American-Eurasian J. Agric. & Environ. Sci., 6 (2): 240-243, 2009
ISSN 1818-6769

Effect of Moisture Content on Some Rheological Properties of Paddy Soils

I.A. Mari, Ji Changying and Zhai Li Xin

Department of Agricultural Mechanization, College of Engineering,
Nanjing Agricultural University, Nanjing, Postal code 210031, China

Abstract: Reliable soil mechanical properties data are required for developing accurate model. The rheological characteristics of paddy soils may be changed by changing moisture content. The present study was conducted to determine how moisture content influences on some rheological properties of paddy soils. A four-element Burgers rheological model generally recommended for paddy soils in South China was used in the study. The paddy soil rheometer was connected with displacement sensor and controlled by computer software (Labview). The displacement was measured at different pressure soil moister content levels from 33 to 40%. The pressuresinkage-time equation of the soil surface under dynamic loading was theologically developed by means of transforming dynamic load to a step function of time approximate. The results indicated that the vertical load significantly changed soil properties at high moisture content level, suggesting that the displacement may appear in case of step or sudden change.

Key words: Displacement sensor · Paddy soils · Moisture content · Soil rheometer

INTRODUCTION

Number of factors influences on rheological behavior of paddy soils. One of the most important and significant factors is the water/moisture content[1]. Vertical loads especially at high water content may bring a step or suddenchangeintherheological behavior of paddy soil [2]. Many models linked to various devices/sensors, computer soft-wares, etc. with emphasis on soil properties are being developed and used to analyze the production potential of paddy soil[3]. The model (four-element Burgers rheological model) tested in this study is generally used forestimationofrheologicalbehavior of paddy soils. Prediction or understanding of rheological behaviormay provide opportunity to change and maintainasoilconditionmoresuitableforcrop growth and development. If one is to be able either to maintainasoil condition or to change it to a more suitablecondition, he must first have an understanding of soil behavior; this behavior must eventually be properlydescribed.Soil conditions and properties, widely varying types of forces and widely varying types of behaviormust all be included in any description before the description can be satisfactory. Therefore, through testing the physical/mechanical properties of paddy fields, the analysis of water/moisture content will helptodeeply understand the rheological behavior of the paddy soils[4].

MATERIALS AND METHODS

Soil Preparation and Analysis: A fertile plow layer soil clay loam was collected from Puku Yonling Farm of Nanging Agricultural, University, China. Soil preparation consisted of soil loosening and compaction. The practice of soil loosening and compaction was done between experiments by watering to soil for 2 to 3 days. After achieving the required moisture content levels, the soil was compacted by applying force through compactor. The soil used in the experiments was analysed to determine some physical properties, including moisture content which are shown in (Table 2). Finally relationship of soil moisture content with measured physical/mechanical properties was estimated through soil bulk density($g.cm^{-3}$), soil moisture content(%), soil porosity(%), soil penetration resistance(MPa) and soil normal stress and shear stress (kPa)[5].

Measurement of Some Soil Rheological Properties: A Four-element Burgers rheological model [6-10] shown in Fig.1 was used in this study.

Table 1: Test soil particle size distribution table

Soil types	Sand	Silt	Clay
Size/mm	0.2~0.05	0.05~0.01	0.01~0.005
Quality /%	09	47	39

Corresponding Author: Ji Changying, Department of Agricultural Mechanization, College of Engineering,
Nanjing Agricultural University, Nanjing 210031, China

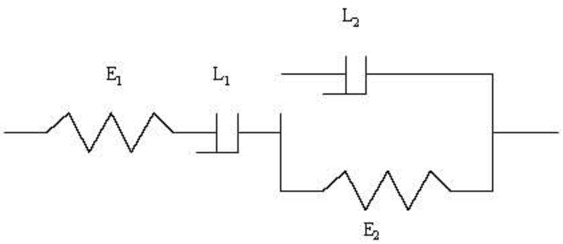

Fig. 1: Four element Burgers model.

Fig. 2: Paddy soil rheometer

Burgers model of stress-strain equation for the operator

$$\alpha = \frac{\lambda_1 \frac{d}{dt} + \frac{\lambda_1\lambda_2}{E_2}\frac{d^2}{dt^2}}{1 + \frac{(\lambda_1+\lambda_2)E_1 + \lambda_1 E_2}{E_1E_2}\frac{d}{dt} + \frac{\lambda_1\lambda_2}{E_1E_2}\frac{d^2}{dt^2}}\varepsilon \tag{1}$$

If the arithmetical symbol of equation (1) can be indicated by D, then:

$$\sigma = D\varepsilon \tag{2}$$

As the theory of EH Lee[11-12]: visco-elastic body of stress and strain analysis and the general media as a row, according to the same basic equation. The difference only lies in the different stress-strain relationship. As long as the stress-strain equation operator set up the basic equations can be solved by the visco-elastic problem [13].

Board will be loaded on the surface of soil samples and weights on the load board, load the plate in Figure 2 record subsidence of the relationship between volume and time. Plotting the volume of subsidence - the time (u-t) diagram and the rheological equation for fitting rheological model can be obtained to calculate the rheological parameters which shown in Figure 5.

By flat-panel set in the semi-infinite elastic body surface subsidence schleicher volume formula to determine:

$$\mu = \frac{\alpha p}{\sqrt{A}} \cdot \frac{3K+4G}{4G(3K+G)} \tag{3}$$

China's GM rice paddy soil rheological model, the rheological equation [14-15]

$$u = \frac{\alpha p}{\sqrt{A}}\left[\frac{1}{E_M} + \frac{1}{E_k}\left(1 - e^{-E_k t/L_k}\right) + \frac{t}{L_m}\right] \tag{4}$$

Where

μ- subsidence volume

α- Bearing surface shape factor: For the round, α= 0.96; the square, α= 0.95; for rectangular (1:3), α= 0.88

p- Applied pressure

A- Load area

K- Shear modulus is also called the stiffness modulus

G- Bulk modulus is also called the compression modulus

μ - Poisson's ratio of soil samples

Em, L_M, Ek and L_k - Rheological parameters

According to the equation (4), we can measure the relationship between the displacement and the time on the condition of the under static and dynamic loading at different soil moisture content. Static load conditions, the rheological parameters are used in static load conditions, the measured creep curve obtained in the soil. Test, the computer automatically collected by the pressure and subsidence of soil volume and after this, we can work out the rheological parameters of the paddy clay loam soil at different soil moisture content which are shown in Table 2 and Figure 5.

Soil moisture content was 33, 38 and 40% as we can seen from Figure 4 the measure with theoretical curve. This shows that the system used to measure the paddy clay loam soil rheological parameters under dynamic loading is quite good.

Table 2: Comparison of soil rheological parameters measured under static and dynamic loading at different soil moisture content

Moisture content (%)	Soil Bulk density (g/cc)	E_M (N/cm^2)	L_M (N s/cm^2)	E_K (N/cm^2)	L_k (N s/cm^2)
33	1.25	26.85	5405	50.64	306.8
36	129	14.98	3475	21.13	107.6
38	127	13.48	4111	26.01	19.99
40	135	11.23	156.7	24.96	25.24

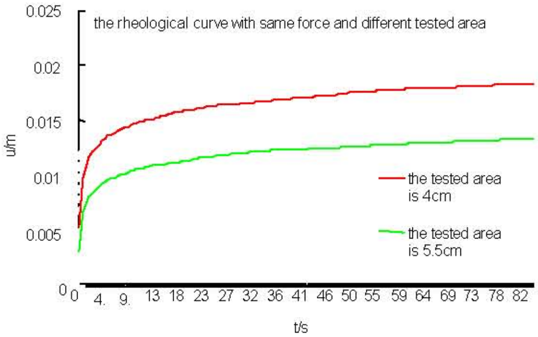

Fig. 3: Different circular plate under the same load volume and time of the subsidence curve

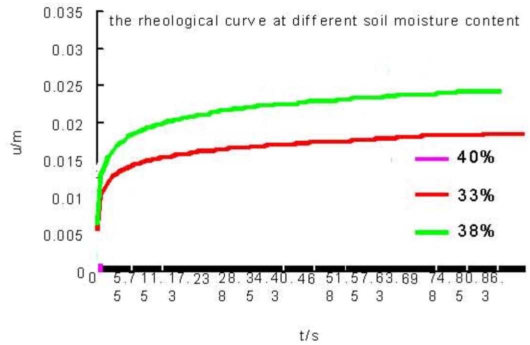

Fig. 4 Different soil moisture content and time of the subsidence curve

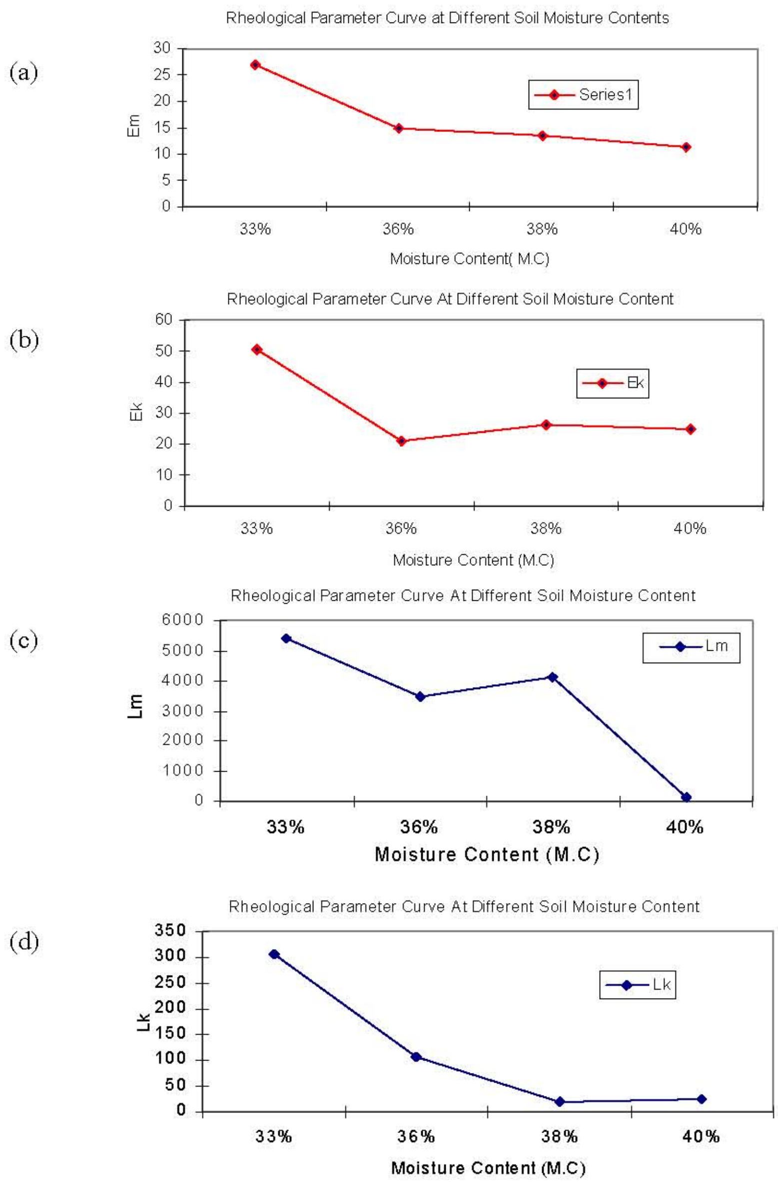

Fig. 5: Rheological parameters curves ate different soil moisture contents, (a)Rheological Parameter Em (b) Rheological Parameter Ek (c) Rheological Parameter Lm (d) Rheological Parameter Lk.

Experimental Process: The experimental device (rheometer) connected with the displacement sensor (for calibration) and computer loaded with Labview software was used in the study. The rheometer was placed on soil bed carefully, so that the accuracy of the experiment is insured. The device was operated by making contact of round plate with soil in fixed position. The output of the device was displayed on computer screen in a shape of set of displacement - time curve as we can see in (Fig. 3 and 4).

RESULTS AND DISCUSSION

The data obtained from the study indicated that the change in the moisture content affected the displacement directly, according to the result and the law of viscoelastic, the rheological model is shown as Fig. 2 which is connected with displacement sensor shows the relationship between displacement and time at 0.1 kg/cm^2 pressure. Measurement results were modeled using simple mechanical analogs (namely; soil rheometer and displacement sensor) and four-element Burgers rheological model to analysis of the results.

Analysis of Test Results: This study describes soil rheological parameters under stress conditions that mimic actual field conditions. The experimentally determined rheological parameter gathered could be used in predicting soil strain and resulting changes in hydraulic properties during compaction of agricultural soil. Soil rheological parameter under steady state and oscillatory stress conditions of paddy clay loam soil were measured using a paddy soil rheometer with displacement sensor in different soil moisture content. The displacement was measured at different pressure soil moister content levels from 33 to 40%. In the study of soil physical/mechanical properties it was observed that moisture content has long been found as one of the numerous factors influencing the rheological behavior of paddy soils. The rheological behavior of paddy soil changes significantly according to the change of the water moisture content (Figure 5). When the vertical load affects on the soil whose water moisture content is high, the displacement may appear the case of step or sudden change which are shown in (Figure 4). So, through the experiment, we can anises the law that water moisture content affect on the rheological parameters, it can help us to know the rheological properties and the law of displacement.

REFERENCES

1. Dong Li Ping and Jiang Chong-yin, 1985. Changes in water flow on the paddy field soil subsidence Characteristics of [J]. Journal of Wu Han Institute of Technology, 3: 50-57.
2. Gupta, C.P. and A.C. Pandya, 1966. Rheological Behavior of Soil Underloading. Trans. ASAE. 5: 9.
3. Berli, M., J.M. Kirby, S.M. Springman and R. Schulin, 2003. Modelling compaction of agricultural subsoils by tracked heavy construction machinery under various moisture conditions. Soil & Tillage Research 73(1-2): 57-66.
4. Gill, William R. and E. Glen, 1968. Soil Dynamics in Tillage and Traction no. 1-13. Washington, D.C.
5. Lee, E.H., 1956. Stress Analysis in Materials J. Appl. Phys, pp: 27.
6. Schiffman, R.L., 1961. Analysis of the displacement of the ground surface due to a moving vehicle. Simposium of Proc. Int. Conf. on Mechanics of Soil-vehicle Systems, pp: 45-62.
7. Hiroma, T. and Y. Ota, 1990. Analysis of normal stress distribution under a wheel using a viscoelastic model of soils. Proc.10th Int. Conf. ISTVS, pp: 241-252.
8. Ji Changying and Pan Junzheng, 1995. Chain-paddle driving mechanism and its pull prediction. J. Terranechanics, 32(2): 63-77.
9. Ji Tian-xun, 1971. Experimental Study on vehicles [J]. Institute of Agricultural Machinery-chi, 3(1): 33-36.
10. Roger Kennedy, Yan Qiao and Pan Zheng, 1982. Study on rheological properties of the soil of paddy fields (first report) - China's paddy field soil parameters of rheological model and rheological analysis [J]. Journal of Agricultural Machinery, 6(2): 43-54.
11. Pan Junzheng, 1986. The general rheological model of paddy soils in South China. J. Terramechanics, 23(2).
12. Lee, H., 1955. Stress analysis in visco-elastic bodies. Q. Applied Mathematics 13(2).
13. Ji Changying and Pan Junzheng, 1994. Shear stress-shear rate-time relationship of wet and soft soils and its application (Part 2). Trans CSAE, China 10(4).
14. Zhenjiang, 1981. Editor in chief of agricultural and mechanical college. Agricultural mechanics (the book) [M]. Beijing: China Agricultural Machinery Press,
15. Signe, H., 1981. Soil cultivation machinery and computing theory [M]. ZHANG Xian-Da, translation. Beijing: China Agricultural Machinery Press.

*Project supported by the National Natural Science Foundation of China (Grant No. 50675107)