$$\sum\left\{\left[\frac{c'b}{F}+W\frac{\tan\phi'}{F}(1-r_u)\right]\frac{\sec\alpha}{1+\frac{\tan\phi'}{F}\tan\alpha}\right\}-\sum[W\sin\alpha]=0$$

$$\frac{1}{F}\sum\left\{[c'b+W\tan\phi'(1-r_u)]\frac{\sec\alpha}{1+\frac{\tan\phi'}{F}\tan\alpha}\right\}=\sum[W\sin\alpha]$$

$$F=\frac{1}{\sum[W\sin\alpha]}\sum\left\{\left[\frac{c'b}{F}+W\tan\phi'(1-r_u)\right]\frac{\sec\alpha}{1+\frac{\tan\phi'}{F}\tan\alpha}\right\}$$

This equation is identical to Bishop's equation (13) if in the latter $\bar{B}=r_u$ and $(X_n-X_{n+1})=0$ (i.e. $\theta=0$).

REFERENCES

Bishop, A. W. (1955). The use of the slip circle in the stability analysis of slopes. *Géotechnique* **5**, No. 1, 7–17.

Bishop, A. W. & Morgenstern, N. R. (1960). Stability coefficients for earth slopes. *Géotechnique* **10**, No. 4, 129–147.

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The Author proposes a two-dimensional limiting equilibrium method of slope stability analysis employing a circular failure surface and parallel inter-slice forces. Then he reports (Spencer, 1968) development of a method of analysis similar to that of Morgenstern and Price (1965) in which a distribution is assumed for the variation in slope of the resultants of the inter-slice forces. He suggests that the most promising type of distribution for the inclination of inter-slice forces is parabolic. I believe that parallel inter-slice forces give better results in certain classes of practical problems.

The inclination of inter-slice forces depends on a number of factors including slope geometry and soil zones, failure surface geometry, soil properties and pore water pressures within the slope. The most important of these factors seems to be pore water pressures within the slope. My recent work with the Morgenstern–Price method of analysis indicates the following:

(*a*) Parallel inter-slice forces generally give the most reasonable results when pore pressures on the failure surface are quite low, i.e. average $r_u<0{\cdot}15$, and a phreatic surface corresponding to steady state seepage, or the set of r_u corresponding to this condition, is used in the stability analysis rather than a constant value of r_u.

(*b*) A parabolic or half sine wave distribution of the inclination of inter-slice forces generally gives the most reasonable results when pore pressures on the failure surface are constant and quite high, i.e. $r_u>0{\cdot}35$, and the slope, or at least a significant part of it, is submerged, e.g. the upstream slope of an earth dam under partial or full reservoir conditions.

(*c*) The most suitable inclination distribution for other pore pressure conditions must in general be found by trial and error; parallel inter-slice forces are recommended as a first trial.

A physical or mechanistic explanation of the observed relationship between pore water pressures and the inclination of inter-slice forces is as follows. In a stability analysis using total unit weights and boundary water forces, the vertical components of inter-slice forces will depend to a considerable extent on hydrostatic uplift. This uplift will reduce the downward components of inter-slice forces due to soil weight. A typical failure mass cut from a slope is deeper and hence heavier per unit width in its middle than at its ends. If this typical failure mass has high pore water pressures all along its base (the failure surface), hydrostatic uplift effects, in terms of the reduction of vertical components of inter-slice forces, will be most significant at the ends where the slices are shallower and lighter. This uplift effect is especially important when a constant and relatively high value of r_u exists across the entire failure surface. It is of course also important at the toe of a slope when the toe is submerged.

A phreatic surface corresponding to a moderate level of steady state seepage generally gives a roughly parabolic distribution of pore pressures across the most critical failure surface in a slope. In this case the lower slice weights at the ends of the failure mass are offset by lower pore pressures at the ends and the vertical components of inter-slice forces do not decrease as much with respect to the horizontal components. This explains the apparent contradiction of parallel inter-slice forces giving better results with steady state seepage conditions, even when the average pore pressure on the failure surface is high.

It has been noted, e.g. by Lane (1967), that the lowest factor of safety for the upstream slopes of many earth dams occurs during filling of reservoirs rather than during rapid drawdown. The mechanism of 'floating the toe' is also believed to explain this more dynamic pore pressure-stability situation.

REFERENCES

LANE, K. S. (1967). Stability of reservoir slopes. *Failure and breakage of rock.* Eighth U.S. Symposium on Rock Mechanics, pp. 321–336. New York:AIME.

MORGENSTERN, N. R. & PRICE, V. E. (1965). The analysis of the stability of general slip surfaces. *Géotechnique* **15**, No. 1, 79–93.

SPENCER, E. (1968). Correspondence on the analysis of the stability of general slip surfaces. *Géotechnique* **18**, No. 1, 92–93.

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PRIMARY AND SECONDARY CONSOLIDATION OF CLAY AND PEAT

(BARDEN, L., *Géotechnique* **18**, No. 1, 1–22)

Probably the chief reason for carrying out laboratory consolidation tests is to forecast the settlement of thick strata under load. In a brief reference to the effect of H in secondary consolidation, Barden states that there is little experimental evidence of the effect of sample thickness on secondary consolidation. As a result of many site and laboratory observations over a period of 20 years (e.g. Hanrahan, 1954, 1964) I am convinced that only negligible, if any, error is involved by assuming that the scaling law for both 'primary' and 'secondary' consolidation depends on H^2. This conclusion is believed to apply to wholly organic peat.

A large volume of site evidence has been accumulated, especially in Canada, to disprove this contention. In nearly every instance, however, the findings are suspect because of the heavy loads involved and the probability of plastic flow (creep) which has been shown (Hanrahan, 1964) to occur at low stress levels. Laboratory evidence may also be invalid because