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DYNAMIC MODULUS OF ELASTICITY OF DENTAL GYPSUM

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Abstract: *The paper describes the influence of water/gypsum ratio to the dynamic modulus of elasticity of dental gypsum. Commercially available dental gypsum Interdent® (with compressive strength 250 MPa after 24 hours) was used in our study. It was assumed that water to gypsum (w/g) ratio would have influence on its mechanical properties. Therefore, five different types of specimens with w/g=0.18, 0.19, 0.20, 021 and 0.22, further denoted as G0, G1, G2, G3 and G4, were prepared. These samples were tested using nondestructive method. The dynamic modulus of elasticity was determined based on measured basic resonant frequency of longitudinal vibration of the specimens. At the end, the comparison of obtained values in dependence on water/gypsum ratio was done.*

Keywords: ***Water/gypsum ratio, dental gypsum, dynamic modulus of elasticity, resonant method, natural frequency.***

1. Introduction

The commercially available dental gypsum was used in our tests. The dental gypsum a little bit differs from the classic gypsum used in building industry. The main difference is in strength of the dental gypsum which should be much higher. Tab. 1 shows types of dental gypsum. Every type is described from a point of view on strength (compressive) of hardened gypsum and expression during hardening. The table concludes expansion rates during hardening and usual value of water/gypsum ratio.

Tab. 1: Types of dental gypsum.

Type of gypsum	Description	Expansion rate [%]	Water/gypsum ratio
Type I	Expression plaster	0.15	0.50
Type II	Model plaster	0.30	0.50
Type III	Hard stone	0.20	0.30
Type IV	Super hard stone (low expansion)	0.10	0.22
Type V	Super hard stone (high expansion)	0.30	0.22

A common gypsum binder on a dental application was used for testing of the determination of dependence between water/gypsum ratio and mechanical properties of gypsum samples. This gypsum binder is an extra hard material for precision techniques during the construction of porcelain crown sand and bridges. The dental gypsum binder is a material with high resistance to compression (resistance after 24 hours is 250 N/mm^2 for a water/gypsum ratio 0.2) with high surface density, resistance to abrasion and low setting expansion (0.1 %).

2. Preparation of specimens

The commercially available dental gypsum Interdent® (with compressive strength 250 MPa after 24 hours) was used in our study. It was assumed that water to gypsum (w/g) ratio would have influence

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on its mechanical properties. Therefore, five different types of specimens with w/g=0.18, 0.19, 0.20, 021 and 0.22, further denoted as G0, G1, G2, G3 and G4, were prepared.

During preparing gypsum specimens, amount of the gypsum binder and amount of water which corresponded with used water/gypsum ratio (in our case five different values) were weighted at first. Than the gypsum was slowly added into the water and vigorously hand mixed with a spade approximately 1 minute until the mass was smooth. The mass was cast into a shape and 30 second vibrated on the vibration table. The specimens were removed from the mould twenty four hours after mixing.

The five specimens of dimensions 40 × 40 × 160 mm with different water to gypsum ratios were prepared and tested (Fig. 1).

3. Impulse excitation method

The impulse excitation method was used for dynamic Young's modulus determination of the gypsum specimens. It is based on measuring the fundamental resonant frequencies. The test arrangement was done for longitudinal vibration (Fig. 1).

The specimen was supported in the middle of its span (Fig. 1), the fundamental longitudinal nodal position. The acceleration transducer Bruel&Kjaer of Type 4519-003 was placed at the centre of one of the end faces of the gypsum specimen (Fig. 1- the right end face). 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 10.5 (Fig. 2). 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 modulus of elasticity E_d can be determined using the relation

$$E_d = \frac{4lmf^2}{bt} \tag{1}$$

where l is the length of the specimen, m is the mass of the specimen, f is the fundamental longitudinal resonant frequency of the specimen, b is the width of the specimen and t is the thickness of the specimen.

Fig. 1: Measurement of the natural frequency of longitudinal vibration.

Fig. 2: Measurement line for the Impulse Excitation Method.

4. Results

At first all three dimensions and weight of the gypsum blocks were measured and weighed (Tab. 2). Based on these properties and the fundamental longitudinal natural frequencies evaluated from FRFs of these gypsum specimens, dynamic modulus of elasticity was evaluated (Tab. 2) using equation (1). The dependence of the 1st natural longitudinal frequency of the gypsum specimens on the water/gypsum ratio is shown in Fig. 1 and the dependence of the dynamic modulus of elasticity of the gypsum specimens on the water/gypsum ratio is shown in Fig. 2.

Tab. 2: The measured characteristics of the dental gypsum specimens.

Specimen:	water/gypsum ratio	Weight [g]	Dimensions [mm]			f [Hz]	E_d [GPa]
			t	b	L		
G0	**0.18**	452	34.8	40	160	11680	28.37
G1	**0.19**	465	35.6	40	160	11648	28.18
G2	**0.20**	481	37.3	40	160	11488	27.27
G3	**0.21**	462	36.5	40	160	11530	26.80
G4	**0.22**	458	36.6	40	160	11380	25.77

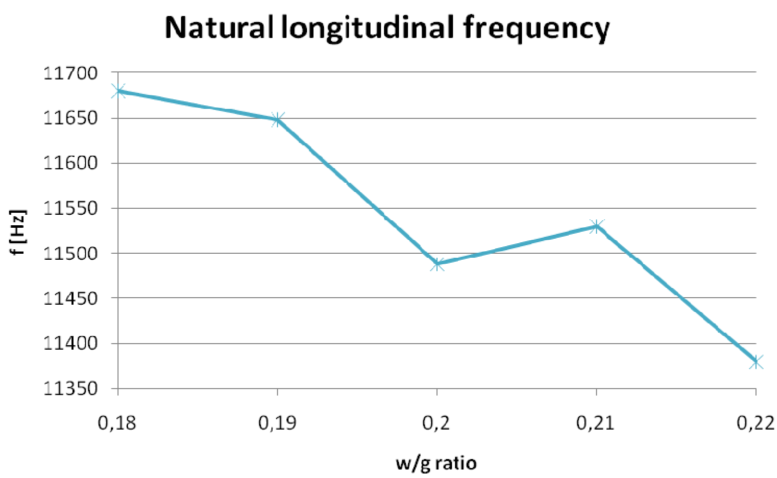

Fig. 3: Dependence of the 1st natural longitudinal frequency of the gypsum specimens on the water/gypsum ratio.

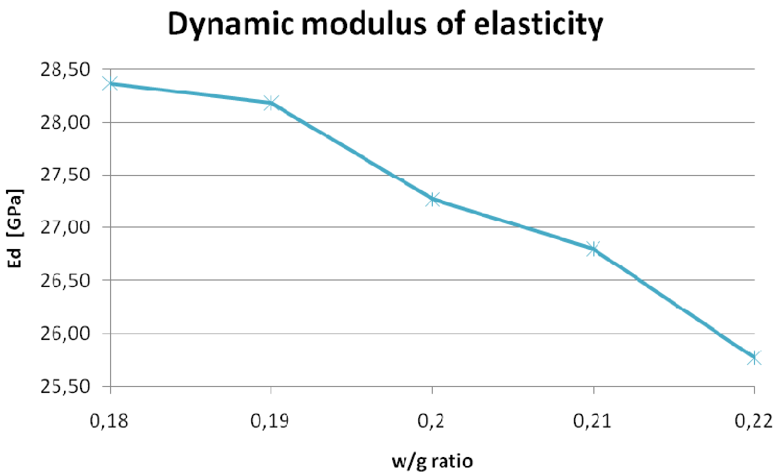

Fig. 4: Dependence of the dynamic modulus of elasticity of the gypsum specimens on the water/gypsum ratio.

5. Conclusions

The paper describes the influence of water/gypsum ratio on the dynamic modulus of elasticity of dental gypsum. The dynamic modulus of elasticity was measured using nondestructive impulse excitation method. From the obtained results (Fig. 2, Tab. 2), it can be seen that the dynamic modulus of elasticity decreases in dependence on increase of the used water/gypsum ratio of the dental gypsum specimens. The total difference between the dynamic moduli of elasticity of the specimens G0 and G4 is about 10 %. Even if we take into account that the accuracy of this method in this case is about 3.5 % of the value E_d, we can say that the water/gypsum ratio influences the value E_d of the dental gypsum specimens.

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