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Satbayev University

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ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН
Satbayev University

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FORMATION OF STRENGTH AND PHASES OF SEQUENCE OF DESTRUCTION OF ARBOLITE COMPOSITES AT VARIOUS LONG LOADS

Annotation. The article discusses the study of the strength and deformation characteristics of sulfur-containing arbolite composites using secondary resources, which is relevant in regions with a hot and sharply continental climate. This is one of the lightest building materials with low thermal conductivity and good sound insulation ability. The aim of this study is to determine the mechanism of strength formation and the destruction of sulfur-containing arbolite composites under various long-term loads and to substantiate the effectiveness of their use in housing construction. The methodological basis of the study was the current provisions of the theory and practice of creating, developing high-strength concrete concrete based on composite sulfur-containing binders. When conducting scientific research, standard measuring instruments and methods for analyzing the physicomechanical characteristics of arbolite composites obtained using modern methods of X-ray diffraction, differential thermal, microscopic analysis and testing equipment were used.

The properties of sulfur-containing arbolite samples were studied at 7, 28, and 90 days old under various conditions and loads. The study of the effect of the resulting deformations on the compression strength of the sulfur-containing arbolyte was based on certain models of concrete structure. The sulfur-containing arbolyte was considered as a two-component system consisting of a fibre of crushed cane and a sulfur-containing solute component, the strength of the solute being variable. Four series of samples from sulfur-containing arbolyte were produced for the study, and a fifth series, for comparison, from sulfur-containing ceramic concrete. Each series consisted of six samples of prisms measuring 150x150x600 mm, three of which (model I) consisted only of a sulfur-containing solute (sulfur-to-pyrite fire ratio of 1:3), and in three other prisms (model II), milled cane fibers of about 18-20 mm diameter were placed in the middle. The prism samples were tested in stages corresponding to a voltage increment of 0.1 to 0.15 MPa, after each load stage the samples were held for five minutes. Readings by indicators (with measurement accuracy of 0.01mm) were taken after application of each load stage and before application of new load. Such a test technique allowed extracting elastic instantaneous deformations and determining the value of the initial modulus of elasticity of sulfur-containing light concrete.

It was established that the destruction of sulfur-containing arbolite occurs sequentially, first the destruction of the solution component occurs, and then the organic aggregate. The results can be used in the manufacture of effective wall material for civil buildings, including seismic areas.

Key words: Sulfur-containing arbolite composites, strength, hardening phase, long-term load, deformation modulus, mortar component, fracture.

Introduction. Due to the rapid development of the construction industry and the expansion of industrial and civil construction in the regions of Kazakhstan, the demand for building materials and structures is increasing every day, which is the creation of structural and heat-insulating materials using secondary resources. Arbolite concrete occupies a special place in the production of building materials in regions with a hot climate, which combines lightness, environmental friendliness, high heat-insulating qualities and may contain plant agricultural waste, which is rich in steppe regions. Also in the regions of Kazakhstan there are also huge raw materials in the form of large-tonnage industrial wastes, their disposal as part of building materials is the first decision of the national economy. However, the increased requirements for the quality of arbolite pose a task to further increase its construction and operational, technological and strength indicators. The aim of the study is the development of highly effective concrete concrete based on composite sulfur-containing binders, the development of scientific foundations for the formation of their structure, composition and properties when used as wall material for housing construction. To achieve the goal, the influence of additives of sulfur-containing waste from the petrochemical industry on the structure formation and physicochemical properties of composite binders, the influence of their main components on the physicomechanical properties of sulfur-containing wood concrete using chopped reed fiber, the mechanism of strength formation and destruction of sulfur-containing wood concrete, depending on the type and method, were studied. loading, analysis of the use of wood concrete in building structures.

Studies have established that it is possible to improve properties, simplify manufacturing technology and increase the efficiency of arbolite production by purposefully changing its properties and structure with various additives of industrial and plant wastes in the composition [1-17]. An analysis of numerous data [18-27] shows that, in contrast to conventional wood crushed wood concrete, where organic cellulose aggregate is most often the least strong component, sulfur-containing components of the mortar part have a significant effect on its strength and deformation characteristics.

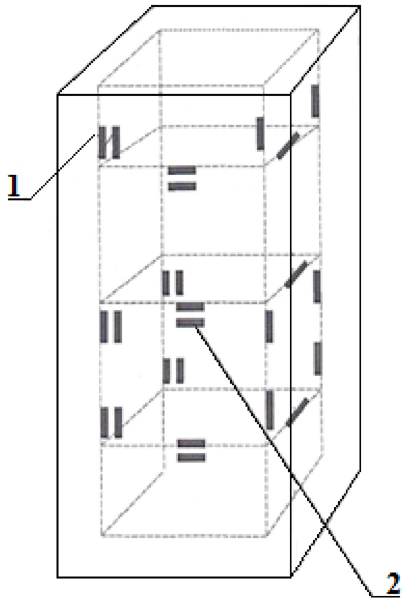
Materials: the object of the study is the industrial waste of enterprises in the region of Kazakhstan in the form of sludges and solids.

1. Portland cement grade 400 Chimkent cement plant.
2. As an additional additive, pyrite cinders of the former JSC "Phosphorhim" were used, consisting mainly of a mixture of iron oxides (II, III) Fe3O4 (Fe2O3), calculated on the iron content of 40–63%, and sulfur impurities of 1-2%. The rest is non-ferrous metal oxides.
3. As a modifying additive, technical sulfur was used - a secondary product of the processing of high sulfur oil from deposits of the Republic of Kazakhstan. Sulfur is a granular product that meets the requirements of GOST 127.1-93.

Shredded reed fibers were used as initial porous aggregates for the production of sulfur-containing arbolites. The physicochemical properties of reed, its chemical and fractional composition were established empirically in accordance with the requirements of GOST 19222, GOST 25820-2000, as well as on the basis of reference and published data [1-20].

Methods. The characteristics of the initial and activated binder were determined in accordance with GOST 30515-97, GOST 31108-2003 and GOST 7473-2010. The tensile strength and bending strength of sulfur-containing binders were determined on beam samples 40x40x160 mm in size using an IP 2710 instrument. Using the X-ray phase analysis, the phase composition of the activated sulfur-containing binder was determined. Radiographic imaging was performed on a DR-ON-3 diffractometer. During the survey, the interval of diffraction angles from 2 to 32° was chosen. The radiographs were decoded on the basis of reference radiographs of the constituent minerals. Differential thermal analysis of hydrated sulfur-containing cement powders was carried out on a MOM Budapest photo-recording derivatograph (Hungary) according to a standard method. The nature of the strength formation and the reasons for the destruction of sulfur-containing arbolite were studied using tensometric equipment and depth strain gauges with a base of 10-50 mm glued to the reed fibers using the "Moment" quick-hardening adhesive, oriented along and perpendicular to the applied load to the prisms installed before concreting. The task of the tests was that deep strain gauge sensors were installed both on the fibers of the chopped reed and in the sulfur-containing mortar component of the material, which made it possible to determine the root cause of the destruction sequence of the individual components of the sulfur-containing material (figure).

Studies were carried out on samples of sulfur-containing arbolite at 7, 28 and 90 days old. The study of the effect of deformations on the compressive strength of sulfur-containing arbolite was based on certain models of concrete structure. Sulfur-containing arbolite was considered as a two-component system consisting of chopped reed fiber and a sulfur-containing mortar component, while the strength of the mortar part was a variable. For the study, four series of samples were made from sulfur-containing



Installation diagram of deep strain gauges. 1- sensor on reed fibers; 2- sensor in the mortar component

arbolite, and the fifth series, for comparison, from sulfur-containing expanded clay concrete. Each series consisted of six samples of prisms 150x150x600 mm in size, three of which (model I) consisted only of a sulfur-containing mortar part (the ratio of sulfur to pyrite cinder was 1: 3), and in three other prisms (model II) fibers of crushed reed were placed in the middle with a diameter of about 18-20 mm. All samples after heat treatment before testing were stored in vivo laboratory. The interval of the maximum load on the test samples varied from 60 to 120 kN, which was determined by the limiting level of loading of the samples, equal to 0.75 Rpr (Rpr is the primary strength of sulfur-containing arbolite). It is known [12–27] that the creep of sulfur-containing expanded clay concrete is mainly determined by the creep of the gel, which is part of the cement stone, therefore, it was suggested that these patterns apply to sulfur-containing arbolite. The compositions of sulfur-containing arbolite and sulfur-containing expanded clay concrete for the manufacture of prototypes are given in table 1 and 2.

Table 1 – Composition of sulfur-containing arbolite prism samples

No. of series of samples	The composition of concrete (by weight),%	Water-cement ratio, W / C	Cement consumption per 1m3 of concrete, kg
1	Cement 33.3%: crushed reed fibers 22.4%: additives in the form of industrial sulfur and pyrite cinder 10.8%: water 33.5%	1,34	321
2	Cement 34.4%: crushed reed fibers 21.4%: additives in the form of industrial sulfur and pyrite cinder 10.8%: water 33.4%	1,37	335
3	Cement 34.9%: ground cane fiber 20.6%: additives in the form of industrial sulfur and pyrite cinder 10.94%: water 33.56%	1,4	345

Table 2 – The Composition of sulfur-containing expanded clay prism samples

No. of series of samples	The composition of concrete (by weight),%	Water-cement ratio, W / C	Cement consumption per 1m3 of concrete, kg
1	Cement 37.8%: expanded clay 20.9%: additives in the form of industrial sulfur and pyrite cinder 10.8%: water 30.5%	0,97	390
2	Cement 38.2%: expanded clay 21.8%: additives in the form of industrial sulfur and pyrite cinder 10.8%: water 29.2%	1,2	400
3	Cement 38.6%: expanded clay 22.7%: additives in the form of industrial sulfur and pyrite cinder 10.8%: water 27.9%	1,1	410

Results. Our studies have shown the following results:

1. Depth strain gauges located in the sulfur-containing mortar component of the material, record the moment of its destruction and the achievement of ultimate tensile sulfur-containing arbolite in prisms perpendicular to the current load of the press. In this case, the arrow of the press gauge falls, that is, the initial destruction of the sulfur-containing material is always observed. At the same time, strain gauge sensors mounted on the fibers of the chopped reed and oriented along and across the current load continue to show an increase in deformations, and the pressure gauge needle of the press continues to show an increase in stresses. These effects are not detected in a sulfur-containing arbolite of a porous or large-pore structure of low density of less than 500 kg / m3.

2. When testing a sulfur-containing arbolite of a dense structure, no simultaneous destruction of the sulfur-containing solution component and organic aggregate occurred. Usually, sequential failure was observed associated with the aggregate, then with the sulfur-containing solution component, but only in the second phase of hardening. The destruction of the sulfur-containing material along the solution component occurred only in the first phase of hardening.

When testing a sulfur-containing arbolite of a dense, porous and coarse-porous structure, the adhesion surface of the fiber of crushed reeds with a sulfur-containing solution component is of significant importance, while for a material of a dense structure, the adhesion strength of the solution component is less than the strength of the organic aggregate. For a porous and porous material, the adhesion strength of the mortar component is greater than that of the organic aggregate.

Discussions. The conducted studies provide the basis for clarifying the hypotheses of strength formation and the causes of the destruction of sulfur-containing arbolite. The strength theory of A. I. Vaganov [7, 25] is acceptable for explaining the process of increasing the strength of a sulfur-containing material during hardening, when the deformability of the sulfur-containing mortar component is less than the deformability of the clogged fibers of shredded reed. To explain the increase in the strength of sulfur-containing arbolite of dense structure in the second phase of hardening, this hardening theory requires additional refinement, since the simultaneous destruction of the organic aggregate and the solution component is not observed. The destruction of sulfur-containing material in the second phase of hardening occurs in steps, first an organic aggregate, then a sulfur-containing solution. The final strength of the sulfur-containing arbolite of a dense structure in all tested samples was determined by the strength of the mortar component. So, with a lower strength of the sulfur-containing solution compared to the strength of the aggregate, single-phase hardening and single-stage destruction occur along the solution. With the high strength of the sulfur-containing solution compared with the strength of the organic aggregate, two-phase hardening and two-stage destruction occur. The strength of the sulfur-containing arbolite of the porous structure is formed in one phase, the destruction occurs in a one-stage process - according to the clogged organic aggregate, the strength of which determines mainly the strength of the material.

Conclusions. The conducted studies allow one to plan to obtain sulfur-containing arbolite of various strengths depending on the grain fraction or fiber length of the organic aggregate. The research results can be widely used in the manufacture of wall materials and structures for all types of public and civil buildings, including areas of high seismicity.

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ӘРТҮРЛІ ҰЗАҚ МЕРЗІМДІ САЛМАҚ ӘСЕРІНЕН АРБОЛИТ КОМПОЗИТТЕРІНІҢ БЕРІКТІГІ МЕН БҰЗЫЛУ БІРІЗДІЛІГІНІҢ ҚАЛЫПТАСУЫ

Аннотация. Мақалада ыстық және күрт айнымалы климатты өңірлерге ыңғайлы және қалдық материалдарды қолдану арқылы жасалатын күкіртті құрамалы арболит композиттерінің беріктік және деформативті қасиеттері қарастырылған. Арболит – жылу өткізгіштігі төмен және дыбыс ұстағыштығы жоғары жеңіл құрылыс материалдарға жатады. Зерттеудің негізгі мақсаты – күкіртті құрамалы арболит композиттерінің әртүрлі ұзақ мерзімді салмаққа шыдас беріп, беріктік қасиетін күшейту механизмін және бұзылысының біріздiлігін анықтай отырып, тұрғын үй құрылысында қолдану тиімділігін анықтау болып саналады. Зерттеудің әдіснамалық негізіне күкіртті құрамалы композитті байланыстырғыштар негізінде жасалған, жоғары беріктік қасиеті мығым арболитбетондар жөніндегі қазіргі заманғы теориялар мен оларды жасап шығару технологиялары негіз болды. Зерттеу жұмыстарын жүргізу барысында арболит композиттерінің физика-механикалық қаситтерін анықтау үшін қазіргі заманғы әдістегі рентгенфазды, дифферациалды-термиялық, микроскопты әдістегі стандартты өлшеу және сынау құралдары қолданылды. Күкіртті құрамалы арболит композиттері үлгілерінің қаситтерін зерттеп үйренуде оларды 7, 28, және 90 тәулік ашық ауада және жылуда ұстап кептіргеннен кейін түрлі салмақ түсіріп сынап көрдік. Күкіртті құрамалы арболиттердің сығылғандағы беріктік шегіне түрлі күштерден пайда болатын деформациялар әсерін үйрену барысында нақты бір құрамдағы бетон моделін жасау қажеттігі туды. Мұнда күкіртті құрамалы арболит ұсақталған қамыс фибрасынан және күкіртті құрамалы ертіндіден тұратын екі компонентті жүйе ретінде қарастырылған және ертінді беріктігі өзгермелі болып келеді. Зерттеу жұмыстарын жүргізу барысында күкіртті құрамалы арболиттен даярланған төрт үлгі және жұмыстарды салыстыру үшін күкіртті құрамалы керамзитті бетоннан жасалған бесінші үлгі сериялары даярланды. Әрбір серия өлшемдері 150х150х600 мм болған алты призма үлгіден тұрады, яғни олардың үшеуі (модель I) күкіртті құрамалы ертіндіден (күкірттің пирит тотығына қатынасы 1:3) жасалса, ал қалған үш призма үлгілердің арасына (модель II) диаметрлері 18-20 мм болған ұсақталған қамыс фибралары орналастырылған. Призма үлгілерді сынау кернеуі 0,1-ден 0,15-ке МПа дейін көбейетін этаптар арқылы жүргізіледі және әрбір салмақ басқышында үлгілерді бес минут ұстап тұрады. Индикаторлардағы есептер (0,01мм дәлдікке дейін) үлгілерге жаңа салмақ түскенге дейін және салмақ түсірілгенннен кейін өлшенеді. Зерттеу барысында кеуек түрдегі күкіртті құрамалы арболиттар беріктігі бір фазалық болып, олардың қирауы бір сатылық, яғни арболит құрамындағы колльматацияланған органикалық толықтырғыш түріне қатыстылығы анықталды. Тығыз түрдегі күкіртті құрамалы арболиттер беріктігін әртүрлі салмақ түсіріп сынағанда олардағы бұзылу біріздiлігі түрінде болатынығы, яғни бірінші фазада байланыстырғыш ерітінді қирап, соңынан екінші фазада органикалық толықтырғыштың үзіліп сынатындығы анықталды. Күкіртті құрамалы арболит композиттерін зерттеу арқалы алынған нәтижелерді тұрғын үй құрылысына, соның ішінде сейсмикалық аудандарға арнап шығарылатын қабырғалық материалдарды даярлау барысында толық қолдануға болады.

Түйін сөздер: күкіртті құрамалы арболит композиттері, беріктік, қатаю фазасы, ұзақ уақыт әсер етуші салмақ, деформация модулі, ертінді құрамасы, қирау.

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ФОРМИРОВАНИЕ ПРОЧНОСТИ И ПОСЛЕДОВАТЕЛЬНОСТИ РАЗРУШЕНИЯ АРБОЛИТОВЫХ КОМПОЗИТОВ ПРИ РАЗЛИЧНЫХ ДЛИТЕЛЬНЫХ НАГРУЗКАХ

Аннотация. В статье рассматриваются вопросы по исследованию прочностных и деформативных характеристик серосодержащих арболитовых композитов с использованием вторичных ресурсов, что является актуальным в регионах с жарким и резкоконтинентальным климатом. Это один из самых легких строительных материалов, обладающих низкой теплопроводностью и хорошей звукоизоляционной способностью. Целью данного исследования является определение механизма формирования прочности и разрушение серосодержащих арболитовых композитов при различных длительных нагрузках и обоснование эффективности их использования в жилищном строительстве. Методологической основой исследования послужили современные положения теории и практики создания, разработки высокопрочных арболитобетонов на основе композиционных серосодержащих вяжущих. При проведении научных исследований использовались стандартные средства измерений и методы анализа физико-механических характеристик арболитовых композитов, полученных с применением современных методов рентгенофазового, дифферациально-термического, микроскопического анализа и испытательного оборудования. Свойства серосодержащих арболитовых образцов изучали в 7-ми, 28-ми, и 90 суточном возрасте в различных условиях и нагрузках.

Изучение влияния возникающих деформаций на предел прочности при сжатии серосодержащего арболита основывалось на определенных моделях структуры бетона. Серосодержащей арболит рассматривался как двухкомпонентная система, состоящая из фибры измельченного тростника и серосодержащей растворной составляющей, при этом прочность растворной части была величиной переменной. Для проведения исследования были изготовлены четыре серии образцов из серосодержащего арболита, а пятая серия, для сравнения – из серосодержащего керамзитобетона. Каждая серия состояла из шести образцов призм размером 150х150х600 мм, три из которых (модель I) состояли только из серосодержащей растворной части (отношение серы к пиритному огарку 1:3), а в трех других призмах (модель II) в середину помещались фибры измельченного тростника диаметром около 18-20 мм. Испытание призм-образцов производилось этапами, соответствующими приращению напряжения от 0,1 до 0,15 МПа, после каждой ступени нагрузки образцы выдерживали в течение пяти минут. Отсчеты по индикаторам (с точностью измерения 0,01 мм) брались после приложения каждой ступени нагрузки и перед приложением новой нагрузки. Такая методика испытаний позволяла выделить упругие мгновенные деформации и определить величину начального модуля упругости серосодержащих легких бетонов.

Установлено, что разрушение серосодержащего арболита происходит последовательно, сначала происходит разрушение растворной составляющей, а затем – органического заполнителя. Полученные результаты можно использовать при изготовлении эффективного стенового материала для зданий гражданского назначения, в том числе для сейсмических районов.

Ключевые слова: серосодержащие арболитовые композиты, прочность, фаза твердения, длительная нагрузка, модуль деформации, растворная составляющая, разрушения.

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