Wastes recycling in the construction

S-A Yu Murtazaev¹², Z Kh Ismailova², M Sh Salamanova¹² and S Kh Ibragimov²

¹Kh. Ibragimov Complex Institute of the Russian Academy of Sciences, 21a, Starpromyslovskoe shosse, Grozny, 366002, Russia
²State petroleum technological university in Grozny named after M. D. Millionshikov, 30, Kadyrov street, Grozny, 364021, Russia

E-mail: madina_salamanova@mail.ru

Abstract. For many years fuel and energy and ore-dressing industries have been the sources of industrial waste which, if treated correctly, can be reused as secondary raw material resources accumulating earlier wasted investments and power costs. The article introduces possible ways of recycling both in our country and abroad. Basing on this, ways of reusing man-produced wastes in Grozny as bottom ash waste and chippings from rock crushing into spalls have been described. Study results showed that secondary man-produced raw material can compete with and substitute non-renewable natural resources as their chemical composition and quality parameters prove their unique nature, also it is possible to take into account solution of ecological problems. Developed formulas of multi-component bindings based on finely dispersed fly-ash and concretes with the use of enriched artificial aggregates promoted recycling of secondary raw materials and improving ecological situation in the region.

1. Introduction
Our country has a rich natural resource potential, but despite the variety and abundance of resources the issue of their rational use and effective preservation is acute. To support environmental safety and balance in nature it is necessary to reuse natural raw materials [1, 2].

Statistics showed that to receive various industrial goods about 1/3 of extracted raw material resources is used, and 2/3 are coproducts and waste [3], which results in ecological disbalance, and pollution of valuable lands.

That is why, waste reuse as a full value raw material base allows solving many economic tasks, such as saving natural resources, preventing water, soil, air pollution, increasing productivity and inventing new composite materials [3, 4, 9, 10].

European countries have high results in it. For example, the Netherlands have 100% of material recycling. Besides, that country has a sustained ecological tendency of improving construction industry based on introduction of continuous non-waste industry with recycling man-made raw material (fig. 1) [6, 7, 15–18].

2. Problem statement
Nowadays, there is a lot of fundamental research [3, 8, 4, 11], allowing utilization of slurry, cinder and ashy waste, wastes of ore-dressing and processing enterprises, refinery waste and so on for the production of nearly all construction materials (fig. 2).
Figure 1. Formation and recycling of secondary resources in European countries [2]

Figure 2. Industrial wastes used in construction material production

Basic list of construction materials received from industrial wastes is as follows: Portland cement clinker, Portland cement with mineral admixtures, blast furnace cement, slag alkali cementing materials,
mixed cement free bindings, aggregates for concrete, slag cotton; slag-glass ceramic, autoclave hardening bindings; nepheline cement; materials for soil stabilization, castable, heat insulating materials and so on.

Thus, industrial waste management in combination with local raw material resources is perspective and profitable in construction material production, in particular, in developing multi component bindings and concrete on their basis.

In the Chechen Republic nowadays there are large accumulations of man-made wastes from fuel and energy industry in the form of bottom ash waste which take huge areas of hundreds hectares of valuable land plots and pollute the environment of the region (fig. 3). At the regional plants of nonmetallic construction materials up to 350 thousand m$^3$ of waste accumulate as stone dust, stone crumbs, and stone milling chippings. Huge areas of valuable lands are used to store the waste, though they could be used for agriculture, but to transport and store the waste significant means from the production work are used [4, 5, 9].

![Figure 3. Industrial waste: a) bottom ash waste; b) crushed stone chippings](image)

### 3. Materials and methods

The work presents results of long term study of bottom ash waste properties and rock crashing waste for further use in developing high quality multi component bindings and concretes on their basis. In tests Portland cement SUE “Chechncement” CEM I 42.5 H, was used as a main binding component which has constant chemical and mineralogical compositions. Its basic characteristics are in table 1, chemical analysis in % by mass: SiO$_2$ = 17.45; Al$_2$O$_3$ = 3.88; Fe$_2$O$_3$ = 3.72; MgO = 1.12; CaO = 71.56; SO$_3$ = 0.76; TiO$_2$ = 0.33; K$_2$O = 1.07; Na$_2$O = 0.11.

![Table 1. Basic cement properties](image)

| Manufacturing plant and kind | Specific area m$^2$/kg | Nytroxilene, % | Density kg/m$^3$ | Time of set, hour – min | Supporting pressure, MPa, 28 days and nights |
|-----------------------------|------------------------|----------------|------------------|-------------------------|-------------------------------------------|
| “Chechncement”              | 330                    | 25             | 3100             | 2-15                    | 52.6                                      |
| CEM I 42.5 H                |                        |                |                  | 3-40                    | 6.2                                       |
For production of multi component binding bottom ash waste was used which meets the requirements of AUSS 25818-91 “Fly ash of heat power plants for concretes. Technical requirements”. The main components of bottom ash waste are ashy microspheres which have such properties as: low density, adequate strength, ideal spherical form, high adhesion with polymer materials, high water hermiticity, low heat loss [6, 9–12].

Studying ashy microspheres from TPP in Grozny with a scanning electronic microscope (fig. 4) showed that they are finely-dispersed particles of grey color, spherical and shiny smooth surface. Also, some unevenness of different structure and size has been determined, covered porous shells in some microspheres have been determined.

Chemical composition of ashy microspheres in % by mass: MgO = 1.49; Al₂O₃ = 23.89; SiO₂ = 62.88; K₂O = 0.48; CaO = 1.7; Fe₂O₃ = 7.95; TiO₂ = 0.11; SO₃ = 0.06; ignition loss = 0.9.

Further, formulas of multi component bindings (table. 2) have been developed which were produced by combined 30 minutes grinding of Portland cement, bottom ash waste and dry super plasticizing admixture Polyplast SP-1. Specific area dependence of the received binding filled with bottom ash waste on the length of grinding and strength development of the new cements is given in figures 5, 6.

![Microphoto of ashy microspheres of bottom ash waste from TPP in Grozny](image)

**Figure 4.** Microphoto of ashy microspheres of bottom ash waste from TPP in Grozny

![Dependence of the surface area of multicomponent bindings on the length of grinding MCB](image)

**Figure 5.** Dependence of the surface area of multicomponent bindings on the length of grinding MCB

![Strength development of multicomponent bindings](image)

**Figure 6.** Strength development of multicomponent bindings
Table 2. Formulas of multicomponent bindings

| №  | Compositions | Activation method | Symbolic designation | Binding components content, % |
|----|--------------|-------------------|----------------------|-------------------------------|
| 2  | 85           | Combined vibroactivation during 30 minutes | MCB-90               | PC 89 Ash microspheres 10 CR-1 1.0 |
| 3  | 85           |                    | MCB-85               | PC 84 Ash microspheres 15 CR-1 1.0 |
| 4  | 75           |                    | MCB-75               | PC 74 Ash microspheres 25 CR-1 1.0 |

4. Results discussion
The results showed that the surface area of the bindings under study increases smoothly with longer period of grinding, but it is necessary to take into account that MCB-75 has the highest granulation factor, possibly it is caused by the character of ash microspheres which are softer than those of Portland clinker [1, 3]. Activity of multicomponent bindings is one of the most important parameters for receiving hard and durable composites.

Compositions of bindings MCB-75 and MCB-85 demonstrated good results which prove that ash microspheres combined with a plasticizing agent promoted full hydration of clinker minerals, moreover, active components of the bottom ash are additional source of the additional hydrated calcium silicate [1, 3].

There is no medium and big natural sand in the republic and application of fine sand results in excess expenditure of cementing components and increase of water demand for the concrete mixture. That is why, to enrich them crush wastes of gravel-sand rocks from Argunsk occurrence, such as chippings were used [4, 5, 9]. Visual survey of the chipping grains showed that these products have sharply angular form and contoured surface of the particles, and grains mostly have fractions of 2.5–1.25 mm and particles less 0.16 mm, that provides better binding in the contact zone of artificial sands with the cementing component and improves the concrete strength. As for the cost, the filler from by-passed stone is much cheaper (up to 6–10 times) than natural sands and their application decreases the prime cost of 1 m³ concrete by 10% [1, 6].

Taking that into account, to receive better filler we combined fine sand of Chervlensk occurrence Mchipings = 1.7 and waste chippings of the gravel crushing into spall from Argunsk open pit Mchipings = 3.8 at the ration 1:1 (it was determined experimentally).

To receive the high quality concrete the cubiform crushed stone from the granitic-diabasic rock from Alagirs occurrence with fractions mixture 5–10 mm and 10–20 mm in the ration 70:30, spalls strength M1200 have been used. Superplasticizing admix Glenium, whose action is caused by the combination of electrostatic and spatial effect, achieved by lateral water repelling molecule chains of polycarboxylate ester was used for mixture plasticization and improving concrete characteristics [4, 18].

Table 3 shows experimental compositions and basic characteristics of high quality concrete with the suggested multicomponent binding MCB-75, fortified finely grained filler based on by-passed stone chippings and the superplasticizing admix Glenium.

Table 3. Compositions and characteristics of high-strength concrete

| no. | Expenditure, kg per 1m³ | MCB-75 | FFF | S | W | Chipp/cement additive | water absorption, % | concrete density, kg/m³ | Concrete compression strength at days, MPa |
|-----|-------------------------|--------|-----|---|---|-----------------------|---------------------|------------------------|------------------------------------------|
| 1   | 480                     | 870    | 880 | 168 | 0.35 | 1.3                   | 3.7                 | 2320                   | 33.1                                     | 42.4                                      |
| 2   | 480                     | 870    | 840 | 168 | 0.35 | 1.3                   | 3.5                 | 2350                   | 49.6                                     | 65.2                                      |
| 3   | 460                     | 840    | 870 | 161 | 0.35 | 1.6                   | 2.8                 | 2390                   | 46.1                                     | 63.9                                      |
| 4   | 500                     | 860    | 870 | 175 | 0.35 | 1.4                   | 2.1                 | 2380                   | 50.9                                     | 66.7                                      |
| 5   | 520                     | 840    | 900 | 182 | 0.35 | 1.8                   | 2                   | 2400                   | 53.2                                     | 71.9                                      |

**Note:** FFF is fractional fine filler: mixture of fine sand from Chervlensk occurrence Mchipings = 1.7 and crush waste chippings from Argunsk open pit Mchipings = 3.8 in the ratio 1:1; S – spalls; W – water
Basing on the results of the experiment it can be noted that complex use of the components: ashy microspheres, finely fractionated filler with sharply angular form and contour surface of chipping screening grains, providing better binding with the cement rock and superplasticizing admix. Glenium promotes structure and strength formation of high-quality concretes.

5. Conclusion

Thus, basing on the use of multicomponent bindings from ash microspheres and fractioned fillers made from rock processing wastes formulas of highly strong concretes with better physico-mechanical properties have been suggested. The results prove practicability of industrial waste utilization, which helps to free valuable lands used for industrial waste storage.

References

[1] Murtazaev S-A U and Salamanova M SH 2015 High strength concrete with graded aggregate from rock processing waste Sustainable development of mountain territories 1(23) 23–8
[2] Hillemeier B, Buchenau G, Herr R, Huttel R, Klubendorf St and Schubert K 2006 Spezialbetone, Betonkalender 1 534–49 (Ernst & Sohn)
[3] Murtazaev S-A U, Salamanova M SH, Bisultanov R G and Murtazaeva T-S A 2016 High-Quality Modified Concretes with the Use of a Binder on the Basis of a Reaction-Active Mineral Component Construction mater. 8 74–80
[4] Zhang S, Lu D and Xu Z 2015 Effect of dolomite powders on the hydration and strength properties of mortar Proc. XIV Int. Cong. on the Chemistry of cement (Beijing, China) 320 p
[5] Nocun-Wczelik W, Szybilski M and Zugaj E 2015 Hydration of Portland cement with Dolomite Proc. XIV Int. Cong. on the Chemistry of cement (Beijing, China) 320 p
[6] Tironi A, Scian A N and Irassar E F 2015 Hydration of ternary cements elaborated with limestone filler and calcined kaolinitic clay Proc. XIV Int. Cong. on the Chemistry of cement (Beijing, China) 320 p
[7] Lukutcova N, Postnikova O, Nikolaenko A, Macaenko A and Tuzhikova M 2014 The improved environmental safety of decorative and fine-grained concrete on the basis of the use of technogenic glauconitic sands Building and reconstruction 1(51) 79–84
[8] Udodov S, Chernykh V F and Chernyi D V 2008 Application of porous filler in finishing compounds for foamed concrete Dry construction mixtures 3 70
[9] Nesvetaev G, Koryanova Y and Zhitnikova T 2018 On effect of superplasticizers and mineral additives on shrinkage of hardened cement paste and concrete MATEC Web of Conf. vol 27 “27th R-S-P Seminar, Theoretical Foundation of Civil Engineering (27RSP), TFoCE 2018” p 04018
[10] Stelmakh S A, Nazhuev M P, Shcherban E M, Yanovskaya A V and Cherpakov A V 2018 Selection of the composition for centrifuged concrete, types of centrifuges and compaction modes of concrete mixtures Physics and Mechanics of New Materials and Their Applications (PHENMA 2018) Abstracts & Schedule, ed by Yun-Hae Kim, I A Parinov and S-H Chang 337
[11] Soldatov A A, Sariev I V, Zhavorov M A and Abduraimova M A 2016 Construction materials based on liquid glass Topical issues of construction, transport, machine-building and technosphere safety Mat. of IV Annual sci.-pract. conf. in North-Caucasus federal university, ed in chief N I Stoyanov pp 192–5
[12] Jeknavorian A, Roberts L, Jardine L et al 1997 Condensed Polyacrilic Acid-Aminated Polyether Polymers as Superplasticizers for concrete Proc. Fifth CANMET//ACI Int. Conf. (Rome, Italy) pp 173–4
[13] Ohta A, Sugiyama T and Tanaka Y 1997 Fluidizing Mechanism and application of Polycarboxylate-Based Superplasticizers Proc. Fifth CANMET//ACI Int. Conf. (Rome, Italy) pp 173–19
[14] Dosho Y 2007 Development of a Sustainable Concrete Waste Recycling System “Application of Recycled Aggregate Concrete Produced by Aggregate Replacing Method” J. of Advanced
Yanagibashi K, Yonezawa T, Iwashimizu T, Tsuji D, Arakawa K and Yamada M 2004 A new recycling process for coarse aggregate to be used concrete structure Environment-Conscious Materials and Systems for Sustainable Development. Proc. of RILEM Int. Symp. (Tokyo) pp 137–43

Lesovik V S, Alfimova N I and Trunov P V 2014 Reduction of energy consumption in manufacturing the fine ground cement Res. J. of Appl. Sci. 9(11) 745–8

Lesovik V S, Zagorodnyuk L K, Mestnikov A E, Kudinova A I and Sumskoi D A 2015 Designing of mortar compositions on the basis of dry mixes Int. J. of Appl. Engineer. Res. 10(5) 12383–90

Bataev D K-S, Uzaeva A A, Uzaeva S A, Uzaev M A and Tuzurkaeva T A 2018 The Study of Shrinking Deformations of Repair Compositions on Barkhan Sands Int. Symp. on Engineering and Earth Sci. (ISEES 2018) Advances in Engineer. Res. vol 177 pp 254–7