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New Technique Assessment of Plastic Limit of Soft Clay Particularly Peat Soils

by

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Abstract

Plastic Limit (PL) is considered as the moisture content at which soil becomes too dry to remain plastic. Both the British Standards Institute (BS 1377 (1990)) and American Society for Testing and Materials (ASTM D4318 (2001)) are consistent with their proposition of determining PL as the moisture content when the soil crumbles upon rolling it to thread of 3 mm diameter. However for challenging soils such as peat which is naturally organic substance derived from the remains of plants, the "rolling method" is not appropriate, particularly in the area of fibrous peat. Very little information is available in the public domain for satisfactory techniques to define PL. Huat (2004) reported that west Malaysia Peat has a PL of 100-200% and Liquid Limit (LL) of 190-360 % Therefore, the aim of this paper is to make a critical evaluation of this and alternative method to determine PL particularly for peat. The authors have investigated the extended adoption of the standard cone penetration (30^0 apex angel , 80g of mass, 20mm penetration) method used in the liquid limit determination recommended in BS 1377 and ASTM 4318. As early as 1978 (Wood and Worth) and as research on 2000 (Feng) the modified cone penetration method has been proposed for the determination of PL but only focusing on cohesive soil. This paper presents the "full range" penetration –water content data obtained at intervals of 5 percent moisture content for four different soils (laterite soil, kaolin, local clay (RECESS) and Peat). The results indicated that the standard method and new techniques give very satisfying result. It is apparent that the author's analysis using the cone penetration method will be more feasible means of measuring Plastic Limit of soil especially for peat soil.

Keywords: Fibrous, Peat, Plastic limit, Rolling thread, Critical analysis, Fall cone test

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1. Introduction

This paper discusses about new assessment technique for determination of the plastic limit particularly for peat soil. Plastic Limit (PL) is considered as the moisture content at which soil becomes too dry to remain plastic. Both BS 1377 and ASTM D4318 are consistent in their proposition of determining PL as the moisture content when the soil crumbles upon rolling it to thread of 3 mm diameter. The standards recommend that plastic limit test is done on a sieve fraction on 425 μm because if the soil contains sand or larger size particles may alter the characteristics of some soils and the fine fraction of granular soil is normally free of organic matter or contains a minimal amount which does not affect the liquid and plastic limit results.

As a rule, the rolling is done between the palms of the two hands or when dealing with cohesive or cohesion less material, the finger or palm of one hand is used to reduce the pressures on the thread. Only in the case the soil becomes too plastic and very difficult to rolling, it is done on the ground-glass plate using either fingers or the palm of the hand (**Fig. 1**). Therefore this method has been the subject of criticism with the some major weakness since the rolling threat methods are dealing with different palm size and pressure. Whyte (1982) in his study stressed that if full saturation and incompressibility are assumed, plasticity theory indicates that the soil yield stress will be a function of a number of parameters such as the pressure applied to the soil thread, the geometry, i.e. The contact area between hand and thread, the friction between the soil, hand and base plate and the rate of rolling. The rolling test also highly subjective in nature and involves over-reliance on operator judgment (Sivakumar et al., 2009).

Fig. 1 Rolling thread method.

Therefore, several studies have been conducted using fall cone test to determine the Plastic Limit (PL) such as Karlsson (1961), Wood and Worth (1978), Feng (2004), Rashid (2005), Muntohar and Hashim (2005), Prakash and Sridaharan (2006), Hazell (2008) and Sivakumar et al. (2009) to introduce an alternative method for the determination of plastic limit but the standard method stated in BS 1377 (Thread Rolling Method) still in use throughout the world. Very little information is available in the public domain for satisfactory techniques to define a PL of peats since most of the studies are focused on cohesive soil. The PL for peat is defined by the content of “free moisture” in the soil, and it is received to differentiate that for the ‘interparticle’ water (IPW). Challenging soils such as peat which is naturally organic substance derived from the remains of plants, the “rolling method” is not appropriate, particularly in the area of fibrous peat. It's also very difficult to determinate the PL for peat soil due to the low plasticity. Peat soil can be molded to the shape but failure occurred due to peat not behaving as a plastic material.

2. Material and Techniques

The British fall cone apparatus in **Fig. 2** (BS 1377, British Standard Institution, 1990) is widely known throughout the world and it is accepted standard in many countries manufactured by ELE (developer and manufacturer of test equipment for construction materials) ; with a 30^o cone and weighing 0.785 N or 80g. The cone is made of stainless steel with an apex angle of 30 ± 1° and a mass of 32.5 grams, with a sharp tip and polished surface. This equipment was used during the experimental investigation. The fall cone apparatus includes a specimen cup of 55 mm in diameter and 40 mm in height. In the BS 1377 test procedure for the penetration shall be in range of depth 15 to 25 mm for determination of liquid limit. However, in the present study, the tests were performed in the range of depth of penetration about 0 to 40 mm (full range penetration –water content data obtained at intervals of 5 percent moisture content). The Fall Cone has the advantage since the operation of the apparatus is not affected by the operator, and the results are thereby comparable independent of the user. Soil samples were collected from the Southern Johor. Sample A- kaolin clay Sample B – RECESS clay from Parit Raja, Batu Pahat, Sample C - laterite also from Air Hitam, Johor, Sample D –peat from Parit Nipah were tested.

Fig. 2 The fall cone test are used during the experiment.

In order to verify the reliability of this technique, the plastic limit values of three types of soils were determined by the conventional thread rolling method and Feng's equation. Feng (2004) suggested using the standard liquid limit cone but with smaller soil container as shown in **Fig. 3** to determine the plastic limit. The penetration depth of 2 mm is used as criteria to determine the plastic limit. A small specimen container with an inside diameter of 20 mm and a depth of 20 mm was designed to contain 6.3 cm3 of soil sample for cone penetration less than 10 mm (Rashid et.al, 2008).

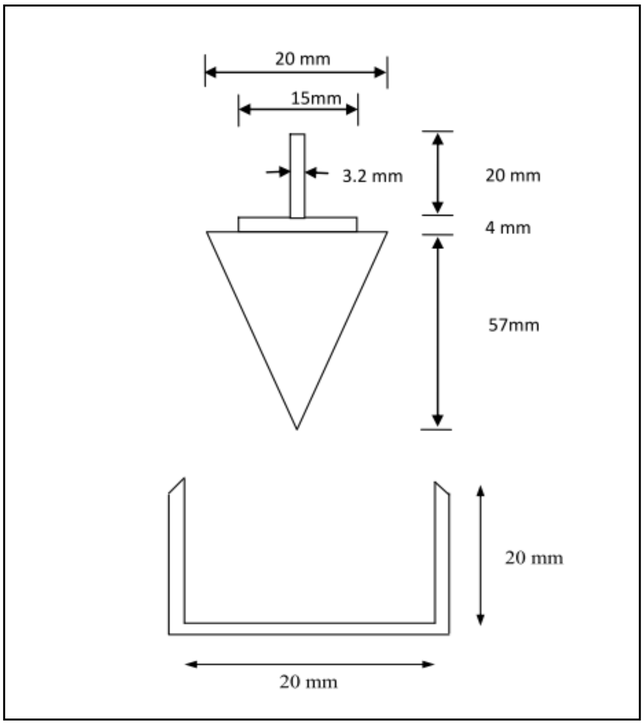

Fig. 3 Schematic diagram of Feng's method.

In this paper, only the equation and technique has been used to compute the plastic limit as stated in Equation 1 and 2

$$PL = c(2)^m \qquad (1)$$

The equation can be expressed by equations:

$$\log w = \log c + m \log d \qquad (2)$$

where w is water content , c is water content at depth of penetration, *d* and m is slope of relationship for log penetration– log water content.

3. Result and Discussion

The authors fall cone technique was conducted with an average 15 points of data. Testing procedures were strictly in accordance with British Standards (BS 1377). The test started with the soil-water mixture that resulted in about 0 mm penetration and proceeded with increasing water content. For each test, the testing procedures were repeated five times, with three different water contents sampled. The graph shows that the relationship is non-linear. Similar plots are made for the data plotted by Harrison (1988), Wood (1978), and Feng (2000) in **Fig. 4**.

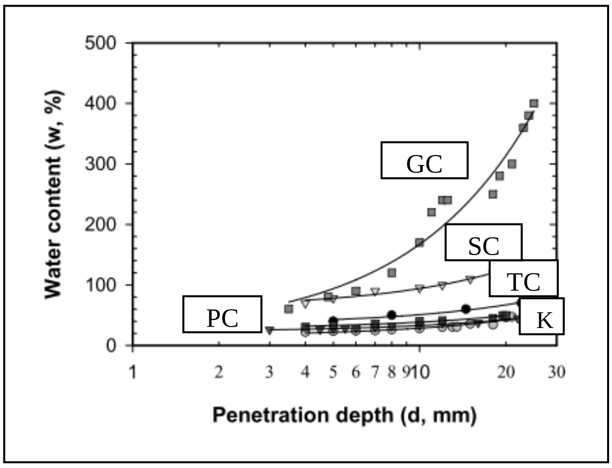

Fig. 4 Cone Penetration Data of Gault clay (GC), Sinjun clay (SC), Taipei clay (TC), Panama clay (PC), and Kaolin (K), (Wood, 1978; Feng, 2000**).**

The technique to determine the value of PL is by taking the assumption of the intersection within two lines as presented in **Fig. 5**, **Fig. 6** and **Fig. 7** which represent the data of Kaolin, Laterite and Recess Clay soil. However due to human judgement, the intersection value is taken as an exact value. This phenomenon indicated that the variation of results was significant, thus, the quality of data was acceptable.

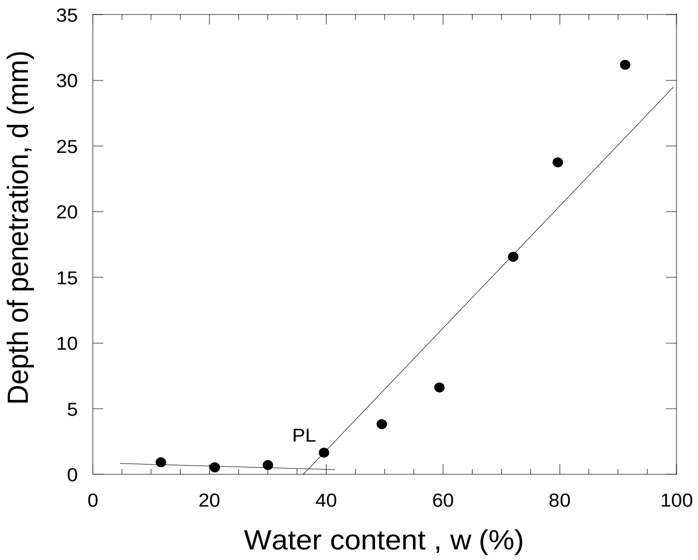

Fig. 5 Full range of fall cone test of Kaolin.

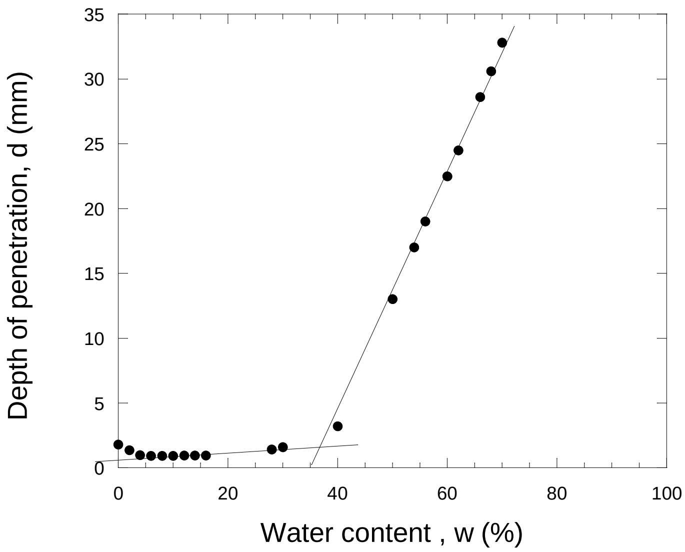

Fig. 6 Full range of fall cone test of Recess Clay.

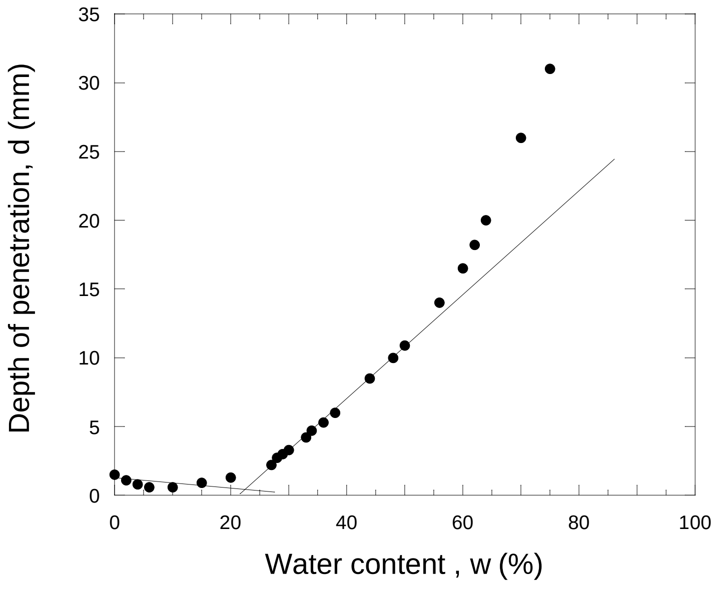

Fig. 7 Full range of fall cone test of Laterite.

The comparison between the plastic limits obtained from the conventional method and those for Kaolin, Laterite and Recess Clay by Feng's Equation and Author Techniques are given in Table 1. The result shows that the plastic limit obtained from the Feng's equation were lower than those from rolling thread method.

Table 1 Plastic Limit (PL) determination using three tools.

Type of Soil	Conventional Rolling Thread Method (%)	Feng's Equation (%)	Difference (%)	Author techniques (Approximate) (%)	Difference (%)
Kaolin	36.150	33.410	7.58	36-37	0.41-2.29
Laterite	23.100	17.850	22.73	23-24	0.43-3.75
Recess Clay	35.800	34.560	3.46	36-37	0.56-3.24

The levels of agreement between the results of those techniques also compare with the rolling thread method. Author techniques giving a regression coefficient (R^2) value 0.99918 while the regression coefficient (R^2) of Feng's Equation is 0.99637 as presented in **Fig. 8**. Even though the regression coefficient (R^2) does not make much difference but the average difference in percentage (%) for Feng's Equation is higher which about 11.26% while author techniques are only 0.45-3.09 %.

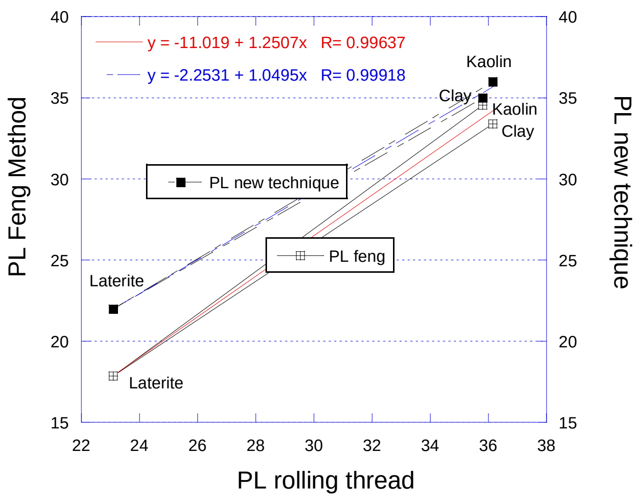

Fig. 8 Comparison between plastic limits obtained using three different tools.

Huat (2004) reported that west Malaysia Peat has a PL of 100-200% and Liquid Limit (LL) of 190-360 % .Therefore to verify the determination of PL for peat, the new technique can be used. But for peat soil, the technique is different by doing backward test which is using the original soil sample taken from the site and dries it by normal temperature. The purpose of doing backward test is to maintain characteristic of peat soil and to make sure all ‘interparticle’ water (IPW) released naturally. Referring to the **Fig. 9** shows that, Plastic Limit (PL) for Parit Nipah peat soil is 183 % while Pontian Peat is 210% as shown in **Fig. 10**.

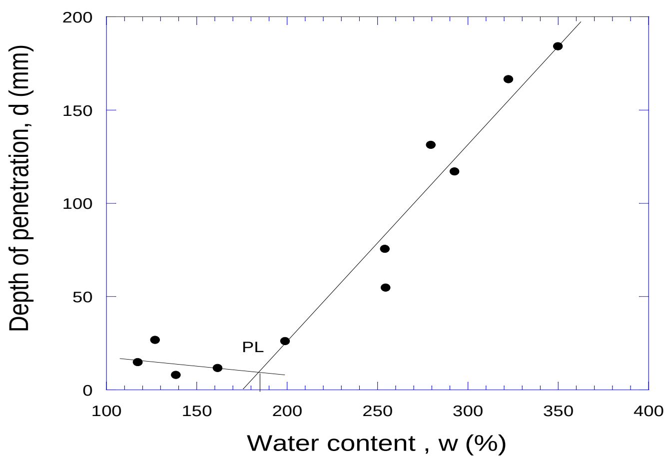

Fig. 9 Full range of fall cone test of Parit Nipah soil.

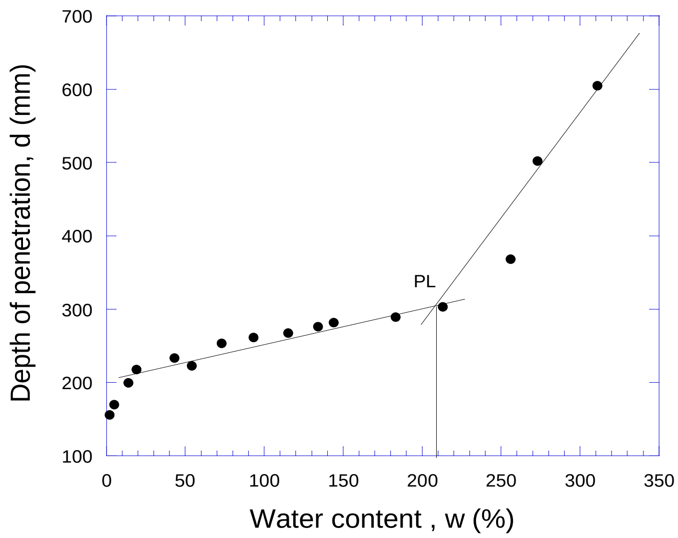

Fig. 10 Full range of fall cone test of Pontian soil.

4. Conclusion

The following conclusions can be pointed out based on the test performed and data analyses presented. Based on the three tools of plastic limit tests, shows that the author technique of fall cone test can apply to all types of soil particularly peat soil. The test shows that the correlation between depth of penetration and water content (d (mm) vs w (%) has clearly appeared as a non-linear relationship in the range of water content from 0 to 100%. The plastic limit can be determined by using the BS-1377 cone penetrometer method at the intersection of two lines. The plastic limit obtained by conventional method and technique proposed by author are compared well with the average difference being about 0.45-3.09 %.

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