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SHEAR MODULUS AND DAMPING PROPERTIES OF PEAT SOILS

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Abstract: Soils are subjected to dynamic loading of various forms. Some of these result from sources such as earthquakes, traffic loads and tidal action. To assess the level of the consequent ground motion of the soil, two parameters those are vital in dynamic analysis; shear modulus (G) and damping ratio (D) properties (Adnan et. al, 2007, Adnan and Wijeyesekera, 2008). Dynamic properties of soils such as sand, silt and clay have been studied for more time in the past (Chen et al., 2007, Hyde and Ward, 1985). However only a insignificant amount of work has been done on the dynamic properties of peat. This paper presents experimental results based on the undrained cyclic tests on different peats. Samples were collected from Holme Fen Post, Cambridgeshire and Solway Post, Carlisle. VJTech Cyclic Triaxial Testing Apparatus was used to measure these parameters. The significance of peat type, microstructure, loading frequency, confining pressure and index properties are also discussed.

1. Introduction:

The response of geomaterials to dynamic loading has been of interest to geotechnical engineers and geophysicists for many years. These depend on the dynamic characteristics of the load that are a consequence of sources such as earthquakes, construction operations, traffic and wheel loads, wind, machinery, or the tidal action of water. Majority of previous research has paid attention primarily to the dynamic response of the inorganic soils such as clay, sand and clayey soils. Previous research on cyclic properties of peat is limited to only a few investigations (Stokoe et al., 1994; Kramer, 1996; Boulanger et al. 1998; Kramer, 2000 and Wehling et al., 2001). The repeated or cyclic nature of the loading arises from the dynamics of the slipping elements of crust and the surrounding rock at soil deposits; a single blow to any flexible system causes a series of waves in the material. Normally the loading pattern is highly complex and unpredictable. This is vital in the understanding of the prime factors that will control structural damage due to the dynamic loadings.

Design of structure that involve dynamic loading of the soil foundation requires the determination of the shear modulus and the damping ratio of the foundation soils. Zhou (2005) stated that adequate information on dynamic soil properties, especially dynamic shear modulus (G) and damping ratio (D), is essential for accurate prediction of ground response and soil interaction problems. Evaluating the seismic behaviour of peat requires addressing the potential for significant strains or strength loss that can contribute to ground deformations or instability during or following the occurrence of cyclic loading. In peat layers, low frequencies (with higher energy capacities) can be transmitted due to low wave velocities.

The shear modulus is normally defined as the slope of a secant line which connects the extreme points on a hysteresis loop at a given shear strain. As the strain level increases, the shear modulus decreases.

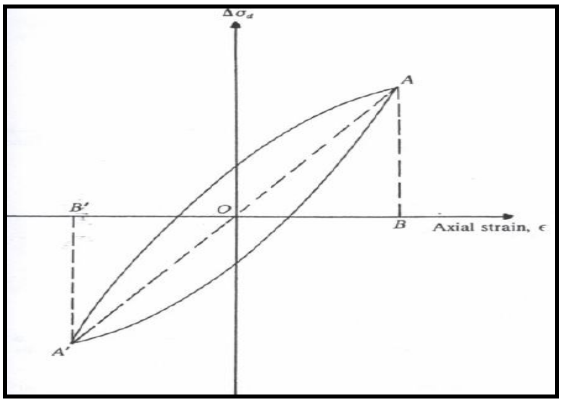

Figure 1: The nature of a hysteresis loop obtained from a cyclic triaxial test.

When cyclic triaxial tests are performed, a similar hysteresis loop will be formed by plotting deviator stress, σ_d, versus axial strain, ε. Figure 1 shows the relationship between deviator stress and axial strain to determine the G and D parameters. The graph also can be plotted with axial load versus axial deformation. The slope of the secant line connecting the extreme points on the hysteresis loop is the elastic modulus, E where;

$$E = \sigma_d/\varepsilon \qquad (1)$$

$$\gamma = (1 + \mu) \qquad (2)$$

$$G = E / 2\,(1 + \mu) \qquad (3)$$

Where μ is passion ratio and may be estimated as 0.5 for saturated, undrained specimens. The damping ratio, D, is a measure of dissipated energy, ΔW, versus elastic energy, W_e and may be computed as;

$$D = \Delta W / W_e \qquad (4)$$

$$= A_L / (4\pi A_T) \; * \; 100 \qquad (5)$$

ΔW is proportional to the entire area enclosed inside the hysteresis loop, and W_e is proportional to 4π times the triangular area below the loop.

2. Characteristics of Tested Peat:

The term ***PEAT*** actually represents an accumulation of disintegrated and composition of plant remains, which have been preserved under condition of incomplete aeration and high water content. It is formed when organic (usually plants) matter accumulates more quickly than it humifies below high water table as in swamps or wetlands (Bujang, 2004).

In terms of geotechnical engineering, peat is commonly recognised as a material with high compressibility and low bearing capacity and therefore being unsuitable as foundation materials for any, construction works (Adnan et al., 2007). Peat deposits found in temperate regions such as in Britain are bog and fen peat. Figure 2 shows the layers for different deposit of peat in Britain. The composition of these peats consists normally of remains from the grasses, sedges and bog mosses. The morphological differences between fen and bog peats are attributed to the types of plant remains that occur in the peat and their mode of origin.

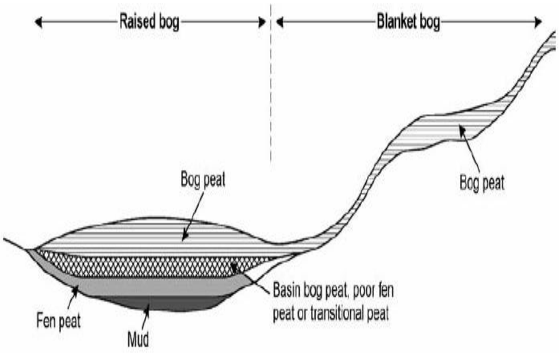

Figure 2: Schematic drawing of different deposit layer of peat (after Hobbs 1986)

The main differences in characteristics between bog and fen peat are; bog receives water solely from rain and/or snow falling on its surface meanwhile fen receives water and nutrients from the soil, rock and groundwater as well as rain and/or snow.

In this research, the peat samples were obtained from two different sites viz; Holme Fen Post, Cambridgeshire and Solway Post, Carlisle. In Holme Post site, two different depths of sampling were chosen; 1.5m and 2.0m. Meanwhile for Solway Post samples only 1.0m depth was collected. Macrostructure tests in laboratory showed that samples from Holme Post are categorized as bog peat for sample 1.5m depth and fen peat for 2.0m depth. Meanwhile, sample from Solway Post is categorized as bog peat.

Figures 3, 4 and 5 show the photograph of three types of peat. The photos were captured in laboratory using the high-resolution digital camera. Observation shows the fibres size for each type of samples were very different. Bog peat from Holme Post shows a structure and size of fibres that are more homogeneous compared to the others sample.

Figure 3: Bog peat sample from Holme Post site, Cambridgeshire

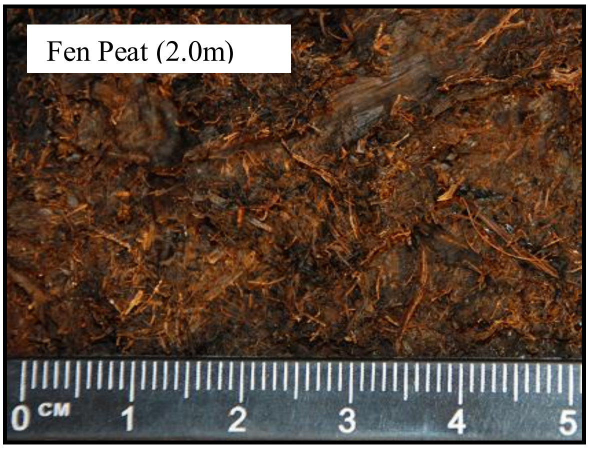

Figure 4: Fen peat sample from Holme Post site, Cambridgeshire

Figure 5: Bog peat sample from Solway Post, Carlisle

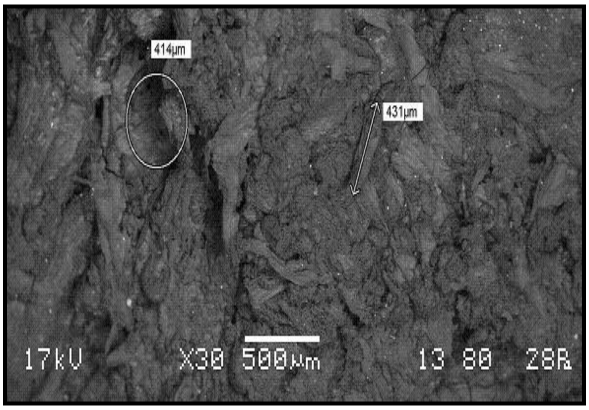

Figure 6: SEM photo for Bog peat (Holme Post site)

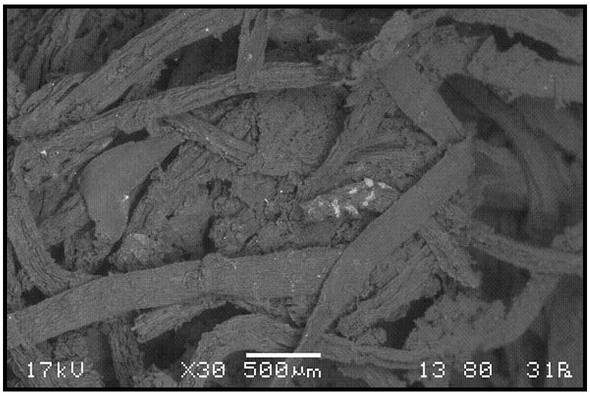

Figure 7: SEM photo for Fen peat
(Holme Post site)

Figure 8: SEM photo for Bog peat
(Solway Post site)

To verify the clearly fibres structure in each type of peat, Scanning Electron Microscopy (SEM) was used. Figures 6, 7 and 8 shows the SEM photo and the differences of the samples. Observation shows that the fibres for bog peat is denser compare to the fen peat.

Table 1 show the comparison physical properties for samples tested.

Samples Designated/ Parameters	Bog Peat (Holme Post) (RbP)	Fen Peat (Holme Post) (FP)	Bog Peat (Solway Post) (BP)
Water Content (%)	300-500	500-700	500-750
Organic Content (%)	91	96	92
Liquid Limit (%)	350	600	650
Specific Gravity	1.25	1.17	1.21
Unit Weight (kN/m^3)	8.5-11.0	9.5-10.5	7.5-10.2

Review of literature indicates that peat soil is very variable in its properties, both from one deposit to another and from point to point in the same deposit (Zainorabidin and Wijeyesekera, 2008). The moisture content for bog peat from Holme Post ranged between 300% to 500%. However, the moisture content from Fen Peat (Holme Post) and Bog Peat (Solway Post) were slightly higher and in the range 500-750.

Compared with the moisture content for Malaysian peat (200-500%), investigated by other researchers (Zainorabidin and Ismail, 2003; Al-Raziqi et al., 2003), these results are slightly higher. Hobbs (1980), explained these differences depend on the type of plant detritus, the degree of humidification and ground water table effect. Further reasons are the influence of different agricultural history of the area and rainfall intensity.

As for organic content, all samples have values that are similar and more than 90%. Accordingly, the liquid limit for the both Bog peats from Holme Post and Solway Post, are much less than that reported by Hobbs (1986), with 800-1500% values for bog peat. However, the fen peat results contradict that reported by Hobbs (1986), ranged between 200-600%. Edil (2003) and Hobbs (1986) reported that the specific gravity for peats were varies in the range of 1.1 to 1.9. The specific gravity values are within an anticipated range.

3. Testing Methodology:

The samples were extruded and prepared using UD tube sample sizes 100 mm diameter and 200 mm long. Due to the sample was too soft, the handling and the set up inside chamber must be done with very carefully.The tests were carried out using undisturbed specimens and samples were consolidated into three different stresses that were 13kPa, 25kPa and 50kPa. These stresses were chosen based on the depth for effective consolidation stress.

All the samples in cyclic tests were subjected to one-way cyclic loading with peak stresses exceeding or remaining half of the monotonic strength. VJ Tech Cyclic Triaxial Machine was used for this research (Refer Figure 9). This testing machine was control with the automatic valve and used CATTS Software programmed. The cyclic controller was high operated based on air pressure supply by centralized high air compressor. Sinusoidal cyclic axial loads was chosen to apply for three different frequencies; 0.5Hz, 1.0Hz and 2Hz.

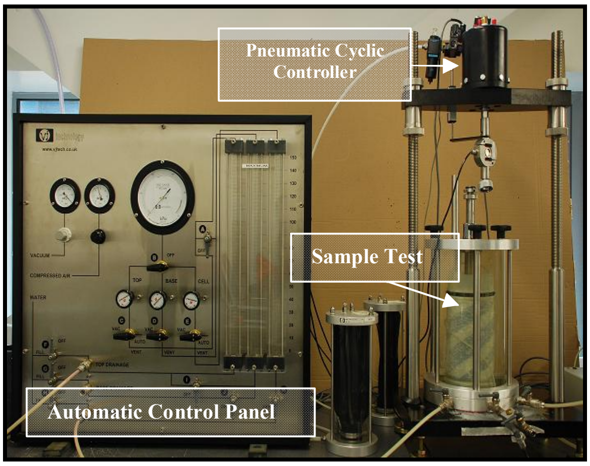

Figure 9: VJTech Cyclic Triaxial Machine

The purpose of choosing these different frequencies was to simulate the different dynamic response. All the tests were stopped when the cycles reach to 500 cycles.

4. Test Results:

Figures 10 and 11 illustrate the typical results from the cyclic tests.

Figures 12, 13 and 14 illustrate a comparison of displacement response observed during all the tests. It is seen that at 1.0 Hz the displacement response is uniformly increased for all samples. The displacement increased maximum until it reached 40 cycles.

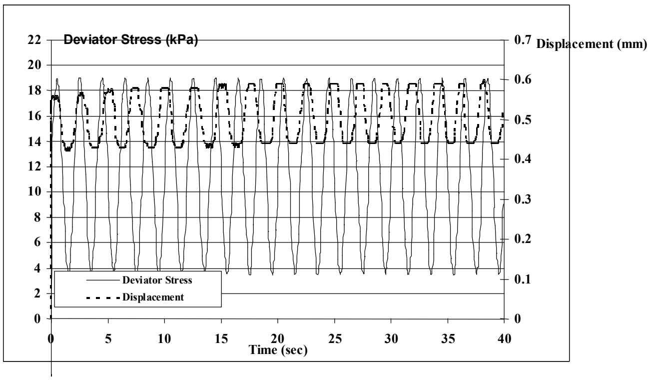

Figure 10: Axial deformation response to cyclic deviator stress application on peat sample

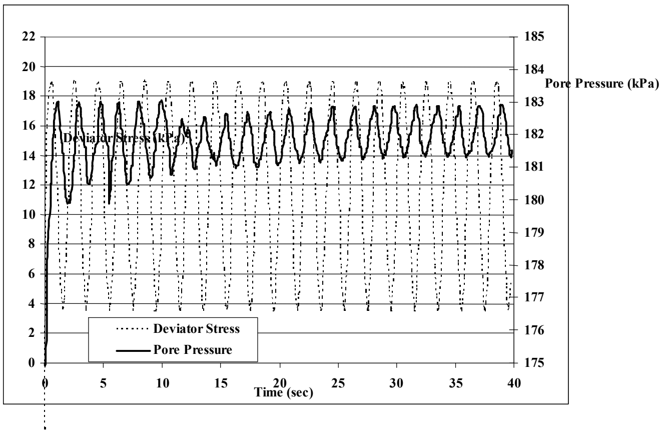

Figure 11: Pore water response to cyclic deviator stress application on peat sample.

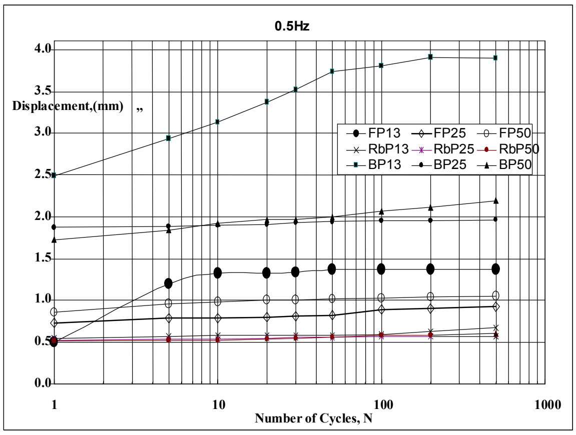

Figure 12: Displacement response to number of cycles on peat sample for 0.5Hz.

Figures 15 and 16 show he results for the dynamic shear modulus and damping ratio. Kramer (2000), described the plastic inorganic soils to often exhibit rate dependency that manifested itself under dynamic loading conditions in the form of frequency-dependent stiffness and damping.

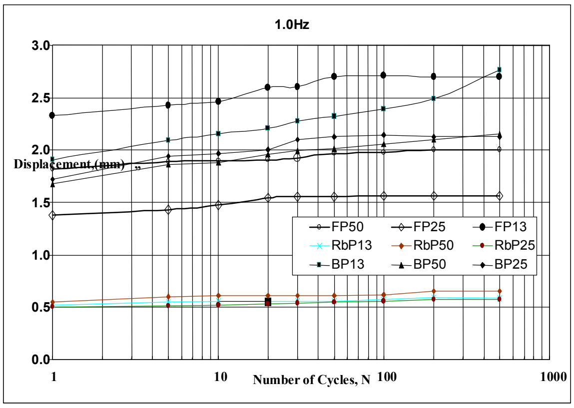

Figure 13: Displacement response to number of cycles on peat sample for 1.0Hz.

He also stated soils exhibit a viscous component of resistance that caused the measured shear modulus and damping ratio to increase with increasing frequency.

The tests results indicate that the dynamic shear modulus increases with increasing frequencies meanwhile damping ratio decreased with increasing frequencies. This compared well with previous research by Boulanger (1998), where similar trends were reported. Nevertheless, the influence of changes in effective confining pressure makes these parameters slightly inconsistent with scatter of results.

These results illustrate the complex nature of the behaviour of these materials, and point out the need to consider a wide range of frequencies to characterize the effects of rate dependence on their response.

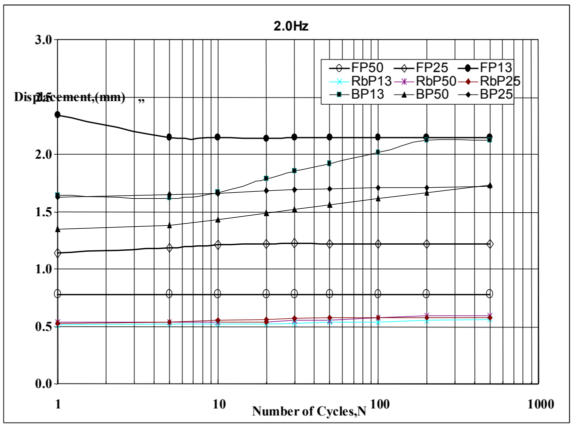

Figure 14: Displacement response to number of cycles on peat sample for 2.0Hz.

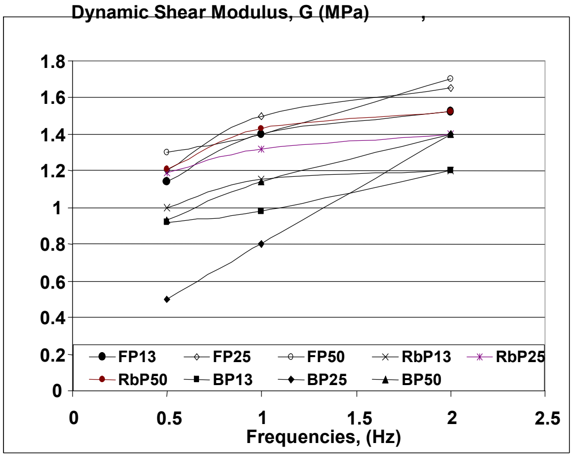

Figure 15: Observation dynamic shear modulus, (MPa) for different frequencies (Hz).

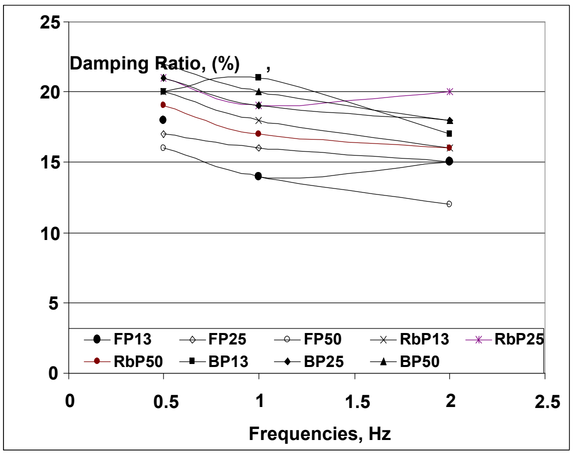

Figure 16: Observation damping ratio, (%) for different frequencies (Hz).

7. Conclusion:

In this paper, some pertinent matters are presented and discussed and these are summarised as follows:

- Different geographical locations in different climates will generate different characteristics.
- Variation of Dynamic shear modulus and damping ratio for the peat with frequency are established
- Research leading to a better understanding of the performance of peat especially in dynamic response is urgently desired for better geotechnical design.

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