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THE EFFECT OF POZZOLANS ADDITION ON CEMENT MORTARS

The addition of microsilica was widely used in concretes and mortars since the second half of the 20th century (in high and very high strength concretes). Silica fume consists of very fine spherical particles. This additive, thanks to its properties, fills the space between cement particles and aggregates which affects: porosity, watertightness, shrinkage reduction and increased strength. The microsilica has pozzolanic properties and reacts with calcium hydroxide and gradually forms a uniform and continuous contact phase C-S-H (calcium-silicat hydrate). The interfacial zone between cement paste and aggregate has been considered as a zone of weakness. Zeolite is a material lesser known in civil engineering which can be used as an alternative to microsilica. The article presents the investigation of the physical properties of mortars containing these two types of pozzolan. In mixes pozzolan additives at 0 to 20 percent by mass of portland cement are used. Testing of such properties of fresh mortar as workability and air content was carried out. The properties of hardened mortar such as strength, water absorption, frost resistance and capillary suction were also determined.

Keywords: cement mortars, microsilica, zeolite, physical properties, freeze-thaw resistance, capillary suction

1. Introduction

In humid, saline or other outdoor environments the classic concrete formula (aggregate, cement, water) has ceased to be sufficient nowadays. Research on improving the composition of mortars and concretes is carried out all the time. The materials currently used must endure the external environment conditions. The following admixtures and additives are widely used nowadays: the ones improving the properties of the finished product, increasing durability, enhancing resistance to aggressive environment and counteracting significant capillary suction. The frost destruction of the material (mortar, concrete) consists in the direct physical action of water freezing inside the pores. Water increases the volume by about 9% during freezing. [1].

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Cement composites have begun to be modified in the first half of the 20th century. Plasticizers in the form of unmodified lignosulfonates have been used at that time [2]. Plasticizers are used to enhance the fluidity of the concrete without adding water. This allows to reduce the cement content in the concrete composition and also influences its properties positively. This article presents the results of research on the influence of pozzolan additives on the physical properties of mortars. Two types of materials are used: silica dust and zeolite. Microsilica is a commonly used addition improving the properties of mortars and concretes. This is a by-product of the production process of metallic silicon and ferro-silicon alloys [3]. This dust consists of particles much smaller than the dimensions of cement grains (about 100 times smaller). The second type of additive used in the research is zeolite. It is an aluminosilicate mineral that has not yet gained popularity and is not widely used as an addition to mortars in construction.

The purpose of the work is to show the effect of adding various amounts of microsilica and zeolite on fresh mortar properties as workability and air content was carried out. The properties of hardened mortar such as strength, water absorption, frost resistance and capillary suction are also determined. Pozzolan additives during the tests are treated as an additional mass, not a replacement for cement. The article assumes that the use of microsilica and zeolite has a similar effect on the properties of the mortar. The additives are supposed to improve the mechanical parameters, reduce capillary suction and increase the frost resistance.

2. Composition of cement mortar

The mortar composition has a constant w/c ratio and different contents of two types of additives. The mortar consistencies are obtained using the same amounts of super-plasticizer at appropriate pozzolan contents. Reference material (marked as Z1) – is a mortar without additives. In mixes is used as a pozzolan at 10 to 20 percent by mass of portland cement. Mortar compositions are shown in Table 1.

Table 1. The content of mortar ingredients

	Z1 [g]	**Z2 [g]**	**Z3 [g]**	**Z4 [g]**	**Z5 [g]**
Portland cement	1 500	1 500	1 500	1 500	1 500
Water	600	600	600	600	600
Sand	3 000	3 000	3 000	3 000	3 000
Plasticizers	15	16.5	27	16.5	27
Zeolite	0	150	300	0	0
Microsilica	0	0	0	150	300

The mortar is prepared by mixing the ingredients in a laboratory mixer according to EN 196-1 [4]. After pre-mixing the material is left for 5 minutes and after this time it is mixed again. To compare the influence of a plasticizer on the consistency of mortars the same amounts of this admixture are used in matching mixtures.

2.1. Characteristics of the main ingredients

Research carried out on microsilica from the Laziska steelworks shows that this additive does not have a radiological hazard. Amorphous silica is a basic component of silica fumes and the chemical composition is very constant. With its proper application, it enables a significant improvement in the strength properties of mortars and concretes. Based on the tests described by Cz. Wolska-Kotanska [1], the addition of silica dust, as a cement replacement in the amount of 10–30% of the cement mass, the water demand increases by 20–40%. The author of the research shows that the influence of microsilica on the strength of mortar is not as explicit as in the case of concrete. Silica fumes affect the transition zone at the interface of the cement matrix and aggregate. Similar studies have been carried out by I. Przerada M. Lubas [5]. The authors has confirmed the above conclusions indicating also the increase in strength along with the lengthening of the hardening process of the mortar and concrete.

The second pozzolan additive is zeolite - a natural volcanic mineral with unique properties. The chemical composition of the zeolite is similar to the composition of fly ash. It is the material with a density of 2.4 g/cm^3 and has a surface area about 50 times greater than cement. Many studies have been conducted on the effects of using zeolite as an additive and as a substitute for cement. Studies conducted by Bundyra-Oracz G., Siemaszko-Lotkowska D. [6] indicate that the presence of zeolite does not significantly affect the setting time. However, it increases the water consumption of the cement paste, which requires the use of an effective plasticizer. Among the carried out tests there are also studies of the addition of zeolite to renovation plasters [7] as a material allowing to reduce costs.

Pozzolan additives thanks to a large fine degree accelerate the increase of strength and durability of the final product. They improve the properties of concrete or cement paste due to the pozzolanic reaction and their role as a micro-filler. This also affects the mortar tightness, because pozzolans react with calcium hydroxide which is released in the hydration process of silicates found in Portland cement. A large fine degree makes the reaction proceeding rapid. The very small pozzolan particles fill the spaces in the cement paste more tightly, which results in a thickening of the fresh mix.

The other ingredients of the mixes are Portland cement CEM I 42.5 R and a superplasticizer based on polycarboxylates.

3. Methodology and test results

The research is carried out in two groups: fresh mortar tests and investigations of hardened mortars. In the first group the following tests are performed: consistency, bulk density and air content. For hardened samples tests are carried out: density, absorbability, linear changes, strength, frost resistance (frost resistance after 50 cycles) and capillary suction.

Constant temperature of 23±2°C and relative humidity RH of 50±5°C are maintained during samples testing and conditioning. The consistency test is performed using the cone penetration procedure in accordance with PN-B-04500 [8].

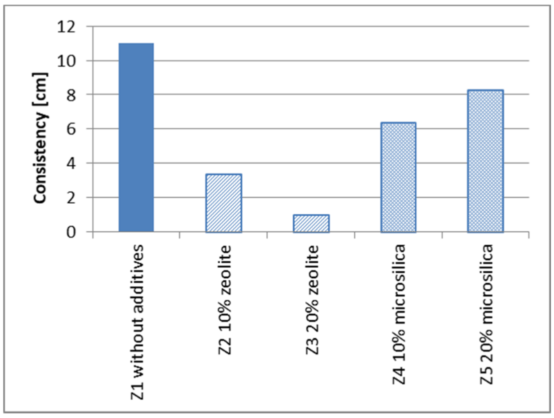

Fig. 1. Consistency test of Mortar

For comparative purposes, identical proportions of plasticizer are used for additives of 10% and 20% pozzolan, respectively. Zeolite thickened the mixture much more than the addition of microsilica. A density test does not show significant changes in individual types of fresh mortar and this parameter is maintained between 2.14 and 2.17 g/cm^3.

The test specifying the air content (Air Meter Method) is made using a special testing device with a metal sample container and a cover assembly [9]. The idea of the test is to compare the known value of air volume (located in a sealed chamber) at a specified pressure to an unknown value of air volume in the sample mortar. The meter is pressurized to the appropriate level and then the pressure is released into the main chamber. The results are recorded as the air content of the mortar.

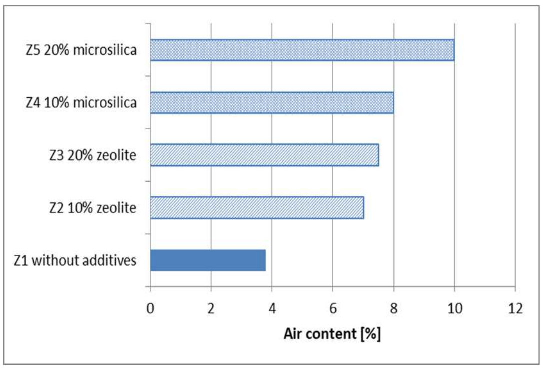

Fig. 2. Air content in fresh mortar

Fig. 3. A measuring device to determine the air content

Increasing the zeolite content in the mortar composition does not cause a significant growth in the air content. It is different considering microsilica. Increasing the addition of silica fume from 10 to 20% results in an increase in the air content by 2%. Higher air content in the paste may improve the frost resistance of the settled mortar. Water absorption tests on absorbability are made for hardened mortars [8].

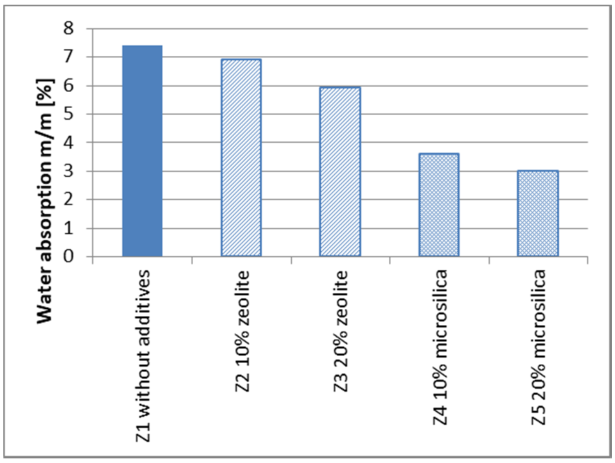

Fig. 4. Water absorption tests

The test allows determining what how much water the sample is able to absorb at normal atmospheric pressure. The greatest water mass (7.4% of the mass) is absorbed by the mortar without additives. Increasing the zeolite content to 20% allows to reduce the absorbability to the level of approx. 5.9%. Relatively better parameters are obtained for microsilica. Its addition allowed to lower the absorbability to 3.6% for Z4 mortar and 3.0% for Z5 mortar.

Compressive strength tests are made according to EN 196-1 [4]. Samples are stored in water after demoulding. The tests are performed after 14, 28 and 90 days from demoulding. The results are shown in Fig. 5 and 6.

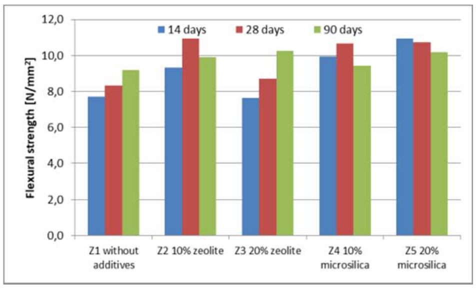

Fig. 5. Flexural strength after time

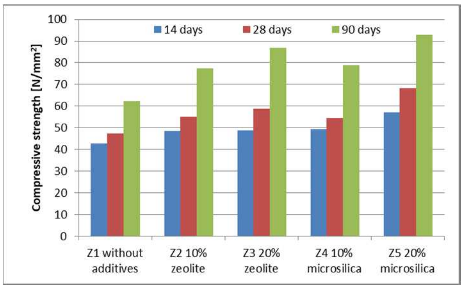

Fig. 6. Compressive strength after time

The results of bending strength tests after application of pozzolan additive oscillate around 10 N/mm^2 which is a very good result in the case of cement mortars. In compressive strength tests, the effect of the mortar maturing over specific time is evident. The use of zeolite has a similar effect as the corresponding microsilica additive.

The frost resistance test is aimed at determining the decrease in strength and weight loss caused by cyclic freezing and thawing of samples. After a 28 day curing time, the samples are dried to a constant weight. The samples are subsequently placed in water until full saturation. Samples are stored in a freezer equipped with automatic temperature control. Freezing lasted 4 hours at -20±2°C, then the samples are placed in water at 20±2°C for 4 hours. The freezing and thawing process is repeated cyclically. The results of compressive strength tests after 50 cycles are shown in Fig. 7, and the reduction in strength compared to the control samples in Fig. 8.

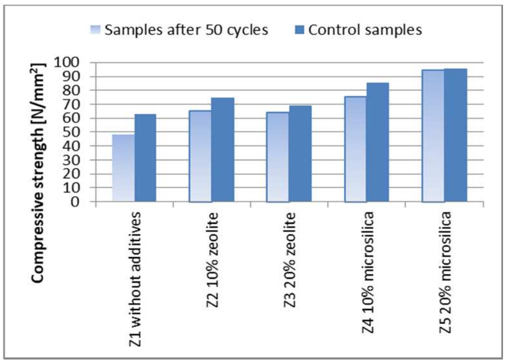

Fig. 7. Compressive strength of control samples and after 50 cycles of freezing – thawing

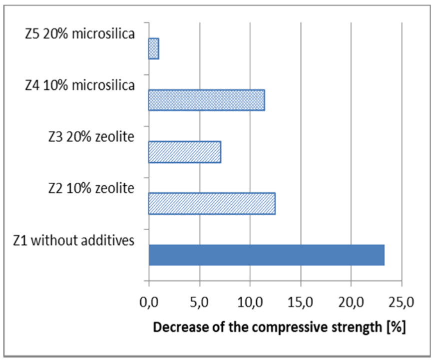

Fig. 8. Decrease of the compressive strength after 50 cycles of freezing - thawing

The greatest decrease in strength after 50 cycles of freezing and thawing is recorded for samples without pozzolan. It is assumed that a reduction of up to 25% is acceptable under frost resistance. Samples without additives are close to this limit. The best results are obtained with a 20% microsilica additive, but the use of zeolite is also an effective method of obtaining frost resistance.

The purpose of the capillary rising test is to determine the level of moisture of the sample stored in the container with water and to determine the increase in its mass. The test is carried out according to EN 1015-18 [10] using beams. The samples are immersed in water in a vertical position. The container is topped up with water at a temperature of 20±2ºC, so that the water reached up to about 1 cm height of beams. During the test, the mass gain was measured after 1, 3, 6 and 24 hours.

The capillary water absorption coefficient is the gradient of the straight line obtained by plotting the cumulative mass of water absorbed per unit area against the square root of time t obtained from this first stage according to the following equation:

$$A_w = \frac{\Delta B}{A \cdot \sqrt{t}} \ [kg/(m^2 \cdot min^{0.5})] \tag{1}$$

where: ΔB – the mass of the absorbed water [kg],
A – the surface area of the cross section of the specimen [m^2],
t – time [min].

This estimation way is known as the one tangent method. The test is carried out on samples after 50 cycles of frost resistance and control samples.

Table 2. The capillary water absorption coefficient [$kg/(m^2 \cdot min^{0.5})$] of comparison mortars and after 50 cycles of freezing – thawing

	Z1	**Z2 10%**	**Z3 20%**	**Z4 10%**	**Z5 20%**
	-	Zeolite		Microsilica	
Control samples	0.23	0.16	0.09	0.06	0.02
Samples after 50 cycles	0.30	0.19	0.13	0.09	0.02

The capillary water absorption coefficient depends on the progressive frost destruction. The mortar containing 20% microsilica does not show changes in this parameter and at the same time the lowest reduction in strength is observed for this material. The addition of pozzolan to the material resulted in its sealing. Samples containing fine aggregate of this additive have lower water absorption coefficient and better frost resistance of the mortar.

4. Conclusions

The article presents the investigation of the physical properties of mortars containing two types of pozzolan. In mixes pozzolan additives at 0 to 20 percent by mass of portland cement are used. Increasing the amount of pozzolan additive two times, causes a small increase in the air content in the fresh mortar, but at the same time reduce the absorbability. The compressive strength test shows that the addition of pozzolan improves this property after 14 days and this tendency remains after 90 days. The use of both zeolite and microsilica in the amount of 20% by weight results in an increase in strength by about 30% after 90 days of hardening, compared to samples without this additive.

The use of pozzolan as an additive while testing frost resistance is an effective method to improve this parameter. Reduction in strength after 50 cycles of freezing - thawing at 10% of the addition of microsilica and zeolite is at a similar level. The most preferred solution is the one with microsilica in the amount of 20% of cement mass. The addition of zeolite on this level is also preferred. After the frost resistance test capillary suction analysis is performed. The addition of microsilica greatly improves mortar properties by sealing it and preventing from the absorption of larger amounts of water.

The addition of pozzolan to the mortar composition has a positive effect on their physical properties. Zeolite can be used as an alternative to microsilica.

References

[1] Wolska-Kotańska C.: Stosowanie pyłów krzemionkowych do wykonywania betonów narażonych na działanie wybranych warunków środowiskowych. Instrukcja ITB nr 362/99. ITB, Warszawa 1999.

[2] Domieszki do betonów. Izolacje 11/12/2012.

[3] https://pl.wikipedia.org/wiki/Dodatki_do_betonu {access 20.04.2018 r.}.

[4] EN 196-1:2016-07: Methods of testing cement. Determination of strength.

[5] Przerada I., Lubas M.: Wpływ dodatku popiołu lotnego i mikrokrzemionki na właściwości zapraw cementowych i betonów Materiały Budowlane 1/2004.

[6] Bundyra-Oracz, G. Siemaszko-Lotkowska, D.: Zeolit – dodatek pucolanowy do betonu Budownictwo, Technologie, Architektura X-XII/2010.

[7] Wpływ dodatku zeolitu na właściwości fizykomechaniczne tynków renowacyjnych Izolacje 9/2014.

[8] PN-B-04500:1985: Mortars. Phisical and mechanical tests.

[9] EN 1015-7:2000 Methods of test for mortar for masonry. Determination of air content of fresh mortar.

[10] EN 1015-18:2003 - Methods of test for mortar for masonry. Determination of water absorption coefficient due to capillary action of hardened mortar.

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