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Heavy Weight Concretes Based On Technological Non-Metallic Production Wastes

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Abstract. The article presents the research results of heavy weight concretes based on nonmetallic production of technological wastes. Quantitative and qualitative characteristics of stone screenings dusts of the quarries Sverdlovsk and Chelyabinsk regions were explored. The research uses a set of standard physicomechanical and chemical methods. The influence of the additive MC-PowerFlow 3100 and Centrament Air 202 on the properties of the concrete mix, the kinetics of the strength and frost resistance of concrete samples with granite and dolomite screenings was determined. It was found that the complex of additives promotes an increase in the degree of cement hydration and a decrease in the capillary porosity of concrete. The compositions of heavy weight concretes with strength quality B22,5 – B40 with granite crushed stone of Rezh quarry and dolomite Satka quarry as fine aggregate have been developed. A comparative cost-effectiveness analysis of heavy weight concretes with non-metallic wastes was carried out. The industrial approbation of the results was performed at the precast concrete factory of the Tyumen region.

1. Introduction

Reduction of the negative impact of human activities on the environment by reducing the amount of solid waste is one of the priority vectors for the development of the industrial economy of the Russian Federation. As the statistics show one of the main polluters of nature are the enterprises producing nonmetallic materials. In this scientific work a choice was made in favor of studying stone screenings dust. The total amount of these wastes produced at the crushed stone plant is about 54 million m^3 including 6-9 million m^3 - screenings of centrifugal-impact grinding. Screenings are mainly stored in multi-storey dumps which are a significant environmental problem for the number of subjects of the Russian Federation, in particular Chelyabinsk and Sverdlovsk region. However, nearby regions have an increasing problem of shortage of crushed stone and gravel small fractions as well as enriched sand.

Concrete mixtures made of stone screening dust are characterized by increased water demand. Nevertheless, using modern developments in the field of chemical additives it became possible to produce heavy concrete with a dense structure, which as good as standard samples of heavy concrete in durability and quality and can be used for the production of reinforced concrete products and especially for laying underground communications and erecting of overpasses elements [1-8].

The best quality of screenings is obtained by crushing fine-medium-grained rocks. The grain surface roughness of such material is characterized by the height of microrelief of about 170-190 μm, which ensures the best adhesion to cement stone in concrete. The disadvantage of using coarse-grained rocks of polymineral composition especially granite is sand of monomineral composition (quartz, feldspar, mica), which differs in cement stone adhesion [9-12].

Concrete mixes with screenings of crushing and increased water demand exclude the possibility of achieving high strength and other performance properties. However, ordinary strength qualities are dependent on water-cement ratio. In other words, any factor increasing water demand raises the consumption of cement and the cost. Another side effect of the use of screenings, associated with water absorption of the aggregate dust particles during the manufacturing and transport process, is manifested in the accelerated loss of mobility of concrete mixtures [13-16]. The carrying-out of the requirement that the rheological properties remain unchanged for two hours becomes difficult in the Ural climate conditions. In its turn, a large aggregate typical for the Urals Federal District is usually represented by intrusive rocks with a crushing grade 1200. However, deviations from the standard percentage of the dust particles content are also common.

The purpose of the study is to develop efficient concretes based on polyfraction aggregates consisting of stone screening dusts for the conditions of Western Siberia from local quarries and chemical additives - regulators of concrete mix properties.

2. Materials and methods

To achieve this goal, an experimental plan including the study of the regional features of quarries in the Tyumen and nearby regions and the development of effective concrete mixes using non-metallic wastes has been drawn up. For research stone screening dusts from the granite quarry of Rezh (Sverdlovsk region) and the dolomite quarry of Satka (Chelyabinsk region) were used.

For the production of concretes with low water content, high strength and frost resistance, an analysis of additives influence on the obtained concrete properties was carried out. In the course of the experimental study, the properties of the developed concrete compositions based on stone screening dusts with MC-PowerFlow hyperplasticizer and Centrament Air 202 air-entraining additive were studied. A set of standard methods was used in experimental studies [17-19].

3. Results

The data obtained as a result of the of stone screening dusts properties study from the granite quarry of Rezh (Sverdlovsk region) and dolomite quarry of Satka (Chelyabinsk region) are given in table 1 and table 2.

Table 1. Properties of stone screening dusts

Main characteristics	Quarry of crushed stone, Chelyabinsk region, Satka	Crushed stone plant, Sverdlovsk region, Rezh
Rock	dolomite	granite
Size modulus	1.7	2.57
Crushed stone fraction 5-10 mm (%)	3.8	5
Content of dust, clay and silty particles (%)	2.0	2.9
Bulk density (kg/m^3)	1380	1450
Ball clay (%)	0.1	0.3
Crushed stone grade	800	1000

Table 2. Results of chemical analysis of stone screening dusts

Testing sample	Content of basic oxides (%)											
	SiO_2	CaO	MgO	Fe_2O_3	Al_2O_3	TiO_2	MnO	P_2O_5	Na_2O	K_2O	CO_2	loss on ignition
390 (granite)	70.82	2.33	1.09	4.00	12.58	0.40	0.08	0.05	3.51	2.22	-	2.85
391 (dolomite)	0.11	31.61	23.04	1.51	2.58	0.09	0.03	0.06	0.33	0.40	40.07	-

It was revealed that, like any building material, stone screening dust has a number of shortcomings:

- the specific shape and quality of the grain surface - mostly angular with a rough surface;

-increased content of mica (stone screening dust of LLC «Rezh crushed stone plant»); mica flakes have low adhesion to cement, which may further cause cracking and consequently reduce the strength of concrete;

- dustiness of screening (undersize No. 0.16 is 16.5%) contributes to increasing the water demand of the concrete mix, which negatively affects the strength of concrete;

-increased water absorption of screening (12-23%) reduces the frost resistance of finished concrete products.

The results of numerous studies [1, 2, 4] show that the frost resistance of heavy weight concretes depends on a large number of different factors, the main of which are the initial water-cement ratio, the type and activity of cement, the composition and conditions of concrete hardening, its age at the time of freezing, frost resistance aggregates. Unfortunately not all factors can be regulated. As a result durability of concrete can be increased in two ways:

• decreasing the water cement ratio by reducing the amount of water in the concrete mix;

• increasing the amount of the entrained air by forming closed pores in the concrete.

The authors of the article carried out development studies of concrete compositions using stone screening dust [5]. Part of the research was carried out according to the program «Challenges in youth science and innovations in the Tyumen region» (grant U.M.N.I.K. 2015).

In the course of the experimental study, the properties of the concrete compositions based on stone screening dusts with the additive of the MC-PowerFlow hyperplasticizer (manufactured by MC Bauchemie, Germany) were examined.

MC-PowerFlow additive in an amount of 0.4 to 0.8% (by weight of cement) in the concrete mix reduces the hardness of the mixture from 26 to 5 seconds and forms a dense contact zone at the surface of the aggregate (stone screening dust) and increases the strength of adhesion to cement stone. The hyperplasticizer reduces the negative effect of fine particles on the water requirement of the concrete mix, increases the wettability of the aggregate, decreasess the viscosity of the concrete mix, reducing the likelihood of formation of discontinuities in the contacts of the cement stone with the aggregate. Besides the MC-PowerFlow hyperplasticizer increases the concrete strength and 28 days later the strength is approximately 32.7-53.2 MPa.

In addition, the effect of a complex additive consisting of MC-PowerFlow 3100 polycarboxylates esters (80% of the complex additive weight) and Centrament Air 202 airßentraining additive (20% of the complex additive weight) on the properties of concretes with stone screening dust was studied. (table 3).

Table 3. Effect of a complex additive on the properties of concretes containing stone screening dust

Main properties of concrete		Concrete compositions							
		1-4	1-5	1-6	1-7	2-4	2-5	2-6	2-7
Additive (% by weight of cement)		0	0.4	0.6	0.8	0	0.4	0.6	0.8
Water cement ratio		0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41
Density, kg/m^3		2250	2310	2360	2390	2230	2250	2310	2350
Entrained air volume, %		0,1	1.4	2.9	5.3	0.4	2.0	3.6	5.9
Compressive strength, MPa		37.5	41.5	47.1	53.2	29.5	32.7	34.8	37.8
Variation of compressive strength during freezing and thawing test (%)	5 cycles	+0.4	+1.6	+1.8	+4.2	+2.0	+1.3	0	+2.5
	10 cycles	+0.1	+0.9	0	0	-1.3	+0.1	-0.4	+0.7
	20 cycles	-8.4	-1.7	-2.1	-2.5	-5.2	-1.4	0	0
	30 cycles	-		-1.5	-3.4	-	-	-	-6.8
	45 cycles	-	-	-	-8.5	-	-	-	-

The porosity of heavy cement concrete with stone screening dust was examined. The obtained results make it possible to state that the introduction of the complex additive into heavy weight concrete with stone screening dust can substantially reduce the total porosity of the samples. There was also an increase in the number of conditionally closed pores and a decrease in their size. In sum, these changes give a significant increase in the frost resistance grades F200-F300 of heavy concrete. That allows to use this concrete in harsh climatic conditions.

The industrial approbation of the results was performed at the precast concrete factory of the Tyumen region. The object of approbation was reinforced concrete trays L-15/2 (Series 3.006.1-2.87.) produced by the precast concrete factory «Rotor» in the village of Vinzili, Tyumen region.

The results of the test showed high economic efficiency of the concrete based on stone screening dust (table 4).

Table 4. The cost price of heavy concretes B30 based on fine aggregates

Concrete compositions	Material consumption per 1 m^3 of concrete mix, kg	Cost of materials, rubles (inc. VAT)
Cement (OAO «Sukholozhskcement»)	400	1508.40
Crushed stone, fraction 5-20 mm (Kurmansky crushed stone plant)	1110	912.40
Coarse-grained sand (Ltd «Tyumenerud»)	800	680.00
Stone screening dust (Rezh crushed stone plant)	800	620.00
Complex additive (MC Bauchemie)	2.8	296.00
Water	150	10.50

The price of 1 m^3 of concrete with the strength quality B30 containing natural sand as an aggregate is 3407.3 rubles, the price of 1 m^3 of concrete with the strength quality B30 containing stone screening dust is 3347.3 rubles, which saves 60 rubles per 1m^3. The given study allows to confirm that stone screening dust in heavy weight concretes is economically efficient.

4. Conclusion

1. The quantitative and qualitative characteristics of granite screenings of Rezh (Sverdlovsk Region) and dolomite screenings of Satka (Chelyabinsk region) have been studied and the possibility of using these wastes in the composition of heavy weight concrete has been proved.

2. The compositions of effective heavy concretes of strength quality B22,5-B40 with the use of stone screening dust from the granite quarry of Rezh and the dolomite quarry of Satka were achieved. Studies revealed that complex additives increased the strength and frost resistance of concrete, as well as the degree of cement hydration and decreased the capillary porosity.

3. The effect of the additives MC-PowerFlow and Centrament Air 202 on the properties of the concrete mix, on the kinetics of the strength and the frost resistance of concrete samples with the use of stone screening dust as a fine aggregate was studied.

4. The industrial approbation of reinforced concrete trays L-15/2 (Series 3.006.1-2.87.) was performed at the precast concrete factory «Rotor» of the Tyumen region (Vinzily, Tyumen region).

References

[1] Leonovich S N, Polejko N L 2016 Performance characteristics of concrete on aggregate from sedimentary rocks *Construction Materials*. Vol. **8.** Pp. 66-69.

[2] Shatov A N 2017 Method for obtaining high-quality commercial concretes taking into account the specificity of the material base of the Urals Federal District *Concrete Technologies*. Vol. **1-2**. Pp. 10-11.

[3] Pushkarskaja O Ju, Gruzdev A A and Klavdieva T N 2009 Comprehensive assessment of building composites based on industial wastes *Reliability and durability of building materials, structures and subfoundations. Materials of the V Int. Conf. Volgograd*. pp. 190 – 192.

[4] Akhtyamov V F, Baturin A S, Elizarov I A and Khafizova E N 2016 Investigation of obtaining high-performance concretes based on wastes from the production of non-metallic materials and polycarboxylates esters additives. *Int. Scientific-practical Conf. of Young Scientists named after D.I. Mendeleyev's*. Tyumen. 2016. pp. 315-318.

[5] Khafizova E N, Akhtyamov V F 2017 Study of technological wastes influence of non-metallic production on concrete properties. *Vestnik of TSUAB*. Vol. 4 pp. 107-116.

[6] Hamidullina D D, Garkavi M S, Jakubov V I, Rodin A S and Kushka V N 2006 Stone screening dust are the effective way to improve the quality of concretes*Construction Materials* vol. **11**. pp. 50-51.

[7] Kharo O E, Levkova N S, Lopatnikov M I and Gornostaeva T A 2003 Use of recycling rock wastes in the manufacture of non-metallic building materials *Materials* vol. **9.** pp. 18-19.

[8] Application of recyclable materials in road construction in Europe and the United States. BINTI. 2002. Vol. 1. pp. 16-18.

[9] Levkova N S, Gornostayeva T A 2003 Increase of complex use efficiency of raw materials due to screenings of crushed stone from igneous rocks. *Bulletin of BSTU named after Shukhov*. Vol. 5. pp. 308-311.

[10] *Malhotra V M, Ramezanianpour A R 1994 Fly Ash in Concrete/ 2nd Ed, CANMET, Energy, Mines and Resources Canada, Ottawa*. Canada p. 307.

[11] Lotov V A, Tarbeev O G and Kutugin V A 2009 Preparation of concrete mixtures for the production of high-strength concrete. *Reports of the 3rd (XI) International Meeting on Chemistry and Cement Technology.* St. Petersburg: ALITinform, p. 141.

[12] Khamidulina D D, Garkavi M S 2006 Fine-grained concrete on the basis of sand from stone screening dust. *Materials of the 64th scientific conference on the results of scientific research for 2004-2005*. Magnitogorsk: GOU VPO "MSTU" pp. 39-42.

[13] Nguyen Viet Kyong, Chumakov L D 2009 Complex use of basalt aggregates in concrete *Scientific and technical journal "Vestnik MSSU"*, vol.**1** pp. 164-167.

[14] Fedosov S V, Akulova M V, Slizneva T E and Padokhin V A 2012 Fine-grained concrete on mechano-magneto-activated water with the addition of a superplasticizer *Bulletin of MGSU*. Vol. **5**. pp. 120-127.

[15] Yakovlev G I, Pervushin G N and Polyansky I S 2014 Concrete of increased durability in the production of power transmission towers *Construction Materials vol.* **5.** pp. 1-3.

[16] Berdichevsky G I, Vasiliev A P, Malinina L A *1989* Manufacture of precast concrete units. *Reference guide: Stroiizdat*. p.447.

[17] Kryuchkova I V 2006 Analysis of the regulatory and legal framework for regulating the market of secondary raw materials for construction. *Voronezh State Architectural and Construction University* p. 5.

[18] State Standard GOST 31424-2010. Non-metallic building materials from screening crushing of dense rocks in crushed stone production. Technical conditions.

[19] State Standard GOST 12730.4-78. Concretes. Methods for porosity determination.

[20] State Standard GOST 10060-2012. Concretes. Methods for frost resistance testing..