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DEVELOPMENT OF A FIELD DEVICE TO COLLECT SOME SOIL PROPERTIES DATA:
I. SOIL PENETRATION RESISTANCE

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ABSTRACT

This paper presented development, calibration and testing steps of a device to collect soil penetration resistance data. This device can be hitched to the tractor through three point hitch system for data collection. The developed device consisted of hydraulic cylinder, open center hydraulic system, electrical control panel, hydraulic hoses, frame with three-point hitch and measuring staffs. At the end of hydraulic cylinder, different parts could be attached for collecting soil properties data. The cone tip is designed as ASAE standard which will provide cone index values with depth. Verification tests for cone index values using locally made hammer penetrometer and commercially static penetrometer were correlated quite well. The developed device seemed to be easy to use in the field as a static penetrometer. Also, constant rate of pushing shaft in the soil will be obtained and this will lead to good accuracy. The collected data were statistically analyzed to find out the effect of site, location, penetration depth and their interactions on the penetration resistances obtained by the three different devices. Also, the significant difference among penetration resistances was estimated by the three different devices (whole data, 56 points were compared by F- test at 1% probability level). The resistance to penetration results showed distinct behaviors for the studied depths, sites and location inside each site indicating the importance of measuring penetration resistances in different location in the experimental field at specified depth due to spatial variations. The mathematical model for soils under study to get penetration resistance was:

$$Y = -19.698 + 0.014 \times X_1 - 0.038 \times X_2 + 2.536 \times X_3 + 28.366 \times X_4 \qquad R^2 = 0.732$$

where Y is soil penetration by developed device (Mpa), X_1 is depth in the range of 5-30 cm, X_2 is soil moisture content in the range of 8.14-33.59 % (db), X_3 is soil bulk density in the range of 1.03-1.46 g/cm^3 and X_4 is soil texture index in the range of 0.665-0.716.

INTRODUCTION

Soil strength is an important character affecting many aspects of agricultural soils, such as the cultivation implements performance, root growth, least-limiting water range and the trafficability. Characterization of soil strength is usually made by measuring the response of a soil to a range of applied forces. Penetrometers are widely used to measure the soil resistance to penetration, expressed as force per unit cross-sectional area of the cone-base (Enough et al., 2001). Previous works in soil penetration resistance area could be divided into the following two categories, the first is the development of empirical statistical models which describe the soil penetration resistance by soil physical properties and the second is the field or soil bin measurements (El Awady et al., 2002). However, the first category is the most numerous one because of expensive penetrometers.

The cone index is a composite soil parameter obtained by pressing a standard cone penetrometer (ASAE, 2006a and b) into the soil at a penetration rate of 72 in/min. It is expressed as the force per unit area required to push the penetrometer through a specified small soil increment. One of the main advantages of the cone penetrometer is its simplicity and ease which it can be used to obtain field data. It appears to be quite useful in predicting motion resistance of agricultural tractors. Motion resistance of off-road vehicles is related to the compressibility of soil and that of the traction device. Therefore, cone index appears to be an adequate indicator of compressive ability of soil (Garciano et al., 2006).

Antonio et al. (2006) mentioned that soil resistance to penetration under mechanization and transportation processes in a sugarcane crop as a function of different numbers of cuts and different working depths could be evaluated by means of a constant-speed electronic penetrometer. The resistance to penetration results showed distinct behaviors for the studied depths, indicating that the weight of vehicles and machinery and the rotating wheel pressure caused alterations in the soil profile.

The standard tool used to measure soil compaction is the cone penetrometer. This device has a cone mounted on a rod that is pushed into the soil. As the rod is pushed into the soil, force readings are taken versus depth to indicate compaction in the soil, which is calculated by dividing the force on the cone by the cross-sectional area of the cone. This pressure is a direct measurement of soil compaction (Garciano et al., 2006).

There are two common types of hand-held cone penetrometers: the static & the dynamic one. Both measure soil resistance to vertical penetration of a probe or cone. The distinction between the two penetrometers lies in how force is applied to the cone. Static cone penetrometer with a 30^o cone has been recommended by the American Society of Agricultural Engineers as the standard measuring device for characterizing the penetration resistance of soils (ASAE, 2006a and b). In this type of penetrometer, one person is pushing on the hand attached to the rod forcing the cone into the soil and the force is indicated on a pressure gauge (Figure 1). As the operator pushes down on the penetrometer, the note keeper records the force values for each depth increment. The force is commonly expressed in kilopascals (kPa), an index of soil strength referred to as the cone index (ASAE, 2006a), or as kg/cm^2 or psi. Cone index depends on cone properties (angle and size) and soil properties (e.g., bulk density, texture and soil moisture) (Herrick and Jones, 2002). However, Zein Eldin (1995) found that the soil penetration resistance is highly influenced by bulk density and moisture content of soil and the relation between these three parameters vary depending on the soil type and penetration depth.

According to Perumpral (1987), moisture content influences penetration resistance however, penetration resistance increases with increasing bulk density and decreases with increasing moisture content. Hayes and Ligon (1981) found that soil penetration resistance was most closely correlated with moisture content, bulk density, percent silt and percent clay in their experiments. Korayem et al. (1996) mentioned that soil penetration resistance depends on soil bulk density and moisture content. Hernanz et al. (2000) used experimental data to develop an empirical model, a linear additive model on a log–log plane, capable of estimating soil bulk density depending on soil penetration resistance, soil moisture content and depth. This model has provided good results under field conditions and has allowed soil bulk density profiles and accumulated water profiles to be accurately estimated.

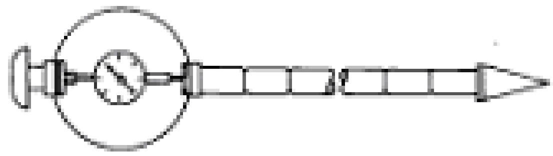

Fig. (1): Hand-held static cone penetrometer.

The dynamic cone penetrometers with recommended 30^{o} cone, apply a known amount of kinetic energy to the cone, which causes the penetrometer to move a distance through the soil (Herrick and Jones, 2002). Dynamic penetrometers use a slide hammer of fixed mass and drop height to apply consistent energy with each blow (Figure 2). Either the number of blows required to penetrate a specified depth, or the depth of penetration per blow are measured, and results can be calculated as a cone index. The weight of the hammer, slide distance, and cone angle influence the energy delivered and can be adjusted to local conditions (e.g., soft vs. hard soils). Measurements are taken by placing the cone on the soil surface with the shaft upright. To minimize variability in starting depth, the cone is pressed into the soil until the soil is level with the base of the cone. The slide hammer is raised until it touches the collar and is released. The depth of penetration is recorded for each blow until a maximum or desired depth is reached. Soil resistance for each soil depth interval is calculated using standard equations that account for differences in hammer drop distance, weight and cone size. Manually operated penetrometers often yield variable results when used by the same operator and especially when used by different operators because of differences in the rate of insertion. Correct interpretation of static penetrometer data also requires insertion into the soil at a constant velocity. Constant probe velocity is difficult to maintain in manually operated penetrometers (Herrick and Jones, 2002).

Fig. (2): Hand-held dynamic cone penetrometer (hammer device).

Although the methods for hand held cone penetrometer operation have been standardized, there are several limitations, which may limit their use. However, since they must be moved through the soil at a constant velocity, different rates of insertion by different observers can yield variable results and affect repeatability (Herrick and Jones, 2002), even the pressure exerted by a single operator can be difficult to apply at a constant and repeatable rate. Also, the penetration rate is hard to maintain a vertical position. If the vertical position of the penetrometer changes, then the soil resistance will be more or less than the actuality and in hard soils considerable effort is required and results vary with operator technique. Finally, penetrometers are driven to depths greater than approximately 30 cm may be difficult to remove from the soil.

In Egypt, instrumented devices that provide cone index values, shear and sinkage characteristics of soil are research devices, imported and costly and they are neither simple nor easy to use. Thus there is a need using local materials to develop a simple, flexible insertion into the soil at a constant velocity and cheap device that can measure soil shear, cone index values and sinkage characteristics. So, the general objective of this study is to develop a simple, flexible and cheap device that can measure soil shear, cone index values and sinkage characteristics of soil in-situ. The specific objective of the study is using the developed device to conduct tests to get measure cone penetrometer in different fields sites using the developed device and verify the results against those obtained using a standard cone penetrometer by a commercially available cone penetrometer and other fabricated dynamic devices.

MATERIAL AND METHODS

Construction details of the developed device:

Construction of the developed device was achieved at the Testing and Research Station for Tractors and Farm Machinery, Alexandria Governorate. It consists of hydraulic cylinder, control valve, electrical control panel, hydraulic hoses, frame with three-point hitch and measuring staffs. At the end of hydraulic cylinder, different parts could be attached for collecting soil properties data. One of these parts is a steel shaft equipped with a cone tip at its end as recommended by ASAE standard (ASAE, 2006a) which will provide cone index values with depth. Two sizes of cone penetrometer prop tip and shaft were constructed: a 20.27 mm diameter base cone and a 15.88 mm diameter shaft for soft soils and a 12.83 mm diameter base cone with a 9.53 mm diameter shaft for hard soil. The complete device has overall dimensions of 80 cm in length, 65 cm in width and 102 cm in height. However, Figs. (3 and 4) depict the schematic diagram and photo of the developed device showing arrangement to collect soil cone index data, respectively. Details of the used steel shafts with its end cone tip are shown in Fig. (5).

In the developing device, open center hydraulic valve was used to maintain constant flow, (Fig. 6) according to Laser Alignment (1992). The hydraulic system of the tractor is used to supply oil to open center hydraulic valve. The open center hydraulic valve is used to control the movement of the steel shaft with its end cone tip through hydraulic cylinder electrically by using 12-volt battery mounted in the control panel of the developed unit. The hydraulic system connections are shown in Fig. (7) and for more details, the reader is refereed to Laser Alignment (1992).

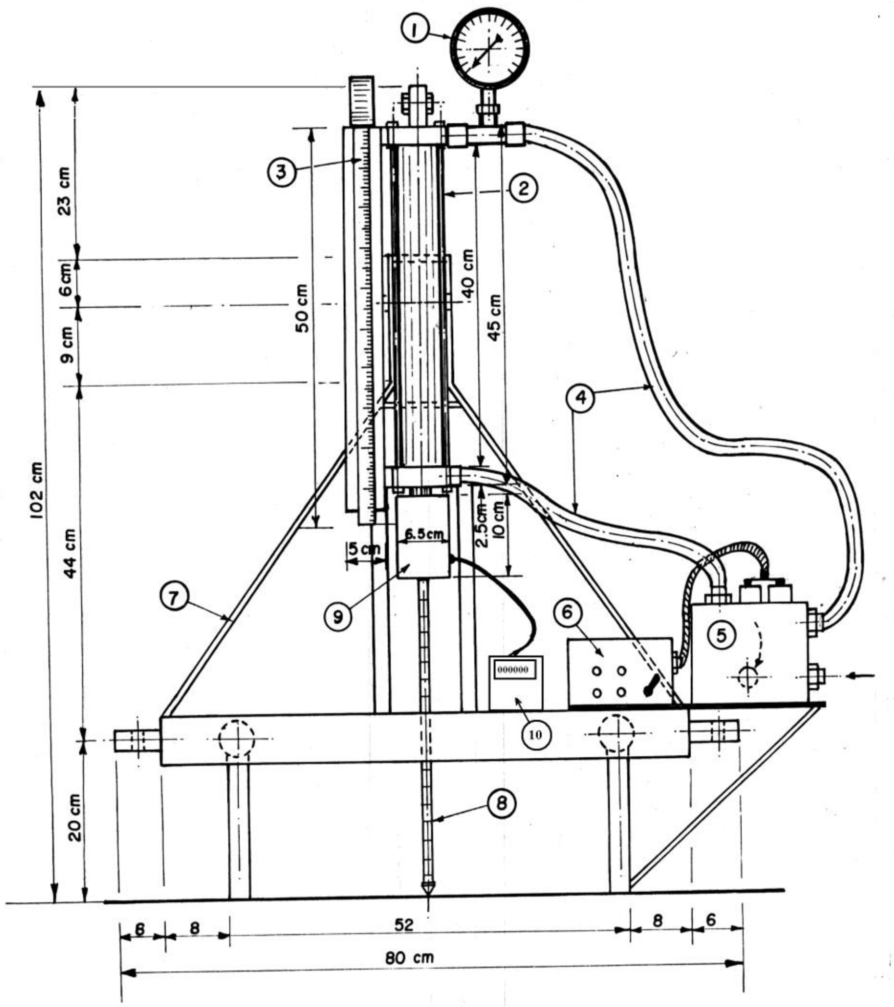

Fig. (3): Schematic diagram of the developed device showing arrangement to collect soil cone index data.

(1)	Hydraulic gage	(3)	Scale	(6) Electrical control panel
(2)	Hydraulic cylinder	(4)	Hydraulic hoes	(7) Three point hitch
(5)	Hydraulic control valve			(9) Load cell
(8)	Steel shaft with its end cone tip			(10)Strain meter

Fig. (4): Photo of the developed device showing arrangement to collect soil cone index data.

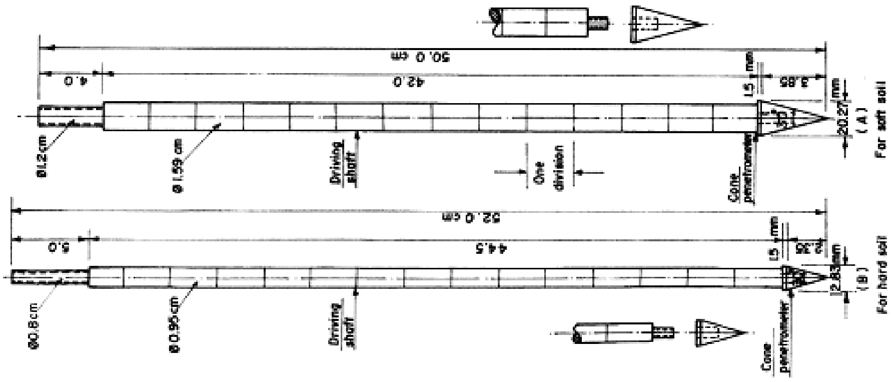

Fig. (5): Details of the used steel shafts with its end cone tip used in the developed penetrometer.

The rate at which the shaft will raise and lower in the soil with its end cone tip is dependent on the amount of oil supplied to the delivery line in the hydraulic cylinder. Where a remote relief valve is used before the control valve, the pressure setting on this valve will change the raise/lower speed. Laser manufacture supplied control valves have pressure control adjustments on both the bypass relief valve and the raise and lower valves.

In this research work, the open center hydraulic system was calibrated with the help of the Laser Laboratory at Testing and Research Station for Tractors and Farm Machinery, Alexandria Governorate to achieve the penetration rate of 30 mm/s as recommendation of ASAE Standard for measuring penetration resistance with hand-held cone penetrometer. This constant rate was achieved by using flow control valves, which regulate the flow of hydraulic fluid in the lines.

An electrical control panel containing ON/OFF switch and a UP/DOWN switch was fitted on the developed unit. The ON/OFF switch is used to operate the open center hydraulic system while the UP/DOWN switch is used to drive the penetrometer into the desired soil depth (Down position) and return it back when it reaches the defined depth (Up position). The soil reaction value was obtained by the load cell. It is mounted directly above the steel shaft, Fig. (3). The force reading could be recorded by digital strain meter (model P-5000). The capacity of the used load cell (22 kN). A fixed scale of length of 3 m on the top of the hydraulic cylinder was used to measure the penetration depth. This fixing way makes the scale slides freely with the shaft as it penetrates the soil. The penetration depth is recorded directly on the scale.

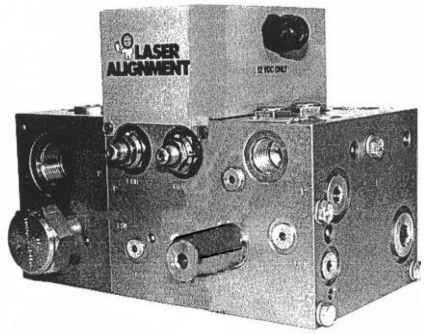

Fig. (6): Open center hydraulic valve
Laser Alignment (1992).

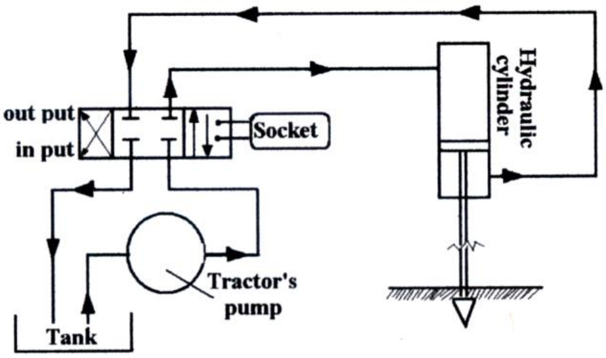

Fig. (7): The hydraulic system connections
Laser Alignment (1992).

Additional alternative uses:

The additional benefit of the developed device is using it as soil samples collector for bulk density and soil moisture content. This is done by removing the load cell and penetrometer group and putting a core sampler unit. The core sampler unit consists of a drive shaft and a steel cylinder with three knives at the bottom as shown in Fig. (8). The unit is operated by pushing the steel cylinder into the soil just like a cone penetrometer. When the cylinder touches the soil, it rotates clockwise and the knives start to cut the soil and lift it up inside the cylinder. The cylinder is removed from the unit easily by using UP/DOWN switch in the electrical control panel.

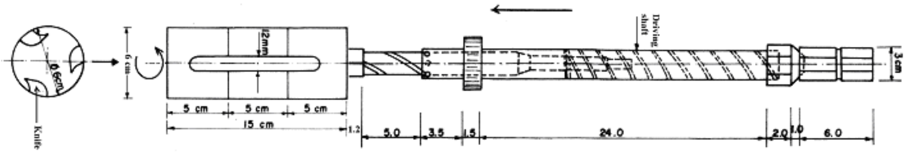

Fig. (8): The soil samples collector.

<u>Calibration of the load cell:</u>

The arrangement for calibration the force is shown in Fig. (9). It consisted of simple set-up as a circle plate of 15 cm diameter to carry the weights acting on the load cell during the calibration. The load cell was connected to strain meter. The calibration setup was loaded in equal steps of 5 kg (49.1 N) from no load to the specific load (i.e 1 kN) and then unloaded in the same steps back to no load.

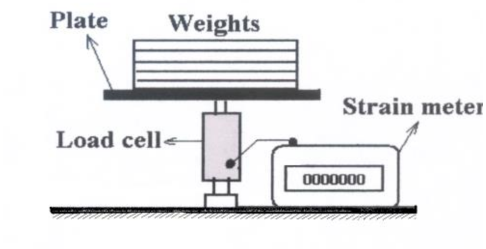

Fig. (9): Calibration set-up for the load cell.

For each loading, the signals proportional to the force from the load cell was sampled and the data were recorded manually for further processing. The test was repeated three times to check for the variability. Then regression analysis was performed on the sampled data to determine the parameters during the calibration test. The calibration results for the range of applied loads are summarized below:

1. The load cell output was linear with coefficient of determination $R^2 = 0.9987$
2. The calibration regression equation is: $Load\ (N) = 9.037 \times strain\ (\mu\varepsilon) - 16.851$; the cone index value (Mpa) = Load (N)/Area of base cone (mm^2).
3. The sensitivity of the load cell was 0.1108 $\mu\varepsilon$ N.
4. The output hystersis was negligibly small.

Field experiments:

The field experiments were carried out at two sites. The first one is Etay El-Baroud (site-I) and the second site was El-Nubaria (site-II). The soils were classified as clay loam with 48 %clay, 31% silt and 21% sand and sandy clay loam with 55.71 %clay, 15.60% silt and 28.69% sand in the first and second sites, respectively. The experiment design was spilt-spilt plot with the site was main plot, location was subplot and depth was sub sub plot. The collected data included soil bulk density and soil moisture content at depths of 5, 10, 15,20, 25 and 30 cm. Table (1) shows the average values of soil bulk density and soil moisture content at each depth. Penetration resistance in each location was obtained by the developed device and using two different devices; locally made impact penetrometer and commercially hand held static penetrometer. However, the penetration resistances were collected at the specified penetration depth. Each measurement was repeated three times. So, 108 data points were collected (2×3×6×3).

Table (1): Average values of soil bulk density and soil moisture content at each depth.

Depth (cm)	Soil moisture content (%,db)		Soil bulk density(g/cm^3)	
	(site-I)	(site-II)	(site-I)	(site-II)
5	10.90	8.14	1.03	1.13
10	15.01	13.22	1.08	1.17
15	20.66	15.46	1.13	1.28
20	25.57	17.75	1.16	1.42
25	30.52	17.90	1.18	1.36
30	33.59	22.93	1.20	1.46

The locally made impact penetrometer consisted of a metal rod (0.95 kg weight and 31.5 cm height) with a conical tip at one end, an anvil or strike plate around the rod and a sliding hammer with a fixed mass at the other end. The cone is pushed into the soil by successive blows of the sliding hammer (2 kg weight) against the anvil. The strike of the hammer applies an amount of kinetic energy determined by the work required to raise the mass of the (frictionless) hammer through a distance influenced solely by gravity (Herrick and Jones, 2002).

Data analysis:

The collected data of penetration resistances were statistically analyzed using ANOVA Proc in SAS software (SAS, 1986) to find out the effect of site, location, penetration depth and their interactions on the penetration resistances obtained by the three different devices. Excel software was used to determine the significant difference among penetration resistances estimated by the three different devices (whole data, 56 points) which the penetration resistance means were compared by F- test at 1% probability level.

RESULTS AND DISCUSSION

Data obtained by statistical analysis (ANOVA), presented in Table (2), showed that site, location and depth have significant effect on soil moisture content (%, db), soil bulk density (g/cm^3) and penetration resistance when using any penetrometer to get penetration resistance (Mpa) at significant level 5%. All interactions have significant effect on soil moisture content (%, db), soil bulk density (g/cm^3) and penetration resistance when using any penetrometer to get penetration resistance (Mpa) at significant level 5%. These results indicate that no variations may be occurred when using different devices to get penetration resistance of soil. So, it is recommended to use the suitable and available one.

Table (2): Source of variation, degree of freedom (DF) and probability (P-values) from ANOVA.

Source of variation	DF	P-values				
		Soil moisture content (%, db)	Soil bulk density (g/cm^3)	Hammer	Develope	Hand
				penetrometer (Mpa)		
Replicates	2	0.0163	0.0189	0.5250	0.0002	0.0001
Site	1	0.0001	0.0001	0.0001	0.0001	0.0001
Main Plot Error	2					
Location	2	0.0001	0.0001	0.0001	0.0001	0.0001
Site ×Location	2	0.0001	0.0001	0.0001	0.0001	0.0001
Subplot Error	8					
Depth	5	0.0001	0.0001	0.0001	0.0001	0.0001
Site × Depth	5	0.0001	0.0001	0.0001	0.0001	0.0001
Location ×Depth	10	0.0001	0.0001	0.0001	0.0150	0.0202
Site ×Location × Depth	10	0.0001	0.0001	0.0001	0.0057	0.0001

In the field, the penetrometer is operated by placing the cone on the soil surface with the shaft oriented vertically. The cone is then pressed into the soil by hydraulic cylinder until it just becomes buried. Because the pattern of soil resistance is not affected by the type of instrumented (Baver et al.1972), both static and dynamic penetrometers can be used to get cone index data (Herrick and Jones, 2002). Fig. (10) depicts the means of penetration resistance data obtained by the developed penetrometer for site-I and site-II at different depths. For data of site-II, the values decreased until depth of 25 cm and at the depth of 30 cm it was decreased.

To verify obtained values from the developed device, verification tests will be conducted using a commercially available cone penetrometer (Model SoilTest) and locally made hammer penetrometer to compare cone index values between the developed device and the cone penetrometers. The same tips were used in all penetrometers. Variation of soil penetration resistances measured by locally made hammer penetrometer and by both developed and hand held penetrometers are depicted in Fig. (11) for the two sites. Using Excel software, no significant difference was obtained among soil penetration resistance obtained by the three devices as shown in Table (3).

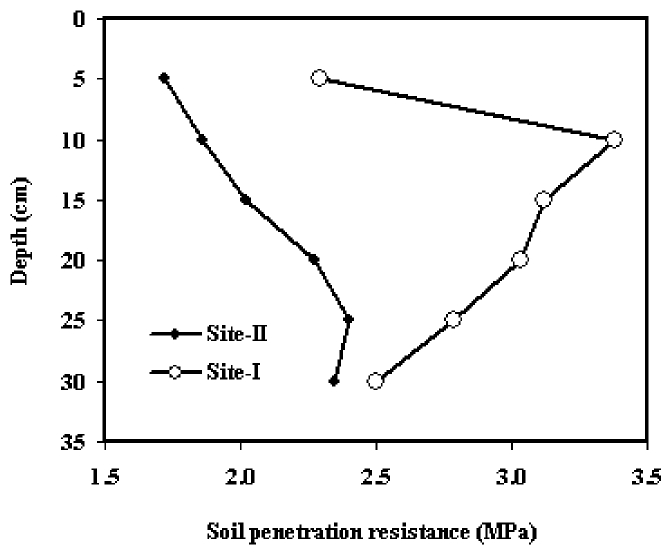

Fig. (10): Means of penetration resistance for site-I and site-II at different depths.

Table (3): Statistical analysis and ANOVA using Excel software to show significant among soil penetration resistance (Mpa) obtained by the three devices for two sites.

Groups	Count	Site-I			Site-II		
		Sum	Average	Variance	Sum	Average	Variance
Hammer penetrometer	54	166.99	3.09	0.235	121.16	2.24	0.272
Developed penetrometer	54	153.99	2.85	0.183	113.53	2.11	0.239
Hand held penetrometer	54	160.88	2.98	0.261	113.01	2.09	0.128
Source of Variation	SS		DF	MS		P-value	
	Site-I	Site-II		Site-I	Site-II	Site-I	Site-II
Between Groups	1.57	0.77	2	0.78	0.39	0.0337	0.1671
Within Groups	36.01	33.89	159	0.226	0.213		
Total	37.58	34.66	161				

DF: degree of freedom, SS: sum of squares, MS: mean square

Mathematical model was derived based on average data of soil penetration obtained by three devices in two sites. The mathematical model has a form as follows:

$$Y = \beta_0 + \beta_1 \times X_1 + \beta_2 \times X_2 + \beta_3 \times X_3 + \beta_4 \times X_4 \quad \text{......................(1)}$$

Where Y is soil penetrations (Mpa), X_1 is depth (cm), X_2 is soil moisture content (%, db), X_3 is soil bulk density (g/cm^3), X_4 is soil texture index (dimensionless) and $\beta_0, \beta_1, \beta_2, \beta_3, \beta_4$ are regression coefficients. The soil texture index (X4) could be obtained as follows (Zein Eldin, 1995):

$$X4 = \frac{\log\ (S_i^{\ C} + S_a)}{100} \qquad (2)$$

Where S_i, S_a and C are % of silt, sand and clay fractions in the soil, respectively. The regression coefficients and coefficients of determination of Eq. (1) are shown in Table (4).

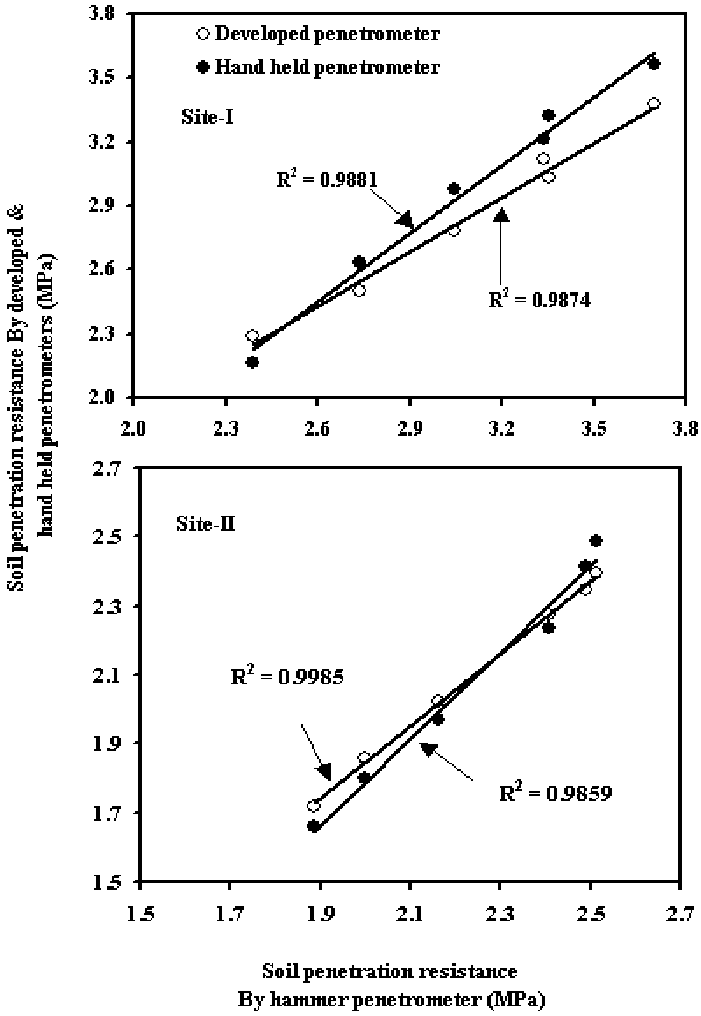

Fig. (11): Variation of soil penetration resistances measured by locally made hammer penetrometer and by both developed and hand held penetrometers.

Table (4): Regression coefficients and coefficients of determination of Eq. (1).

Variables	Hammer penetrometer	Developed penetrometer	Hand held penetrometer
	(Mpa)		
Intercept	-20.142	-19.698	-20.868
X1	0.008	0.014	0.024
X2	-0.029	-0.038	-0.038
X3	2.562	2.536	2.320
X4	29.124	28.366	30.284
R^2	0.709	0.732	0.703

The trend of the affecting variables on soil penetration resistance is the same when getting data by any of the three devices. However, coefficient of determination (R^2) of developed penetrometer is 0.732. These models are valid in the range of 5 to 30 cm for depth, 8.14-33.59 %, db for soil moisture content and 1.03-1.46 g/cm^3 for soil bulk density and 0.665-0.716 for soil texture index.

In practices, the developed device was calibrated by comparing its readings against the values of another device or device known to have much higher accuracy. First specify the error of indication of the instrument, from the calibration test, thus error at any point = measured value – standard value. These error values may be positive or negative. The cone index full scale for site-I = (1000 N/129.18 mm^2) = 7.74 Mpa and for site II, the cone index full scale =(1000N/322.54 mm^2) = 3.10 Mpa.

By analyze the error when compared to the developed one with the commercial device, the maximum error was -0.292 Mpa at site–I and -0.090 Mpa at site–II, Table (5). So, the accuracy is obtained as follows (Adams,1981):

$$Accuracy\ (Error\ \%\ f.s.d) = \frac{\pm \max imum\ error\ \ in\ range}{full\ scale\ value} \times 100 \quad \text{.....................(3)}$$

Hence the accuracy of the developed device would be specified as ± 3.78% and ± 2.89% for site-I and site-II, respectively.

Table (5): Errors in cone index values when using developed penterometer.

Depth (cm)	Soil moisture content (%,db)		Soil bulk density (g/cm^3)		Cone index (Mpa)				Error (Mpa)	
					Developed penetrometer		Hand held penetrometer			
	Site-I	Site-II	Site-I	Site-II	Site-I	Site-II	Site-I	Site-II	Site-I	Site-II
5	10.90	8.14	1.03	1.13	2.29	1.72	2.17	1.66	0.124	0.060
10	15.01	13.22	1.08	1.17	3.38	1.86	3.56	1.80	-0.183	0.060
15	20.66	15.46	1.13	1.28	3.12	2.02	3.21	1.97	-0.092	0.053
20	25.57	17.75	1.16	1.42	3.03	2.28	3.32	2.23	-0.292	0.042
25	30.52	17.90	1.18	1.36	2.79	2.40	2.98	2.49	-0.192	-0.090
30	33.59	22.93	1.20	1.46	2.50	2.35	2.63	2.41	-0.129	-0.068

CONCLUSION

A device that measures soil penetration resistance was developed. This device can be hitched to the tractor three point hitch for manual data collection. Field tests were conducted. Verification tests for cone index values using locally made hammer penetrometer and commercially static penetrometer correlated quite well. The benefits of this device are summarized in the following points:

1. Easy to use in the field as a static penetrometer and constant rate of pushing shaft in the soil will be obtained.
2. It can be used as a soil sampler collector for soil bulk density and moisture content samples in easy way.
3. Accuracy reading for cone index data could be obtained, as the sensing force unit is load cell. However, the accuracy of the developed device would be specified as ± 3.78% and ± 2.89% for site-I and site-II, respectively.
4. During measurements of cone index in the field, no special arrangements were taken.
5. The resistance to penetration results showed distinct behaviors for the studied depths, sites and location inside each site indicating the importance of measuring penetration resistances in different location in the experimental field at specified depth due to spatial variations.
6. The mathematical model to get penetration resistance was:
   $Y = -19.698 + 0.014 \times X_1 - 0.038 \times X_2 + 2.536 \times X_3 + 28.366 \times X_4$ $R^2 = 0.732$
   where Y is soil penetration by developed device (Mpa), X_1 is depth in the range of 5-30 cm, X_2 is soil moisture content in the range of 8.14-33.59 % (db), X_3 is soil bulk density in the range of 1.03-1.46 g/cm^3 and X_4 is soil texture index in the range of 0.665-0.716.

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تطوير جهاز حقلي لتجميع بعض بيانات لخصائص التربة:
I . مقاومة اختراق التربة

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في هذا البحث تم تقديم خطوات تطوير ومعايرة واختبار جهاز حقلي لتجميع بعض بيانات لخصائص التربة وبالأخص مقاومة التربة للاختراق. يمكن تعليق هذا الجهاز في أذرع الشبك الهيدروليكية للجرار لسهولة حمله وتشغيله. يتكون الجهاز المطور من عدة مكونات وبصفة رئيسية منظومة هيدروليكية مفتوحة المركز للمساعدة في التحكم في سرعة عمود الاختراق للمحافظة على سرعته ثابتة أثناء العمل الحقلي من خلال اسطوانة هيدروليكية. ولمعرفة قدرة الجهاز المطور في تجميع قيم مقاومة اختراق التربة، استخدم مع نوعين مختلفين من التربة مقارنة بجهازين آخرين واحد منهم ديناميكي محلي الصنع والآخر استاتيكي مستورد. استخدم التحليل الإحصائي لمعرفة تأثير نوع التربة وموقع أخذ القراءات داخل نوع التربة وعمق الاختراق على قيم مقاومة التربة للاختراق. وكذلك الفروق الإحصائية بين القراءات المأخوذة من الأجهزة الثلاثة المستخدمة. وأوضحت النتائج أنه لا يوجد فرق معنوي بين قراءات مقاومة التربة للاختراق بأي نوع من الأجهزة ، ولكن كان هناك تأثير معنوي لنوع التربة وموقع أخذ القراءات وعمق الاختراق على قيم مقاومة التربة للاختراق بأي من الأجهزة الثلاثة المستخدمة. ومن هذه النتائج يمكن التوصية بأنه عند تجميع بيانات مقاومة التربة للاختراق في حقل التجربة لابد من استخدام أجهزة سهلة التشغيل، سرعتها ثابتة أثناء اختراق التربة. وتم استنباط علاقة تربط بين مقاومة التربة للاختراق (ميجابسكال) وعوامل التربة كما يلي:

$$Y = -19.698 + 0.014 \times X_1 - 0.038 \times X_2 + 2.536 \times X_3 + 28.366 \times X_4 \qquad R^2 = 0.732$$

حيث X_1 عبارة عن عمق الاختراق في الحدود من 5-30سم ، X_2 المحتوى الرطوبي للتربة في الحدود من 8.14-33.59 % على أساس جاف ، X_3 عبارة عن الكثافة الظاهرية للتربة في الحدود 1.03-1.46 جرام/سم^3 ، X_4 عبارة عن دليل قوام التربة بدون وحدات في المدى من 0.665-0.716.