EAN 2012
50th annual coference on experimental stress analysis

Evolution of the Dynamic Young's Modulus of Grey Gypsum in Time

Tomáš Plachý[1], Michal Polák [2] & Pavel Tesárek [3]

Abstract: The paper presents the evolution of the dynamic Young's modulus of grey gypsum in time. The determination of the Young's modulus was done using two nondestructive methods: resonant method and ultrasound method. The specimens were made with the standard water/gypsum ratio 0.71. Their dynamic properties were monitored during the first week with special attention paid to the first two hours after removing the specimens from the mould.

Keywords: Gypsum; Non-destructive testing; Resonant Method

1. Introduction

The gypsum, as other building materials, is classified according to the valid standards. In the Czech Republic, the valid standard for gypsum is ČSN 72 2401 Gypsum binding materials [1]. This standard specifies the testing of the gypsum binders according several criteria which than can be used for simple classification of the gypsum binders. Based on this classification the most appropriate application areas are recommended.

The classification principle of the gypsum is relatively simple and the main criterion is the two-hour compressive strength of the specimens 40/40/160 mm. The values of the two-hour strength are half of the strength of the hardened gypsum after 28 days. This is valid for constant laboratory conditions with the temperature 20 °C and with relative humidity 50 %. The biggest changes of the mechanical properties of the hardened gypsum occur during the first week after making the specimens [2].

For determination of dynamic properties evolution of gypsum it is usually used sets of specimens, which are tested destructively in different time instants to determine the time dependence. The disadvantage of this procedure is the need of big amount of specimens. The next problem is to keep exact technological procedures during making the specimens to not influence their mechanical properties. The other method how to determine the mechanical properties is nondestructive testing. Then the same set of specimens can be tested in different

[1] *Ing. Tomáš Plachý, Ph.D.; Department of Mechanics, Faculty of Civil Engineering, Czech Technical University in Prague, Thákurova 7, 166 29, Czech Republic; plachy@fsv.cvut.cz*
[2] *doc. Ing. Michal Polák, CSc.; Department of Mechanics, Faculty of Civil Engineering, Czech Technical University in Prague, Thákurova 7, 166 29, Czech Republic; polak@fsv.cvut.cz*
[3] *Ing. Pavel Tesárek, Ph.D.; Department of Mechanics, Faculty of Civil Engineering, Czech Technical University in Prague, Thákurova 7, 166 29, Czech Republic; tesarek@fsv.cvut.cz*

time instants [2]. The nondestructive resonant method and ultrasound method were used in this experiment. The dynamic Young's modulus of gypsum was monitored during the first two weeks with special attention paid on the first two hours after removing the specimens from the mould.

2. Specimens

The gypsum specimens of dimensions 0.04 × 0.04 × 0.160 m were made with the standard water/gypsum ratio 0.71 in a stainless mould with three sections. Tested specimens were made according to Czech standard CSN 722301 from the commercial gypsum grey which is produced by company Gypstrend. This binder is made from two different dehydrates, namely naturally gypsum and gypsum from chemistry industry, ratio is half to half.

3. Resonant method

The resonant method was used for determination of the dynamic Young's modulus. The method is based on measuring fundamental resonant frequencies of longitudinal or transversal vibrations of the specimens.

3.1. Longitudinal vibration

The specimen was supported in the middle of its span, the fundamental longitudinal nodal position. The acceleration transducer Bruel&Kjaer of Type 4519-003 was placed at the center of the end face of the gypsum specimen. The end face of the gypsum specimen opposite to the face, where the transducer was located, was struck by the impact hammer Bruel&Kjaer of Type 8206. Both signals, the excitation force and the acceleration, were recorded and transformed using Fast Fourier Transform (FFT) to the frequency domain, and the Frequency Response Function (FRF) was evaluated from these signals using the vibration control station Bruel&Kjaer Front-end 3560-B-120 and program PULSE 13.5. The test was repeated five times for each gypsum specimen and resultant readings were averaged. From an averaged FRF, the fundamental longitudinal resonant frequency was determined for each specimen. Based on the equation for longitudinal vibration of the beam with continuously distributed mass with free-free boundary condition, the dynamic Young's modulus E_{dl} can be determined [3] using the relation

$$E_{dl} = \frac{4lmf_l^2}{bh} \tag{1}$$

where l is the length of the specimen [m], m is the mass of the specimen [kg], f_l is the fundamental longitudinal resonant frequency of the specimen [Hz], b is the width of the specimen [m] and h is the thickness of the specimen [m].

3.2. Transversal vibration

The specimen was simply supported in the distance 0.224 of the span on both ends, the transversal nodal positions of the first mode of transversal vibration. The acceleration transducer was placed at the end of the specimen on the upper face. The upper surface of the opposite end of the specimen was struck by the impact hammer.

The first transversal resonant frequency was evaluated using the same procedure as the above described longitudinal one.

The dynamic Young's modulus E_{df} based on transversal resonant frequency can be determined using the relation

$$E_{df} = \frac{0.9465 l^3 m f_f^2 T_1}{b h^3} \tag{2}$$

where f_f is the fundamental transversal resonant frequency of the specimen [Hz] and T_1 is correction factor for fundamental flexural mode to account for finite thickness of bar, Poisson's ratio, and so forth. It is defined in [3].

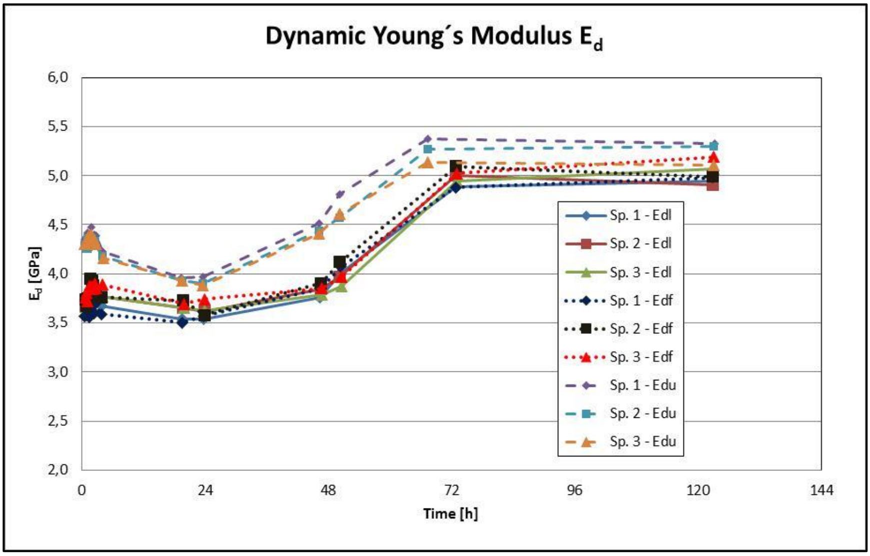

Fig. 1. The evolution of the dynamic Young's modulus of the gypsum.

4. Ultrasound method

The second nondestructive method used for monitoring of the mechanical properties evolution of the gypsum in time was ultrasound method. The ultrasound analyzer METEX with two probes of the frequency 55 kHz was used. One probe was placed at the center of one of the end faces of the gypsum specimen. The second probe was placed at the end face of the gypsum specimen opposite to the face, where the first probe was located. One probe (transmitter) sends ultrasound through the specimen and the second probe (response transducer) detects the time of signal traveling through the specimen.

$$E_{du} = \rho v^2 = \frac{m}{bhl}\left(\frac{l}{t}\right)^2 \tag{3}$$

where m is the mass of the specimen [kg], l is the length of the specimen [m], b is the width of the specimen [m], h is the thickness of the specimen [m], and t is the time of signal traveling through the specimen [s].

5. Experimental results

The Fig. 1 shows the evaluated dynamic Young's moduli determined based on the longitudinal resonant frequency E_{dl}, based on the transversal resonant frequency E_{df} and based on ultrasound method E_{du}. The graph shows the evolution of the dynamic Young's modulus of the gypsum in the first 5 days after making the specimens.

6. Conclusions

The paper presents the time dependent changes of the dynamic Young's modulus E_d of grey gypsum. The monitoring of the dynamic Young's modulus was done using two nondestructive methods: resonant method and ultrasound method. The trend of E_d changes is the same for both methods (see Fig. 1), just results from ultrasound methods are 20% higher. During the first two days the E_d a little bit decreased and then it rapidly increased. The assumption that the changes of E_d are big during the first two hours was not confirmed. The next step of our work will be correlation of macromechanical and micromechanical properties, which will be determined by nanoindentation [4].

Acknowledgements

This outcome has been achieved with the financial support of the Czech Technical University in Prague – SGS12/117/OHK1/2T/11.

References

[1] ČSN 72 2301, *Gypsum binding materials*, Czech standard (in Czech), ČNI, Praha 1979. 17 p.

[2] Plachý, T., Tesárek, P., Ťoupek, R., Polák, M. Nondestructive Determination of Young's Modulus of Gypsum Specimens Using Impulse Excitation Method. In *Proceeding of the 48 th International scientific Conference of Experimental stress Analyses.* 2010, pp. 339-344. ISBN: 978-80-244-2533-7.

[3] ASTM E1876-01, Standard Test Method for Dynamic Young's Modulus, Shear Modulus, and Poisson's Ratio by Impulse Excitation of Vibration, *Annual Book of ASTM Standards*, American Society for Testing and Materials, 2006.

[4] Tesárek, P., Němeček, J. Microstructures and micro-mechanical study of gypsum, *Chemické listy*, 105, 17, 2011. pp. 852-853. ISSN 0009-2770.

[5] Plachý, T., Tesárek, P., Padevět, P., Polák. M. Determination of Young's Modulus of Gypsum Blocks Using Two Different Experimental Methods, in *Proceedings of the 5th WSEAS International Conference on Applies and Theoretical Mechanics, (Mechanics'09)*, Book Series: Mathematics and Computers in Science and Engineering, 2009, pp. 109-113. ISBN: 978-960-474-140-3.

[6] Melzerová L., Kuklík P., Variability of Strength for Beams from the Glued Laminated Timber, in *Proceeding of Experimental Stress Analysis 2010*. Olomouc: Palacky University, 2010, p. 257-260. ISBN 978-80-244-2533-7.