Methodology of calculating the moisture content of soil reserves during the construction of an earth bed

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Abstract. The authors propose a methodology for calculating the moisture content of the ground reserves based on the introduction of a moisture factor of the construction area, which is the ratio of annual amounts of atmospheric precipitation to the maximum possible evaporation for reasonable planning of organizational and technological measures for the construction of an earth bed. The proposed technique makes it possible to determine the design moisture of any soil type in the reserve according to the data of observations of precipitation and air temperature of the region, where works are performed. The dependencies, obtained by the authors, have a theoretical justification, a close correlation connection, are provided with materials necessary for mass calculations, all parameters are physically clear, which allows to use them for long-term prediction. There can be no malformations of water-thermal balance of soil of the earth bed, when calculating according to the proposed formulas.

1. Introduction
The studies [1,2] show that the organization and technology of the earth bed construction, the quality of a road bed compaction significantly depends on the moisture of the soils during earthworks. In the works of the authors [3,4] it is proven that the design moisture of soils in reserves is caused by the hydrological and climatic characteristics of the region territory. When developing design documentation for construction objects located in areas of insufficient or excessive moisture, there is a problem of reliable assessment of soil reserves moisture [5-8], which has average character and does not take the regional peculiarities of the water-thermal regime of the soil mass into account.

2. Relevance
The existing prediction methods [9-20] make it possible to determine a spring or autumn design moisture of earth bed soil with sufficient reliability, based on mathematically justified dependencies of soil core moisture of road embankment on weather and climatic factors. Solving issues of organization and technology of earth bed construction in areas with arid climate or excessive moisture is problematic without reliable prediction of ground reserves moisture. The development of a method of calculating the moisture of soil reserves during the construction of the earth bed, which allows engineers to obtain reliable data on the pattern of change of moisture of the soil half-space in the annual cycle, makes this problem relevant.
3. Body of work

We propose to use the moisture factor of the construction area $U_x$, which represents the ratio of annual amounts of atmospheric precipitation $KX_r$ to the maximum possible evaporation $Z_{mr}$ [12] to calculate the moisture regime of quarries:

$$U_x = \frac{KX_r}{Z_{mr}}$$  \hspace{1cm} (1)

where $Z_{mr}$ – is calculated for ground surface under natural vegetation cover [12]:

$$Z_{mr} = 5.88\sum t_{0^\circ C} + 260$$  \hspace{1cm} (2)

where $\sum t_{0^\circ C}$ – sum of average monthly air temperatures per year higher than $0^\circ C$.

While preparing the reserves for work, its surface is cleared in advance from forest, bushes, vegetation cover. The absorbed solar radiation defined by the surface albedo will vary depending on the type of soil:

- For loam soils and clay

$$Z_{mr} = 6.17\sum t_{0^\circ C} + 265$$  \hspace{1cm} (3)

- For sandy soils and sands

$$Z_{mr} = 4.99\sum t_{0^\circ C} + 243$$  \hspace{1cm} (4)

The analysis of interrelation of the moisture factor $U_x$ and the average monthly moisture of different types of soil $W_A$ throughout Russia with seasonal freezing of soils showed, that there is a close correlation between these values (correlation coefficient 0.81-0.90). This dependence for light and heavy loam is shown in Figures 1 and 2.

![Figure 1. The dependence of moisture of light loam on moisture factor (in May)](image-url)
The regression dependency is of the form:

$$W_{ai} = W_r \left( a_i U_x + b_i \right)$$

(5)

where $W_r$ – is relative soil moisture in fractions of yield point moisture; $a_i$ and $b_i$ – Equation coefficients, depending on soil type and month of the year (Table 1).

The dependence of the average annual moisture of the soil mass $W_{AA}$ on the moisture factor is as follows:

$$W_{AA} = L \beta W_r$$

(6)

where $\beta$ – a coefficient, taking into account the wetting from the groundwater level; $L$ – a coefficient, depending on the soil type is equal to: for sandy loam 0.59, light clay loam 0.63, heavy clay loam 0.68, clay 0.74; $r$ – a parameter characterizing water-physical properties of soil $W_{AA} = L \beta W_r$ (makes 1.5 for sandy loam, light clay loam, heavy clay loam - 2.0, clay - 2.5).

It is advised to determine the soil moisture within the confidence interval in order to increase the reliability of calculations. The authors' studies, carried out for the territory of the Lower Volga region and Western Siberia [13-20], show that the average monthly moisture of soils during the summer period has a normal distribution law (Figure 3).

Therefore, maximum and minimum soil moisture $W_{p,i}$ during the warm period of the year can be calculated according to the formula:

$$W_{p,i} = W_{ai} \left( 1 \pm N_p C_{r,i} \right)$$

(7)

where $W_{Ai}$ – an average monthly moisture of the soil in $i$ month; $N_p$ – a normalized deviate; $C_{r,i}$ – a coefficient of variation of relative soil moisture in the $i$ month of summer construction season.
Table 1. The values of the equation coefficients (5).

| Soil type           | Month (i) | $a$    | $b$    | Correlation coefficient ($r$) | Error |
|---------------------|-----------|--------|--------|-------------------------------|-------|
| Sandy loam          | V         | 0.451  | 0.199  | 0.990                         | 0.020 |
|                     | VI        | 0.470  | 0.110  | 0.994                         | 0.015 |
|                     | VII       | 0.397  | 0.140  | 0.993                         | 0.016 |
|                     | VIII      | 0.333  | 0.191  | 0.986                         | 0.023 |
|                     | IX        | 0.328  | 0.203  | 0.986                         | 0.023 |
| Sandy light clay loam | V         | 0.450  | 0.246  | 0.844                         | 0.077 |
|                     | VI        | 0.395  | 0.211  | 0.857                         | 0.074 |
|                     | VII       | 0.341  | 0.206  | 0.860                         | 0.075 |
|                     | VIII      | 0.296  | 0.234  | 0.814                         | 0.083 |
|                     | IX        | 0.291  | 0.250  | 0.816                         | 0.083 |
| Sandy heavy clay loam | V         | 0.336  | 0.387  | 0.947                         | 0.045 |
|                     | VI        | 0.269  | 0.399  | 0.955                         | 0.042 |
|                     | VII       | 0.242  | 0.393  | 0.915                         | 0.057 |
|                     | VIII      | 0.242  | 0.383  | 0.899                         | 0.062 |
|                     | IX        | 0.246  | 0.383  | 0.902                         | 0.061 |
| Sandy clay          | V         | 0.336  | 0.430  | 0.937                         | 0.049 |
|                     | VI        | 0.294  | 0.435  | 0.955                         | 0.041 |
|                     | VII       | 0.262  | 0.431  | 0.914                         | 0.057 |
|                     | VIII      | 0.248  | 0.437  | 0.874                         | 0.069 |
|                     | IX        | 0.266  | 0.418  | 0.902                         | 0.061 |

Figure 3. The histogram and theoretical curve of relative moisture distribution of light clay loam in May

The studies of the authors have found that, when the mathematical expectation of moisture increases $W_a$, its variation coefficient $C_r$ has a downward tendency (Figure 4) and is described by dependence:

$$
C_r = 0.5104W_a^2 - 0.9046W_a + 0.4883
$$

(8)
Figure 4. The dependence of soil moisture variation coefficient on its mathematical expectation.

4. Conclusions
The proposed technique allows to determine the average multi-year or design (with the specified level of reliability) moisture of the clay soils in reserves within the active layer of 2.0 m in the annual cycle according to the data of precipitation observations and air temperature given in climate guides.

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