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FABRIC OF PEAT SOILS USING IMAGE ANALYSIS

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Abstract: Peat is primarily derived from the decomposition of plant and animal matter when they are kept under anaerobic conditions for long periods. The fabric of peat is therefore totally different from inorganic soils such as clay, sand and gravel. In geotechnical engineering, the interpretation of soil genesis based on fabric analysis is essential to ascertain its influence on the analysis of its engineering behaviour. Aydemir et al. (2004) suggested the use of image analysis in research to identify more clearly the composition and structure of the fabric in a soil. Literature shows its usage to be focused more on inorganic soils. This paper explains and presents the imaging technique that was used in the laboratory by the authors to analyse different types of peat soils. The peat soils from different locations have been used in this study. The influence on the geotechnical behaviour due to the fabric composition is discussed. This paper will help the geotechnical engineer to classify the peat soils more appropriately.

1. Introduction

The concepts of soil description and the approach to soil micro-morphology have changed over the years with the new techniques developed to describe them. The term, ‘Soil Fabric’ is usually defined as the geometrical aspects of a particle and the associated inter particle forces between adjacent particles (Raymond et al., 1975). In this paper, ‘soil fabric’ is discussed with respect to the total organisation of a soil, expressed by the spatial arrangement of soil constituents, their shape and size.

Meanwhile, ‘peat’ is described as an accumulation of disintegrated and decomposed plant remains, which have been preserved under condition of restricted aeration and high water content. It is formed when organic (usually plants) matter accumulates more quickly than it humifies below a high water table as in swamps or wetlands (Bujang, 2004).

The fabric of peat is totally different to that of inorganic soil (clay, sand and gravel) by virtue of the abundance of fibrous material. Macroscopically, peats can be divided into three basic groups such as fibrous, hemic, or sapric. Fibrous peats are the least decomposed and comprise of intact fibre. Hemic peats are somewhat decomposed, while sapric are the most decomposed.

Image analysis is one of the methods adopted by previous researchers to analyse the morphology of the fibres. Anand et al. (2004) explained the use of digital imaging methods as providing numerous opportunities for direct or indirect fabric analysis. Joanne et al. (2007) agreed with this method that can be used to measure and quantify more accurately the size and shape distribution of all the particles. This enables researchers to obtain a better understanding of the soil structure and behaviour.

Comprehensive literature reviews on fabric analysis on peat have been made by Landva and Pheeney (1980), Kruse (1998), O'Loughlin and Lehane (2003) and Landva (2007). However, these studies concentrated more on the use of Optical Microscopy and Scanning Electron Microscopy (SEM) (see examples of appropriate micrographs Figure 8 and Figure 9 respectively). The sample preparation for these two methods is very costly and laborious. The representability of such a high magnification photomicrograph is still questionable.

The main objective of this paper is to present the application of image analysis which has been used by authors to identify and quantify the presence of fibres in peat and have focussed on four different types of peat. These were collected from Cambridgeshire (UK), Carlisle (UK) and Johore (Malaysia). Authors have obtained the images with a digital camera and the image was subsequently analyzed using two different software, viz; PICASA 3 and analySIS®.

2. Characteristics of the Peat

The physical characteristics of peat can be variable through out the same deposit (Zainorabidin and Wijeyesekera, 2008). This makes peat an inhomogeneous soil. Table 1 compares physical properties of four different types of peat. These can be categorised into two different groups; fibrous and hemic. The classifications are based on the fibre content. HF1 and HF2 peats are categorised as fibrous peat, as they have a fibre content of more than 70%.

The Malaysian and Solway peat are categorised as hemic peat with a fibre content between 43-63%. Field moisture content for HF2 is the highest at 775% compared to the other samples. The sampling, was from a depth of more than 1.5m and near to the water table level.

Liquid limit results for fibrous peat are higher (180%) than hemic which is in the range 140%-150%. The high fiber content in peat made the determination of plastic limit difficult and impossible. Similar experience is recorded from previous researchers (O'Loughlin and Lehane, 2004; Bujang, 2004).

Table 1. Comparison of basic physical properties for the samples tested.

Samples Designated/ Parameters	Holme Fen 1 (HF1)	Holme Fen 2 (HF2)	Malaysia Peat (MP)	Solway Peat (SP)
Type of Samples	Fibrous	Fibrous	Hemic	Hemic
Degree of Humification	H3	H3	H6	H5
Moisture Content (%)	670	775	472	554
Fibre Content (%)	73	75	43	63
Organic Content (%)	88	92	92	96
Liquid Limit (%)	180	240	140	150
Specific Gravity	1.46	1.30	1.14	1.40
Uniformity Coefficient (dry)	8.57	4	4.9	3.9
Uniformity Coefficient (wet)	7.5	5	3.25	3.2
$C_{g\ dry}$	1.05	1	1.22	1.75
$C_{g\ wet}$	0.79	0.87	1.39	0.56
Aspect Ratio (L/W)	10-4	6-3	4-2	3.5-2

The degree of humification of each peat was assessed by the Von Post Squeeze Test (Von Post, 1922). Peat samples were hand squeezed on site. The colour and form of fluid that extruded between the fingers was observed. Based on the Von Post Classification, HF1 and HF2 peats were further classified as H3 with slightly decomposed soil. The samples released some muddy brown water and the plants remained still identifiable.

The Malaysian Peat, is classified as H6 and Solway Peat as H5. Generally in this classification, the samples are moderately decomposed peat, which releases very muddy water and there is only a very small amount of amorphous granules that escape between the fingers.

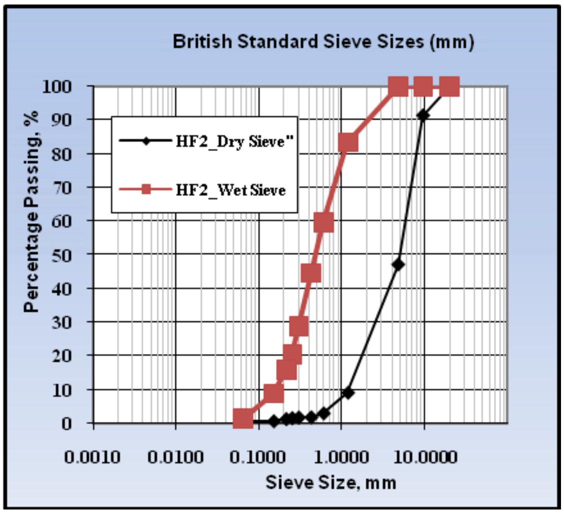


Figure 1 Typical sieve analysis for wet and dry samples of HF2. (D_{10dry}=0.12, D_{10wet}=1.2, D_{30dry}=0.3$_{dry}$, D_{30wet}= 2.5, $D_{60\ dry}$=0.6, D_{60wet}= 6)

The typical graph for sieve test analysis for peat is shown in Figure 1. The curves for wet sieving show a higher uniformity coefficient compared to that of the dry sieving results. Authors explain this as being due to the ease of separation of fibre in the wet condition. British Standards 1997: Part 2 defines a uniform sample as that which has a uniformity coefficient less than 3. Meanwhile if the value is more than 3, it is categorised as a well graded soil. Most well graded soils will have grading curves that are mainly flat or slightly concave, giving values of coefficient of gradation (*C*g) between 0.5 and 2.0.

Fibrous samples show that they have the highest uniformity coefficients both in dry and wet states. Contrarily the coefficient of gradation is higher for hemic samples. HF1 peat has the highest value of uniformity coefficient in the dry state compared to other peats. Authors also investigated the aspect ratio of the particles in each sample. Aspect ratio is the ratio between length and width of the particles. Aspect ratio for both fibrous peats is higher (10-3) compared to hemic peats (4-2). These demonstrate that the size of fibrous peat particles were larger than the hemic peat.

3. Fabric Analysis

One of the challenges of preparing the samples for image analysis is to minimise the sample disturbance. Authors avoided cutting the surface of the samples using scissors or a sharp knife as it will disturb the particle arrangement in the sample. A new technique was adopted by authors to prepare the sample.

Undisturbed samples were obtained directly from the U100 samples by extrusion and trimming. A minimum 300mm height of sample is necessary to minimise sample disturbance. To prepare an undisturbed surface, both ends of the sample were glued using a very strong adhesive (Boskit) and attached to a glass plate. The sample was then left dry to make sure the sample and glass plates would bond together. Air dry method was chosen by authors to minimise the otherwise rapid shrinkage of the samples.

After the glass plates were bonded together, the sample was split into two parts by carefully pulling apart the glass plates. This technique was adopted to ensure that the surface of the sample was not touched or disturbed by hand. This step was very crucial and important.

The samples were imaged using a digital camera Canon S5IS lens with a close up 500D attached to a frame grabber. The height of the frame grabber to hold the camera was adjustable. To ensure an enhanced quality of the image, the process of photographing was done in a dark room.

To analyse the images, authors used PICASA 3 and analySIS® software. This suitable software showed the conjunction of interfaces that ensured the appropriate observations for different fields. PICASA 3 software has an advantage of enhancing and differentiating the image to a better perspective.

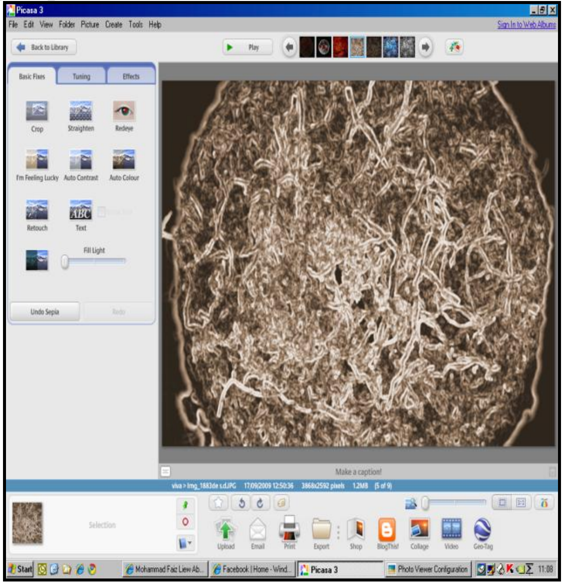


Figure 2 Image Analysis using PICASA 3 software

Figure 2 shows the fibrous sample (HF1) image enhanced after using PICASA software. It shows the fibre arrangement more clearly. It helped authors in the initial differentiation of the fibrous and hemic peats. AnalySIS® software was used to investigate detailed particle arrangements. Further it can also be used to demonstrate the presence of void and cracks in the sample as shown in Figure 3.

Another important feature of this software is that, authors can set the Region of Interest (ROI) as shown in Figure 4. In this paper, authors defined ROI as the percentage area of fibre to the total area selected. ROI is an area of arbitrary shape and is valid for particle analysis only. The ROI'S must be applied for each image separately. It helps authors to assess or describe the fabric of the peat in a more statistically reliable way in order to better ascertain its fabric.

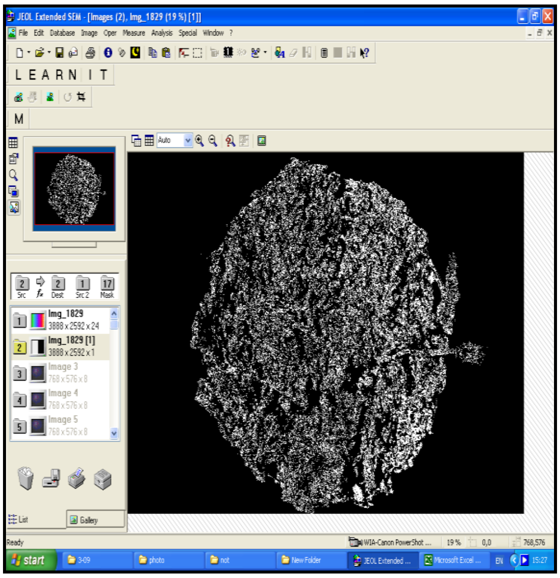


Figure 3 Image Analysis using analySIS® software

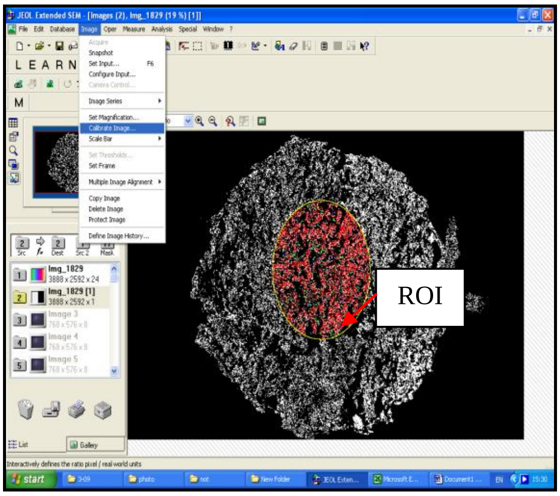
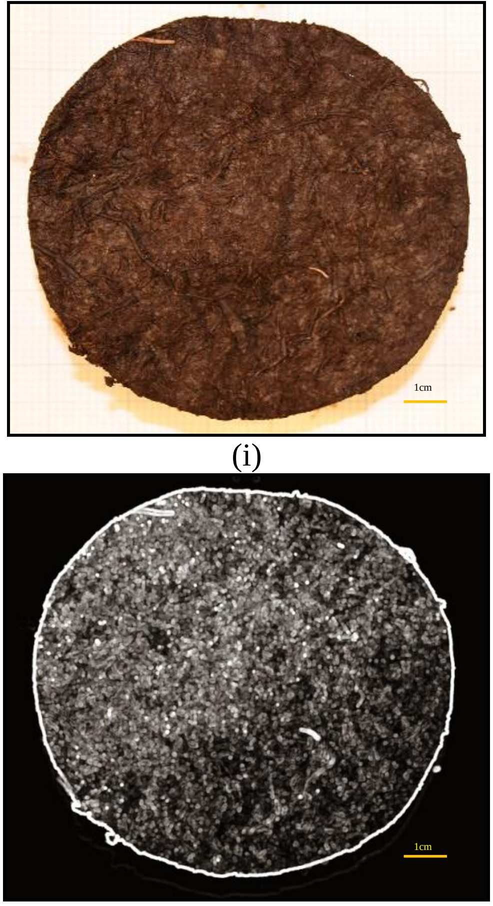


Figure 4 Defining the Region of Interest (ROI) using analySIS®.

4. Results and Discussion

Figure 5(i) shows the image of a 100mm undisturbed peat samples. Before image enhancing using PICASA3 software, the sample appeared to be of one colour, in which it was difficult for the authors to differentiate between particles constituents.



(i)

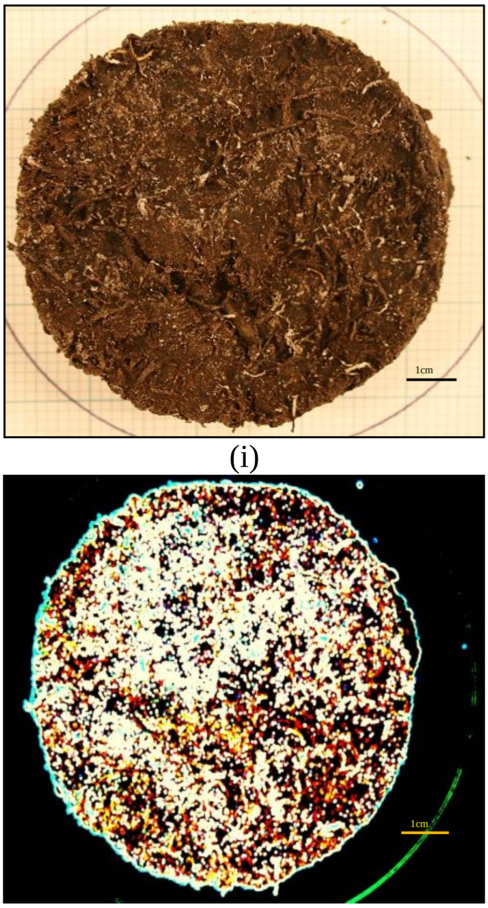
(ii)

Figure 5 (i) Undisturbed Wet Sample for HF1 (ii) Image enhanced using PICASA 3 for wet HF1 sample (Magnification of 0.5).

When the image was transformed into a selected colour, observations were made possible between the pores and particles of the sample as shown in Figure 5(ii). In the case of dry sample [Figure 6(i) and (ii)], the image showed more clearly the differences between pores and particles in the sample.

The potential of linear shrinkage or cracking for the sample was also measurable.

As mentioned in Section 3, the sample is then analysed using analySIS® software. Figure 7 shows the typical image enhanced clearly with the presence and the orientation of the fibres. For each sample, five different points were selected by the authors and the results are compared and given in Table 2.



(i)

(ii)

Figure 6 (i) Dry Sample for HF1 (ii) Image enhanced using PICASA 3 for dry HF1 sample (Magnification of 0.5).

Results in Table 2 show both hemic samples MP and SP give the highest area of fractions in the range of 20-31% and 25-37% respectively for both dry and wet conditions. Similarly, for fibrous samples HF1 and HF2, the percentage values lie between 11-12% for wet state and 15-18% for the dry state.

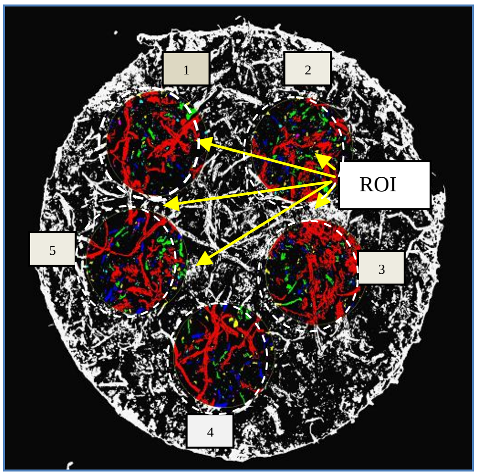


Figure 7 Location of ROI'S using analySIS® software .

Table 2. Percentage of area of fraction of samples.

Point/ Sample	1	2	3	4	5	Mean
$HF1_{WET}$	10.7	11.0	11.1	11.4	11.3	11.1
$HF1_{DRY}$	18.4	18.4	18.4	17.9	18.0	18.2
$HF2_{WET}$	12.9	12.8	12.8	12.4	12.5	12.7
$HF2_{DRY}$	15.6	15.5	15.4	15.3	15.6	15.5
MP_{WET}	20.1	19.4	23.4	22.1	21.5	21.5
MP_{DRY}	24.5	26.1	26.3	27.1	25.1	25.8
SP_{WET}	30.5	30.8	31.8	31.6	31.0	31.2
SP_{DRY}	37.4	39.2	38.3	37.3	36.9	37.8

It can be concluded that for fibrous peat, the percentage area of fraction is lower than that for the hemic peat due to the high fibre content in the soil (>70%) compared to hemic peat (<65%). The high moisture content for fibrous peat (>600%) also affected the reduced percentage of the area fraction. The fabrics have also been made with a thin section study. The image (see Figure 8) was taken using a petrographic microscope.

This figure shows the detailed orientation of the fibre at x100 magnification. To understand more about the cell structure, an image from the Scanning Electron Microscope was also made (see Figure 9). The main purpose of this step was to classify the fibre structure based on whether it is shrub rootlets, plant root hairs, rhizods or rootlike.

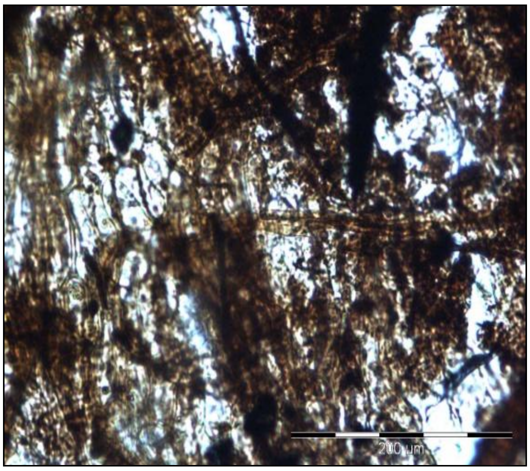


Figure 8 Image from optical microscopy for sample (HF1).

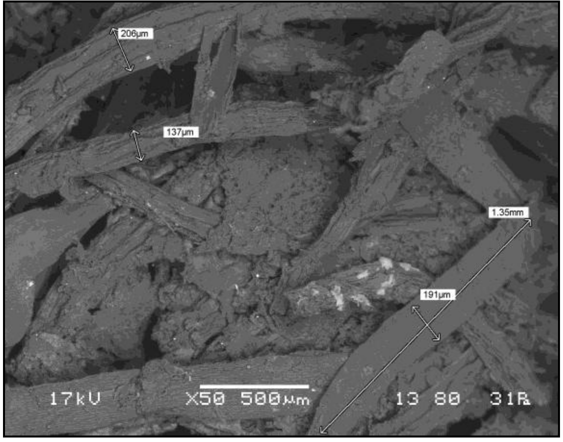


Figure 9 Image from Scanning Electron Microscopy for fibrous peat (HF1).

Comparing the techniques, the image analyses of a digital image was more representative as the analysis was carried out on the whole sample. Therefore, it is necessary for the engineers to appreciate the various techniques available in image processing to investigate the particle arrangement.

5. Conclusions

Fabric analysis of peat is very essential in order to reveal how the physical properties are related to the particle associations and arrangements. The direct image analysis and characteristic pattern of soil structure observed using a photographic technique and image analysis software is very useful in understanding the spatial distributions of peat. This technique represents a significant improvement to qualitative assessment and it allows simple and quick routine identification. The advantage of using this technique is that the cost of sample preparation is less compared to the cost of Petrographic Microscope or Scanning Electron Microscope (SEM) techniques. The representability is an important factor to describe the fibre of the peat samples. This technique can be also extended to investigate the effect of sample disturbance in tube sampling due to the expansion of soil when extruding the sample out.
The classification of peat is generally based on the agricultural view point and need to be expanded to a geotechnical perspective. In this study, authors differentiate fibrous and hemic samples by making fabric observations and contributing to the classification based on the aspect ratio of fibres, percentage of area, uniformity coefficient and coefficient of gradation.

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