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EFFECT OF A WATER-GYPSUM RATIO ON MECHANICAL PROPERTIES OF GYPSUM

P. Tesárek[*], A. Hájková[*], T. Plachý[*]

Abstract: *Water-gypsum ratio is one factor of material parameters, which has a significant influence on the behavior of materials at the macro level. The article presents the dependence of selected mechanical properties on the water-gypsum ratio for several materials based on gypsum, which are modified using different types of additives as plasticizers, water proof agents and PP fibers.*

Keywords: ***Flue gas desulphurization gypsum, water-gypsum ratio, mechanical properties, gypsum.***

1. Introduction

The process changing gypsum – hemihydrates – into hardened gypsum – dehydrate – is hydration; it is typical effect for hydraulic binders. During this process, a solid material structure is formed, and the accompanying phenomenon is the generation of hydration heat and a volume increase – expansion. Hydration is set off after mixing water with gypsum. The process of gypsum hydration and setting relies on multiple factors: the temperature during preparing of the gypsum paste, the water-gypsum ratio, the method of gypsum mixing, the mixing intensity and time, the fineness of grinding, purity of gypsum binder, composition of gypsum binder – ratio of individual components, its mean anhydrite in different forms, hemihydrates and dehydrate of calcium sulfate etc. (Wirsching, 1983).

One of the important factors, as it has already been said, is the water-gypsum ratio. It is the ratio of the mass of water and gypsum. The water-gypsum ratio has a fundamental influence on the basic characteristics of hardened gypsum, such as its volume density, total open porosity and other related characteristics like its moisture, mechanical, thermal and sound insulation material properties. The theoretical water-gypsum ratio necessary for the hydration of calcium sulphate hemihydrates into calcium sulfate dehydrate is 0.187. Additional water, in a so-called over stechiometric quantity, is necessary for the processing of the hardening gypsum paste.

Proper modification is a possibility how to eliminate gypsum negative properties and how to contribute to a wider utilization of gypsum even in exterior applications. The second effect of modifications lies is improving of hardened gypsum properties (e.g. mechanical properties, lower volume density and thermal properties). Depending on the type of modification, two basic groups may be distinguished. The first option is to modify the input raw material during its production, while the second choice is to modify the final product. In the modification of input raw materials, substances are added to input raw materials with the aim of changing, or affecting the properties of the basic raw materials. Additives may be classified by their effect on the gypsum binder into the following basic groups: plasticizers, hydrophobic agents, setting regulators, foaming. Sometimes, the effect of modifiers can be double-edged:

- Using of plasticizer yields reduction of gypsum/water ratio and reduction of total open porosity and improvement of mechanical and hygric properties. On the other hand, it can worsen thermal properties,
- Hydrophobic agents cause improvement of hygric properties (transport of liquid water) but can deteriorate mechanical properties and other parameters.
- Foaming agents increase the total open porosity and cause improvement of thermal properties. However, they deteriorate mechanical and hygric properties (transport of liquid water), etc.

[*] Ing. Pavel Tesárek, Ph.D., Ing. Andrea Hájková and Ing. Tomáš Plachý, Ph.D.: Czech Technical University in Prague, Faculty of Civil Engineering, Department of Mechanics; Thákurova 7, 166 29 Prague 6 - Dejvice, Czech Republic, e-mails: tesarek@fsv.cvut.cz, andrea.hajkova@fsv.cvut.cz, plachy@fsv.cvut.cz

2. Test samples and additives

Flue gas desulphurization (FGD) gypsum from Počerady (ČEZ) was used for testing, this one is investigated according ČSN 72 2301 classified as G-13 BIII (binder = finely ground, normal setting-up with a compressive strength 13 MPa after 2 hours). This gypsum mixture was made by five different materials. The four of them were added to one or more ingredients (Table 1). The sample labeled S0 is free of additives, thus the reference. Selected ingredients were the plasticizer *Peramin SMF 20*, the hydrophobic agent *Imesta IBS 47* and *Zonyl 301*. For one set of samples, there was used as a filler of polypropylene fibers: *Fibrexcrete*.

Tab. 1: Composition of tested gypsum samples.

Material	***Kind of additives***	***Name of additives***	***Quantity [%]***	***Water-gypsum ratio***
S0	-	-	-	*0.627*
S1	*plasticizer*	*Peramin SMF 20*	*0.5 % wt.*	*0.500*
S3	*hydrophob. ingred.*	*Imesta IBS 47*	*0.5 % wt.*	*0.627*
S5	*hydrophob. ingred.*	*Zonyl 301*	*5 % of solution*	*0.627*
S6	*plasticizer* *hydrophob. ingred.*	*Peramin SMF 20* *Imesta IBS 47*	*1 % wt.* *1 % wt.*	*0.500*
S7	*plasticizer* *hydrophob. ingred.* *PP fibres*	*Peramin SMF 20* *Imetsa IBS 47* *Fibrexcrete*	*1 % wt.* *1 % wt.* *1 % wt.*	*0.500*

Each set of samples in the form figures a 40×40×160 mm were manufactured using two different water-gypsum ratios: 0.627 and 0.500 in accordance with the standard ČSN 72 2301 (ČSN 72 2301, 1978). Samples were made and kept in constant laboratory conditions of 23 °C ± 1 °C and relative humidity of 30 ± 2 % for four weeks. At a specific time intervals the samples were tested.

3. Experimental results

Before the evaluation of strength tests, it was necessary to determine for each set: bulk density, density of matrix and total open porosity (Tab. 2). These characteristics have great influence on the final compressive strength and bending strength, and corresponded with the values presented in Tab. 1.

Tab. 2: Bulk density, density of matrix and total open porosity of the tested gypsum samples

Material	***Kind of additives***	***Density [kg/m^3]***	***Density matrix [kg/m^3]***	***Total open porosity [%]***
S0	-	*1170*	*1900*	*38*
S1	*plasticizer*	*1270*	*1950*	*35*
S3	*hydrophobic ingredients*	*1100*	*1900*	*42*
S5	*hydrophobic ingredients*	*1120*	*1900*	*41*
S6	*plasticizer, hydrophobic ingredients*	*1280*	*1900*	*33*
S7	*plasticizer, hydrophobic ingredients, PP fibres*	*1265*	*1880*	*33*

Tab. 2 shows that the influence of additives and polypropylene fiber on bulk density and the density of matrix are almost negligible, as well, as the impact of different water-gypsum ratio. In contrast, the strength values (Figs. 1 and 2) are different. Fig. 1 shows the values for compressive strengths and Fig. 2 for bending strengths. Both figures are done in time intervals of 2 hours, 3, 7 and 28 days after mixing the gypsum with water.

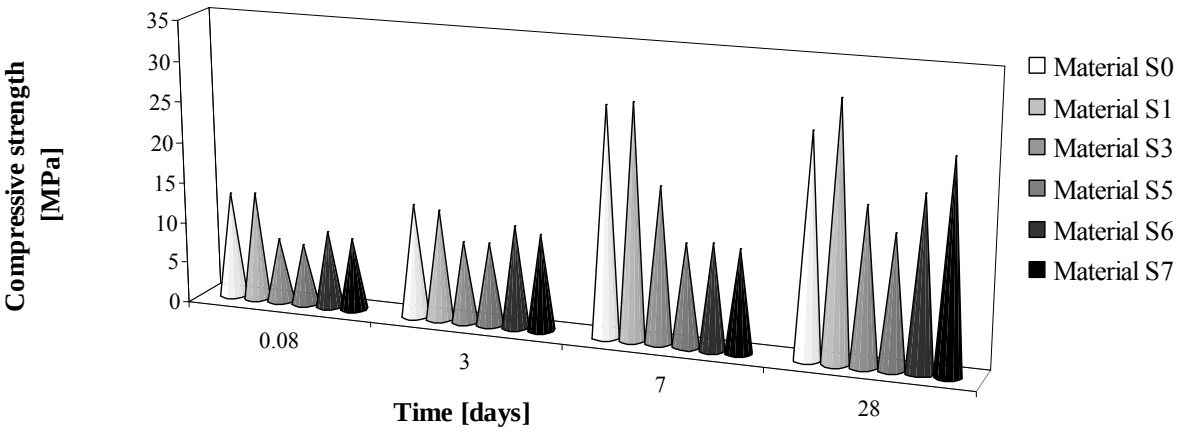

Fig. 1: The compressive strengths at various time intervals.

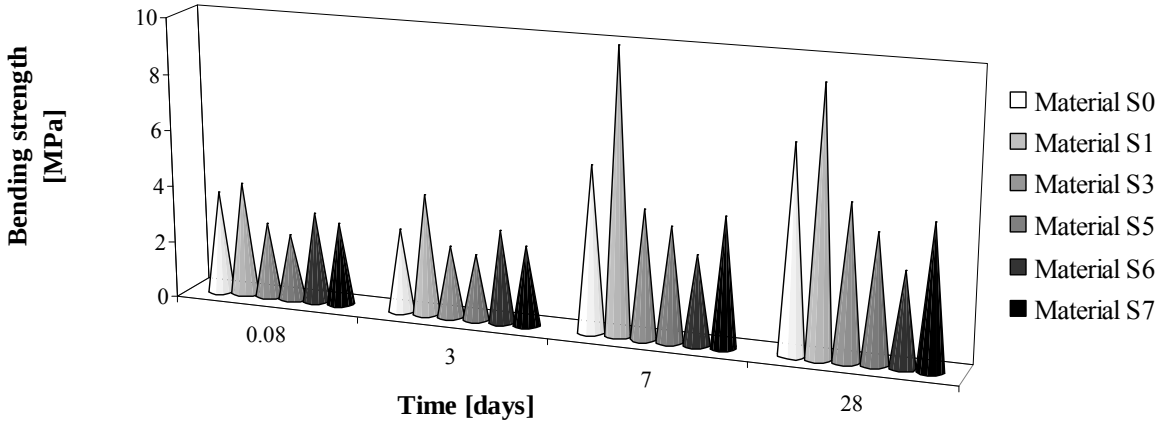

Fig. 2: The bending strengths at various time intervals.

4. Conclusions

The presented results show that for most materials are 2 hours, 1 and 3 days strengths nearly identical, then there is a significant increase in strengths. For the materials S0 and S1, the value of compressive strengths is doubled. The materials S6 and S7 behave somewhat different, which can be obtained according to previously observed values of the time dependence of compressive strength, which is an increasing trend in the reporting period. For the material with the addition of plasticizer (S1), compressive strength positively increased in comparison with untreated FGD gypsum – S0 material. The strength of this material is about 5 MPa higher (Shater et al, 1983) in comparison with the material after 28 days. For other materials, we can observe a reduction in compression strength values compared with the reference material. This effect was most pronounced for samples S3 and S5 produced with the addition of hydrophobic additives but with the same water-gypsum ratio. The least negative effect was achieved with material S3, but even here the 28-day strength decreased by 8 MPa. For S5 material, this value is lower by 10 and 11 MPa. The combination of plasticizer, hydrophobic additives, and lower water-gypsum ratio (0.500) for materials S6 and S7, which also includes the PP fibers, have led to improved compressive strength. Strength after 28 days is lower, only about 6.0 or 1.5 MPa compared with the reference material S0.

Similarly in Fig. 2 comparison of bending strength of materials, depending on time was investigated. The time intervals are the same as in the previous figure. From these results we can see that the reduction of water-gypsum ratio for material S1 resulted in an increase in bending strength in comparison with the reference material S0. Trend of increasing the bending strength was similar to that for compressive strength. For the first three measurement periods the measured values for each material was almost identical. Then the increase follows, which was between 3 and 7 day, it was the

highest for the material S1. The plasticizer, which was used on material S1 compared with S0 material, seems to be preferable because its bending strength increased by 2 MPa after 28 days. Hydrophobic additives led to reduction in strength in comparison with the reference material. It had the least negative impact on material hydrophobization S3, where the strength decreased by 2 MPa, S5 fell by nearly 3 MPa with the same water-gypsum ratio as the reference sample S0. The strength of material S6 still decline about 4 MPa. The combination of plasticizer, hydrophobic additives and lower water-gypsum ratio had such a positive influence on compressive strength (Jianquan et al, 2005). Some improvement was achieved in the S7 material, in comparison with the material S6 which also includes PP fibers. Here, the measured bending strength is 2.2 MPa lower than for the reference material S0.

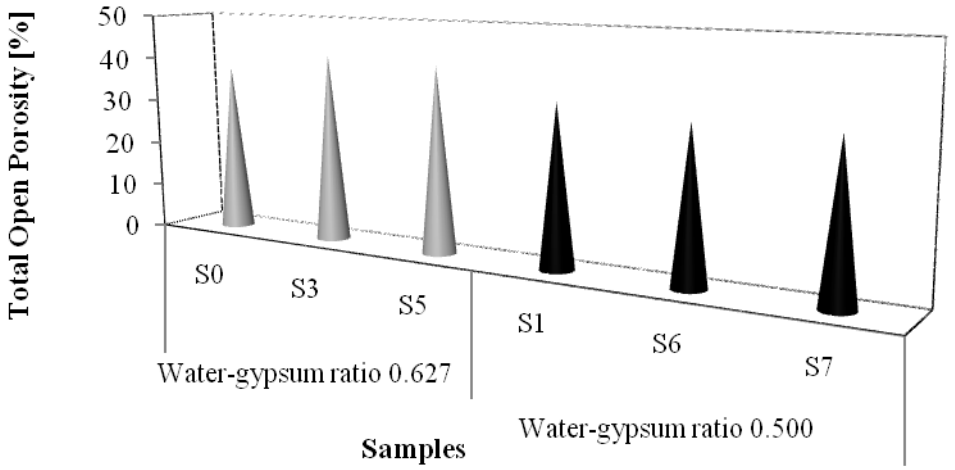

Fig. 3: Relationship between the total open porosity and water-gypsum ratio.

In the Fig. 3, there are clearly visible the differences in the values of total open porosity depending on the water-gypsum ratio. The difference of total open porosity for gypsum samples with the water-gypsum ratio 0.627 and 0.500 is more then 17 %. Taking into account that the value of 0.627 water-gypsum ratio is about 20 % higher than the value 0.500 then we can consider almost direct proportionality between water-gypsum ratio and total open porosity (Kuechler et al, 2002). Very interesting is the total open porosity shown in spite of added ingredients and PP fibers for the material S7.

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References

ČSN 72 2301 (1978) Sádrová pojiva. Klasifikace. Všeobecné technické požadavky. Zkušební metody. Prague: Czechoslovak standardization institutions, pp. 17.

Wirshing, F. (1983) Calcium Sulfate, In: Ullmanns Encyclopedia of Industrial Chemistry, Volume 6, Weinhein, Wiley-VCH Verlag, pp. 90 – 94.

Shater, M. A. & Mosalamy F. H., El-Sheikh R. & El-Didamony H. (1983) Mechanism of the hydration of tricalcium aluminate and gypsum of 1:3 mole ratio at low water/solid ratio and in suspension, Thermochimica Acta, Volume 69, Issue 3, pp. 379-388.

Jianquan Li, Guozhong Li, & Yanzhen Yu (2005) The influences of gypsum water-proofing additive on gypsum crystal growth, Material Letters, Volume 61, Issue 3, pp. 872-876.

Kuechler R., Noack K. & Zorn T. (2002) Investigation of gypsum dissolution under saturated and unsaturated water conditions, Ecological Modelling, Volume 176, Issues 1-2, pp. 1-14.