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 of the complication of incremental loading. It is probable that pure peat never comes to final equilibrium (Hanrahan, 1964). Therefore many of the expressions used by Barden, e.g. degree of compression, stable equilibrium, e versus p plot, are meaningless when applied to the peat of my experience. The effect of pressure increment ratio, e.g. Fig. 8, is not unique and almost any desired behaviour can be achieved for the load increment simply by varying the duration of the previous load. The 100% efficiency of consolidation–acceleration devices (Hanrahan, 1965) in peat is valuable confirmation of the dependence of the scaling law on H^2.

A major criticism of laboratory studies of consolidation is the dependence on the one dimensional test, which because of undefined boundary stress conditions is little better than an empirical test. There is mounting evidence (Hanrahan and Walsh, 1965; Hanrahan, 1967) of the complexity of this test, e.g. internal tension, non-uniform distribution of internal strains and pore-pressure. With a view to increasing the reliability of this test I have proposed a method of evaluating the lateral stresses (Hanrahan, 1968). Recently a simple modification of the triaxial test has been devised which permits a plane strain, one dimensional consolidation test to be carried out with continuous observation of vertical and lateral pressures. In one such test the σ_1/σ_3 ratio (total stresses) was observed to fall from 1:1 initially to 5:1 after a few minutes. After a few hours the lateral pressure had fallen to zero. Barden's rheological model (Fig. 3) would have to be modified to take into account this drastic reduction of σ_{oct}. The latter confirms many previously observed phenomena and is likely to be the chief cause of the rapidity with which the pore-pressure is commonly observed to fall off in one dimensional tests on peat.

REFERENCES

HANRAHAN, E. T. (1954). An investigation of some physical properties of peat. *Géotechnique* **4**, No. 3, 108–123.
HANRAHAN, E. T. (1964). A road failure on peat. *Géotechnique* **14**, No. 3, 185–202.
HANRAHAN, E. T. (1965). A design method for construction on peat. *Trans. Instn civ. Engrs Ire.* **92**, November.
HANRAHAN, E. T. & WALSH, J. A. (1965). Investigation of behaviour of peat under varying conditions of stress and strain. *Proc. 6th Int. Conf. Soil Mech.* Montreal.
HANRAHAN, E. T. (1967). The fallacy of plain strain in consolidation. *Civ. Engng publ. Wks Rev.* June.
HANRAHAN, E. T. (1968). Analysing strain in real solids. *Civ. Engng publ. Wks Rev.* March.

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Based on his long experience of the material and its engineering behaviour, Dr Hanrahan has raised a number of interesting points on the consolidation of peat.

His first comments refer to the effect of H on secondary consolidation, where there seems to be a wide divergence of general opinion. One empirical treatment has been suggested by Wilson et al (1965); another is by Hanrahan (1964) who claims that the H^2 law associated with primary consolidation also applies during the secondary consolidation of peat and his Fig. 8 gives empirical evidence in support of this. I fail to see the physical basis for such an H^2 law once the pore pressure in the *macro*-pores (i.e. the measurable pore pressure) is sensibly zero. Accurate mid-plane pore pressure measurements using transducers on samples of Irish and Canadian peats, back pressured to 20 lb/sq. in. to minimize the problems of gas, have revealed that the measurable (macro-) pore pressure excess is sensibly zero during secondary and hence that the long term deformation is not governed by *primary* pore pressure