Application of man-induced raw material resources as a way to solve ecological problems

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Abstract. The article deals with the issue of man-made resources utilization in the form of ceramic crushed bricks and production fault with fine and big fillers for small objects production from the ceramic-concrete. This wasteless technology of wall materials production allows saving the environment. There is a peculiarity of preparing forming ceramic-concrete compositions as well as in structures of these compositions. There are formulas of light-weight concretes based on ceramic brick filler and parameters necessary for quality and durable small-piece materials. Such characteristics as density, thermal conductivity, cold resisting property and compression strength have been studied as exactly these characteristics are under special attention. Developed compositions of light ceramic-concretes had rather low thermal conductivity within 0.49–0.98 W/(m·K), ceramic-concrete type by cold resisting property was within F50 to F100 limits, density changed from 1300-1700 kg/m³, compression strength was 41 MPa. Using crushed bricks in light concretes allows reducing the cost by 30–35.

1. Introduction
Nowadays there are a lot of ecological problems in the world, so issues of rational use and effective conservation of natural resources are rather acute for the high standards of living in every country. It is necessary to note that resource saving of the natural potential means introduction of wasteless and low waste technologies, based on the secondary use of raw material resources, that allows supporting environmental safety [1, 2, 5, 8].

A construction industry has an important role in resource- and power-saving, as it efficiently uses man-made (secondary) raw material which does not require spending on search and pit development, processing and transportation from other regions. These cheap man-made resources are buildings' and structures’ demolition wastes, production faults as crushed bricks, in order to receive secondary filler big and fine. The issue arises what is the amount of these waste, as statistics [3, 4, 6, 9, 10] shows, annually our country cumulates more than 22 mln tons of the man-produced construction wastes, 60 % of this resource is ceramic crushed bricks and concrete (fig. 1).

2. Problem statement
The article gives results of studies on production of light ceramic-concretes with the use of secondary filler in the form of ceramic crushed brick (CCB) and production fault bricks (PFB). Ceramic concrete is used for wall materials production, so it must have low density and thermal conductivity, cold resisting...
property and compression strength to 30 MPa. In the compositions under study special attention is given to porous filler, as ceramics nature, grain-size composition and properties influence strength parameters of the concrete brick.

![Figure 1. Emergency removal of brick buildings](image1)

The composition of the light concrete was done by the special methodology, as ceramic filler demands a lot of water and influences structure and strength formation of the ceramic-concrete. In the composition under study there are hard, liquid and gaseous stages, and mixing water is redistributed among them in a specific way and changes technological and rheological characteristics of a formation concrete mix. While preparing forming mixture, added mixing water is instantly absorbed by the ceramic brick filler, fine and big, that promotes formation of the primary capillar-porous structured joint. But in some time, absorbed water in its pores and micro flows gradually release water into the hardening, getting strength concrete system, as a result rather hard structure of the concrete brick is forming [7, 11, 14, 18].

3. Materials and methods
The forming concrete mixture had the components ratio given on figure 2a, the fine filler from ceramic crushed brick had Abram’s fineness module 2.5 and fractional composition shown in figure 2b. In some compositions natural silica sand of Chervlensk origin was used. It refers to the class of fine ones with Abram’s fineness modulus 1.8.

![Figure 2. The ratio between concrete mixture components (a) and a fracture composition of the fine filler from crushed brick (b)](image2)
Superplasticizing admixtures GP-9 with the dosage 1.5 % from the binding component and C-3 in the amount 2 % from the binding were used while studying the influence of plasticizers on the technological parameters of the ceramic-concrete mixture. Portland cement without additives CEM I 42.5 Н from SUE “Chechencement” was used as a main binding component. Its characteristics correspond to GOST 31108-2003.

Formulas and properties of samples from light ceramic-concrete are in table 1 and figure 2.

| № | Composition | Materials expenditure, kg for 1 m$^3$ | W/C | Concrete density, kg/m$^3$ | $R_{28\text{compression}}$, MPa | Thermal conductivity, Вт/(м·°С) | Cold resisters property |
|---|-------------|--------------------------------------|-----|-----------------------------|-------------------------------|-------------------------------|------------------------|
| 1 | Common light ceramic concrete | C 240 CCB 820 S 540 W 290 GP 9 - | 1.10 | 1674 | 11.4 | 0.48 | 50 |
| 2 |  | 330 745 520 299 - - 0.93 1703 | 20.9 | 0.52 | 50 |
| 3 |  | 315 790 560 230 6.2 0.75 1735 | 24.7 | 0.53 | 50 |
| 4 |  | 315 800 530 238 4.7 0.78 1744 | 24.5 | 0.53 | 50 |
| 5 |  | 405 755 500 230 8.0 0.59 1757 | 35.9 | 0.52 | 75 |
| 6 |  | 405 745 115 225 8.0 - 0.57 1835 | 41.1 | 0.97 | 100 |
| 7 | Coarse pored light ceramic concrete | 255 975 - 282 - - 1.1 1312 | 7.3 | 0.35 | 25 |
| 8 |  | 410 915 - 285 - - 0.80 1397 | 17.3 | 0.38 | 25 |
| 9 |  | 405 952 - 266 8.0 - 0.66 1415 | 18.9 | 0.36 | 35 |

Note: composition 6 is a mixture of two kinds of sands (115 kg is CCB sand, and 400 kg is dense silica sand of Chervlensk origin).

4. Results discussion

By the results we can notice that there is dependence between the density of the light ceramic concrete and the density of the cement rock itself. It is necessary to take into account the amount of the mortar stage is only 40–44 % from the volume of the whole composite [12, 13, 16–19]. Cement component is present in greater amount in the space between pores, cavities, caves whose sizes are in millimeters. We can see that in composition 7 minimal parameter is in thermal conductivity, and the most expensive
component – cement – is minimal, the weight decreases significantly, thus, coarse-pored ceramic concrete can be used for non-constructional walling products.

In the coarse pored concretes there is a deficit of the binding component, the structure is more porous, cement covers the filler surface in a thin layer, and inter-grain space is almost not filled. As the result there are latent closed cavities and pores, which reduce thermal conductivity.

The study of the thermal conductivity of the light concretes with the use of ceramic brick filler was conducted with specially prepared samples 250x250x30 mm in size (figure 3) with the apparatus for determining thermal conductivity ITP-MG4.

In the formulas of light ceramic concretes with the use of fine ceramic artificial sand the thermal conductivity parameters change within 0.48–0.97 Wt/(м·°C), and if compared with the common heavy concrete, whose thermal conductivity is 1.5–1.87 Wt/(м·°C), it proves the efficiency of the suggested developments. Sample test for cold-resisting property, showed that the studied compositions are characterized by the type of cold resisting property from F50 to F100.

It is necessary to note that the best cold resisting property parameter is in type 6 – F100 type, there was natural silica sand in this composition, and may be it improved the cold resisting property. It is important to note that the presence of dense silica sand (400 kg) had a negative influence on thermal conductivity and density of the sand.

Better values in thermal conductivity are in coarse pore light ceramic concretes within 0.35–0.38 Wt/(м·°C), the density lowers till 1310–1410 kg/m³, but a big amount of open pores and cavities has a negative influence on the cold resistant property.

In the compositions of the light concrete, the attention is paid to secondary ceramic brick filler, that is why adhesion of the mortar phase with the porous filler is a determining factor. It is especially important because having high values of strength characteristics in the contact zone, there will be a better, unloaded condition of the matrix binding system, and it will function as a whole, increasing the strength of the composite. To receive higher adhesion strength concretes of big fillers from hard and strong rocks are used. The combination of these fillers with the concrete matrix will mutually compensate depleted strength characteristics of every stage – mortar phase or filler, which will provide significant strengthening of the composite, due to unloading of the matrix system and high filler characteristics. In this case the concrete will have a “reinforcing effect” of the composite with the filler from the inside.

Studying the destruction mechanism of the samples of the projected light concrete (fig. 4) we can note that in the compression test, the cube destructed along the filler, and not in the zone of contact of the cement rock with the ceramic filler. It evidences that the adhesion strength of the filler with the cement rock and the mortar part are significantly higher, than the strength of the filler from the crushed brick itself.
Energy dispersive microanalysis of the studied light ceramic concrete sample (composition 5), with an electronic microscope Quanta 3D 200 i with the integrated system of microanalysis Genesis Apex 2 EDS from EDAX showed the following microphotos at scaling by 1000, 2500, 5000 times and the chemical composition given in table 2. The results prove dense structure, the contact zone is nearly invisible (fig. 5). In the zone of contact there are evenly distributed all structural oxides.

It has been determined [1,3,7,8,19] that the parameter of the adhesion strength in the contact zone “cement rock – filler” and composite strength in general are greatly influenced by the nature and properties of the filler. The following factors influence the concrete strength:
1. Form and surface roughness of the filler grain, its purity;
2. Chemical and mineralogical filler composition;
3. Strength parameters of the cement rock;
4. Chemical and mineral additives which improve adhesion strength;
5. Microdefects in the structure at the contact zone;
6. Water content of the concrete to the testing moment.

Table 2. Oxide composition in the contact zone of the mortar binding part and the filler from CCB

| Oxides | Values at every part |
|--------|----------------------|
|        | 1   | 2    | 3    |
| Na₂O   | 2.55 | 0.72 | 0.62 |
| MgO    | 2.44 | 0.87 | 1.48 |
| Al₂O₃  | 8.34 | 11.33| 8.85 |
| SiO₂   | 27.33| 27.09| 28.18|
| SO₃    | 4.06 | 2.77 | 5.25 |
| K₂O    | 0.57 | 0.57 | 1.29 |
| CaO    | 51.68| 51.85| 44.57|
| TiO₂   | 0.25 | 0.26 | 0.41 |
| Fe₂O₃  | 2.79 | 4.54 | 9.35 |

5. Conclusion
The following conclusions can be drawn:
- The properties of crushed bricks after building demolishing in the form of CCB have been studied;
- Man-made secondary fillers for the formulas of light and coarse pored ceramic concretes have been suggested;
- The formulas of light ceramic concretes with the use of CCB as fine and big fillers have been developed;
- The processes of structure formation and strength development as well as the properties of light ceramic concretes have been suggested.

It has been determined that using secondary man-made raw material is a topical issue for our region and for the whole world, as the ecological issue and ways of resource and power saving are acute nowadays.

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