Effect of Particle Size Distribution Waste Micronized Marble Powder on the Mechanical Properties of the Cement Composite

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Abstract: This article deals with influence of the process of micronizing marble powder on the mechanical properties of the cement composite. The tested material consisted of cement CEM I 42.5R (Radotín) and non- / micronized marble powder. The difference between individual mixtures are the use of different fineness of micronized of marble powder. The investigated mechanical parameters were dynamic modulus of elasticity, flexural strength and compressive strength for 28 days old sample.

Keywords: marble powder; mechanical properties; cement composite; recycling; micronization.

1 Introduction

Marble industry produces annually more than 10 million tons of waste [1]. Waste is dumped in nearby factories and thereby creating environmental risk and prevents the development of marble industry. The most interesting part of the waste is marble sludge (powder) for which it is almost nil usage and has a negative impact on the environment by increasing the incidence of dust, damage to flora, fauna and human resources. For these reasons, it is important to create an application this waste, which should result in improved safety and health by reducing dust in the air, lower price for storage, transport and handling of waste and the possibility of potential income from the sale of recycled materials [2].

There are several work dealing with the use of marble sludge in cement composites. It was found that adding a small amount (5 – 10 wt. %) marble sludge into cement composites will improve the mechanical properties of the material such as compressive strength and flexural strength [3, 4, 5]. This application has a positive effect on the mechanical properties of the cement composite, but is insufficient in terms of the amount of used waste. If they had used larger quantities of waste (marble sludge), there would be a rapid decrease of mechanical properties [6]. New options to eliminate or limit this effect is the use of high-speed milling from Ltd Lavaris. The resulting product is micronized marble powder. This high-speed milling process of guaranteeing separation of all grain of marble sludge and drying recycled material [7]. The high-speed milling process was successfully used for micronized of recycled concrete [8]**.**

2 Used Materials and Samples

Mixture composed of 20 wt. % Portland cement CEM I 42.5R (Radotín) and 80 wt. % non- / micronized marble powder has been prepared for investigating the impact of micronizing. Marble powder was created by high speed milling of marble sludge from the West Bank of Jordan. Testing was performed on beams of dimensions equal to 40 × 40 × 160 mm. Six samples were tested from each mixture. Samples were demolded the day after production, and the samples were stored loosely in a laboratory environment at 22 ± 1 ° C and relative humidity 50 ± 2 %. The investigated mechanical parameters were dynamic modulus of elasticity, flexural strength and compressive strength. Mixture A contains non-micronized marble powder and serves as a reference sample. Mixtures B, C and D contain differently micronized marble powder. Amount of water was designed to maintain the same workability of fresh mixture. Consistency of the mixtures was determined using flow expansion test. The composition of individual mixtures can be seen in Table 1.

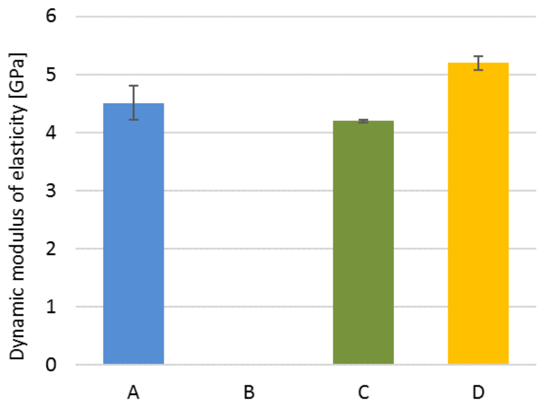
Tab. 1: Composition of the mixtures.

Set/ Material	Cement [hm. %]	Marble powder [hm.%]	Fraction of marble powder [μm]	Average grain size of marble powder [μm]	Water ratio
A	20	80	0 – 60	5.37	1.7
B	20	80	0 – 40	4.19	1.9
C	20	80	0 – 40	4.11	2.0
D	20	80	0 – 30	3.69	2.1

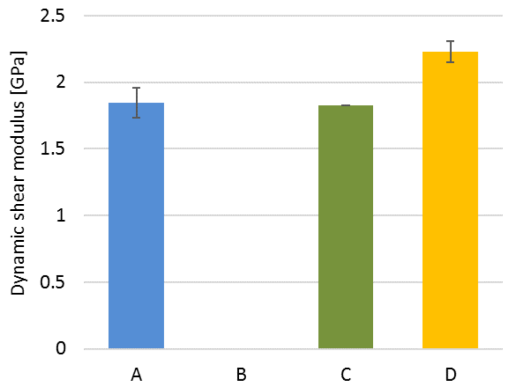
3 Experimental Methods and Results

Resonance method is used for non-destructive testing; its principle was explained in the works of Klapálek et al. and Topič et al. [9, 10]. Measurement of the dynamic modulus of elasticity was carried out using the measurement line from Brüel & Kjær, consisting of a measuring unit type 3560-B-X12 impact hammer type 8206 and an acceleration sensor type 4519-003 53422 assembly was connected to the control computer. The mass of all specimens was measured and the dimensions were recorded before the resonance method was applied.

The flexural and compressive strength were determined using the Heckert device, model FP100 on the 28 days old specimens. The testing was displacement controlled at a constant rate of 0.1 mm/s in the case of four-point bending and 0.3 mm/s for the compressive test. The distance between supports for four-point bending test was equal to 100 mm. The uniaxial compressive test was performed on the broken halves of the specimens with effective dimensions of 40 × 40 × 80 mm.

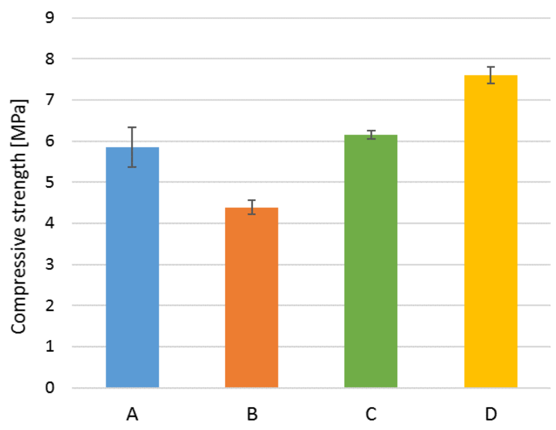


a) comparison of dynamic modulus of elasticity (with standard deviation).

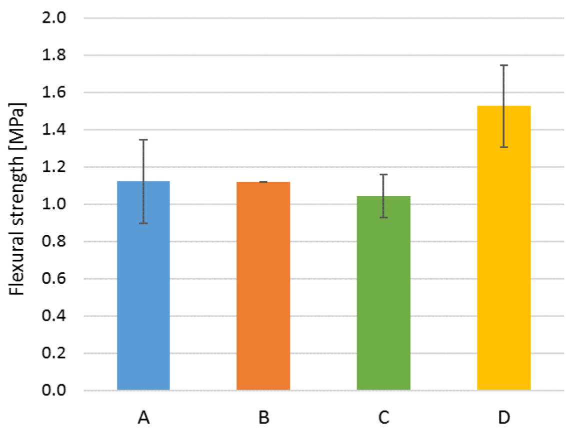


b) comparison of dynamic shear modulus (with standard deviation)

Fig. 1: Comparison of mechanical properties of the 28-day old material from/set non-destructive tests.



a) comparison of compressive strength (with standard deviation)



b) comparison of flexural strength (with standard deviation)

Fig. 2: Comparison of mechanical properties of the 28-day old material/set from destructive tests.

All test materials had approximately the same bulk density. The value of bulk density was 1430 ± 50 kg/m^3. The results (Fig. 1 and Fig. 2) show the effect of fineness of micronizing marble powder on the mechanical properties of the cement composite. Mixture with non-micronized marble powder (A) had the average value of compressive strength after 28 days 5.85 ± 0.45 MPa and mixture with the finely micronized marble powder (mixture D) had average value of compressive strength 7.61 ± 0.20 MPa. Samples of mixture B contained cracks and therefore, the resultant compressive strength was less than the reference sample (mixture A). Cracks in samples (B) also had an effect on the measurements using the resonance method, because it was not possible to capture the response impulses from excitation pulse "hammer" and dynamic modulus and dynamic shear modulus could not be measured. Similar trends as the compressive strength were observed in the flexural strength, dynamic modulus of elasticity and dynamic shear modulus. (Fig. 1 and Fig. 2a). Flexural strength of material (A) was equal to 1.12 ± 0.20 MPa. Set (D) had the average value of compressive strength 1.53 ± 0.20 MPa.

4 Conclusion

Using micronized marble powder was an increase in compressive strength of about 30% against the reference mixture. The results show that micronized marble powder performs the function of microfiller. The investigated materials have the potential for economic reasons, because this waste has almost zero cost, and thus it becomes very promising for the civil engineering. In the future, we will focus the possibility of involvement of micronized marble powder in the hydration process, secondly we will try to map the involvement marble powder to microstructure of cement composite and third we will focus our attention on the study of microstructure and micromechanical properties to follow the studies of e.g. [11, 12].

Acknowledgement

Financial support from the Faculty of Civil Engineering, Czech Technical University in Prague (SGS project SGS16/201/OHK1/3T/11). The authors also thank the Center for Nanotechnology in Civil Engineering at the Faculty of Civil Engineering, Czech Technical University in Prague, Faculty of Mechanical Engineering Czech Technical University in Prague and the Joint Laboratory of Polymer Nanofiber Technologies of the Institute of Physics, Academy of Science of Czech Republic, and the Faculty of Civil Engineering, Czech Technical University in Prague.

References

[1] M. A. Mashaly, A. O. Shalaby, B. N. El-Hefnawi, Characterization of The Marble Sludge of The Shaq El Thoaban Industrial Zone, Egypt and Its Compatibility for Various Recycling Applications 6 (2012) 153–161.

[2] M.S. Ibrahim, et al., Health Risk Assessment of Marble Dust at Marble Workshops, Nature and Science, 9 (2011) 144-154.

[3] A. A. Aliabdo, A. E. M. Abd Elmoaty, E. M. Auda, Re-use of waste marble dust in the production of cement and concrete, Constr. Build. Mater. 50 (2014) 28–41, http://dx.doi.org/10.1016/j.conbuildmat.2013.09.005.

[4] H. Binici et al., Durability of concrete made with granite and marble as recycle aggregates, J. Mater. Process. Technol. 208 (2008) 299–308, http://dx.doi.org/10.1016/j.jmatprotec.2007.12.120.

[5] V. M. Shelke, P. Pawde, R. Shrivastava, Effect of marble powder with and without silica fume on mechanical properties of concrete, J Mech Civ Eng 1 (2012) 40-45, http://dx.doi.org/10.9790/1684-0114045.

[6] B. Demirel, The effect of the using waste marble dust as fine sand on the mechanical properties of the concrete, Int. J. Phys. Sci. 5 (2010) 1372–1380.

[7] Z. Prošek, et al., Effect of micronized recycled materials on mechanical properties of cement mortar with crushed bricks, A R Research publication 4 (02) (2015), 120–124, ISSN 2319-8354.

[8] Z. Prošek, et al., Influence of recycled concrete composition on its elastic stiffness, Key Engineering Materials 677 (2016) 288-291, http://dx.doi.org/10.4028/www.scientific.net/KEM.677.288.

[9] P. Klapálek, L. Melzerová, Methods of non-destructive assessment of timber, Applied Mechanics and Materials 732 (2015) 369-372, http://dx.doi.org/10.4028/www.scientific.net/AMM.732.369.

[10] J. Topič et al., Effect of PVA Modification on the Properties of Cement Based Composite, Acta Polytechnica 55 (2015) 64-75, http://dx.doi.org/10.14311/AP.2015.55.0064.

[11] P. Tesárek et al., Micromechanical properties of different materials on gypsum basis, Chemicke Listy, 106 (2012) s547-s548. ISSN 0009-2770.

[12] P. Tesárek, J. Němeček, Microstructural and micromechanical study of gypsum, Chemicke Listy, 105 (2011) s852-s853.