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The Changes of the Gypsum Mechanical Properties in Dependence on the Number of the Freeze-Thaw Cycles

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Abstract. The paper presents the changes of the modulus of elasticity of the gypsum samples in dependence on the number of the freeze-thaw cycles. The moduli of elasticity were determined using an impulse excitation method. For the freeze-thaw cyclic loading, the samples were saturated with water at 20 °C then the samples were removed from the water bath and placed in a freezer with a temperature lower than - 20 °C. The temperature in the freezer was measured using thermometers during the freeze-thaw cycles. The difference from the 'dry' frost resistance was that the samples of hardened gypsum were exposed to the extreme load of the samples with the external climatic conditions.

Introduction

The most of the building materials, which are used for building envelopes at present time, must satisfy resistance to the external climatic conditions. One of the important parameters of the porous building materials, which will be used in an exterior, is the frost resistance. Several studies [1, 2] of the gypsum use in exteriors were done abroad. Also some research teams studied materials, which are available in the Czech Republic. They determined e.g. the frost resistance experimentally according to the methodology for plasters, because such methodology for gypsum does not exist [3], and the resistance to the external climatic conditions for samples freely stored in exterior [4]. There is one problem that each kind of gypsum, resp. gypsum according to the locality and a production method, has different properties and it is necessary to specify each particular material [5, 6].

Experimental Methods and Samples

The non-destructive impulse excitation method was used for an investigation of the modulus of elasticity changes in dependence on the number of the freeze-thaw cycles. The non-destructive method was chosen primarily because the same samples can be tested in a changing environment. Then there is certainty that the results presented changes of the mechanical properties of a particular sample and the results obtained have the higher reliability than that obtained from the destructive testing [7] and not only in the case of using the “traditional” destructive methods, when the damage of the sample is caused during the testing and other “same” measurements on the same sample cannot be carried out [8], but also in the case of use of “traditional” methods configured to the nondestructive methods [9, 10].

The grey gypsum produced by the company Gypstrend, s.r.o. was chosen for the purpose of these tests. The samples were made with the water/gypsum ratio 0.71. The tests started at the age of the samples 28 days.

The wet variant of the freeze-thaw cycles was used for the determination of the sample resistance. Before starting the tests, the samples were placed to the water bath of the temperature 20 °C. The samples were in the bath for four hours till the full water saturation. The freeze-thaw cycle is composed from two phases, during the first one the water saturated sample was placed to the freezer with the temperature - 20 °C at minimum and it was in the freezer for 8 hours. After 8 hours, the sample was put to the water bath of the temperature 20 °C for another 8 hours.

The Impulse Excitation Method (IEM) was chosen to determine the dynamic Young's modulus because of its non-destructive character. The mechanical characteristics were determined based on the equation for vibration of an isotropic beam with a continuously distributed mass, based on the measured resonant frequencies of longitudinal vibration of the samples, their dimensions and mass.

The measurement line consisted of the acceleration transducer Brüel&Kjær of Type 4519-003, the impact hammer Brüel&Kjær of Type 8206, the vibration analyzer Brüel&Kjær Front-end 3560-B-120 and the program PULSE 14.0. The vibration was induced by the strike of the impact hammer. The waveforms of the excitation force and the acceleration were recorded and transformed using the Fast Fourier Transform (FFT) to the frequency domain. The Frequency Response Function (FRF) as the ratio of the acceleration to the excitation force was evaluated from these signals using the vibration analyzer and the program PULSE 14.0. The test was repeated four more times for each sample and the averaged function FRF was saved. From an averaged FRF, the fundamental resonant frequency was determined for each sample. The specimen was supported in the fundamental longitudinal nodal position in the middle of its span (Fig. 1). The acceleration transducer was placed at the center of one end surface of the specimen (Fig.1 – right side). The opposite end surface of the specimen was struck perpendicular to the surface by the impact hammer (Fig.1 – left side).

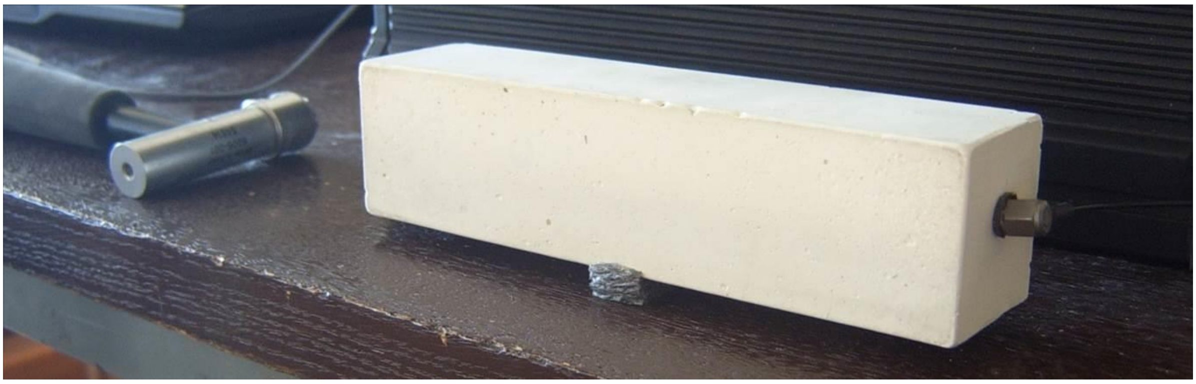

Fig. 1 Test arrangement for the longitudinal vibration

The mass and dimensions of the sample were measured, the FRF was evaluated and the dynamic Young's modulus E_{dl} was determined using the relation

$$E_{dl} = \frac{4lmf_l^2}{bt} \qquad (1)$$

where: E_{dl} is the dynamic modulus of elasticity [Pa], f_l is the fundamental longitudinal resonant frequency [Hz], b is the width of the sample [m], t is the height of the sample [m], l is the length of the sample [m], m is the mass of the sample [kg].

Experimental Results

The main goal of this experiment was the determination of changes of the modulus of elasticity of the gypsum in dependence on the number of freeze-thaw cycles using the impulse excitation method.

Table 1 The dynamic modulus of elasticity [GPa] of the gypsum samples after the 1st, 5th, 11th and 15th freeze-thaw cycles.

Sample No.	Number of the freeze-thaw cycles				
	0	1	5	11	15
1	5.31	5.31	5.07	4.36	4.31
2	5.41	5.40	5.16	4.57	4.42
3	5.32	5.32	5.02	4.24	4.40
4	5.06	5.02	4.83	4.93	3.97
5	5.20	5.15	4.94	4.25	4.15
6	5.20	5.15	4.91	4.29	4.20

The time dependent changes of the modulus of elasticity of the gypsum samples are shown in Fig. 2. The character of these changes is very similar for all six samples. The modulus of elasticity decreased about 20 % after the 15 freeze-thaw cycles. It is interesting that values of modulus of elasticity for water saturated samples decreased only about 8 %.

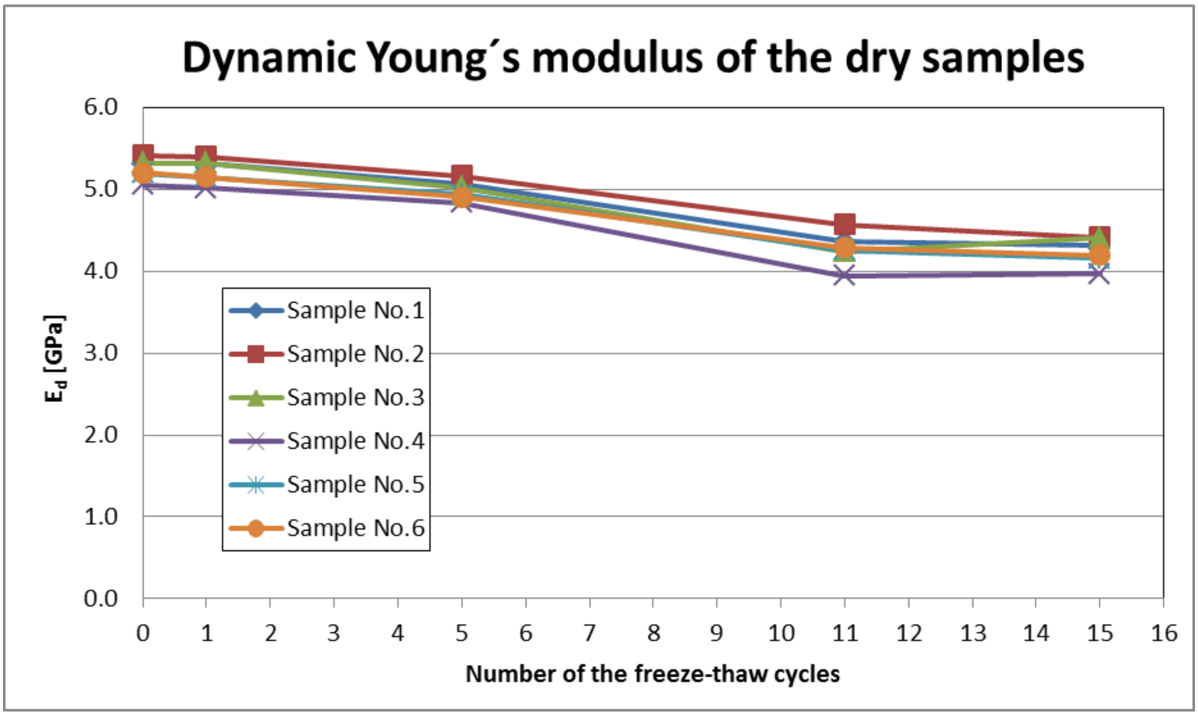

Fig. 2. Dynamic modulus of elasticity of the gypsum samples with natural water content after the 1st, 5th, 11th and 15th freeze-thaw cycles.

We did also the visual inspection of the samples after each of the freeze-thaw cycle. The surface of the samples is still undamaged without any visible cracks or flaking parts. The surface of the samples after 15 freeze-thaw cycles looks like the surface of the samples in the virgin state.

Conclusions

The paper presents the changes of the modulus of elasticity on the samples of hardened gypsum according to the number of freeze-thaw cycles determined using the impulse excitation method. The modulus of elasticity of the samples has decreased approximately about 20% after 15 freeze-thaw cycles but the surface is not damaged. In this case, the decrease of the moduli of elasticity can be explained by the solubility of gypsum, which is approximately 0.2 g in 100g of water [4]. It has to be also noticed that the samples were extremely loaded in this case because they were dried after each freeze-thaw cycle in contrary to the "wet" frost resistance testing.

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