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Mechanical Properties of Paddy Soil in Relation to High Clearance Vehicle Mobility

[1]M. S. Abubakar, [1]D. Ahmad, [1]J. Othman and [2]S. Sulaiman

[1]Department of Biological and Agricultural Engineering, Universiti Putra Malaysia
[2]Department of Mechanical and Manufacturing Engineering, Universiti Putra Malaysia

Abstract: This study reports the mechanical properties of paddy soil in respect to vehicle mobility in Sungai Burong, Tanjung Karang, Malaysia. Soil samples were taken from the topsoil layer of 0-5 cm and subsoil layers of 5-15 cm, 15-25 cm and 25-35 cm depths at fifteen different locations in triplet replications using 216 cm^3 volume core samplers. Soil shearing characteristics, parameters that include water content, bulk density, soil cohesion, angle of internal friction, shear deformation modulus were determined in the laboratory using oven and direct shear box apparatus. The load-sinkage test was carried out in field using soil bearing capacity apparatus. The mean values of paddy soil water content and bulk densities obtained were 47.08 %, 60.65 %, 79.78 %, 94.07 % and 9. 8 x 10^{-10} g/cm^3, 1.24 x 10^{-9} g/cm^3, 1.30 x 10^{-9} gc/m^3, 1.45 x 10^{-9} g/cm^3 at depths of 0-5 cm, 5-15 cm, 15-25 cm and 25-35 cm respectively. Mean values of soil cohesion, angle of internal friction and shear deformation modulus were found to be 6.22 kN/m^2, 5.03 kN/m^2, 3.15 kN/m^2, 1.40kN/m^2 and 30.73°, 27.87°, 18.22°, 17.86° at depths of 0-5 cm, 5-15 cm, 15-25 cm and 25-35 cm respectively. It was found that the *in-situ* shearing strength of the paddy soil dropped from 3.32 kN/m^2 to 2.16 kN/m^2 to 1.74 kN/m^2 and to 1.59 kN/m^2 as the depths increased from 0-5 cm, 5-15 cm, 15-25 cm and 25-35 cm respectively. This shows that vane blade size and depth had significant effect on the *in-situ* shearing strength. It was also observed that the plate sinkage in the paddy soil increased with increasing pushing load.

Key words: soil cohesion, angle of internal friction, shear deformation modulus, shearing strength, bearing capacity and paddy field.

INTRODUCTION

Rice is the staple food of approximately one-half of the world's populations. Much of the paddy is grown and consumed in Asia. Paddy is usually grown by transplanting seedlings under flooded conditions. This wet, soft soil field presents extremely unfavorable conditions for vehicle traction and mobility in the paddy field and is the most important cause for slow progress of mechanization of rice cultivation processes. Increase in precipitation towards the end of the growing season often causes mobility problems in the fields. Poor mobility also causes damage in topsoil structure through soil compaction (Awadhwal and Singh, 1985; Bockari-Gevao *et al.,* 2005). The key to off-road vehicle performance prediction lies in the proper evaluation of mechanical properties of the field. Mobility expresses a relationship between soil state and the vehicle. To evaluate the vehicle mobility over a paddy field, it is very important to develop appropriate methods for identifying and measuring the mechanical properties of the paddy soil that are considered to be relevant to vehicle mobility. To properly identify the mechanical properties of paddy soil from off-road vehicle mobility point of view, measurement need to be taken under loading conditions similar to those exerted by a vehicle. The vertical load that off-road vehicle exerts on the paddy soil results in sinkage while horizontal load applies to the soil surface through the vehicle wheels results in the development of shearing strength and associated slip. Vehicle performance depends greatly upon the amount of traction that can be developed from the soil and the amount of sinkage that the traction element will develop as a result of the imposed normal and shear stresses (Bekker *et al.,* 1969; Chang and Baker, 1973; Soltynski, 1979). The determination of the mobility of vehicles running off-road requires a good knowledge of surface soil mechanics, as it is necessary to determine the power transmission between the vehicle and the soil by means of wheels (Soltynski, 1979; Dahab and Mohamed, 2002). This paper reports the field and laboratory results for the determination of the mechanical properties of paddy soil. Soil shearing characteristics, parameters that include water content, bulk density, soil cohesion, angle of internal friction, shear deformation modulus were determined in the laboratory using oven and direct shear box apparatus. The load-sinkage test was carried out in field using soil bearing capacity apparatus.

Corresponding Author: M. S. Abubakar, Department of Biological and Agricultural Engineering, Universiti Putra Malaysia
E-mail:abubakarms@gmail.com

MATERIALS AND METHODS

Study Area:

The field test was conducted at Sungai Burong, Tanjung Karang, Malaysia. The study area was a flat plain with a mean annual rainfall of about 1600 mm and a standard deviation of 75 mm. Climate is semi and subtropical continental with mean monthly temperature of 28ºC. The soil type in the study area is predominantly silty clay, belonging to the Selangor soil series (Vertic to Typic Dystropept) with mechanical analysis of 1.1% sand (2000-50 µm), 45.4% silt (2-50 µm), and 53.5% clay (< 2µm) (Bockari-Gevao *et al.,* 2004) as shown in Figure 1. The water field capacity was almost at saturation level and walking on such soil condition was very difficult. The dominant features of this site may be described as high water content and low bearing capacity soil that could easily be disturbed by vehicle movements.

Fig. 1: Experimental site

Data Collection:

A plot of 325 m x 45 m size was used for soil sample collection. The overall area was divided into five equal area blocks and each block was further divided into three equal sub-blocks. Soil moisture content, bulk density, soil cohesion, angle of internal friction and shear deformation modulus were obtained in the laboratory while soil bearing capacity and vane shearing strength were obtained in the field.

Soil Water Content and Bulk Density:

Undisturbed core soil samples were taken from the topsoil layer of 0-5 cm and subsoil layers of 5-15 cm, 15-25 cm and 25-35 cm depths at fifteen different locations in triplet replications using 216 cm^3 volume core samplers as shown in Figure 2. The samples were used to determine the water content and bulk density of the soil. Soil water content under field condition was obtained by drying the soil in an oven at 105ºC for 24 hrs. The water content of the soil sample was taken as percentage ratio difference between the mass of the wet sample and that of the oven-dried sample divided by the mass of the wet sample. Bulk density was computed as the ratio of the mass of the oven-dried sample to the volume of the wet sample taken from the field.

Soil Cohesion, Angle of Internal Friction and Shear Deformation Modulus:

A Wykeham Farrance International (WFi) SL1 4HW shear box laboratory apparatus was used to obtain cohesion, angle of internal friction and shear deformation modulus of the soil as shown in Figure 3. The soil samples taken at different points and depths in triple replicates were prepared in a rectangular box and subjected to a consolidation load of 1kg and 2kg and 3kg for 24 hours before the shear test. Then the shear box apparatus was set up to rotate at a shear rate of 0.025 cm/s and a maximum shear displacement of 1.2 cm. Readings on the shear displacement in cm and shearing stress in kN/m^2 were taken until failure occurred on the sample. The method adopted in this test was similar to the one reported by Ataur *et al,* (2004). This shear box laboratory test apparatus can measure shear strength of cohesive soil of even less than 0.3 kg/cm^2 which triaxial or unconfined tests cannot measure. From the relationship between normal stress and shearing stress and the interpretation of normal strength versus shearing strength of the soil samples at different depths, the cohesion and the angle of internal friction were calculated. Shear deformation modulus of the soil and pressure-sinkage characteristics were computed using the equations proposed by Wong *et al,* (2004).

Fig. 2: Soil sampling in the field

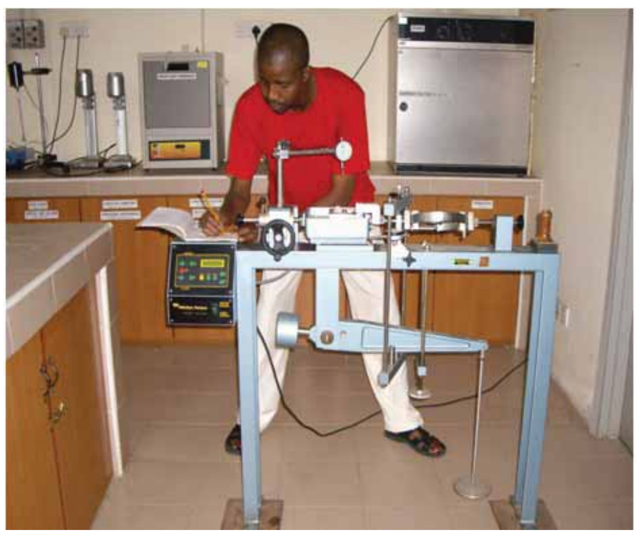

Fig. 3: Laboratory shearing strength test

$$K_w = -\frac{\sum\left(1-\frac{\tau_s}{\tau_{\max}}\right)^2 j^2}{\sum\left(1-\frac{\tau_s}{\tau_{\max}}\right)^2 j\left[\ln\left(1-\frac{\tau_s}{\tau_{\max}}\right)\right]} \tag{1}$$

Where K_w is the shear deformation modulus in cm, τ_{max} is maximum shearing stress in kg/cm^2, τ_s is the shear stress in kg/cm^2 and j is the shear displacement in cm.

***In-situ* Shearing Strength:**

A RMU 1012 digital vane field test apparatus which comprises a set of hollow rods for holding the vane blade, a twisting instrument on the upper end for twisting the rod set and a digital measuring gearbox powered by 12 V DC battery for measuring the twisting torque was used to compute the *in-situ* shearing stress of the paddy soil. The vane shear field apparatus was set up to rotate at a twisting torque ranging between 500 kg cm - 600 kg cm at an accuracy of 1 kg cm resolution. Three vane blades with diameters of 4.4 cm, 5.4 cm and 6.4 cm were used to determine the *in-situ* shear stress of the soil samples at different depths when the twisting instrument on the upper end for twisting the rod set was rotated at a speed of 12 °/s. Reading on the twisting torque was taken for every 8 s until its completes 360° revolution, then the maximum twisting torque to complete 360 ° revolution was also recorded. The method adopted in the test study was similar to the one reported by Ataur *et al.,* (2004).

Measured values were used to compute the *in-situ* shearing strength of the soil using the equation proposed by Wong *et al.,* (2004) below

$$\tau_s = \frac{3T}{2\pi r^2 (2r + 3H)} \quad (2)$$

Where τ_s is calculated shearing stress in kN/m^2, T is the torque in kg cm, r and H are the radius and the height of the shear vane in cm respectively.

Soil Bearing Capacity:

Soil bearing capacity is the capacity of soils to support trafficability. Bearing and traction capacities of soils are functions of their shearing resistances (Wong, 2001; Elwalee *et al.,* 2006). Shearing resistance is measured by the cone penetrometer or load sinkage plate and is expressed in terms of cone index (CI). The soil sinkage test considers the penetration of a plate in the soil at constant speed by means of a force application (Wong *et al.,* 1979). The experiment in this study was conducted using load sinkage plate test which is the approach widely used to provide information of bearing capacity of soils. The apparatus was set up to run at a proving ring constant of 0.2 kg/division which comprises a proof ring with a dial gauge for measuring the force, a shaft with a diameter of 1.59 cm and length of 45 cm for transferring load to sinkage plate for measuring the sinkage. The plate sinkage test was conducted by pushing manually the long shaft attached with two circular plates of different diameters 10 cm and 15 cm at different sinkage depths of 0-10 cm, 10-20 cm and 20-30 cm with an approximate speed of 2.5 cm/s into the soil. The soil penetration resistance was measured at nine different locations. Measurements of the vertical displacement (z) in cm of each plate and the pushing load (L) in kg applied to the plate were taken for every 2 cm plate sinkage from the area (A) of the plate in cm^2. The average contact pressure (p) in kg/cm^2 was determined from the equation below

$$p = \frac{L}{A} \quad (3)$$

RESULTS AND DISCUSSION

Paddy Soil Water Content and Bulk Density:

Table 1 shows the values of water content in soil at the different depths of 0-5 cm, 5-15 cm, 15-25 cm and 25-35 cm. It was observed that an increase in depth caused proportional increase in soil water content. Soil bulk density was found to increase with increasing in depths at different points. Mean values of paddy soil water content and bulk densities obtained were 47.08 %, 60.65 %, 79.78 %, 94.07 % and 9. 8 x 10^{-10} g/cm^3, 1.24 x 10^{-9} g/cm^3, 1.30 x 10^{-9} g/cm^3, 1.45 x 10^{-9} g/cm^3 at the depths of 0-5 cm, 5-15 cm, 15-25 cm and 25-35 cm respectively (Figures 4 and 5).

Soil Cohesion, Angle of Internal Friction and Shear Deformation Modulus:

Paddy soil cohesion, angle of internal friction and shear deformation modulus values at different depths are shown in Table 2. It was observed that the mean values of soil cohesion decreased from 6.22 kN/m^2 to 5.03 kN/m^2 to 3.15 kN/m^2 and to 1.40 kN/m^2. The angle of internal friction decreased from 30.73° to 27.87° to 18.22° and to 17.86° while mean values of shear deformation modulus increased from 1.20 cm to 1.33 cm to 1.40 cm and to 1.73 cm with increasing depths of 0-5 cm, 5-15 cm, 15-25 cm and 25-35 cm respectively.

Shearing Strength:

Laboratory shearing strength values of the paddy soil at different depths are presented in Table 3. It was found that the mean values of soil shearing strength of paddy soil increased from 8.10 kN/m^2 to 9.42 kN/m^2 and 8.10 kN/m^2 to 14.70 kN/m^2 at the depth of 0-5 cm, 10.66 kN/m^2 to 12.18 kN/m^2 and 10.66 kN/m^2 to

16.69 kN/m^2 at the depth of 5-15 cm, 11.41 kN/m^2 to13.82 kN/m^2 and 11.41 kN/m^2 to 19.59 kN/m^2 at the depth of 15-25 cm, and then 9.52 kN/m^2 to 11.89kN/m^2 and 9.52 kN/m^2 to 15.97 kN/m^2 at the depth of 25-35 cm when the normal stress increased from 2.50 kN/m^2 to 5.35 kN/m^2 and 2.50 kN/m^2 to 6.75 kN/m^2 respectively. From the result of analysis of variance ANOVA between the mean effects of normal stress and shearing stress on depth, it was found that there was a highly significant relationship between the normal stress and shearing strength when interacted at different depths at 95% confidence level. This finding agrees with that of Ataur *et al.,* (2004); Wong *et al.,* (1982); Mark *et al.,* (1993). However it was also observed that shear strength of the paddy soil decreases with increasing soil water content (Table 3). Shearing strength decreased from 19.59 kN/m^2 to 15.97 kN/m^2 at the depth of 15-25 cm to 25-35 cm respectively when the normal stress was 6.75 kN/m^2 at each depth.

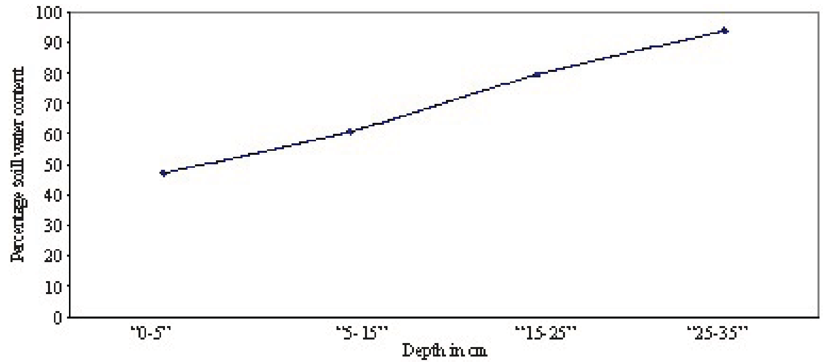

Fig. 4: Mean values of soil water contents at different depths

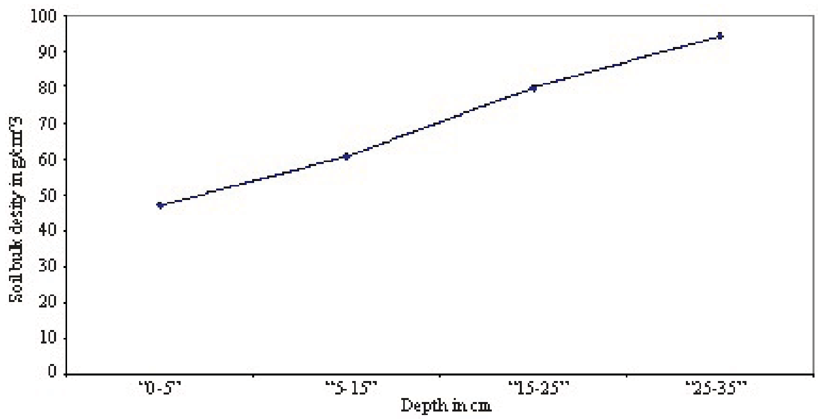

Fig. 5: Mean values of soil bulk densities at different depths

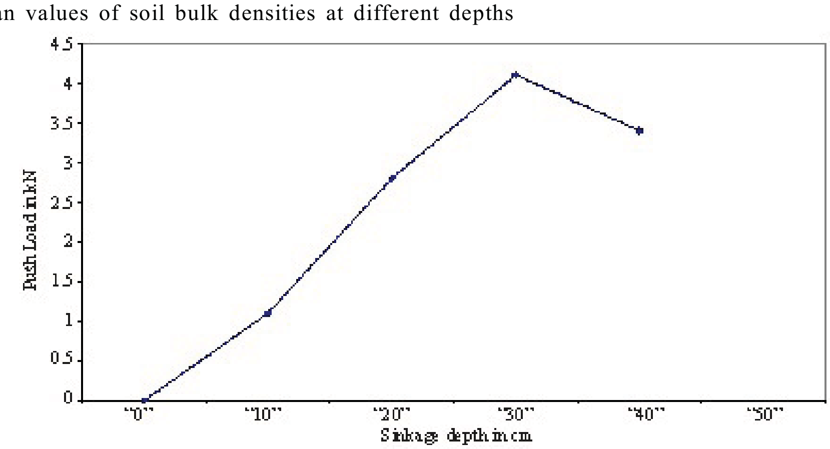

Fig. 6: Paddy field load-sinkage pattern

In-situ Shearing Strength:

Table 4 presents the mean values of paddy field *in-situ* shearing strength at different depths mentioned above. It was found that the in-situ shearing strength of the paddy soil dropped from 3.32 kN/m^2 to 2.16 kN/m^2 to 1.74 kN/m^2 and to 1.59 kN/m^2 as the depths increased from 0-5 cm, 5-15 cm, 15-25 cm and 25-35 cm respectively. It was also observed that the *in-situ* shearing strength decreased with increasing vane blade size. ANOVA test for the variance of mean effects of depth and blade size on paddy soil *in-situ* shearing strength shows highly significant relationships at 0.05 level of significance. This agrees with the findings of Ataur *et al.,* (2004); Wong *et al.,* (1982).

Soil Bearing Capacity:

A with The result of paddy field bearing capacity is shown in Table 5. Based on the load-sinkage test result, it was observed that the plate sinkage increased with increasing pushing load. Table 5 shows that increase in plate size resulted in an increase in sinkage. Similar results were reported by Benoit and Gotteland, (2004); Gotteland and Benoit, (2006). Statistical analysis proves the significant relationship between depths, push load and plate size, at 0.05 level of significance. Plate sinkage increased with depth, push load and plate size. Figure 6 shows the pattern of paddy field load-sinkage at different depths.

Conclusions:

The experimental results of both laboratory and field tests show that the mean values of paddy soil water content and bulk densities obtained were 47.08 %, 60.65 %, 79.78 %, 94.07 % and 9. 8 x 10^{-10} g/cm^3, 1.24 x 10^{-9} g/cm^3, 1.30 x 10^{-9} g/cm^3, 1.45 x 10^{-9} g/cm^3 at the depths of 0-5 cm, 5-15 cm, 15-25 cm and 25-35 cm respectively. Mean values of soil cohesion, angle of internal friction and shear deformation modulus were found to be 6.22 kN/m^2, 5.03 kN/m^2, 3.15 kN/m^2, 1.40kN/m^2 and 30.73°, 27.87°, 18.22°, 17.86° at the depths of 0-5 cm, 5-15 cm, 15-25 cm and 25-35 cm respectively. It was found that the *in-situ* shearing strength of the paddy soil dropped from 3.32 kN/m^2 to 2.16 kN/m^2 to 1.74 kN/m^2 and to 1.59 kN/m^2 as the depths increased from 0-5 cm, 5-15 cm, 15-25 cm and 25-35 cm respectively. This shows that vane blade size and depth had significant effect on the *in-situ* shearing strength. It was observed that the plate sinkage in the paddy field increased with increasing pushing load.

Table 1: Paddy soil water content at different depths

Depth, D (cm)	Soil water content, θ (%) of the field experimental treatment														
	B1	B2	B3	B4	B5	B6	B7	B8	B89	B10	B11	B12	B13	B14	B15
0-5	47.50	46.25	48.15	48.05	47.28	46.80	49.25	47.20	46.55	48.12	47.80	46.25	45.90	47.12	49.15
	47.12	45.55	46.50	47.20	47.15	46.20	48.50	46.50	47.15	46.80	47.50	47.55	47.80	46.25	46.20
	46.50	47.00	46.25	46.50	46.35	47.00	47.15	46.80	48.00	47.15	46.50	47.00	46.80	47.15	47.15
Mean	**47.04**	**46.27**	**46.97**	**47.25**	**46.93**	**46.67**	**48.30**	**46.83**	**47.23**	**47.36**	**47.27**	**46.93**	**46.83**	**46.84**	**47.50**
5-15	62.35	60.25	60.15	62.50	60.80	62.00	62.50	61.50	61.55	62.25	60.80	62.15	62.35	60.50	61.45
	60.50	58.50	62.50	60.50	60.15	61.50	60.25	59.50	61.15	60.50	58.90	61.20	61.50	58.65	60.15
	60.45	60.90	59.90	61.15	59.80	59.20	58.80	60.15	60.10	59.40	60.35	59.10	58.90	61.25	60.50
Mean	**61.10**	**59.88**	**60.85**	**61.38**	**60.25**	**60.90**	**60.52**	**60.38**	**60.93**	**60.72**	**60.02**	**61.08**	**60.92**	**60.13**	**60.70**
15-25	80.25	78.10	79.20	81.15	80.50	79.80	78.50	78.15	80.15	81.50	80.00	81.10	78.90	78.15	79.00
	80.15	79.15	79.00	80.50	79.90	79.15	80.25	79.80	78.50	80.15	80.25	80.45	79.55	80.15	79.55
	80.05	80.15	80.05	79.90	78.80	80.25	81.20	81.50	80.50	78.90	78.80	79.45	80.00	79.90	79.80
Mean	**80.15**	**79.13**	**79.42**	**80.52**	**79.73**	**79.73**	**79.98**	**79.82**	**79.72**	**80.18**	**79.68**	**80.33**	**79.48**	**79.40**	**79.45**
25-35	92.34	95.70	94.60	95.50	96.15	93.80	95.25	92.90	94.45	93.80	94.50	95.15	93.50	93.55	95.60
	92.50	93.50	93.80	94.45	94.25	92.40	94.15	93.45	92.50	93.15	93.45	92.90	92.25	93.45	94.50
	92.45	92.50	94.15	93.45	93.50	94.50	92.90	92.55	93.25	93.50	94.25	94.00	93.45	92.80	93.45
Mean	**92.43**	**93.90**	**94.18**	**94.47**	**94.62**	**93.57**	**94.10**	**92.96**	**93.40**	**93.48**	**94.07**	**94.02**	**93.07**	**93.27**	**94.52**

Key: B1 - B15 = field experimental treatments

Table 2: Soil cohesion, soil angle of internal friction and shear modulus at different depths

Depth, D (cm)	B1		B2		B3		B4		B5		B6		B7		B8		B9		
	c (kN/m2)	φ (°)	c (kN/m2)	φ (°)	c (kN/m2)	φ (°)	c (kN/m2)	φ(°)	c (kN/m2)	φ (°)	c (kN/m2)	φ (°)	c (kN/m2)	φ (°)	c (kN/m2)	φ (°)	c (kN/m2)	φ (°)	kw (cm)
0-5	6.35	30.15	6.15	30.24	6.10	30.10	7.10	30.25	6.50	30.20	6.15	30.10	6.20	30.15	6.20	29.80	6.05	30.35	1.20
	6.15	39.50	6.40	30.45	6.25	29.85	6.05	29.65	6.10	30.25	6.15	30.20	6.45	39.65	6.15	30.10	6.25	30.25	1.25
	6.25	30.25	6.05	29.50	6.40	30.15	6.25	29.55	6.00	29.65	6.25	29.85	6.15	29.55	6.05	30.20	5.90	29.85	1.15
Mean	**6.25**	**33.3**	**6.20**	**30.06**	**6.25**	**30.03**	**6.47**	**29.82**	**6.20**	**30.03**	**6.18**	**30.05**	**6.27**	**33.12**	**6.13**	**30.03**	**6.07**	**30.15**	**1.20**
5-15	5.15	28.50	4.90	27.50	4.85	26.25	5.45	29.15	4.85	28.35	4.55	28.50	5.20	28.50	5.25	27.35	5.05	28.20	1.35
	5.05	27.25	5.15	27.25	5.10	28.10	5.15	28.25	4.90	28.10	4.95	29.25	5.15	28.35	4.80	27.50	5.25	28.35	1.30
	5.10	27.40	4.45	27.15	5.05	27.05	5.35	27.30	5.00	28.50	5.15	27.25	4.95	27.90	4.95	28.15	5.15	27.15	1.35
Mean	**5.10**	**27.72**	**4.83**	**27.30**	**5.00**	**27.13**	**5.32**	**28.23**	**4.92**	**28.32**	**4.88**	**28.33**	**5.10**	**28.25**	**5.00**	**27.67**	**5.15**	**27.90**	**1.33**
15-25	3.50	18.50	3.65	19.15	3.20	18.00	3.15	18.20	3.45	18.10	3.10	18.25	3.15	18.00	3.20	17.95	2.85	18.10	1.35
	3.25	17.50	3.45	18.25	2.95	18.40	3.45	18.25	3.25	18.25	3.35	17.85	2.85	18.65	3.05	18.40	3.20	18.25	1.40
	3.20	19.05	2.90	18.15	2.80	18.20	2.65	17.90	3.02	18.30	3.20	17.95	2.90	18.45	3.25	18.55	3.15	17.20	1.45

Tablr 2: Continue

Mean	**3.32**	**18.35**	**3.33**	**18.52**	**2.98**	**18.20**	**3.08**	**18.12**	**3.24**	**18.22**	**3.22**	**18.02**	**2.97**	**18.37**	**3.12**	**18.30**	**3.07**	**17.85**	**1.75**
25-35	1.55	17.85	1.40	18.15	1.35	18.00	1.35	18.65	1.30	18.15	1.40	18.10	1.40	18.10	1.55	18.20	1.40	17.65	1.40
	1.45	17.90	1.35	17.65	1.90	17.90	1.40	17.85	1.45	17.35	1.25	17.25	1.25	17.90	1.25	17.90	1.25	17.85	1.80
	1.40	17.35	1.55	17.85	1.40	18.25	1.55	17.45	1.30	17.90	1.35	17.85	1.45	17.65	1.35	17.50	1.30	18.05	1.65
Mean	**1.47**	**17.70**	**1.43**	**17.88**	**1.55**	**18.05**	**1.43**	**17.98**	**1.35**	**17.80**	**1.33**	**17.73**	**1.37**	**17.88**	**1.38**	**17.87**	**1.32**	**17.85**	**1.73**

Key: B1 - B9 = field experimental treatments, c = soil cohesion ? = soil angle of internal friction, kw = shear deformation modulus

Table 3: Soil shearing strength from laboratory test at different depths

Depth, D (cm)	Normal stress, τ_n (kN/m$_2$)	Shearing strength, τ_s (kN/m$_2$)									
		B1	B2	B3	B4	B5	B6	B7	B8	B9	Mean
0-5	2.50	8.25	8.60	8.15	7.85	7.55	8.05	8.25	8.05	8.15	8.10
	5.35	9.95	10.15	8.90	8.75	8.45	10.90	9.20	9.15	9.35	9.42
	6.75	13.25	14.90	15.15	14.15	13.35	15.55	13.95	16.35	15.65	14.70
5-15	2.50	10.15	10.35	10.45	10.65	11.45	10.35	11.20	10.15	11.20	10.66
	5.35	11.55	11.15	12.05	11.50	13.15	12.55	12.20	12.35	13.15	12.18
	6.75	14.85	16.90	17.20	16.20	17.45	16.30	17.15	16.85	17.35	16.69
15-25	2.50	10.75	11.10	11.65	12.05	11.55	10.90	11.60	11.05	12.05	11.41
	5.35	12.35	13.50	14.50	14.25	13.65	12.25	15.45	13.15	15.25	13.82
	6.75	20.15	18.35	21.35	19.40	18.50	19.50	19.25	18.30	21.50	19.59
25-35	2.50	9.05	9.50	9.25	9.65	9.40	9.20	10.05	9.65	9.90	9.52
	5.35	11.20	11.90	11.55	10.90	10.65	11.35	11.15	10.75	11.25	11.89
	6.75	15.90	16.55	15.45	16.20	14.90	15.70	15.55	16.35	17.15	15.97

Table 4: Paddy field in-situ shearing stress at different depths

Depth, D (cm)	Vane blade size, d (cm)	Shearing strength, τ_s (kN/m2)									
		B1	B2	B3	B4	B5	B6	B7	B8	B9	Mean
0-5	d = 4.4	3.50	3.45	3.05	3.45	3.25	3.90	2.85	3.15	3.25	3.32
	d = 5.4	3.10	3.05	2.90	3.00	2.85	3.05	2.15	2.90	2.90	2.88
	d = 6.4	2.90	2.75	2.35	2.55	2.35	2.65	1.90	2.05	2.10	2.40
5-15	d = 4.4	2.15	2.20	2.05	2.15	2.25	2.15	2.20	2.25	2.05	2.16
	d = 5.4	1.90	1.85	1.90	2.00	1.85	1.80	1.85	1.75	1.90	1.87
	d = 6.4	1.25	1.45	1.65	1.85	1.70	1.65	1.35	1.40	1.55	1.54
15-25	d = 4.4	1.85	1.70	1.85	1.75	1.70	1.60	1.80	1.75	1.65	1.74
	d = 5.4	1.75	1.55	1.60	1.50	1.35	1.25	1.45	1.55	1.35	1.48
	d = 6.4	1.35	1.30	1.45	1.35	1.20	1.15	1.25	1.30	1.15	1.28
25-35	d = 4.4	1.45	1.65	1.50	1.40	1.55	1.70	1.55	1.85	1.65	1.59
	d = 5.4	1.30	1.50	1.80	1.25	1.30	1.55	1.35	1.50	1.25	1.42
	d = 6.4	1.60	1.55	1.65	1.35	1.20	1.30	1.40	1.25	1.30	1.40

Table 5: Paddy field soil bearing capacity

Sinkage (cm)	Plate diameter (cm)	Pressure applied (kg/cm2)									
		B1	B2	B3	B4	B5	B6	B7	B8	B9	Mean
0-10	10	1.2	1.3	1.2	1.2	1.3	1.2	1.3	1.3	1.2	1.1
	15	1.8	1.7	1.7	1.6	1.8	1.8	1.7	1.6	1.8	1.7
10-20	10	2.2	2.2	2.1	2.2	2.2	2.1	2.1	2.2	2.2	2.2
	15	3.1	3.3	3.2	3.1	3.1	3.1	3.0	3.2	3.1	3.1
20-30	10	4.2	4.1	4.1	4.2	4.1	4.2	4.2	4.1	4.3	4.2
	15	5.3	5.2	5.2	5.1	5.3	5.2	5.3	5.1	5.2	5.2

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