LABORATORY DETERMINING OF SOIL STRENGTH PARAMETERS IN CALCAREOUS SOILS AND THEIR EFFECT ON CHISELING DRAFT PREDICTION.

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Abstract: *This study was conducted to determine the effect of soil strength parameters; ploughing depth and rake angle on chiseling force when ploughing with 7 narrow blade chisel plough in calcareous soils. Laboratory experiments were achieved by using direct shear device on the soil at moisture content of 12, 16, 20 and 28 % d.b. and bulk density of 1.4, 1.5 and 1.6 g/cm^3. Linear regression equations were found to explain the relation between soil strength parameters and both soil moisture content and soil bulk density. The obtained equations of main soil strength parameters i.e. angle of internal friction of soil (Φ-degrees) and soil cohesion (C- g/cm^2) were applied to fined the actual general soil strength parameters at the actual conditions when ploughing at different levels of depth (12.2, 17.3 and 22.17 cm). The actual main soil strength parameters were found out at the soil moisture content of 21.51, 22.72 and 24.64% d.b. and soil bulk density of 1.4, 1.5 and 1.6 g/cm^3 which were determined at the previous actual ploughing depths. The statistical linear regression analysis of the laboratory experimental data and the obtained linear regression equations appeared that each of soil adhesion, soil metal friction angle, angle of internal friction of soil and soil cohesion were inversely proportional to soil moisture content and were directly proportional to soil bulk density. In the same time, the soil shear plan had a contrary manner when affected by both soil moisture content and bulk density. The field experimental data were subjected to the analysis of variance (ANOVA) and all treatments were compared using the least significant difference method (L.S.D.) at 5% probability level. The analysis revealed a significant relationship between tillage depth, rake angle and their interaction and the net pulling force. The minimum pulling force (5.38-5.72 KN/7blades) was occurred at tillage depth of 15 cm and a range of rake angle from 16 to 22^o. Also, a linear regression equation was drawn out to predict the net pulling force of a 7 narrow blades chisel plough when ploughing in calcareous soils* **(***Maryut area). The predicted force was affected by soil strength parameters, ploughing depth and rake angle, 3.4km/h ploughing speed and at the levels explained before*
Key words: *soil strength parameters – chisel draft force – rake angle – ploughing depth*

INTRODUCTION

Like other engineering materials, a soil may be loaded until it fails. This failure will normally be a shear failure, and the maximum resistance of the soil to shearing stresses is the shear strength.

The shear strength or shearing resistance of a soil depends on a large number of factors, but is generally considered to be made up of: (a) the internal friction between the grains, and (b) the cohesion of the grains. Cohesion appears to be largely due to the intermolecular bond between the adsorbed water surrounding each grain, especially in fine-grained soils. Therefore, the value of the cohesion will thus vary with soil water content, grain size of soil and its compaction.

In this direction, the aims of this research work were:

1. Determining the soil strength parameters of the calcareous soil in Maryut area in the laboratory by using a direct shear box device.
2. Studying the effect of both soil moisture content and soil bulk density on the previous parameters due to shear.
3. Developing a relation between each of the determined soil strength parameters and soil physical properties i.e. soil moisture content and bulk density.
4. Applying the developed relation in finding out the actual soil strength parameters when using samples from different levels of ploughing depth to estimate both actual soil moisture content and actual soil bulk density in these depths.
5. Studying the effect of both ploughing depth and rake angle of the chisel plough on measured draft force at the field by means of a dynamometer when ploughing at 3.4 km/h.

6. Developing an equation for draft force predicting depending on soil strength parameters, ploughing depth, rake angle at ploughing speed of 3.4km/h when using a 7 narrow blades common chisel plough in such soil.

Review of literature

Many authors like **Ekwue and Stone (1995)** proved that soil shear strength is very important in studying draft of tillage tools. In other words, the draft of farm implements is

mainly affected by shear strength of soil.

Okello (1991) mentioned that to predict the traction forces, soil shear strength must be measured by determining soil cohesion and angle of internal friction of soil.

Hettiaratchi et al. (1970) demonstrated that tool draft increases with increasing angle of internal friction of soil, soil cohesion, soil adhesion and angle of soil metal friction. They added that these soil strength parameters are significantly affected by the moisture status of cohesive soil. In this direction, **Korayem et al. (1971)** showed that the first fundamental principle of a successful ploughing operation is to plough the soil at the right moisture content within the friable range of consistency. Also, **Ohu et al. (1985)** found that the shear strength of sandy loam soil increases with increasing moisture content up to a maximum value and decreases with higher moisture content.

Korayem et al. (1996) determined regression equation relating soil strength parameters to both soil bulk density and moisture content in sandy loam soil as follows:

$$C = 0.0865 \times \rho^{2.53} \times M^{-0.0277} \quad (1),$$

$$\Phi = 0.761 - 0.0122\, M \quad (2)$$

where: ρ = Soil bulk density (g/cm^3);

C = Soil cohesion (k.Pa).

M = Soil moisture content (% d.b.);

Φ = Internal friction angle of soil (degree).

Metwalli et al., 2002 conducted a research work on a clay loam soil to study the effect of forward speed (km/h), ploughing depth (cm) and inflation pressure (k.Pa) on pull force of chiselling operation. Chiselling implement was 7 shares with a 1.75 m tillage width. They developed the following equation to predict chiselling pull draft depending on

$$F = -15.214+1.11H+1.876V+0.71P \quad (R^2= 0.952) \quad (3)$$

the previous factors at the following available ranges (Vfrom 2.6 to 4.9 km/h); (H = 10.15 and 20 cm) and (P = 90, 108 and 118 KPa) respectively.

Ismail (2002) carried out experiments on sandy clay loam soil using soil bin of Ag. Eng. Dept., Fac. of Agric., Alexandria Univ. He suggested the following model: D = f (S, d, w, α, MC, ρ) and used the following levels of the variables involved in the model as:

D = predicted draft force (N/share); S = forward speed (18.5; 37.51 cm/s)

d = tillage depth (6; 12 cm); w = tool width (narrow 5 cm);

α = rake angle of tool (10; 17and 25 degrees); MC = soil moisture content (1.5; 6.5;14.3 and 18.99% d.b.); ρ = soil bulk density (1.35; 1.65; 1.75 and 1.88 gm/cm^3)

He determined the following regression equation to predict the value of soil draft as a function of the previous levels of variables and soil type.

$D=-120.24+3.99MC+58.37\rho-0.093\ MC^2-1.61\ MC.\rho+2.88\ \alpha+2.096\ d+0.328$

$S (R^2 = 0.868)$ (4)

Finally, he concluded that the previous variables increased linealy the predicted soil draft besides moisture content. It increased the soil draft up to a certain value then increasing moisture content decreased it.

Material and Methods

1- Laboratory measurements and devices

- **Soil texture**

Soil samples were taken from Maryut area (calcareous soils) and analyzed by **Block et al (1965)** in the laboratory at Soil Conservation Dept., Disert Research center, Cairo to determine soil texture. Each sample contained soil from four depths (0-5; 5-10; 10-20 and 20-30 cm)

- **Soil moisture content**

Four soil moisture contents were used (12%; 16%; 20% and 24% d.b.). They were prepared by mixing a known dry weight of soil with water by means of a manual sprayer.

- **Soil bulk density**

Three different soil bulk densities (1.4; 1.5 and 1.6 g/cm^3) were set up for these laboratory tests by using the constant base area of the shear box (36 cm^2) and 3 cm height .The soil bulk density was generally computed according to the following equation:

$$\rho = Ms/Vs \quad (5)$$

Where :ρ = Soil bulk density g/cm^3;

Ms = Mass of soil sample (g) and

Vs = Volume of sample (108 cm^3)

Soil was compacted layer by layer, scratches were made in soil after each layer to obtain a uniform cohesion between layers.

Direct shear box device **(model D- 110 Ay, U.S.A)** as shown in Fig (1) was used to measure soil shear strength parameters.

Soil shear strength parameters:

Soil was prepared to the required moisture content. Then it was packed to the calculated height in shear box, which gives the desired bulk density. Dial gages were adjusted to zero reading; one gage on the proving ring was for measuring the shearing force, while the other was for measuring the movement of the upper half of the shear box for strain calculations. The upper half of the shear box was covered by its gripper plate and the loading bar was adjusted to floot above it to give zero normal loads on the hanger.

Four levels of normal load were used. Normal stress was calculated by dividing the normal load by cross-section area of the soil sample.

Shearing stress was obtained from the dial of proving ring readings.

Shearing stress(τ) = shear force (kg) / cross-section area of the sample(36 cm^2) (6)

When the soil sample failure is accrued, (τ max) is recorded. The maximum shear stress (τ max) was plotted versus normal stress (σ) five times at each level of the four levels of soil moisture content (12, 16, 20 and 28 % d.b.) and the three levels of soil bulk density (1.4; 1.5 and 1.6 g/cm^3). The slope of the line curve represents the angle of internal friction of soil (Φ) and the

intercept represents soil cohesion (C). from the following equation by coulomb (**Arora 1988):**

$$\tau = c + \sigma \tan \phi \quad (7)$$

The soil adhesion (Ca) can be calculated from the following relation by **(Perumpral, 1983)**:

$Ca = 0.5\ C$ (8)

The soil metal friction angle (β) as a function of the internal friction angle of soil (Φ) was calculated due to the following equation:

$\beta = \tan^{-1}[(\tan \Phi)/2]$ degrees **(Mckyes , 1985)** (9)

The angle of soil shear plane (δ) was determined as follows:

$\delta = [45 - (\Phi/2)]$ degrees ……………………….(10)

1- <u>Field measurements and method of pulling force measuring:</u>

- **Soil moisture content.**

Soil samples were taken at three different depths 15, 20 and 25 cm by a screw auger. Soil moisture content was determined using the standard oven method. Samples were weighed, and then they were dried at 105 ^oC up to 24 hours by an electric oven. Soil moisture content was calculated according to **Black et al (1965)** as follows:

$MC = ((Sw - Sd) / Sd) * 100$ ………………………..(11)

Where:

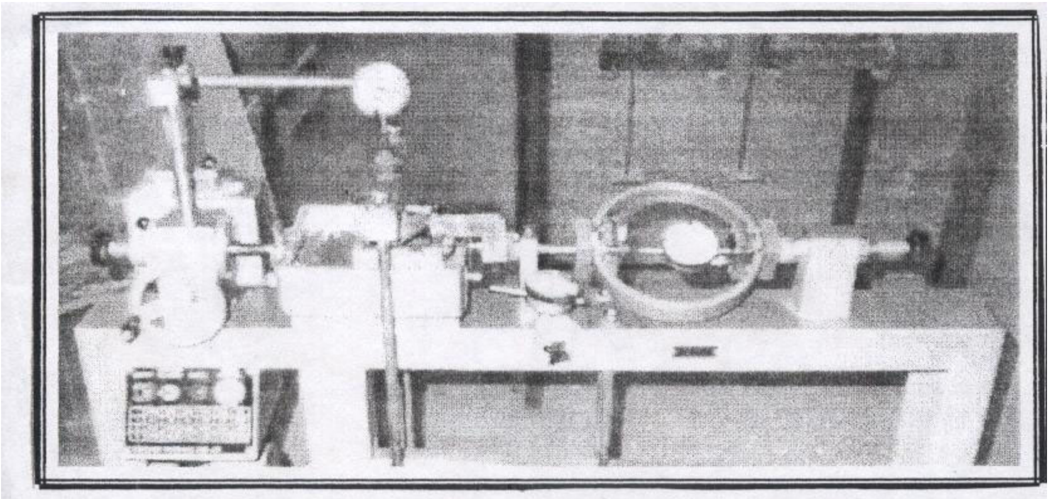

Figure 1. Shear box device

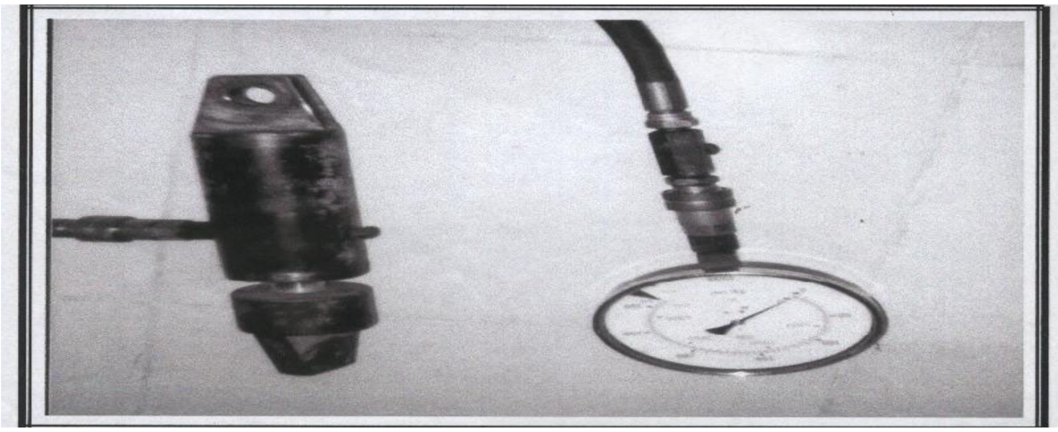

Figure 2. The hydraulic dynamometer hitching between the two tractors for chiseling force measurements

MC= Soil moisture content (% d.b.), Sw = Mass of wet soil (g); Sd = Mass of dry soil (g)

- **Soil bulk density:**

Soil samples were taken using cylindrical core (100-cm^3 volume) at three different depths of (15, 20 and 25 cm). The core samples were immediately weighed, and then they were dried at 105 ^oC for 24 hours. Soil bulk density before ploughing was determined according to **Black et al (1965)** using the following formula:

$$B.D = Wd / Tv \quad (12)$$

Where:

B.D= Soil bulk density (g/cm^3),

Wd= Mass of dry soil (g),

Tv = Total soil volume (cm^3)

- **Net pulling force using Chisel plough, tractors, hydraulic dynamometer and ploughing forward speed:**

A 250 kg weight and seven narrow blades chisel plough with the facility to change its rake angle was used with four levels of (10, 16, 22 and 28 degree). The blades were double acting shovels with 8 cm width, 28 cm curvature length. Its shares were in a staggered position resulting a space of 25 cm between each two consecutive shares in which were arranged in two rows. Two 70 HP tractors **(Ursus C-385)** were used. A hydraulic dynamometer was coupled between the two tractors, where the chisel plough was attached with the rear one, to estimate pulling force. The pull force was recorded for both levelS of ploughing depth and rake angle. The dynamometer has a hydraulic cylinder, which transmits pressure to the pressure gauge. It can calibrate to read in kg pull directly. The pulling force was estimated as follows:

Pulling force = (reading of pressure gauge)* (area of the hydraulic piston)

$$= [\, P * \pi (D^2 - d^2) / 4 \,],\ kg/cm^2 \quad (13)$$

Where: D = Piston diameter (6.94 cm), d = Piston rod (2.08 cm), P= Pressure (kg / cm^2)

$$\pi (D^2 - d^2) / 4 = (34.42\ cm^2)$$

Hitching the hydraulic dynamometer was always adjusted as to keep the angle between the line of pull and the horizontal to minimum as shown in Figure (2) the maximum pressure gauge was 100 kg/cm^2 with 2 kg/cm^2 accuracy.

The net drawbar pull force was calculated using the following equation:

$$N.P = P – RR \quad (14)$$

Where:NP = Net drawbar force for ploughing (Newton)

P = The recorded force when the chisel plough is in action (Newton) at 3.4

km/h traveling speed.

RR = The force required to move both the tractor and the chisel plough in a lifted position over the ground test (Newtons). This value presented the arithmatic mean of ten readings at the same travell speed 3.4 km/h (Sayedahmed, 1999)

The ploughing speed used to conduct all field experiments was 3.4 km/h (0.94 m/s).

Results and discussions.

Table (1) illustrates the particle size distribution and the soil texture of the samples of the experimental area. It could be noticed that the soil texture was sandy clay loam.

60 laboratory experiments on the sandy clay loam soil using direct shear box apparatus of laboratory of soil mechanics in the Faculty of Engineering, Menoufia Univ., were conducted to determine soil shear strength parameters. Experiments were carried out as a combination of three levels of soil bulk density (1.4; 1.5 and 1.6 g/cm^3), four levels of soil moisture content (12;16;20 and 24% d.b.) and the max shear load (kg) was found at five of normal loads(0; 5; 10; 15 and 20 kg) for each experiment.

Table 1. Maryut area soil texture (33 km to the North west Cost of Alexandria).

Depth (cm)	Coarse sand 2 - 0.2 (mm) (%)	Fine sand 0.2 - 0.02 (%)	Silt 0.02 - 0.002 (%)	Clay < 0.002 (%)	Ca CO_3 (%)	Texture
0 - 5	18.37	37.20	19.22	25.21	37.57	Sandy clay loam
5 - 10	17.35	40.21	17.77	24.67	39.83	Sandy clay loam
10- 20	13.52	46.45	17.75	22.28	40.24	Sandy clay loam
20 - 30	12.11	42.49	22.16	23.24	42.45	Sandy clay loam

Figure (3) presents the effect of soil moisture content and soil bulk density on soil strength parameters related to soil shear tests including angle of soil shear plane, soil adhesion, soil metal friction angle, angle of internal friction of soil and soil cohesion. It is clear from the results as given in table (2) and Figure (3) that increasing soil moisture content at all levels of soil bulk density decreased soil adhesion, angle of soil metal friction, angle of internal friction of soil and soil cohesion. These results are in agreement with **Panwer et al (1972).** They found that soil cohesion in silty clay loam soil decreased with increasing soil moisture content at soil bulk density over 1.2 g/cm^3 and also they reported that the angle of internal friction of soil decreased with increasing soil moisture content. Further confirmation was done by **Koraym et al (1996)** who found that soil cohesion increased with increasing the initial bulk density and decreased with increasing soil moisture content in sandy loam soil.

Furthermore, increasing soil bulk density increased the above mentioned soil strength parameters at the same soil moisture content. These results are in a confirmity with those of **Stafford et al (1970)** who reported that soil adhesion increased with increasing soil bulk density. On the other side, **Korayem et al** reported that the effect of soil bulk density of sandy clay loam soil was not sensible and significant.

From Figure (3) the soil moisture content seams to have another effect on the angle of soil shear plane with different levels of soil bulk density. The general trend is that it increases with increasing the soil moisture content and at the same level of moisture content the angle of soil shear plane decreases with increasing soil bulk density.

Statitical linear regression analysis were aplied to the obtained data to find out the trends of soil shear strength parameters as a function of soil moisture content and bulk density. The statistical multible linear reggression equations were as follows:

δ = Angle of soil shear plane (degree)=39.30+0.218M-8.938 BD(R^2 = 0.97) (15)

Ca = Soil adhesion (kg/cm^2)=1.34-0.977M+20.875 BD (R^2= 0.99) (16)

B = Soil metal friction angle (degree)=5.76-0.276M+10.400 BD(R^2 = 0.98) (17)

Φ = Internal friction angle of soil (degree)=13.5-0.450M+16.600 BD(R^2= 0.98) (18)

C = Soil cohesion (kg/cm^2) =- 0.4-0.020M+0.700 BD (R^2 = 0.98). (19)

Where:M = Soil moisture content (% d.b.); BD = Soil bulk density (g/cm^3).

The statistical analysis clarified the relationship between each of soil shear strength parameters and both of soil moisture content and soil bulk density. It is obvious that each of soil adhesion, soil metal friction angle, angle of internal friction of soil and soil cohesion were inversely proportional to soil moisture content and were directly proportional to soil bulk density. In the same time, the analysis revealed that the angle of soil shear plan had a contrary manner when affected by soil moisture content and soil bulk density, than the other soil shear strength parameters. Generally, the analysis of this investigation especially for the main soil shear strength parameters (C&Φ) as indicated is in accordance with those of **Linder (1963)**, **Freitage (1971) Korayem et al (1971), Staford et al (1977) and Panwer et al (1972)**. However, **Korayem et al** added that they found an increasing in cohesion and adhesive resisting force due to the increase of soil moisture below the lower plastic limit for clay soil. Also, **Panwar et al** had the following limited addition that soil cohesion decreased with increasing soil moisture content at bulk density over 1.2 g/cm^3 in the silty clay loam soil.

The present analysis proved a significant relationship between both (soil moisture content and soil bulk density) and soil strength parameters presented especially in internal friction angle of soil (ϕ-degrees) and soil cohesion (C-Kg / cm^2. Furthermore, the mentioned soil characters (soil moisture content and soil bulk density revealed an effective relation with changing soil depth as confirmed by Zein El-Din (1985), Meharban et al (1998) and Niwa et al (1999). They demonstrated that deep ploughing in silty clay or silty clay loam soils lead to decreasing in soil bulk density and increasing the pore space filled with gravitational water. In this direction equations (18,19) were used for finding out the values of (C-kg / cm^2 and ϕ degree) depending on both soil moisture content (M-%d.b) and soil bulk density (BD- g/cm^3) determined at the actual depths (12.2, 17.31and 22.17 cm) for tillage. These depths were very closed to those used at field experiments for chiseling pull force measuring by the dynamometer. The obtained results were presented in Table (3) which, indicate the main soil strength parameters at different soil depths.

Table 3. Main soil strength parameters as affected by the actual soil bulk density and

soil moisture content due to changing of the actual soil depth used in tillage.

Soil depth (cm)	Soil bulk density (g/cm^3)	Soil moisture content (%d.b)	Angle of internal friction of soil (ϕ-degree)	Soil cohesion ($C\text{-}Kg/cm^2$)
12.2	1.4	21.51	27.2	15.37
17.31	1.5	22.72	28.1	19.2
22.17	1.6	24.64	29.4	24.2

A series of field experiments were conducted to estimate net chiseling pull force by means of hydraulic dynamometer using equation (14) and different levels of ploughing depth (10; 20; and 25 cm) in the sandy clay loam soil at different levels of blade angle (10; 16; 22 and 28^o) with the aim to study the effect of previous factors on chiseling draft force. Also to develop regression equation through statistical regression analysis for chiseling pull force prediction in such soils. The draft prediction mainly depends on the ploughing depth (d-cm) as an operational factor of the chisel plough, soil strength parameters (angle of internal friction of soil (ϕ-degree) and soil cohesion ($C\text{-}kg/cm^2$)), rake angle of ploughing blades (α-degree) as an engineering factor of the chisel plough; and at ploughing speed of (3.4 Km/h) in all treatments.

The field data were obtained as indicated in Table (4) and presented graphically in figure (4) when chiseling was achieved by a 7 narrow blades chisel plough with 8cm thichness as described before.

The data presented in figure (4) and table (4) are the mean values of 6 replications for net pulling force (KN) as affected by soil ploughing depths (which, their changes affect both Φ and C as a soil strength parameters due to the changes in the values of moisture content and bulk density of soil at every depth) and different ploughing rake angles.

Table 4. The field experimental data for net chiselling draft (H-KN) measurements due to changing in ploughing depth and rake angle of chisel plough blades. (7 narrow blades with 8-cm thickness).

Tillage depth (d-cm)	Rake angle (α-degree)	The mean values of measured net pulling force (H-KN)
15	10	9.25^{C}
	16	5.38^{F}
	22	5.72^{F}
	28	$7.51D^{E}$
20	10	10.82^{B}
	16	7.37^{E}
	22	8.15^{D}
	28	9.09^{C}
25	10	12.03^{A}
	16	9.07^{C}
	22	9.66^{C}
	28	11.24^{B}
L.S.D at significant level 5 %		
Tillage depth = 0.72 Rake angle = 0.83 Tillage depth X Rake angle = 1.4		

Mean values followed by the same letter are not significantly different at 5% level according to Duncan's multible range test.

It may be noted from data presented in the table and illustrated in the figure that increasing the ploughing depth increased the net pulling force i.e. the net pulling force (H-KN) directly propotional to the ploughing depth (d-cm). Furthermore, the net pulling force decreases at rake angle of 16^o and 22^o where, it becomes minimum at rake angle of 16^o for all depths used in this investigation. It starts with high values at rake angle of 10^o due to the initial penetration in such type of soil and decreases sharply to minimum at rake angle of 16^o ,then it begins to increase slightly with increasing the rake angle of ploughing. These results were confirmed by El-Sayed (1991). He stated that the minimum values of measured and predicted draft force were found at a blade angle between 16^o and 22^o with all ploughing depths and forward speeds used in ploughing operation. Also, Mathur et al (1992) found that the optimum value of rake angle to achieve minimum specific draft was 25^o when practicing four levels (20; 25; 30 and 35^o) using an indoor soil bin filled with sandy loam soil. Data were subjected to the analysis of variance (ANOVA) and the treatments were compared using the least significant difference method (L.S.D) at 5% probability level “Sendecor and Cochran (1982) and Steel and Torrie (1980)”. The statistical analysis revealed a significant relationship between both tillage depth and rake angle and net pulling force. Generally, it is clear that the minimum pulling force is occurred at tillage depth of 15 cm and a range of rake angle from 16^o to 22^o. This can be explained by the following:

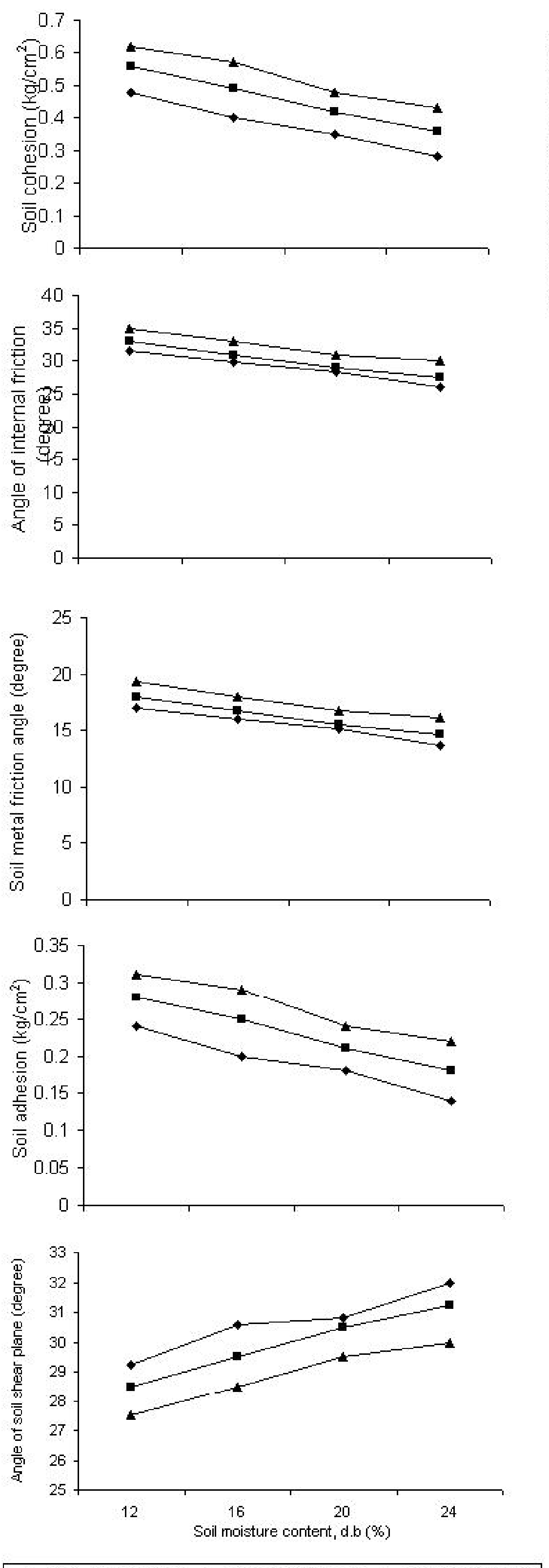

Figure (3): The effect of soil moisture content and soil bulk density on soil shear strength parameters.

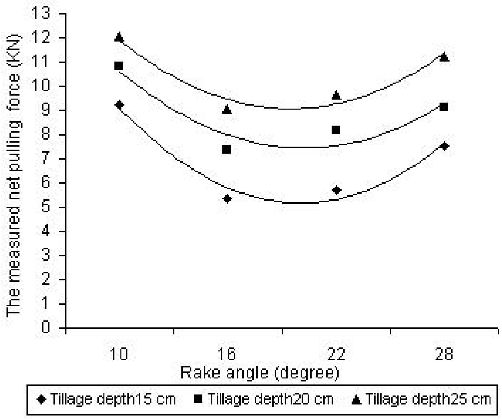

Figure (4): The measured net pulling force due to different tillagedepths and rake angles at 3.4 km/h ploughing speed for ploughing by 7 narrow double acting shovels chisel plough.

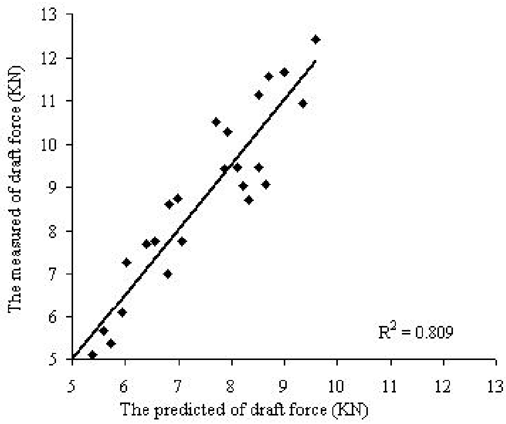

Figure (5): Comparison between the predicted and experimentally measured draft force of tillage tool in calcareous soils.

The initial higher draft at a low level of rake angle is due to the increasing of underside length of the blade which, rubs on the soil. In the same time, this underside length decreases when the rake angle increases, but at some point the effect of more soil being failed by the blade start to increase the draft force. So, at rake angles of 16^o and 22^o the soil exerts a downward force on the blade which, help it to penetrate together with its spring action when it moves through the soil without more additional weight resulting from the ploughing soil.

When the blade advances through the soil a series of shear planes are formed resulting blocks of soil failing and sliding along the blade from bottom to top. Therefore, when the rake angle decreases under 16^o the soil slices which, slide along the blade, will be in a forme of succession on the blade because the slices will be in a conflict with the shank of the plough which, will make a very acute angle with the blade. In this case, the soil resistance will increase when the rake angle increases more than 22^o the soil slices slide to a high rise and need more energy. This besides that, the soil slices drop in front of the blade resulting an increasing in ploughing soil weight on the blade (Gill and Vandern (1968) and Tanner (1960))

Data were subjected to statistical multible regression to develop a multible regression equation. It appears the relationship of chiseling draft and (angle of internal friction of soil, soil cohesion, rake angle and ploughing depth) at ploughing speed of 3.4 km/h. The multiple regression equation obtained after analyzing data was as follows:

$$H = -4.545+0.065\ d-0.169\ \alpha+0.005\ \alpha\ d+0.308\ \Phi+12.752\ C (R^2 =0.809) \quad (20)$$

Where: H = chiseling draft force fore 7 blades kN, d = ploughing depth (cm), α = rake angle (degree), Φ = angle of internal friction of soil (degree), C = soil cohesion kg/cm^2. Fig. (5) shows the relationship between both the predicted and experimentally measured draft force. The observed R^2 value (0.809) indicated an excellent correlation of draft force predicted with the observed values.

CONCLUSIONS

Maryut area was selected as a calcareous soil to study the effect of the following important factors on the chiseling force when ploughing with chisel plough, the most common and economical seedbed preparation implement in Egypt.

1- Factors related to soil i.e. soil strength parameters (soil cohesion, angle of internal friction of soil, soil adhesion, angle of shear plan, soil metal friction angle).

2- An engineering factor related to chisel plough i.e. rake angle.

3- An operational factor (ploughing depth) at optimum ploughing speed 3.4 km/h.

This study was conducted because of its important in determining the draft requirement in such areas and discussing the most effective parameters related to it, especially, when using such common plough in ploughing this type of soil.

Experiments of this study were divided into laboratory and field ones. The laboratory experiments were conducted for developing particular relations between both moisture content and bulk density of Maryut soil and its shear strength parameters. The effect of these soil physical parameters at different levels on soil strength parameters was discussed.

Field experiments were achieved by taking soil samples at different depths (which will be practiced as actual ploughing depths when ploughing for chiseling pull force measuring at different levels of rake angle) to determine the actual soil moisture content and the actual soil bulk density at these depths. The soil physical properties delivered were used in the previous developed relations for actual soil strength parameters estimating. Data obtained from field experiments for measuring draft force by using dynamometer were affected by different levels of ploughing depth and rake angle, soil strength parameter condition at the actual ploughing depths and at a ploughing speed of 3.4 km/h. The results were subjected to analysis of variance statistical method, and using least significant difference at 5% significant level compared means of all treatments. The statistical analysis revealed significant relation between all the variables involved in this relation and also their interaction and the measured draft force. The minimum draft force was obtained at all depths used and at rake angle of 16^o.

A multiple linear regression analysis clarified the previous result and a multiple linear equation was developed. The equation proved that the soil strength parameters i.e. soil cohesion (kg/cm^2) and angle of internal friction (degrees); ploughing depth (cm) and interaction of ploughing depth and rake angle were directly proportional to draft force. In the same time, the rake angle (degrees) was inversely proportional to draft force especially, at low levels when its value varied from 10 to 22^o and this behavior began to change by increasing its value from 22 to more. The values of draft force predicted by the equation were compared by the actual values obtained at the field with R^2 = 0.809.

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