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The mathematical model accuracy estimation of the oil storage tank foundation soil moistening

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The mathematical model accuracy estimation of the oil storage tank foundation soil moistening

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Abstract. The oil storage tanks foundations preparation technologies improvement is the relevant objective which achievement will make possible to reduce the material costs and spent time for the foundation preparing while providing the required operational reliability. The laboratory research revealed the nature of sandy soil layer watering with a given amount of water. The obtained data made possible developing the sandy soil layer moistening mathematical model. The performed estimation of the oil storage tank foundation soil moistening mathematical model accuracy showed the experimental and theoretical results acceptable convergence.

Key-words: soil foundation, moistening, mathematical model, accuracy, tank

1. Introduction

Quality preparation during the soil foundation construction is one of the key factors to ensure the oil its refinery products storage vertical steel tank sustainability during the operating period [1]. The earlier researches revealed the soil moisture significant impact on its deformation properties [2]. The existing technologies for the tank soil foundation preparation include premoistening before compaction [3]. For choosing the compaction rational process parameters there is a need to develop the mathematical model of the tank foundation soil moistening with a limited amount of water. Obviously, the accepted mathematical model accuracy is required to be estimated for confirming its correctness.

2. Study subject

The study subject is the accuracy of the finite thickness sandy soil moistening with a given amount of water describing by the proposed mathematical model.

3. Experimental

Initially, the moistening laboratory studies of the medium sized sandy soil layer weighing 16 kg, placed into the specialized stand presented in figure 1A were carried out. Sandy soil layer thickness h=0.4 m is defined by the vertical steel tanks soil foundations construction existing technologies. The amount of water, applied for watering the sandy soil selected from the top, was calculated on the basis of the assumption of achieving the optimum moisture content of 11% and constituted 1.7 kg. The specialized stand design made possible the periodic soil sampling with a mass of 2÷3 g from the predetermined depths for the current humidity control. Soil samples humidity control was carried out by using the halogen moisture analyser HC103, in this case the soil samples mass measurement accuracy was 0.001 g. The obtained experimental results allowed estimating the medium sized sandy soil moistening character both over time and in the sample depth (figure 1B).

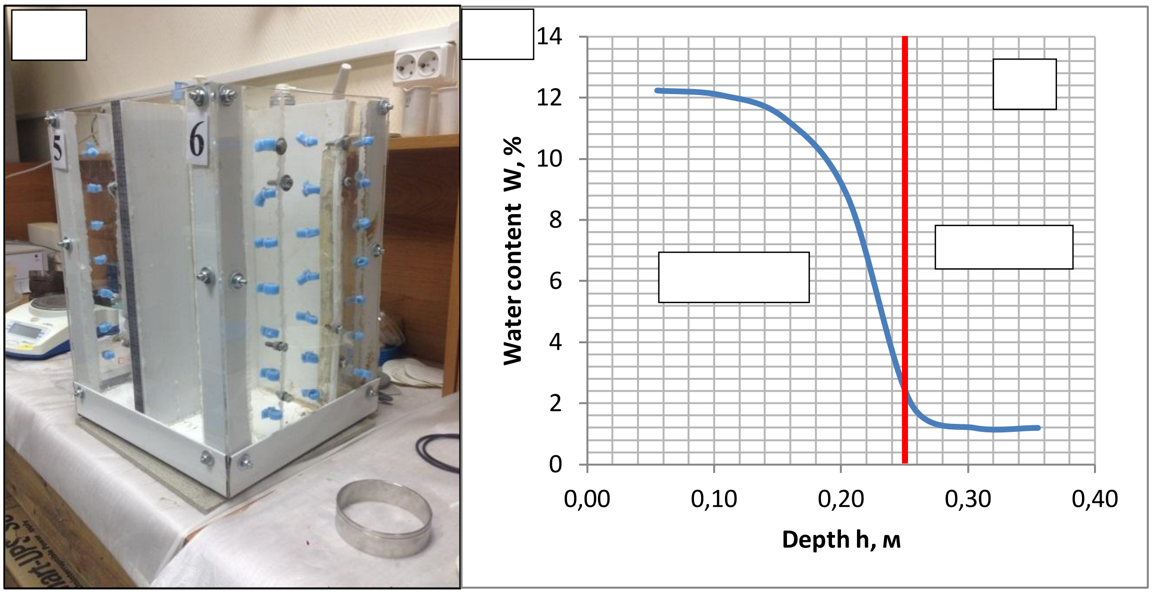

Figure 1. The specialized stand for the experiment (A); the sandy soil sample water content change in depth, 10 minutes after its moistening (B).

4. Theoretical studies

At the stage of theoretical studies, the obtained laboratory data analysis made it possible to identify two specific sections of the soil water content dependence *w* on the depth *h*: the wetted section (section I: depths are from 0 to h` (t), m) and the section with the initial water conent (section II: depths are from h` (t) to 0.04, m), where h` (t) is the humidity boundary depth variation over time. For section I approximation, the third degree polynomial is proposed to be used:

$$w = a_0 + a_1 * h + a_2 * h^2 + a_3 * h^3 \quad (1)$$

where *w* is the actual soil water content at the given depth *h*, u.f.; *h* is the given depth, m; a_0, a_1, a_2, a_3 are the coefficients defined in accordance with the experimental results.
The proposed mathematical model coefficients of the previously performed laboratory studies were determined by the least squares method (table 1).

Table 1. The laboratory data processing.

Depth h, m	Experimental moisture w, %	Mathematical model coefficients	
0.055	12.2	a_0	14.704
0.105	12.1	a_1	-808.393
0.155	11.3	a_2	80961.430
0.205	8.8	a_3	-2726667
0.255	1.5		

5. Results discussion

At the final stage of the studies for confirming the proposed mathematical model correctness (1), its accuracy was estimated. The obtained laboratory data statistical analysis has shown that the carried out measurements error is properly described by the normal distribution law. The humidity experimental values normal distribution hypothesis was tested according to the Pearson chi-square test with 95% confidence level, the Pearson test calculated value is $\chi_p^2 = 17.9$ which is less than the accepted theoretical value of $\chi_m^2 = 25.0$ [4]. Thus, the finite thickness sandy soil layer wetting with a given amount of water is proposed to be described by the following dependence:

$$w = 14.704 - 808.393 * h + 80961.430 * h^2 - 272667 * h^3,\ at\, h < h`. \quad (2)$$

For identifying the water content determination absolute error, the mathematical model adequacy dispersion S_{ad}^2 of the oil storage tank foundation soil watering is necessary to be calculated. The mathematical model adequacy dispersion is determined by the formula (3) [6]:

$$S_{ad}^2 = \frac{m}{N-l} \cdot \sum_{i=1}^{N} (\overline{y_i} - \hat{y}_i)^2 \quad (3)$$

Where m is the concurrent experiments quantity;
N is the number of units;
$\overline{y_i}$ is the average value of the output quantity;
$\hat{y}_i$ is the investigated object regression equation value including the statistically significant coefficients;
l is the significant coefficients number defined as a result of the conducted experiments N.
The soil moisture specifying absolute error can be determined in accordance with the proposed mathematical model by using the following equation [5, 6]:

$$\Delta = 2 \cdot \sqrt{\frac{S_{ad}^2}{F_T}} = 2 \cdot \sqrt{\frac{0.038}{7.71}} = 0.13 \quad (4)$$

where the theoretical F-test F_T with 95 % confidence level for the third-degree polynomial is F_T=7.71.

6. Conclusions

The increased requirements for the oil storage tanks sandy foundation preparation quality needs the the soil premoistening technology improvement. The tank foundation preparation quality is influenced by factors such as the moistened layer thickness, required water amount and time needed for achieving the optimum water content by the sandy soil layer. The preparation process rational parameters choice could reduce the material costs and spent time for the planned work performance. To solve this problem, the oil storage tank foundation sandy soil finite layer wetting mathematical model with the given amount of water to the final water content required values is suggested to be used. The conducted laboratory studies showed that the sandy soil moistening with a given amount of water has a complex, non-linear nature. Based on the results of laboratory data processing, the sandy soil moistening mathematical model was proposed and suggested mathematical model using error was estimated.
The oil storage tank foundation soil moistening proposed mathematical model presented by the third degree polynomial makes it possible to calculate the humidity dependence on the soil depth at the soil depth of less than 0.3 m, with the absolute error of 0.13% and 95% confidence level.

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