PRACTICAL METHOD FOR CALCULATING CREEP OF FOUNDATIONS OF HYDRAULIC STRUCTURES

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In conformity with the construction specifications and regulations SNiP II-16-76, to calculate foundations with respect to deformations it is necessary to know not only the conditionally instantaneous (elastoplastic) deformation but also the deformation with time. Determination of these deformations is complicated by the fact that consolidation due to seepage and creep occur simultaneously [1, 2].

Below is presented an approximate method for use in practical calculations in which the total displacement (settlement and horizontal movement) is regarded as the sum of the conditionally instantaneous elastic displacement and displacement due to creep. This approach is based on the fact that if we look at settlement in time [3] we can note a discontinuity in the curve of the settlements of structures \( \approx 2 \) years (in compact clays) after completion of construction (Fig. 1). Ter-Martirosyan [2] suggests that this discontinuity occurs at the time of dissipation of the pore pressure. The discussion in the present article pertains to calculation of creep beyond the point of discontinuity (stage of operation).

To describe creep shear strains an equation of viscoplastic flow is used in [2] and an equation based on flow theory is used in [4]. In another method [5, 6] the calculated parameter when describing shear strains and consolidation deformations during operation is the variable viscosity coefficient [5, 6], taken according to the Maslov–Perzots formula.

On the basis of the data from field observations and experimental investigations for the stage of operation after dissipation of the pore pressure at a consistency of clays \( B < 0.5 \) we can use the unified theory of viscoplastic flow both for the creep shear strains and for the consolidation deformations. In this case the calculated displacement as obtained from the effect of the total tangential stress \( \tau_c \) should be reduced by the coefficient \( (\tau_c - \tau_{lim-c})/\tau_c \) (\( \tau_c \) is the total contact stress; \( \tau_{lim-c} \) is the creep threshold of the soil at the contact of the structure with the foundation). In the presence of considerable expansion of the foundation after excavating the pit such correction need not be introduced.

A constant (averaged) viscosity coefficient can be taken over a short time interval \( \Delta t \), which corresponds to a model of a perfectly viscous medium or secondary creep. With the use of this model and also the theory of the strain rate tensor [7], the determination of creep in interval \( \Delta t \) can be reduced to a solution of the conditionally elastic problem by computer, but with replacement of strain by the strain rate and the shear modulus by the viscosity coefficient [8]. For conditions of plane strain in time interval \( \Delta t \) during the operating period the following relations are used:

a) equations of equilibrium

\[
\begin{align*}
\frac{\partial \varepsilon_x}{\partial x} + \frac{\partial \varepsilon_y}{\partial y} &= 0; \\
\frac{\partial \varepsilon_x}{\partial x} + \frac{\partial \varepsilon_y}{\partial y} + p &= 0;
\end{align*}
\]

b) equation of continuity of the strain rates

\[
\frac{\partial \varepsilon_x}{\partial y^2} + \frac{\partial \varepsilon_y}{\partial x} = \frac{\partial \gamma_{xy}}{\partial x}.
\]

c) physical equations

\[
\begin{align*}
\sigma_x - \varepsilon_{xy} &= 2 \mu (\varepsilon_x - \varepsilon_{xy}); \\
\sigma_y - \varepsilon_{xy} &= 2 \mu (\varepsilon_y - \varepsilon_{xy}); \\
\tau_{xy} &= \mu \gamma_{xy};
\end{align*}
\]

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Fig. 1. Graphs of the load (a) and settlements (b) for section No. 8 of the powerhouse of the Volga–Lenin hydroelectric station.

Fig. 2. Diagrams illustrating the calculation of settlements (a) and displacements (b) of structures with time.

here

\[ \dot{\varepsilon}_v = \frac{1}{3} (\varepsilon_x + \varepsilon_y + \varepsilon_Z); \]

\[ \dot{\varepsilon}_s = \frac{1}{3} (\varepsilon_x + \varepsilon_y - \varepsilon_Z); \]

\[ \eta_i = \frac{\eta_0}{2 (1 + \mu_s)}; \]

\[ \dot{\eta}_i = \frac{\eta_0}{\eta_i}; \]

\[ \eta_i \text{ is the viscosity coefficient; } \eta_0 \text{ is the average compressive viscosity coefficient (according to E. F. Vinokurov, linear viscosity) during time } \Delta t. \]

The rate of change of volume strain will be expressed so:

\[ \dot{\varepsilon}_v = \frac{3(1 - 2\mu_s)}{\eta_i} \dot{\varepsilon}_v; \]

\[ \dot{\varepsilon}_s = \dot{\varepsilon}_v; \]

here the dot denotes a partial derivative with respect to time.

Equations (1)-(3) can be solved by means of available computer programs with the replacement of \( \varepsilon \) by \( \varepsilon \) and \( G_i \) by \( \eta_i \) in time intervals \( \Delta t \), taking in this time interval the average value of the viscosity coefficient \( \eta_i \) and in the remaining intervals the viscosity coefficient according to the Maslov–Perzots formula.

As a result of solving Eqs. (1)-(3) the rates of settlements \( \dot{S} \) and horizontal displacements \( u \) are obtained. The settlement and displacement of the structure, respectively, will be determined by the following equations:

\[ S_i = \int \dot{S} \, dt - \sum_{1}^{n} \dot{S} \, dt; \]

\[ u = \sum_{1}^{n} \dot{u} \, dt. \]