DETERMINATION OF THERMAL PROPERTIES OF SOIL IN SOLAR GREENHOUSES

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Abstract. *In all countries of the world, in particular Uzbekistan, special attention has recently been given to the issues of energy and resource conservation, environmental protection, and the search for alternative energy sources to replace traditional energy resources in the future. At the moment, there is intensive growth in the use of renewable energy sources, with solar energy and power plants based on solar energy being considered the main developing area. Solar systems can be used primarily in the country's southern regions, characterized by favorable climatic conditions, abundant sunny days, and high solar radiation intensity.*

The article discusses the study of heavy loamy soils, under the same conditions, the thermal conductivity is always lower than that of light and medium loamy soils. Thus, it is confirmed by the conducted experiments that the substrate layer 0-30 cm accumulates about the same amount of heat, and with increasing humidity, the thermal conductivity slowly grows.

Keywords: *heat-retaining properties, thermal conductivity of soil, soil surface, density, thermophysical characteristics, solar energy, thermal diffusivity.*

Introduction

In all countries of the world, in particular, in Uzbekistan, special attention has recently been paid to the issues of energy and resource saving, environmental protection, and the search for alternative energy sources that will replace traditional energy resources in the future. Currently, the use of renewable energy is experiencing rapid growth, with solar energy and solar power stations being the major development area. One of the promising areas for large-scale deployment of solar energy technologies, which currently has the highest degree of technological readiness in the world, as well as in Uzbekistan, is its use in hot water supply systems to cover the needs of social and industrial sectors

Solar systems can be used mainly in the southern parts of the country, which are characterized by favorable weather conditions, abundant sunny days, and a strong intensity of solar radiation.

The climate and weather conditions of the south of Central Asia make it possible to use solar energy for heating solar greenhouses. Part or all of the technical heating becomes unnecessary, which results in a significant fuel economy, so the cost of production is reduced. Compared to other areas of the central strip of the country in the south of our region, the illumination and solar radiation are 5-6 times higher, the number of clear and sunny days is 4-5 times, and the heating season is three times less. All this opens up great opportunities for using solar greenhouses in our region. Long-term operation of solar greenhouses with heat accumulators in the conditions of the Kashkadarya region showed that the annual savings are 300 ... 400 tons of conventional units of fuel per 1 hectare of usable area.

Methods and materials

As is known, the moisture and density of the root layer of the soil play an important role in the growth of plants and determine the thermophysical characteristics of the soil. Information on actual moisture and soil density (even approximate) allows for more accurate characterization of heat storage properties and heat storage properties, both surface and depth.

During the experience, soil samples were taken at various depths using drill and subsurface sizes, preserving the natural structure. Samples were taken 3-6 hours after watering and the day before the next watering. Moisture was determined by the most common thermal drying method [2-3].

Results

The measurement results are shown in Fig. 1 and 2. As can be seen from Fig. 1, the average moisture content (by weight) of the soil varies within $15 < w < 17\%$, changes linearly with depth and is expressed by the following dependence

$$w_x = w_0 + 3x \quad (1)$$

where, w_x and w_0 - weight soil moisture at a depth 3x and soil surface in %; x - depth from the soil surface, m;

Dependence (1) may occur through a specific density

$$\rho_{б} = \rho_0 + 30x \quad (2)$$

where, ρ - specific soil density in kg/m^3

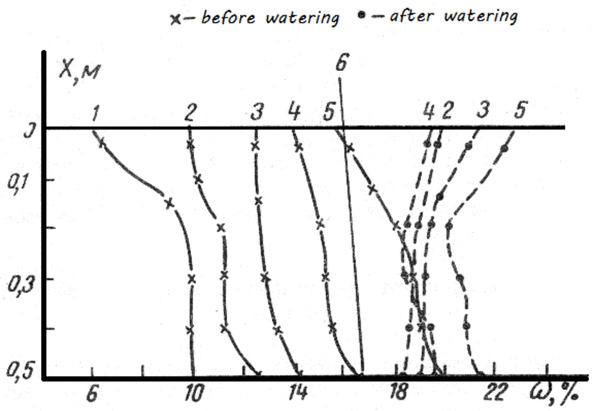

Fig. 1. Soil moisture change by depth: 1-more than two months; 2-between watering month; 3-12-13 days, 4-7-9 days, 5-3-4 days.

In the interval $0,2 < x < 0,3$ m, the graph expressing the change in density with depth has a bend in Fig. 2. This is due to the agrotechnical tillage, the depth of which in the protected ground usually does not exceed 0.3 m.

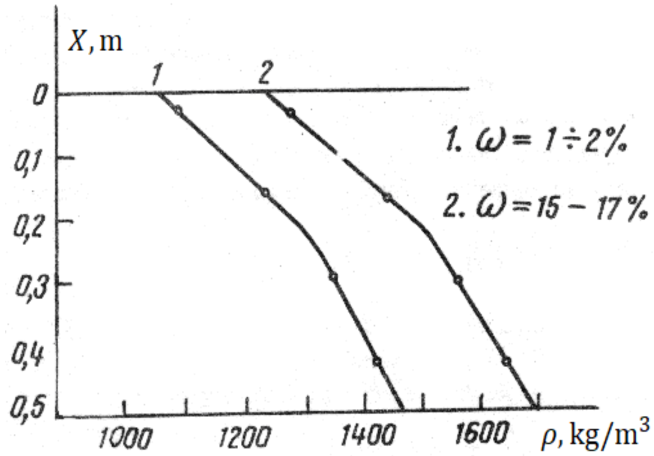

Fig. 2. Change in soil density by depth: w - weight soil moisture.

Density almost also changes linearly and is defined by an expression:

$$\rho_x = \rho_0 + 480\,x \quad (3)$$

Taking into account (2) we get:

$$\rho_x = \rho_0 + 510\,x \qquad (4)$$

As is known, with all the variety of soil types, the specific heat capacity of dry soil does not differ by more than 10-15% and is in the range of $0,71 < c_p < 0,8$ *kJ/kg·K.* The volumetric thermal conductivity of the soil, taking into account moisture content, is determined by the formula, taking $c_p = 0,71 - 0,8$ *kJ/kg·K*

$$\mathrm{C}_v = \left(c_p + \frac{\omega}{100}\right)\rho \qquad (5)$$

If soil moisture ω_0 and soil surface density ρ_0 are known, it is possible to determine the specific heat capacity at depth x

$$\mathrm{C}_v = \left(c_p + \frac{\omega}{100}\right)(\rho_0 + 510\,x) \qquad (6)$$

As can be seen from formulas (3) and (6), the values C_v can have very different values not only for different soils but also within the same soil, since moisture and density can vary within significant limits.

If we accept $\omega_0 = 16\%$, $\mathrm{c}_p = 0,75$ *kJ/kg·K,* $\rho_0 = 1065$ *kg/м³* then

$$\mathrm{C}_v = 970\,\frac{kDj}{m^3K} \qquad (7)$$

For depth *x = 0,5 m*

$$C_v = 1201\,\frac{kDj}{m^3K} \qquad (8)$$

Thus, in our case, when determining the heat storage characteristics in the upper soil layer, the value must be taken (7), and at the depth of the accumulating channels [2] at *x = 0,5 m*, the values (8) shall be taken.

In solar greenhouses, solar energy is accumulated in the upper and storage layers of the soil. To find the amount of accumulated energy, it is necessary to have data characterizing the thermophysical properties of the soil.

Thermophysical characteristics are interconnected by dependencies:

$$\alpha = \frac{\lambda}{c_v};\ \ c_v = c_p\rho;\, b = \sqrt{\lambda \cdot c_v} \qquad (9)$$

where, c_ρ and c_v - specific and volumetric heat capacity;

ρ - density, volume weight;

$\alpha,\ \lambda,\ b$- coefficients of temperature and thermal conductivity, heat absorption.

It can be seen from expression (9) that to fully characterize the thermophysical properties of the soil, it is necessary to have data on three quantities:

$$\alpha, c_v, b$$

As a comparative analysis shows, when using the reference values of thermophysical quantities, for example, from [4], the calculated characteristics (the amount of accumulated energy, the depth of penetration of the temperature wave in the soil) differ significantly from the experimental ones up to 30%. This discrepancy does not allow us to accurately characterize the energy supply of solar greenhouses in the cold season.

Discussion

To determine the actual thermophysical properties of the soil, the authors tested measurements of the temperature and thermal conductivity of the soil in solar greenhouses depending on moisture and density.

The thermal diffusivity is determined by regular mode using a cylindrical calorimeter [4]; probe method – thermal conductivity [4, 5]. A copper probe with a diameter of 6 mm and a height of 20 mm, inside which there is a copper-constant thermocouple and a nichrome spiral for heating, is filled with paraffin.

Errors depending on the accuracy of construction [5], instrument readings, and calculations are for the thermal diffusivity +5,5%, and thermal conductivity +7,5%. The thermal diffusivity increases with increasing moisture up to a certain point, after reaching which its value drops and the volumetric heat capacity increases linearly with increasing moisture. The change in the thermal diffusivity is first determined by the increase in the thermal conductivity, but when the value of the latter fades, approaching the thermal conductivity of water, the ratio with c=2 decreases. Consequently, the thermal diffusivity curve also falls.

The soil under consideration is heavily loamy and has a slow growth of thermal conductivity with increasing moisture. The quantitative values of the thermal conductivity coefficient for heavy loamy soils, other things being equal, are always lower than for light and medium loamy soils [3], which is confirmed by the measurement data in Figs. 3.

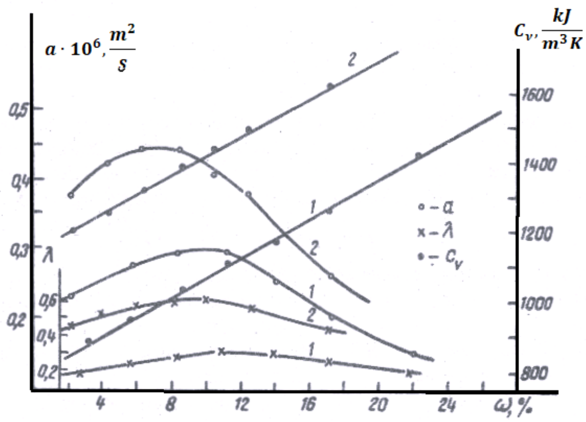

Fig. 3. Dependencies graph: $\alpha = f(\omega)$; $\lambda = \varphi(\omega)$; $c_v = \varphi(\omega)$

When determining the heat accumulation of the upper soil layer, values corresponding to a depth of 0-30 cm for the accumulation channels are needed. At a depth of *x = 0.5 m* [2], data are required for depths of 40-60 cm.

Errors depending on the accuracy of construction [6], instrument readings, and calculations are for the thermal diffusivity ±5,5%, and thermal conductivity ±7,5%.

In the studied heavy loamy soils under the same conditions, the thermal conductivity is always lower than in light and medium loamy soils [6,7,8], which is confirmed by the experiments carried out in Fig.3

Conclusion

We measured the thermophysical characteristics of greenhouse soil at a moisture content of 16-17% and obtained the following results:

x, cm	*ω, %*	*λ, Vt/mK*	$\alpha \cdot 10^6$ *m/s*	*kJ/m³·K*	*ρ, kg/ m³*
0-8	06	0.272	0.223	1244	1240
0-8	07	0.256	0.254	1270	1251
13-21	1	0.344	0.244	1402	1442
13-21	17	0.322	0.288	1430	1454
25-33	06	0.408	0.264	1525	1566
25-33	17	0.377	0.246	1555	1579

38-46	16	0.464	0.287	1507	0644
38-46	17	0.432	0.265	1638	1658
50-58	06	0.521	0.304	1669	1722
50-58	07	0493	0.282	1710	1736

Thus, it can be assumed that about the same amount of heat accumulates in the substrate layer of 0-30 cm, and with increasing, moisture, the thermal conductivity slowly grows.

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