Optimization Parameters of Plaster Composites

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Abstract: This study is aimed on comparison mechanical properties changes of plaster composites reinforced by different kinds of fibrous dispersion. The trend in recent years is the substitution of conventional materials with composite materials. The reason for their using is to achieve the same (or better) properties at much lower weight. Application of these materials is constantly expanding to new sectors. Glass and basalt microfibers of a certain length were added as a reinforcing element into plasters. Another way how to reinforce plaster materials is use of polyvinyl butyral nanofibers. As the last kind of plaster reinforcement was selected leno weave of basalt. This way produced samples were tested for tensile, flexural, compressive and impact strength. Most improvements resulted in bending stresses when reinforced with glass. The results showed possible improvement in properties at reinforcing microfibers. When used basalt leno weave as reinforcement element showed the greatest improvement in the compressive strength. Using the nanofiber reinforcement led generally to a deterioration of their mechanical properties. The greatest deterioration occurred in bending stress.

Keywords: plaster composites; ThermoUM Xtra; basalt microfiber; glass microfiber; polyvinyl butyral nanofiber.

1. Introduction

A standing trend in the field of material engineering is development of materials with tailored properties allowing us their effective use. The composite materials meet this requirement and their principle is based on addition of some dispersion components into the elemental matrix. In this way we can get better material properties for particular applications [1]. The disadvantage of plaster materials is their gradual degradation, which is generated by moisture. Due to this problem physical and chemical processes could occur and they undermine the cohesive properties between the plaster and masonry, also some visual defects can be noticeable. To limit the occurrence of these defects and reduce brittleness of the plaster the fibrous reinforcement is added to the base matrix, which leads to the load transfer between the fibres and the matrix [2]. For this process the fibres length is an important factor. This so called critical length must be capable of transferring a tension caused by load transfer from the matrix through a shear stress which acts on an interface the fiber - matrix. By using the short fibres we can improve the properties in all directions of the composite. Therefore, the short glass and basalt microfibers were used in experiments [3, 2]. For the integrity of the information about all standardly used reinforcement materials also leno weave of basalt, which represents a bi-directional reinforcement, was used.

2. Materials

Variety of fiber reinforcement are nowadays used for plaster composites. The most frequently used are fibers of glass, carbon, aramid, ceramic, basalt and polypropylene. When selecting was given emphasis on the mechanical properties, the ability to withstand alkaline environment which in the plaster is, their environmental friendliness, and thermal insulating properties. Glass, basalt and carbon fiber have been chosen for the experiment after considering their individual properties. Due to the good toughness and adhesion to various surfaces for the electrostatic spinning method, the polyvinyl butyral fibers were selected. For plaster composites with micro fiber reinforcement to compute the critical fiber length:

$$l_c = \frac{R_{mV} \cdot d}{2\tau_m} \tag{1}$$

Where l_c [mm] is the critical fiber length, R_{mV} [MPa] fiber strength, d [mm] is the diameter of the fibers and τ_m [MPa] strength of the interface between the fibers and the matrix in shear.

The critical fiber length is the minimum length of fiber which is still capable of transmitting tension. This length can be achieved only with difficulty, due to the very small size. To calculate the effective length (2) of the fibers was determined by the formula [2] by W. D. Callister:

$$l = 15 \cdot l_c \tag{2}$$

These formulas are for composites with polymeric matrix. Due to the fact that in the experiment was used a different matrix, is needed for calculating the effective length adjusted so employed relationship shape factor (aspect ratio), which was calculated by the real length of the fiber reinforcement:

$$\propto = \frac{l}{d} \tag{3}$$

The final length of fiber reinforcement l_v [mm] was determined as the effective length multiplied by aspect ratio α:

$$l_v = l \cdot \alpha \tag{4}$$

The final length of the fibrous reinforcement for the glass fibers is 6.7 mm and 7.3 mm in the case of basalt fibers. The content of the fibrous reinforcement in concrete materials is usually 6%. Blending the plaster and fibers with thus high content causing problems in their bonding. For this reason the content of the fibrous reinforcement has been set to 1%, 2% and 3%. The calculation (5) of the mixing ratio [1] is based on the percentage of the components in the composite and their densities:

$$w_i = \frac{V_i \cdot \rho_i}{\sum V_i \rho_i} \tag{5}$$

Where w_i [%] is the mass fraction of the i-th component, V_i [%] the volume fraction of the i-th component and ρ_i [kg/m^3] is the density of the i-th component.

Reinforcement in the form of nanofibers was created in two ways. The first one was based on a winding a wispy smoke rising from the electrodes on the rotary drum. That led to producing of nanofibrous layer, which was inserted into test specimens. The second method based on a mixing of the nanofibrous wispy smoke directly with the plaster was used. After blend creating was necessary to obtain individual fibers and whole mixture was grinded [4]. For the last method was used leno weave of basalt 5x5 mm with a bulk density 125 g m^{-2}. Test specimens for all types of reinforcement were made according to standard DIN EN 1015-11 Methods of test for mortar for masonry.

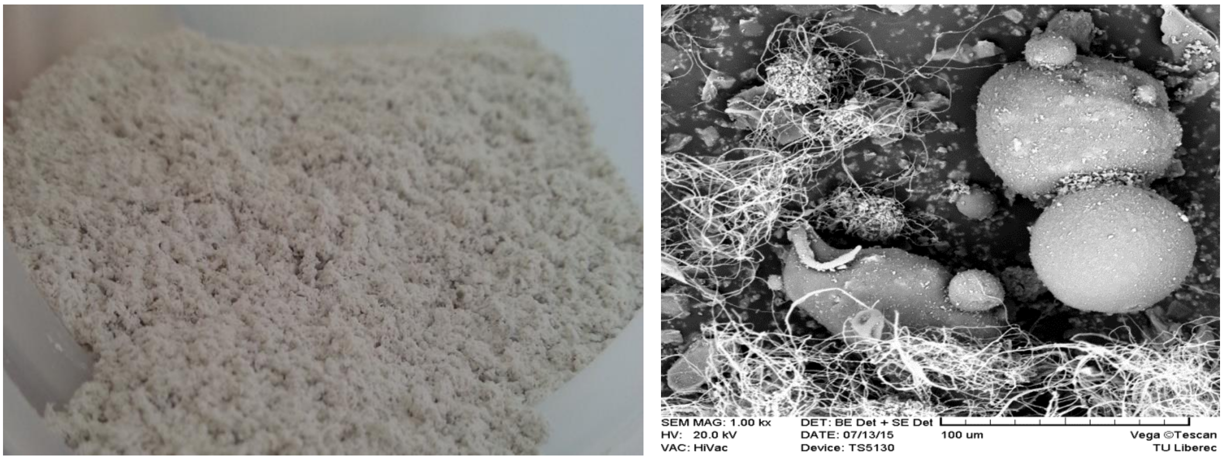

Fig. 1: Reinforcement in the form of nanofiber (photo, scanning electron microscopy)

3. Experiment

With using the standard laboratory tests for bending, compression and impact strength of the samples, it was necessary to find the changes of their mechanical properties.

Before creation of the test objects was necessary to measure the strength of the interface between the fibers and the matrix in shear. The test samples containing the bundle of fibers (glass, basalt). The individual bundles were placed into the plaster at different depths and subsequently measured on the dynamometer (Fig. 2). The results were used to calculate the aforementioned fiber critical length.

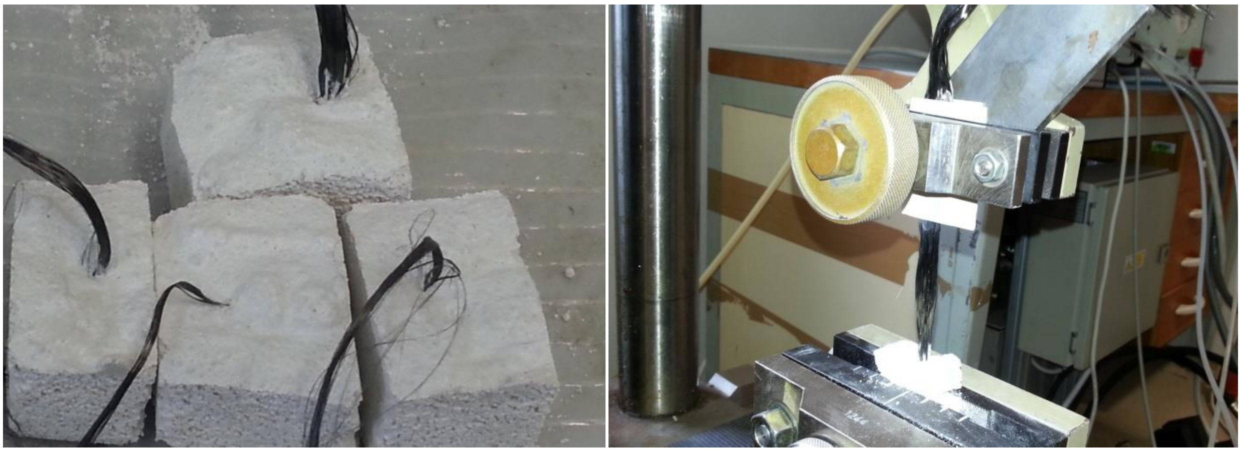

Fig. 2: Critical length of fiber and testing strength of the interface between the fibers and the matrix

The flexural strength was tested by three-point bending. The test was carried out in accordance with standard [5]. The compressive strength was tested on a dynamometer. The diameter of the compression plates was 75 mm. In both of these tests took place the burdening rate of 2 mm min^{-1} so a breach of solids occurred in the interval from 30 to 90 sec. For the method was used the standard ČSN EN 1015-11 [6]. These basic characteristics were extended to impact resistance. The energy necessary to breach test piece was measured with a Charpy hammer [7]. Based on the collected data the impact toughness was calculated (6), which represents the ability of a material to quickly absorb energy.

$$A_\omega = \frac{E_c}{b \cdot h} \tag{6}$$

Where A_ω [J/mm^2] impact toughness, E_c [J] strain energy consumed to shift the sample, b [mm] the sample width and h [mm] height of the sample.

Breach of the samples occurred with only a very small deflection. This is caused by the fact that some equilibrium processes in the material have not enough time for realization. For the method was used the standard DIN EN ISO 179-2 Plastics [7]. These basic characteristics were extended to impact resistance.

4. Result and discussion

These basic characteristics were extended to impact resistance. The values of these properties were evaluated and compared with all types of reinforcement. Results of these parameters are indicators of the lifetime of the plaster, which can be influenced by the addition of fibrous reinforcement. We found that the use of nanofibrous reinforcement in plaster composites not improve the above mentioned properties. The reason are nanofibres which are not lengthen. From figure 3 it is seen that the bending stress characteristics improving effect showed 1% content of fibrous reinforcement in both fibrous types. To increase the elastic modulus was only glass mat at 1% ratio. Other ratios exhibit a deterioration of the modulus of elasticity.

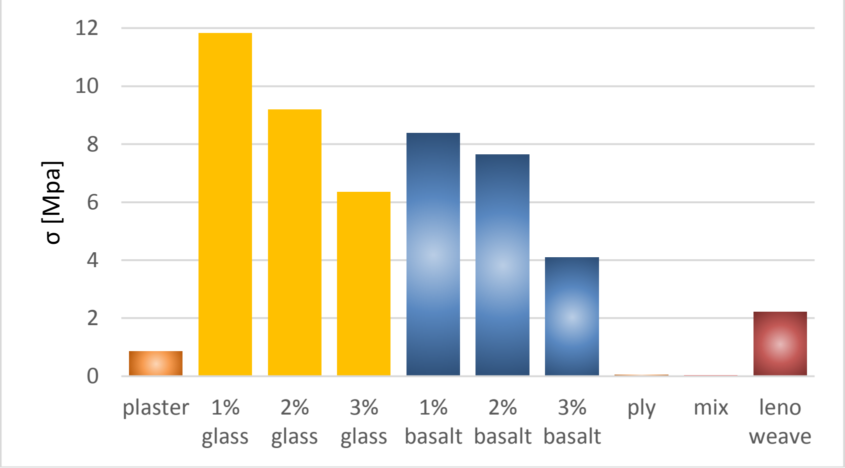

Fig. 3: Bending stress

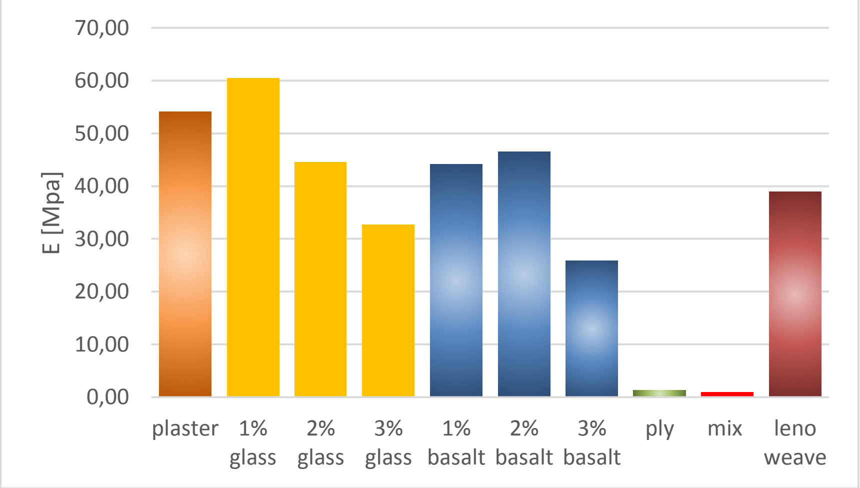

Fig. 4: Modulus of elasticity

The increasing content of fibers leads to increasing the impact resistance (Fig. 4). The greatest reinforcing effect was observed in basalt leno weave, which also prevented the destruction of the samples during the tests. Similar effect with less effect was also reflected by the sample reinforced by nanofiber ply. The best improvements in compressive strength is clearly demonstrated in samples of basalt leno weave. In Figure 6 it can be seen that the more increase the content of fibrous reinforcement in the test body, the more the compressive strength is decreasing.

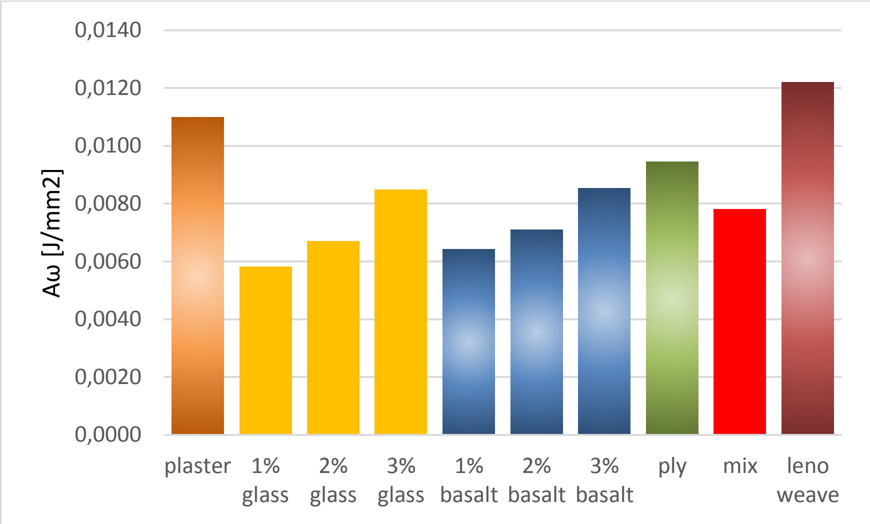

Fig. 5: Impact resistance

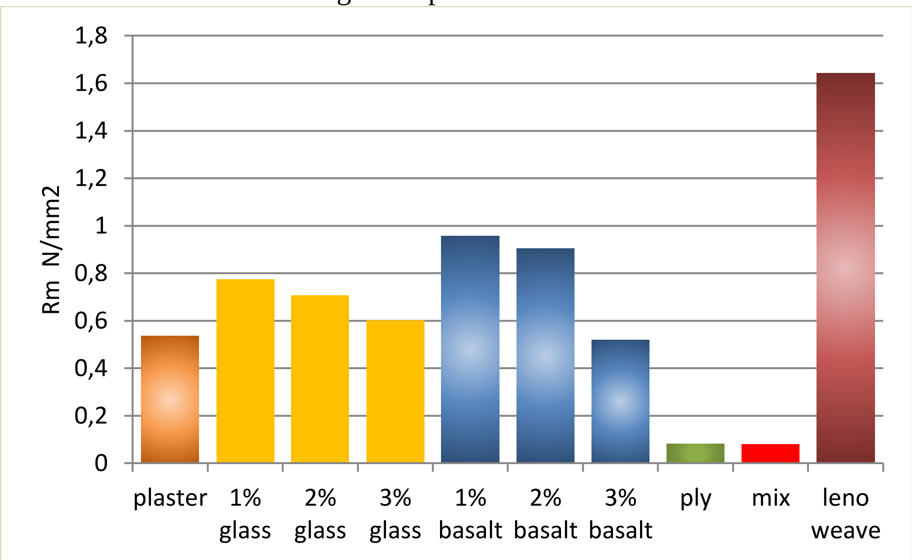

Fig. 6: Compressive strength

5. Conclusion

In this publication several sorts of fiber reinforcements and their effect on improvement of mechanical properties have been compared. For comparison the properties of the actual plaster and the reinforced plaster composites the compressive strength, bending stress, modulus of elastic and impact resistance were selected. The measuring results show that suitable fibrous reinforcement could improve all of the observed properties. Using the nanofiber reinforcement has proved as unsuitable despite the fact that the results of the impact strength is better than of basalt or glass reinforcement. To improve resistance against mechanical stress plaster is suitable basalt or glass reinforcement in the form of the leno weave or 1% by weight of the fibrous constituents.

Acknowledgments

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