CHARACTERISTICS OF THE DETERMINATION OF THE PHYSICAL PROPERTIES OF GYPSUM SOILS

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UDC 624.131.43:624.131.29

The prevention of deformations in the bases of buildings and structures, which frequently lead to failure, is one of the most important problems of modern construction.

For reliable design of gypsum soil bases, it is necessary to have at one's disposal methods of reliable determination of their physicomechanical characteristics and of prediction of the possible changes in these characteristics during the desalination process.

The presence, in the soil, of crystalline gypsum possessing special physicochemical properties, which differ sharply from the properties of other minerals of the soil, complicates the determination of the water content, the specific gravity of the particles, the grain-size distribution, and consequently, other characteristics connected with them.

As shown by the analysis of previous investigations [1, 2], and also by the results of special water-content determinations carried out by the writer for soils having different gypsum contents, the drying temperature of 80 ±2°C adopted in the current norms (GOST 5180-75) is insufficiently substantiated, since the possibility of liberation of crystallized water from the gypsum composition is not excluded. It is well known that the temperature of start of conversion of calcium hydrate ($CaSO_4 \cdot 2H_2O$) into semiwater gypsum is 80-90°C. However, as shown by some investigations [1], the temperature depends on the gypsum dispersion, the mineralogical composition of the soil, and the organic inclusions, and can be below the above-mentioned value. Thus, for instance, the temperature of start of conversion of gypsum into semiwater gypsum for the white earths of Erevan, which contain from 5 to 47% of gypsum and occur in the air-dried state (Fig. 1), is 65-70°C. From Fig. 1 it is seen that full conversion of $CaSO_4 \cdot 2H_2O$ into $CaSO_4 \cdot 0.5H_2O$ is completed for all practical purposes when $t = 140°C$, and the water content due to the liberated crystallized water for $t = 80°C$ varies between 0.04 and 0.12.

From the above considerations it follows that in the determination of the water content of gypsum soil for $t = 80 \pm 2°C$, significant uncontrollable errors are possible as a result of gypsum dehydration.

Using the experimental relation [2]

$$W_h = 1.23\, W_h^{60},$$

the writer obtained the following equation for calculation of the water content W of gypsum soil, based on data determined by drying at a temperature of 60 ±2°C.

$$W = W^{60}\, \frac{1 + 1.23\, W_h^{60}}{1 + W_h^{60}} + \frac{0.23\, W_h^{60}}{1 + W_h^{60}}, \qquad (1)$$

in which W_h is the hygroscopic water content of nongypsum sands and clays; W_h^{60}, hygroscopic water content determined for $t = 60 \pm 2°C$; W, calculated value of the water content of the gypsum soil corresponding to the water content determined for $t = 105 \pm 2°C$ under conditions excluding liberation of crystallized water; and W^{60} is the water content of the soil for $t = 06 \pm 2°C$.

Since the hygroscopic water content of the soils varies within narrow limits and amounts to 0.01-0.02 for sands and to 0.03-0.04 for most clays, the following equation can be used, with sufficient accuracy, instead of Eq. (1), for sands

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ArmNIISA Institute of the Government Committee for Construction (Gosstroi) of the Armenian SSR. Translated from Osnovaniya, Fundamenty i Mekhanika Gruntov, No. 1, pp. 20-21, January-February, 1986.

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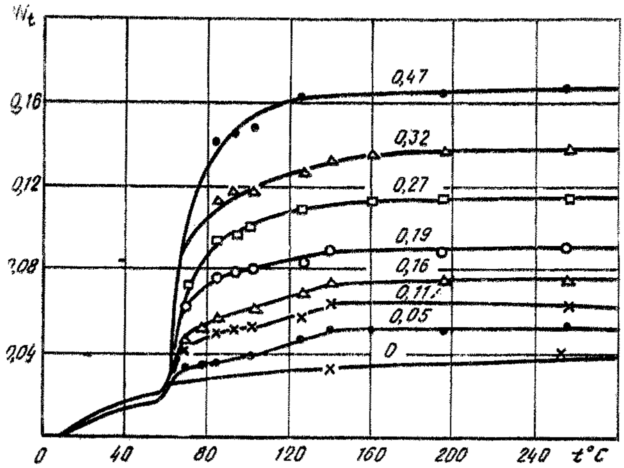

Fig. 1. Relation between water content W_t of gypsum soil and drying temperature t for specimens having different gypsum contents d (from 0 to 47%).

$$W_{\text{sand}} = W^{60}\,1.003 + 0.003,$$

and the following equation can be used for clays

$$W_{\text{clay}} = W^{60}\,1.007 + 0.007.$$

From these relations it is evident that even if the corrections are disregarded, the errors are insignificant (less than 1%). This indicates the high accuracy of this method of determining the water content for t = 60°C.

An important characteristic of gypsum soils is the variation of their physicomechanical properties under seepage desalination. If for ordinary soils the mass of solid particles is assumed to be constant, for gypsum soils the mass of solid particles per unit volume varies in conditions of absence of volumetric strains under desalination. Moreover, the specific gravity of the gypsum soil particles increases under desalination, since the specific gravity of the gypsum particles ($\gamma_s^g = 2.32$ g/cm^3) is significantly lower than the specific gravity of the other minerals in the soil. This phenomenon must be taken into account for design of gypsum soil bases.

For determination of the physical characteristics of a gypsum soil with any degree of desalination it is necessary to know the laws of their variation. From analytical computations, the writer obtained the following equation for determining the variations in the specific gravity of the gypsum soil particles during the desalination process.

$$\gamma_{st} = \frac{\gamma_{s_0}\,\gamma_s^g(1-d_0)}{\gamma_s^g(1-d_t) - \gamma_{s_0}(d_0-d_t)}\,, \tag{2}$$

in which γ_{st}, γ_{s_0}, and γ_s^g are the specific gravities of the soil particles during the desalination process and before desalination, and of the gypsum particles, respectively; d_0 is the initial gypsum content (ratio of gypsum mass in soil to dry soil mass before desalination); and d_t is the current gypsum content (ratio of remaining quantity of gypsum in the soil to dry soil mass after the given degree of desalination).

From Eq. (2) it is easy to obtain an expression for calculating the initial specific gravity γ_{s_0} of the gypsum soil by determining the specific gravity $\gamma_{s\,\text{fin}}$ of the particles under full desalination conditions:

$$\gamma_{s_0} = \frac{\gamma_{s\,\text{fin}}\,\gamma_s^g}{d_0\,\gamma_{s\,\text{fin}} + \gamma_s^g(1-d_0)}\,. \tag{3}$$

As shown by investigations of clay gypsum soils (ordinary and sandy loams) of different regions of the USSR, the specific gravity of the particles after complete leaching is $\gamma_{s\,\mathrm{fin}} = 2.72\text{–}2.74$ g/cm^3. Using this, we obtain

$$\gamma_{s_0} = \frac{6.33}{0.41\, d_0 + 2.32}. \tag{4}$$

Equation (4) confirms the emprical relation $\gamma_{s_0} = 2.65 - 0.02\, d_0$ previously obtained by M. N. Terletskaya [3].

However, from Eq. (4) an inversely proportional relation between the specific gravity of the particles and the gypsum content ensues, whereas in Terletskaya's equation this relation is linear. Moreover, the last-mentioned equation does not satisfy the boundary conditions $d_0 = 1$ and 0.

Thus, Eq. (4) makes it possible to determine with sufficient accuracy the specific gravity of the particles of clay gypsum soils, if their initial gypsum content is known.

One of the most important indices which determine the mechanical properties of soils is the compactness. For gypsum soils this characteristic assumes special importance since there is a direct relation between the compactness and the mechanical characteristics of the soils. Furthermore, the compactness determines the soil permeability, which is undoubtedly the chief parameter of seepage desalination.

As a result of removal of solid particles under desalination, the variation of the void ratio of gypsum soils is of a complex nature and is described by the expression

$$e_t = \frac{(e_0 + 1)\,(1 - \theta)}{1 - \dfrac{\gamma_{s_0}\,(d_0 - d_t)}{\gamma_s^g\,(1 - d_t)}} - 1, \tag{5}$$

where e_t is the void ratio during desalination; e_0 is the initial void ratio; and θ represents the volumetric strains during desalination.

Under conditions excluding the possibility of desalination ($d_0 = d_t$), and for $d_0 = d_t = 0$, Eq. (5) takes the well known form of the relation between the void ratio and the volumetric strain for ordinary soils

$$e = e_0 - (1 - e_0)\,\theta. \tag{6}$$

All the obtained relations have been experimentally confirmed. Hence, their use can be recommended both for determining the physicomechanical properties of gypsum soils and for analyzing bases under suffosion leaching.

Based on analytical and experimental investigations, as well as on analysis of existing data, an equation has been obtained for determining the water content of gypsum soils which eliminates the inaccuracy that occurs, due to the gypsum dehydration, when the water content is determined by the procedure of the GOST 5180-75 Norms. Relations for the variation of the specific gravity of the particles and the void ratio of gypsum soils during the desalination process have been obtained also.

LITERATURE CITED

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