Technological aspects for the treatment of magnesium silicate waste

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Abstract. Magnesium silicate waste from the mining industry occurs in substantial volumes and is almost never used. This paper outlines that the waste can be used as a mineral additive in the production of Portland cement. The influence of the quantity of troctolite additive and the specific surface area on the mechanical properties of cements has been analyzed. The technological parameters in cement production with mineral additive are determined. The study also found that the introduction of troctolite in quantity of 25 % at a specific surface area of 450 kg/m2 leads to improved strength characteristics of cement compositions. The use of magnesium silicate waste in cement production can reduce the environmental impact of cement manufacturing by reducing the consumption of natural resources, electricity and by decreasing of carbon dioxide and dust emissions. The study concluded that it will also help to solve environmental problems of mining industry.

1. Introduction and Background

In the world there is a huge number of mining waste including overburden rocks and adjacent strata formed during the development of mineral deposits. Most of them are silicate rocks consisting of a considerable number of magnesium silicate rocks which are used in the construction engineering.

Among them are basalts used for the purpose of mineral fiber production [1–6]. These rocks can replace crushed stone and sand which are traditional aggregates in the preparation of concrete mix [7, 8]. To obtain fibrous concrete [9–12], foam fibrous concrete [13, 14] and fiber-cement boards [15] basalt fiber is added to the cement which improves its quality. Moreover, the use of basalts as an additive in cements allows not only to improve their physical, mechanical and operational characteristics [16–20], but also to reduce the share of natural resources included in the raw material mixture. Serpentinite can be introduced into the binding material to increase the strength and durability [21, 22]. In addition to these rocks in the overburden dumps magnesium silicate rocks are located in the form of trotolites, which are not used but remain in the dumps and damage the ecological environment. Therefore, the use of magnesium silicate rocks in the production of new outputs is an urgent problem for the geoecological safety of the planet. The aim of current study is to develop the technological basis for the use of magnesium silicate waste of the mining industry in the production of mixed cements.

2. Materials and Methods

The following raw materials were used in the current research: Portland cement clinker of Temlyakov cement plant and inorganic mineral additive. Magnesium silicate wastes of the mining industry were used as an additive. They are the overburden rocks and adjacent strata of the North Baikal ore zone in the form of troktolites of the following chemical composition, wt. %: SiO_2 – 40.6; Al_2O_3 – 12.0; MgO – 28.6; CaO – 5.6; (Fe_2O_3 + FeO) – 10.6; (Na_2O+K_2O) – 0.1.

The method of mechanical activation was used in the work. Grinding of raw materials was carried out in a vibrational shredder of 75T-DRM brand with their maximum loading in the amount of 0.5 kg.

Physical and mechanical characteristics of the obtained materials met the requirements of State All-Union standard 310.1-76 "Cements. Methods testing. General ", State All-Union standard 310.2-76 "Cements. Methods of tests of fineness of grind", State All-Union standard 310.3-76 "Cements. Methods of tests consistency, times of setting and of soundness", State All-Union standard 310.4-76 "Cements. Methods of bending and compression strength determination".

3. Experimental Section

There are large volumes of waste materials that are produced by mining industry and accumulated on the territory of Russia. The fact demonstrates that there is a need of their reduction through the application in the production cycle of new products. One of the promising areas is the production of construction materials, particularly cement.

As far as is known, cement production is expensive and hazardous process for the environment. It requires a large number of natural raw materials and consumes a significant amount of electricity and releases a huge amount of carbon dioxide and dust into the atmosphere. Reduction of these figures can be achieved by using as a mineral additive magnesium silicate waste in the form troctolites. Troctolite additive is potentially active and can be used cement production.

The main technological parameters of cement production are the specific surface area [23] and the quantity of the additive to be added. In order to determine the dependence of physical and mechanical characteristics of cement on the technological parameters of their preparation, samples from paste of normal consistency were prepared – cubes with the size of the ribs 2 cm. The samples were kept for 3, 7, 14 and 28 days in the container with hydraulic gate, and then tested according to State All-Union standard 310.4-76. The results obtained after hardening of cements with the addition of troctolite for 28 days under normal humidity conditions are presented in table 1.

Table 1. Influence of technological parameters on the strength of cements.

The number of troctolite additive	Resistance to compression, MPa at specific surface area			
	280 m^2/kg	340 m^2/kg	450 m^2/kg	560 m^2/kg
0	52.2	56.6	64.2	57.5
5	52.7	57.8	65.3	58.1
10	53.1	59.6	66.1	59.5
15	53.4	64.2	66.9	60.8
20	53.8	66.8	67.6	62.0
25	57.5	67.4	69.8	63.8
30	53.5	62.3	66.8	60.5
35	52.2	59.8	62.1	58.7
40	50.0	56.9	60.5	55.1

The table data demonstrate that the specific surface area has an impact on the mechanical characteristics of cements. The cements with the addition of troctolite crushed to a specific surface area of 450 m^2 / kg show the greatest strength characteristics. Hydration of more finely crushed material does not lead to an increase in the strength of the samples. Evidently, superfine fractions appear that contribute to the aggregation of particles and affect the hydration activity of cements.

The quantity of magnesium silicate waste additive also affects the resistance to compression of cement samples which is higher than the Portland cement control sample. An increase of troctolite additive to 25 % contributes to the increase of material strength after which this figure is reduced.

Analyzing the curing time of samples one can conclude that the cements becomes solid in the first fourteen days (more than 50 %) reaching a maximum value by twenty-eight days, then the changing of values stops.

The development of technological solutions for the cement production with mineral troctolite additive is based on technological parameters obtained in the process of investigation. The process flow diagram is shown in figure 1.

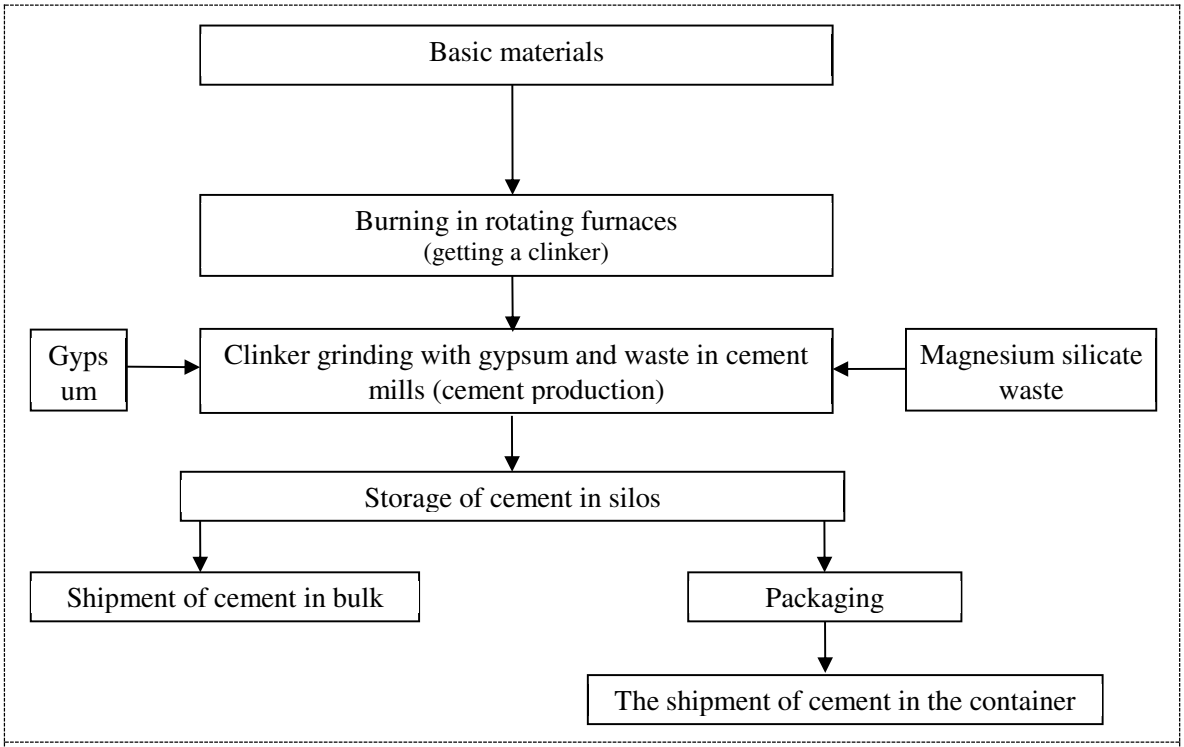

Figure 1. The process flow diagram of the cement production with mineral troctolite additive.

The production of cement with mineral additives excludes the introduction troctolite in the raw material mixture for burning that positively effects on the cost of cement and influence on the environment.

4. Results and Discussion

As far as is known, the type of mineral additive, its quantity and specific surface area have a direct impact on the hydration activity of Portland cement. Used as an additive, magnesium silicate waste (troctolites)

contains about 30 % magnesium oxide, 10 % iron oxides and consists of minerals of the olivine group as well as labrador, anorthite and albite. In the initial state, they are inactive and have a negative affect the hydration of cement. To activate them, the method of mechanical activation was used.

Mechanical activation allows to change the particle size of raw materials leading to structural failure and their distribution in the ground mass. A new surface with activity centers is formed as a result of which the chemical activity of the fine material increases. This process also depends on the volume of the mineral additive.

The quantity of added troctolite regulates the total content of SiO^2 that forms the new formations of cement and affects the accumulation of low-basic CSH gel passing into CSH(1). In addition, an increase in the percentage of the additive leads to a decrease in the amount of $Ca(OH)^2$ in the cement stone due to its chemical interaction with the minerals of troctolite and the new formations.

The addition of troctolite in the quantity of 25 % to Portland cement clinker at the grinding stage allows to intensify the process of hydration of the ground to the specific surface area of 450 m^2/kg of Portland cement. As a result, calcium, magnesium, iron hydrosilicates are formed as well as their mixed varieties with fibrous, tape and chain structures. Their type and number determines the strength of the resulting compositions.

5. Summary and Conclusion

Thus, magnesium silicate wastes that are produced by mining industry in the form of troctolites can be used as a mineral additive in the production of Portland cement. At the same time, the quality of it will depend on the technological parameters of production. The most optimal conditions are: the quantity of troctolite additive of 25 %, the specific surface area – 450 m^2/kg when the mechanical characteristics of cement will be maximum.

The addition of magnesium silicate waste allows to replace the appropriate quantity of Portland cement clinker at the cement grinding stage which will significantly reduce the negative impact of cement production on the environment by reducing the consumption of natural raw materials and electricity, dust and carbon dioxide emissions. The utilization of mining waste will solve environmental problems in the development of mineral deposits.

References

[1] Khodakova N N, Uglova T K, Firsov V V, Tatarintseva O S 2013 Minerals Caucasus for production of basalt fiber *Polzunovskii Vestnik* **1** pp 138–142
[2] Khudyakova L I, Buyantuev S L and Voiloshnikov O V 2013 Mineral fiber obtained using low-temperature plasma *Glass and Ceramics* **70(7-8)** pp 297–299
[3] Kumbhar V P 2014 An overview: basalt rock fibers – new construction material *Acta Engineering International* **2(1)** pp 11-18
[4] Kunal S 2012 A short review on basalt fiber. *International Journal of Textile Science* **1(4)** 19–28
[5] Siddiqui R, Naseer S and Uddin B 2015 Basalt: unconventional uses of a conventional rock. *International Journal of Science and Engineering* **3** Special Number ICRAESM pp 116–123
[6] De Fazio P 2011 Basalt fibra: from earth an ancient material for innovative and modern application *Energia Amblente Innovazione* **3** pp 89–96
[7] Curbanov R M, Hadgishalapov G N and Hegev T A 2013 Research of heat-resistant concrete on the basis of basalt filler for concreting of metal designs *Herald of Dagestan State Technical University. Technical Sciences* **4(31)** pp 61–65
[8] Nguyen Viet Kyong and Chumakov L D 2009 Complex use of basalt aggregates in concrete *Vestnik MGSU* **1** pp 163–167

[9] Kasper E A and Bochkareva O S 2015 Fine grained concrete dispersed-reinforced by basalt fiber. *Systems. Methods. Technologies* **1(25)** pp 135–138
[10] Babaev V B, Strokova V V and Nelyubova V V 2012 Basalt fiber as a component for micro-reinforcement of cement composites *Vestnik BSTU named after V. G. Shukhov* **4** pp 58–61
[11] Borhan T M 2013 Thermal and mechanical properties of basalt fibre reinforced concrete. *International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering* **7(4)** pp 334–337
[12] High C, Seliem H M, El-Safty A and Rizkalla S H 2015 Use of basalt fibers for concrete structures. *Construction and Building Materials* **96** pp 37–46
[13] Bozylev V V and Dragel A A 2013 To the question of the strength indicators of products from non-autoclaved foamed concrete increasing. Vestnik of Polotsk State University. Part F. Constructions. Applied Sciences. **16** pp 77–83
[14] Zhukov A D and Rudnitskaya V A 2012 Foam concrete reinforcement by basalt fibres *Vestnik MGSU* **6** pp 83–87
[15] Fadeyeva T A 2015 Modern finishing concrete obtained by pressing and filtration *Science Time* **12(24)** pp 788–791
[16] Andrade F R D, Pecchio M, Bendoraitis D P, Montanheiro T J and Kihara Y 2010 Basalt mine-tailings as raw-materials for Portland clinker *Cerâmica* **56** pp 39–43
[17] El-Didamony H, Helmy I M, Osman R M and Habboud A M 2015 Basalt as pozzolana and filler in ordinary portland cement *American Journal of Engineering and Applied Sciences* **8(2)**: 263.274 doi: 10.3844/ajeassp.2015.263.274
[18] Mendes T M, Guerra L and Morales G 2016 Basalt waste added to portland cement *Maringá* **38(4)** 431-436 doi: 10.4025/actascitechnol.v38i4.27290
[19] Eroshkina N A and Korovkin M O 2015 Properties of geopolymer binders based on disperse waste of basalt extraction and processing *PGUAS Bulletin: Construction, Science and Education* **1** pp 25–28
[20] Dobiszewska M and Beycioğlu A 2017 Investigating the influence of waste basalt powder on selected properties of cement paste and mortar *IOP Conf. Series: Materials Science and Engineering* 245 022027 doi:10.1088/1757-899X/245/2/022027
[21] Lazarevich E V, Nikitenko N E, Gilevich A A and Orlov A A 2017 Development of nonfired materials by serpentine *Architecture, Urbanism and Design* **12** pp 15–19
[22] Lee J-K and Soh J-S 2016 Performance of magnesia cement using $MgCO_3$ and serpentine *Journal of the Korean Ceramic Society* **53(1)** 116-121 doi: 10.4191/kcers.2016.53.1.116
[23] Khudyakova L I, Voiloshnikov O V and Kotova I Yu 2015 Influence of mechanical activation on the process of formation and properties of composite astringents *Building Materials* **3** pp 37–41