ENVIRONMENTAL SAFETY OF CONSTRUCTION AND MUNICIPAL SERVICES

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INDUSTRIAL WASTES AND ENVIRONMENTAL SAFETY OF CONSTRUCTION AND MUNICIPAL SERVICES

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Statement of the problem. One of the important directions of solving problems to ensure ecological safety of construction and municipal development is environment-friendly energy and sustainable technologies for the production of building materials with the inclusion in the composition of their raw mixtures of various waste industry.
Results. The opportunities for management strength characteristics of composite stone slag-alkaline binder by introducing minerals are discussed. Resource and energy saving without additives and composite slag-alkaline binders, mortars and concretes based on blast furnace slag, alkali mortars and mineral supplements — waste industry are obtained. The nature of the effect of additives claydite dust and blast-furnace slags of various compositions and fineness of the complex with lime and superplasticizers on the properties of plaster, the introduction of which allows one to obtain a waterproof artificial stone with more dense and fine-grained structure comparing with an initial binder without additives is identified.
Conclusions. Competitive with conventional Portland cement in price and quality quality of composite slag-alkaline binders and water resistant, clinker-free composite gypsum binders containing from 20 to 50 % of anthropogenic raw material have been developed.

Keywords: composite slag-alkaline binder, granulated blast-furnace slag, claydite dust, composite gypsum binders, artificial stone.

Introduction

A prominent French natural scientist of the late 18th and the early 19th century Jean-Baptiste Lamarck can be quoted as saying “A humankind is probably here to destroy themselves and make the Earth an impossible place to live in the process”.

In 1972 in a report in the Club of Rome an American cybernetician D. Meadows (International Association for Modern Global Problems) concluded that a current rate of the economic growth and development will lead to humankind dying out in 2100. A likelihood of that happening is significantly due to industrial development and recycling of contaminants.

The humankind striving to engage in a number of industrial activities for millennia resulting in the contamination of the biosphere has led to a number of worldwide problems [1—2]:

– 50 tones of wastes per capita annually;

– raw material wastes of up to 97—99 %;

– increasing smog levels in large cities where 50% of the world's population live;

– 150 mln. tones of solid substance are emitted annually;

– global warming resulting in devastating natural disasters.

Russia's industries largely contribute to toxic and corrosion substances as well as gas products. Presently, there are the following dumped and stored:

– mining wastes account for over 80 billion tones with 3.7 billion tones adding to the number annually; up to 2 % of the recycled mass are dust wastes;

– ash and slag waste of thermal power plants and heat and power plants contributing over 1.2 billion tones with 100 mln. tones adding to the number annually;

– ferrous and non-ferrous metallurgy wastes contribute over 600 million tones with 0.4 – 0.65 tones of wastes for a ton of steel, up to 15 tones for nickel, up to 30 tones for copper;

– toxic wastes account for about 1.5 million tones with 150 million tones contributing to the number.

All the mining and processing industries emit aerosols and gas products, waste water, chemicals leading to growing disease as well as failure of building structures as a result of severe corrosion.

Urban industrial activities contribute varying amounts of dust, smoke black, carbon monoxide, lead, etc. Industrial sewage waters entering urban drainage systems contain different combinations of these:

– mineral and organic suspensions;

– dissolved inorganic substances, i.e. chlorides, sulphates, cyanides, copper, chrome, lead, cadmium, etc.;

– dissolved organic substances, i.e. surfactant species, phenols, oil products.

Industrial wastes emitted into the environment were one of the reasons why as few as 19% out of 1037 cities are not facing any major environmental issues.

The analysis of consequences of increasing human impact on the environment at the end of the 20th century gave rise to an idea of the civilization. In 1992 during the Rio Summit the "Agenda 21" was made public according to which relentless scientific and technological advances give way to sustainable development. Resource and energy saving and environmental protection were at the heart of this action plan [3].

Addressing these issues would involve the use of industrial wastes in the production of construction materials as their extraction and production are more cost-efficient compared to other industries and large amounts of them can be recycled. Therefore wastes might not burden the environment but in contrast benefit it and help tackle environmental uncertainty, resource and energy saving.

Due to these, scientific investigation of resource and energy-saving wastes including the use of contaminants and toxic wastes as well as safe production technologies for construction materials is crucial to environmental safety of construction and cities.

The authors of this paper have been conducting a comprehensive study of the development of safe resource and energy-saving construction materials using different industrial wastes as their raw components [4—12]. Below are some of the results of a relevant study.

1. Developing resource and energy-saving additive-free and composite slag lime binders, solutions and concretes using blast-furnace slag, lime sealers and mineral additives (industrial wastes)

The authors investigated the production of additive-free slag lime binders, slag lime composite binders, solutions and concretes using them with blast-furnace slag of particular metallurgical plants.

The major constituents of slag lime composite binders were a neutral slag of Orsk-Khalilovsk Metallurgical Plant and two oxide slags of Magnitogorsk and Chelyabinsk Metallurgical Plants.

The chemical composition of the slag of Orsk-Khalilovsk Metallurgical Plant (in mass percentages) was SiO_2 — 40.02; CaO — 42.02; Al_2O_3 — 8.22; MgO — 6.26; K_2O+N_2O — 0.66+0.44; MnO — 0.34; SO_3 — 1.45. The lime factor is M_l — 1.0; the activity factor is M_a — 0.205; the quality coefficient is K_q — 1.4.

The chemical composition of the slag of Magnitogorsk Metallurgical Plant (in mass percentages) was SiO_2 — 36.63; CaO — 38.24; Al_2O_3 — 13.49; MgO — 7.31; K_2O+N_2O — 0.76+1.04; MnO — 0.16; SO_3 — 1.09. The lime factor is M_l — 0.9; the activity factor is M_a — 0.368; the quality coefficient is K_q — 1.57.

The chemical composition of the slag of Chelyabinsk Metallurgical Plant (in mass percentages) was SiO_2 — 37.49; CaO — 36.22; Al_2O_3 — 12.86; MgO — 8.61; K_2O+N_2O — 1.59; MnO — 0.50; SO_3 — 2.00. The lime factor is M_l — 0.91; the activity factor is M_a — 0.309; the quality coefficient is K_q — 1.43.

The mineral composition of the slags is represented by an akermanite mineral, i.e. 8—10 % of helenite (Orsk-Khalilovsk Metallurgical Plant), 11 % (Magnitogorsk Metallurgical Plant), 3—5 % (Chelyabinsk Metallurgical Plant), the rest is X-ray amorphous phase.

Let us consider the obtained results for the development of resource and energy-saving additive-free slag lime binders, slag lime composite binders, solutions and concretes using blast-furnace slag, lime sealers and mineral additives (industrial wastes) [5—10].

The authors have studied potentials of a mineral matrix of slag-lime binders that will improve in dispersion of the slag constituent in the range of 300—900 m^2/kg. Slag grinding from 300 to 600 m^2/kg was found to significantly influence the strength of slag-lime binders, solutions and concretes using them and to have no significant impact on the selection rate. Subsequent grinding of slag with 600 to 900 m^2/kg enhances extra strength potentials following 3 days of hardening with the strength rates followed by the strength rates of an artificial stone using slag-lime binders considerably slowing down.

The specific surface limit of ground slag was found to be 600—700 m^2/kg when slag lime binder stones, solutions and concretes using them have the greatest density and smallest water absorption strength compared to those with the specific surface of 300 m^2/kg. An increase in the mark strength of slag lime binder solutions is M400—M500 using soda, M700—M1000 (slag of Chelyabinsk Metallurgical Plant) and M800—M1100 (slag of Orsk-Khalilovsk Metallurgical Plant) using liquid glass, for slag lime binder concretes M300—M500 (using soda), M600—M900 (slag of Chelyabinsk Metallurgical Plant) and M700—M1000 (slag of Orsk-Khalilovsk Metallurgical Plant) using liquid glass. However, an increase in the specific surface of the slag from 300 to 600—700 m^2/kg causes a reduction in freeze resistance and water resistance of slag lime binder concrete in the total range from F600-800 to F400-500, W20-25 to W10-15.

In the conditions of standard humid hardening the introduction of slag lime composite binders of the following additives:

– of 30-50% of mass percentage of oxide fly ash ground till its specific surface 200 m^2/kg results in an equally strong binder compared to an additive-free one and adding 30 % of fly ash with the specific surface 500—800 m^2/kg allows a 30—60 % increase in the strength of a binder;

– of up to 50% of mass percentage of molding sand waste ground till 500—800 m^2/kg keeps the strength of slag lime composite binders the same as that of an additive-free binder;

– of 3—7 % of mass percentage of microsilica allows a 27—105 % increase in the strength of slag lime composite binders depending on a slag and hardening conditions.

– of 28—33 % of mass percentage of ground ceramic brick improves the strength of slag lime composite binders by 20—40 % depending on a slag, a lime sealer and hardening conditions.

Compositions of standard, quickly and particularly quickly hardening slag lime concretes were obtained using hardening activators with carbonate and sodium silicate with the additives of ground ceramic brick, microsilica, cement stone, cement solution from the strength label M300 to M1100C, freeze resistance from F300 to F800 and water resistance W10—W15.

2. Results of developing composite plaster binders with ground industrial mineral wastes and materials using them

A follow-up was the development of environment-friendly resource and energy-saving composite plasters with lime, ground expanded clay dust and blast-furnace slags of different plants [11—12]. We made use of a construction plaster G-6CP produced by Ltd. "Arakchino Plaster". Let us look at the results.

Introducing of up to 20—30 % of different expanded clay dust additives and specific surface of 250—800 m^2/kg caused no significant reduction in the strength (from 16.2 to 14.3—11.8 MPa) and softening coefficient (from 0.35 to 0.31—0.23) of artificial stone plaster, which allowed the use of plaster expanded clay binders along with additive-free construction plaster of the original label.

The compression strength of composite plaster binder stone ranges from 13.5—17.3 MPa depending on the composition, dispersion and the percentage of expanded clay dust additive as well as that of lime, while the softening coefficient goes up to 0.67. The highest strength and water resistance with 20 % of mass percentage of expanded clay dust additive ground to 500 m^2/kg and 5% of mass percentage of lime.

Depending on the content of additives of different superplasticizers, the compressive strength and softening coefficient of artificial stone using composite plaster lime expanded clay binder with 20% of mass percentage of different expanded clay dust and dispersion of 500 m^2/kg increases from 17.3 MPa to 19.0—25.3 MPa and from 0.67 to 0.68—0.78 respectively. The introduction of additives of 0.5—1.0 % superplasticizers *Melment F*15*G* and "Polyplast SP-1" results in the best performance of the artificial stone.

The compression strength and relative linear deformation of the artificial stone using a composite plaster lime expanded clay binder in the range of 0.15—0.22 % remains almost the same with the samples being in dry-air, standard-humid and humid conditions for up to a year.

Plaster lime expanded clay slag binders with a binary mineral additive containing 20 % of expanded clay dust and 30 % of blast-furnace slag with the dispersion of 500 m^2/kg result in obtaining an artificial stone with the compression strength of up to 27.5—30.2 MPa and softening coefficient of up to 0.81—0.96 depending on a slag. For an artificial stone using plaster lime expanded clay slag binder there is a 2.86 reduction in water absorption, 34.4 % decrease in the overall strength and 14.2% in the amount of open pores.

The developed plaster lime expanded clay slag binders in terms of their physical and mechanical properties can be used in the production of a wide range of construction materials and structures as well as those operated in humid conditions. Solutions and concretes using composite plaster binders with 30 % of mass percentage of ground expanded clay dust and up to 60 % of its combination with ground blast-furnace slag were developed outperforming its industrial counterparts in terms of operation, technology and economy.

Conclusions

1. Energy and resource-saving composite slag lime and plaster binders and construction materials using them with ground industrial wastes: blast-furnace slag, fly ash, molding sand wastes, microsilica, ground expanded clay brick, expanded clay dust, cement stone and cement solution have been produced for the first time.
2. The results of the study are expected to give rise to scientific investigation and development of resource and energy-saving materials and technologies for environmental safety of construction and cities.

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