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Resource-saving potential of brick scrap from demolition of buildings

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Abstract. The composition and properties of crushing products of brick scrap of different sizes were studied. It is shown that a large (5–40 mm) and small (0.16–5.0 mm) fraction of brick scrap crushing products may be of interest for replacing natural aggregates, while a pulverized (0–0.16 mm) fraction has pozzolanic activity. The presence of cement masonry mortar in the composition of products for crushing scrap brick walls of buildings is the main obstacle to their use as a large aggregate for light concrete: the average density of crushed brick grains in this case was 890 kg/m^3, while for crushed cement grains – at least 1350 kg/m^3. With an increase in the degree of crushing of these wastes, their material composition and physical properties are averaged and therefore more suitable for reuse in construction, including as a fine aggregate for mortars.The chemical and mineral composition of brick scrap, studied on the example of a dusty fraction, allows us to predict its good prospects for replacing natural mineral raw materials in the production of firing materials, for example, Portland cement.

1. Introduction

The need for economical and careful attitude to natural resources is becoming more and more obvious. A particular concern of modern society is the depletion of non-renewable mineral resources, which are the raw material base of the most important sectors of material production, such as metallurgy, chemical industry of inorganic materials, construction and others. The importance of these problems, their specificity and possible solutions are reflected in UN documents as part of the Sustainable Development Agenda for the period until 2030 [1].

To ensure sustainable development, both social and technological innovations are developed and proposed, and the assessment of the sustainability of any material object is based on an assessment of its life cycle [2–7]. In a simplified form, the life cycle of an object consists of the following stages: design, manufacture, operation, and disposal (burial).On each of them, in one way or another, the object interacts with the environment, ‘consumes and/or allocates’ material and energy resources. It is obvious that from the point of view of preserving non-renewable natural raw materials, it is necessary to ensure the closed, ‘cyclical’ nature of the existence of products, regardless of their purpose.

Among the most material-intensive industries, metallurgy seems to have achieved the greatest success in product recycling [8,9]. The situation is much worse with the recycling of waste from the construction industry, which includes the production of building materials. According to various

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sources, about 20 million tons of construction and demolition waste is generated annually in the Russian Federation, and their utilization rate does not exceed 10–20 %. Publications by Yu M Bazhenov, M O Korovkin, V S Lesovik, S-A Yu Murtazayev and other authors indicate that there is a certain domestic experience in the processing and utilization of concrete scrap, while the use of construction scrap from the demolition of brick buildings has been studied worse.

The purpose of this work is to study the composition and properties of the products of crushing brick scrap of different sizes and determine the possible directions of their return to the construction industry to replace natural mineral raw materials.

2. Initial materials and research methods characteristic

For research, crushed scrap of wall structures from the demolition of a building built in the 60s of the 20th century (Yekaterinburg, Sverdlovsk region) was used. The maximum size of fragments is up to 150 mm (Figure 1).

Figure 1. Appearance of crushed scrap of wall structures.

The content of cement mortar in this sample was quite high – at least 30 % of the total mass of the brick scrap (usually, according to literature data, 10–15 %). So, 3 samples (types) of material was subjected to additional crushing: brick scrap in the natural state (BS), pre-selected fragments of ceramic brick (CB) and fragments of cement mortar (CM). After crushing, the resulting products were sieved on sieves and 3 fractions were isolated: particles with a grain size from 5 to 40 mm (large aggregate), from 0.16 to 5 mm (fine aggregate) and less than 0.16 mm (pulverized, or dust, fraction).

The study of the properties of granular materials was carried out in accordance with the requirements of regulatory documents: GOST 8267–93 'Crushed stone and gravel of solid rocks for construction works. Specifications'; GOST 32496–2013 'Fillers porous for light concrete. Specifications'; GOST 32021–2012 'Hard rock aggregates and fillers for production dry building mixes. Specifications'; GOST 8736–2014 'Sand for construction works. Specifications'.

Physical and mechanical parameters of the BS dust fraction were determined in accordance with GOST 30744–2001, a chemical composition – according to GOST 5382–91 'Cements and materials for cement production'. Chemical analysis methods, and its mineral composition was studied by x-ray-graphic method on a MiniFlex 600 diffractometer (Cuka-radiation, λ=1.541862 Å, survey interval – 3.00–90.00) 'Rigaku-Carl Zeiss' (Japan).

The pozzolan activity of the BS dust fraction was determined by the method [10].

3. Experiment results and discussion

The average grain density of crushed material is an important characteristic, since it determines whether it can be used as a filler in heavy or light concretes. According to GOST 8267–93, the grain density of aggregates intended for heavy concrete must be between 2000 and 3000 kg/m^3. In this case, the CM grains correspond to the required density, but the density of CB fragments, and therefore of all crushed BS, is less, therefore they are not suitable for heavy concrete and road construction (Table 1).

Table 1. Comparative characteristics of the components of crushed brick scrap.

Property	Brick scrap	Ceramic brick	Cement mortar	GOST 32496–2013 requirements
Bulk density, kg/m^3	940	890	1350	100–1200
Average grain density, kg/m^3	–	1800	2000	not rated
Fraction (grain size), mm	10–20	10–20	10–20	5–10 10–20 20–40
Mass loss during calcination, %	5.10	0,70	11.72	3

Analysis of the BS bulk density and its comparison with the requirements of GOST 32496–2013 shows that crushed brick scrap is suitable as a large aggregate for the production of light concrete (Figure 2). Its bulk density is comparable to such a porous artificial aggregate as agglоporite crushed stone (400–900 kg/m^3).

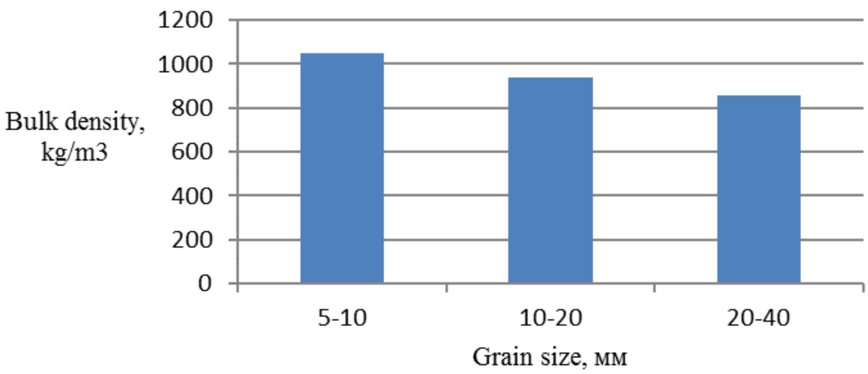

Figure 2. Bulk density of crushed brick scrap of different fractions

At the same time, the investigated batch of BS, due to the significant content of CM, does not meet the regulatory requirements for mass loss during calcination (Table 1). The compression strength in the BS cylinder (0.10–0.25 MPa) and its frost resistance (mass loss after 15 cycles of freezing and thawing was 12%, and no more than 8% is allowed) also do not meet the requirements of GOST 32496–2013. Therefore, the possibility of using crushed brick scrap as a large aggregate in light concrete can not be excluded, but in each case, additional research will be required.

Tests of the fine-grained BS fraction (0.16–5.00 mm) have shown that it meets the regulatory requirements (Table 2).

As for the powdery fraction of crushed BS, its output depends on the conditions and the number of crushing cycles of concrete scrap. According to the results of our research, it is from 3 to 20 %. The specific surface area of the dust was 300 m^2/kg. The chemical composition of the dust fraction, %: 53.68 SiO2; 21.72 CaO; 10.88 Al2O3; 7.17 F2O3; 6.28 loss of heat; 0,27 etc. X-ray-graphic analysis showed that the dust contains crystalline phases: the highest intensity among them is characterized by quartz reflections (4.25; 3.35; 2.45; 2.29). The presence of calcite cannot be excluded (3.85; 3.03; 2.45), tobermorite (3.05; 2.78; 1.82), anorthite, and other phases.

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Table2. Fine aggregate characteristics.

Property	BS	GOST 32021–2012 requirements
Bulk density, kg/m^3	1400	1300–1600
Real density, kg/m^3	2510	2 000–28000
The fineness modulus	2.5	1.5–2.5
Grain content of lamellar (bream) and needle-shaped grains, %	19	15–35

The chemical and mineral composition of the dust obtained as a result of BS crushing seems to correspond to the average composition of BS. This suggests that such a material has prospects for use as a raw material component in the production of firing construction composites and Portland cement. There is a well-known experience of producing clinker and cement using crushed concrete waste [11].

It was found that the test sample of the dusty fraction has pozzolanic activity: the dough made from lime (80 %) and the test powder (20 %) when stored in air-wet conditions solidified after 72 hours (allowed for later than 7 days) [10]. Therefore, such an additive can be used as part of construction composites for partial replacement of Portland cement.

4. Conclusion

When choosing the optimal ways to dispose of brick scrap, you should take into account the heterogeneity of its composition due to the presence of cement mortar, the amount of which can be from 10 to 30 %. For this reason, the use of large fraction crushing products (particle size greater than 5 mm) in the form of crushed stone in the composition of concretes is unlikely. At the same time, the fine fraction (0.16–5.00 mm), due to its higher uniformity, can be successfully used to replace natural sand in construction composites after checking its compliance with the requirements of regulatory documents.

The dust formed when crushing brick scrap has pozzolanic activity, therefore, it can be used as part of construction composites for partial replacement of Portland cement.

The chemical and mineral composition of brick scrap (the total content of silicon and aluminum oxides is not less than 60%), studied on the example of a dusty fraction, allows us to predict its good prospects for replacing natural mineral raw materials in the production of firing materials, for example, Portland cement.

Thus, several resource-saving areas for using brick scrap from building demolition can be distinguished: for replacing crushed rocks, which act as aggregates in concrete and mortars, instead of siliceous rocks such as diatomite as a pozzolanic additive, as well as for partial replacement of clays and marls in high temperature synthesis technologies, for example, in Portland cement technology.

References

[1] Sustainable Development Goals Fund 2016. Goal 12: Responsible consumption and production. *United Nations Development Programme.* Available online: https://www.un.org/sustainabledevelopment/ru/sustainable-consumption-production/ (accessed on 01.06.2020)

[2] Leismann K, Schmitt M, Rohn H and Baedeker C 2013 Collaborative consumption: Towards a resource-saving consumption culture. *Resources* **2 (3)** pp 184–203

[3] Cook M 2004 *Understanding the potential opportunities provided by service-orientated concepts to improve resource productivity.* Tracy Bhamra; Bernard Hon (eds.). Design and Manufacture for Sustainable Development (John Wiley and Sons) p 125

[4] Vezzoli C, Ceschin F, Osanjo L, M'Rithaa M K M, Moalosi R, Nakazibwe V and Diehl J C 2018 Sustainable Product-Service System (S.PSS). *Designing Sustainable Energy for All. Green Energy and Technology*. (Springer, Cham)

[5] Robèrt K H, Schmidt-Bleek B, Aloisi De Larderel J, Basile G, Jansen J L, Kuehr R and Wackernagel M 2002 Strategic sustainable development - Selection, design and synergies of applied tools *J. of Cleaner Production* **10** (3) pp 197–214 https://doi.org/10.1016/S0959-6526(01)00061-010

[6] Frischknecht R, Jungbluth N, Althaus H J, Doka G, Dones R, Heck T and Spielmann M 2005 The ecoinvent database: Overview and methodological framework. *International Journal of Life Cycle Assessment.* https://doi.org/10.1065/lca2004.10.181.1

[7] Ortiz O, Castells F and Sonnemann G 2009 Sustainability in the construction industry: A review of recent developments based on LCA. *Construction and Building Materials* **23** pp 28–39 https://doi.org/10.1016/j.conbuildmat.2007.11.012

[8] Smirnov V V 2018 Recycling is a strategic direction for improving the efficiency of metallurgy in the Russian Federation *Accounting. Analysis. Audit* **5 (4)** pp 30–9 Available online: https://cyberleninka.ru/article/n/retsikling-strategicheskoe-napravlenie-povysheniya-effektivnosti-metallurgii-v-rossiyskoy-federatsii (accessed on 01.06.2020)

[9] Matinde E, Simate G S and Ndlovu S 2018 Mining and metallurgical wastes: a review of recycling and re-use practices. *J. S. Afr. Inst. Min. Metall.* vol. **118** no. **8**

[10] Butt Y M and Timashev V V 1973 *Practice on chemical technology of binding materials* [In Russian] (Moscow: Higher school Press) p 504

[11] Isore L 2018 Production of clinker and cement using crushed concrete waste *J. Cement and its application* **2** pp 50–3