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Long-time Investigation of Gypsum Composite Material Properties: Mechanical Properties

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Abstract. The paper presents results of nondestructive testing of mechanical properties of composite gypsum material. The specimens were cut from the gypsum block. One side of this block was exposed to the climatic influences for four years, because the block was put to the façade of the building. The matrix of 6 × 4 specimens of dimensions 40 × 40 × 160 mm were cut from the block after its removal from the façade. After 6 and 9 years, the Young's moduli and shear moduli of these specimens were determined from the transversal, longitudinal and torsional vibrations using the impulse excitation method.

Introduction

A calcined gypsum as a low-energy material can be produced with advantage from the waste products of either flue gas desulphurization in thermal power plants or phosphoric acid, hydrofluoric acid, citric acid and boric acid production in chemical plants by its dehydration at the temperatures of 110 to 150 °C. The solid structure of calcined gypsum can then be created by reverse hydration. Due to the very low price and large availability of waste gypsum, the material has a good potential for applications in buildings not only for dividing structures as with the most current gypsum applications but in some cases also for load-bearing structures [1,2]. However, in that case some modifications of this material are necessary which are supposed to enhance its original properties and increase its service life. For instance, use of plasticizers or fiber reinforcement can increase the mechanical strength of gypsum products, hydrophobization can protect the material from water penetration, fillers can decrease the necessary amount of binder in a composite material. Therefore, it is necessary to determine the properties of gypsum (bulk density, matrix density, open porosity, bending and compressive strengths, modulus of elasticity, thermal conductivity, volumetric heat capacity, water absorption coefficient, apparent moisture diffusivity, sorption and desorption isotherms) before starting to use it as the part of load-bearing structure. In modification of the utility properties of the gypsum, it is suitable to design a mixture using the additives and fillers but not to deteriorate other properties. The example is the usage of such amount of hydrofobization additives, which decrease the water absorption of the specimen but they have the negative influence on mechanical properties. Thus it is necessary to find a suitable compromise – suitable concentration of the components/additives, which influences the respective properties [3,4].

The paper presents long time monitoring of mechanical properties of the gypsum based composite material. The gypsum is a building material which has far wider potential for its use in construction than it is at present time. The gypsum can also be modified to improve its utility properties [2,3]. The main aim of the paper is to present the results of long time investigation of the gypsum based material, which seems to be promising and which has the potential to be applied in the building industry, for example in the form of components for building envelopes. The dynamic Young's modulus can be determined using ultrasonic or resonant methods. Ultrasonic methods are based on measuring the transit time and resonant methods are based on measuring resonant frequency. The big advantage of dynamic methods over static methods is its really nondestructive character and wide variety of specimen shapes and sizes to be used [5].

Experimental Methods

Impulse excitation method was chosen especially because we could measure the mechanical properties of the same samples at different times and thus eliminate the inaccuracies incurred in the production of the samples. The measurement was done using a measuring line Brüel & Kjær containing measuring analyzer Front-end 3560-B-120, the acceleration transducer type 4519-003, the impact hammer type 8206 and a control notebook (Fig. 1). Dynamic modulus of elasticity was evaluated at first from the measured basic longitudinal natural frequencies of the samples and then it was checked modulus calculated from measured basic flexural natural frequencies of the samples. Dynamic shear modulus was evaluated by measuring the basic torsional natural frequency [5,6].

Fig. 1. The measurement line – control notebook, vibration control station Bruel&Kjaer Front-end 3560-B-120, impact hammer Bruel&Kjaer of Type 8206 (left); the tested gypsum samples (matrix 6 × 4) after cutting from the exposed gypsum block (right).

Tested Material and Samples

The tested composite material is produced based on the gypsum from the power plant Počerady (of the company ČEZ) modified using the plasticizer (Peramin SMF 20 – 1 wt. %), a hydrophobic additive (Imesta IBS47 – 1 wt. %) and a Polyprophylen fibers (of the length 4 mm and a diameter 18 μm – 1 wt. %). The water-gypsum ratio was 0.627. The test samples of the dimensions 40 × 40 × 160 mm were made from the gypsum block of dimensions (350 × 250 × 600 mm), which was made in 2005 (see Fig. 1). The total number of the samples made from the block was 24. The gypsum block was placed in the façade of the building D of the Faculty of Civil Engineering, Czech Technical University in Prague [4]. The paper builds on the previous measurements, which were carried out on these samples in the past, and from which the partial results have already been published [3, 4].

Experimental Results

Results of dynamic modulus of elasticity for tested samples are shown in the Fig. 2 and summarized in the Table 1. The bulk density of the samples was 1150 ± 23 kg/m^3. The values measured in the year 2014 (9 years old samples) are shown in the Fig. 2. There are also shown values measured in the year 2011 (6 years old samples). In both cases it is visible a good agreement between obtained results in sets of specimens and also between corresponding sets.

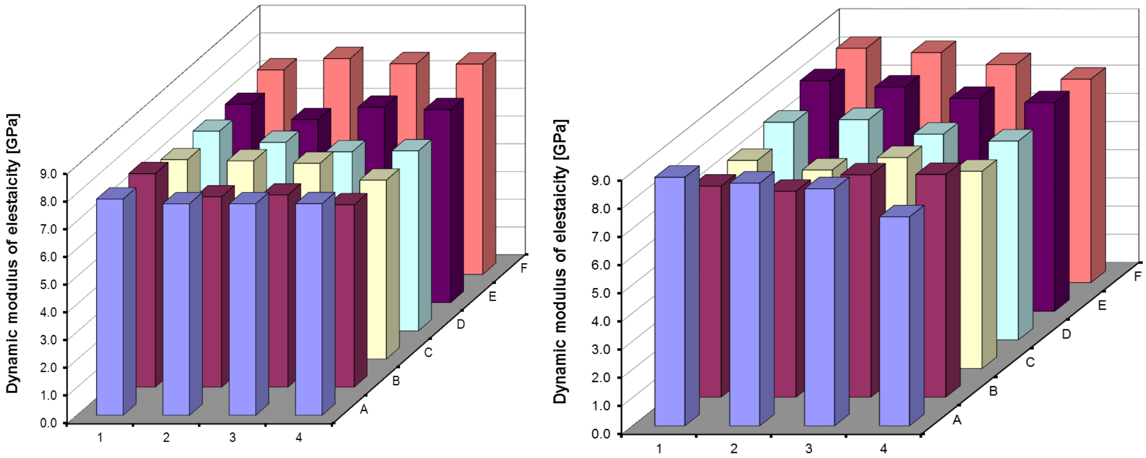

Fig. 2. Dynamic modulus of elasticity for 6 years old samples (left) and for 9 years old samples (right).

Table 1. Comparison of measured values of the dynamic modulus of elasticity $E_{d,}$ dynamic shear modulus G_d and Poisson's ratio μ for different times.

Property/Time	6 years	9 years
E_d [GPa] – longitudinal vib.	7.63 ± 0.43	7.65 ± 0.16
E_d [GPa] – transversal vib.	7.49 ± 0.59	7.53 ± 0.31
G_d [GPa]	3.11 ± 0.13	3.19 ± 0.06
μ	0.24 ± 0.04	0.21 ± 0.04

The results from Fig. 2 are summarized in the Table 1. All values are calculated as an average of 20 measured values (matrix of 6 × 4 samples after removal of the 2 lowest and 2 highest values of the samples). The Table 1 shows that there is a very good agreement among results. The dynamic moduli were determined based on longitudinal and also transversal vibrations to check the results, the differences are within the uncertainty of a measurement. The values of the shear modulus are also in a good agreement. We obtained the higher differences only for the Poisson's ratio. If we compare the mean value of the dynamic Young's modulus after 6 years 7.15 ± 0.51 MPa measured on another part of the block (the 2nd matrix 6 × 4 samples) with the mean value of the static modulus 6.85 ± 0.35 MPa, which was measured on the same set of samples, we obtain the difference about 5%. This difference is lower than the usual difference between static and dynamic moduli, which is in most cases in the range from 10 to 20 % [4].

Conclusions

The presented results show that the values of gypsum samples do not change over time. And also the comparison of the results from destructive tests (compressive strength) evaluated 28 days after production and results from tests after 9 years show that the compressive strength has not changed. In a follow-up research, we would like to use also other methods to specify the mechanical properties of gypsum and especially at the micro level using nanoindentation techniques [7,8].

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