Electrical Analogy Equipment for Solving Non-stationary Two-dimensional Flow Problems

Équipement pour Essais par Analogie Électrique pour la Résolution des Problèmes Relatifs aux Courants Non-stationnaires à Deux Dimensions

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Summary

A description is given of an electrical equipment for solving non-stationary two-dimensional flow problems. This equipment consists of about 400 capacitors, connected in an electrical resistance network.

When the characteristic soil constants are known, the equipment can be used to solve various kinds of problems, such as consolidation processes and pore pressures in foundation and earth dams.

It is shown how the equipment was employed for determining the pore pressures in two actual dams.

Sommaire

Le présent rapport est une description d'un équipement pour la résolution par analogie électrique des problèmes relatifs aux courants non-stationnaires à deux dimensions. Cet équipement comprend environ 400 condensateurs insérés dans un réseau de résistances électriques.

Quand les constantes caractéristiques du sol sont connues, on peut utiliser cet équipement pour résoudre divers genres de problèmes, tels que les processus de consolidation et les pressions interstitielles dans les fondations et les barrages en terre.

Les auteurs décrivent l'application de l'équipement pour essais par analogie électrique à la détermination des pressions interstitielles dans un barrage existant et un autre barrage, qui est en cours de construction.

In many problems concerning the consolidation and the stability of earth dams it is necessary to determine the magnitude of the changes in pore pressure resulting from variations in overload or head water pressure. The calculation of the pore pressures under non-stationary conditions is by mathematical methods which are very difficult and time wasting, particularly when different cases are to be investigated.

Fig. 1 The electrical analogy equipment
L'équipement pour essais par analogie électrique

For this reason an electrical analogy equipment has been designed and constructed at the Swedish State Power Board. When the characteristic soil constants are known, this equipment can be used to solve various kinds of problems, such as (1) consolidation processes in foundations and earth dams during and after construction; (2) comparative study of consolidation and pore pressure in dams of various design; (3) effect of filter layers in homogeneous dams; and (4) changes of pore pressure during damming-up and during draw-down.

The analogy equipment, shown in Fig. 1, consists of about 400 capacitors which are inserted in an electric resistance network. The capacitors are connected to relays which are automatically controlled by an electric stop watch. A special voltmeter was constructed for measuring the charge of the capacitors.

By means of this equipment the pore pressure u at the time t can be determined in the following equation for the two-dimensional process of consolidation

$$\frac{\partial u}{\partial t} = c_v\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2}\right)$$

where c_v is the coefficient of consolidation. The value of this coefficient is obtained from triaxial consolidation tests.

For the use of the equipment in studying consolidation processes, the effect of the weight and potential of water must be taken into account. In such cases a linearly decreasing voltage is applied to the network.

The consolidation process, which may go on during several months or years in earth embankments, takes less than a second in the analogy equipment. The time of consolidation can be regulated by the electric stop watch, which has a precision of 0·01 sec. This makes it also possible to study the consolidation process step by step.

An account is given of some actual cases which have been studied by means of the analogy equipment. Fig. 3 shows a homogeneous earth dam which was built at Ransaren in the years 1954–55. The wet-fill method was used in the construction. The fill consisted of a silty moraine with a permeability of about 3×10^{-7} cm/sec., and the wet density varied within the limits from 2·2 to 2·3 kg/dm³ (136 to 142 lb./cu. ft.). Fig. 3 shows the lines for equal pore pressure measured with the aid of the analogy equipment in two cases: (a) after first season construction; and (b) after a draw-down of 9 m at a rate of 0·2 m per 24 hours.

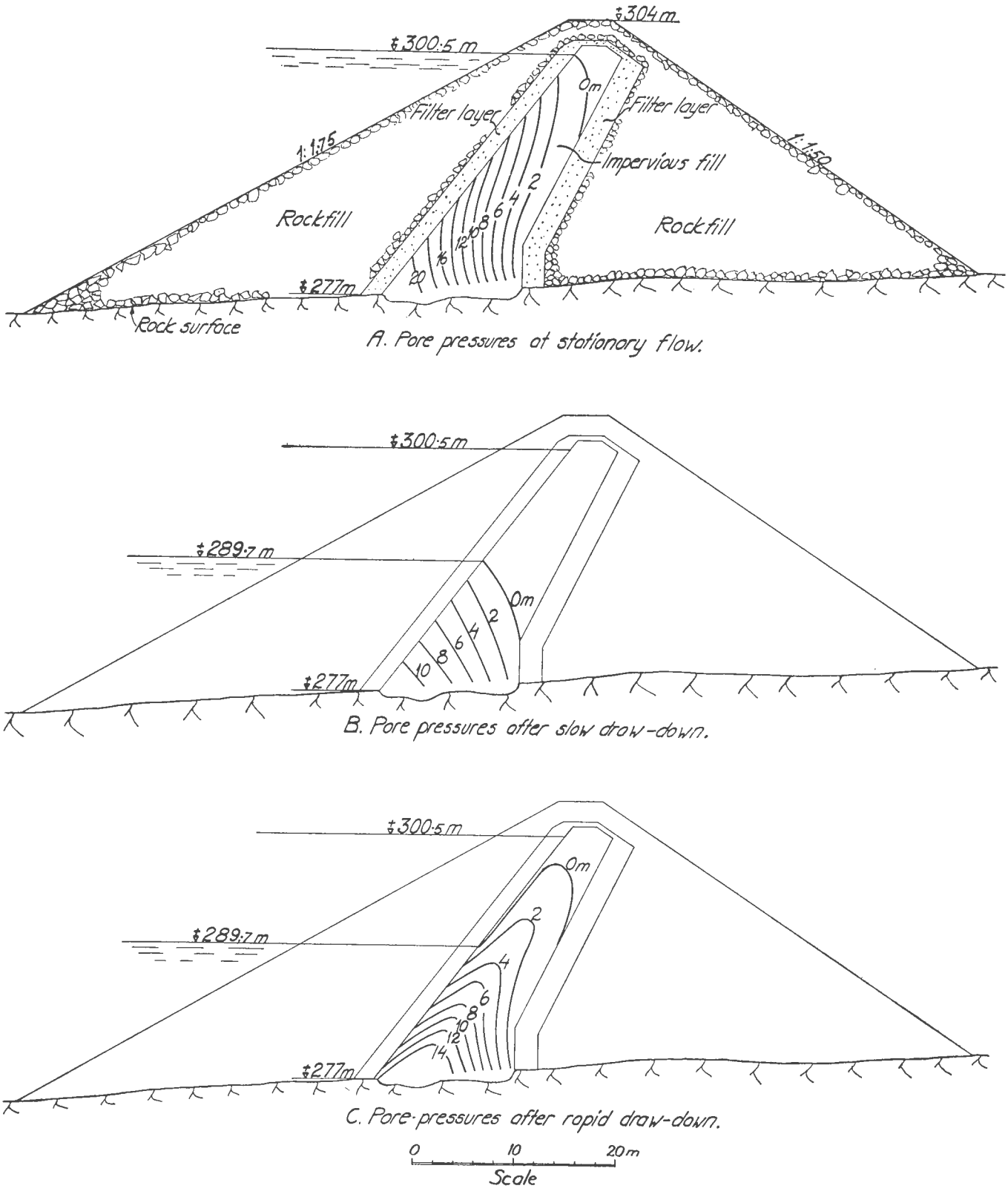

Fig. 2 The earth dam at Grundfors. Pore pressures determined by means of the analogy equipment
Le barrage en terre à Grundfors (Suède). Les pressions interstitielles déterminées au moyen de l'équipement pour essais par analogie électrique

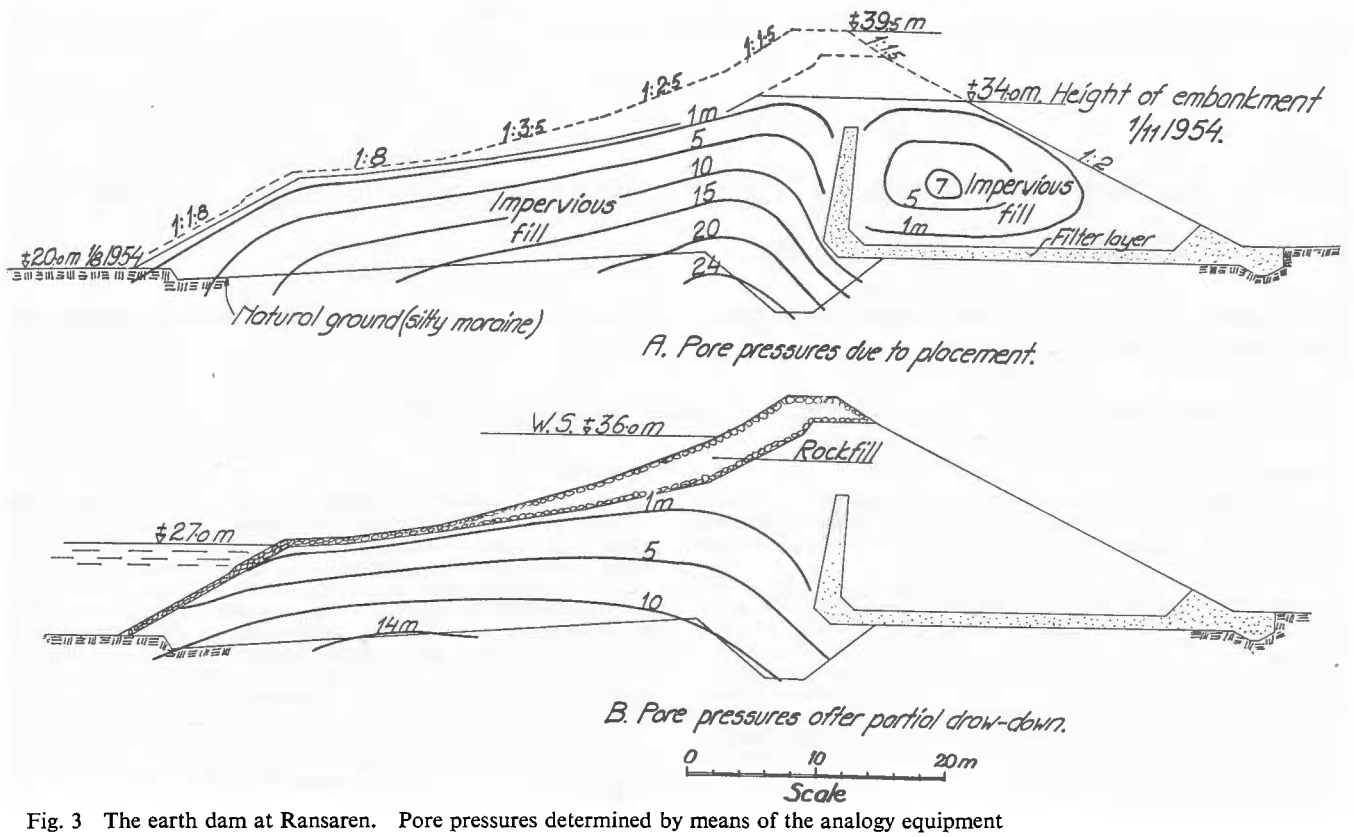

Fig. 3 The earth dam at Ransaren. Pore pressures determined by means of the analogy equipment
Le barrage en terre à Ransaren (Suède). Les pressions interstitielles déterminées au moyen de l'équipement pour essais par analogie électrique

The earth dams in Sweden are often constructed with rockfill and an impervious moraine zone. Fig. 2 shows such a dam which is now under construction at Grundfors. The moraine in the impervious zone has a permeability of about 3×10^{-6} cm/sec. and the wet density is about 2·2 kg/dm^3 (136 lb./cu. ft.). In Fig. 2 the lines for equal pore pressure are shown in the following three cases: (A) the stationary flow after damming; (B) after a slow draw-down of 10·8 m at a rate of 0·5 m per 24 hours; and (C) after a rapid draw-down of 10·8 m in 8 hours.

The coefficients of consolidation were obtained from triaxial consolidation tests, which were made with regard to the different conditions in cases A, B and C.

The analogy equipment was designed and constructed by C. E. Rolf Nilsson under the supervision of Dr B. Löfquist at the Swedish State Power Board: the authors are grateful to him for many helpful discussions during the work.