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I e 18

THE EXTREME INCLINATION OF SLOPES WITH GROUND WATER PASSING THROUGH THEM 1). 2)

WALTER BERNATZIK
Innsbruck, Austria

The slope of an accumulation of cohesionless material reaches the limit of its stability as soon as its inclination to the horizontal forms an angle of ρ and an angle of $90^\circ - \rho$ is reached with the vertical, whereby ρ represents the angle of interior friction within the aforesaid material. As soon as the slope is subjected to the in- or outflow of groundwater, the limit of its inclination is either reduced or increased. If, therefore, a new field of flow-pressure is superimposed over the field of gravitation which acts vertically, the extreme inclination of the new slope must again form an angle of $90^\circ - \rho$ with the direction of the resulting field. 3)

Extreme inclinations of slopes formed by sand have been tested and examined by the author with the help of a contrivance which is shown in diagram by fig. 1. For the horizontal slope the corresponding flow pressures were found in accordance to Terzaghi's irruption equation.By transporting the flow pressures found from pole O according to their size and direction (see fig. 1 and 2 respectively) we find that their ends are situated on a circular line (the so-called "slope circle").

Conditions are shown by fig. 3. At a given inclination of the slope the maximal flow pressure, providing it is vertical to the slope,is calculated as follows:

$$p = \frac{\gamma_R}{\sin\rho} - \sin\ (\rho - \beta) \qquad (1)$$

and if parallel to the slope

$$p_p = \frac{\gamma_R}{\cos\rho} - \sin\ (\rho - \beta) \qquad (2)$$

whereby γ_R is the weight per unit of volume of the material under water, ρ is its friction angle, and β the inclination of the slope to the horizontal.
Flow pressure that is vertical to the slope takes effect under water in the case of outflowing groundwater, whilst if parallel to the slope, it is encountered whereever the slope

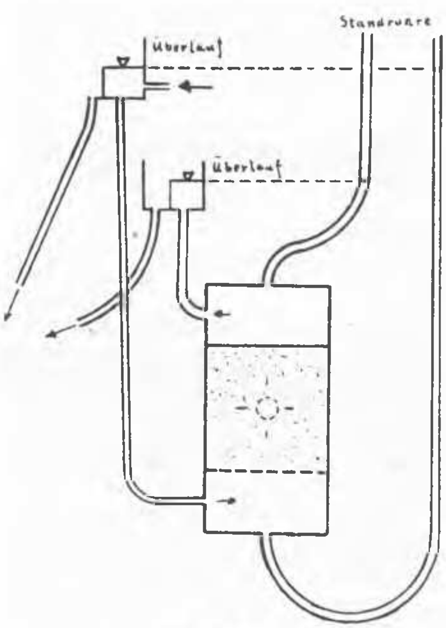

FIG. 1

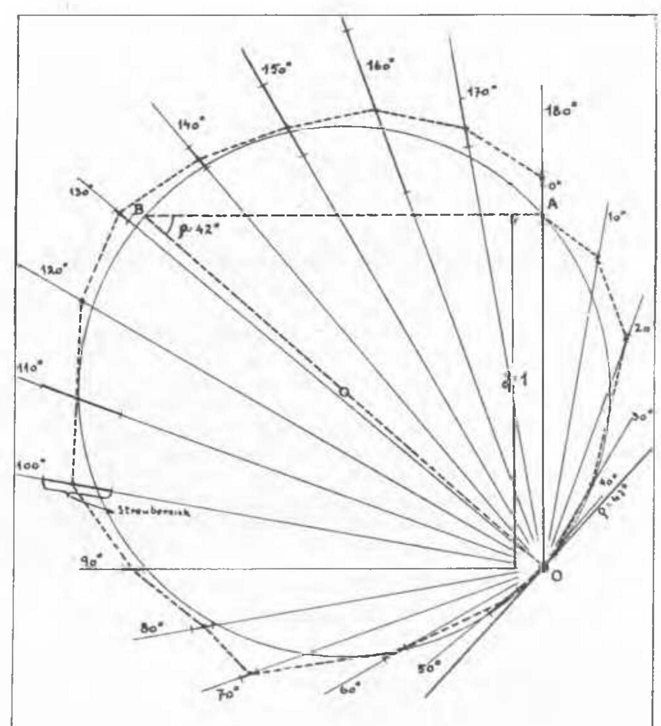

FIG. 2

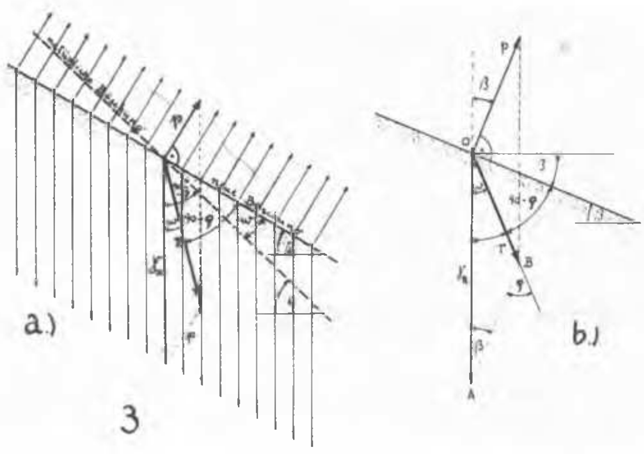

FIG. 3

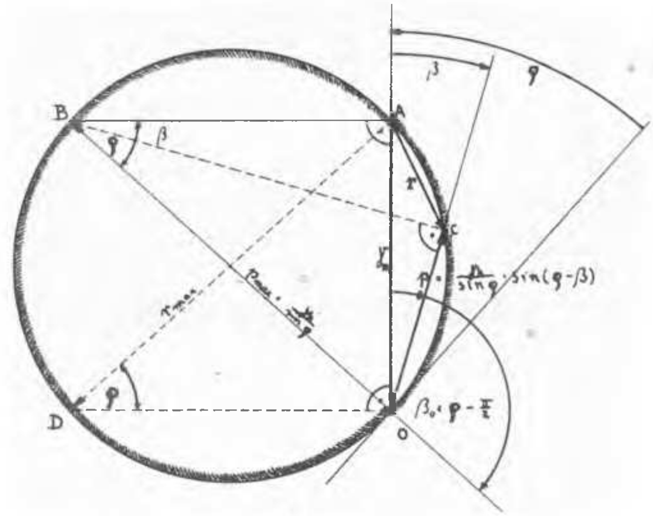

FIG. 4

is within the sphere of the capillary rise. The slope circle derived from equation (1) is represented by fig. 4. Section A -C-O is for groundwater leaving the slope, and section O - D - B - A for such entering it.
The flow pressure parallel to the slope being

$$p_p = \gamma \cdot i$$

whereby γ is the specific weight of water = 1, and i the hydraulic gradient, it follows in connection with equation (2) that:

$$Tg\ \beta_{max} = tg\ \rho \cdot \frac{\gamma R}{\gamma R + \gamma} \qquad (3)$$

The equation (3) is independent of the depth of the point under consideration below the surface, and, as any existing cohesion may be looked upon as an additional load or increased depth of the point under consideration below the surface, the equation applies also to coherent material.
It may be said therefore of slopes through which groundwater passes parallel to its surface, i.e. whereever the pores are saturated with water held at a certain level by capillary force and no matter whether the material is sand or clay, that they are stabile in all cases when their inclination β to the horizontal does not exceed the value indicated by the equation (3).

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SLIDING SURFACES AND STABILITY CALCULATIONS FOR SOIL MASSES OF CULVILINEAR PROFILE

I e 19

M. FRONTARD
Inspecteur Général des Ponts et Chaussées

SUMMARY OF THE FRENCH REPORT

In continuation of mathematical studies already published, the author now tackles in all its aspects the problem of the sliding of a heavy mass whereof the free surface follows any curve, in respect of Rankine's condition of equilibrium.

Adopting the following notation:

C = cohesion of the material composing the mass,
φ = angle of friction,
= specific weight,
y = vertical, downward ordinate in relation to an axis Ox, of arbitrary direction and origin, at any point P of the profile X of the mass,
y' = ordinate of point M of the slide curve under consideration G, situated on the same vertical,
ρ = radius of curve at M,
q = horizontal thrust at M,
η = gradient of the tangent at P with the horizontal,
α = angle made by the directions of the two tangents at P and at M; the author shows that y and y' are related by the following equation:

$$y'-y = \frac{C \cos\varphi}{\Delta} \cdot \frac{\cos(2\alpha+\varphi)}{m \cos\eta[\sin\eta - \sin\varphi\cos(2\alpha-\eta+\varphi)]} \qquad (1)$$