International Journal of Applied Engineering Research ISSN 0973-4562 Volume 10, Number 24 (2015) pp 45082-45090
© Research India Publications. http://www.ripublication.com

Using Ferruginous Quartzite Tailings In Dry Building Mixes

Svetlana V. Sverguzova, Irina V. Starostina, Galina I.Tarasova, Ekaterina V. Fomina
Belgorod State Technological University named after V.G. Shukhov,
Russia, 308012, Belgorod, Kostyukov Street, 46

Abstract- This paper presents the results of the study on the possibility of using ferruginous quartzite tailings (FQT) in dry building mixes in self-compacting compositions for floor construction. We have studied both physico-chemical and mechanical properties of FQT and quartz sand as the composite elements of dry building mixes. We have found that the FQT composition includes up to 72% of quartz and large amount of fine particles as compared with quartz sand. The morphology of the FQT particles is represented mainly by sharp-angled fragments with a rough surface, which in combination with high dispersion ensures a more dense packing of the material matrix with the increase in the average density of the solution. Active centers of a highly-developed roughened surface of refuse particles contribute to the absorption of plasticizer and the binder hydration intensification. Using FQT with the addition of the plasticizer "Linamiks PK" in the mortar mixes allows completely replacing the quartz sand with the technogenic refuse, which increases the mobility of the solution by 50% while maintaining the water demand. FQT-containing mortar mixes are characterized by high water-holding capacity, enhancement of raw mix mobility and the strength of hardened mortar by 18%, and fully comply with the requirements of the relevant GOSTs.

Keywords: ferruginous quartzite, tailings, refuses, disposal, dry building mixes, aggregates.

Introduction

Dry floor mixes are widely used in the construction of various purpose buildings. They are divided into roughing and finishing ones [1]. In the first case, the mortar is used to perform the screed. In such mixes, either cement or gypsum serve as binder. The use of modifiers ensures the formation of a flat surface upon pouring [2].

Dry mixes for floor construction should be characterized by the following properties according to GOST 31357-2007 [3]: a mortar mix, ready to use, should be highly mobile; self-leveling; the solidified mortar should have high values of strength and fracture toughness; characterized by high adhesion to the underlying layer without the need for surface sanding for subsequent application of a quick finish.

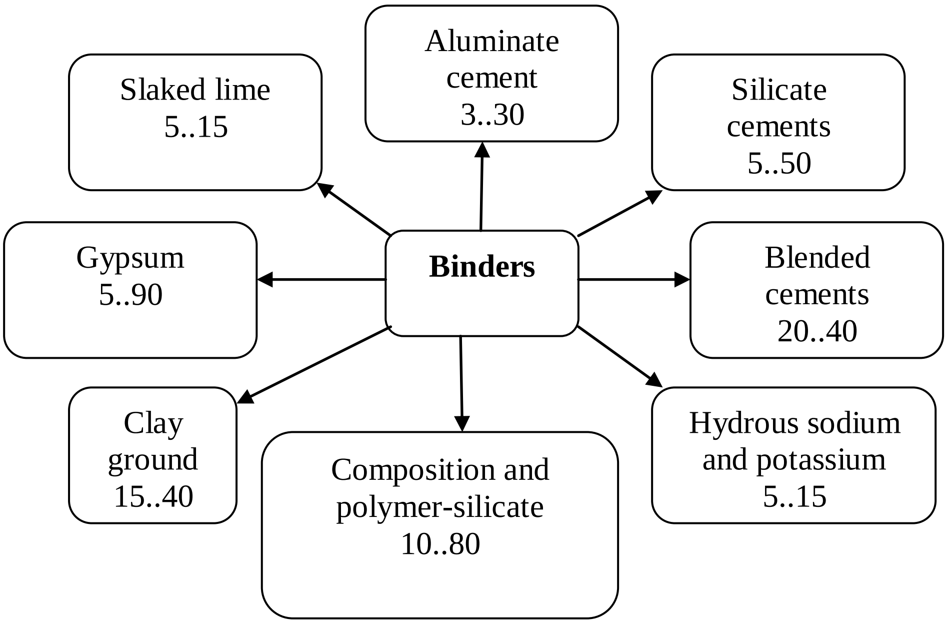
The largest size of the aggregate grains in floor mixes is determined by the floor covering layer thickness and should not exceed ¼ thereof.

Content of the largest grains shall be no more than 5% in concrete and mortar mixes and not more than 2.5% - in dispersed mixes.

The ready-to-use mix mobility is determined by:

- cone slump CS – for concrete sealing mixes;
- cone penetration CP - for mortar sealing mixes;
- ring spread RS - for dispersed self-compacting mixes.

According to the content of main components (binders, aggregates, fillers, and additives) and based on intended purpose, the compositions of dry mortar mixes are characterized by a wide range of concentrations of each components, % by weight (Fig. 1 and 2).



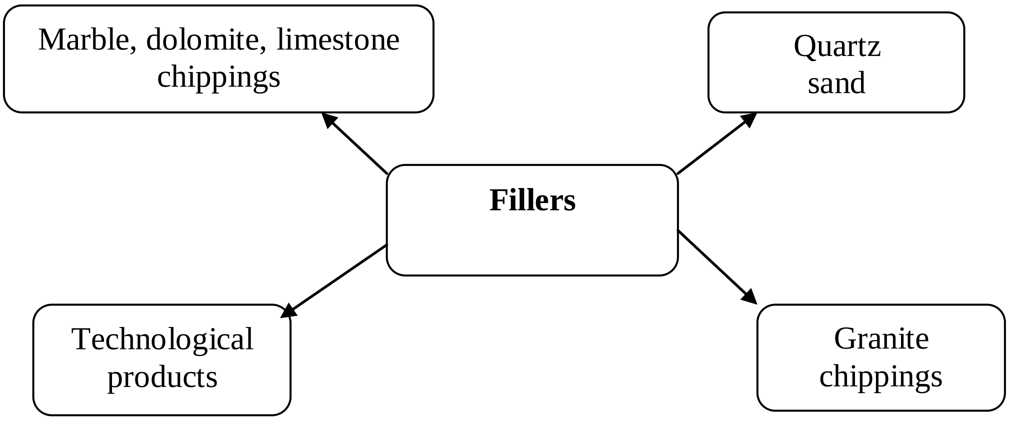


Fig. 2. Aggregates for dry flooring mixes (particle diameter > 0.16 mm)

Calcite (ground marble, limestone); dolomite powder, and quartz are used as a filler for dry building mixes [4-6]. Functional additives are plasticizers, water-retaining admixtures, accelerators and retarders, reinforcers (for fiber), etc.. The use of man-made products such as ash, slag, stone processing waste, etc. in dry building mixes is an important factor for increasing their effectiveness [7-9] and solving the environmental protection problems [10-13].

Methods

The granulometric composition of the raw material was determined by sieving with the use of a standard sieve set [14].

Basic physico-chemical and mechanical parameters of the studied materials were determined according to GOST 8736-93 [15], and standard methods for cement mortars [16].

X-ray diffraction analysis (XRDA) of the samples was conducted on a diffractometer DRON-4 with the use of Cu-anode radiation (Ni-filter for [beta]-component emission reduction) by the method of powder diffraction patterns. Diffraction patterns were identified in accordance with the ICDD catalogue (International Centrefor Diffraction Data (USA)) [17].

Thermal analysis (DTA) was performed by using the 3431 Q-1500 derivatograph and the STA 449 F1 simultaneous thermal analysis instrument.

Changes in the main quality indicators of the mixes were studied in accordance with GOST 31356-2007 [3]. Changes in the rheotechnological properties of the mortar mixes were studied in accordance with GOST 28013-98 [18].

The material microstructure was studied on the scanning electron microscope 3 TESCAN MIRA LMU (Poland).

Main part

The following materials were used in this study:

- Portland cement CEM I 42.5 N manufactured by CJSC "Belgorod cement" (Russia);
- quartz sand from Nizhneolshanskoe deposit, city of Belgorod (Russia);
- the refuse of Lebedinsky mining processing plant (LMPP) after iron ore processing - ferruginous quartzite tailings (FQT), city of Belgorod (Russia);
- "Linamiks PK" Polyplast plasticizer based on polyoxyethylene derivatives of polycarboxylic acids and polyethylene glycol.

Table 1. Chemical composition, %

Mineral	Fe_{total}	SiO_2	Al_2O_3	Fe_2O_3	FeO	CaO	MgO	S	P	CO_2	$Na_2O + K_2O$	other impurities percentage
FQT	10.24	71.27	2.53	8.55	7.22	2.62	4.32	0.16	0.18	3.63	1.66	1.49
Quartz sand	-	92.4	2.36	0.77	-	1.88	0.2	-	-	-	-	1.95

Based on FQT chemical composition, it includes up to 72% of quartz sand (Table 1), therefore we have proposed using it as a filler in self-compacting dispersed mixes. The FQT refuse represents a fine powder (Table 2), which is mainly composed of quartz sand (Fig. 3)

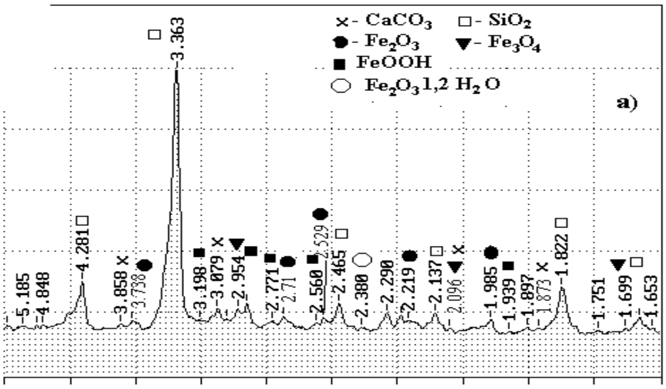


Fig. 3. FQT X-ray pattern

According to XRDA, the FQT mineralogical composition is mainly represented by SiO_2, as evidenced by the presence of corresponding peaks d(A) = 4.281; 3.357; 2.287; 2.241; 2.132; 1.983; 1.822; and 1.674. Reversible polymorphic transformations of quartz from [alfa] - to [beta]-modification are also confirmed by the results of XRDA, which is evidenced by endoeffect at 580°C. The refuse contains Fe_3O_4 d(A) = 2.95; 2.542; 2.092; 1.701, α-Fe_2O_3 d(A) = 2.698; 2.542; 2.209; and 1.857. According to the XRDA results, exothermic effect at 470°C corresponds to the transition of [gamma]-Fe_2O_3 into [alfa]-Fe_2O_3 , and at 650°C - transition into Fe_3O_4 [alfa] -Fe_2O_3. The refuse contains calcite as an impurity, which is confirmed by the presence of corresponding peaks with sufficient intensity d(A) = 3.909; 3.074; 2.505; 2.341; 1.951; and 1.882 (Fig. 3a).

According to the results of sieve analysis (Table 2), FQT contains 0.94% of particles larger than 1.4 mm, which meets the requirements of GOST 31358-2007 (less than 5% of the total weight).

Table 2. Grain size analysis of quartz-containing components, % weight

Fraction size, mm	>1.4	1–1.4	0.63–1.0	0.315–0.63	0.25–0.315	0.14–0.125	0.08–0.14	0.063–0.08	0.05–0.063	<0.05
FQT	0.94	0.82	3.09	16.71	1.99	21.14	24.34	24.7	5.63	0.64
Quartz sand	3.68	1.15	10.73	37.71	3.48	37.03	5.32	0.53	0.19	0.18

Comparison of FQT and quartz sand particle size shows that the amount of fractions with a particle size >0.25 mm in quartz sand is 2.63 times higher as compared with the amount of a similar fraction in FQT, while the amount of fine particles of 0.08 to 0.14 in FQT is 24.34%, and in quartz sand - 5.32%; the amount of fine particles of 0.063 to 0.08 in FQT is 24.7% and in quartz sand - 0.53%.

Some physico-chemical and mechanical properties of FQT and quartz sand are shown in Table 3.

Table 3. Physico-chemical and mechanical parameters of the studied materials

Material	Criteria				
	Bulk density, g/sm^3	Real density, g/sm^3	Loss on ignition	Fineness modulus	Water absorption
FQT	1260	2850	5.18	0.63	21
Quartz sand	1167	2630	1.04	1.12	7.5

As can be seen from the indicators show in Table 2, the FQT and quartz sand properties are similar, which allows suggesting that FQTs may be incorporated into the compositions of dry floor mixes provided partial or full replacement of silica sand. We should note that the FQT water demand is almost three times higher than of quartz.

Within this study, we prepared the compositions of cement-sand raw mixes at a cement-to-quartziferous component ratio of 1:2. Quartz sand-based composition was taken for control. During the experiment, we determined the main quality indicators of dry self-compacting mixes such as mortar mobility on the ring spread, maintenance of mobility, water-holding capacity, mix setting-up time, and water demand (Table 4).

Table 4. Composite binder main indicators

No.	Binder mixing ratio, %			Mortar mobility (ring spread), cm	Mobility maintenance, min	Water retention capacity, %	Setting-up time, min start/end	Water demand, %
	Cement	Quartz sand	FQT					
1	100	-	-	11.5	20	92	150/220	0.26
2	30	70	-	19.0	30	95	190/300	0.40
3	30		3.5	11.0	30	95	180/310	0.40
4	30		10.5	11.0	32	95	175/306	0.45
5	30	52.5	17.5	12.0	34	97	170/300	0.50
6	30		24.5	12.0	37	97	167/290	0.53
7	30		31.5	13.0	39	98	165/278	0.55
8	30	35	35	14.0	45	98	159/270	0.56
9	30	-	70	11.0	48	99	150/270	0.60
GOST requirements				18-22	No less than 30	No less than 95	-	-

High water demand of FQT in comparison with quartz sand affects the properties of the raw material binder mix. An increase of FQT ration in the mix composition increases its water demand; 100%

replacement of quartz sand for the refuse has increased it by 50%. Time of mix setting up with FQT slows down with an increasing water retention capacity of mixes, which complies with the requirements, subject to which it should be no less than 95%. However, according to the GOST requirements, the mobility of dispersed self-compacting mixes shall range 18-22 cm, which corresponds to Pk4 [3]. Mobility of FQT-based mixes decreases to 11-13 and is within the parameters of PK2.

High water demand of FQT is due to the specifics of the surface morphology.

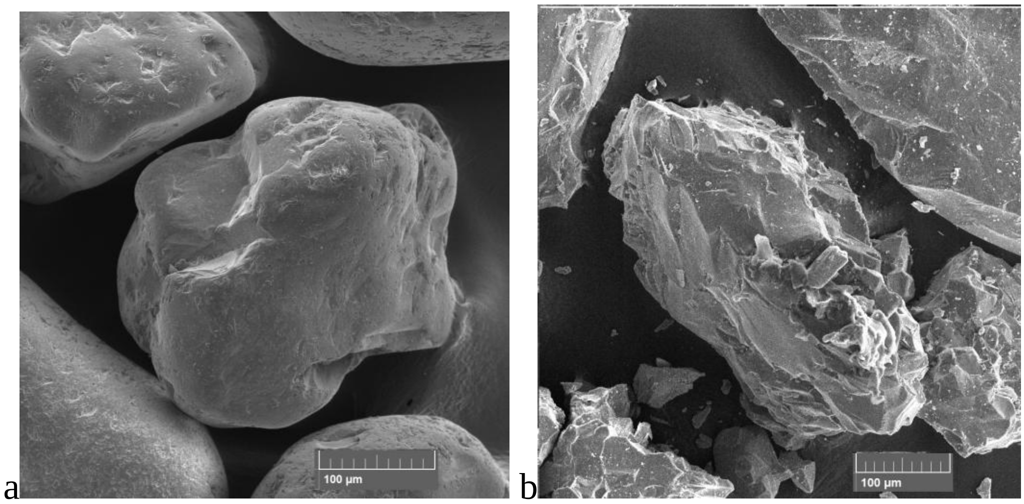


Fig. 4. Particles surface morphology: a - quartz sand, b - FQT

FQT refuse consists mainly of unrounded quartz particles represented by sharp-angled fragments with a rough surface, which, in combination with high dispersion of the particles, ensures high water-absorbing capacity of the refuse (Fig. 4).However, this morphology and particle size will contribute to a more dense compaction of the material matrix and increase the average density of the solution, which is an important factor for self-compacting dispersed mixes [7].

Based on the fact that the mix mortars should be highly mobile at low water demand to regulate the rheological properties of the FQT-based raw mixtures, we have used a liquid plasticizer "Linamiks PK". The amount of plasticizer was considered on a dry basis.

Rheological properties were assessed by the mobility of the cement suspensions with the use of mini-cone in accordance with a method developed by Concrete and Reinforced Concrete Research Institute (Fig. 5). The method involves measurement of the diameter of the cement suspension spread under gravity [16]. The measurements were taken after stirring the mortar for 3 minutes at a steady speed. The amount of mixing water was taken in accordance with normal consistency of the composite binder and corresponded to 0.4%.

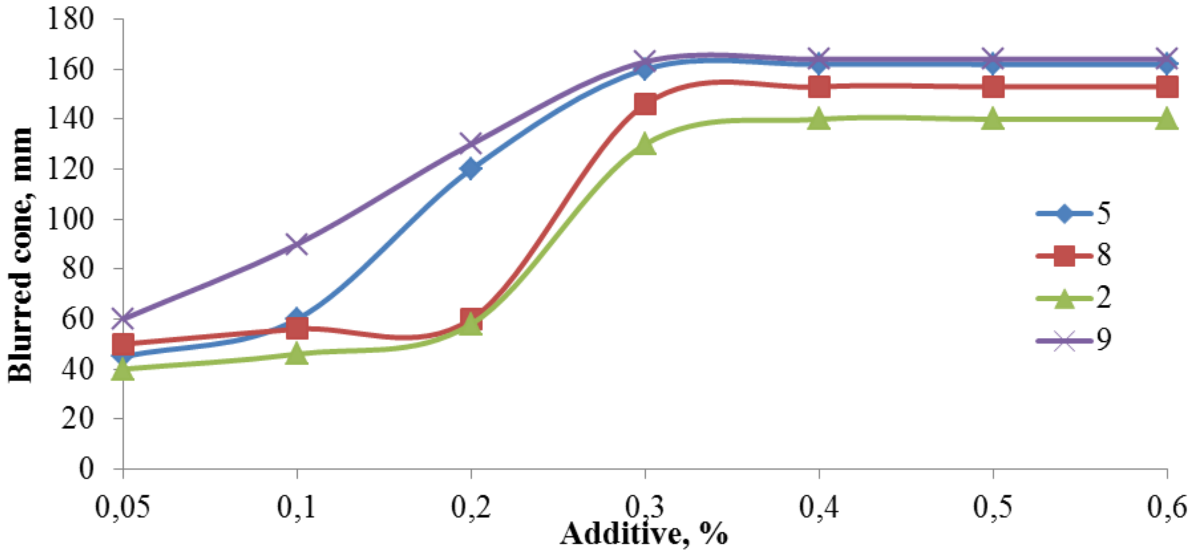


Fig. 5. Mortar mix cone spread based on the amount of plasticizer: composition numbers according to Table 4

A highly-developed rough surface of the refuse in combination with fine particles are the active centers of the plasticizer adsorption, which contribute to the water-repellent treatment of the solid phase and the increase in the system strength. Thus, the cone spread increases by 50% and remains the water demand of a mix already by both adding a plasticizer in the amount of 0.05% to the mix and fully replacing quartz sand with FQT. Maximum cone spread of compositions was at a plasticizer dose of 0.3%, while the mobility of the refuse-based composition (Fig. 5, composition 9) is 25% higher than the same composition with quartz sand (Fig. 5, composition 2).

The quality of the resulting raw mix was evaluated by the compressive strength on day 1, 7, and 28 (Fig. 6). Compositions 2 and 9 from Table 4 were compared with an optimum amount of plasticizer 0.3% added.

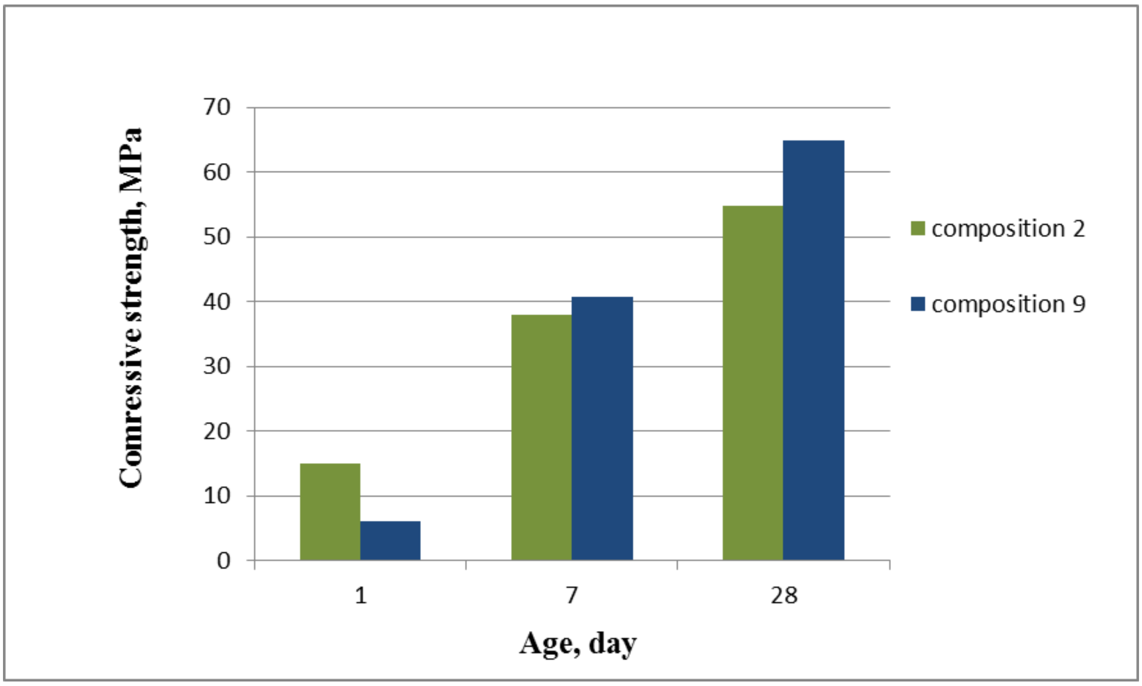


Fig. 6. Cement stone compressive strength variation

Analysis of the results shows the high quality of the developed FQT-based dry building mixes and mortars. The FQT-based mix compositions are characterized by improved physico-mechanical characteristics as compared with the similar mortars on quartz sand basis. We should note that the curing process of the one-day-old refuse-based cement stone is lengthy. This is due to the effect of plasticizer on the temporary blocking of C_3A hydration [1]. By day 3 of curing, there is an increase in the hydration degree of the cement stone with increased strength, which increases further by 18% at the age of 28 days in comparison with the control composition. The large number of structural defects on the surface of the refuse particles ensures acceleration and improvement of the interaction with the clinker minerals during the binder hydration and formation of a hydrosilicate newgrowth complex, which results in a denser and stronger cement stone.

Conclusion

We have found that the FQT composition includes up to 72% of quartz with predominant amount of fine particles of 0.063 to 0.08 µm. Comparison of the surface morphological characteristics has shown that the sand particles have smooth rounded shape, and the FQT particles are mainly represented by sharp-angled fragments with a rough surface, which ensures high water demand of the refuse and the binder raw mixes on its basis. Active centers of a highly-developed roughened surface of refuse particles contribute to the absorption of plasticizer with the increase in the cone spread by 50% as compared with quartz sand-based composition. Maximum plasticizing effect of binder raw mixes is achieved at replacing quartz sand with FQT and at a plasticizer dose of 0.3%. The large number of structural defects on the particles surface in combination with fine-grained components of the refuse intensifies the interaction with the clinker minerals during the binder hydration, which results in a denser and stronger cement stone with increase in strength by 18%.

Summary

In the course of this study, we have determined the main principles of FQT application in dry building mixes for self-leveling floors. We should note the efficiency of the complete replacement of quartz sand with the FQT refuse in the binder raw mix in combination with the plasticizing admixture "Linamiks PK”. FQT-containing mortar mixes are characterized by high water-holding capacity, enhancement of raw mix mobility and the strength of hardened mortar by 18%, and fully comply with the requirements of the relevant GOSTs. Using FQT in the compositions of dry building mixes and their building mortars will ensure complete replacement of quartz sand with the technogenic refuse, improve the quality of mortar mixes, which is comprehensively aimed at addressing the issues of resource saving and environmental pressure reduction.

Acknowledgement

The research was performed with financial support from the Russian Foundation for Basic Research and the Government of the Belgorod region in the framework of the research project. No. 14-41-08054 р_офи_м.

References

1. Korneev, V.I., P.V. Zozulya, 2010. Dry building mixtures (composition, properties). M.: REEF "building Materials", PP: 320.
2. Popova, T.K., 2015. D-5: high performance multifunctional additive to concrete, mortar and dry construction mixtures. Building materials, equipment, technologies of XXI century, 2 (193):16-17.

3. Russian standard 31356-2007 "dry building Mixtures with cement binder. Test methods"

4. Golik, V.I., S.G. Stradanchenko and S.A. Maslennikov, 2015. Experimental study of waste-free recycling of tailings ferruginous quartzite. Advanced materials, 7: 64-71

5. Loganina, V.I., L.V. Makarova, R.V. Tarasov and K.A. Sergeev, 2013. The choice of optimal parameters of technology of synthesis of filler for dry building mixtures. Bulletin of BSTU named after V.G. Shukhov, 1: 24-25.

6. Gorshkov, S.P., N.P. Nesmeyanov, 2013. A description of the process of changes in the concentration of key component in obtaining dry construction mixtures. Bulletin of BSTU named after V.G. Shukhov, 1: 45-48.

7. Lesovik, V.S., 2009. Improving the efficiency of production of construction materials with account of the Genesis of rocks: Scientific publication. Moscow: Publishing house ASV, pp: 526.

8. Gorshkov, S.P., N.P. Nesmeyanov, 2012. Integrated new ways to reduce energy costs in obtaining dry construction cement mixes. Bulletin of BSTU named after V.G. Shukhov, 2: 49.

9. Shapovalov, N.A, L.K Zagorodnyuk, I.V. Tikhonova, A.Y. Shchekina and A.V. Shkarin, 2013. Slags of metallurgical production – effective feedstock for production of dry construction mixtures. Fundamental research, 1-1: 167-172.

10. Sverguzova, S.V., V.S. Lesovik, J.A. Sverguzova and T.A. Vasilenko, 2006.The Ecological Condition of water resourses in Belgorod region. Evco-eco, Hannover: 30-31.

11. Bloom, D.E., 1995. International public opinion on the environment. Science, Vol. 269: 354-358.

12. Kristoferson, L., 1995. Enviromental security and cooperation in the Baltic Sea region: a review of some recent publications. Ecological security of the Baltic States, Nordic countries and North-West Russian: 12-19.

13. Swiderska-Broz, M. S., 2003. Wtórne zanieczyszczenie jej wody w systemie dy-strybucji. Microzanieczyszczenia czlowieka w środowisku: mat. Naukowy International conf. Częstochowa, Poland: 13-22

14. Russian standard 2093-82 "Fuel solid. Sieve method for determining the granulometric composition".

15. Russian standard 8736-93 "Sand for construction works".

16. Butt, Y.M., V.V. Timashev, 1973. Workshop on chemical technology of binding materials. Moscow: Higher school, PP: 504.

17. ASTM. Diffraction data cards and music from alphabetical and grouped numerical index of the X–ray Diffraction data. Philadelphia, 1969. PP: 863.

18. Russian standard 28013-98 "Mortars"