

Parameters of Alumina Cement and Portland Cement with Addition of Chalcedonite Meal

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Abstract. Aluminous cement is a quick binder with special properties. It is used primarily to make non-standard monolithic components exposed to high temperatures, + 1300°C. It is also a component of adhesives and mortars. It has a very short setting time. It is characterized by rapid increase in mechanical strength and resistance to aggressive sulphates. It can be used in reinforced concrete structures. Laying of concrete, construction mortar made of alumina cement can be carried out even at temperatures of -10°C.

This article discusses a comparison of the parameters of hardened mortar made of alumina cement GÓRKAL 40 and Portland cement CEM I 42.5R. The mortars contain an addition of chalcedonite meal with pozzolanic properties, with particle size of less than 0.063µm. The meal was added in amounts of 5% and 20% of cement weight. Chalcedonite meal used in the laboratory research is waste material, resulting from chalcedonite aggregate mining. It has the same properties as the rock from which it originates. We have compared the parameters of hardened mortar i.e. compressive strength, water absorption and capillarity. The addition of 20% chalcedonite meal to mortars made from aluminous cement will decrease durability by 6.1% relative to aluminous cement mortar without addition of meal. Considering the results obtained during the absorbency tests, it can be stated that the addition of chalcedonite meal reduces weight gains in mortars made with cement CEM I 42.5 R and alumina cement. Use of alumina cement without addition of meal in mortars causes an increase of mass by 248% compared to Portland cement mortars without additions, in the absorption tests. The addition of chalcedonite meal did not cause increased weight gain in the capillary action tests. For the alumina cement mortars, a lesser weight gains of 24.7% was reported, compared to the Portland cement mortar after 28 days of maturing.

1. Introduction

Aluminous cement is not widely used in the construction industry due to the phenomenon of conversion, which means the transition of hexagonal hydrates into thermodynamically stable regular phase C_3AH_6 .

This is due to release of water and decrease in compressive strength over a longer period of operation of a given object [1]. The main phase of the alumina cement is monocalcium aluminate CA. In the maturing process, involving calcium aluminate cement, there are also other phases. Their type depends on the type and variety of cement. The most widely used alumina cements are cements with a lower alumina content from approx. 36% to 40%, referred to as plain cements [2], which are most commonly used in construction. Continuous development of construction industry and increasing requirements for materials used in mortars force scientists to search for new applications and to seek



answers to questions regarding all factors that may affect changes in characteristics and rheological parameters of hardened mortars. In published laboratory studies, there are articles on the properties of mortars formed from mixtures of two cements, i.e. alumina and Portland. These mixes, according to the authors [3], work only in specific proportions. It is hard to predict the impact of a cement mix on the parameters of an element in the long run. Another option of inhibiting the phenomenon of conversation is to introduce mineral additives into the composition of the mortar, which will contain reactive silica in their composition. The reactive silica can undergo reactions in the hydrating alumina cement environment. The effect may be a reduction or halting of decrease in strength of components made of alumina cement. In literature, researchers have added the following to aluminous cements: fly ash, blast furnace slag and other waste materials with pozzolanic properties, as cement replacements. In literature, authors report that, after the introduction of an additive with pozzolanic properties, strätlingit is formed. This is a hydrate that is not transformed at 20÷70°C. It is assumed that strätlingit precedes the C-S-H phase. The presence of pozzolanic additives in the alumina cement environment is not clear [4]. It is advisable for the mineral additive containing silica to participate in the formation of the structure, because the resulting C-A-S-H-type products positively affect the strength of the element made of alumina cement. The parameters of hardened mortar made of alumina cement depend on the type of cement, the additives, maturation temperatures or w / c ratio [3, 4, 10, 11]. The specific chemical composition of alumina cement and the fact that, during hydration, calcium hydroxide is not released, allows the cement paste to resist many aggressive factors [12].

2. The research program

Mortars were prepared in a standardized laboratory mixer. The samples were prepared with dimensions of 40x40x160mm and the composition shown in Table 1.

Table 1. Mortar compositions.

Name	mark 0%	mark 5%	mark 20%	mark G	mark 5G	mark 20G
cement CEM I 42,5R	450	427,5	405	0	0	0
Alumina cement Górkal 40	0	0	0	450	427,5	405
Chalcedonite meal	0	22,5	45	0	22,5	45
Water	225	225	225	225	225	225
Sand	1350	1350	1350	1350	1350	1350

The properties of alumina cement and Portland cement are presented in Tables 2 and 3.

Table 2. Properties of Górkal 40 alumina cement.

Chemical composition	Special properties	Mineralogical composition
content Al_2O_3 - min. 40%	Refractoriness 128 sP	BASIC PHASE:
content CaO -min. 36%	Weight density 3,0 g/cm ³	calcium monoaluminate CA
content SiO_2 -2 - 4%	Bulk density 1,1 g/cm ³	ACCOMPANYING PHASES:
content Fe_2O_3 <14%	Specific surface area per Blaine 3100 - 3800 cm ² /g	brownmillerite C_4AF
	Grain size in range 0 - 63 μm min 80%	calcium aluminate C_{12}A_7
	Working temperature minus 10°C	gehlenite C_2AS

Chalcedonite dust used in laboratory studies is a waste material, resulting from chalcedonite aggregate mining. It has the same properties as the rock from which it originates. Therefore, it is not dangerous, but it has a negative impact on the environment. Currently, dusts are not used for the production of concrete as a mineral supplement [5, 6, 9].

Table 3. Mechanical properties of Górkal 40 alumina cement mortars.

Hydraulic properties	Mechanic properties
-start no earlier than after 90 min -end no earlier than after 8 hrs.	RESISTANCE TO BENDING: -after 24 hours min. 6 MPa RESISTANCE TO SQUEEZING: -after 6 hours min. 30 MPa -after 24 hours min. 50 MPa

The test batches made of alumina or Portland cement were mixed with chalcedonite dust in the amount of 5% and 20% cement mass. The effect of addition on the following parameters of hardened mortar was then tested: compressive strength, water absorption and capillarity.

Table 4. The chemical composition of chalcedonite dust.

Compound	Content of elements [%]
F	0.06
Na ₂ O	0.09
MgO	0.15
Al ₂ O ₃	3.04
SiO ₂	91.8
P ₂ O ₅	0.04
SO ₃	0.05
K ₂ O	0.42
CaO	0.45
TiO ₂	0.11
Fe ₂ O ₃	1.28
ZrO ₂	0.01

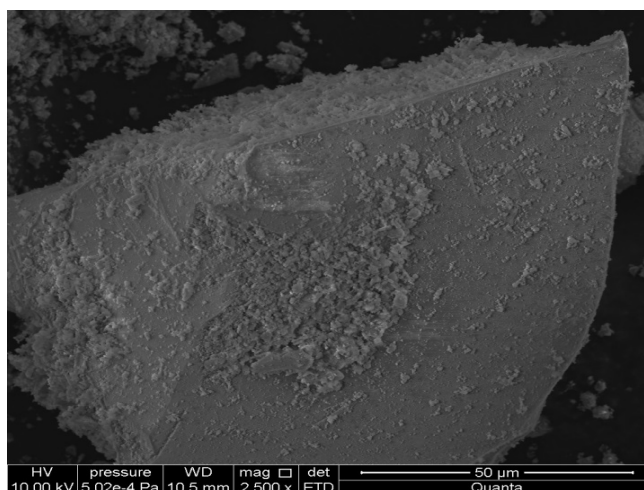


Figure1. Chalcedonite dust microstructure

Particle size of chalcedonite meal was measured by laser diffractometer.

$$x_{10} = 0,28 \mu\text{m} \quad x_{50} = 3,87 \mu\text{m} \quad x_{90} = 25,53 \mu\text{m} \quad \text{SMD} = 0,90 \mu\text{m} \quad \text{VMD} = 9,50 \mu\text{m}$$

$$x_{16} = 0,44 \mu\text{m} \quad x_{84} = 22,38 \mu\text{m} \quad x_{99} = 34,99 \mu\text{m} \quad S_V = 6,64 \text{m}^2/\text{cm}^3 \quad S_m = 66392,20 \text{cm}^2/\text{g}$$

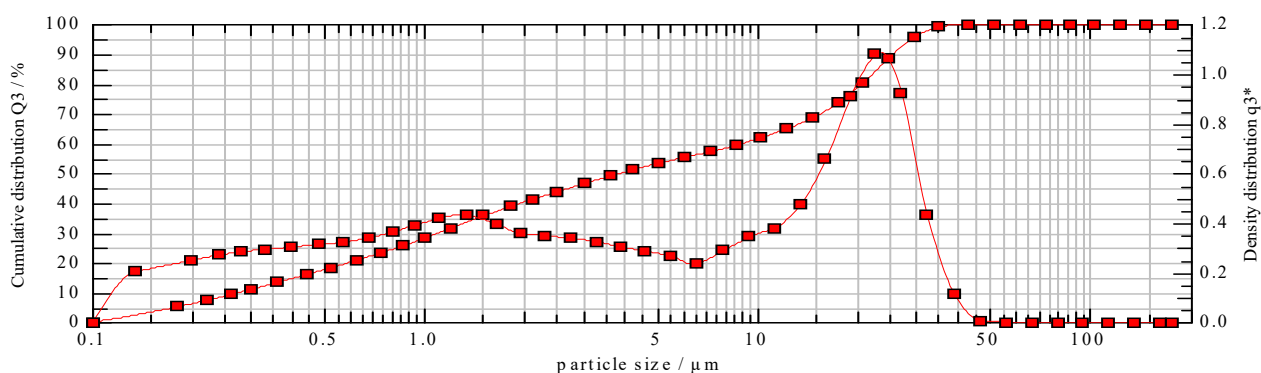


Figure 2. Particle size of chalcedonite powder

The compressive strength of the cement mortars was marked after 6 and 24 hours and 7, 14, 28 days from moulding. The mortars, after de-moulding, matured in water at + 18 ° C until testing. Only the samples for strength testing after matured in air, at a temperature of + 18 ° C, after 6h from moulding. The compressive strength of mortars made with Portland cement CEM I 42,5R was tested after 7, 14, 28 days. The samples, throughout the whole maturation period, were immersed in water, at + 18 ° C [7,8,12].

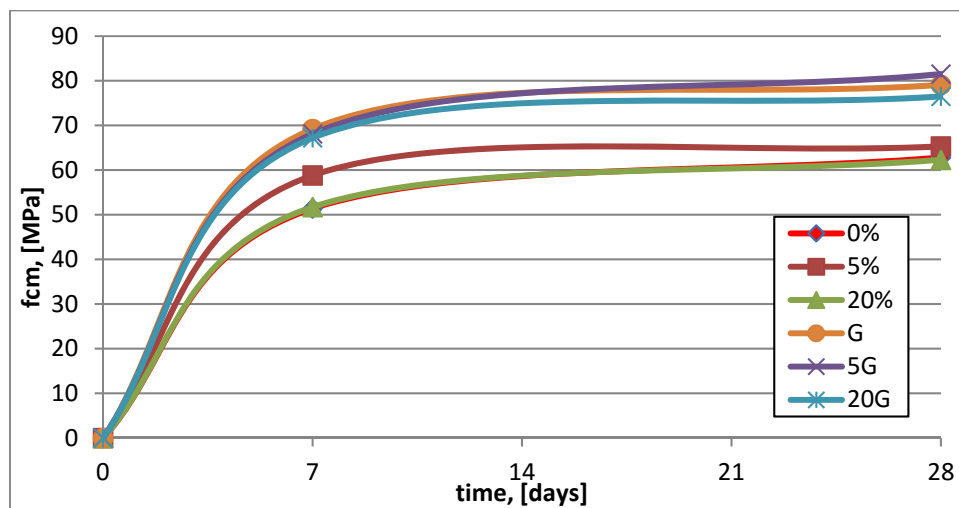


Figure 3. The increase in compressive strength of Portland cement and alumina cement mortars.

The study of absorption for Portland cement and alumina cement mortars was performed on samples with dimensions of 40x40x160mm. Samples matured in water at + 18 ° C for the first seven days, and a further 21 days in dry air environment at + 18 ° C. The samples were then dried until obtaining solid mass. Samples were placed in a bathtub tank, dipping half their height in water. After 24 hrs., the samples were immersed to + 1 cm above the surface of samples. The measurement of mortar mass was performed each 24 hrs, until obtaining two identical measurements.

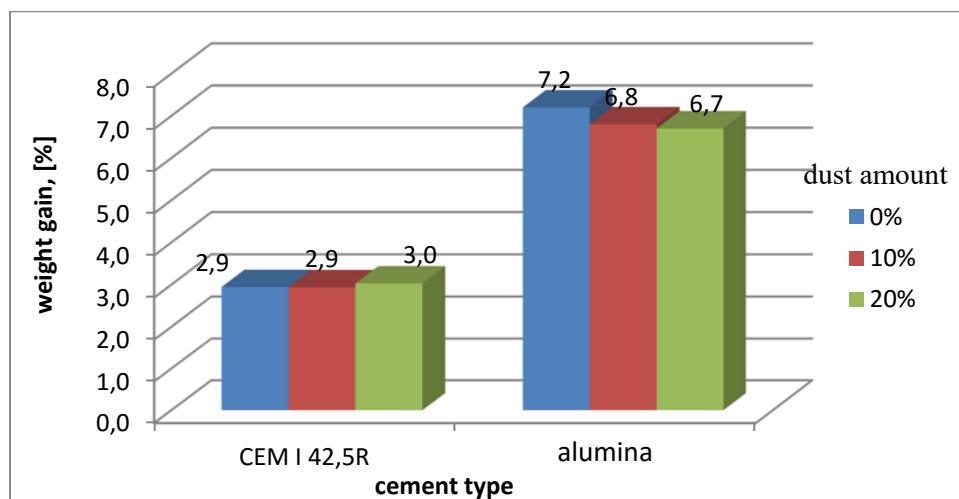


Figure 4. Weight gain of mortars in absorption study after 28 days of maturing

Samples for capillary action testing were prepared identically as for absorption studies. The difference was that, after drying the samples to solid mass, they were immersed in water to a height of

3 mm on supports made of plastic. The samples sides were insulated with foil against uncontrolled consumption of moisture from the environment.

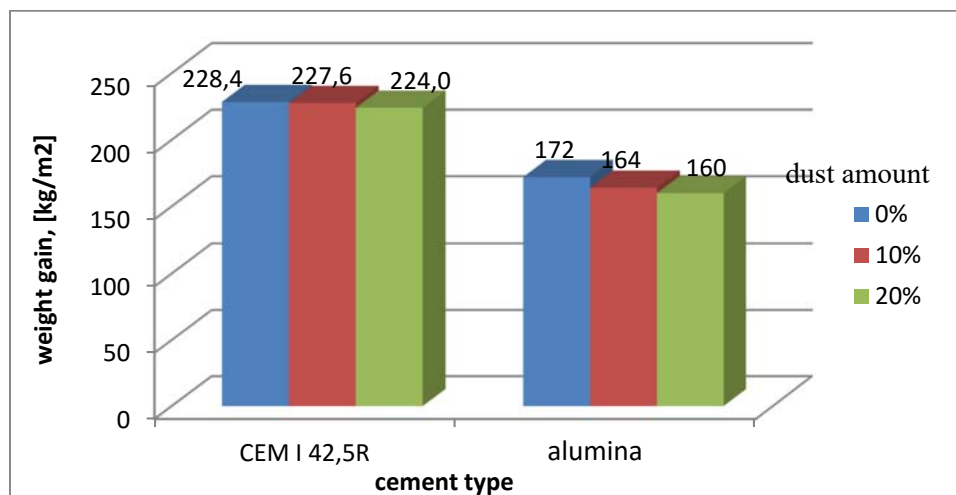


Figure 5. The weight gain of mortars in the capillary action tests after 28 days of maturing

3. Results and discussions

Analysing the results, it can be seen that alumina cement mortars have better compressive strength. The addition of 20% of chalcedonite dust to aluminous cement mortars will decrease strength by 6.1% relative to aluminous cement mortar without the addition of dust. In case of Portland cement mortar, the strength loss due to dust addition is not greater than 1% relative to mortars without additives. Comparing cements used for mortar specimens, the alumina cements display a larger strength increase of 22.9%, as compared to Portland cement mortar at 28 days of maturing. The compressive strength of the alumina cement mortars rises quickly, the samples after 6 hours of maturing obtain value of $f_{cm} = 55,1 \text{ MPa}$ for mortars without additives.

Considering the results, it can be stated that the addition of chalcedonite dust reduces weight gain in mortars made with cement CEM I 42.5 R and alumina cement. In the alumina cement mortars, the observed differences are 6.9%. The use of the alumina cement in mortars without the addition of dust causes an increase in weight gain by 248%, as compared to Portland cement mortars without additives. Analysing the results, it can be seen that the addition of chalcedonite dust does not cause increased weight gain in the study of capillary action. For the alumina cement mortar, lesser weight gain of 24.7% was observed, as compared to the Portland cement mortar after 28 days of maturing.

4. Conclusions

Based on laboratory tests, it can be concluded that the addition of waste chalcedonite dust has a positive impact on the parameters of hardened mortar made from Portland cement CEM I 42.5 R and aluminum cement GÓRKAL 40.

Higher compression strength was observed for the mortar made of alumina cement. An increase in compressive strength for mortars with alumina cement occurs rapidly and has reached 55,1MPa after 6h from moulding. The addition of 20% of chalcedonite dust causes strength loss of 6.1% compared to that of the reference mortars made of alumina cement. The study of capillary action, the addition of chalcedonite dust causes a decrease in weight gain for the alumina cement mortar no greater than 7%. The differences observed in absorption are on the verge of measurement error and amount to 2.3% for alumina cement mortars. For alumina cement mortars without the addition of dust, a weight loss of 5.1% was observed, in relation to Portland cement mortars without additives.

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