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THERMAL INSULATION MATERIAL, USING WASTE COTTON PRODUCTION AS A PLACEHOLDER

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The results of investigations to determine the thermal conductivity of cotton fiber waste to be used as filler for efficient insulating materials are used in the article.

In Central Asia and Europe, large amounts of production comes from mineral wool release as an effective insulation, but also special attention to technologies for production of thermal insulation materials is given to the fibrous waste of plant origin, formed after the collection or processing of the crop. Plant waste is not only an additional source of environmentally friendly raw materials, and provides expansion of the range of local building materials, but also contributes to the preservation and rational consumption of non-renewable natural resources. These criteria are aimed at developing new effective insulation based on plant fiber materials; contribute to the development of contemporary trends in the production of thermal insulation.

The most widely used in insulation materials among the fibrous raw material are mineral wool plates and mats, molded from basalt and glass fibers. Mineral wool materials with a density of 30–190 kg/m^3 provide the coefficient of thermal conductivity 0.032– 0.048 W / (m · ° C) and the water vapor permeability coefficient of 0.3 mg / (m · h · Pa), absorption coefficient – 0.75 – 0.9, the compressive strength at 10% deformation – 0,005 –0.08 MPa [1]. According to the flammability group, plates and mats are non-combustible materials. With high thermal characteristics, mineral wool insulation has significant drawbacks. At first, they are a high water absorption more than 100% by weight, a significant increase in the volume of water-saturated state. When mineral wool is frozen in a water-saturated state, irreversible destructive processes occur in the thermal insulation layer. The use of synthetic resins, including those based on phenol formaldehyde has a negative impact on human health and the environment. To resolve this problem, the German company «Knauf» in recent years has begun using modified starch in bonding fibers, however, until now, only soft basalt plates are produced on an environmentally safe binder, which are unsuitable for the device of thermal fur coats and ventilated facades with insulation.

Serious alternative mineral wool plates and mats are insulation materials on fillers of plant origin. Thus, in Belarus and Russia they produce insulating panels «AKOTERM FLAKS» and «Ekoteplin" on the basis of flax fibers used for thermal and acoustic insulation of walls and ceilings of residential and public buildings [2, 3]. In the composition of the plates «AKOTERM FLAKS» synthetic polyester fibers in an amount of 15% by weight of the aggregate are used as a binder. Thermal conductivity coefficient of plates «AKOTERM FLAKS» equals to 0.038 W / (m · ° C) at a density of 32 kg / m^3. Plates have the flammability group G4 so high flammability is a major drawback of insulator. The specificity of molding technology does not allow manufacturing rigid plates; as a result, soft insulation cannot be used when the device is thermal fur, which limits the scope of application of the material.

Insulation plates "Ekoteplin" are manufactured using starch as a binder component, and for fire and biosecurity fibers are treated with boron salts [3]. As a result the plates correspond to combustibility group G1 and low-combustible materials. At a density of 32–34 kg/m^3, the thermal conductivity of plates "Ekoteplin" corresponds to 0.037 W / (m · ° C) and the vapor permeability is 0.4 mg / (m · h · Pa). Due to the low density, insulation has application limitations and quickly passes water and gets wet, to eliminate this disadvantage isolation of insulated walls with a special membrane is done. One more disadvantage, in spite of the environmental safety of plates, is the high cost of an insulator.

At present, the Department of Construction industry of Polotsk State University the study of physical and mechanical properties of the insulation developed on the basis of linters flax fibers, and liquid glass are conducted. Plate heat insulation of flax fibers is characterized by the coefficient of thermal conductivity 0.036– 0.041 W / (m · ° C) and a compressive strength at 10% strain 0.11 – 0.33 × 10^{-2} MPa at a density of 50–110 kg/m^3 [4]. The high heat-insulating ability of flax fiber plates is caused by the presence of elementary fibers 8–12 microns in diameter, separated from the disheveled bundles, with a randomly oriented arrangement in the volume and the presence of hollow channels in the 4–6 microns elementary fibers, which is comparable to the sizes of solid fiber mineral wool that ensures the formation of effective insulating structure.

In tropical latitudes of Asian and African regions there is a considerable interest in the possibility of using fibers of the oil palm bark as a filler for insulation [5]. The obtained samples of insulation plates during the tests showed the following characteristics: thermal conductivity of 0.054 W / (m · ° C), density of 50 kg/m^3. It should be noted that during testing insulation material showed absolute resistance to occurrence of moldy fungi on the fiber surface at a relative humidity of 97% due to the chemical composition of the fibers themselves and climatic conditions of growth of palm oil.

It is known the use of jute fibers for the production of thermal insulation materials with high resistance to rotting and harmful effects of insects [6]. Jute fibers are obtained from plants and to bind together into a web they are passed through a needling machine. With the heater density of 150 kg/m^3 coefficient of thermal conductivity reaches 0.036 W / (m · ° C) and the water vapor transmission rate is up to 0.4 mg / (m · h · Pa). The main negative factor in the operation is the fire hazard of the material.

Coconut fibers also have found their use as filler in the manufacture of insulation plates produced in Russia under «Bauplit Cocos» trademark [7]. In the structure, material comprises 85% coconut and 15% polyester fibers. In the molding process, the mixture of fibers is treated with hot air and polyester fibers are fused, glued to each other and coconut fibers, thereby forming a continuous structural lattice. Thermal conductivity coefficient of plates «Bauplit Cocos» is 0,038–0,042 W / (m · ° C) and the water vapor transmission rate equals to 0.59 mg / (m · h · Pa). But this material has several disadvantages. For fire, insulation refers to a group of flammability T4. Also low density of 30 kg/m^3 restricts application of «Bauplit Cocos» due to the lack of strength compression. In addition, insulation «Bauplit Cocos» has a high cost, as it is made from imported raw materials.

On the basis of wood fibers in Germany and Poland insulation plates "STEICO" using paraffin as a binder are produced. Insulation «STEICO» is universal and applied for thermal insulation of external walls, roof slabs, roofs [8]. The thickness of the insulation plates may reach 200 mm. At a density of 50– 270 kg/m^3 plates have thermal conductivity in the range 0.038–0.07 W / (m · ° C) and a compressive strength equal to 0.04 – 0.2 MPa. In addition to high prices for thermal insulation plates «STEICO», main disadvantages are brittleness and crumbling under abuse conditions of transportation and stacking technology. In the USA after a series of research scientists came to conclusion that while burning paraffin allocates hazardous chemical compounds containing benzene and toluene, which are hazardous substances to human life [9].

Based on the foregoing additional source of raw material for the production of thermal insulation materials may be waste cotton fibers. Such wastes in large quantities are produced in Central Asia, including Turkmenistan.

In the process for manufacturing of the investigated samples was used as a filler fiber waste cotton production. Waste is obtained in a preliminary stage of preparation of fibers on cotton plants (Turkmenistan) and meet the requirements of GOST 6015. In the studies waste cotton fiber with the length of 10 cm was used.

In the manufacture of insulation plates sodium water glass produced by JSC "Domanovo Production and Trade Plant" (Belarus), corresponding to the requirements of GOST 13078, was used as a binder component.

In the first series the samples were formed without a binder. The connectedness of the structure was provided by the interweaving of fibers. The required amount of material was placed in a mold of 250 × 250 mm and pressed in layers to a sample thickness of 30 mm. The resulting soft plate was removed from the mold to determine the average density and placed in the device ITP - MG4 to establish the thermal conductivity.

For the compositions of the second series of samples, liquid glass was used together with fiber waste. Previously, the dosage of the components was made. The waste fiber was laid in the form of layer-by-layer impregnation with liquid glass and pressed. Samples were kept in the form for 4 hours at a temperature of 20 ± 2 °C and then dried for 6 hours in a drying oven at a temperature of 40 – 45 ° C. After that the average density and thermal conductivity of semi-rigid boards were determined.

The average density and the thermal conductivity of the samples was determined according to GOST 17177 and 1618 respectively on the plates of 250 × 250 × 30 mm.

The average density of the first series of samples ranged from 40 to 120 kg/m^3. The range of average densities taken for the study is explained by an attempt to determine the minimum coefficient of thermal conductivity for plates of cotton fiber waste. Results of determining the average density and the thermal conductivity are shown in Table 1.

Table 1. – Physical characteristics of insulation plates From waste cotton fibers

№ batch of samples	The average density, kg/m^3	Coefficient of thermal conductivity, W / (m · ° C)
1	40	0,039
2	50	0,037
3	60	0,037
4	70	0,038
5	80	0,039
6	90	0,039
7	100	0,041
8	120	0,044

Analysis of the data reveals that the lowest thermal conductivity index 0.037 W / (m · ° C) Corresponds to the density of the fibers of waste 50 – 60 kg/m^3 (batch of samples 2, 3). The best result of thermal conductivity is achieved by reducing the volume and size of voids while simultaneously localizing into separate closed micro spaces that do not bind to each other. At the same time, the functioning of the end-to-end air flow stops. Such an organization of the inner air space is caused by optimal number of contact (contact points between the fibers).

Reduction of density 40 kg/m^3 already causes an increase of thermal conductivity by 0, 002 W / (m · ° C)%, which can be explained by decompression fibrillation leading to reduction in the number of contact points between the fibers and facilitating the passage of air flow through the material.

Increasing the density of the first series of plates in 1.6 – 2 times (batch samples 5 - 8) with respect to batches of samples 2, 3 also leads to a gradual increase in the thermal conductivity. So, at a density of 100 – 120 kg/m^3 coefficient of thermal conductivity is increased by 11 – 19% relative to batches of samples 2 and 3. Presumably data samples gradually reduced the number of closed micro cavities, with the lack of air circulation therein, area and number of point contacts between the fibers increases, which eventually leads to increased thermal conductivity.

When liquid gas was put into the batches of samples 2, 3, the thermal conductivity increased slightly to 0.039 W / (m · ° C). Thus, according to research results an effective insulating material in the form of semi-rigid plates on the basis of waste cotton fibers and water-glass was obtained for Turkmenistan and other countries of Central Asia.

REFERENCES

1. Обзор каменной ваты [Электронный ресурс]. – Режим доступа: http://tutknow.ru/building/uteplenie/6213-obzor-kamennoy-vaty.html – Дата доступа: 14.01.2017.
2. Плиты теплоизоляционные звукопоглощающие. Технические условия : ТУ BY 391129716.001-2015. – Введ. 27.07.2015. – Ореховск, 2015. – 10 с.
3. Советников, Д.О. Оптимальная толщина утеплителя наружной стены для создания энергоэффективного и экологичного здания в условиях Санкт-Петербурга / Д.О. Советников, Д.О. Семашкина, Д.В. Баранова // Строительство уникальных зданий и сооружений. – 2016. – № 12 (51). – С. 7–19.
4. Романовский, С.А. Применение микроскопического анализа для оценки перспективы использования очесов волокна льна в производстве теплоизоляционного материала / С.А. Романовский, А.А. Бакатович // Вестн. Полоц. гос. ун-та. Сер. F, Прикладные науки. Строительство. – 2017. – № 8. – С. 14–18.
5. Romanovskiy, S. Influence of the Fibrous Structure on the Physical and Mechanical Characteristics of Insulating Slabs from Flax Noils / S. Romanovskiy, A. Bakatovich // Scientific Journal of Riga Technical University «Construction Science» – 2017. – vol. 20. – P. 10–16.
6. Что такое джут, джутовый утеплитель: характеристики [Электронный ресурс]. – Режим доступа: http://fb.ru/article/ 249861/chto-takoe-djut-djutovyiy-uteplitel-harakteristiki/ – Дата доступа: 14.01.2017.
7. Утеплитель из кокоса Bauplit [Электронный ресурс]. - Режим доступа: http://g-b-t.ru/collection/kokosovye-utepliteli/product/uteplitel-iz-kokosa-bauplit-cocos. – Дата доступа: 25.05.2017.
8. STEICO [Электронный ресурс] // Дома ЭЗ. – Режим доступа: http://steico-rus.ru/katalog – Дата доступа: 14.01.2017.
9. Вреден ли парафин [Электронный ресурс]. – Режим доступа: http://vredno-ili-net.ru/ostalnoe/vreden-li-parafin.html – Дата доступа: 14.01.2017.