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The Abrasion Resistance of Mortars Containing Natural Zeolite Analcime

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Abstract

It is always an expectation that to minimize of damage caused by abrasion as a result of increase of abrasion resistance of construction materials. Therefore, the influence of analcime on the abrasion resistance of cement mortars was investigated in this study. Analcime is a natural pozzolan and is one of the valuable minerals of zeolite group. The cement mortars were produced by using blended cements containing analcime. The abrasion losses by friction at the end of 28 days of the mortar mixtures were determined by Bohme surface abrasion tests in accordance with TS 2824 EN 1338. The abrasion tests were carried out to cement mortar mixtures produced with different cement replacement ratio (0%, 10%, 30% and 50%). The results obtained from test series were compared with each other. The test results showed that, abrasion losses of mortars containing analcime were lower than portland cement mortars as 25% approximately. It is believed that this positive effect of natural zeolite in the development of abrasion resistance is due to pozzolanic reactions.

Key words

Abrasion, Analcime, Mortar, Natural Zeolite.

1. INTRODUCTION

Natural zeolites have recently become widely used as additive material in blended cement productions. Because, natural zeolites are pozzolanic materials containing abundant amounts of silica and alumina. When zeolite is replaced with clinker at optimum ratio, they form additional binder components by reacts with $Ca(OH)_2$ which is a result of cement hydration. These additional binders improve strength and durability of mortar/concrete. It is obtained advantages such as reducing of CO_2 emissions, energy saving and economy according as reducing of clinker consumption in blended cement applications containing zeolite. Also, natural zeolites are preferred to synthetic zeolites because of their reserve and economic status. The natural zeolites formed by the alteration of the vitric pyroclastic deposits are more reactive materials than the fly ash and furnace slags between mineral additives [1]. Natural zeolites have reserve declared as hundred billions tons in the world [2]. The using of these zeolite reserves will be possible with investigation performed on different zeolite minerals. Analcime is a natural pozzolan and is one of the valuable minerals of zeolite group. Analcime is a feldspathite mineral with a very large amount of hydrated sodium aluminosilicate ($Na(AlSi_2O_6).H_2O$) in its structure.

Abrasion is a physical and mechanical event that is slowly occurred. The reduction in size and mass occurred by friction of abrasive materials on surfaces of objects that make contact with each other and move relative to each other is defined as abrasion loss. Generally, the amount of abrasion depends on type of material, state of abrasion surface, friction conditions and chemical effects of environment.

As a result of optimizations carried out on all of mortar/concrete components, it is known that the abrasion resistance can be increased to desired level. Therefore, it can be possible to minimize damages caused from abrasion with increasing properly of abrasion resistance of mortar/concrete in some cases such as pavement, concrete roads, factory floor surfaces, water structures, chimneys etc.

In literature, the study made with analcime is very limited [3, 4, 5]. Furthermore, there is no study to examine abrasion resistance on mortar or concrete samples containing analcime. It is always an expectation that to minimize of damage caused by abrasion as a result of increase of abrasion resistance of construction materials. Therefore, the influence of analcime on the abrasion resistance of cement mortars was investigated in this study. The abrasion tests were carried out on mortar mixtures produced with different cement replacement ratio (0%, 10%, 30% and 50%). And, pozzolanic activity of analcime were determined. The results are compared with each other.

2. MATERIALS AND METHODS

The cement used in tests is CEM I 42.5 R type of Portland cement (PC) produced in accordance with TS EN 197-1 [6]. The analcime were used as replaced material by cement. The analcime (A) that is type of natural zeolite were obtained from Ordu/Perşembe regions of Turkey. The analcime samples were finely grinded in a ball mill. The amount of analcime used in mixtures were 0%, 10%, 30% and 50% of cement weight. So, the mixtures were produced with the labels PC, A10, A30 and A50.

The CEN (The European Committee for Standardization) standard sand in accordance with EN 196-1 [7] was used in mortar mixtures. The sand-to-cement ratio is constantly 3 and water-to-cement ratio is constantly 0.5. It was used superplasticizer (at 1%, 1.5% and %2 ratios) complying with TS EN 934-2 [8] by adding to mixture water to recover of adverse effect on mortar consistency of natural zeolites in mixtures. In the production of all samples, water that does not contain organic substances and mineral salts that may be harmful is used. The flow values of mortar mixtures are about 150 ± 20 mm.

All mortar mixtures were prepared by applying the standard mixing, molding and curing procedures stated in TS 196-1. Samples was prepared in laboratory environment where temperatures are 20±2ºC and relative humidity is 60±5%. The samples taken from molds after 24 hours from their productions were kept in the curing tank at a temperature of 21 ± 1ºC until the test days.

X-Rays Fluorescence Spectrometer (XRF) analysis was performed to determine chemical composition of analcime. X-Ray Diffraction (XRD) analysis was performed to determine mineralogical composition of analcime. Some views were also obtained using a Scanning Electron Microscope (SEM).

2.1 Test of Pozzolanic Activity

Pozzolanic activity can be defined as the ability to react with $Ca(OH)_2$ of active silica which is in the pozzolan. At the end of this reaction the amount of portlandite ($Ca(OH)_2$) is reduced, calcium silicate hydrate (CSH) is increased.

The pozzolanic activity tests were performed on 40x40x160mm prismatic samples. In TS 25 [9], the pozzolanic activity test is defined as a characteristic determined in terms compressive strength of the mortar obtained by mixing natural pozzolan which is grinded at a certain fineness with water, standard sand and calcium hydroxide (CaOH2). The amounts of materials required to prepare three test samples for tests on pozzolanic activity are given in Table 1.

Table 1. The amounts of materials for tests on pozzolanic activity

Materials	TS 25	The amounts for tests
Slaked lime ($CaOH_2$)	150gr	150gr
Pozzolan	2x150x(density of pozzolan /density of $CaOH_2$) (gr)	2x150x(2.28/2.15) = 318.14gr
Standard sand	1350gr	1350gr
Water	0.5x (150+pozzolan) (gr)	0.5x(150+318.14) = 234.07gr

The moulds of the prepared samples were covered with a glass plate to prevent evaporation. The samples were allowed to stand at room temperature for 24 hours (23 ± 2)ºC. And then, they were left for 6 days in an drying oven at 55 ± 2°C without removing the moulds. The samples removed from the oven were left to cool until the room temperature reached. Finally, the compressive strengths of samples were performed in accordance with TS EN 196-1.

2.2 Test of Abrasion Resistance

Three cube moulds of 70.7 mm were used for each mixture in abrasion tests. The mortars were produced by using blended cements containing analcime. The abrasion losses by friction at the end of 28 days of the mortar samples were determined by Bohme surface abrasion tests in accordance with TS 2824 EN 1338 [10] (Fig. 1).

Before tests, initial volumes and initial weights of samples were determined. The abrasive force of 294 N was applied to samples placed on rotary disk of Bohme apparatus.

The samples were subjected to abrasive effect of 20 g corundum powder poured on friction path together with operation of device. Total of 16 periods that each of them is 22 cycles were applied to samples. At the end of the test (at the end of the 352 cycles), volumetric abrasion losses (ΔV) in samples were determined.

In calculations, it was used formula at (1) which denote ΔV ($cm^3/50\ cm^2$); volumetric abrasion loss, Δm (gr); weight loss at end of 16 cycles, ρ (g/cm^3); density.

$$\Delta V = \Delta m / \rho \quad (1)$$

Figure 1. Bohme abrasion test device

3. RESULTS AND DISCUSSION

3.1. Some properties of portland cement, analcime and blended cements

Some properties of portland cement (PC), analcime (A), blended cements (A10, A30 and A50) are presented in Tables 2, 3 and 4. Densities of analcime is 26.92% lower than PC. Specific surface area of analcime is 48.91% higher than PC. This situation depends on mineral structure, porosity and fragilement properties of zeolite. Cumulative passing (%) of 45 µm sieve for Portland cement and analcime are 67.11% and 70.80%, respectively. Densities of blended cements have decreased with increasing of zeolite ratios. Fineness of blended cements containing zeolite has increased with increasing of zeolite ratios.

Table 2. Properties of portland cement (PC).

Chemical composition	(wt.%)	Physical and mechanical properties of portland cement			
SiO_2	19.53	Density, (g/cm^3)	3.12		
Al_2O_3	5.33	Initial set, (h)	2.50		
Fe_2O_3	3.56	Final set, (h)	4.15		
CaO	62.26	Volume expansion, mm	2.00		
MgO	0.99	Specific surface (Blaine) (cm^2/g)	3210		
SO_3	3.02	The compressive strengths	2 days	7 days	28 days
Loss of ignition	3.06	(MPa)	32.30	44.60	53.00
		Over sieve	45µm	90 µm	200 µm
		(%)	32.89	12.15	2.73

Table 3. Properties of analcime

Chemical composition	Analcime (wt.%)	Physical properties	
SiO_2	46.71		Analcime
Al_2O_3	17.24	Density, (g/cm^3)	2.28
Fe_2O_3	9.21	Blaine fineness (cm^2/g)	4780
CaO	3.03		
MgO	5.29	Over sieve (%)	
Na_2O	4.84	45µm	29.20
K_2O	4.08	90 µm	9.80
Loss of ignition	7.00	200 µm	2.15

Table 4. Properties of blended cements

Physical properties	PC	A10	A30	A50
Specific surface (cm^2/g) (Blaine fineness)	3210	3752	3918	4449
Density, (gr/cm^3)	3.12	2.79	2.75	2.71

3.2 Pozzolanic Activity of Analcime

Pozzolanic activity of analcime are given in Table 5. According to Table 5. In TS 25, one of the conformity criterias for pozzolans is the 7 day compressive strength of samples prepared with lime-natural pozzolan mixture. The limit value of the compressive strength is at least 4 MPa. In test study performed for analcime, the average compressive strength value for the lime-zeolite (pozzolan) mixture samples was determined as 6.30MPa. It has also been emphasized that the sum of $SiO_2 + Al_2O_3 + Fe_2O_3$ in TS 25 should be at least 70% by mass. The value of this total was found to be 73.16% for analcime. At the same time, the specific surfaces of the pozzolans should be greater than 3000 cm^2/gr. The specific surface of pozzolan which is used in this study were found to be 4780 cm^2/gr for analcime (Table 3). In pozzolanic activity tests. Because of the specific surface of natural zeolite were below of portland cement fineness, the reaction which is between pozzolan and lime was increased. It is thought that, this situation was lead to an increment at value of pozzolanic activity. These value show that the zeolite used in study have an usability potential as a pozzolan.

Table 5. Pozzolanic activity of analcime

TS 25 limit values	Analcime
Lime-pozzolan mixture 7 days compressive strength > 4MPa	6.30MPa
$SiO_2+Al_2O_3+Fe_2O_3$ wt. content >%70	%73.16
Specific surface area > 3000cm^2/gr	4780 cm^2/gr

3.3 Mineralogical Composition of Analcime

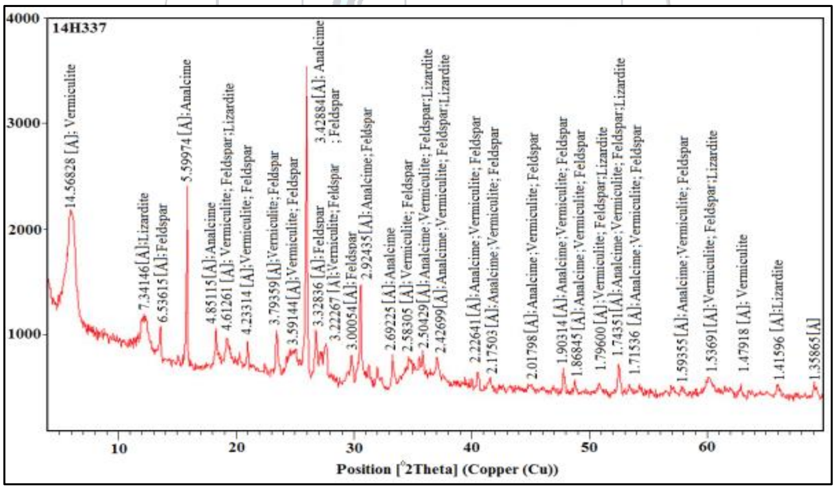

Figure 2. XRD diffraction patterns of analcime

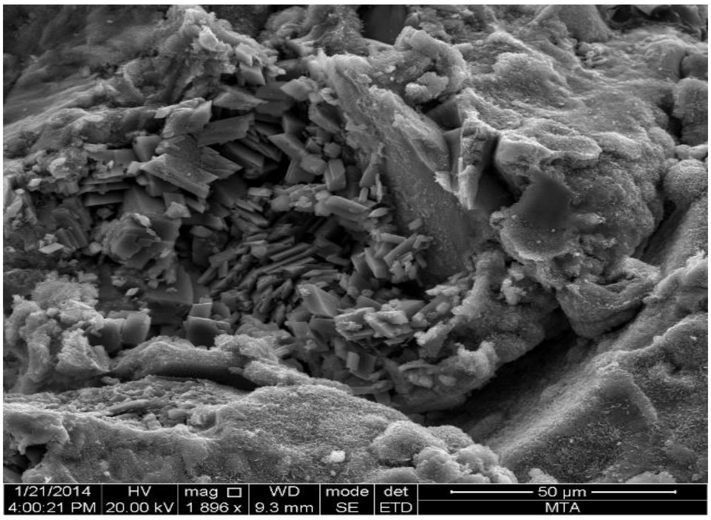

Figure 3. SEM view of analcime

XRD diffraction patterns and SEM views are presented in Figs. 2 and 3. According to the mineral modal ratios at the mineralogical composition results determined by the X-ray diffraction analysis (XRD) of analcime sample, the analcime rock is a vitric tuff and consists of glass splinters and crystal components. Glass splinters are converted to zeolite and chlorite, which are heavily altered. The analcime samples confirm the requirements of national and international standards for zeolite applications.

3.4 Abrasion Resistance of Mortars

Abrasion losses ΔV ($cm^3/50cm^2$) are given in Table 6. Abrasion losses variations for mortars are presented in Fig. 4.

Table 6. Volumetric abrasion losses and densities of mortar

Mortars	**PC**	**A10**	**A30**	**A50**
Density (gr/cm^3)	2.42	2.16	2.13	2.10
ΔV (cm^3/50cm^2)	11.84	8.97	9.17	10.23

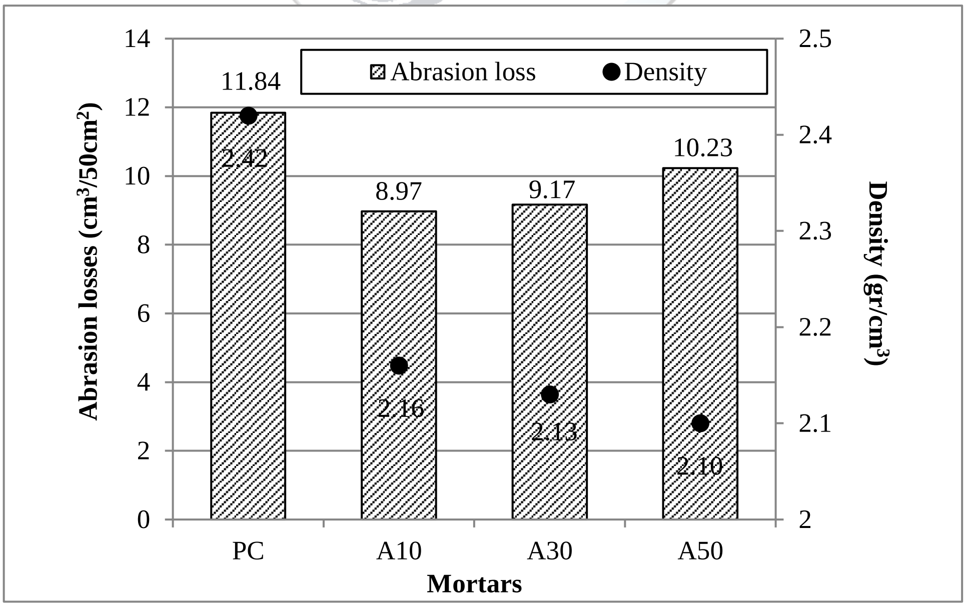

Figure 4. Abrasion loss and density variation for mortar

The volumetric abrasion losses for mortars with blended cements containing analcime (A10, A30 and A50) were 25%, 23% and 14% less than mortars with PC, respectively. In other words, it has been found that the abrasion losses of mortars with blended cement are less than mortars with PC for all replacement ratios. This positive effect in abrasion resistance is probably performance increasing occurred at aggregate-cement paste interface and cement paste due to pozzolanic reactions of zeolite. Also, as analcime replacement ratio increases, the densities of mortars decrease.

4. CONCLUSIONS

1. Since the density of analcime is lower than that of Portland cement, the densities of mortars produced by blended cement containing analcime are less than that of mortars produced by Portland cement.

2. The properties of natural zeolite analcime investigated in this study such as pozzolanic activity, mineralogical structure, high silica-alumina content, high specific surface, low density are sufficient for sustainable blended cement productions.

3. The abrasion losses of mortars containing analcime were lower than that of mortars containing portland cement for all replacement ratios. In other words, abrasion resistances of mortars containing analcime has increased up to 30% replacement ratio. It is believed that this positive effect of natural zeolite in the development of abrasion resistance is due to pozzolanic reactions.

4. A larger number of studies should be carried out on zeolites named analcime obtained from different regions to reduce amount of cement and to improve of cement performance.

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