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Utilization of Boron Waste Borogypsum with Silica Fume as a Supplementary Cementitious Material in Mortar

Murat Ozturk[1], Umur Korkut Sevim[1*]

Iskenderun Technical University, Department of Civil Engineering, Iskenderun, Turkey

Abstract— *In the current study, borogypsum and borogypsum with silica fume mixtures are added to cement clinker partially. Flexural tensile strength, compressive strength and water absorption tests are performed on mortar samples which contain borogypsum and silica fume and also high temperature effect on the mortars are investigated. As a result of the tests it is revealed that 5% addition of borogysum and borogypsum-silica fume mixtures to cement clinker are altered strength behaviors of the mortars.*

Keywords— Borogypsum, High Temperature, Mortar, Silica Fume, Waste.

I. INTRODUCTION

Large amount of waste have been produced with industrial and technological development. It is difficult to reuse industrial, domestic and agricultural wastes. 12 billion ton waste products had been produced during year of 2012 and this amount is increasing year by year. It is foreseen that the produced waste amount will be 19 billion ton at 2025 [1]. To dispose the wastes there is a need for large storage areas. Thus, it is a big issue for civil ad environmental engineers [2-3].

Fly ash, blast furnace slag, silica fume, waste boron etc. are waste or by-products which are used in concrete providing major advantages for environmental concerns. The primary advantage of re-use of these wastes is that it minimizes the need to remove environmental impacts and also the need for large storage areas for waste disposal.

Many natural and artificial materials with pozzolanic properties have been used for a variety of purposes in the field of construction and concrete production since ancient times. These materials, which are not basic compounds of concrete, are also known as additives, are used in developing concrete technology to change various physical, mechanical and durability properties of concrete and also these materials provide economy in concrete production.

Although the mineral admixtures used in concrete have similar physical properties with similar mineralogical and chemical compositions to portland cement, the vast majority do not have binding capabilities on their own. These substances change binding structure by exhibiting activity in the formation of hydration products due to pozzolanic activities. Thus, while the various properties of the concrete are improved, mineral additives with high pozzolanic activity can improve the void structure, results denser structure, increases adherence at the aggregate-cement paste interface and makes the structure achieve high strengths.

Some waste materials, which are very similar to portland cement and have pozzolanic characteristics in terms of their basic composition, can be used as a material for bonding in cement and concrete production in the construction sector. By forming part of portland cement and replacing some amount of portland cement which is used in concrete production in concrete cement production provide an economy that can not be underestimated in terms of both environmental problems and cost of concrete.

Turkey has the largest boron mineral reserve and has the secant boron mineral production after ABD. Colemanite, ulexite and tinkal are the boron minerals which are produced by Turkish mine industry. These minerals are concentrated to produce boric acid and borates. To produce boric acid, colemanite reacts with sulphuric acid. After that process a byproduct, borogypsum, is gathered from the filters. The amount of this waste is nearly 550,000 tons annually [4].

In this study; It is aimed to evaluate colemanite concentrator waste in Kütahya-Emet region and silica fume which is waste of Anyalya ETI Elektrometalurji AŞ. factory as an additive to cement. It is also the aim of this study to reduce the energy costs of cement production and improving the mechanical properties of the cement. Colemanite concentrator waste-silica fume and colemanite concentrator waste mixtures were added to cement clinker at different ratios. The effects of additives on the compressive- tensile strength and water absorption of the mortars are investigated. The most important feature of this research is the addition of previously untested binary mixtures of silica fume and colemanite

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concentrator wastes, which are abundant as waste in our country and cause environmental problems, as an additive to the cement and the effect of these additives on the mechanical properties of the cement.

II. EXPERIMENTAL STUDIES

2.1. Materials and Mixture Properties

CEM I (PC 42,5), silica fume, borogypsum which is taken from Kütahya-Emet Eti Bor A.Ş. mine reservuar as dried and grinded. The chemical composition and physical properties of the borogypsum and silica fume is given in Table 1 and 2 respectively. Fine aggregates are used for the mortar sample production. Nominal maximum size of 4 mm fine aggregate is used in the mixture. Fine aggregates has fineness modulus of 2.79, and specific gravity of 2.58 respectively. A superplasticizer is used because of the reducing effect of borojips and silica smoke on the consistency of concrete. In the experiments, "glenium 51" super plasticizer was used.

Table.1: Physical properties and chemical composition of the borogypsum

B_2O_3(%)	1,05
SiO_2(%)	13,17
Al_2O_3(%)	2,39
Fe_2O_3(%)	1,08
CaO(%)	37,33
MgO(%)	3,10
SO_3(%)	32,17
Porozity (e)	0,624
Density (g/cm^3)	2,62
Blaine (cm^2/g)	12850

Table.2: Chemical komposition of silica fume

SiO_2(%)	93-95
C (%)	0.8-1
Fe_2O_3(%)	0.4-1
Al_2O_3(%)	0.4-1.4
MgO(%)	1-1.5
CaO(%)	0.6-1
Na_2O_3(%)	0.1-0.4
K_2O(%)	0.5-1
S(%)	0.1-0.3

Thirteen different mortar mixtures are prepared which contain 5, 10, 15, 20% borogypsum; 5, 10, 15, 20% borogypsum with 5% silica fume and 5, 10, 15, 20% borogypsum with 10% silica fume replacement with cement by weight. Binder-aggregate-water ratios of the mixtures are kept constant as 1:2,75:0,485 respectively. Details of the mixtures are given in Table 5. A speed controlled power-driven revolving pan mixer is used for mixing process. Prism (40x40x160 mm3) specimens are casted and vibrated for each mixture. The specimens are demolded after casting 24 hours.

III. TEST METHODS

Flexural tests were performed on 40x40x160 mm3 prisms and compression tests were performed on 40x40x40 mm3 cubes, which come from flexural tests, by a 15kN and 25kN tension and compression capacity testing machine according to ASTM C348 [5] and ASTM C349, respectively [6].

Water absorption test is an experiment that determines how much water a sample absorbed. The mortar sample is dried for 24 hours at 105 ± 5ºC and then the dry weight of the sample is weighed. Completely dry sample is left in the curing tank to absorb water for 48 hours. After 48 hours the sample is removed and the saturated sample is surface dried and weighed again so that the amount of water absorbed by the concrete is calculated.

IV. RESULTS AND DISCUSSIONS

After demolding, the mortar samples cured in a water tank for 28 days. The tests are performed on the dry samples which are air dried, dried under 250ºC for 2 hours and dried under 500ºC for 2 hours. For all curing conditions three specimens are produced and the results shown in the figures are mean value of these three specimens. It is important to mention before the the test results are examined and discussed that Compared to many building materials, concrete is more resistant to high temperature effects. At temperatures below 250 degrees, there is no decrease in mortar strength. Between 250 and 300ºC, the loss of water in aluminum and iron oxide components causes the compressive strength to decrease. Ca(OH)2 is converted to CaO around 400 ºC. In the range of 400-600 ºC, C-S-H structure is destroyed and causes a large decrease in strength.

4.1. Flexural strength

Flexural strength test is performed on prism (40x40x160mm3) mortar samples which are air dried, dried under 250ºC for 2 hours and dried under 500ºC for 2 hours. Before performing the test the samples are waited under room temperature for cooling down. Flexural strength test results are presented in Fig.1. According to test results samples including 5% borogypsum have close flexural strength value to control samples which do not contain any admixtures. When the samples including both borogypsum and silica fume (B5S5 and B5S10) examined, they have greater flexural strength then both samples including only borogypsum (B5) and control samples. It is due to that silica fume which has high amount of SiO2 is coused alteration of puzzolanic activation of borogypsum. Samples, cured under 250 Celsius degree for two hours, containing 5% silica fume and borogypsum has less flexural strength loss relatively. It is considered that a part of portlandite in the structure of borogypsum transformed to calcium-silicat-hydrate gels with the contribution of silica fume.

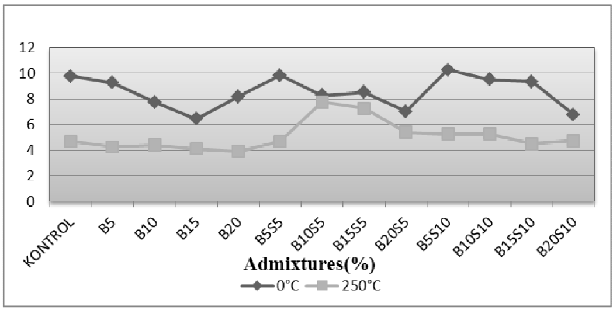

Fig.1: Flexural strength of the test specimens

4.2. COMPRESSIVE STRENGTH

Compressive strength test are performed on the same samples with the sample used for flexural strength test which are divided into two parts due to flexing. The test results are shown in Fig.2. Addition of 5% borogypsum to cement clinker increased compressive strength of the mortars. The alteration of the compressive strength value of this mixtures are consistent with the literature [7]. Kavas et al. studied microstructure of mortars containing borogypsum. According to their research mortars including borogypsum has less etrengite when compared to control mortar samples which do not contain any admixtures. Beside that they concluded that borogypsum addition into the mortars caused a denser structure in the mortars [8]. Mixtures containing 5% borogypsum and 5-10% silica fume have greater compressive strengths then control samples. It is again considered that puzzolanic activation of borogypsum is altered with the contribution of silica fume. Similar results are seen in the compressive strength test values of samples cured for 2 hours at 200 °C and 2 hours at 500 °C. Transformation of CaO to C-S-H gels at 400 °C caused a reduced damage that the high temperature has done.

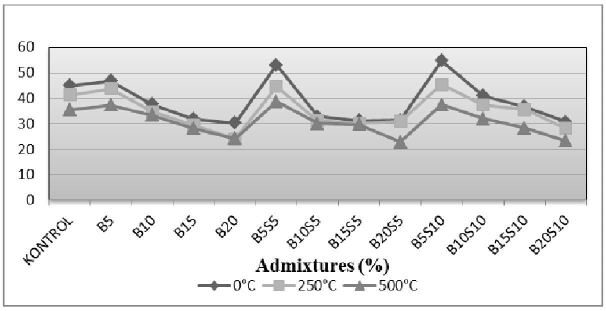

Fig.2: Compressive strength of the test specimens

4.3. WATER ABSORPTION

Water absorption capacities of the mortar samples are presented in Fig. 3. As is it seen in the figure ıncreasing curing temperature causes more absorbed water. To explain cause of behind this behavior void ratio of the specimens are evaluated. Thus the results showed that the more void ratio the more absorbed water. The void ratio test results are shown in Fig. 4.

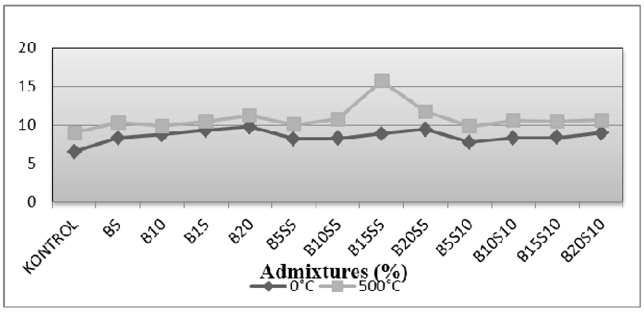

Fig.3: Water absorption capacity

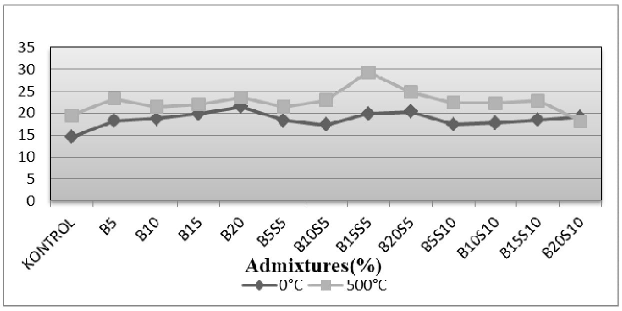

Fig.4: void ratio of mortar specimens

V. CONCLUSION

- When the compressive strength test results are determined; mixtures containing 5% borogypum B5, B5S5, B5S10 samples cured at room temperature, under 250 and 500 °C temperature are found to have greater strength then control samples which do not contain any admixtures.
- The addition of silica fume increased the compressive strength as expected.
- Similar to the studies in the literature, 10% or more borogypsum addition in the mortar have caused significant reductions in compressive strength. This is due to the limited pozzolanic nature of borogypsum.
- Flexural strength loss of the samples cured under 250 °C is considerably higher than the compressive strength. Flexural strengths of specimens containing 5% borogypsum were high similar to those of compressive strength.
- When the results of water absorption and apparent void ratio are examined, it is seen that all the samples containing additives absorb more water than the control sample and have more apparent void ratio. Beside that water absorption and apparent void ratio of the specimens cured under 500 °C have greater values when compared to the other conditions.of the paper. Although a conclusion may review the main points of the paper, do not replicate

the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

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