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Granular materials based on expanded sands and their production waste

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ABSTRACT

The article presents the results of studies of granular materials obtained by non-firing technology. For the formation of granules, composite cement and magnesia binders containing waste products of expanded perlite and expanded clay are proposed. Mechanical activation of composite binders intensifies the processes of hydration and structure formation, contributes to increasing the strength of materials. The combination of a binder with a filler in the form of waste from the production of porous aggregates ensures a decrease in the density of the binder, the formation of a finely dispersed porous structure of the composite material, the formation of stable hydrates. The porous structure of the granules is provided by the use of porous sand to form the core of the granules. Studies of the structure of granules by electron microscopy revealed that the reliable adhesion of particles of porous sand with a composite binder stone provides high strength of porous granular materials. Cement granules based on expanded perlite sand are characterized by a density of 300 – 400 kg/m^3 and a compressive strength of 1.8 – 2.6 MPa. Magnesia granules based on expanded clay sand have a density of 450 – 500 kg/m^3 and compressive strength of 3.5 – 5.7 MPa. The work is aimed at creating effective building materials using resource-saving technology, at the rational use of production waste.

Keywords: granular material, expanded perlite, expanded clay sand, composite binders, porous structure.

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Introduction

To ensure energy efficiency of construction, we need materials that provide not only the required bearing capacity of structures, but also have heat-shielding properties. These materials include lightweight concrete. Lightweight concretes are characterized by low density, the values of which, as a rule, do not exceed 2000 kg/m^3. Main physical and mechanical properties of lightweight concrete are due to a highly developed porous structure, which is formed using foam and gas formers (cellular concrete) or due to porous aggregates.

Lightweight concretes based on porous aggregates, compared to cellular concretes, have increased strength, lower shrinkage and creep, which expand the scope of their application [[1], [2], [3], [4], [5]]. The structure of lightweight concretes based on porous aggregates is mainly controlled by the aggregate. Porous aggregates have been used since ancient times in the form of volcanic rocks. Modern porous aggregates are artificial materials made with a variety of raw materials and manufacturing processes. The characteristics of lightweight aggregates vary widely.

In modern technology of lightweight concretes, expanded clay is the most common. Optimization of technological process ensures expanded clay gravel production with a bulk density of 350 – 600 kg/m^3; expanded clay concrete is characterized by a density of 600 – 1200 kg/m^3 and strength of 2 – 12 MPa [[6], [7], [8], [9], [10], [11], [12]]. Possibilities for further improvement of expanded clay technology are often limited by the state of raw material base [[13], [14], [15]].

Among the promising porous aggregates is expanded perlite, which is used to produce lightweight concrete with a density of 450 – 900 kg/m^3 [[16], [17], [18], [19]]. Expanded perlite is distributed mainly in regions where aggregates are produced. When producing porous aggregates, waste is generated at various stages of technological process; chemical and disperse composition of which depends on the conditions of formation. The problem of rational use of such waste remains relevant.

Along with porous firing concrete aggregates, granular materials which are made without the use of high-temperature technological processes have become widespread [[20], [21]]. Unfired porous aggregates favorably differ in reduced cost due to exclusion of an energy-intensive process. Non-firing porous aggregates are obtained by hardening granular raw mixtures, which include a binder and components that provide pores formation. The variety of components of the raw mix provides extensive raw material base for granular materials production. The growth of requirements for construction and technical properties of lightweight concretes necessitates the improvement of porous aggregates technology and expansion of the raw material base due to available sources.

The purpose of the work is to study influence of material composition of the raw mixture on formation and properties of unfired granules.

Experimental part

To obtain granulated materials, raw mixtures consisting of a composite binder and porous particles were used. Composite binders were prepared on the basis of Portland cement and production wastes of expanded perlite sand, caustic magnesite and expanded clay production wastes. Expanded perlite sand (cement mixes) and expanded clay sand (magnesia mixes) served as porous particles for granulated raw mixes.

The main characteristics of Portland cement CEM I 42.5N (GOST 31108 – 2016): specific surface 330 ± 10 m^2/kg, initial setting time is 1 hour and 40 minutes, time of final setting is 3 hours, activity is 26 MPa at the age of 2 days.

Caustic magnesite PMK – 75 brand contains 75 – 80% of MgO, is characterized by specific surface of 300 ± 10 m^2/kg, initial setting time is 25 minutes, time of final setting is 2 hours 10 minutes, compressive strength at the age of 2 days is 34 MPa, at the age of 28 days – 52 MPa.

Expanded perlite production waste is a dispersed material with an average particle size of 0.1 - 1.2 mm («Oskolsnab» JSC, Stary Oskol) Chemical composition of waste, wt. %: SiO_2 – 75; Al_2O_3 – 12.5; Fe_2O_3 – 0.7; CaO – 1.6; MgO – 0.6; (K_2O + Na_2O) – 4.6; others – 5.0.

Wastes of expanded clay production are mainly represented by particles of 0.2 – 1.0 mm (Ust-Kamenogorsk expanded clay plant). Chemical composition of waste, wt.%: SiO_2 – 67.5; Al_2O_3 – 10.8; Fe_2O_3 – 5.7; CaO – 5.4; MgO – 2.3; (K_2O + Na_2O) – 4.5; others – 3.8.

Expanded perlite sand is a granular material with a particle size of up to 5 mm, obtained by thermal treatment of crushed perlite, a volcanic rock. The bulk density of expanded perlite sand is 75 – 500 kg/m^3. In this work, expanded perlite sand with a fraction of 0.16 – 1.25 mm and a bulk density of 200 ± 10 kg/m^3 was used.

Expanded clay sand is a granular mass of particles 0-5 mm in size, obtained by crushing Keramzite grains. Bulk density is 500 – 650 kg/m^3. In the experiments, particles of expanded clay sand with a fraction of 0.16 – 1.25 mm with a bulk density of 510 ± 10 kg/m^3 were used.

Composite binders were being obtained by mechanical activation of a mixture of the original binder with waste products after porous filler production in «E-max» activator mill during 30 minutes. The specific surface area of the binders was evaluated using a photosedimentometer.

Water (cement mixtures) and magnesium chloride solution with a density of 1230 kg/m^3 (magnesia mixtures) were used to mix the molding masses.

Granules were molded on a drum-type laboratory unit. Rotation of the metal drum ensured pelletization of raw mixtures loaded into the unit. Presence of a restrictive mechanism prevented materials from sticking to the walls of the drum. The method of granules forming as follows: particles of porous sand with a part of mixing agent were placed in a pre-installed unit; then the composite binder was poured. After 2 minutes of rotation of the drum unit, the remaining amount of mixing agent and composite binder was added. Rotation of the granulating unit for 10 min ensured the formation of a dense shell on the surface of granules.

Raw mixture granulation includes the processes of wet rolling of a composite binder onto porous sand grains until raw pellets are formed.

Adjusting the duration allows you to get spherical granules with a size of 5 – 15 mm.

The mode of hardening of raw granules was settled taking into account the nature of binders hardening. Cement granules hardened in the air-humid environment, magnesia granules in air,

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Қопсыған құмдар және олардың өндіру қалдықтарының негізінде алынған түйіршіктелген материалдар

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ТҮЙІНДЕМЕ

Мақалада күйдірілмейтін технология бойынша алынған түйіршіктелген материалдарды зерттеу нәтижелері келтірілген. Түйіршіктерді қалыптастыру үшін құрамында қопсыған перлит пен керамзит өндірісінің қалдықтары бар композициялық цементті және магнезиалды тұтқыр заттар ұсынылады. Композициялық тұтқыр заттардың механикалық белсендірілуі гидратация және құрылымды қалыптастыру процестерін күшейтеді, материалдардың беріктігін арттыруға көмектеседі. Кеуекті агрегаттар өндірісінің қалдықтары түріндегі тұтқыр заттың толтырғышпен бірігуі тұтқыр заттың тығыздығының төмендеуін, композициялық материалдың ұсақ дисперсті кеуекті құрылымының қалыптасуын және тұрақты гидраттардың пайда болуын қамтамасыз етеді. Түйіршіктердің кеуекті құрылымы түйіршіктердің ядросын қалыптастыратын кеуекті құмды қолдану арқылы қамтамасыз етіледі. Түйіршіктердің құрылымын электронды микроскопия әдісімен зерттеу арқылы кеуекті құм бөлшектерінің композициялық байланыстырғышының таспен берік тұтасуы кеуекті түйіршікті материалдардың жоғары беріктігін қамтамасыз ететіндігін анықталды. Қопсыған перлит құмына негізделген цемент түйіршіктерінің тығыздығы 300 – 400 кг/м^3 және сығылу күші 1,8 – 2,6 МПа болады. Керамзит құмына негізделген магнезия түйіршіктерінің тығыздығы 450 – 500 кг/м^3 және беріктігі 3,5–5,7 МПа құрайды. Бұл жұмыс ресурс үнемдейтін технологияны пайдалана отырып, тиімді құрылыс материалдарын жасауға, өндіріс қалдықтарын ұтымды пайдалануға бағытталған.

Түйін сөздер: түйіршікті материал, қопсыған перлит, керамзит құмы, композициялық тұтқыр зат, кеуекті құрылым.

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Гранулированные материалы на основе вспученных песков и отходов их производства

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АННОТАЦИЯ

В статье приведены результаты исследований гранулированных материалов, полученных по безобжиговой технологии. Для формирования гранул предложены композиционные цементные и магнезиальные вяжущие вещества, содержащие отходы производства вспученного перлита и керамзита. Механическая активация композиционных вяжущих интенсифицирует процессы гидратации и структурообразования, способствует повышению прочности материалов. Сочетание вяжущего с наполнителем в виде отходов производства пористых заполнителей обеспечивает

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снижение плотности вяжущего, формирование мелкодисперсной пористой структуры композиционного материала, образование устойчивых гидратов. Пористая структура гранул обеспечивается использованием поризованного песка для образования ядра гранул. Исследованиями строения гранул методом электронной микроскопии выявлено, что надежное сцепление частиц поризованного песка с камнем композиционного вяжущего обеспечивает высокую прочность пористых гранулированных материалов. Цементные гранулы на основе вспученного перлитового песка характеризуются плотностью 300 – 400 кг/м^3 и прочностью при сжатии 1,8 – 2,6 МПа. Магнезиальные гранулы на основе керамзитового песка имеют плотность 450 – 500 кг/м^3 и прочность при сжатии 3,5 – 5,7 МПа. Работа направлена на создание эффективных строительных материалов по ресурсосберегающей технологии, на рациональное использование отходов производства.

Ключевые слова: гранулированный материал, вспученный перлит, керамзитовый песок, композиционные вяжущие, пористая структура.

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