The variation in the bulk total stress $\theta=\sigma_x+\sigma_y+\sigma_z$ is recognized as the source of much complexity in Biot type treatments of truly three dimensional consolidation based on linear elastic theory (Gibson and Lumb, 1953; Davis and Poulos, 1968), and in a generalization of the rheological model to three dimensional triaxial conditions (Barden, 1968) consideration has been given to the effects of the term $\partial\theta/\partial t$. However, the proposed *one dimensional model* does not require modification for the reason suggested by Dr Hanrahan.

The reduction in the lateral stress has been measured on Irish peat tested in a 10 in. Rowe cell containing a number of total stress transducers set in both the base and the side wall. However, in tests conducted to date the reduction in lateral stress has not been as marked as reported by Hanrahan, the $K_0$ value stabilizing at a value of about 0·3 and remaining sensibly constant over a period of weeks. In the majority of tests on peat the measured pore pressure dissipation is much faster than suggested by rates of settlement and this is in agreement with viscosity effects (see Figs 5 and 6 of the Paper). It is therefore suggested that while a drop in $\theta$ can be important, particularly in three dimensional cases, the main reason for the rapid fall off in pore pressures in peat is the dominant effect of structural viscosity. These tests include samples of remoulded Irish fibrous peat generously supplied by Dr Hanrahan.

I should like to thank Dr Hanrahan for his discussion and express complete agreement that, mainly because of its large strain behaviour, the compression of peat merits further investigation of stress and strain distribution, possibly incorporating X-ray techniques.

## REFERENCES


Akai, K. & Adachi, T. (1965). Study on the one-dimensional consolidation and the shear strength characteristics of fully saturated clay. *Proc. 6th Int. Conf. Soil Mech.*, vol. 1, p. 146.

Barden, L. (1968). Time dependent deformation of normally consolidated clays and peats. Submitted for publication.

Bjerrum, L. (1967). Engineering geology of normally-consolidated marine clays as related to the settlement of buildings. *Géotechnique* **17**, No. 2, 83–117.

Burland, J. (1967). The deformation of soft clay. Ph.D. Thesis, University of Cambridge.

Davis, E. H. & Poulos, H. G. (1968). The use of elastic theory for settlement prediction under three-dimensional conditions. *Géotechnique* **18**, No. 1, 67–91.

Gibson, R. E. & Lumb, P. (1953). Numerical solution of some problems in the consolidation of clay. *Proc. Instn civ. Engrs* **2**, Part 1, 182–198.

Hanrahan, E. T. (1964). A road failure on peat. *Géotechnique* **14**, No. 3, 185–202.

Rowe, P. W. (1959). Measurement of the coefficient of consolidation of lacustrine clay. *Géotechnique* **9**, No. 3, 107–118.

Sirwan, K. Z. (1965). Deformation of soil specimens. Ph.D. Thesis, University of Cambridge.

Taylor, D. W. (1942). *Research on the consolidation of clays.* Serial 82, M.I.T. Publication.

Wilson, N. E., Radforth, N. W., MacFarlane, I. C. & Lo, M. B. (1965). The rates of consolidation for peat. *Proc. 6th Int. Conf. Soil Mech.*, vol. 1, p. 407.


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## AN APPARATUS FOR FORMING UNIFORM BEDS OF SAND FOR MODEL FOUNDATION TESTS

(Walker, B. P. & Whitaker, T., *Géotechnique* **17**, No. 2, 161–167)

I have conducted some foundation studies on sand and wish to offer the following comments on this topic, which is of vital interest to research workers in foundation engineering everywhere.

The problem of forming a relatively big sand bed at a desired density which is uniform throughout and which is reproducible without difficulty has confronted research workers in the field of foundation engineering for a considerable time. I have tried various methods but none has been found absolutely satisfactory from every respect.

The easiest method of forming a loose sand bed seems to be by pouring dry sand through a funnel keeping the tip of the same at a constant height above the sand already poured. A dense bed can be produced if this sand is poured in layers and each layer is compacted using a tamper with a falling weight. The density can be varied by varying the thickness of each layer and the number of blows delivered per layer. The density was uniform as could be ascertained from penetration records obtained by tests using an arbitrary falling weight penetrometer. The sand used had effective size$=0{\cdot}34$ mm, uniformity coefficient $=1{\cdot}53$ and fineness modulus$=4{\cdot}10$. Loose density obtained by pouring was 97·2 lb/cu. ft ($n=41{\cdot}5\%$) and a density of 105·2 lb/cu. ft ($n=36{\cdot}6\%$) was obtained by delivering 36 blows/sq. ft on layers 3 in. thick using a tamper which had a base 6 in.$\times$6 in., falling weight 2·5 lb and height of fall 18 in. This method even though satisfactory is time consuming.

To obtain better uniformity and speed of work an attempt was made to induce a draft on the soil in the funnel by letting in compressed air from an air compressor into the stem of the funnel in the direction of flow. The uniformity of the resulting bed was excellent but the density was found to be insensitive to air pressure and the maximum density obtained was 100 lb/cu. ft at a pressure of 60 lb/sq. in.

The best results in terms of maximum density and speed of work were obtained by using a concrete pin vibrator (2850 rpm) working on a three-phase supply. Densities of 104 lb/cu. ft could be easily obtained by centre vibrating a bed 3 ft square and 4 ft deep for 6 minutes. The needle was initially inserted to the bottom of the bed and it was found to be travelling up on being rejected by the bottom layers as they were getting compacted. A disadvantage of this method was that there was observed concentration of density around the point of vibration. To overcome this defect a concrete shutter vibrator (2950 rpm) working on a three-phase supply was tried by moving the same over sand poured in layers. The uniformity in the horizontal plane was excellent but for getting better uniformity in the vertical direction surface vibration had to be carried out on a number of layers. The results, however, were found to be quite satisfactory.

Attempts are now being made to employ the principle of fluidization using an aeropump for this purpose.

The problem of forming a large clay bed with uniform consistency at a reasonable speed is much more difficult and unless a suitable method is devised foundation research will continue to be confined to sand only.

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## THE ANALYSIS OF THE STABILITY OF GENERAL SLIP SURFACES

(MORGENSTERN, N. R. & PRICE, V. E., *Géotechnique*, **15**, No. 1, 79–93)

In the correspondence by Spencer (1968) he disputed the claim made by the Authors that in this method all equilibrium and boundary conditions are satisfied. In particular he stated that the equations of vertical equilibrium are not satisfied. We believe that the arguments presented by Spencer are false for the following reasons.

The equation of equilibrium in two directions, $N$ and $S$, given in equations (3) and (4) was combined with the failure criterion to give equation (7). Provided the force distributions $E'$ and $X$ satisfy equation (7) then normal and tangential forces $dN'$ and $dS$ on the base