DISCUSSION

IGNITION LOSS AND OTHER PROPERTIES OF PEATS AND CLAYS FROM AVONMOUTH, KING'S LYNN AND CRANBERRY MOSS

(SKEMPTON, A. W. & PETLEY, D. J. (1970). *Géotechnique* **20**, No. 4, 343–356)

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Laboratory and field studies of the load-deformation characteristics of peat are at present being conducted in Kingston, Canada (Hosang, 1971; Hollingshead and Raymond, 1971). Organic contents and Atterberg limits of three Kingston area peats, Lyndhurst, Cataraqui, and Kingston Swamp, have been determined as part of this programme (Hosang, 1971).

The Lyndhurst peat is a 'fine-grained', highly decomposed, amorphous–granular peat with a natural water content of approximately 390%. This peat is classified as $H_7B_5F_1R_1V_1$ by the von Poste system and the surface vegetation as AF by the Radforth system.

Kingston Swamp peat is an amorphous–granular peat in a less advanced state of decomposition than the Lyndhurst peat. It has a natural water content of 590% and is classified $H_{4-5}B_5F_1R_1V_3$ (von Poste). The surface vegetation is classified DF (Radforth).

Cataraqui peat is an amorphous–granular peat in the same stage of decomposition (H_{4-5}) as Kingston Swamp peat but with a much higher content of fine non-woody fibres. The natural water content is 530% and its classification is $H_{4-5}B_5F_3R_1V_0$ (von Poste). The surface vegetation is classified CF (Radforth).

The loss-on-ignition test was used exclusively for the organic content determinations, because of its simplicity and applicability to peats of high organic content. Unfortunately, a standardized procedure for this test does not exist; Table 1 provides examples of the wide range of temperatures and burning times reported in the literature. A study was conducted to find the minimum burning temperature and time required to permit complete oxidation of the Kingston area peats.

Organic contents were based on initial dry weights at 75–80°C, a temperature sufficiently low to prevent oxidation of the Kingston area peats. No visible signs of charring occur at this temperature but at higher temperatures oxidation is quite extensive, particularly on exposed surfaces.

Samples of each peat type, initially dried at 75–80°C, were burnt at temperatures of 800, 1000, 1200, 1400 and 1600°F. Weight determinations were made at intervals of ten minutes to two hours until constant weights were obtained. Only in the cases of 1400 and 1600°F did this latter weight become equivalent to the ultimate organic content, therefore at the other temperatures the samples were subjected to further burning at 1400°F in order to determine the ultimate organic content (Table 2). This is apparent in Fig. 1 where, in order to present the data graphically, the term 'percentage ultimate organic content' (PUOC) was introduced where:

$$\text{PUOC} = \frac{\text{'organic content' at time } t}{\text{ultimate organic content}} \times 100$$

The organic content at time t is based on the assumption that the weighed residue is entirely ash. The typical plot of PUOC against burning time (Fig. 1) for a Kingston area peat illustrates that for the peats studied an ultimate ash content is not determined for temperatures of 800, 1000 and 1200°F, even after a burn time of 500 min. The 1400 and 1600°F burns reached the ultimate ash content in 180 and 100 min, respectively, at which times the ash had a grey-white colour, typical of an oxidized peat. In these tests no correction was made for the free

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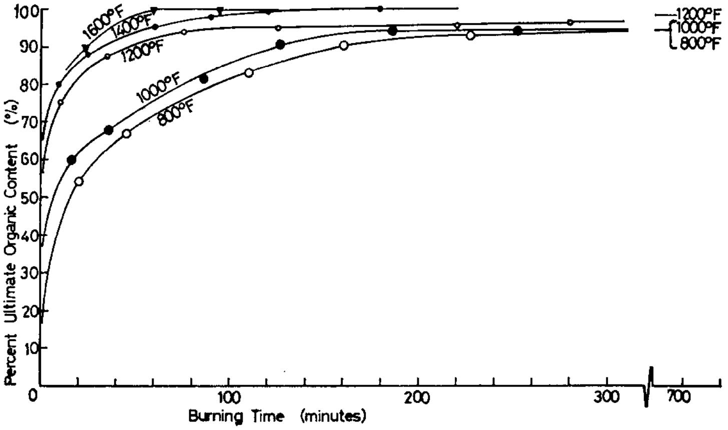

Fig. 1. Oxidation curves for Kingston Swamp peat

Table 1. Loss on ignition test: historical summary of test conditions

Reference	Temperature, °F	Burning time
Cook, 1956	1400	3 h
Goodman & Lee, 1962	1112*	Several hours
Lea & Brawner, 1963	1400	3 h
MacFarlane & Allen, 1964	1112–1652†	Until all black disappeared
Farnham, 1968	752‡	N/A

* 600°C; † 600–900°C; ‡ 400°C.

Table 2. Organic content of three Kingston peats

Peat	Organic content		No. of tests
	Average, %	Range, %	
Lyndhurst	78·9	78·6–79·1	7
Kingston Swamp	87·5	87·1–87·7	7
Cataraqui	87·9	87·1–88·4	7

Table 3. Plasticity tests of three Kingston area peats

Peat type	LL		PL		PI	Organic content*
	Av.	Range	Av.	Range		
Lyndhurst	342	340–343	231	229–232	111	73·7
Kingston Swamp	445	437–452	378	370–386	77	81·2
Cataraqui	558	557–560	471	463–479	87	85·9

* Organic content of material passing No. 40 sieve.

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water contained in the 'dried samples', a fact which may cause a minor variation in the determined organic contents but which does not influence the technique for the determination of burning temperature and time.

Thus with the highly organic peats of the Kingston area, burning temperatures higher than the 550°C recommended by the Authors are required to determine the ultimate organic content. If a standardized technique is to be developed, burning temperatures and times for various 'classes' of peats and organic soils may have to be determined.

Liquid and plastic limit tests on the peat were conducted in accordance with American Society for Testing Materials designations D423-66 and D424-59(1965), respectively. In following these standards the peats are sieved through the No. 40 sieve, thus all coarse woody fractions and fibrous materials are removed. The liquid limits and the plasticity indices for the Kingston area peats (Table 3) plot within a band crossing the plasticity chart at a low angle as noted by the Authors.

Both the liquid and plastic limits increase with organic content, however, the plasticity index tends to decrease with an increase in organic content. Thus the organic content appears to contribute little to the plasticity of the material but much to the water-holding capacity. The latter fact indicates that the Atterberg limits may serve as indicators of the compressibility of a peat.

The value of organic content as an index property of peat is generally accepted in the literature (MacFarlane, 1969). On the other hand, the use of Atterberg limits is a carry-over from soil mechanics and has yet to be meaningfully correlated with other peat properties, an aim which can only be resolved by studies such as that of the Authors and by the use of limits as a 'descriptive' index in all reported studies on peat.

Index properties are used for classification and estimating properties of soils; these objectives must not be forgotten when using soil indices for peats. In all probability new indices should be established to describe the complexities of peats.

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In an excellent manner, the Authors have shown the errors that can be introduced in determining the organic content of soils by combustion at high temperatures, such as 950°C.

The Writer (Arman, 1969) has determined that the ignition at 950°C of soils containing montmorillonitic clays may lead to errors as high as 11·6% (Fig. 1). For example: at 600°C, soils with an actual organic content of 1% had a weight loss of 5·2%—an error of 4·2%. Like the Authors, the Writer found that the error is minimal at higher organic contents: in his case, above 50%. Thus, the Writer has recommended a five-hour period of combustion

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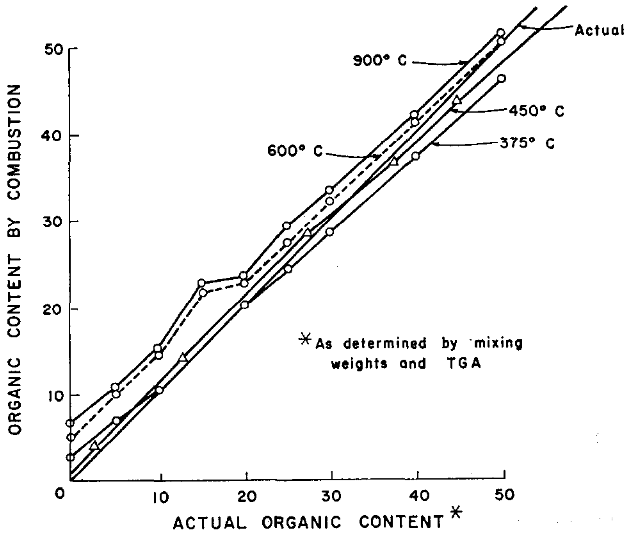

Fig. 1 (above). Percentage weight loss by combustion at varying temperatures

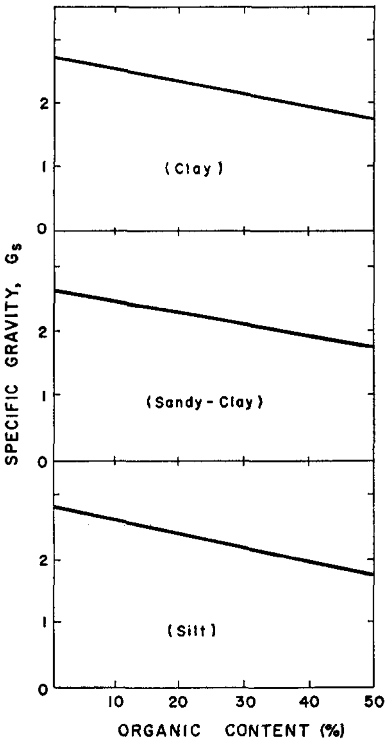

Fig. 2 (right). Specific gravity/organic content relationships for three types of organic soil

at 440–450°C rather than 550°C and recently the Louisiana Department of Highways revised its method of testing in accordance with these findings.

The Writer strongly agrees that there is a need for standardized combustion temperatures. The value of liquid and plastic limit tests for soils with more than 30% organic material is rather questionable (Arman, 1970). Water contents measured at these limits are greater than the true amounts contributing to the plasticity or liquidity of an organic soil. Of the total moisture, a large portion is absorbed in the organic matter and does not necessarily affect the consistency of the soil. However, if this absorbed moisture remains constant during the tests for liquid and plastic limits, the error is self-cancelling in obtaining the plasticity index, which may thus be assumed to be correct.

The assurance lessens, however, when these results are to be used to determine consistency of natural deposits. The amount of water absorbed by the organic portion will depend on the length of time allowed for absorption. Water table fluctuations that are caused by tides and precipitation, besides long-term water level changes, reduce the chances for obtaining samples containing the maximum absorbed water.

In addition, whenever fibrous organic material is present in a soil, the Atterberg limits cannot be obtained accurately. The fibres interfere with the performance of plastic limit and liquid limit tests. Fibres have the effect of tiny reinforcing bars binding soil particles together. At organic contents of 30% or higher in liquid limit tests, the 'groove' will close as a result of the two halves of the soil in the cup sliding together rather than the soil 'flowing' as is the intention of the test. The plastic limit test is also affected because of the binding characteristics of organic fibres. There is a definite electrochemical attraction between clay and organic particles.

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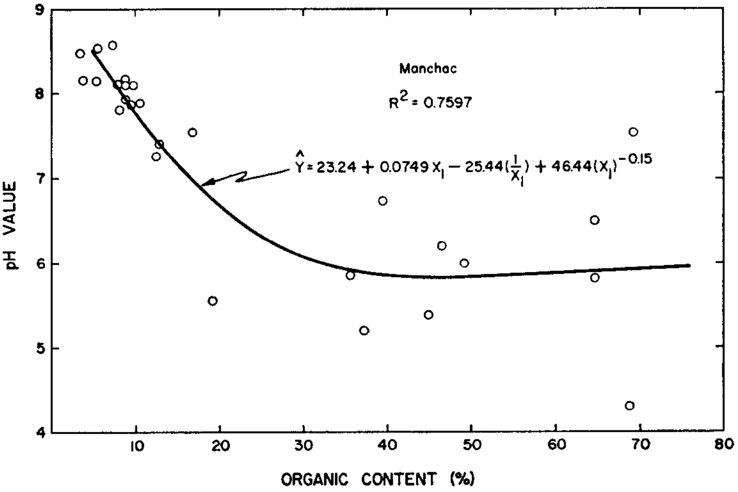

Fig. 3. pH/organic content relationship for soils from the Manchac area

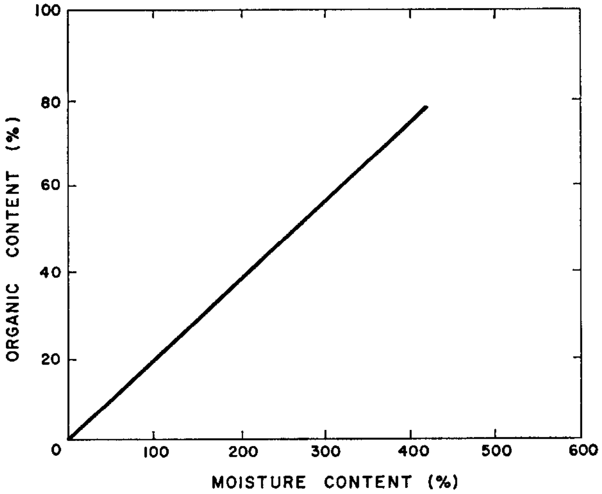

Fig. 4. Organic content/percentage moisture relationship

Table 1. Radiocarbon age of organic cores

Isotope sample location	Depth, ft	Age, years		
		$-\delta C^{14}$	B.P.	Date
Manchac	3	59 ± 11	490 ± 95	A.D. 1460
Veterans Hwy	2·5	45 ± 11	370 ± 95	A.D. 1580
Veterans Hwy	2·5–5	180 ± 10	1590 ± 95	A.D. 360
Veterans Hwy	5–7·5	211 ± 10	1900 ± 100	A.D. 50
Veterans Hwy	10–12·5	238 ± 10	2180 ± 100	230 B.C.
Raceland—DesAllemands	10–11·5	217 ± 10	1970 ± 100	20 B.C.

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For permanently submerged organic soils in south Louisiana, it was found that the specific gravity, pH, and natural moisture content could be used in a given small area as preliminary indicators of organic content and compressive strength (Figs 2–4).

Because the Writer's samples contained fibrous organic material with carbon-14 ages ranging from 370 to 2180 years (Table 1), he could hardly expect to have total agreement with the specific characteristics of soils used by the Authors. However, it is refreshing to find that the Authors have undertaken the investigation of a much neglected subject, the properties and mechanics of organic soils.

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EXPERIMENTAL AND THEORETICAL INVESTIGATIONS OF A PASSIVE EARTH PRESSURE PROBLEM

(JAMES, R. G. & BRANSBY, P. L. (1970). *Géotechnique* **20**, No. 1, 17–37; Discussion (1971) **21**, No. 2, 173–175)

R. G. James and P. L. Bransby

Dr Meyerhof suggests that earlier passive earth pressure investigations on sand (Rowe and Peaker, 1965) and observations of the inclinations of rupture surfaces in triaxial compression tests on sand indicate that the observed rupture surface directions agree fairly well with the predictions based on the average Coulomb friction angle on the rupture surfaces.

Unfortunately, conventional triaxial tests with rough end platens are likely to produce complex stress and strain distributions within the sample, even at small strains, and therefore any rupture surface observed on the boundaries of the sample is likely to be a poor reflection of the curved rupture surfaces within the sample, especially as these curved rupture surfaces may well have different inclinations to the vertical at different points within the sample. Furthermore, accurate measurement of the apparent inclination of a rupture surface can only be made with confidence after extreme deformations of the soil sample, and it is in this state that there is least knowledge about the local principal stress directions.

In contrast, plane strain tests using lubricated end platens are likely to provide more reliable data of rupture plane inclinations. King and Dickin (1970) observed that the rupture surface formed in a typical plane strain test (PB6) on dense sand was inclined at 36° to the major principal stress direction. The corresponding observed angle of dilation, ν, was 14°, and thus the zero extension direction was at $(45°-\nu/2)=38°$ to the major principal stress direction, in good agreement with the observed rupture plane. The observed peak angle of friction $\phi=45°$ indicates that the stress characteristics were inclined at $(45°-\phi/2)=22\frac{1}{2}°$ to the major principal stress direction.

The observations of rupture surfaces by Rowe and Peaker (1965) in their passive earth pressure tests on sand do not entirely support the concept that rupture planes form along stress characteristics. For example, Rowe and Peaker state on page 76 of their paper, when discussing data from tests on loose sand, 'It was found repeatedly in the region near the sand surface remote from the wall where Rankine passive states are normally assumed to occur, that the slopes of the slip paths were much steeper than for the case of $\phi'_{\max}=34°$. The slopes conformed more with $\phi'_m=10°$.' The rupture surfaces must therefore have emerged at 40° to the horizontal, which corresponds to $\nu=10°$, a reasonable value for loose sand at large strains. The stress characteristics would be at $(45°-\phi_m/2)=28°$ to the horizontal.

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