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STRENGTH CHARACTERISTICS OF INSULATIONS FROM NATURAL FIBERS

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Options for structure-forming materials of plant origin are presented for the production of thermal insulation materials based on fibers of plant origin. The production of jute and coconut fibers is described. The results of studies of the strength characteristics of the developed thermal insulation materials are presented.

Environmental friendliness is a characteristic that is a stumbling block when choosing insulation for a home. Formally, all building materials that can be found on the domestic market today have appropriate environmental certificates. But, in most cases, when choosing thermal insulation, heated debates arise regarding the environmental friendliness of these insulation materials.

For example, supporters of stone wool claim that the foam contains harmful styrene. Fans of foam plastic in response hint at phenol-formaldehyde binders of mineral wool insulation. As a result, everyone remains to their own, although both groups of materials are of synthetic origin. At the same time, people are increasingly striving to choose natural, natural materials for building a house. This is not just a fashion trend, but also a concern for one's own health, well-being and safety [1]. This article discusses several options for structure-forming materials for further use in the manufacture of insulation materials.

Jute refers to an annual herbaceous plant, shrub and subshrub, otherwise called Calcutta hemp. There are up to 80 species of this plant in the world. The stem of jute is erect and branched with a tap root and oval-lanceolate leaves with appendages, serrated along the edges. The flowers are bisexual, small, and have a yellow tint. The fruit is a ribbed capsule, which, depending on the type, is pod-shaped or spherical. The seeds are small and may be grey, green or brown in color..

The height of jute, depending on conditions, can reach more than 3 m. Jute consists of plant fibers such as lignin (a key component of wood fiber), cellulose, which is a combination of ligninocellulose fibers, which at the same time have the qualities of wood and textiles.

Jute grows in the tropics and subtropics of Asia, Australia, America, and Africa. It has become especially widespread in Bangladesh and India. In many densely populated areas of South Asia, where the lion's share of world production of this crop is concentrated, jute fibers are of great economic importance. This is due to the fact that jute fibers there are a key source of income for small family farms.

Plant ripening continues within 120−150 days, after which harvesting begins. Collection and preparation of raw materials is a labor-intensive process. The harvest is harvested by hand, tied into sheaves, and the cut stems are left on the field for 3 days. During this period, the leaves fall and the bundles are soaked for 5–15 days in ponds to destroy the connecting plates and facilitate the separation of the fibers. The next stage involves thorough washing and drying of the raw materials. The average productivity of a jute plant varies from 1,5 to 2 t/ha. To remove excess moisture, raw materials are hung on poles to dry and sent for processing.

For many hundreds of years, people have used jute fiber to make rough clothing and rope, but over time the situation has changed. New technologies that have emerged have made it possible to expand the range of products made from jute to several hundred types of goods. These include bag containers, ropes, wallpaper materials, linoleum, and carpeting. And the best varieties are used for the production of fabric and tufted jute carpets [2, 3]. Thus, jute fibers have a fairly wide range of applications, but finding ways to maximize the effective use of jute fibers for the human environment remains an open question.

Not so long ago, products made from coconut fiber were exotic. Currently, it is a common and widely used natural material in various spheres of people's lives and activities. The desire for maximum environmental friendliness has made this product one of the most widely used materials in our everyday life.

History says that, according to some sources, the coconut palm originated in the Malaysian archipelago. The coconut palm is one of the most ancient trees on the entire globe, growing even in the era of dinosaurs. Fossilized fruits were discovered in New Zealand. It is also known that palm trees have been growing in India for 4000 years. Therefore, many scientists believe that this type of palm tree originated on the coasts of the Indian Ocean. The coconut is also believed to be native to Southeast Asia, Polynesia, India, the Pacific Islands, Hawaii, South Florida, the Caribbean and Southern California.

Currently, the exotic fruit today exists both in the wild and in cultivation in the Philippines, Africa, Sri Lanka, South America, India, Brazil, Thailand and the Antilles. All these countries have a fairly hot tropical climate. Coconut palms are cultivated mainly in developing countries [4].

In total, 54,716,444 tons of coconuts are grown in the world per year. The Philippines is the leader in coconut production – 19,500,000 tons of coconuts per year. In second and third place are Indonesia and India, which grow 15,319,500 and 10,894,000 tons of coconuts per year respectively.

All other countries lag significantly behind. Brazil - 2,759,044 tons of coconuts per year, Sri Lanka - 2,200,000, Thailand - 1,721,640. And then Mexico, Vietnam, New Guinea and Malaysia (total 555,120 tons of coconuts per year). It turns out that Thailand is far from a leader in this matter, and Malaysia even more so. But the Philippines has taken the coconut issue seriously. Many Philippine islands are densely planted with coconut palms, especially the less developed and less populated islands [5].

The material obtained from the pericarp or, more simply, the coconut shell is coconut fiber. The shell of a ripe coconut fruit itself is a fairly durable material. But when soaked in water for a long time, it is divided into its constituent fibers - coir. The fibers are combed out and sorted into fractions depending on length and thickness. The quality of the fibers and some parameters depend on the water in which the coconut is soaked. Fiber soaked in sea water contains some sea salt and is stiffer. Fibers obtained from freshwater soaking are softer and lack mineralization [6].

Coconut fibers have a wide range of applications; the longest and medium ones are used to make fishing nets, ropes and ropes that do not get wet and do not sink in water, mats, etc. Coarse lignified fibers are used, for example, to make brush products. Made from short and tangled coconut fibers - filler for mattresses and furniture [7]. It is worth noting that the given geography of growth of the raw materials under consideration indicates the possibility of developing, obtaining and practical implementation of thermal insulation based on coconut fibers in almost various regions of the world.

To determine the strength characteristics of insulation materials, the average density was varied from 60 to 100 kg/m^3 with changes in the structure-forming material and binder consumption. The quantitative composition of heat-insulating boards made of jute fibers is given in Table 1. The average density and compressive strength at 10% deformation of samples made of jute fibers were determined on samples measuring 100×100×100mm.

Table 1. – Quantitative composition based on jute fibers

№ composition	Component consumption, kg/m^3		№ composition	Component consumption, kg/m^3	
	jute fibers	liquid glass		jute fibers	liquid glass
1	52	8	9	78	12
2	62	8	10	88	12
3	72	8	11	44	16
4	82	8	12	54	16
5	92	8	13	64	16
6	48	12	14	74	16
7	58	12	15	84	16
8	68	12			

Indicators of average density and compressive strength at 10% deformation are presented in Figure 1. Analysis of the results obtained allows us to establish that an increase in the density of thermal insulation materials due to an increase in the amount of structure-forming material leads to an increase in compressive strength at 10% deformation. With an average density of 60 kg/m^3 and a liquid glass consumption of 8 kg per 1 m^3 (composition 1), the compressive strength is 1 kPa. Increasing the amount of jute fibers to 92 kg per 1 m^3 (composition 5) increases the compressive strength at 10% deformation by 4 times to 3,9 kPa. Samples of thermal insulation materials based on jute fibers with a maximum density of 100 kg/m^3 (composition 10) achieve a strength of 4.4 kPa. A decrease in density to 60 kg/m^3 causes a decrease in the compressive strength value at 10% deformation by 3.7 times. An increase in the average density of cube samples from 60 kg/m^3 (composition 11) to 100 kg/m^3 (composition 15) leads to an increase in compressive strength by 3,2 times. It was also found that an increase in compressive strength at 10% deformation occurs due to an increase in the consumption of liquid sodium glass (Fig. 1). At a density of 60 kg/m^3 (compositions 1, 6, 11), a 2-fold increase in binder from 8 kg per 1 m^3 to 16 kg per 1 m^3 leads to an increase in compressive strength by 50%; at a density of 70 kg/m^3 the increase is 40%; at 80 kg/m^3 – 38%; at 90 kg/m^3 – 27%. Increasing the amount of jute fibers to 92 kg per 1 m3 (composition 5) increases the compressive strength at 10% deformation by 4 times to 3.9 kPa. Samples of thermal insulation materials based on jute fibers with a maximum density of 100 kg/m3 (composition 10) achieve a strength of 4.4 kPa.

To determine the strength characteristics of thermal insulation boards, the average density was changed from 70 to 145 kg/m^3 with varying coconut fibers and sodium liquid glass consumption. The quantitative composition of thermal insulation boards made from coconut fibers is presented in Table 2.

The dependences of compressive strength at 10% deformation on the average density of thermal insulation materials based on coconut fibers are presented in Figure 2. According to the data obtained (Figure 2), it was established that an increase in the density of thermal insulation due to an increase in the amount of structure-forming material from coconut fibers leads to an increase in strength compression at 10% strain. An increase in the average density of cube samples from 70 kg/m^3 (composition 1) to 145 kg/m^3 (composition 6) leads to an increase in compressive strength by 6,4 times. With an average density of 70 kg/m^3 and a liquid glass consumption of 14 kg per 1 m^3 (composition 7), the compressive strength is 16 kPa. Increasing the amount of coconut fibers to 131 kg per 1 m^3 (composition 12) increases the compressive strength at 10% deformation by 5,4 times to 86 kPa. Cube samples of thermal insulation materials based on coconut fibers with a maximum density of 145 kg/m^3 (composition 18) achieve a strength of 98 kPa. A decrease in density to 70 kg/m^3 causes a decrease in the compressive strength value at 10% deformation by 4,5 times to 22 kPa. It was also found that an increase in compressive strength at 10% deformation occurs due to an increase in binder consumption (Fig. 2). At a density of 70 kg/m^3 (compositions 1, 7, 13), a 2,5-fold increase in binder from 8 kg per 1 m^3 to 20 kg per 1 m^3 leads to an increase in compressive strength by 83%; at a density of 85 kg/m^3 the increase is 75%; at 100 kg/m^3 – 50%; at 115kg/m^3 – 36%; at 130 kg/m^3 – 33%; at 145 kg/m^3 – 27%.

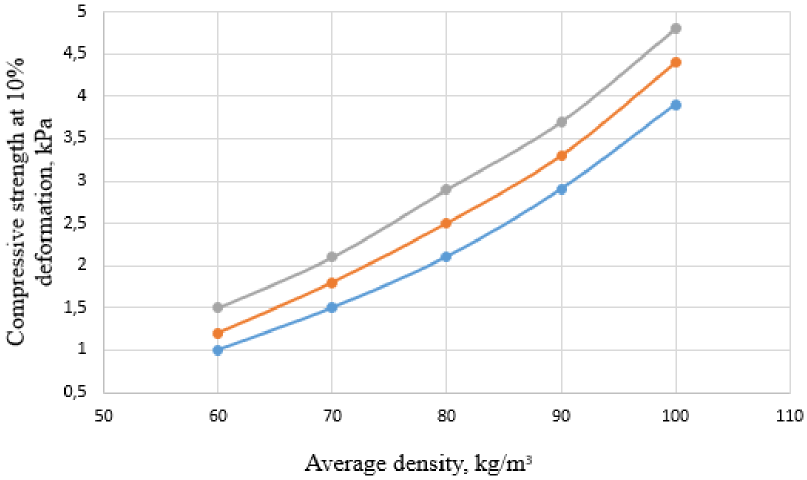

Figure 1. – Dependence of compressive strength at 10% deformation of jute insulation on average density

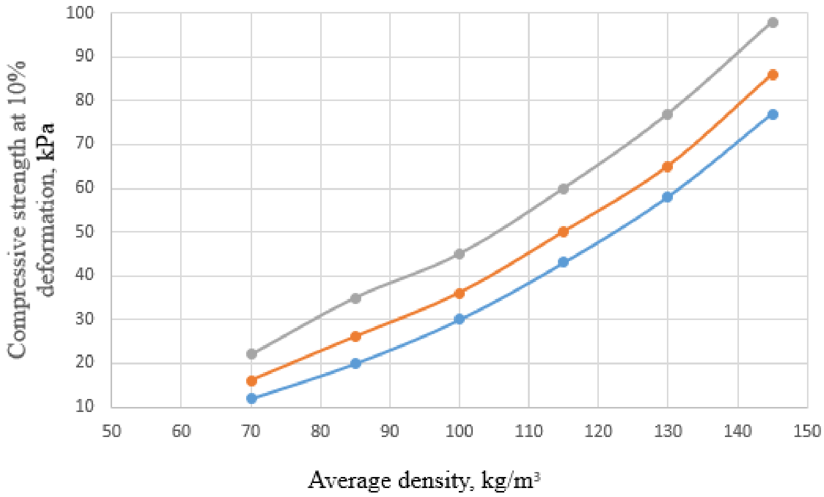

Figure 2. – Dependence of compressive strength at 10% deformation of coconut insulation on average density

Table 2. – Quantitative composition of insulation based on coconut fibers

№ composition	Component consumption, kg/m^3		№ composition	Component consumption, kg/m^3	
	coir	liquid glass		coir	liquid glass
1	62	8	10	101	14
2	77	8	11	116	14
3	92	8	12	131	14
4	107	8	13	50	20
5	122	8	14	65	20
6	137	8	15	80	20
7	56	14	16	95	20
8	71	14	17	110	20
9	86	14	18	125	20

In most countries, it is possible to use fibers of natural or agricultural origin in the production of insulation materials. Considering the volumes of waste jute and coconut fibers and the ways of further use, the use of these fibers as the main components of thermal insulation materials can be an innovative and promising solution for the use of these wastes.

The conducted studies allow us to conclude that in the considered ranges of component consumption, the compressive strength at 10% deformation of heat-insulating boards based on jute fibers varies from 1 to 4,8 kPa, and for heat-insulating boards based on coconut fibers it varies ranging from 12 to 98 kPa.

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