect was noted for samples containing 1 % by mass. The additive was of particular importance in the case of tests in which the sample was in contact with water – in adhesion tests after immersion in water and after freeze-thaw cycles.

The most beneficial effect of the additive was observed in the case of the deformability test.

The obtained results allow us to positively assess the possibility of using Micronized Rubber Powders in deformable tile adhesive mortars. Such a solution, in addition to improving the key properties of this type of mortar, is in line with the current assumptions of the sustainable development strategy, as it is associated with the management of troublesome waste.

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