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Briefing: Water content determinations of peaty soils using the oven-drying method

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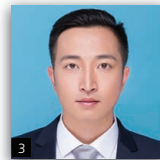
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In order to prevent possible charring, oxidation and (or) vaporisation of substances other than pore water, many researchers have adopted oven-drying temperature (t) values in the range 60–90°C for water content determinations of peat and other highly organic soils. This paper investigates the oven-drying characteristics of six very different highly decomposed peaty soils retrieved from south-west China for t values of 65, 85 and 105°C. Based on the presented experimental data, it is concluded that the standardised t value of 105°C used for testing of inorganic soil is also appropriate (and preferable to using lower t values) for routine water content determinations of these soils, which is in line with the growing consensus formed by other researchers on this topic. Further, the authors recommend a wet specimen mass of approximately 50 g and a 24 h oven-drying period in performing the oven-drying tests for $t = 105^\circ\text{C}$. The paper also describes an existing approach to comparing and standardising water content values determined for the same organic soil, but on the basis of different t values, with the new data presented herein for the six Chinese soils used to strengthen its wider applicability in geotechnical engineering practice and related fields.

Notation

H_n	von Post humification number
$m_{x^\circ\text{C}}$	specimen equilibrium dry mass for oven-drying temperature of $x^\circ\text{C}$: g
$m_{105^\circ\text{C}}$	specimen equilibrium dry mass for oven-drying temperature of 105°C: g
N	loss on ignition: %
P	maximum relative difference: %
t	oven-drying temperature: °C
$w_{x^\circ\text{C}}$	water content value for oven-drying at $x^\circ\text{C}$: %
$w_{65^\circ\text{C}}$	water content value for oven-drying at 65°C: %
$w_{85^\circ\text{C}}$	water content value for oven-drying at 85°C: %
$w_{105^\circ\text{C}}$	water content value for oven-drying at 105°C: %
$\alpha_{105^\circ\text{C}}$	water content parameter
$\beta_{105^\circ\text{C}}$	gradient of $\alpha_{105^\circ\text{C}}$ against drying temperature trend line: °C ⁻¹
ρ	bulk density: Mg/m ³
ρ_s	particle density: Mg/m ³

Introduction

Peat (mire) deposits cover large areas of the world's landmass. They are formed by the gradual accumulation of the remains of waterlogged dead plant vegetation at various stages of

decomposition (Hobbs, 1986; Huat *et al.*, 2014). Other highly organic soils include biosolid, sewage sludge, water-treatment residue (O'Kelly, 2016, 2018a; O'Kelly and Quille, 2009, 2010) and paper-mill sludge (Moo-Young and Zimmie, 1996) materials. By their very nature, peat and other highly organic soils usually have extremely high water (moisture) content, which is a most significant physical characteristic because its value can be routinely determined by the oven-drying method (definitive procedure used in standard laboratory practice (ASTM, 2010, 2014a; BSI, 1990)) and then related to likely engineering performance (Farrell, 2012; O'Kelly and Sivakumar, 2014). For instance, correlations between water content and a number of engineering properties have been widely developed for various organic soils (see the papers of Baroni and Almeida (2017), Huat *et al.* (2014), McCabe *et al.* (2014), O'Kelly and Quille (2009) and O'Kelly *et al.* (2018b), to name a few).

The oven-drying temperature and period adopted for the removal of pore water from a test specimen are of great importance, influencing the measurement result because different physical states are produced (O'Kelly and Sivakumar, 2014). For inorganic soils, the standard oven-drying temperature (t) ranges of 105–110°C (BS 1377-2:1990 (BSI, 1990)) and $110 \pm 5^\circ\text{C}$ (ASTM D 2216-10

(ASTM, 2010)) are invariably employed for water content determinations. However, oven-drying tests performed at these standard t ranges may not produce correct water content values for peat and other highly organic soils, soils in which the pore water contains dissolved solids, or those containing significant amounts of halloysite, mica, montmorillonite, gypsum or other hydrated materials (O'Kelly, 2014). For instance, some charring, oxidation and (or) vaporisation of susceptible organic matter may occur for these standard t value ranges when applied to peat and other highly organic soil materials. From the viewpoint of performing water content calculations, the associated reductions in the specimen's equilibrium dry mass are incorrectly interpreted as evaporation of pore water, thereby resulting in apparently higher values than the correct water content value (O'Kelly, 2004).

Consequently, as summarised in the papers by O'Kelly (2014) and O'Kelly and Sivakumar (2014), there has been much debate regarding the appropriate t range for water content determinations of peat and other highly organic soils using the oven-drying method. Numerous researchers, including Boylan and Long (2010), Goodman and Lee (1962), Hosang and Locker (1971), Landva *et al.* (1983), Marachi *et al.* (1983) and Ng and Eischens (1983), have recommended using lower t values in the range 60–90°C for water content determinations of these soils, which is continued as routine practice to the present day in some commercial and research laboratories. However, as demonstrated experimentally for very different organic soils in the papers by O'Kelly (2004, 2005a, 2005b, 2005c) and Skempton and Petley (1970), all of the relevant water is not fully evaporated from the test specimen at these lower t values, with the residual pore water interpreted as dry solids from the viewpoint of performing the water content calculations, thereby resulting in apparently lower values than the correct water content value (O'Kelly, 2004).

A related issue is the oven-drying period required to achieve an equilibrium dry mass condition, which not only can increase significantly in duration with reducing oven temperature but also depends on other factors, including soil type, the test specimen mass (size) and its initial water content, the oven type employed (i.e. gravity convection or forced ventilation), the specimen placement location within the oven chamber (when temperature variations occur therein) and the amount of wet soil relative to the drying power of the oven (O'Kelly, 2004, 2005a, 2005c, 2014; O'Kelly and Sivakumar, 2014). Based on experimental oven-drying data obtained for a range of different peat and organic clay soil materials, Skempton and Petley (1970), O'Kelly (2014) and O'Kelly and Sivakumar (2014) concluded that for practical purposes, the use of the standard t value of 105°C is appropriate for routine water content determinations and preferable to using lower t values in the range 60–90°C, particularly when correlating water content with other engineering properties.

Hence, in summary, there are two bipolar views presented in the literature regarding the appropriate t range for water content determinations of peat and other organic soil materials – that is,

t values in the range 60–90°C (see the papers of Boylan and Long (2010), Goodman and Lee (1962), Hosang and Locker (1971), Landva *et al.* (1983), Marachi *et al.* (1983) and Ng and Eischens (1983), to name a few) or the standard t value of 105°C (O'Kelly, 2014; O'Kelly and Sivakumar, 2014; Skempton and Petley, 1970), although the latter studies mainly investigated soils from Ireland and England. For consistency, O'Kelly (2014), O'Kelly and Sivakumar (2014) and Skempton and Petley (1970) recommended that the values of water content corresponding to the t value of 105°C should be deduced and used in place of measured or reported water content values determined on the basis of lower t values, with methods presented in the papers by O'Kelly (2004, 2005a), O'Kelly and Li (2018) and Skempton and Petley (1970) for the purpose of performing these calculations.

Based on the test results for soil cores retrieved from south-west China, this paper reports the oven-drying characteristics of six highly decomposed peaty soils with a wide range of organic contents. Given the bipolar views presented in the literature, a primary aim of this investigation was to establish the significance of adopting t values in the range 60–90°C, compared with the standard t ranges of 105–110°C and $110 \pm 5^\circ\text{C}$, for water content determinations of these organic soils. The study also widens the geographic spread of the previously investigated soils, which were mainly sourced from Ireland and England, but also included a few different soils from Canada, Japan and the USA. Furthermore, given that lower values of t and greater initial wet specimen mass require longer oven-drying periods to achieve an equilibrium dry mass condition, another aim of this study was to establish guidelines for these soils regarding adequate oven-drying periods for different t and initial specimen wet mass values. Finally, using the experimental data gathered for these soils, the authors also investigated the wider use and further validation of the methods presented in the papers by O'Kelly (2004, 2005a) for comparison and standardisation of water content values determined for organic soil on the basis of different t values.

Methodology

Materials

Using a ring-lined split-barrel drive sampler with inner and outer diameters of 96 and 108 mm, respectively (Figure 1), soil cores were retrieved inside two steel tubes positioned within the splitting tube from depths of between 6.8 and 9.2 m below ground level (bgl) at a site located on the north-east shore of Dianchi Lake in Kunming City, Yunnan, China. The groundwater table was located at approximately 1.0 m bgl.

Six distinctly different samples (termed 'Twc-1' to 'Twc-6') were obtained from the organic sublayers identified (based on their characteristic dark-brown to black colour) in the retrieved 2.4 m long soil core. A visual inspection suggested that each of these samples was homogeneous. The widely used von Post hand squeeze test (after the paper of von Post and Granlund (1926) and also described in the papers by Landva and Pheeny (1980) and Hobbs (1986), to name a few) was performed on representative

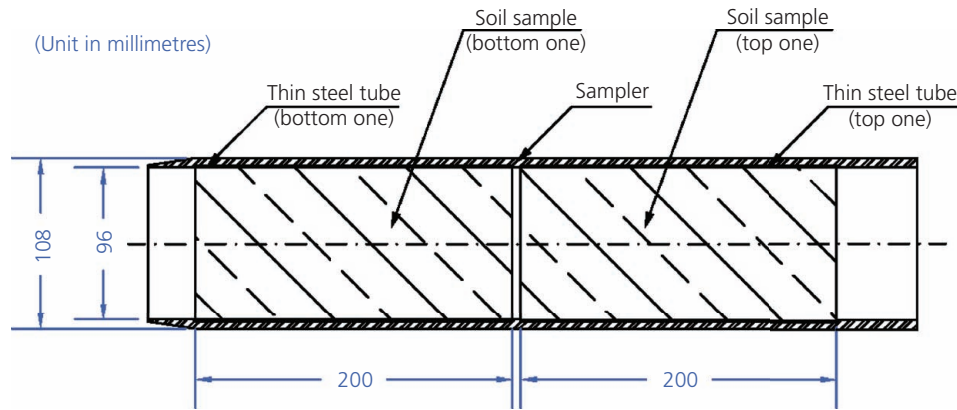


Figure 1. Ring-lined split-barrel drive sampler used to retrieve the peaty soil cores

subsamples. This test examines the material in the hand regarding its wetness, level of decay and the fibre and shrub constituents, with the degree of humification of the organic material classified by determining its humification number (H_n) on a scale of H_1 to H_{10} – that is, the plant structure can range from easily identified to not discernible (undergone no decomposition and completely decomposed state, respectively). Although the term ‘humification’ strictly means the content of humic substances in peat, it is commonly taken to mean, in this context, the same thing as decomposition (Hobbs, 1986; O’Kelly and Pichan, 2013). In the von Post classification system, the organic fractions of the sampled peaty soils were categorised as highly decomposed – that is, their measured humification numbers ranged H_7 – H_{10} . The parent material from which these peaty soil layers were formed was mainly *Phragmites* plants.

Index testing

The physical characteristics of the six peaty soil samples were assessed in terms of the water content and bulk density (ρ) values of the retrieved core and their particle density (ρ_s) and organic content values, as determined using ASTM standard tests. In summary, the water content was determined using the oven-drying method for an oven temperature of 105°C (i.e. $w_{105^\circ\text{C}}$) in accordance with ASTM D 2974 (ASTM, 2014a). The ρ values were calculated from the known mass and volume of undisturbed specimens obtained from the retrieved cores using a 61.8 mm inner dia. \times 20 mm high sampling ring.

The ρ_s values were determined using the small pycnometer method in accordance with ASTM D 854 (ASTM, 2014b), with kerosene employed in place of distilled water as the liquid in the density bottles. The same approach is used for particle density testing of other organic soils, including biosolid, sewage sludge and water-treatment residue materials (O’Kelly, 2016, 2018a), since organic solids that would otherwise float in water sink in the lower density kerosene and the biodegradation of susceptible organic solids during the testing is also prevented (O’Kelly, 2018b).

The organic content was determined as the percentage loss on ignition (N) of representative disaggregated specimens initially oven-dried to a constant mass at a temperature of 105°C and then ignited in a muffle furnace at 440°C, in accordance with ASTM D 2974 (ASTM, 2014a). In other words, the soil inorganic fraction is assumed inert for this ignition temperature value and it remains as the ash residue in the specimen crucibles after ignition, with the N value (as %) calculated as 100 minus the percentage ash content. The determination of the fibre content of the sampled materials was deemed not necessary given their highly decomposed states (i.e. negligible fibre contents).

Oven-drying tests

The oven-drying programme was performed as two series of tests using a 2 kW forced-ventilation drying oven (model number 101-1A manufactured by Beijing Zhongxingweiye Instrument (BZI) Company Ltd, Beijing, China). The chamber temperature of the 450 \times 450 \times 350 mm³ (height \times width \times depth) oven was automatically controlled to an accuracy of $\pm 1^\circ\text{C}$ for the set temperature value (BZI, 2018).

The first series of tests investigated the oven-drying characteristics of the Twc-1 and Twc-2 test materials, which had significantly different N values of 80.1 and 32.3%, respectively. For each of these materials, the sampled soil was subdivided into three test specimens, each with a wet mass (specimen initial mass) in the range 25–40 g. The wet soil comprising each test specimen was sliced into smaller pieces and then placed in its own aluminium tin, which had an inner diameter of 70 mm and an internal height of 35 mm (Figure 2).

For both of these materials, one test specimen was oven-dried over an extended period at the set t value of 65°C, the second test specimen at 85°C and the third specimen at 105°C. The t values of 65 and 85°C were adopted since they fall near the extremities of the 60–90°C range deemed appropriate for water content determinations of peat and other organic soil materials in the



Figure 2. Wet specimens prepared for the oven-drying tests. Note that the specimen tins are resting on the lids used to cover them during the cooling periods in the desiccator

papers by Boylan and Long (2010), Goodman and Lee (1962), Hosang and Locker (1971), Landva *et al.* (1983), Marachi *et al.* (1983) and Ng and Eischens (1983), to name a few. The value of 105°C is the standard t value for water content determinations of inorganic soils and is also deemed appropriate for peat and other organic soil materials in the papers by O'Kelly (2014), O'Kelly and Sivakumar (2014) and Skempton and Petley (1970).

At intervals during the drying process, the specimen tins were removed from the oven chamber and a lid was fitted to each of them before they were placed in a desiccator for a 1 h period in order to allow them to cool to the ambient laboratory temperature of 21°C. The tins were covered during the cooling periods to prevent any loss or take-up of water by the test specimens. Otherwise, the measured specimen mass would refer to the hygroscopic condition (depending on the relative humidity of the closed desiccator chamber) or, if the desiccator was open, any pore water evaporated during the 1 h cooling periods on account of heat generated by the aluminium tins would be lost. All of the tins and their lids were individually labelled to avoid any mix-ups. Once cooled to ambient temperature, the lids were removed from the tins and the mass of each tin and dried specimen was measured to the nearest 0.0001 g using an electronic balance from which the dry mass of specimen was determined. The specimen tins were then placed back into the oven without further delay and the drying process continued. The accumulated drying period values reported later in the paper do not include the duration of these cooling periods.

Table 1. Some physical properties of the retrieved soil core

Parameter	Sampled material					
	Twc-1	Twc-2	Twc-3	Twc-4	Twc-5	Twc-6
Water content, $w_{105^{\circ}\text{C}}$: %	352	176	206	365	185	254
Bulk density, ρ : Mg/m ³	1.00	1.21	1.11	1.04	1.20	1.13
Particle density, ρ_s : Mg/m ³	1.49	2.08	1.86	1.60	2.09	1.88
Loss of ignition, N : %	80.1	32.3	38.8	73.4	32.5	47.9
von Post humification number	H_7	H_{10}	H_9	H_8	H_{10}	H_8

The second series of tests investigated the drying characteristics of the Twc-3 to Twc-6 materials when subjected to step increases in the t value. In other words, each test specimen was initially dried at an oven temperature of 65°C and included periodic measurements of the specimen dry mass during the extended drying process. The same procedures as described for the first series of drying tests were also followed for cooling and weighing these test specimens. The drying process was continued for $t = 65^{\circ}\text{C}$ until the differences in successive weighings at 2 h intervals for the cooled specimen was less than 0.05 g (mostly ≤ 0.02 g in practice). Once achieved, the oven temperature was incremented to 85°C, continuing the drying process to reach a new equilibrium condition value for the same test specimens, and finally to 105°C, with periodic measurements of the specimen dry masses obtained by following the same procedure described earlier. In other words, for instance, the specimen final dry mass at the end of the drying process for $t = 65^{\circ}\text{C}$ equals the specimen initial dry mass at the start of the drying process for $t = 85^{\circ}\text{C}$.

Experimental results and analyses

Some physical properties of the retrieved Twc-1 to Twc-6 samples are reported in Table 1, with their N values ranging 32.3–80.1%. As expected, higher N values correlated with higher natural water content and lower ρ and ρ_s values.

Figure 3 presents the results for the Twc-1 and Twc-2 materials from the first series of drying tests. Included in these plots are indications of the oven-drying periods required to achieve an equilibrium dry mass condition, which was deemed to have occurred for the present study when the differences in successive weighings of the cooled specimen at 4 h intervals did not exceed 0.1% of the specimen initial wet mass, as defined in BS 1377-2:1990 (BSI, 1990). This approach was adopted since no such definition is given in the ASTM standard D 2974 (ASTM, 2014a) used for the determination of the water content of peat and other organic soils.

The general trends evident from the experimental data presented for the Twc-1 and Twc-2 materials in Figure 3 are the following: (a) with increasing drying period, the specimen mass decreases to reach an equilibrium value and (b) the reduction in the specimen mass occurs faster, with the equilibrium condition achieved within a shorter time period, for higher t and smaller initial wet mass values. For instance, despite their significantly different initial water content and N values, oven drying of the three specimens of the Twc-1 ($w_{105^{\circ}\text{C}} = 352\%$; $N = 80.1\%$) and Twc-2 ($w_{105^{\circ}\text{C}} = 176\%$;

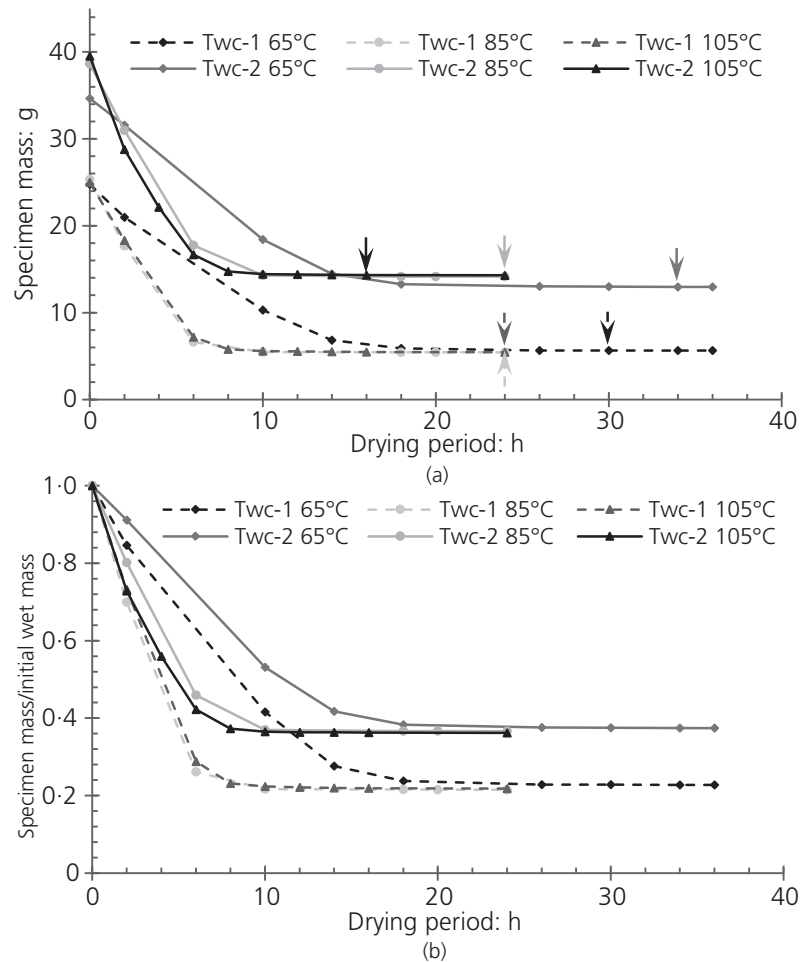


Figure 3. Oven drying for maintained oven temperatures of 65, 85 and 105°C: (a) specimen mass plotted against drying period; (b) specimen dry mass to initial wet mass ratio plotted against drying period. In (a), note that each arrowhead indicates the time needed to reach the equilibrium dry mass condition

$N = 32.3\%$) materials for $t = 85$ and 105°C required approximately similar drying periods of 12 h to achieve equilibrium, compared to approximately 30 h for $t = 65^\circ\text{C}$. Figure 3(b) presents the data on the specimen dry mass to initial wet mass ratio against oven-drying period. Despite experiencing significantly different set t values of 65, 85 and 105°C , all three specimens for both of these materials apparently achieved practically the same ratio value for the equilibrium condition. In other words, this figure suggests that for a given material, the specimen equilibrium condition was practically independent of the t value for the range $65\text{--}105^\circ\text{C}$, but significantly longer drying periods were required to achieve equilibrium for the lower t value of 65°C investigated.

Figure 4 presents the results for the Twc-3 to Twc-6 materials from the second series of oven drying tests. The general trends evident from the experimental data presented in this figure are the following.

- Despite the huge difference between their initial wet mass, water content and N values ($w_{105^\circ\text{C}} = 185\text{--}365\%$; $N =$

$32.5\text{--}73.4\%$), all of the test specimens required broadly similar time periods of approximately 50–54 h to achieve the equilibrium condition for drying at the initial t value of 65°C investigated. Compared to the approximately 30 h period at $t = 65^\circ\text{C}$ for the Twc-1 and Twc-2 specimens investigated in the first series of drying tests, the longer drying periods of approximately 50–54 h required for the Twc-3 to Twc-6 specimens can be simply explained by their greater initial wet masses, which were in the range 50–80 g, compared to 25.0 and 34.7 g for the Twc-1 and Twc-2 specimens, respectively.

- After the 54 h drying period at 65°C , the oven temperature was increased to 85°C and maintained at this value for an 18 h period. Compared to $t = 65^\circ\text{C}$, the maximum percentage reduction in the equilibrium dry masses of the Twc-3 to Twc-6 specimens for $t = 85^\circ\text{C}$ was only 3.29% and occurred for the Twc-4 specimen. This specimen had the lowest initial wet mass but the highest water content and N values among the Twc-3 to Twc-6 materials investigated.

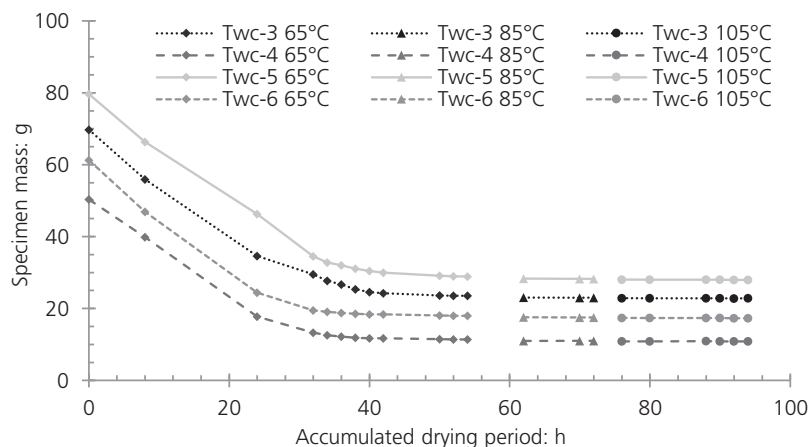


Figure 4. Specimen mass plotted against accumulated drying period for step increases in oven temperature from 65 to 85°C and finally 105°C

- After the 18 h drying period at 85°C, the oven temperature was then increased to 105°C and maintained at this value for a 22 h period before terminating these drying tests. Compared to $t = 85^\circ\text{C}$, the maximum percentage reduction in the equilibrium dry masses of the Twc-3 to Twc-6 specimens for $t = 105^\circ\text{C}$ was only 1.59% and again occurred for the Twc-4 specimen. Further, the vast majority of this mass reduction (i.e. 1.27% in the case of the Twc-4 specimen) occurred during the initial 4 h drying period at $t = 105^\circ\text{C}$.

Discussion

Significance of different t values for water content determinations

According to the method presented in the papers by O'Kelly (2004, 2005a, 2005b), the water content value corresponding to $t = 105^\circ\text{C}$ (i.e. $w_{105^\circ\text{C}}$) can be computed from the water content value measured for a lower t value of $x^\circ\text{C}$ (i.e. $w_{x^\circ\text{C}}$) using the following equation

$$1. \quad w_{105^\circ\text{C}} = (w_{x^\circ\text{C}} - \alpha_{105^\circ\text{C}} + 1) / \alpha_{105^\circ\text{C}}$$

where $w_{105^\circ\text{C}}$ and $w_{x^\circ\text{C}}$ are expressed in dimensionless form (i.e. not as % values) and $\alpha_{105^\circ\text{C}}$ is the water content parameter ($\alpha_{105^\circ\text{C}} \leq 1$ for $t < 105^\circ\text{C}$), defined as

$$2. \quad \alpha_{105^\circ\text{C}} = m_{105^\circ\text{C}} / m_{x^\circ\text{C}}$$

where $m_{105^\circ\text{C}}$ and $m_{x^\circ\text{C}}$ are the specimen equilibrium dry masses corresponding to t values of 105 and $x^\circ\text{C}$, respectively.

In the present study, the sensitivity of the specimen equilibrium dry mass to increasing oven temperature was investigated in terms of the $\alpha_{105^\circ\text{C}}$ parameter values determined for the Twc-3 to Twc-6

materials (see Figure 5). The Twc-1 and Twc-2 materials investigated in the first series of drying tests were not considered in this analysis since their specimens had not been subjected to step increases in the oven temperature value.

Consistent with the earlier observations, Figure 5 clearly demonstrates that compared to $t = 85^\circ\text{C}$, the $\alpha_{105^\circ\text{C}}$ values (and hence the specimen equilibrium dry masses) for $t = 65^\circ\text{C}$ have significantly greater disparity in relation to the t value of 105°C . As a practical example, the significance of adopting different t values in performing water content determinations of the Twc-3 to Twc-6 materials is demonstrated using the data presented in Table 2.

Table 2 lists the natural water content values (determined for a t value of 105°C ; i.e. $w_{105^\circ\text{C}}$) of the Twc-3 to Twc-6 materials, along with their water contents for t values of 65 and 85°C deduced using Equation 1 and their experimental $\alpha_{105^\circ\text{C}}$ values presented in

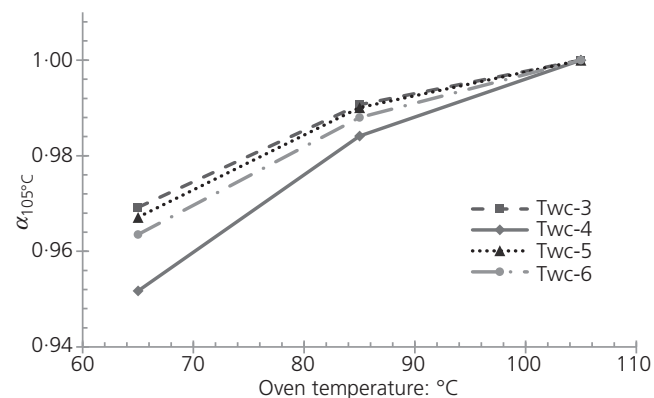


Figure 5. Parameter $\alpha_{105^\circ\text{C}}$ plotted against oven-drying temperature

Table 2. Natural water content values determined for different oven-drying temperatures

Parameter	Test material			
	Twc-3	Twc-4	Twc-5	Twc-6
Measured water content, $w_{105^{\circ}\text{C}}$: %	206	365	185	254
Deduced water content, ^a $w_{85^{\circ}\text{C}}$: %	203	358	182	250
Deduced water content, ^a $w_{65^{\circ}\text{C}}$: %	197	343	176	241
$(w_{105^{\circ}\text{C}} - w_{85^{\circ}\text{C}}) \times 100/w_{105^{\circ}\text{C}}$: %	1.5	2.0	1.5	1.7
$(w_{105^{\circ}\text{C}} - w_{65^{\circ}\text{C}}) \times 100/w_{105^{\circ}\text{C}}$: %	4.5	6.1	5.1	5.0

^a Calculated using Equation 1 and employing the $\alpha_{105^{\circ}\text{C}}$ values presented in Figure 5

Figure 5. Based on these data, the maximum relative difference (P , as %) between the values of $w_{65^{\circ}\text{C}}$ and $w_{105^{\circ}\text{C}}$ for the Twc-3 to Twc-6 materials ($w_{105^{\circ}\text{C}} = 185\text{--}365\%$) was determined according to Equation 3 as 6.1% for the Twc-4 material.

$$3. \quad P = \left(\frac{w_{105^{\circ}\text{C}} - w_{65^{\circ}\text{C}}}{w_{105^{\circ}\text{C}}} \right) \times 100$$

Similarly, the maximum relative difference between the values of $w_{85^{\circ}\text{C}}$ and $w_{105^{\circ}\text{C}}$ for these materials was determined as only 2.0%. However, as discussed in the papers by O’Kelly (2014) and O’Kelly and Sivakumar (2014), these levels of measurement error may be significant in correlating water content with other measured properties for peat and other organic soil materials. For instance, O’Kelly (2014, 2016) and O’Kelly and Sivakumar (2014) investigated the effect of different t values in the range 80–110°C on water content–undrained strength correlations for water-treatment residue and amorphous and fibrous peat materials, respectively. As concluded in the papers by O’Kelly (2014, 2016), O’Kelly and Sivakumar (2014) and Skempton and Petley (1970), the authors also conclude that the standard t value of 105°C employed for inorganic soil is appropriate and preferable to using lower t values for performing routine water content determinations of peat and other organic soil materials. Although the associated measurement error is less significant in profiling the spatial water content distribution for peat deposits since the in situ water content values typically vary sharply over very small distances owing to the natural heterogeneity, particularly for less humified organic soils (Hobbs, 1986; O’Kelly and Pichan, 2013, 2014; O’Kelly and Sivakumar, 2014), the authors still recommend using the t value of 105°C for performing routine water content determinations of these materials.

Computing and comparing water content values determined on the basis of different t values

O’Kelly (2005a) reported that the levels of susceptibility of organic soils to charring for $t \geq 85^{\circ}\text{C}$ are approximately related to their N values, which was subsequently investigated in the paper by O’Kelly and Sivakumar (2014) for 18 very different organic soils with $N = 5.5\text{--}99\%$. For each of these soils, they computed the gradient of the best-fit line to the $\alpha_{105^{\circ}\text{C}}$ against drying

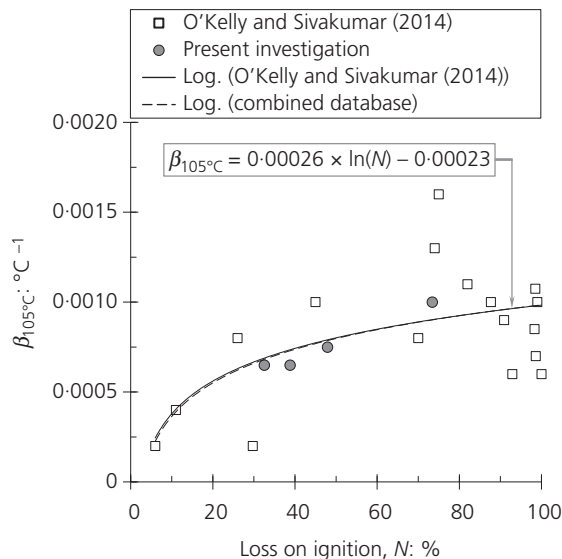


Figure 6. Parameter $\beta_{105^{\circ}\text{C}}$ plotted against loss on ignition

temperature plot for $t \leq 105^{\circ}\text{C}$, which they denoted as the $\beta_{105^{\circ}\text{C}}$ parameter, and presented it as a function of the N value, as shown in Figure 6.

The deduced $\beta_{105^{\circ}\text{C}}\text{--}N$ relationship given by Equation 4 and also shown in Figure 6 indicates that these parameters are correlated, with $\beta_{105^{\circ}\text{C}} < 0.0015^{\circ}\text{C}^{-1}$ for all but two of the 18 soils considered in their investigation.

$$4. \quad \beta_{105^{\circ}\text{C}} = 0.00026 \times \ln(N) - 0.00023 \quad (n = 20)$$

Some scatter evident in the O’Kelly and Sivakumar (2014) data set was partly explained by differences in the experimental t ranges considered in calculating the $\beta_{105^{\circ}\text{C}}$ values – that is, in some instances, the t range available and used was 80–105°C, whereas it was 60–105°C for other soils.

Table 3 lists the $\beta_{105^{\circ}\text{C}}$ values for the Twc-3 to Twc-6 materials investigated in the present study. These values were computed from the gradient of their $\alpha_{105^{\circ}\text{C}}$ against t plots presented in Figure 5, considering the discrete t ranges of 65–105 and 85–105°C. The mean $\beta_{105^{\circ}\text{C}}$ values for these materials are also

Table 3. $\beta_{105^{\circ}\text{C}}$ values for test materials investigated in the present study

Material	N : %	$\beta_{105^{\circ}\text{C}}: ^{\circ}\text{C}^{-1}$		
		65–105°C	85–105°C	Mean
Twc-3	38.8	0.0008	0.0005	0.00065
Twc-4	73.4	0.0012	0.0008	0.00100
Twc-5	32.5	0.0008	0.0005	0.00065
Twc-6	47.9	0.0009	0.0006	0.00075

plotted in Figure 6. As evident from this figure, there is excellent agreement between the best-fit curve determined for the O'Kelly and Sivakumar (2014) data set and the extended database including the Twc-3 to Twc-6 values, thereby demonstrating the more general applicability of the empirical Equation 4 for other organic soils.

Summary and conclusions

The primary aims of this investigation were to establish appropriate oven-drying temperature and drying period values for routine water content determinations of the six highly decomposed peaty soils sourced from south-west China. Despite their very different initial water contents and a wide N range of 32.3–80.1%, the equilibrium dry mass condition was achieved using a forced-ventilation type oven for drying periods of <24 h for $t = 105^\circ\text{C}$ (and 85°C), compared to a minimum of 48 h for $t = 65^\circ\text{C}$. Furthermore, compared to $t = 85^\circ\text{C}$, the maximum percentage reduction in the specimen equilibrium dry masses for $t = 105^\circ\text{C}$ was only 1.59% – that is, corresponding to a maximum relative difference in the $w_{85^\circ\text{C}}$ and $w_{105^\circ\text{C}}$ values of only 2.0% for the natural water content of these materials which ranged 185–365%. On this basis, the authors conclude that the standard t value of 105°C and typical 24 h oven-drying period employed for inorganic soil are also appropriate for routine water content determinations of the peaty soils investigated. Oven-drying of these soils at $t = 105^\circ\text{C}$ is also preferable from the point of view that longer drying periods are generally required to achieve the equilibrium dry mass condition for lower oven temperatures. Further, the authors recommend a specimen wet mass of approximately 50 g for performing water content determinations of these soils. These findings are consistent with the recommendations presented in the papers by O'Kelly (2014, 2016), O'Kelly and Sivakumar (2014) and Skempton and Petley (1970), which investigated peaty clay and amorphous and fibrous peat materials mainly sourced from Ireland and England.

The correlation between the $\beta_{105^\circ\text{C}}$ parameter and N reported for other peat and highly organic soil materials in an earlier paper by O'Kelly and Sivakumar (2014) has been further validated by repeating their analysis on an extended database compiled in the present investigation. The outcome is the correlation given by Equation 4. In other words, the $\beta_{105^\circ\text{C}}$ value for a specific organic soil under investigation can be estimated from its measured or reported N value and using Equation 4. Thence, the pertinent $\alpha_{105^\circ\text{C}}$ value employed in Equation 1 for making comparisons and standardisation of water content values determined on the basis of different t values can be estimated from the deduced $\beta_{105^\circ\text{C}}$ value and the difference in the t values employed. In other words, water content values determined for $t < 100^\circ\text{C}$ can be standardised to the recommended t value of 105°C using the estimated $\alpha_{105^\circ\text{C}}$ value and Equation 1.

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