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Development of technology for foaming keratin based on sheep's wool

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Abstract. The purpose of this article is to evaluate the effect of wool fibers on the thermal conductivity and mechanical properties of cement. The use of sheep's wool as a cement admixture for the production of mortar or plaster provides a number of advantages for the environment and the energy sector. Moreover, in some regions of the country, it is considered as a waste, therefore, its use is characterized by a low cost. Currently, synthetic materials that do not ensure the stability of the foam mass, adversely affect the strength of cellular concrete and do not allow to obtain high-quality concrete with the specified physical and mechanical properties prevail. The use of protein foaming agents, characterized by high quality indicators, environmental cleanliness and production safety, is becoming more and more popular.

Keywords: *cellular concrete, sheep wool, protein foaming agent, insulation material, hydrolysis.*

1. Introduction

Methods for producing cellular concrete by introducing pore-forming substances into the mixture were invented in 1890. The practical application of cellular concrete began in 1923. E. S. Bayer (scientist from Denmark) he was the first to describe the production processes of such concrete. The process of structuring during autoclave and non-autoclave solidification is important in improving the structure of cellular concrete. It is known that foam concretes have low strength and physical and technical characteristics in comparison with autoclaved cellular concretes. To get a competitive foam concrete, it is necessary to create a keratin foaming agent, which in terms of physical and technical characteristics is not inferior to other best foaming agents. That is, the technical foam obtained from the developed foaming agent must have high resistance when mixed with mineral components of foam concrete. In this regard, methods and techniques aimed at developing and studying the properties of a foam-forming structure containing protein, as well as technologies for the production of effective heat-insulating building materials and products based on it, are very relevant. An in-depth analysis of the economic indicators of foaming agent production showed that the type and price policy of manufacturing enterprises has a decisive influence on the quality and cost of finished products. For example, the price for a liter of protein foaming agent produced using German technology by the only enterprise «Unipor» (Kostanay) is 2500 tenge. Again, there are problems with the timely delivery of foam concentrates to remote regions of the country. Mainly Kazakhstani foam concrete producers buy from the company «Unipor». It should be noted that this company strictly observes in secret the material composition and technological parameters of the production of protein foaming agent. The lack of domestic technology for the production of protein foam concrete generally hinders the widespread development of foam concrete production in the regions of Kazakhstan. Physical and technical properties of cellular concrete, as shown in many works, can be regulated in a wide range of strength, porosity, thermal conductivity, various hydrophysical properties, etc. by modifying raw materials, using modifiers and methods of their manufacture. Meanwhile, the protein structure of concrete can be obtained in two ways: first, chemically – the flow of chemical reactions accompanied by the release of gas in the mixture when the gas - forming mixture is introduced into the binder dough; second, mechanically-the introduction of technical foam into the mixture of the binder and the siliceous component during preparation.

2. Materials and methods

It is obvious that high-performance products made of cellular concrete are produced during heat and wet treatment in autoclaves. They provide the production of calcium hydrosilicates of various characteristics by appropriately assigning material types, temperature, and vapor pressure.

Autoclave technology for cellular concrete requires large capital investments in equipment and costs for maintaining large production areas. However, such costs were justified, since the resulting products are characterized by increased strength and lower shrinkage compared to cellular concrete that has not been autoclaved. By density and purpose, cellular concrete is divided into the following groups:

a) thermal insulation (density 500 kg/m^3 or less);

b) structural and thermal insulation (density from 500 to 900 kg/m^3);

c) structural (density over 900 kg/m^3).

3. Results and discussion

3.1. Determination of protein foaming agent in concrete

The research relates to the construction materials industry and can be used for the production of foam concrete, as well as for the production of environmentally friendly foam complexes. The achieved technical result is a simplification of the process, an increase in the stability and multiplicity of foam.

This method uses alkaline hydrolysis-caustic soda at a temperature of 120-150°C for 2-2.5 hours and for 2-2.5 hours,containing raw materials-sheep wool; neutralize pH to 8.5-9, stabilize pH to 6-6.5, in the ratio of components: sheep wool-25 g, caustic soda-75-85 g, water-500 ml.

The technical result is achieved by the recommended method of obtaining a protein foaming agent for foam concrete, including alkaline hydrolysis, neutralization, stabilization of protein-containing materials at a high pH temperature of up to 11-13, but unlike sheep wool, known as protein-containing material, hydrolysis is carried out at a temperature of 120°-150°C for 2-2.5 hours, neutralization is carried out at a pH of up to 8.5-9%, and stabilization to pH 6-6.5.

Table 1. Research materials by methods

Ingredients					Temperature, time
sheep wool	iron (II) sulfuric acid	Ammonia 20 %	caustic soda	water	
25 g		25 ml		500 ml	120°C, 2 hours
25 g	25 ml			500 ml	120°C, 2 hours
25 g		25 ml 25 ml	25 ml	500 ml	150°C, 2.5 hours
25 g			25 ml	500 ml	150°C, 2.5 hours

3.2 Research results and discussion

Several methods were used during the results of the study. The most effective one was selected and the necessary composition was determined.

According to the first method, 25 g of wool, 500 ml of water and 10 g of ammonia were mixed and the SNOL was dried in a laboratory electric oven 58/350 for 2 hours (Figure 1).

Figure 1. Solution mixed with 20% ammonia

Figure 2. Remaining wool after drying in the oven for 2 hours

As shown in Figure 2, with the 1st method, all the water disappeared, and dry wool with a burnt underside remained at the bottom.

According to method 2, we apply the above-mentioned ferric (II) sulfuric acid in the amount specified in method 1. The original image is shown in Figure 3.

Figure 3. Residue from the solution when using ferruginous (II) sulfuric acid

The results of these two studies are invalid, because protein must be obtained to make foam concrete. Well, in the case of the 1st and 2nd methods, the sheep's wool did not fully bloom.

In the 3rd method, I prepared a solution using caustic soda. Using this method, I prepared a solution by taking 25 g of wool, 500 ml of water and 200 g of caustic soda (Figure 4).

Figure 4. Caustic soda

According to the 3rd method, the remainder of sheep's wool remained.

Figure 5. Solution residues when using caustic soda

The sheep wool remaining from the solution, as shown in Figure 5, is almost completely dissolved. However, due to the large amount of salt, it (the remainder of sheep's wool) has become hard.

The most effective method is that sheep wool is pre-dissolved in a mixture of NaOH (20%) and water, and then dried in the oven at 150°C according to the 3rd method. Considered situation: the content of caustic soda is 80 g. If we take animal hair, hair, or cloth dissolved in a 20% NaOH solution, it will dissolve in the solution and take on an elastic shape. Therefore, the 4th scheme is considered the most effective.

Figure 6. Solution in a mixture of NaOH (20%) and water

Figure 7. Sheep musk pre-dissolved in NaOH (20%) solution in a laboratory electric oven for 2 hours at 150°C

According to the results of the study, 4 methods were most effective, which used untreated sheep wool pre-dissolved in a mixture of NaOH (20%) and water. The reason is that the wool fibers dissolved in the pre-mix are dissolved under the action of alkali. Then we put the melted wool in an iron dish mixed with caustic soda and water in the oven at 150°C for 2.5 hours. As a result, the melted wool turns into foam.

3.3 Development of a rational technology for processing sheep's wool

Primary preparation of raw materials for subsequent steelmaking processes is one of the most important problems of complex analysis of technological processes for the production of foaming substances based on keratin-containing raw materials. From the point of view of increasing efficiency, raw material efficiency, reactivity and product quality improvement may depend on this.

Before the initial processing of sheep's wool, a number of problematic issues arise related to sanitary safety during its transportation and storage after slaughtering the animal or after shaving the animal's skin. This is because the sheep's wool has just been cut, or at least the recently slaughtered sheep's wool contains blood clots and various other pollutants.

Therefore, the following issues should be considered in order to solve the above situations related to the primary processing of wool:

- transportation of wool from the place of slaughter of livestock in compliance with sanitary standards;
- organization of wool storage, prevention of its spoilage;
- organization of technological wool distribution sites;
- organization of a technological section for wool grinding;
- organization of technological placement of wool processing after the release of pollutants in the wool.

To solve these problems, we offer the following technological scheme for the primary processing of wool.

Sheep's wool is transported by road from the slaughterhouse to the warehouse.

After delivery to the warehouse, wool should be stored in special places to ensure its safety.

For further processing of wool, places should be organized that separate the wool from pollutants. The process of separating wool from pollutants is cleaned manually by special people.

After that, the wool is sent for further processing to the grinding department. Sheep's wool should be very fine, 1-2 cm in size, crushed. The crushed sheep's wool is sent to a special storage box. It is fed from a storage box to a reactor specially designed for their hydrolysis using dispensers.

The scheme of primary preparation of sheep wool for the production of foaming agent is shown in Figure 8.

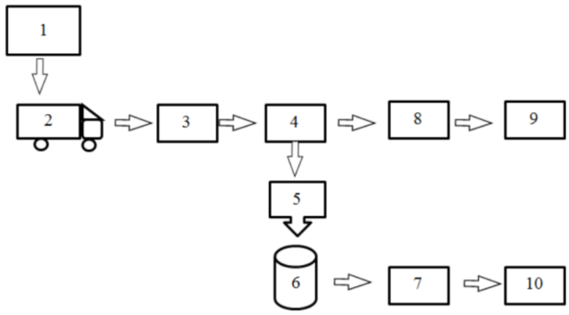

Figure 8. Scheme of primary preparation of sheep wool for foaming agent production. 1-slaughterhouse; 2 - transportation by road; 3-storage warehouse; 4 - places for separating wool from unwanted pollutants; 5 - place for crushing wool; 6-dispenser (dispenser); 7-specially designed reactor for hydrolysis of wool; 8-release to consumers; 10-ready foaming agent

Study of the composition of horns and hooves. The color of the hydrolysate is from light to dark brown (depending on the pH of the medium), a homogeneous solution with a slight specific smell. To obtain foamy substances from the neutralized hydrolysate, it is necessary to add stabilizers.

Thus, in the described methods, even with acidic and alkaline destruction of keratins, solutions of a neutralizer are introduced into the hydrolysate, and then a stabilizer. In this case, the volume of the liquid phase increases significantly (especially in the case of high concentrations of alkalis and acids), and the concentration of proteins in this volume decreases significantly. To obtain a high-quality foaming protein, it is necessary to remove excess water from the neutralized and stabilized protein hydrolysate. For these purposes, doctors of technical sciences recommend concentrating the foaming substance by evaporation [19]. They recommend that this process be carried out to a concentration of 45-55%. Well, this leads to additional energy costs. In addition, during prolonged heat treatment, such as the evaporation process, it is possible to break down amino acids, which leads to a decrease in the foaming properties of protein solutions.

This article also discusses the development of optimal hydrolysis parameters for raw materials to preserve all amino acids with a high crude protein content and high water solubility. The process of selecting optimal conditions was carried out according to such parameters as the duration of the process, temperature conditions, and the ratio between the components. For experiments, the setup shown in Figure 9 is used [20].

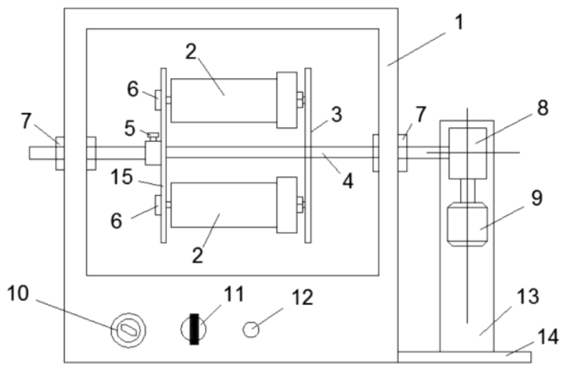

Figure 9. Equipment for the preparation of foam concentrate. 1-drying cabinet; 2-hydrothermal bombs; 3-crosspiece

(crosspiece); 4-shaft; 5-fixing screw; 6-clamping screw; 7-bushing (footer); 8-gearbox; 9-electric motor; 10-temperature sensor; 11-switch; 12-lamp; 13-frame; 14-stand; 15-movable cross

As shown in experimental projects, three hydrolysis parameters are created depending on time conditions, so that the fourth remains unchanged, and the fourth is variable.

Hydrolysis is carried out at a temperature of 120°-130°C, since at this temperature the raw material is completely dissolved and the desired hydrolysate quality is achieved. At low temperatures, there is a lot of unreacted waste in the mixture, and hydrolysis at high temperatures leads to additional energy costs and does not significantly affect the quality of the resulting product.

The optimal hydrolysis time is 5-6 hours. When the hydrolysis time is reduced, the product contains residues of insoluble wool, which indicates that the duration of hydrolysis was insufficient and the reaction did not go through to the end. As the hydrolysis time increases, the resulting product becomes viscous and coy, which is undesirable.

hydrolysis below pH 11 does not allow the reaction to be completed, and suspension above pH 13 leads to improper excessive consumption of alkali. Neutralization with a sulfuric acid solution to a pH value of 8.5-9 gives the required foam multiplicity, and stabilization to pH values of 6-6. 5 gives the necessary foam stability. In addition, the use of solutions with a neutral pH allows you to get an environmentally friendly foaming agent and store it in any container.

Raw materials containing keratin-sheep wool, previously cleaned of debris and other impurities, is boiled in an aqueous solution of sodium hydroxide at a temperature of 120-130°C for 5-6 hours (raw materials containing keratin do not require crushing, homogenization of the solution during hydrolysis is observed after 2 hours). After hydrolysis is completed, the solution is cooled to room temperature. The resulting hydrolysate is neutralized with technical sulfuric acid to pH 8.5-9 and stabilized with acidic iron sulfate ($FeSO4_4$*7H2O_2) to pH 6-6.5 and used in this form.

To determine the foaming capacity and stability of the foam, air passes through the foaming solution for 1 minute, and the volume of foam obtained is recorded. The foaming capacity of solutions is estimated by the foam multiplicity, calculated as the ratio of foam to the volume of solution spent on its formation.

To determine the foam stability coefficient in the cement dough, an equal volume of cement dough (water-cement ratio=0.45) and foam are mixed for 1 minute, after which the volume of the resulting foam concrete mass is measured.

Typically, sheep's wool contains about 80% keratin proteins with a sulfur content of about 3%.

3.4. Study of physical and technical properties of foam concrete

One of the main indicators of sustainability is frost resistance. Currently, this is the only standardized indicator of the strength of cellular concrete. After 28 days of normal curing, the samples are alternately frozen and thawed to detect it.

The strength of foam concrete samples that have hardened within 28 days under normal conditions is reduced when stored in a humid environment. Thus, after 25 cycles, the strength of the samples is reduced by 5% compared to the original. Shrinkage deformation is an important indicator of the properties of cellular concrete. Reducing shrinkage is the most difficult stage of improving the technology of naturally hardening foam concrete. The degree of shrinkage of cellular concrete decreases with increasing average density.

Complete shrinkage consists of three components: anti-air, wetған and carbonizedған. Counter-precipitation develops during a period of intense chemical reactions. The decrease in humidity is determined by the movement and evaporation of moisture. Reduced carbonation causes changes associated with exposure to carbon dioxide in the atmosphere.

One of the main functional properties that distinguish cellular concrete from other building materials is thermal conductivity. The thermal conductivity of cellular concrete largely depends on its average density. Ambient temperature and humidity also has a significant impact. As they increase, the thermal conductivity of a low-density material decreases faster than that of a heavier material. The thermal conductivity of cellular concrete is determined in dried samples, but when working, the products operate at a certain humidity, so it is necessary to determine the effect of sample humidity on their thermal conductivity.

4. Conclusions

Analysis of scientific and technical literature and experience in using cellular concrete has shown that it is an effective wall material that helps save indoor heat during the heating period and electricity in the summer. At the same time, the development of foam concrete production requires the development of domestic defoamer technologies, which are currently imported from abroad. From the point of view of economic efficiency, the development of a keratin foaming agent from animal wool, including sheep wool, and leftover waste is of the greatest interest.

Test results of raw materials-indicate compliance with the requirements of current regulatory documents for the production of cellular concrete in terms of basic physical and technical characteristics. The raw materials used are not in short supply for the construction complex of Kazakhstan.

Based on raw materials containing local keratin, a new foaming protein was developed. It was found that organic raw materials contain keratins with a fibrillar structure, and their removal should be carried out carefully at a temperature of 130ºC.

In foam concrete mixes, the effect of keratin foaming protein (in terms of increasing the start and end time of cement solidification) is less pronounced than in traditional foam concrete. This is explained by the high activity of cement and sand, that is, ordinary cement acquires the property of rapidly hardening cement.

The results show that sheep wool fibers are suitable for use as an insulating material, since they have low thermal conductivity and high temperature resistance.

In addition, sheep wool has convenient hygroscopic properties, its water absorption exceeds 35% by weight, which makes it suitable for leveling internal humidity.

When used as a reinforced fiber for composite materials, sheep wool improves the tensile and compressive strength of samples and, in particular, flexural strength by reducing their adaptation to cracking.

However, more research is needed to improve the performance of cement-based composites reinforced with sheep wool fibers. It is also necessary to provide a special method for obtaining homogeneous sheep wool fibers and changing their surface.

The technology of obtaining protein foaming agent from sheep wool for the production of cellular concrete is more environmentally friendly and reliable than the first simple method. However, when making cellular concrete, it is necessary to carefully monitor the materials that make up its composition. Also, the materials must be economical and environmentally friendly. However, although the use of natural insulation materials, such as sheep wool, has not yet become widespread, in some cases it has been limited to the laboratory period.

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Қой жүніне негізделген кератинді көбіктендіру технологиясын әзірлеу

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Аңдатпа. Бұл мақаланың мақсаты - цементтің жылу өткізгіштігі мен механикалық қасиеттеріне жүн талшықтарының әсерін бағалау болып табылады. Ерітінді немесе сылақ өндіру үшін қойдың жүнін цемент қоспасы ретінде пайдалану қоршаған ортаға және энергетика саласына бірқатар артықшылықтар береді. Оның үстіне, еліміздің кейбір аймақтарында оны қалдық ретінде қарастырады, сондықтан оны пайдалану құнының төмендігімен сипатталады. Қазіргі уақытта көбік массасының тұрақтылығын қамтамасыз етпейтін, ұялы бетонның беріктігіне кері әсер беретін және көрсетілген физикалық-механикалық қасиеттері бар жоғары сапалы бетон алуға мүмкіндік бермейтін синтетикалық материалдар басым. Жоғары сапа көрсеткіштерімен, экологиялық тазалығымен және өндіріс қауіпсіздігімен сипатталатын ақуызды көбіктендіргіштерді қолдану барған сайын сұранысқа ие болуда.

Негізгі сөздер: *ұялы бетон, қой жүні, ақуызды көбіктендіргіш, оқшаулағыш материал, гидролиз*.

Разработка технологии вспенивания кератина на основе овечьей шерсти

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Аннотация. Цель данной статьи - оценка влияния шерстяных волокон на теплопроводность и механические свойства цемента. Использование овечьей шерсти в качестве добавки к цементу при производстве строительного раствора или штукатурки дает ряд преимуществ для окружающей среды и энергетики. Более того, в некоторых регионах страны он считается отходом, поэтому его использование отличается невысокой стоимостью. В настоящее время преобладают синтетические материалы, которые не обеспечивают устойчивость пенной массы, отрицательно влияют на прочность ячеистого бетона и не позволяют получить качественный бетон с заданными физико-механическими свойствами. Все более популярным становится использование белковых пенообразователей, характеризующихся высокими показателями качества, экологической чистотой и безопасностью производства.

Ключевые слова: *ячеистый бетон, овечья шерсть, белковый пенообразователь, изоляционный материал, гидролиз.*

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