Application of waste products of crop processing in the production of building materials for agricultural facilities

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Abstract. The article examines the use of waste from the crop-growing branch of agriculture in the manufacture of eco-friendly composite materials used in the reconstruction, modernization and construction of objects of the agro-industrial complex (AIC). As fillers for the manufacture of composite construction and finishing materials, waste products from the processing of agricultural crops of plant origin, such as fiber-like particles obtained from the straw of annual plants and remaining after harvesting raw cotton in the form of cotton stalks, are proposed.

1. Introduction
Most of the modern agricultural facilities were created in the middle of the last century, so these facilities need reconstruction and modernization. In addition to updating the old fund of agricultural facilities, new facilities are being built at a rapid pace that meet all the necessary modern construction trends. Modern construction of agricultural facilities cannot be carried out without the use of innovative composite environmentally friendly structural and finishing materials that will have all the necessary properties: environmental friendliness, strength, frost, atmospheric, bio and water resistance, as well as the ability to process, finish and hold fasteners. In the past, such materials were obtained mainly from wood filler and polymer or mineral matrix (binder). Previously produced materials, although they had a large margin of safety, but were not environmentally safe, since a synthetic binder containing free phenol and formaldehyde was used as a matrix. Modern binders do not have such disadvantages, because, thanks to modification, the content of harmful substances in them is maximally reduced, while in the cured state they have the necessary strength and water resistance.

When conducting modern agriculture, more precisely, when processing plant agricultural raw materials, a large amount of waste is formed, which has the ability to accumulate and which must be somehow disposed of. There is an opinion [1-4] that in the foreseeable future, the technology of production of composites based on annual plants will be greatly developed, since the limited forest resources are increasingly increasing and the need for high-quality construction materials is growing. It is also important to note that the presence of a rich raw material base in the form of various annual plants exists in almost all regions of our country or any other country in the world. In this paper, the use of fiber-like particles made from straw of annual plants and waste remaining after harvesting raw cotton in the form of cotton stalks as fillers for the manufacture of composite materials is proposed.

There is a well-known experience of using the lignified part (bonfires) of the stems of spinning plants (flax, hemp and others) for the manufacture of heat-insulating slab fireballs, fuel briquettes, paper and other materials for various purposes. Bonfire in these plants is about 70% of the mass of the bast stem, in its chemical composition and structure of the fire is very close to wood, because it...
includes: up to 59% cellulose, up to 29% lignin and up to 23% pentosans. Along with kostra, straw of cereals and legumes (wheat, barley, rye, rice and others) can be used in the manufacture of construction and thermal insulation composites [5-8].

2. Materials and methods

Laboratory studies conducted for this work were devoted to the production of composite materials for various purposes with the use of recycled waste of various types of raw agricultural plant components (annual plants) as a filler. Special attention was paid to the study of the possibility of using fiber-like particles (fibers) obtained by grinding cotton stalks and wheat straw in the manufacture of fiber boards. Such boards are analogous to fiberboard, which are based on fibers obtained by grinding wood. During the research, it was revealed that the products of processing of vegetable agricultural raw materials are quite capable of replacing wood in the manufacture of structural or heat-insulating composite materials.

The work was carried out in two directions, in the first case, the stems of annual cotton were used as a filler, and in the second – wheat straw. In the course of the conducted scientific experiments, a set of specialized laboratory equipment for the production of fiberboard manufactured in Poland by Elpa was used: an aggregate for hot chip grinding, a DVP-3 device for evaluating linear fiber sizes, a mixer and a hot press [5; 6; 9].

Preparation of cotton stems was carried out in several stages. The initial stage is grinding-obtaining a section from cotton stalks in the form of particles up to 32 mm long. The next step is plasticizing the section by cooking in hot water for 2 hours in the absence of additional chemicals. Grinding was carried out in separate portions, after which the fiber was dried under normal conditions to a humidity of 20±2%, while lumps were formed from the resulting mass, which were then passed through a centrifugal fan in order to break the lumps to a homogeneous mass then the resulting mass was dried at a temperature of 108 °C to a final humidity of 2% the next step was mixing (tarring) the resulting mass with a urea binder. The amount of binder was 15% by weight of the fiber by dry matter. The binder consisted of the following components: ammonium chloride (hardener) – 1% dry matter and 30% paraffin emulsion the fiber plates were made by hot pressing at 190 °C with a specific exposure of 0.42 min/mm. The thickness of the finished plates is 9 mm. This is a dry method for producing fibrous plates, which is characterized by the absence of excess water and other liquids.

The production of fibers from wheat straw was also carried out in several stages. First, by primary grinding, a section with a length of up to 50 mm was obtained. Further, after hydrothermal treatment, the necessary fiber-like particles were also obtained by grinding. The size of the fibers was determined using optical measuring eyepiece-micrometers of the BCH-2 and BCH-3 brands. Up to 100 particles were taken for measurement with a random sample. Plates with the use of these fibers were made by the wet method by hot pressing at a temperature of 190 °C, the total holding time in the press was 7.5 minutes.

Evaluation of the physical and mechanical properties of the obtained composite materials was carried out according to well-known standard methods regulated by GOST 4598-86 [10] and GOST 32274-2013 [11].

3. Results

The composition of the fibrous mass from cotton stems for the production of materials according to the dry production method was analyzed by the length and content of the number of fibers in 7 intervals from 0.1 to 36 mm. The data of this analysis are presented below (table 1).

Analysis of Table 1 shows that up to 10% of the particles in the resulting mass have a length of less than 1.5 mm. It is possible that these particles were formed from the core part of the cotton stalk. Up to 10% of the fibrous mass consists of particles with a length of more than 20 mm [5; 6; 9].

In parallel, under similar conditions, as a control sample for comparison, fiberboard was made from wood fiber. The results of laboratory studies of the properties of the obtained slab materials are presented in table 2.
Table 1. Analysis of the fiber from the cotton plant.

| The interval number of particles | Length of fibrous particles, mm | The content of the fibrous particles, % |
|----------------------------------|----------------------------------|----------------------------------------|
| 1                                | 0.1-5.0                          | 23.0                                   |
| 2                                | 6.0-10.0                         | 38.0                                   |
| 3                                | 11.0-15.0                        | 22.6                                   |
| 4                                | 15.0-20.0                        | 7.1                                    |
| 5                                | 21.0-25.0                        | 5.3                                    |
| 6                                | 26.0-30.0                        | 2.4                                    |
| 7                                | 31.0-36.0                        | 1.6                                    |

Table 2. Quality indicators of slab materials.

| Indicator                                      | Control | Numerical value of the indicator |
|-----------------------------------------------|---------|----------------------------------|
|                                              |         | 1 | 2 | 3 | 4 | 5     |
| Plate density, kg/m³                          | 770     | 643 | 700 | 760 | 790 | 785 |
| Bending strength, MPa                        | 36      | 22 | 25 | 28 | 32 | 38   |
| Tensile strength perpendicular to the formation, MPa | 0.62 | 0.45 | 0.52 | 0.53 | 0.58 | 0.64 |
| Swelling in water, %                         | 18      | 22 | 20 | 18 | 18 | 16   |
| Formaldehyde emission, mg/100 grams of plate | 6.5-7.5 |

For the production of the fifth sample, a fiber with a removed dust fraction, the amount of which was about 8%, was used.

Table 2 shows that the plates obtained with the use of crushed cotton stalk have high physical and mechanical characteristics, and in terms of formaldehyde emission, they belong to low-toxic materials of class E1. Such materials can be used without damage and harm for the modernization, reconstruction and construction of agricultural facilities [5; 6; 9].

The properties of the fiber obtained from wheat straw were also evaluated, the results of the evaluation are summarized in table 3.

Table 3. Analysis of wheat straw fiber.

| Indicator                                      | The value of the index |
|-----------------------------------------------|------------------------|
| pH                                            | 4.92                   |
| Fiber length, mm                              | 0.1-20                 |
| The length of the fiber, mm                    | 0.01-1.2               |
| The degree of grinding of the fiber, DS (defibrator-second) | 113                   |

Analysis of the fiber particle size allowed us to conclude that the majority of the fibers have a small thickness and length, about 10% of the fibers have the shape of a flat particle, more than 80% of the particles in length do not exceed 6 mm. All this is safely consistent with the indicator of the degree of grinding of the mass (113 DS) and suggests that when pressing the mass in a wet state, problems with its dehydration may arise. To confirm or refute this assumption, the influence of fiber concentration on the dehydration process was studied [5; 6; 9]. The rate of dehydration was determined using a laboratory device Defibrator-second. For comparison, coniferous wood-fiber mass was used, which is successfully used in the manufacture of fiber boards by the wet method. To analyze the rate of dewatering, the fibrous carpet was refilled at different concentrations of fiber mass (table 4).
Table 4. Dependence of the time of dehydration of the fibrous mass on its concentration.

| Fiber concentration at low tide of the carpet, % | The time of dehydration, ДС |
|-------------------------------------------------|-----------------------------|
| 0.1                                             | 21                          |
| 0.2                                             | 28                          |
| 0.4                                             | 39                          |
| 0.8                                             | 84                          |
| 1.2                                             | 113                         |
| Concentration of wood fiber mass, %             | 1.2                         |
|                                                 | 21                          |

The fibrous mass obtained from wheat straw was additionally pressed in a cold pre-press, while the fibrous carpets spread under load and lose their shape, which is undesirable. Therefore, the fibrous mass from straw in the manufacture of boards by the wet method can be used in a mixture with coniferous fibrous mass. To test this hypothesis, slabs were made with different content of straw fiber mass (0, 10, 25 and 50%) depending on the coniferous wood fiber mass. In the process of obtaining carpets, an assessment of the speed of dehydration and their thickness after low tide and additional cold pressing was carried out. Also, the weight loss of slabs was monitored, which allowed us to judge the amount of mass lost at low tide, which amounted to almost 30% as the content of straw fiber increased [5; 6; 9].

Further, under the previously mentioned conditions, fiber boards were made according to the wet production method, with different content of straw fiber. The physical and mechanical characteristics of the obtained plates are presented in table 5.

Table 5. Physical and mechanical characteristics of the obtained plate materials.

| Indicator                           | The amount of straw fiber in the composition with wood fiber mass, % |
|-------------------------------------|---------------------------------------------------------------------|
|                                     | 0                  | 10                 | 25                 | 50                 |
| Plate density, kg/m³                | 936                | 931                | 933                | 872                |
| Bending strength, MPa               | 23.9               | 23.4               | 35.7               | 21.4               |
| Water absorption by the front surface of the plate, % | 97                 | 118                | 154                | 192                |

The analysis of Table 5 allows us to conclude that the plates obtained with the use of straw fiber have quite high physical and mechanical characteristics, which indicates the possibility of using agricultural plant raw materials in a composition with wood raw materials for the manufacture of fibrous materials in a wet way.

4. Discussion

In this work, the possibility of using crushed cotton stalks and wheat straw, which are formed in large quantities in the plant-growing branch of agriculture, as fillers in the manufacture of fibrous plates, was considered and proved.

As a result, it was found that in the manufacture of plates according to the dry production method, crushed cotton stalk is suitable as filler; this is indicated by the analysis of the physical and mechanical properties of the obtained materials.

In the manufacture of boards using the wet production method, crushed wheat straw in a composition with softwood fiber is better suited. Studies have shown that it is advisable to use this fibrous material in an amount of 10 to 20% of the weight of wood fiber. A further increase in mass is undesirable, since it will lead to a decrease in density and a drop in the strength characteristics of the plates. Also, with an increase in straw fiber, there is an increased water absorption by the front surface of the plates, which is also undesirable. In addition, in the manufacture of plates, strengthening
additives and hydrophobic substances should be used, which will provide the resulting plates with the necessary physical and mechanical characteristics [10; 11].

5. Conclusion
In conclusion, it is important to note that the products of waste processing of agricultural annual plant raw materials can become a good and promising alternative to long-term renewable wood raw materials in the production of composite structural and finishing materials.

In addition, at the same time, the problem of waste disposal of agricultural plant raw materials and the main production task will be solved – reducing the cost of structural materials for the reconstruction, modernization and construction of agricultural facilities. This is justified, since the materials obtained are of high quality and low toxicity, which is a prerequisite for agricultural facilities.

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