Consolidation under Special Load Condition

Consolidation sous Condition de Charge Spéciale

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Summary

This paper is the description of a consolidation process by which the loads under the foundation surfaces vary continually between two limit values. It seems to be, but is not, an interpolation, because the load variation takes place in infinite time. So, the variation law of total pressure at any point of the soil is assumed to be linear with the amount of effective pressure, in order to make this process suitable as a solution for settlement problems when loads are reactions of continuous beams or associated rigid frames.

Sommaire

Ce rapport décrit le processus de consolidation qui se produit quand les charges qui s'exercent sur la fondation varient d'une façon continue entre deux valeurs. Il ne s'agit pas, contrairement à ce que l'on pourrait penser, d'une interpolation, car la variation de la charge s'effectue en un temps infini. La loi de variation de la contrainte totale, en tous points du sol, est supposée être une fonction linéaire de la contrainte effective, afin que cette méthode puisse s'appliquer au problème des tassements, sous les appuis des poutres continues ou d'assemblages de cadres rigides.

The processes of consolidation are studied through the variation of the load or the pressure applied on the surface of the clay. All of them are presented as an analytical function of time t as independent variable.

The variation of load is considered with the progress of construction in its initial phases when the load is increasing, but it becomes constant at the end.

The possibilities of load variation depend not only on the increase in load during construction but sometimes are related to the structural rigidity. This effect is recognized by structural engineers in designing problems of continuous structures resting on elastic soils. The support reactions are variables by transference of load when settlements take place.

The correlated consolidation theoretical problem has been considered as very difficult to solve by FADUM (1948) but I have myself presented the solution for a particular case (SILVEIRA, 1948) and CHAMECK (1955) obtained the values for total settlements.

The knowledge of the total settlement makes possible the determination of variation of the reactions and so it is possible to know the total pressure during the consolidation process on the basis of some interpolation criteria.

The difference between initial and end value of pressure must become zero with time, which may be infinite. However, the assumptions concerning the elasticity of a structure permit it to be considered through an intermediate variable—the effective pressure—on which depends the settlement.

The condition assumed must at least be true for the vertical load and it is true if we consider:

$$p_t = p_0 - (p_0 - p_1)p_e/p_1 \quad \ldots\ (1)$$

where p_t is the total pressure at time t; p_0 is the same at $t = 0$ and p_1 is at $t = \infty$, and p_e is the effective pressure for any point (x, y, z) of the clay mass.

As at any time the total pressure is the sum of effective pressure p_e and the excess pore water pressure w_t:

$$p_t = p_e + w_t \quad \ldots\ (2)$$

From equations 1 and 2 results:

$$w_t = p_0(1 - p_e/p_1) \quad \ldots\ (3)$$

The derivative with respect to time t is:

$$\frac{\partial w_t}{\partial t} = -\frac{p_0}{p_1}\frac{\partial p_e}{\partial t} \quad \ldots\ (4)$$

By the theory of consolidation it is possible to relate the variation of effective pressure to the one of porosity:

$$-\frac{1}{m_v}\frac{\partial n}{\partial t} = \frac{\partial p_e}{\partial t} = \frac{p_1}{p_0}\frac{\partial w_t}{\partial t} \quad \ldots\ (5)$$

The same theory shows that the variation of porosity with time (TSCHEBOTARIOFF, 1951) is equal to the variation of velocity with the depth z in one-dimensional flow:

$$-\frac{\partial n}{\partial t} = \frac{\partial v_z}{\partial z} = -\frac{k_w \partial^2 w_t}{\gamma_w \partial z^2} \quad \ldots\ (6)$$

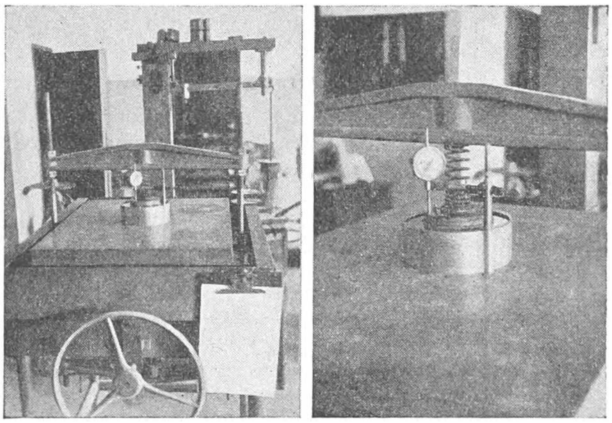

Fig. 1 Photographs of the loading device used in the experiments. The consolidation cell is on the scale of a triaxial testing machine and one micrometer dial can be seen ready for settlement measurements

Photo de l'appareil de chargement employé pour les essais. La cellule de consolidation est à l'échelle de l'appareil de compression triaxiale et on peut voir le cadran du micromètre pour la mesure du tassement

From equations 5 and 6 results:

$$\frac{\partial w_t}{\partial t} = \frac{k_w}{m_v \gamma_w}\frac{p_0}{p_1}\frac{\partial^2 w_t}{\partial z^2} \quad \ldots\ (7)$$

This is the consolidation equation for variable load. It is very similar to the classical equation of consolidation for one-dimensional flow (TERZAGHI and FRÖHLICH, 1936) if the consolidation coefficient C_v is assumed to be corrected by the factor p_0/p_1 that relates the load variation as a consequence of

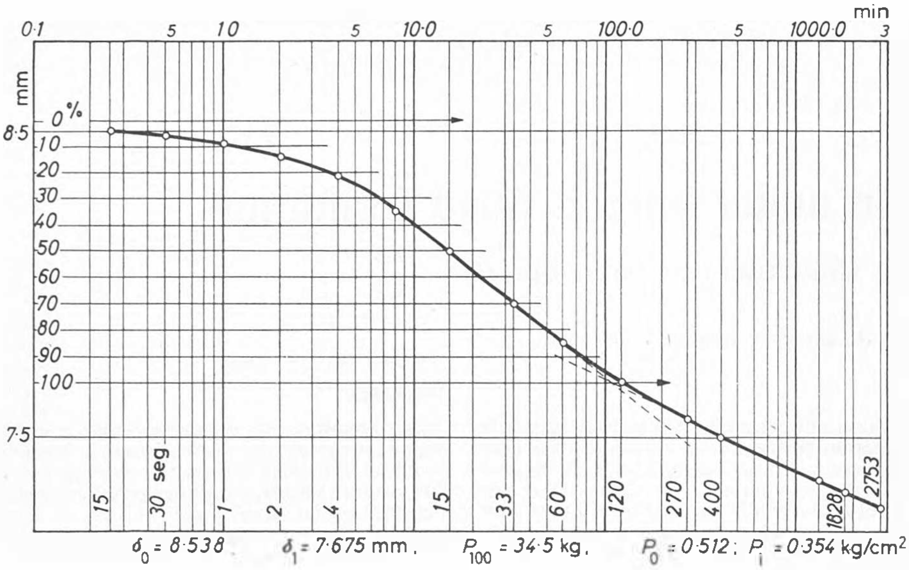

Fig. 2 Consolidation curve obtained in log t plotting does not differ from the usual consolidation curve, and the common methods (Lambe, 1951) can be used to determine C. The correction for C' is based on settlement and the spring constant for 100 per cent consolidation

Courbe de consolidation en fonction de log t. Cette courbe ne diffère pas de la courbe habituelle de consolidation, et les mêmes méthodes (Lambe, 1951) peuvent être employées pour déterminer C. En ce qui concerne C' sa correction est basée sur le tassement et la constante correspondant à 100 pour cent de consolidation

the settlement itself. So the new consolidation factor C'_v is obtained:

$$C'_v = C_v(p_0/p_1) \quad \ldots . (8)$$

This is very important because it is clear that the solutions of Terzaghi and Fröhlich are suitable for this process of consolidation, and tables and graphs can be worked out if the new coefficient C'_v, is considered instead of C_v. For many cases of one-, two- and three-dimensional flow it is a one only correction in the factor time:

$$T' = T(p_0/p_1) \quad \ldots . (9)$$

Important conclusions to this consolidation process are obtained from equations 8 and 9 and must be emphasized:

(1) The graphs of time *versus* settlements are of the same

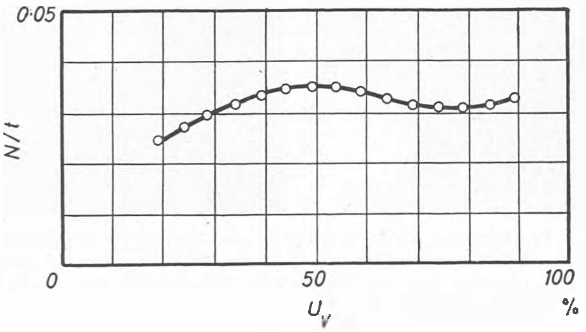

Fig. 3 N/t values plotted against U_v per cent; a graphical form to compare theory and practice

Valeurs N/t par rapport à U_v pour cent. Graphique permettant la comparaison entre la théorie et la pratique

shape as obtained through constant load. The variation of load produces only a variation of the consolidation coefficient. A test was made experimentally using a spring model (Fig. 1) of the structure to load the piston of the consolidation cell. Loads were applied suddenly in a triaxial scale device P_0, after which the scale was fixed but the spring could relax with settlement. The curves using $\sqrt{t}$ or log t give different conventional 100 per cent consolidation, so the end loads (P_1) are different (Fig. 2), because they depend on the spring deformation ($\delta_0 - \delta_1$) for the load increment.

The agreement between theoretical and experimental curves was examined through T_v/t or N/t values plotted *versus* U_v (Fig. 3). The t values were obtained from experimental curves. The constant T/t in this curve represents a perfect agreement of theory and practice. Little discrepancy was obtained when U varied from 30 to 90 per cent.

(2) The variation of load has no interference with the geometric boundary conditions and the general consolidation equation for isotropic soil can be written in terms of the Laplace operator (∇):

$$C' \nabla^2 w_t = \frac{\partial w_t}{\partial t} \quad \ldots . (10)$$

(3) The variation of Poisson's ratio (μ) could not be observed in consolidation curves, if its variation is linear with the increasing of the effective pressure but producing the difference between initial excess pore water pressure and grain to grain end pressure.

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