Influence of Calcination Level of Recycled Gypsum on the Physical Properties of Hardened Gypsum Slurry

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Abstract: This article examines the effect of incomplete calcination of wasted recycled hardened gypsum. Waste gypsum originated from the process of recycling plasterboard. As part of the processing, the cardboard is separated from the hardened gypsum and the gypsum is physical and mechanical activated (calcined) by means of high-speed grinding. As part of recycling, there is no complete calcination of hardened gypsum. In the resulting gypsum composite, these uncalcined grains have a fundamental influence on the process of hydration and its resulting physical properties of hardened gypsum slurry. In the research, the percentage of uncalcined grains was simulated by adding non-activated recycled hardened gypsum to the mixture in the required amount from 0 to 1 wt. %. Compressive strength and flexural tensile strength were measured on hardened gypsum slurries measuring 40 × 40 × 160 mm. The possible processing time of gypsum slurry (setting time) was other monitored parameters.

Keywords: recycled gypsum; calcination; compressive strength; flexural strength.

1 Introduction

Currently, the issue of recycling building materials is being dealed worldwide. In connection with this issue, concrete is most often mentioned material for recycling. Concrete is not the only material used in the construction industry. There are other widely used materials that should be recycled and further processed. However, the recycling of some building materials is problematic, as is the case with waste from other industries and is therefore landfilled [1, 2]. Among the materials that are not effectively processed today is plasterboard waste.

In recent years, there has been a growing interest in dry construction and with it interest in plasterboard systems. With the growing demand for plasterboards, the amount of waste generated from plasterboard production, constructions, reconstructions and demolitions is also increasing [3]. At present, the vast majority of plasterboards waste is landfilled and a relatively small part is reused [4].

What is usually forgotten in the concept of solutions for recycling plasterboards and gypsum products is the fact that in terms of recycling and reuse, it is a completely unique material that is 100% recyclable to infinity. And above all, it is unique in that the properties of gypsum do not change during recycling [5]. From the point of view of construction, gypsum is a unique material that has been used for several thousand years (eg in ancient Egypt), it is mainly valued for its good thermal-technical properties, mechanical properties and fire resistance. Other advantages of gypsum include the possibility of its modification by means of additives and admixtures which modify its useful properties. Calcined gypsum ($CaSO_4 \cdot \frac{1}{2}H_2O$) is not found in nature (only in the form of $CaSO_4$ anhydrite or $CaSO_4 \cdot 2H_2O$ calcium sulphate). Calcined gypsum is made from calcium sulphate (which is either of natural or artificial origin) by using high temperatures, so-called calcination. The calcination usually takes place at temperatures above 180 °C in such a way that water is released from the gypsum (calcium sulphate dihydrate) at a temperature above 150 °C [6].

The basic equation of gypsum production is as follows (Eq. (1)):

Tab. 1: Composition of individual samples.

Mixtures	Gypsum binder [g]	Waste gypsum [g]	Water [g]	Setting time [min]	Bulk density [kg/m^3]
ref.	1,000	-	640	6.1	1,165 $\pm$ 16
0.25	997.5	2.5	640	3.2	1,155 $\pm$ 7
0.50	995	5	640	2.4	1,122 $\pm$ 4
0.75	992.5	7.5	640	1.5	1,120 $\pm$ 14
1.00	990	10	640	1.3	1,132 $\pm$ 16

$$CaSO4 \cdot 2H_2O + heat = CaSO_4 \cdot \frac{1}{2}H_2O + 1.5H_2O\,. \tag{1}$$

Rehydration of gypsum (formation of hardened gypsum) occurs after mixing with water according to equation Eq. (2):

$$CaSO_4 \cdot \frac{1}{2}H_2O + 1.5H_2O = CaSO_4 \cdot 2H_2O + heat\,. \tag{2}$$

According to the above equations, it is therefore possible to recycle the gypsum several times at relatively low costs using high temperatures (calcination) and grinding to the required grain size. The properties of the resulting calcined gypsum are directly dependent on the grain size and the level of calcination (amount of uncalcined gypsum grains). Grain size and the amount of uncalcined gypsum grains affect the process of hydration. The smaller grain size increases the specific surface area of the grains and thus leads to a faster reaction during hydration. Uncalcined grains create nucleation centers for the formation of calcium sulphate and thus the whole hydration process is accelerated. Thus, both parameters accelerate hydration time and thus reduce the processability time and setting time [7].

2 Materials and samples

Individual samples were composed of gypsum binder from the company Knauf Praha and uncalcined recycled waste gypsum. The gypsum binder was formed by calcination of energy gypsum (FGD gypsum). FGD gypsum is a by-product of the combustion of brown coal by the flue gas desulphurisation process in a power plant. In our case, it was FGD gypsum from the Počerady power plant, which has a very high purity (on average 96 %) and is used as the main material in the production of plasterboards.

Uncalcined waste recycled gypsum originated from plasterboard waste. Gypsum plasterboard waste originated from the construction process and it was gypsum plasterboard with the designation A for common use according to the ČSN EN 520 + A1 standard [8]. During recycling, cartons were separated from the gypsum slurry and the waste gypsum slurry was ground using a high speed mill. The resulting uncalcined waste gypsum was of high purity and was 95 wt. % composed of gypsum. In the research, the percentage of uncalcined waste gypsum was simulated by adding non-activated recycled hardened gypsum to the mixture.

Tab. 1 shows the composition of the individual mixtures. Each mixture consisted of 6 samples measuring 40 $\times$ 40 $\times$ 160 mm were cast to the rectangular molds. After casting, these samples were kept in the molds for 1 h at the laboratory with the temperature 22 °C. After demolding, these samples were deposited in the laboratory environment. All mixtures had the same water content of 0.64. The setting time was measured during sample preparation.

3 Experimental methods

The samples were destructively tested after 7 days to determine the flexural strength and compressive strength by using FHF Strassentest device. The flexural strength was determined by a three-point bending test. The testing of flexural strength was displacement controlled at a constant rate of 0.5 mm/min. The distance between supports for three-point bending test was equal to 100 mm. The compressive strength was determined

by using uniaxial compressive test. The uniaxial compressive test was performed on the broken halves of the samples after bending test with effective dimensions of 40 × 40 × 40 mm. The testing of compressive strength was displacement controlled at a constant rate of 1 mm/min.

All tests were performed according to ČSN 72 2301 standard [9]. The resulting average values of compressive strength and flexural strength were calculated excluding the highest and lowest values determined during testing.

4 Results and discussion

The results showed that all mixtures had the same bulk density (the differences were up to the size of the standard deviation) and the uncalcined particles had a high effect on the setting time (Tab. 1). The results show that uncalcined gypsum particles form nucleation centers and thus accelerate the entire hydration.

The results of the destructive tests can be seen in Fig. 1 and Fig. 2. Due to the accelerated hydration, more heat is released in a shorter time. As a result, microcracks form in the sample due to volume changes. For example, sample with 1 wt. % of uncalcined gypsum had an average flexural strength of 3.04 ± 0.22 MPa. In contrast, the reference sample had a flexural strength of 4.20 ± 0.16 MPa. Microcracks have a major effect on flexural strength. For this reason, the flexural strength is reduced due to uncalcined gypsum. In the case of compressive strength, a similar effect can be observed. Fig. 2 shows the decrease of compressive strength due to uncalcined gypsum and a mixture with 1 wt. % of uncalcined gypsum has about half the average compressive strength.

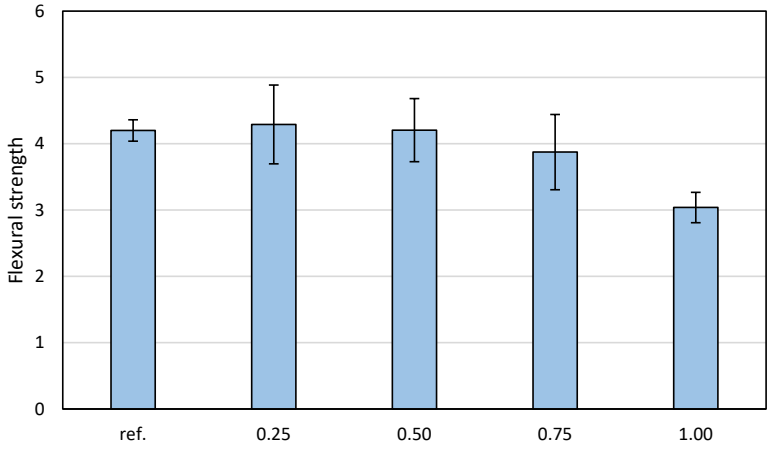

Fig. 1: Comparison of flexural strength (with standard deviations).

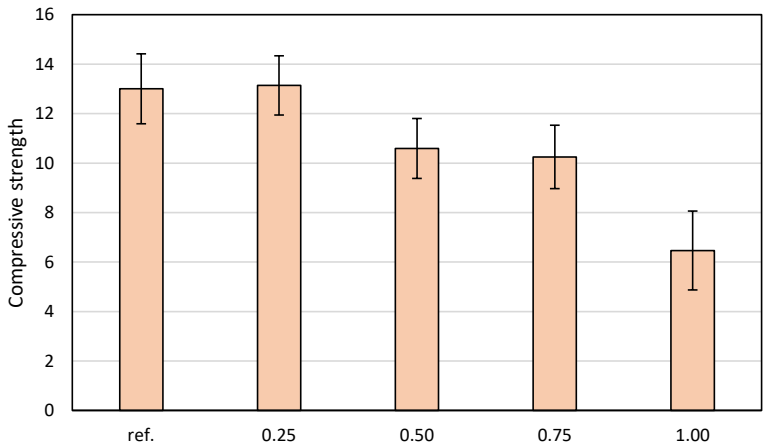

Fig. 2: Comparison of compressive strength (with standard deviations).

5 Conclusion

The results of this work will be used as a basis for the design of a recycling line, which will be used to grind and calcine gypsum-based waste materials. The results show that the calcination level of the resulting recycled material must be 99.5 %. Thus, the recyclate may contain 0.5 wt. % of uncalcined gypsum. In the case of a lower level of calcination, the mechanical properties will be affected. In the future work will deal directly with calcined recycled material from the recycling line and the possibility of using setting retarders.

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