Influence of Organosilicon Additives on Strength of Sod Peat

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Abstract. The results of experiments to study the drying process of crumble peat with water-soluble organosilicon additives are presented. The analysis has found that a hydrophobic agent can be used to reduce the initial water content in moulding and, thus, to reduce energy consumption and improve the production performance. Subject to the optimal concentrations of additives, a significant increase in strength at the same drying intensity can be achieved which improves the quality of the finished product.

1 Introduction

The almost complete displacement of peat products from the energy fuel market in the Russian Federation calls for the development of new non-traditional applications of peat. Its unique properties can be used as the basis to produce many products for various sectors of economy [1-4].

At the same time, hydrophobization of peat has become of particular relevance. To begin with, hydrophobization is necessary to increase the storage and transport lives of products without losing their physical properties. Long-term after-production storage of peat products in the warehouse has a negative impact on its consumer properties as peat absorbs water vapour from the air. Another important reason to conduct research on peat hydrophobization is that a solid household fuel manufactured from hydrophobized peat has increased strength, reduced water permeability and water absorption, and some other useful properties.

2 Review

Sod peat is used as a solid household and power engineering fuel for utilities as well as feedstock for gas and chemical processing. It is produced by extruding the prepared plastic peat mass through moulding pipes, followed by drying to working moisture content. When used as a fuel, sod peat releases approximately 11–13 mJ/kg of thermal energy during combustion, which is comparable to firewood and brown coal.

Peat deposits of high-, transition- and low-moor types having a degree of decomposition of at least 15% and an ash content of no more than 23% are suitable for sod peat production. Sod peat is extracted at a moisture content of 45–50%. When it is stored, its moisture content decreases especially when mechanical ventilation of piles is used (Fig. 1) [2]. Technological calculations are carried out at a conditional moisture content of 33%.

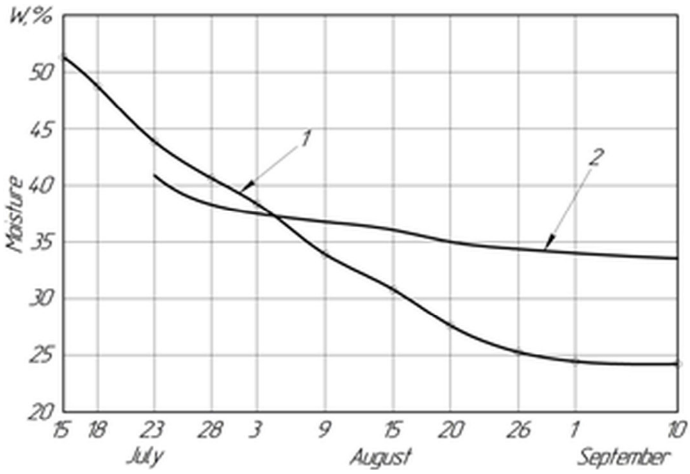

Fig. 1. Decreasing stockpile moisture of sod peat: *1* - with active ventilation; *2* - with natural ventilation

One of the main characteristics of sod peat is a strength of its individual pieces affecting the amount of fines in the products and regulating technical operations. Strength mainly depends on the degree of peat processing and the its moulding quality as well as drying conditions, a piece size and operating moisture content. The Kalinin branch of All-Russian Research Institute of Peat Institute (VNIITP) [5] established the dependence of a piece strength on the above factors:

$$P = P_0 \exp(-\mathrm{bKi}) \tag{1}$$

where P – compression strength; b – the value not depending on the drying mode, the piece size and the initial moisture content; Ki - Kirpichev number

Kirpichev number is determined from the ratio

$$\mathrm{Ki} = \frac{i_c d}{\mathrm{a}\gamma_a W_c} \tag{2}$$

where: i_c - the intensity of drying a piece in a constant period; d – a piece diameter; a - a potential conductivity coefficient; γ_a – density of absolutely dry peat; W_c – a piece initial moisture content.

The strength of a piece was found to decrease with increasing Ki (Fig. 2). Besides, the value of Ki was found to drop with increasing W_c. Thus, when piece sizes are constant, the strength can be increased by increasing the initial moisture content, which, of course, will lead to a deterioration in technological parameters, but will improve the quality of products. The studies have established that the necessary strength can be obtained with peat initial moisture content of 78% and higher up to 86% when the pieces being moulded begin to blur.

One of the disadvantages of moulding peat of low humidity is the ‘ruffling’ of piece surfaces and layering. The chemical modification significantly improves physical and mechanical characteristics of sod peat [6-9] which makes it possible to organize its production in deposits of any peat type and at low initial moisture content. A chemical additive affects the process of structure formation and mass transfer in a peat system reducing the formation of cracks. The actual practice requires such a method of processing organic peat in combination with chemical modification which would make it possible to impart hydrophobic properties to the hydrophilic compounds included in its composition.

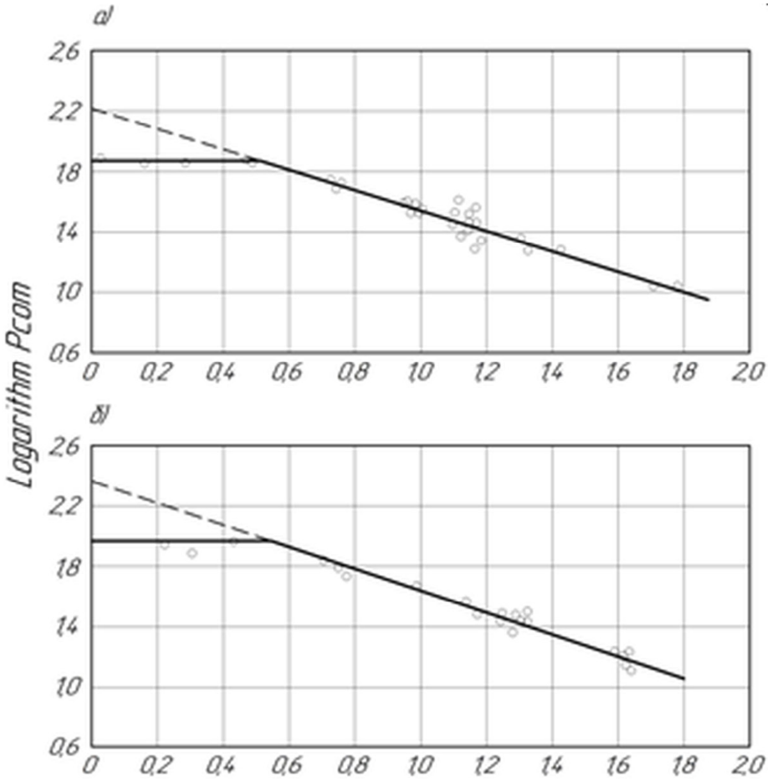

Fig. 2. Strength dependence on the maximum value of Kirpichev number
a) low-moor peat R = 25%, S_0 = 6100 cm^2 / g, $k_{y.e.}$ = 0.95;
b) high-moor peat R = 25%, S_0 = 5600 cm^2 / g, $k_{y.e.}$ = 0.9

The processes of peat-based solid fuel structure formation were studied with a complex technique consisting of two main stages. At the first stage, experimental samples of sod peat were obtained and prepared for the analysis. At the second stage, the strength and water-physical characteristics of the moulded samples were estimated with a hydrophobic agent. An organosilicon compound GKZh-11 was chosen as a modifying additive. It was chosen for reasons of its effective application as well as the availability, cost and environmental safety [10-12]. It should also be noted that the organosilicon compound is fire- and explosion-proof, non-toxic, and is introduced into initial peat in the form of an aqueous solution of low concentration.

In this work we used a method of bulk modification of peat mass with its subsequent moulding on a screw extruder, a shear stress being close to the upper plastic limit (5–5.5 KPa). A single-tube cylindrical mouthpiece was used as a moulding nozzle. Lots of control and experimental samples (60 pieces each) with 40 mm diameter and 60 mm length were formed. The mass concentration of the active hydrophobic component in the experimental samples was 1% on absolutely dry basis.

The moulded samples were dried in a laboratory environment at a temperature of T = 22–25°C and a relative air humidity of φ = 75–85% on metal trays. During the drying process their sizes, weight loss, and uniaxial compression strength were determined daily.

Experimentally, the modifier was not found to affect significantly the drying process intensity, but its use can reduce the initial moisture of moulding due to the increased peat mass plasticity.

The greatest effect of hydrophobic modification was obtained when the moulded peat strength was assessed (Fig. 3).

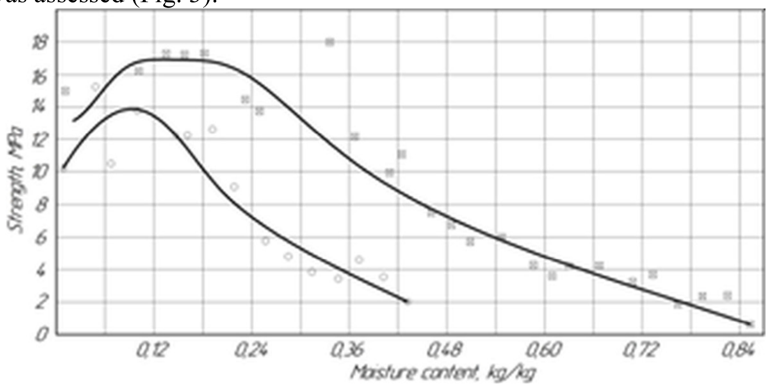

Fig. 3. Comparative estimation of the strength of the experimental (■) and control (○) moulded peat samples

The experimental data analysis shows that the strong sample structure, which is minimally stated by a laboratory press (≈ 2 KPa), is formed at a moisture content of about *W* = 1 kg/kg for modified samples, and at *W* = 0.36 kg/kg for control samples. In the moisture content range of 0.6–0.28 kg/kg, the modified peat strength is 1.7–4 times higher.

4 Conclusion

The mechanism of formation of a finished product solid structure is very complex since its strength is influenced not only by a physical and chemical nature of peat (a degree of decomposition, a content of humic substances, a type of their supramolecular structures, etc.) but also some technological factors (processing intensity, a drying mode, etc.).

When moisture evaporates from a piece of peat under the action of capillary forces, it shrinks which leads to the dry matter content increase per unit volume, and therefore, the number of intermolecular and hydrogen bonds and, ultimately, to the increase in the peat piece strength. The strength increases with decreasing a peat sample size.

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