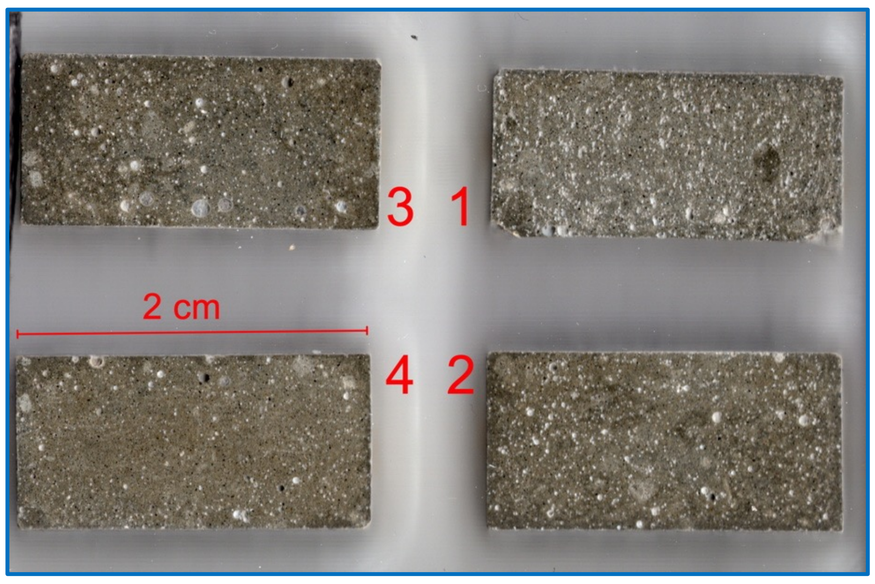
37th Danubia-Adria Symposium on Advances in Experimental Mechanics
21.-24. September 2021, Linz, Austria

Poster ID
44

Olaf Lahayne, Luis Zelaya-Lainez, Thomas Buchner, Josef Eberhardsteiner
TU Wien, IMWS - Institut für Mechanik der Werkstoffe und Strukturen

Influence of Nano-Additives on the Elasticity of Cement



To survey the influence of nano-additives in Portland cement, samples with four mixtures of additives have been produced by the Belorussian National TU and analyzed at the TU Wien. The additives were:

- Superplasticizer (SP),
- SiO_2 nanoparticles (NP), and
- Multi-walled carbon nanotubes (MWCNT).

For the four tested sample types, the additives were composed as follows:

1. 0.4 % mass fraction of SP,
2. 0.39 % SP, 0.06 % NP,
3. 0.39 % SP, 0.4 % MWCNT, and
4. 0.39 % SP, 0.4 % MWCNT, 0.06 % NP.

← Fig. 1: One set of cement samples with types 1 to 4.

Three test methods were used to investigate the effect of the additives:

Ultrasonic tests

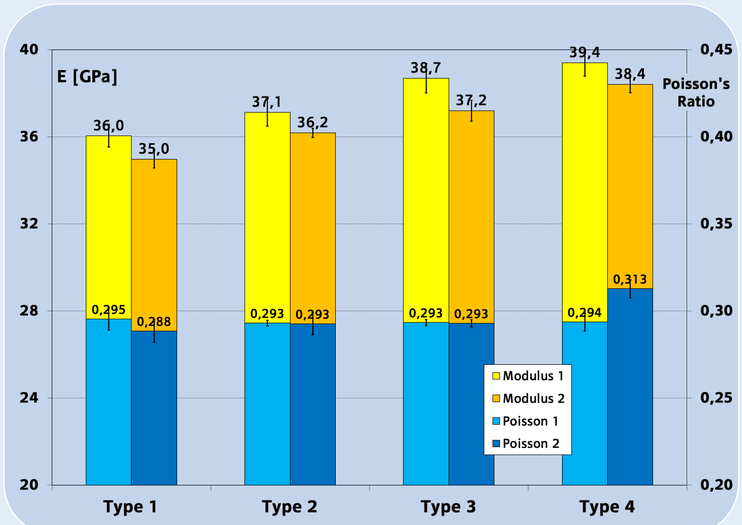


Fig. 2: Results of ultrasonic tests on two sample sets

Indentation tests

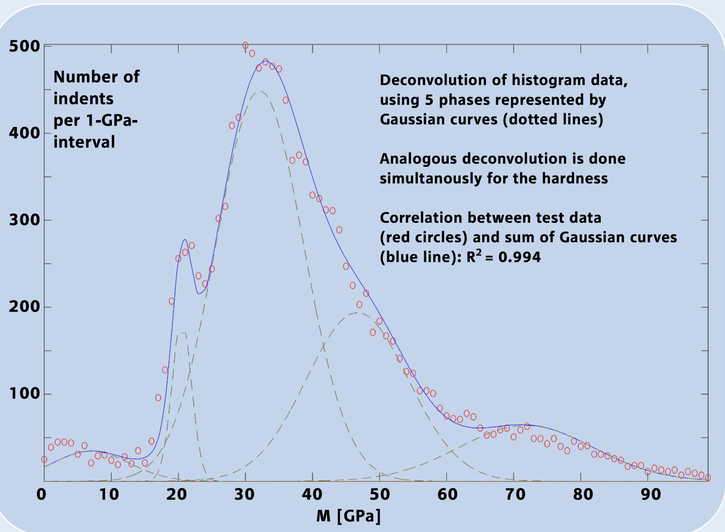


Fig. 3: Histogram of results for indentation modulus

Energy-dispersive X-ray spectroscopy

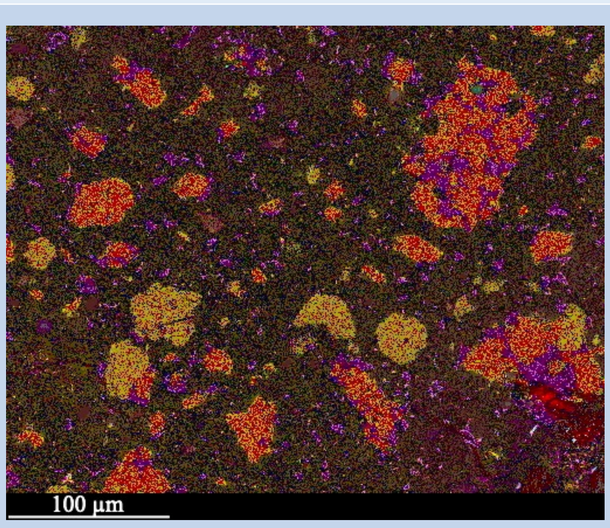
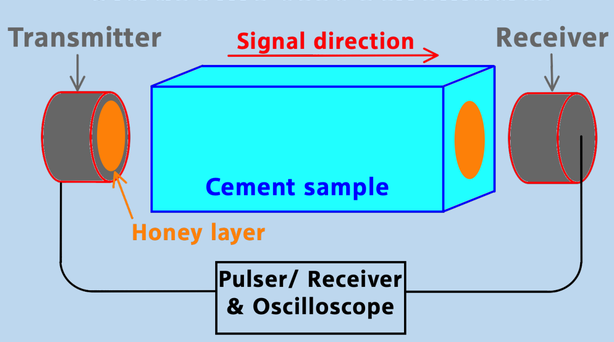


Fig. 4: Result of EDX-measurement on one sample

2 sets of 4 samples (1 per type, see Fig. 1) were used for ultrasonic tests. First the density was measured, which was increasing by about 10 % from type 1 to type 4. Afterwards, the samples were tested with transversal wave transducers at a frequency of 5 MHz. Young's modulus E and Poisson's ratio ν were calculated based on the measured signal velocities (see Fig. 2) [1]. While Poisson's ratio is always in the region of 0.30, for Young's modulus there is an increasing tendency between type 1 and 4 for both sample sets.

Ultrasonic test schematics



For 1 sample per cement type we polished planes of 2 x 1 cm² (see Fig. 1). On these 4 samples we performed nanoindentation test series with the same settings. Altogether, some 13000 indents were analyzed according to the method of Oliver and Pharr [2]. Based on the latter, the values were calculated for the indentation modulus M and the hardness H. The results can be displayed as histograms for M (see Fig. 3) and H. Using a deconvolution method developed for a similar application [3] with 5 phases represented by Gaussian curves, we calculated the expectation values and fractions of the five phases of this material.

Phase number	Material	Modulus [GPa]	Hardness [GPa]	Fraction [%]
1	Pores	6.9	0.14	3.6
2	LD-CSH	20.5	1.13	4.9
3	HD-CSH	32.1	1.78	53.2
4	CH	46.7	3.17	26.7
5	Clinker	71.8	6.44	11.6

By means of SEM, we performed an energy dispersive X-ray analysis to gather information about the chemical composition of the material. Figure 4 displays the chemical analysis of a representative test area. The table below lists the proportions of the predominating elements. Comparing such results with the optical images, the phases as given in the table can be identified and quantified.

Element	Fraction of Weight [%]	Fraction of atom [%]	Error [%]
C	2.5	4.6	14.2
O	46.4	64.4	10.0
Mg	0.6	0.5	12.2
Al	1.9	1.6	6.9
Si	10.1	8.0	4.5
Mo	0.8	0.2	16.1
S	1.1	0.7	7.3
Ca	34.2	18.9	1.7
Fe	2.2	0.9	6.6

Conclusions

With the first set of inspections, the phases and their compositions have been identified and quantified. With the ultrasonic tests, a significant influence of the additives have been shown. As next step, the deconvolution will be done separately for all 4 types, to pinpoint and quantify the effect of the additives on the characteristics of the 5 phases itself and on their fractions in the respective types. This way, we hope to illuminate which mixture of additives will be most helpful and effective for improving the characteristics of Portland cement.

Acknowledgements

We are grateful to S.N. Leonovich and E.N. Polonina of the Belorussian National Technical University for providing the test samples.

References

[1] C. Kohlhauser, C. Hellmich: Ultrasonic contact pulse transmission for elastic wave velocity and stiffness determination: Influence of specimen geometry and porosity, Engineering Structures 47 (2013) 115–133
[2] W.C. Oliver, G.M. Pharr: An improved Method for determining hardness and elastic modulus using load and displacement sensing indentation experiments, Journal of material research, 1992, 7 (6), 1564-1583.
[3] P. Dohnalík, B.L.A. Pichler, L. Zelaya-Lainez, O. Lahayne, G. Richard, C. Hellmich: Micromechanics of dental cement paste, Journal of the Mechanical Behavior of Biomedical Materials, 2021 (Draft)