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Abrasion resistance of concrete containing selected mineral powders

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Abstract

In this study the results of research that focused on abrasion resistance of concrete containing selected mineral powders are presented. The influence of replacing part of the cement on the physical properties of concrete was studied in the article. The concrete mixtures were modified by addition of basalt, quartz and quartz-feldspar powders in amount of 10, 20 and 30 % of the weight of the cement. The results showed that using mineral powders can reduce or increase concrete surface abrasion resistance depending on the type of mineral powder and its concentration in concrete mixture.

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Keywords: concrete; mineral admixture, abrasion resistance

1. Introduction

The abrasion resistance is a very important feature which affects the concrete durability. It is very important to take this fact into consideration when constructing such construction as floors or pavements [1-4]. The following factors have influence on abrasion resistance of concrete: aggregate size and its quantity, mixture proportion, concrete strength and addition of cementious materials or fibers [5]. It was also proved that the structures of pores on surface can influence the abrasion resistance [6]. Utilization of byproducts is now being more popular trend in civil engineering [7-14]. One of the examples of such utilization is the use of mineral powders in concrete production. According to that it can be assumed that using mineral powders, which fill the pores on the surface, can increase abrasion resistance.

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There are studies on the effects of using such admixtures as mineral powders in concrete. But most of them concern mechanical and rheological aspects [15-17]. There are also few researches about the influence of waste powders on abrasion resistance [18-25]. Unfortunately none of them refer to effects of replacement part of the cement by mineral powders on abrasion of concrete. In accordance with mentioned above the purpose of the present study is to analyze the abrasion resistance of concrete when replacing part of the cement with quartz (Q), quartz-feldspar (QF) and basalt (B) powder (up to 30%).

Nomenclature

ΔV [mm^3/5000mm^2]	loss of volume after 16 periods of wear
P_t [%]	porosity
a [%]	absorptivity

2. Preparation of concrete mixes

In this study the cement CEM I 42,5 R [26], supplied by Cement Ozarow S.A. was used. In Tab. 1. its physical properties are given. The parameters of the sand and limestone used in the study are presented in Tab. 2.

Table 1. Physical parameters of cement CEM I 42,5 R (according to [26]).

Physical parameters	Result
Initial setting time [min]	171
Compressive strength [MPa]	
2 days	3.31
28 days	56.6
Surface area [mm^2]	4260

Table 2. Parameters of sand and limestone used in the study (according to [27]).

Parameter	Sand	Limestone
Seed size	0/2	2/8
Seed shape	-	FI_{20}
Seed density	2,62 Mg/m^3	2,62 Mg/m^3
Graining category	G_F 85	G_C 80-20
Graining tolerance	GT_F 10	GT_F 20/17,5
Silt content	f_3	f_2
Absorptivity	WA_{24}0,6	WA_{24}0,8
Frost resistance	-	F_1
Resistance to crushing	-	LA_{25}
Abrasion resistance	-	M_{DE}15
Acid-soluble sulphate content	$AS_{0,2}$	$AS_{0,2}$
Total sulfur content	S_1	S_1
Alkali silica reactivity	0	0

The superplasticizer used in concrete mixes was an admixture based on sodium dodecylsulfate, which was added as a constant [%] of the cement [28, 29]. For the concrete mixes various proportion of basalt, quartz and quartz-feldspar powder were used to replace part of the cement. The chemical composition of these powders and cement is presented in Tab.3.

Table 3. Selected chemical components of quartz, quartz-feldspar and basalt powder.

Type of the powder	Component [%]						
	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	K_2O+Na_2O	MgO	CaO
Quartz (Q)	min. 99.00	max. 1.00	max. 0.05	max. 0.05	-	-	-
Quartz-feldspar (QF)	74.00-78.00	12.50-14.00	0.20-0.40	max. 0.05	7.50-8.50	max. 0.50	max. 0.50
Basalt (B)	49.5	15	3.7	-	1.2	6.8	-

All the concrete mixes were prepared in a laboratory under controlled environment. The control concrete mixture was composed in accordance with the three equations method. The mixtures with mineral powders were prepared by replacing 10%, 20% and 30% of the cement. The composition of mixes is presented in Tab. 4.

Table 4. Composition of applied concrete mixes (weight per m^3 of concrete, kg)

Reference	0	Q10	Q20	Q30	QF10	QF20	QF30	B10	B20	B30
Cement	352	316.8	281.6	246.4	316.8	281.6	246.4	316.8	281.6	246.4
Mineral powder	0	35.2	70.4	105.6	35.2	70.4	105.6	35.2	70.4	105.6
Water	176	176	176	176	176	176	176	176	176	176
Sand	676	676	676	676	676	676	676	676	676	676
Limestone	1205	1205	1205	1205	1205	1205	1205	1205	1205	1205
Superplasticiser	2	2	2	2	2	2	2	2	2	2

All dry components were mixed until they were homogenous. Water was mixed with a superplasticizer and then gradually added to the mix. The concrete was mixed for about 3 minutes. The method of preparation was the same for all the mixes.

The moulds of 150x150x150 mm were filled with concrete mixtures. Then all the specimens were covered ~~by~~ with plastic foil for 48 hours and after that they were removed from moulds and kept at ~~a~~ temperature of 20°C (±2°C) and humidity of 60% (±5%). After 28 days the concrete cubes of 71x71x71 mm were cut out of the specimens and they were used for abrasion testing. At the same time 3 concrete bars (40x40x160 mm) of each mix were prepared for mechanical and physical properties testing.

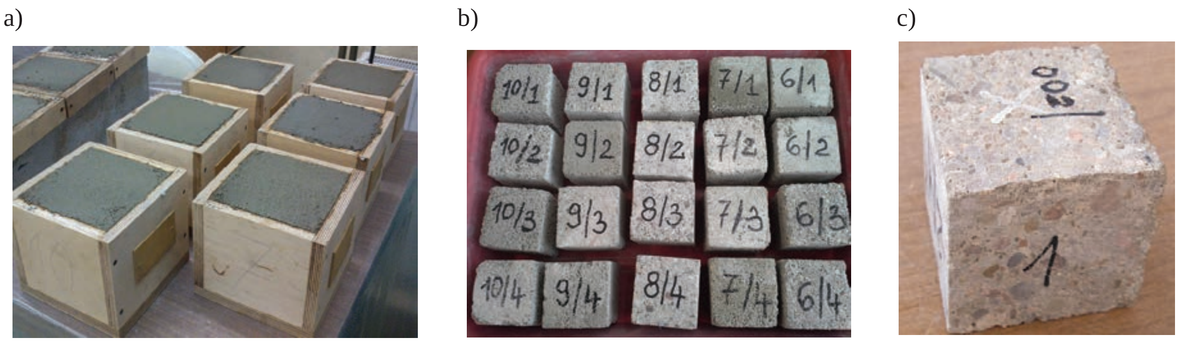
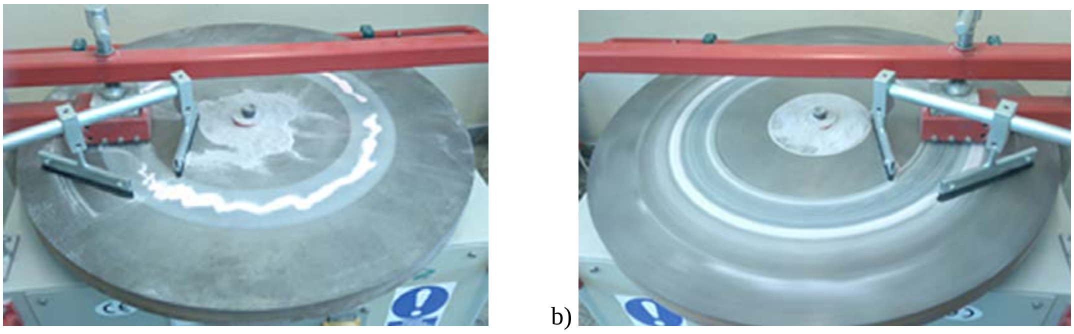


Fig. 1. View of a testing specimens: a) moulds of 150x150x150 mm filled with concrete mixtures with the admixture of mineral powders., b) all used in the test specimens b) the specimen of 71x71x71 mm

The abrasion test was conducted according to [30, 31]. In the test of abrasion resistance 20 g of corundum wear dust was spread on the Boehme disc. Then the concrete specimen was placed under the load of apparatus lever. Then the disc was rotated for four periods (22 cycles each). After each period the specimen was rotated 90°, the disc was cleaned and the new portion of corundum was spread. After every 4 periods the dust on the specimen was brushed and the concrete cubes were weighed. The role of the first 4 periods was to pre-grind concrete surface to remove all the outstanding surface peaks. Then 16 periods of the testing procedure took place.



a) b)

Fig. 2. View of abrasion test apparatus: a) with wear dust spread on the disc, b) during the test.

3. Results and discussion

The results of abrasion resistance results are presented in Tab. 5. The abrasion resistance is expressed as loss of volume of concrete after 16 periods of wear. These results show that using quartz powder in concentration of 10 and 20 % of cement mass can increase abrasion resistance of concrete surface by 13 and 20 % respectively. Addition of all other powders reduce the abrasion resistance, even by 45 % (S-30-QF). The most abrasive surfaces were those with the lowest tensile and compressive strength (Fig. 3a and 3b). There is also a correlation between abrasion resistance and some physical parameters of concrete (Fig. 3c and 3d). Concrete specimens with the most abrasion-resistant surface (S-10-Q and S-20-Q) were the least porous and absorptive. That confirms that mechanical and physical parameters of concrete strongly influence its abrasion resistance.

Table 5. The average values of abrasion resistance of concrete.

Sample	Loss of volume after 16 periods of wear ΔV [$mm^3/5000mm^2$]
S-0	6950
S-10-Q	6070
S-20-Q	5508
S-30-Q	8449
S-10-QF	8878
S-20-QF	8454
S-30-QF	11216
S-10-B	8446
S-20-B	8176
S-30-B	10126

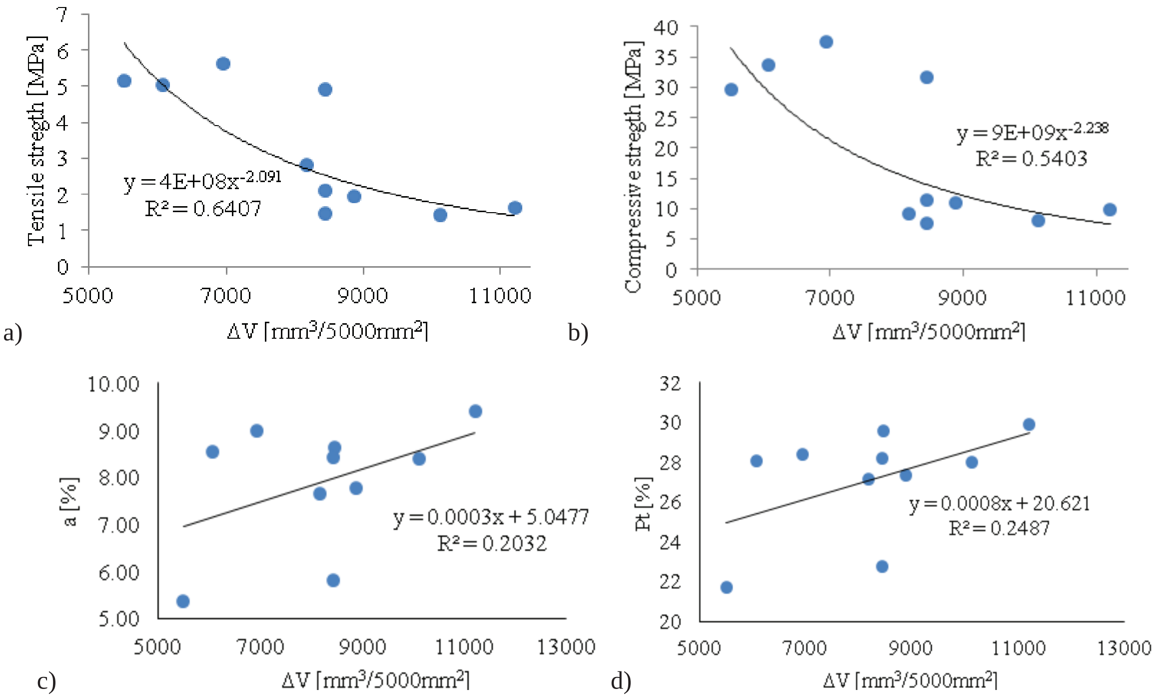


Fig. 3. Correlation between abrasion resistance and: a) compressive strength, b) tensile strength, c) total porosity, d) absorptivity.

4. Conclusions

It was found that replacing part of the cement with mineral powder in concrete changes its abrasion resistance. The fact whether the level of abrasion increases or decreases is dependent on the type of mineral powder and its concentration. The addition of quartz powder up to 20 % can increase abrasion resistance while all the other powders reduce this parameter.

Moreover, in this study the strong correlation between abrasion resistance of concrete surface and its mechanical and physical properties was shown. Usually lower strength and more porous and absorptive concretes are also more abrasive.

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