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# Effects of Additives Increasing Biological Resistance of Gypsum on Mechanical Properties of Resulting Composite

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**Abstract.** The article focuses on the effects of additives increasing biological resistance of gypsum on mechanical properties of resulting gypsum composite. In this study we use Silver Nitrate as an additive that improves biological resistance of gypsum composites. We investigate influence of four different amount of Silver Nitrate ($AgNO_3$), namely, 0.5 wt. %, 1 wt. %, 1.5 wt. % and 2 wt. %. The determined mechanical properties were flexural strength and compressive strength. The mechanical properties were investigated on the 7 days old samples with dimensions equal to 40 × 40 × 160 mm. The results obtained from these samples were compared with reference material. The results show a negative effect of $AgNO_3$ on flexural strength.

## Introduction

The gypsum is widely used material in civil engineering especially for production of plaster-board, gypsum plaster, gypsum masonry blocks [1]. Gypsum composites are more environmentally friendly and production is faster than cement composites. Mainly due to lower greenhouse gas production and sustainability [2]. Use of gypsum composites in civil engineering is significantly restricted because they have low moisture resistance. The moisture content of the material adversely affects the formation of molds and the reproduction of microorganisms. [3]. Molds belong to microorganisms, that commonly appear on inner and outer surfaces of building materials and can cause sick building syndrome which limits or completely restrict the use of the building [4]. From these reason, it is very important created biological resistance materials that resist mold formation on their surface and also in the inner of material.

Biological resistance of gypsum composites can be improved by adding antibacterial components (such as silver [5], $TiO_2$[6], cooper [7]) or hydrophobizing additives (such as waxes [8], saponifying agents [9], emulsifier [10]). This paper deals directly with using silver as additives increasing biological resistance. The silver was almost abandoned when penicillin were discovered. But today, with the emergence of antibiotic-resistant strains, it has gained new interest [11]. Silver was reported to be an efficient bactericidal antibacterial agent in the several works [12-14]. Also gypsum composite with antibacterial components is being developed and researched [15], but some of its properties are still unknown, for example mechanical properties which is important properties for using materials in civil engineering.

## Materials and Samples

Testing samples were composed of gypsum from Počerady (Knauf, Praha) and different amount of Silver Nitrate ($AgNO_3$), which increases the biological resistance of the resulting composites. Four concentrations of Silver Nitrate were tested: 0.5 wt. %, 1.0 wt. %, 1.5 wt. % and 2.0 wt. %. The samples were compared with reference sample composed of gypsum only. In all cases, the water coefficient was equal to 0.6. The samples composition is shown in Table 1. Each set consisted of 6 samples with dimension equal to 40 × 40 × 160 mm.

Table 1: Composition of the testing samples

| Set | Gypsum [g] | TiO2 [g] | Water [g] | Bulk density (kg/m$^3$) |
|---|---|---|---|---|
| ref. | 1500 | 0 | 900 | 1071 ± 10 |
| 0.5 % | 1492.5 | 7.5 | 895.5 | 1062 ± 8 |
| 1.0 % | 1485 | 15 | 891 | 1062 ± 1 |
| 1.5 % | 1477.5 | 22.5 | 886.5 | 1062 ± 4 |
| 2.0 % | 1470 | 30 | 882 | 1065 ± 17 |

## Experimental Methods

The flexural and the compressive strength were determined using the Web Tiv Ravestein devices on 7 days old the hardened gypsum samples. The resulting value was determined as the average of values excluding the lowest and highest values, and the standard deviation was determined.

The flexural strength was determined by three-point bending test. The test is performed on a beam with dimensions of 40 × 40 × 160 mm supported on two supports, which is loaded by force in the centre of the beam. The flexural strength was determined from the relationship between achieved the maximum force and the dimensions of beam at the fracture point as

$$f_b = \frac{3 \cdot F_{b,max} \cdot L}{2 \cdot h \cdot b} \quad (1)$$

where $F_{b,max}$ is the maximum force reached during the test, $L$ is a distance between supports equal to 100 mm, $h$ is height of the sample and $b$ is width of the sample [16]. Six samples were tested from each set. The testing was displacement controlled at a constant rate of 1 mm/min.

The compressive strength was determined by uniaxial compressive test on the half samples with dimensions of 40 × 40 × about 80 mm (broken parts of samples after bending test). The loading area was 40 × 40 mm. Twelve samples were tested from each set. The testing was displacement controlled at a constant rate of 3 mm/min. The compressive strength calculation was performed according to the equation [16]:

$$f_c = \frac{F_{c,max}}{h \cdot b} \quad (2)$$

where $F_{c,max}a$ is the maximum force reached during the test.

## Results and Discussion

Fig.1 shows investigated mechanical properties. The results show the effect of the Silver Nitrate on the flexural strength and the compressive strength of gypsum composites. The results show that the Silver Nitrate has a negative effect on the resulting flexural strength, with a difference of approximately 0.5 MPa for 0.5 % concentration of $AgNO_3$ and 1 MPa for higher $AgNO_3$ concentrations (1.0 %, 1.5 %, 2.0 %). It can be concluded that the introduction of inert $AgNO_3$ result in a less compact structure of hardened gypsum samples, leading to a deterioration of flexural strength.

The compressive strength was approximately the same for all tested samples (differences were up to the standard deviation) except for the 1% concentration of $AgNO_3$. The compressive strength samples with 1% concentration of $AgNO_3$ was about 3 MPa lower than reference samples.

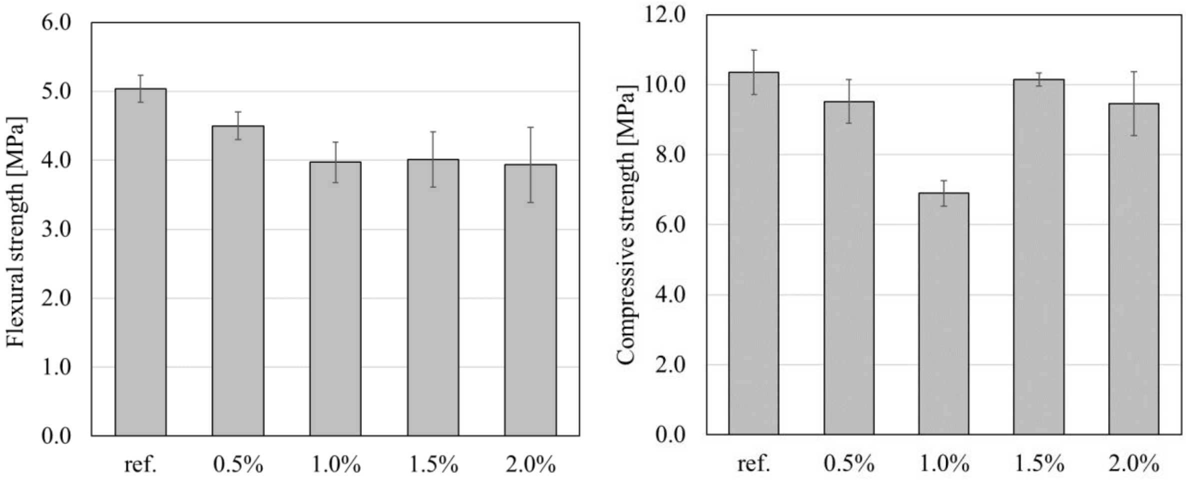


Fig. 1: Comparison of flexural strength – left and compressive strength – right (with standard deviations)

## Conclusions

This work was focused on the effects of Silver Nitrate increasing biological resistance of gypsum on mechanical properties of resulting composites. The tested samples were composed of Gypsum from Počerady and Silver Nitrate. The difference between individual samples was in the concentration of Silver Nitrate. Based on the results, it can be concluded that results the introduction of inert Silver Nitrate result in a less compact structure of hardened gypsum samples, leading to a deterioration of flexural strength and the compressive strength was approximately the same for all tested samples.

In the future, the research will focus on confirming effects of Silver Nitrate on mechanical properties gypsum composites by using scanning electron microscope with X-ray microanalysis by confirms the inert effect of Silver Nitrate on the phase composition of the composite.

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