The dynamics of the decrease in the strength of wood-cement compositions in soil conditions

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Abstract. The intensive felling of plantations, in the process of logging, leads to a decrease in the forest area, reducing their quality. Natural and artificial reforestation is the work aimed at compensating the reduction of forest area. Reforestation with seedlings with a closed root system in containers is a modern trend used worldwide. The article is devoted to the study of the properties of wood-cement composite material in relation to the possibility of its use for the manufacture of biodegradable planting containers, mainly for large-sized planting material. As a result of experimental studies, strength properties and dynamics of their decrease depending on the time of the material in natural soil conditions are determined. The reduction of the compressive strength of the material from 3.36 MPa to 1.65 MPa for 42 months was found.

1. Introduction
The Russian Federation has significant reserves of wood (about 82 billion m³), ranking second in the world after Brazil, where 126.2 billion m³ are concentrated [1]. The volume of forest harvesting in Russia reaches 214 million m³. According to this indicator, it is among the top ten world leaders [2]. The increase in the area of felling inevitably leads to the need to find effective ways of reforestation and the introduction of new forms of forestry, including plantation. If we analyze the applied technologies of reforestation on the territory of the Russian Federation, we can make a conclusion that almost universal successful natural reforestation is declared. However, there are a number of factors limiting the use of natural reforestation. The presence and degree of preservation after felling viable undergrowth of economically valuable species dictates the need for artificial reforestation.

Non-compliance with logging technology, low culture of work, incomplete clearing of cutting areas leads to massive damage to the undergrowth, which limits the prospects of natural reforestation. According to some data, up to 59% of viable undergrowth is destroyed during logging [3]. Significant damage to the undergrowth takes place even if the requirements of logging technology are met during intensive mechanized felling of plantations [4]. This occurs even if more than 3 thousand pieces of undergrowth are preserved per hectare of felling, which is the threshold value for successful natural reforestation, there is not a single intact one [5].

A competing mechanism of reforestation is the technology of forest crops. When implementing this technology, the problem of survival of seedlings of economically valuable species when transplanting them from nurseries to cuttings inevitably arises. The main problem by transplanting seedlings with an open root system is the climatic factor, the time limit of planting terms due to the peculiarities of the vegetation of plants, as well as the factor of relative transport inaccessibility of cutting areas during the spring and autumn thaw, when transplanting seedlings can be most successful. The solution to this
problem can be the use of seedlings with a closed root system, i.e. container planting material. In Russia, such a technology is relatively rare. Whereas, for example, in Finland, 95% of the planting material is delivered with a closed root system (in containers) [6, 7]. The cultivation of planting material using container technology is widespread and continues to improve in the United States and Europe [8]. The planting material, being in the container, is provided with the presence of a nutrient substrate and adapts faster, its root system is less damaged. Container planting is possible throughout the growing season, including the summer period, when most of the cutting areas can be transported after the spring season. In addition, container planting creates the prerequisites for the mechanization of reforestation technology with the use of high-performance planting machines, because there is a fixed labor item and container (shape), in contrast to planting material with an open root system, where there is a wide variety of shapes and sizes of seedlings. In Sweden, in 2013, 99% of pine seedlings, 81% of spruce seedlings and 20% of birch seedlings were grown with a closed root system [9].

2. Results and discussion
The main point determining the technology of forest planting material with a closed root system is the size, design, shape and material of the forest planting container. The container should be cheap, environmentally friendly and meet the requirements of sustainable development of the root system of forest planting material. The industry produces planting containers in the form of containers made of rolled polyethylene (Ontario), polystyrene and polyurethane foam (Styroblock, Cellpot), and recycled cardboard (Paperpot). These containers are successfully used with a basal lump capacity of up to 400 cm³. In the case of reforestation by large-sized planting material, the strength of such containers may be insufficient. In addition, the characteristics of the container affect the formation of the root system of seedlings. For example, the ribs or slots on the container inner walls minimize twisting of the roots. Slots and openings facilitate drainage and facilitate the penetration of nutrients. Studies [10] showed that the root system has morphological and functional differences depending on the development in containers of different shapes and sizes and develops better in large containers. A good development of the root system in containers of significant volume leads to an increase in the amount of water absorbed by the root system, which intensifies the growth and development of shoots [11]. Studies prove that the use of large-volume containers improves the accumulation of nutrients during the first growing season after transplantation [12]. Since seedlings in containers experience less root damage during transplantation than seedlings with an open root system, they are more competitive and provide rapid growth, especially on depleted soils. This is most pronounced when using large forest containers [13].

Large-sized forest containers, as a rule, are made of plastics, i.e. crude oil refining. Oil reserves are limited and not renewable, therefore, the direction of manufacturing containers from secondary, environmentally friendly resources is promising. For example, from wood-binder composites made from soft wood waste (sawdust and crushed wood chips). During the research, the containers were pressed based on the wood-cement composition. The material used was a compounding of sawdust and cement. In terms of 1 m³ were used 210 kg of cement M400, 600 kg of sand and 210 kg of sawdust. For mineralizing 20 g of liquid glass and 10 g of aluminum sulfate were used. After 28 days, the strength of the material averaged 2.5 MPa (under compression) [14].

In the process of pressing wood pulp, containers were obtained as shown in figure 1. The strength of the starting material of the container corresponds to the strength index of the semi-horizontal soil of low strength (according to GOST standard 25100-2011 Soils. Classification), for which the tensile strength is 1...3 MPa. It is obvious that the planting material placed in such a container, during the growth of the root system, will overcome the wall of the container. And the growth of the root system in an environment corresponding to the rock soil of low strength cannot be considered a favorable regime.
The purpose of the research is to determine the mechanical properties of the wood-cement composition and the dynamics of the loss of strength when in the soil in a mode close to the seedling growth conditions during the container planting method.

**Figure 1.** Containers made of wood-cement composition.

The subject of the research is the effect of low temperatures, precipitation, humidity on the strength properties of wood-cement material, in relation to the possibility of making containers from such material for planting seedlings with a closed root system.

In the course of experimental studies, samples were made in the form of a cube with a face size of 50 mm. Portland cement (PC 400-D20), GOST standard 31108-2003) produced by Krasnoyarsk Cement LLC, liquid sodium glass GOST standard 13078-81, aluminum sulfate GOST standard 12966-85 were used as a binder. As a filler, sand was used, the module size of 0.2-3.5 mm. The dosage of the components was carried out by weight. The resulting samples were placed in natural soil. Climatic conditions were Krasnoyarsk city; observation period was from May 2016 to October 2019. Thus, the samples were exposed to climatic factors corresponding to the actual conditions in which the planting material is in the process of reforestation. Twice a year (in April and October) samples were extracted from the ground and tested for strength. The strength tests of the samples were carried out on a hydraulic testing machine. The average humidity of the samples was 44% with wide variations (up to 89% in spring and up to 23% in summer). Laboratory processing of experimental data was carried out, statistical indicators were determined, with the level of reliability R-0.95.

The results of the compression strength tests are shown in figure 2.

**Figure 2.** Tensile strength, MPa at compression depending on the holding time in the ground.
The graph shows that when placing the wood-cement composition in the soil and the impact of precipitation, freezing and thawing, salts contained in the soil, there is a decrease in strength indicators. The strength of the samples is reduced from 3.36 MPa to 1.65 MPa (when in the ground for 42 months). The final strength of the sample of 1.65 MPa corresponds to the indicators of heavy sandy loam (1.4...of 1.7 MPa).

Wood-cement composition is a system of two materials cement stone and wood particles, the mechanical properties of which are largely different. When samples are found in ground conditions, they are affected by a wide range of factors, which can be divided into chemical and physical factors. The chemical mechanism of destruction of cement stone is due to the influence of dissolved salts, such as carbon dioxide, in the presence of water. Carbon dioxide reacts in the presence of moisture with hydration products of lime, in particular, Ca (OH) 2, which causes the formation of calcium carbonate (CaCO3) and H2O. In the case of monolithic concrete stone, these processes occur for a sufficiently long (decades) period of time. But when exposed to wood-cement composite is the destruction of the cement shell, enveloping the wood particles. These phenomena occur quite intensively due to the high porosity of the material. As soon as the excess moisture, due to the destruction of the cement stone, becomes available for water absorption by wood particles, the process of intensive water absorption begins. And under the action of freezing and thawing cycles of the sample with high humidity, the destruction of the wood – cement stone bonds occurs due to the increase in the volume of frozen wood.

3. Conclusion

The steady positive dynamics of the rate of deforestation forces to look for effective ways of reforestation. The expansion of the use of planting material with a closed root system is a global trend. Further improvement of the technology of planting seedlings with a closed root system in the directions of justification of the shape, size and material of containers is one of the ways to ensure successful reforestation.

In the development of technology and materials for planting containers, especially the containers for large seedlings, there is a wide field of activity in the search for material for the formation of the container. Currently used materials (plastics, cardboard) do not always provide the necessary requirements for the life of the planting material. In addition, they may be environmentally unsafe. The technology of biodegradable containers made on the basis of wood-cement compositions, using organic wood waste, will find its place in the nomenclature of reforestation. Wood-cement composition based on sawdust and Portland cement allow obtaining a composite material, the properties of which allow to produce planting containers. Such material can be especially effective in the production of containers for large-sized planting material, when the strength of traditional container materials is insufficient.

In the process of research, the dynamics of reducing the strength of the wood-cement composition was found when it was in soil and ground conditions for 42 months. The reduction of the compressive strength from 3.36 MPa to 1.65 MPa was established. The root system of forest planting material in the process of its development will inevitably be forced to overcome the volume of the planting container, to go beyond it. The strength indicators of the wood-cement composition after being in the ground during the surveyed period allow the root system of the seedling to go beyond the container and continue growth and development.

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