ANALYSIS OF THE POTENTIAL OF RICE STRAW AS A FIBROUS FILLER OF COMPOSITE GYPSUM SHEETS

Adilkhodjaev A.I., Igamberdiev B.G., Shaumarov S.S.
Tashkent Institute of Railway Engineers (Tashkent, Uzbekistan)

Abstract: The article discusses the possibility of using a treated rice straw as a fibrous filler in composite gypsum boards and describes the method of thermochemical treatment of this agricultural waste in order to increase its dispersion-reinforcing effect. The research findings on the synergistic effect by the modifying additive "FremNanogis" on the formation of the structure of the gypsum-fiber composition are presented.
Keywords: rice straw, fiber aggregate, renewable non-wood raw materials, gypsum fiber sheet.

In the construction industry, in recent years, interest has been steadily growing in the use of plant materials in the production of building materials. This is due to the requirement to search for alternatives to the synthetic materials used today, which often have a negative impact on the environment and human health [1-4].

Agricultural waste, including cereal straw and flax fire, forms a significant raw material resource around the world. One of the ways of rational use of such wastes is their use as a reinforcing fiber in the production of building materials. An example of such a material produced using natural plant raw materials is a gypsum fiber sheet, which has high thermal and physical and mechanical parameters [5-7].

Gypsum fiber sheet is a homogeneous, environmentally friendly building material, which is a gypsum sheet dispersedly reinforced with cellulose fibers. It is used in interior decoration, in particular in the construction of prefabricated floor bases and in the installation of wall cladding.

The gypsum fiber sheet acquires all its technical properties from the synergy of the combined use of fibers and gypsum. There are a number of building materials where the use of fibers has the same synergistic effect. For example, even in ancient times, the Egyptians noticed that if straw, sheep wool or reed cane were added to the clay used for the construction of dwellings, the structure acquired higher strength qualities and was less prone to cracking [8].

Dispersed reinforcement increases the strength of sections of compressed, bent and stretched structural elements, increases crack resistance, thermal resistance, impact strength and many other physical and mechanical parameters.

However, the production of traditional, cellulose fiber-reinforced gypsum sheet from recycled cellulose in Uzbekistan is difficult due to the scarcity of such raw materials, and the use of local cotton or imported softwood cellulose fibers costs a huge amount, which makes gypsum fiber sheet uncompetitive. Therefore, the goal of the authors was to develop a technology for the production of gypsum-fiber board, where available raw materials will be used as reinforcing fibers - local agricultural waste of a fibrous nature.

Technologies for the utilization of crop waste in the form of composite aggregates are used in many countries, which indicates a significant interest and demand for this direction in the construction industry. Preferred examples of bulk fiber containing local agricultural waste

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are the stems and hulls of rice straw, and licorice root meal. In this article, we will consider rice straw stalks as raw materials.

Rice straw is a renewable resource; it is available in the regions where grain crops are grown as a by-product of agricultural production, which, unfortunately, is not widely used at this time. The main reason for the unpopularity of rice straw as a feed additive, for example, for livestock, is the high content of indigestible fiber, which can lead to a decrease in the nutritional value of the feed mixture by 15-20%, despite the relatively higher amount of digestible protein than in corn straw. When cows fed rice straw more than 1.5 kg per day, there was a deterioration in the quality of milk, expressed in a decrease in the density of the oil obtained from it [9].

Chemical analysis showed that rice straw cellulose is mainly composed of α-cellulose (up to 80%). Pentosans, lignin, easily hydrolysable substances remain in the cooking liquors during processing.

The mass fraction of rice straw is 42-62% of the total ground part of plants, and husk - 20% of the mass of produced commercial rice [9].

According to the State Statistics Committee of the Republic of Uzbekistan, in 2019, 300.9 thousand tons of rice were obtained [10]. When processing rice grain, a large amount of waste is generated in the form of husks and straws. On average, when receiving 1 ton of rice, 1 ton of straw is formed. This means that every year the country produces about 250-300 thousand tons of rice straw, 80-90% of which still does not find its rational method of use, bringing economic benefits.

To use rice straw cellulose as a fibrous filler in a building gypsum sheet, it is first necessary to get rid of the fatty layer of the stems and delignify the remaining mass. Due to the fact that experiments with the use of rice straw are insufficiently covered in the literature, the authors considered traditional methods of destructuring cellulose-containing raw materials. In search of the most optimal option, a number of tests were carried out. Preference was given to heat treatment in the presence of a weak aqueous solution of NaOH, because this method of delignification of plant raw materials is effective due to the selectively high nitrating and oxidative activity of oxide nitrogen compounds in relation to straw lignin.

Boiling dry and cut in 12-20 mm rice straw was carried out with an aqueous solution of NaOH under the following conditions: the ratio of straw-solution - 1/8; the amount of NaOH - 1-6% of the amount of rice straw; processing temperature - 90 ° C; the duration of the temperature rise - 15 minutes; the duration of alkaline treatment is 60-240 minutes. The resulting fibrous material was washed with distilled water until neutral, sieved, abraded, dried and weighed. The results of preliminary studies of alkaline cooking of rice straw and the dependence of the yield of the fibrous product on the concentration of alkali and the duration of processing are shown in table. 1.

Fiber yield relative to the initial amount of rice straw in alkaline cooking

Table 1

Alkali solution in relation to straw,%	Duration of alkaline cooking, min			
	60	120	180	240
6	75,8 %	67,5 %	61,4 %	49,1 %
4	80,0 %	71,2 %	60,5 %	51,4 %
2	88,2 %	81,1 %	73,8 %	72,4 %
1	94,2 %	89,5 %	84,1 %	79,9 %

Judging by the table, at an alkali concentration of 6% and a treatment time of 240 min, a significant decrease in the yield of fibrous aggregate is observed, therefore, a further increase in the alkali concentration and treatment duration seems to be inappropriate.

When visually inspecting the material boiled in 1-2% alkaline solution, it was noted that the treatment, even with a duration of 240 minutes, does not provide the required values in terms of yield and quality. The data obtained after cooking the first batch of rice straw make it possible to establish a range for further research: alkali concentration - from 3 to 5%, processing time - from 60 to 240 minutes.

After a series of experiments, it was possible to find the optimal conditions for alkaline cooking of rice straw: cooking duration - 240 min; alkali concentration - 3, 5%, a fibrous aggregate was obtained with a yield of 57.1%, visually resembling cotton fibers.

In order to study the obtained material as a filler, comparative tests were carried out. To improve the adhesion of the fibers to the gypsum, to increase the setting time of the dough for forming the future sheet, and also to increase the strength of the gypsum stone itself, a modifier was used.

During the tests, stucco was used as the main binder, the filler was the fibers obtained by the above method from rice straw. The additive for gypsum mixes "FremNanogips" produced by CJSC "Plant of additives and lubricants" FRAME "was used as a modifying additive. The fibers in the material were randomly arranged.

To prepare samples, they were mixed with dry fibers into a gypsum binder. The mass obtained after mixing was poured into a cup with water, taken in an amount necessary to obtain a dough of standard consistency. After filling, the mixture was intensively stirred with a hand mixer until a homogeneous dough was obtained, with which a pre-oiled 40x40x160 mold was poured. The mold was shaken several times to remove entrained air.

Determination of the compressive strength The halves of the samples were placed between two plates and subjected to compression on a press with a maximum load of up to 5-10 MPa. The compressive strength of one specimen was determined as the quotient of the value of the breaking load on the working area of the specimen equal to 25 sm^2. Compressive strength was calculated as the arithmetic mean of the results of six tests without the highest and lowest results [11-12].

Below are the dependences of the ultimate strength in bending and compression of gypsum fiber samples on the content of fibrous filler and additives for gypsum mixtures "FremNanogips" (Tables 2-3).

Flexural strength of gypsum fiber samples at the age of 28 days, depending on the content of the modifier and filler

Table 2.

Fiber filler amount,%	"FremNanogips" additive content,%			
	0	1	2	3
1	4,35 MPa	4,61 MPa	4,35 MPa	3,01 MPa
2	3,68 MPa	5,02 MPa	3,35 MPa	3,01 MPa
3	3,35 MPa	3,81 MPa	3,01 MPa	2,98 MPa

Flexural strength of gypsum fiber samples at the age of 28 days, depending on the content of the modifier and filler

Table 3.

Fiber filler amount,%	"FremNanogips" additive content,%			
	0	1	2	3
1	8,2 МПа	11,4 МПа	12 МПа	8,8 МПа
2	5,8 МПа	10,4 МПа	9,2 МПа	8,2 МПа
3	5,6 МПа	9,2 МПа	8,2 МПа	8 МПа

As can be seen from the tables, the introduction of the modifier into the composition of the gypsum-fiber mixture has a different effect on the ultimate strength in bending of the samples, depending on the volume content of the fiber filler. With an increase in the content of the modifier in the mixture (0-1%), the ultimate strength in bending increases by 12.1-40.8%. A further increase in the modifier content leads to a decrease in strength. It should be noted that the maximum increase in strength is achieved with a lower content of fibers in the mixture (1%), which, in our opinion, is due to the better anchoring ability of the matrix based on the modified binder.

The maximum index of the compressive strength of gypsum fiber samples based on a modified matrix is also achieved with a fiber content of 1%. In this case, the strength increases by 39-51%. A further increase in the amount of modifier in the mixture leads to a decrease in strength.

It should be noted that when a modifying additive is added even to a 1–2% fiber-containing mixture, the water demand of the mixture decreases, which leads to an increase in the density of the product. Due to a decrease in water demand, mixing of the dough is easier, and with a further increase in the number of fibers, their maximum threshold shifts by 2-3 percent.

The addition of the Frem Nanogips modifier promotes the compaction of the matrix due to the formation of a protective layer on the surface of the filler, which reduces the possibility of diffusion of easily hydrolyzed sugars from the straw into the gypsum dough. At the same time, this layer also improves the adhesion of the straw fibers to the gypsum crystals.

Considering the above, we can conclude that the introduction of the additive into the gypsum mixtures "FremNanogips" can significantly increase the ultimate strength of the dispersed-reinforced gypsum stone with a low content of fibers in the matrix. Thus, the maximum increases in the values of the ultimate strength in bending (5.02 MPa) and compression (11.4 MPa) are achieved with the introduction of a modifier into the composition of the gypsum-fiber mixture in an amount of 1%.

The results obtained indicate the effectiveness of fiber aggregate obtained by alkaline cooking from rice straw for dispersed reinforcement of a modified gypsum matrix based on low-grade gypsum. In addition, the maximum tensile strength values are achieved when the fiber aggregate is added to the composition in an amount of 2% in bending and 1% in compression.

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Adilhodzhaev Anvar - doctor of technical sciences, professor, vice rector for research and innovation, Tashkent Institute of railway engineers, Telephone: +998-71-299-00-06, *e-mail:* anvar_1950@mail.ru

Shaumarov Said - doctor of technical sciences, associate professor, head of the "Masters" department, Tashkent Institute of railway engineers, Telephone: +998-71-299-00-09, *e-mail:* shoumarovss@gmail.com

Igamberdiev Bunyod – assistant of the department "Construction of buildings and industrial structures", Fergana Polytechnic Institute.