MEASURMENTS OF SOIL PARAMETERS RELATED TO TRACTION

M Watany
Faculty of Engineering, Helwan University, Cairo, Egypt

Abstract It is well known that the soil with different load bearing capacity is exposed compressive stress of the same magnitude. This results in the formulation of a dense layer within the soil mass, which is poor in hydraulic conductivity and aeration. However a fully instrumented device to measure -soil properties relevant to traction has been developed. The device can measure soil sinkage parameters (sinkage constant and exponent) utilizing sinkage plates. Field tests were conducted using four-different circular plates (sinkage tests) in a four different soil type. The results show that the device works well.

INTRODUCTION AND REVIEW OF LITERATURE

The ability of traction device to develop high tractive effort with an optimization of soil compaction depends on traction device characteristics; load applied, and soils type and conditions. Proper evaluation of soil properties will lead to successful prediction of vehicle-terrain performance [1]. The determination of soil strength and other properties can be best performed in the laboratory where tests are conducted under controlled conditions and evaluation procedures are well established. Also, soil properties can be obtained in field (in situ methods). In situ methods of soil strength measurement are to be preferred to laboratory techniques because they have minimum disturbance to the soil and therefore more realistic [2]

Different techniques have been used over the years to measure the mechanical properties of soil and tractive performance of traction device and they have their advantages and disadvantages. Among these techniques was the bevameter, cone penetrometer, shear annulus, van shear test, triaxial shear test, and direct shear test are the techniques most frequently used for evaluating soil mechanical properties. Tire tractive ability depends on tire type (radial , bias), tire geometry (width, overall diameter, section height), lug design, inflation pressure, dynamic load on axle, and soil type and conditions. Soil type and conditions are the most important factors that influence traction [3]. Most empirical traction prediction models use soil cone index to represent soil type and condition. The bevameter technique originally conceived and developed by Bekker [4-5], is based on the measurement of vertical and horizontal load-deformation of soil under loading condition similar to those exerted by an off-road vehicle. A penetrometer is a simple device used to characterize the soil in numerical terms. Field measurements of the resistance of soil to static or dynamic penetration of cones of various sizes and shapes are widely employed in a variety of purposes. The cone penetrometer developed by U. S. Army Engineering Waterways Experiment Station (WES) is used for off-road vehicle mobility evaluation [6]. Upadhyaya *et al.* [7] have presented a review of empirical traction prediction relations which utilize soil cone index to represent soil strength. The soil cone index is a very convenient parameter to use ill predictilig traction, since it can very easily be obtained in the field. Soil cone index is a composite soil parameter which depends on compressive and shear properties of soil. Since traction is also dependent on compressive and shear characteristics of soil, it is argued that soil cone index can be used to predict traction. from a theoretical standpoint. An analogue device such as Bevameter is often used to obtain soil sinkage and shear characteristics [1,8]. This device has provision for conducting plate penetration tests and torsional shear tests. Bekker [4-5] has described these types of instrtnnents and their principle of operation in detail.

The objectives of this study are:

(1) To develop a portable instrument to measure soil physical parameters related to traction in *situ.*

(2) To test the suitability of this device for measuring soil sinkage .

INSTRUMENTED DEVICE

The Single Wheel Tester [8] with its initial design is capable of measuring the tractive performance of off-road traction device. The test rig was modefied to measure both palte sinkage and shear stress parameters. The plate sinkage kit has been made to measure force-diplacement relation in different soil types. Fig 1 shows the instrumented device developed to measure soil sinkage characteristics. The kit consists of:

1- displacement transducer
2- force transducer
3- adaptore
4- displacement transducer holder
5- penetration plates

The insturument is pressed firmly to the ground during the tests by a hydraulic cylinder attached to the rear of the tractor. The vertical sinkage of the plate is measured by a displacement tranceducer, while the penetration resistance measured by force tranceducers. Four different penetration plates (50, 70, 85, and 100 mm diameter) have been made to simulate the effect of tyre width on the tractive performance of the tractiobn devices. Different size plates can be easily mounted on the to the load cell.

EXPERIMENTAL PROCEDURE

The mechanical properties of soil is mainly influnced by its type and moisture contents. Three different types of soil have been used in the analysis and analysed at the soil lab to identify soil texture and moisture contents, Table 1and 2.

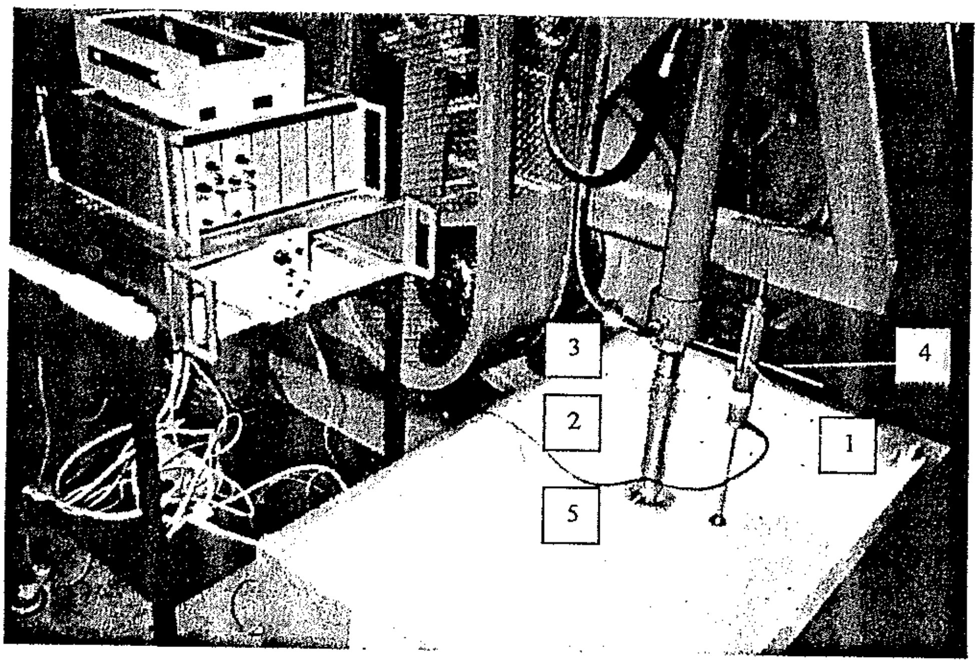

Fig (1) Pate-sinkage kit attaced to the rear of the tractor

Table 1 Soil Texture

Sample No	Equivalent Categories	Mass(gm)	%	Sieve Diameter	Classification
1	Gravel	22	7.3	>2mm	Sandy Loam
	Coarse sand	25	8.3	2:1.18	
	Fine sand	193	64.3	1.18:0.075	
	Silt	60	20.1	<0.075	
2	Gravel	12	.4	>2mm	Sand
	Coarse sand	13	4.3	2:1.18	
	Fine sand	250	83.4	1.18:0.075	
	Silt	25	8.3	<0.075	
3	Gravel	2	0.67	>2mm	Sand
	Coarse sand	13	4.3	2:1.18	
	Fine sand	288	95	1.18:0.075	
	Silt	-	-	<0.075	

Table (2) Moisture content

Sample 1	Can+wet sample (gm)	69.75	62.55	66.67
	Can+dry sample (gm)	85.11	58.42	62.69
	Can (gm)	46.84	42.05	47.48
	Wc%	39.8	25.2	26.17
Sample 2	Can+wet sample (gm)	81.11	79.19	86.68
	Can+dry sample (gm)	78.25	76.54	83.86
	Can (gm)	45.87	45.2	46.68
	Wc%	8.83	8.46	7.58
Sample 3	Can+wet sample (gm)	97.73	73.89	78.22
	Can+dry sample (gm)	97.66	73.78	78.19
	Can (gm)	64.89	36.51	46.69
	Wc%	0.21	0.3	0.22

The testes were performed by pushing the sinkage plate rame into the soil. The normal load and vertical displacement are automaticaly recoded by means of data aquesation system connected to the rig. The process is repeated witrh different plate size in each soil type. FORTRAN programs have been built to do the analysis of the collected data based on the following: The Bekker's pressure-sinkage equation has been used,

$$p_i = \left(\frac{k_c}{b} + k_\phi\right) z_i^n \qquad (1)$$

where

- p is the ground pressure, kN/m^2
- i is the plate number
- b is the radius of circular plate, m
- z is the sinkage, m
- n is the exponent of deformation, non dimensional
- k_c and k_ϕ are soil parameters.

Taking the logarithm of each side will produce,

$$\log(pi) = \log(keq) + n\log(z_i) \qquad (2)$$

where:

$k_{eq} = (k_c/b) + k_\phi$

The least square method has been used to fit the relation between log(p) and log(z). At each site, four different values have been collected and the average of n for each site was calculated as follows:

$$n = (n1 + n2 + n3 + n4)/4 \qquad (3)$$

By the same way, the values of k_{eq} have been used to plot the relationship between k_{eq} and 1/b, and the least square method has been used to fit a line where the intersection of this line gives k_ϕ and the slop determines k_c.

Typical results of plate-sinkage test are shown in Figs 2 to 7.

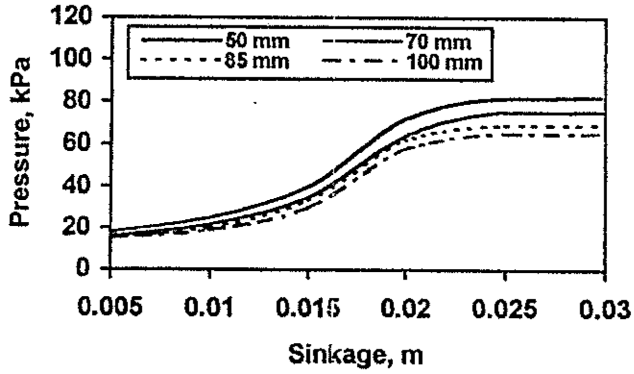

Fig 2 Plate sinkage test in Sandy loam soil

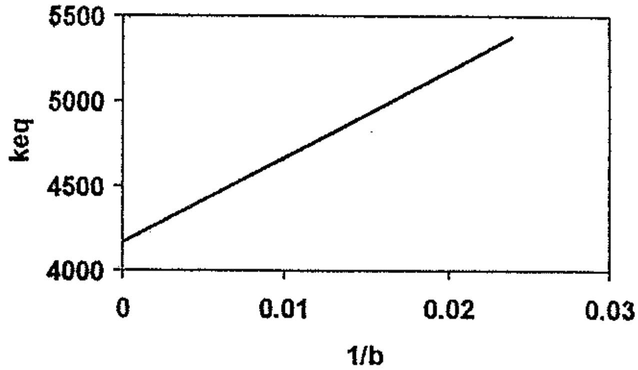

Fig 5 keq vs 1/b in Sand I

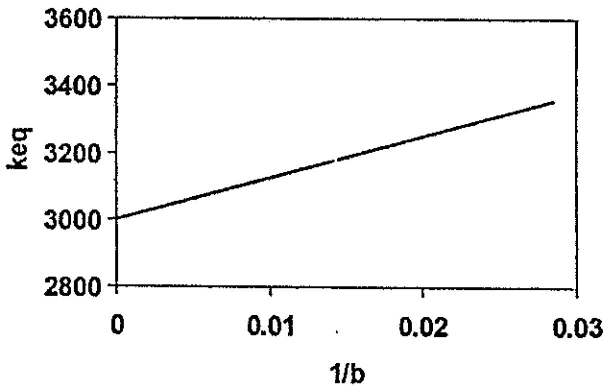

Fig 3 keq vs 1/b in Sandy loam soil

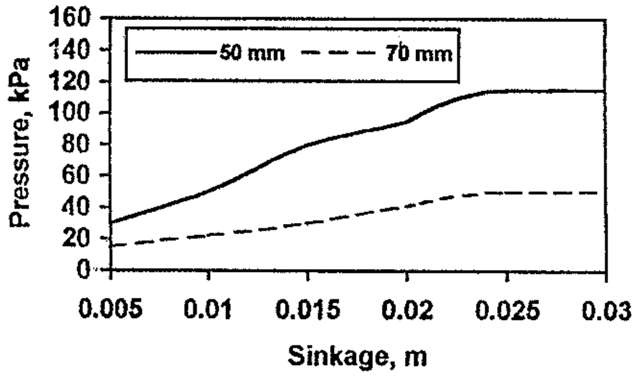

Fig 6 Plate sinkage test in Sand II

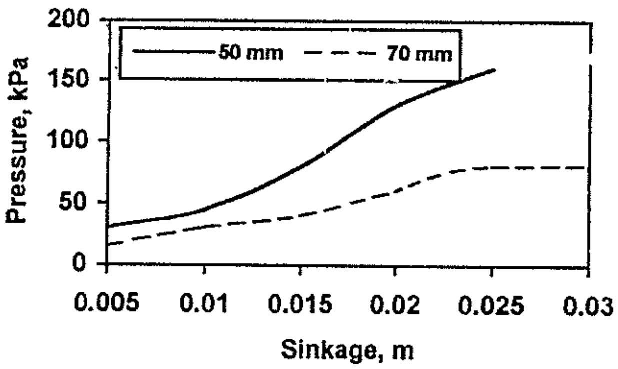

Fig 4 Plate sinkage test in Sand I

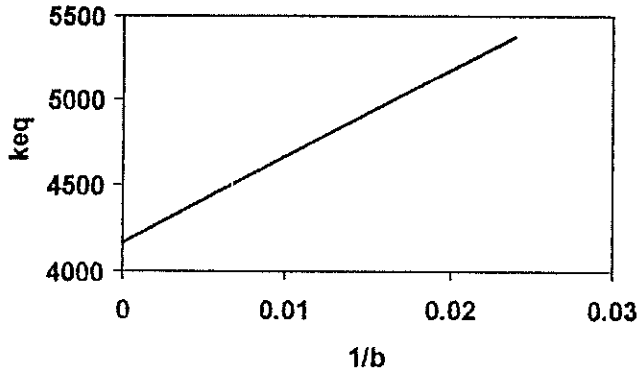

Fig 7 keq vs 1/b in Sand II

Table 3 shows the calculated values of plate-sinkage parameters k_c, k_ϕ, and n.

Table (2) Plate-sinkage parameters

Soil type	k_c (kN/m^{n+1})	$k\phi$ (kN/m^{n+2})	n
Sandy loam	29.35	2700	1.03
Sand I	193	1315	1.01
Sand II	55	1235	0.9

CONCLUSIONS

Based on this study the following conclusions could be reached :

(1) The fully instrumented soil test device has the ability to measure the plate-sinkage parameters with good accuracy.

(2) The device is very simple to use in both laboratory and field.

(3) The device should be completeed to measure shear parameters.

REFERENCES

[1] M Watany 'Investigation of traction system soil interaction and performance' , Ph D thesis, Helwan university, 1995

[2] J. A.,Okello, "A Review of Soil Strength Measurement Techniques for Prediction of Terrain Vehicle Performance", J. of Agricultural Engineering research, 50, pp. 129-155, 1991.

[3] S. K. UPADHYAYA, D. WULFSOHN and G. JUBBAL, Traction prediction equations for radial ply tires. J. Terramechanics 26 (2), 149-175 (1989).

[4] M. G., Bekker, : Theory of Land locomotion, The University of Michigan Press, Ann Arbor, 1956.

[5] M. G., Bekker, :Off-the-Road Locomotion, The University of Michigan Press, Ann Arbor, 1960

[6] D. R., Freitag, "Penetration Test for Soil Measurements", Paper No. 67-652 presented at Winter Meeting of the American Society of Agricultural Engineers at Detroit, Mich., December 1967.

[7] 5. K. UPADY'YAYA and D. WULFSOHN, -Review of traction prediction equations. ASAE Paper No. 90-1573.ASAE, St. Joseph, MI 49085 (1990).

[8] A Abdel-Bary 'Evaluattion of off road-vehicle mobility' M Sc thesis, Helwan university, 1996.