

Parameters of Concrete Modified with Glass Meal and Chalcedonite Dust

Anna Kotwa ¹

¹ Kielce University of Technology, Al. Tysiąclecia Państwa Polskiego 7, 25-314
Kielce, Poland

a.ceglarska@tu.kielce.pl

Abstract. Additives used for production of concrete mixtures affect the rheological properties and parameters of hardened concrete, including compressive strength, water resistance, durability and shrinkage of hardened concrete. By their application, the use of cement and production costs may be reduced. The scheduled program of laboratory tests included preparation of six batches of concrete mixtures with addition of glass meal and / or chalcedonite dust. Mineral dust is a waste product obtained from crushed aggregate mining, with grain size below 0,063µm. The main ingredient of chalcedonite dust is silica. Glass meal used in the study is a material with very fine grain size, less than 65µm. This particle size is present in 60% - 90% of the sample. Additives were used to replace cement in concrete mixes in an amount of 15% and 25%. The amount of aggregate was left unchanged. The study used Portland cement CEM I 42.5R. Concrete mixes were prepared with a constant rate $w / s = 0.4$. The aim of the study was to identify the effect of the addition of chalcedonite dust and / or glass meal on the parameters of hardened concrete, i.e. compressive strength, water absorption and capillarity. Additives used in the laboratory tests significantly affect the compressive strength. The largest decrease in compressive strength of concrete samples was recorded for samples with 50% substitutes of cement additives. This decrease is 34.35%. The smallest decrease in compressive strength was noted in concrete with the addition of 15% of chalcedonite dust or 15% glass meal, it amounts to an average of 15%. The study of absorption shows that all concrete with the addition of chalcedonite dust and glass meal gained a percentage weight increase between $2.7 \div 3.1\%$ for the test batches. This is a very good result, which is probably due to grout sealing. In capillary action for the test batches, the percentage weight gains of samples ranges from 4.6% to 5.1%. However, the reference concrete obtained the lowest water absorption as compared to other batches.

1. Introduction

Additives used for production of concrete mixtures affect the rheological properties of the mix and the characteristics of hardened concrete.

By their application, the use of cement and production costs may be reduced. Mineral additives allow to reduce the amount of cement, reduce heat emissions and adjust the selected parameters of concrete. The most popular additives are stone meals, fly ashes, ground granulated blast furnace slag and silica dust. The specific surface area of mineral additives is at least equal with the cement (and usually considerably higher). By their mere presence, additives in the concrete mix reduce the amount of free water. The use of mineral additives affects the rheological properties of the mixture in various



ways, depending mainly on their type, amount and properties, the properties of cement and the presence and characteristics of chemical admixtures [5]. Also relevant here are the economic and ecological aspects, associated with waste management and reduction in the consumption of cement and the energy required for its manufacture. The management of by-products is a subject widely discussed in recent literature [1,7,8,9]. Waste products from production of crushed chalcedonite aggregates include chalcedonite dust, produced by chalcedony rocks. Chalcedony usually arises as a result of recrystallization of opal (amorphous silica or in form of cristobalite, tridymite - forms stable at high temperatures), so it can coexist with them. It is microporous in structure and contains small amounts of water. The structure of quartz forming chalcedony is defected, which facilitates its chemical interactions. Based on microscopic features, the distinguished forms are: chalcedony-LF (proper), chalcedony-LS (quartzite) and lutecite. Sometimes also the non-fibrous, cryptographic and microcrystalline quartz is taken for chalcedony. This can be justified by its defected structure, similar to that which occurs in the fibrous forms. Micro-crystalline quartz is a silica phase, forming isometric crystals with sizes from 1 to 20 μm . The micro- and crypto-crystalline quartz, similarly to fibrous chalcedony, is produced by recrystallization of opal silica phases [6]. This reactivity is due to the large specific surface area on which chemical reactions could potentially occur. In view of the chalcedony reactivity and other, accompanying forms of reactive silica, there is a potential application in the building materials industry for production of cement and concrete. This is due to the fact that the reactive silica in an aqueous medium may react with the calcium hydroxide in so-called pozzolanic reactions, facilitating the increase of technological parameters. In hydrating cement, aside from calcium hydroxide, there are many more compounds which can react with chalcedonite. Each component of the cement, which is dissolved in water, can potentially react with chalcedonite or affect such reactions [1, 6]. The second recycled additive used for concrete mixes is glass meal. This material is identical to glass granulate, produced from the same species of glass, but due to finer grain sizes and a slightly different preparation processes, it is an ideal filler for use in chemical, rubber and ceramic industries. It is a material with a very fine grain size, down to 65 μm . Broken glass is poured into a specially prepared crusher, which then converts it into a glass powder. This material is an ideal filler, used for example in manufacture of ceramics (roof-tiles, ceramic tiles), since it reduces the absorption of the final products [4].

2. The research program

The program of laboratory tests included preparation of six batches of concrete mixtures with addition of glass meal and / or chalcedonite dust. Additives replaced cement in concrete mixes in amounts of 15% and 25%. The amount of aggregate was left unchanged. The study used Portland cement CEM I 42.5R. Concrete mixes were formed with a constant rate $w / s = 0.4$. The aim of the study was to identify the effect of chalcedonite meal and / or glass meal on the parameters of hardened concrete, i.e. compressive strength, water absorption and capillarity. Concrete mixes were prepared according to composition shown in Table 1.

Table 1. Compositions of concrete mixes per 1m³; glass meal used in tests has grain size below 65 μm

Name of component	batch 1	batch 2	batch 3	batch 4	batch 5	batch 6
Cement	480	408	360	408	336	240
Chalcedonite meal	----	----	----	72	72	120
Glass meal	---	72	120	----	72	120
Water	192	192	192	192	192	192
Aggregate 4-8	543,3	543,3	543,3	543,3	543,3	543,3
Aggregate 8-16	829,2	829,2	829,2	829,2	829,2	829,2
Sand	717,5	717,5	717,5	717,5	717,5	717,5
Plasticizer admixture	1,7	1,7	1,7	1,7	1,7	1,7

Table 2. Chemical composition and grain size of glass meal.

Chemical composition		Grain class	
SiO ₂	70-73%	14mm	0.0%
Al ₂ O ₃	0.5-2%	10mm	0.0-0.2%
CaO	7-11%	4.3mm	0.0-2%
MgO	3-5%	1.5mm	0.0-8%
Na ₂ O+K ₂ O	13-15%	1.0mm	0.0-15%
Fe ₂ O ₃	max:0.1%	0.63mm	5.0-40%
TiO ₂	max: 0.1%	<0.63mm	60-90%

Table 3. Physical and chemical properties of glass meal.

Quality	Value
Hardness	6 - 7 in Mosh scale
Bulk density	1.5 kg/l
Color	white, green, brown
Shape	Sharp-edged
Smell	Neutral
Softening	from 600°C
Solubility in water	n/a
pH value in water	< 11
Flammability	n/a
Explosiveness	n/a
Radioactivity	n/a

Table 4. Information on basic properties of the cement.

No.	Cement type	Chemical composition, %					Blaine	Resistance, MPa	
		SiO ₂	CaO	MgO	Fe ₂ O ₃	Al ₂ O ₃	cm ² /g	R ₂	R ₂₈
1	CEM I 42,5R	19.84	63.2	2.08	2.72	4.65	4086	32.0	53.0

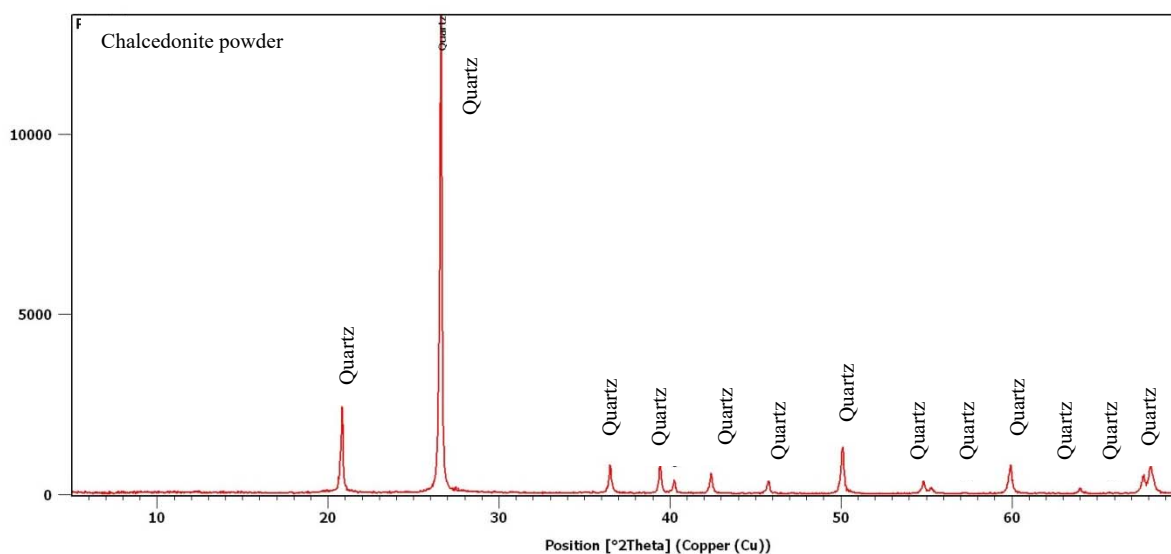


Figure 1. The result of tests of chalcedonite powder using the XRD method

A test was carried out on chalcedonite powder using the XRD method, to investigate the composition of the additive using an X-ray diffractometer. The analysis of the graph shows that the main component of chalcedonite powder is quartz. Due to an additional (but less intense) reflex range angle 2θ from 18 to 22 ° (maximum at 19.923 °), it can be concluded that the sample is in the form of silica moganite. This form of silica is hardly detectable, but often occurs together with chalcedonite [1]. Particle size of chalcedonite powder was measured by laser diffractometer.

$$\begin{aligned} x_{10} &= 0,28 \mu\text{m} & x_{50} &= 3,87 \mu\text{m} & x_{90} &= 25,53 \mu\text{m} & \text{SMD} &= 0,90 \mu\text{m} & \text{VMD} &= 9,50 \mu\text{m} \\ x_{16} &= 0,44 \mu\text{m} & x_{84} &= 22,38 \mu\text{m} & x_{99} &= 34,99 \mu\text{m} & S_V &= 6,64 \text{ m}^2/\text{cm}^3 & S_m &= 66392,20 \text{ cm}^2/\text{g} \end{aligned}$$

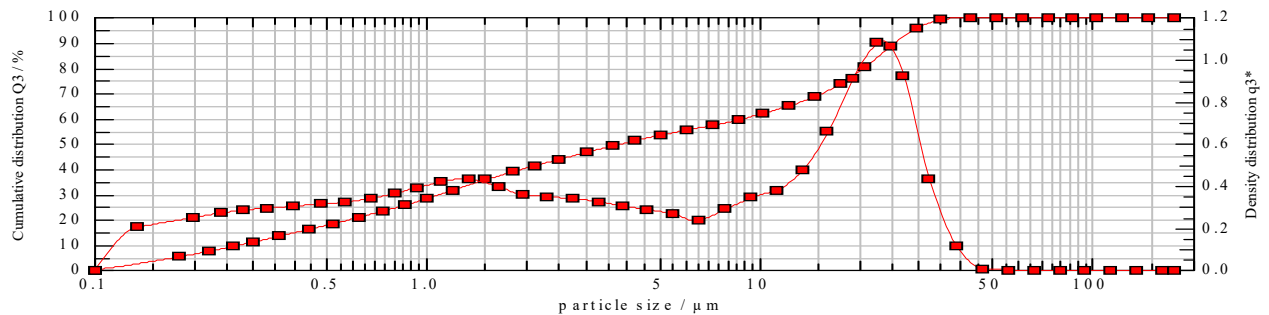


Figure 2. Particle size of chalcedonite powder.

Compressive strength was tested after 7, 14 and 28 days of molding. Parameter was tested on cubic samples, 10 cm side. After formation, the samples were stored in water at + 18 ° C. Six samples of concrete were tested at the same time [2].

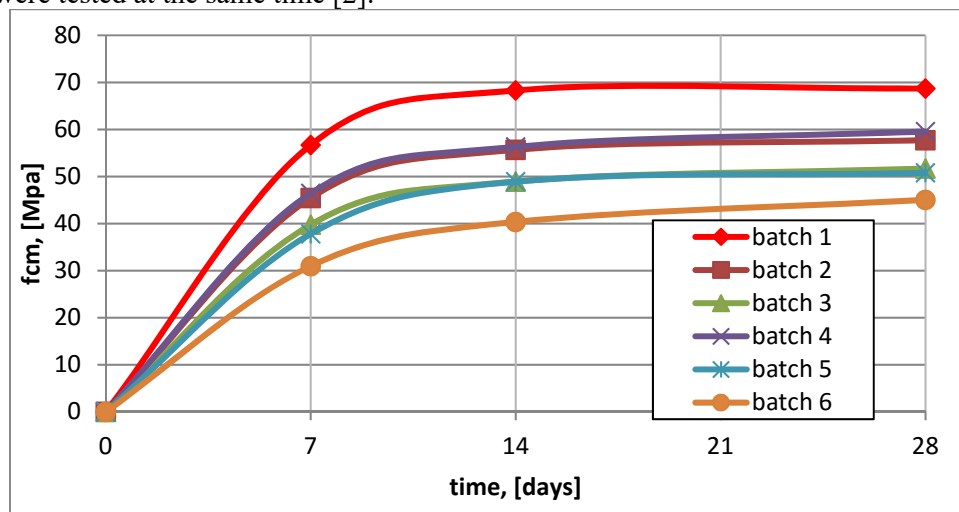


Figure 3. Increase in compressive strength over time

Table 5. A tabular summary of the average compressive strength development over time, [MPa]

Maturing time, [days]	Compressive strength, [MPa]					
	batch 1	batch 2	batch 3	batch 4	batch 5	batch 6
7	56.7	45.5	39.8	46.4	37.8	31.0
14	68.3	55.7	48.9	56.3	48.9	40.4
28	68.7	57.7	51.7	59.6	50.8	45.1

The study of absorption was performed in accordance with PN-88 / B-06250 on cubic samples of 10 cm side. The test was performed after 28 days of maturing. The samples were de-molded after 24 hours and stored in water for six days, followed by 21 days airing at temperatures of + 18 ° C. The test samples were arranged in a bathtub tank, on a plastic material grid support, so that the distance between samples was at least 10 mm. The tank was filled with water, temperature of approx. 18°C, with level at half the height of the samples. After 24 hours, the samples were filled up with water to such a level that the water level was at least 10 mm above the upper surface of the samples. Samples were removed from the tank daily, dried and weighed on a laboratory scale with a precision of 1 g. The impregnation of samples with water was carried out until obtaining two identical measurements. The samples were then placed in a drying oven. The samples were dried at a constant temperature of 105°C until obtaining solid mass [3,4].

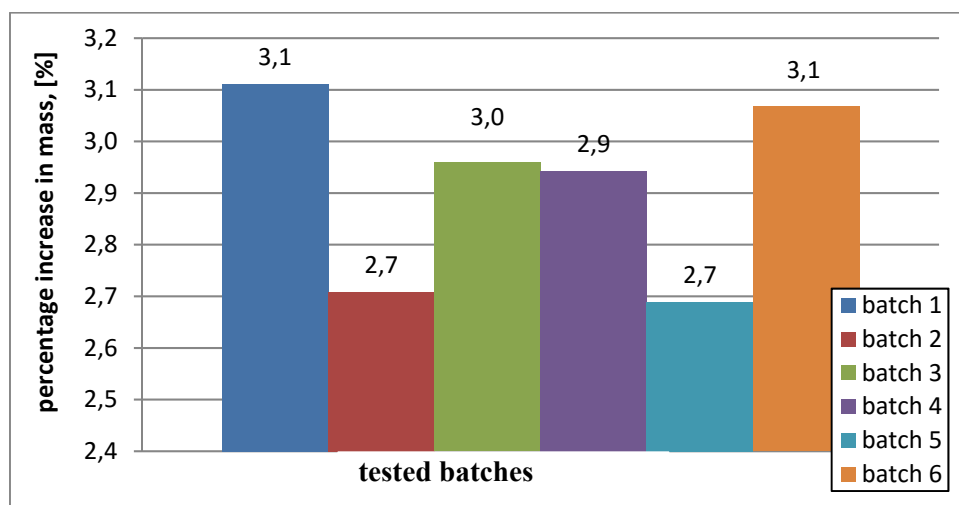


Figure 4. The percentage weight gain of concrete in the study of absorption

Capillarity was carried out on cubic samples of concrete, with 10cm side. Samples were de-molded after 24 hours from the time of molding, ± 15 min. Over the next six days the samples were cured in water at + 18 ° C. The samples were then removed from water and matured in dry air environment for 21 days.

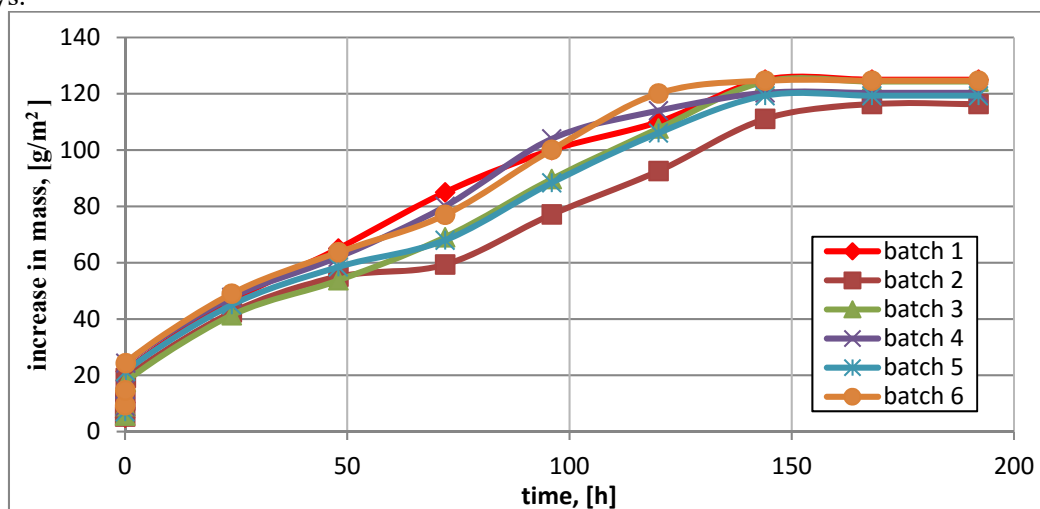


Figure 5. Weight gain of concrete in capillary action tests

After this time, the samples were placed in a bathtub tank, on a plastic grid support. The sample side surfaces were insulated with foil against uncontrolled consumption of moisture from air. The samples were immersed at the height of 1-3mm. The water was gradually supplemented. The first-day measurement of mass took place after 15 minutes, 1 hour, 4 hours of immersion in water. In the following days, the measurement was taken once a day, until obtaining two identical results. The samples were removed from the water, dried and weighed on a laboratory scale with an accuracy of 1g. Finally, the samples were placed in a climatic chamber and dried at a temperature of + 105 ° C until obtaining solid mass [3].

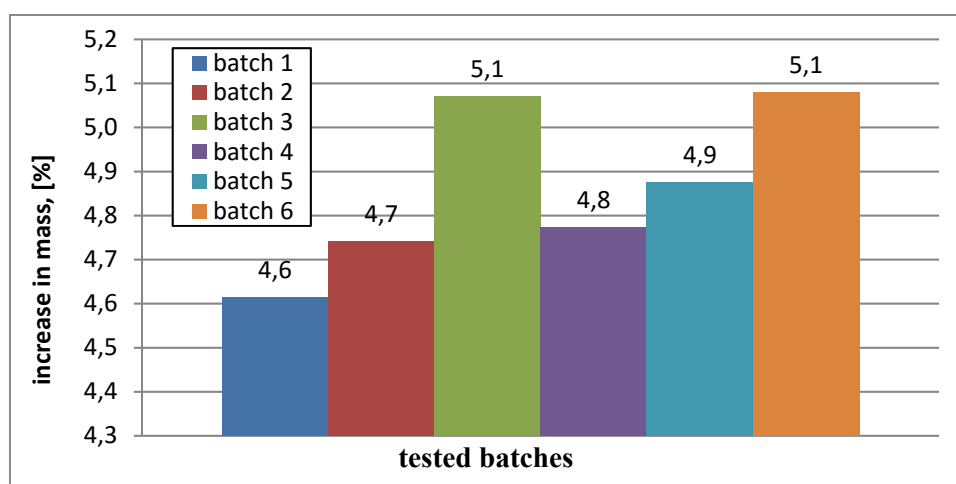


Figure 6. Percentage weight gain of concrete in capillary action tests

3. Results and discussions

From the analysis of the results in Table 5 and Figure 3, the largest increase in the compressive strength of concrete was achieved without additives (batch 1). Comparable compressive strength at 28 days of maturing was observed for concrete batch 2 (15% chalcedonite powder) with batch 4 (15% glass meal) and comparable batch 3 (25% chalcedonite meal) with batch 5 (15% glass meal + 15% chalcedonite dust). The lowest strength was displayed by concrete samples in which the amount of additives was replaced by 50% of cement (batch 6). The decrease in the strength of batch 6, as compared to the reference concrete, is 34.35%.

The performed study shows that all concretes with the addition of chalcedonite mal and / or glass meal obtained a percentage weight gain between 2.7 ÷ 3.1%. This result is very good, because it meets the very strict requirements of the Regulation of the Minister of Transport and Maritime Economy of 30th May 2000 on the technical conditions to be met by road engineering objects and their location which have a limit of concrete absorption up to 4% mass gain.

The study shows that the percentage weight gain in tested concretes with additives ranges from 4.6% to 5.1%. The lowest weight gain for capillary action was observed for concretes without additives. The greatest weight gain was observed in batch 3 samples (glass meal 25%) and batch 6 (25% glass meal and chalcedonite meal) and amounts to 5.1%. All test batches show water absorption of up to 5.1%

4. Conclusions

In summary, it can be concluded that the additives in form of glass meal and chalcedonite dust, replacing cement in an amount of 15% and 25%, will decrease the compressive strength. The smallest decrease in strength of concrete specimens was observed in batch 2 (15% chalcedonite dust) and batch 4 (15% glass meal) and it amounts to an average of 15%. The lowest compressive strength was

displayed by batch 6, with a total of 50% replacement with cement additives, with a decrease of 34.35%.

The study of absorption shows that all concrete with addition of chalcedonite dust and / or glass meal obtained a percentage weight gain between $2.7 \div 3.1\%$ for test batches. This is a very good result, which is probably due to grout sealing.

The capillary action tests for test batches, the percentage weight gain in samples ranges from 4.6% to 5.1%. However, the reference concrete obtained the lowest absorption in comparison to the other batches. The differences between measurements are 0.5%.

References

- [1] A. Kotwa, "Properties of concrete made with cement CEM II / B-V 32.5 R and addition of mineral dust, Eco-innovations in materials and construction technologies", Monograph, Częstochowa pp. 121-132, 2015.
- [2] PN-EN 206-1:2003, "Concrete. Part 1: Specification, performance, production and conformity".
- [3] EN 06265:2004, "National supplement standards PN-EN 206-1:2003".
- [4] J. Wawrzeńczyk, A. Molendowska, A. Kłak, "Concrete water absorption tests", Cement Wapno Beton, vol. 5/2015, pp. 304-312, 2015.
- [5] A. Kuśnierz, "Recycling glass, Scientific Works of Institute of Ceramics and Construction Materials", Warszawa–Opole 2010, vol. 6, pp. 22-33, 2010.
- [6] M. Kosior-Kazberuk, „The new mineral additives for concrete”, Civil and Environmental Engineering, nr 2/2011 pp. 47-55
- [7] A. Bolewski, Mineralogy General, Geological Publishing, Warszawa 1990.
- [8] R. Rykart , Quarz-Monographie - "The characteristics of berrystal, smoke quartz, amethyst, chalcedony, agate, opal and other varieties", Ott Verlag, Thun, 1995.
- [9] M. Dobiszewska, „Concrete with mineral dust waste”, Materiały Budowlane vol. 5/2015, s. 63-64, 2015.