THE CLAY CONTENT EFFECT ON THE SOIL DEFORMATION IN THE FORMATION OF SHALLOW MOLE DRAINAGE

Siti Suharyatun[1)]

[1)]Agricultural Engineering Departement,Faculty of Agriculture, Lampung University,
Jl Sumantri Brononegoro no. 1, Bandar Lampung, Indonesian
Email: sitisuharyatun149@gmail.com

ABSTRACT

Clay content is one of the parameters which affect the physical and mechanical properties of soil. In the formation of shallow mole drainage, the clay content will affect the mole, especially on soil deformation due to the tillage force. This study aimed to explore the effect of clay content on soil deformation in the mole drainage formation. The following parameters were used in approaching the soil deformation namely, the mole's hole area (A_l), the leg slot (C_l), the disturbed soil area (T_p), the surface area of soil fracture (A_p) and cracks in the leg slot wall (P_r). The results showed that the width of the mole's hole area (A_l) in the soil with clay content of 13.12% (T_A), 41.17% (T_B) and 53.63% (T_C) were almost the same. They were T_A = 7.03 cm^2, T_B = 6.98 cm^2 and T_C = 6.95 cm^2. The width of mole's hole area T_A = 0.31 cm, T_B = 0.35 cm and T_C = 0.88 cm. The clay content influenced the disturbed surface area (T_p) and the surface area of soil fracture (A_p). The larger the clay content the soil had, the greater its A_p and T_p. The measurements showed that T_C soil (0.0570 cm^2/cm^2) had larger T_p than that of T_B soil (0.0283 cm^2/cm^2). The disturb surface area of T_B soil was larger than that of T_A (0.0087 cm^2/cm^2). The surface area of soil fracture of T_C soil (32.2806 cm^2) was larger than that of T_B (24,3467 cm^2). The surface area of soil fracture of T_B soil was larger than that of T_A (13.8000 cm^2). The crack length of leg slot wall of each type of soil were subsequently T_A = 0,5001 cm/cm^2, T_B = 0,3523 cm/cm^2 and T_C = 0,4141 cm/cm^2.

***Keywords*:** clay content, soil deformation, mole drainage**.**

INTRODUCTION

Mole drainage is mainly purposed to remove excess water from the surface of the land or from the layers which formerly formed a perched water table. Water flows into the mole drainage through the cracks formed during the making of the mole. Mole drainage is also used in areas with soil moisture content and paddy soil (Soong and Wei, 1985).

Application of mole drainage at paddy soil is purposed to increase the rate of lowering soil moisture of top soil so that the soil condition is suitable for the early growth of non-rice crops. In paddy soil for cultivating non-rice crops, the mole drainage is installed above hardpan layer, with puddle soil structure. The hardpan layer is at a depth of 20-40 cm and the mole should be made at relatively shallow distances (Sharma et.al.: 1986). This application of mole drainage at relatively shallow distances is in contrast to the mole drainage uses which used to be made deep enough, more than 60 cm in depth (Rozaq, 1993).

Some researchers have conducted researches on shallow mole drainage for paddy fields. Among others are Rozaq (1992), Rozaq et al (1993), Purwantana (1993, 1994), and Kusnadi (2008). The following are some important findings of their researches, namely; 1) the success of mole drainage application in various soil types was influenced by moisture content and soil volume. Clay content and moisture content affected the quality and stability of the mole (Rozaq, 1992); 2) soil with clay content of 20% up to 50% was a fairly good condition for the application of mole drainage (Kusnadi, 2008); 3) the making of mole drainage was ineffective both in the soil with clay content of more than 60% and less than 15%. It is because the excessive narrowing slag lot happened in the soil with clay content of more than 60% and the excessive fracture happened in the soil with clay content of less than 15%. The excessive fracture may cause the mole drainage unable to perform optimally (Purwantana 1993). Further research should be conducted since none of the researchers above has studied the clay content effect on the soil deformation in the formation of shallow mole drainage.

This study aimed to examine the effect of clay content on soil deformation occurring in the formation of shallow mole drainage. The deformation of the soil was approached by observing some parameters such as the width of mole's hole area (A_1), the leg slot (C_1), the disturbed soil area (T_p), the surface area of soil fracture (A_p) and cracks in the slot wall (P_r).

METHODOLOGY

The study is a physical-based model that is conducted in laboratory by using mole plow of soil bin. The physical-based model of mole plow used in this study was 19 cm in length, its cutter was 1.5 cm, its expander was 3 cm, and its slope of cutting angle was 30^0. The soil was put in a box with dimensions of size 70 cm x 50 cm x 40 cm (p x l x t), and maintained homogeneous. The box filled with soil up to the height of about 3 cm below the surface of the box. The mole drainage was put right in the middle of the box at a depth of 20 cm from the soil surface.

The soil used in the research were T_A soil with clay content 13.12%, T_B soil with clay content 41.17%, and T_C soil with clay content 53.63%. The soil texture used in the study is presented in Table 1.

Table 1. Soil texture

Soil	Soil fraction percentage (%)			Soil texture
	clay	Silt	sand	
T_A	13.12	36.24	50.61	loam
T_B	41.17	28.85	29.97	clay
T_C	53.63	24.16	22.21	clay

The parameters measured in this study were: (1) the mole's hole area (A_1), measured by using a planimeter on its picture which had been taken using digital camera (Figure 1a); (2) the leg slot width (C_1), measured by using a caliper on its picture which had been taken using digital camera, (Figure 1 (a)); (3) the disturbed soil area (T_p), measured by using a planimeter on its top-view picture of the mole drainage (Figure 1 (b)); (4) surface area of soil fracture (A_p), measured at the end of the tillage, see (Figure 1 (c)) and (5) cracks in the leg slot wall (P_r), the length of cracks was measured per unit area (P_r, cm / cm2) (Figure 1 (d)).

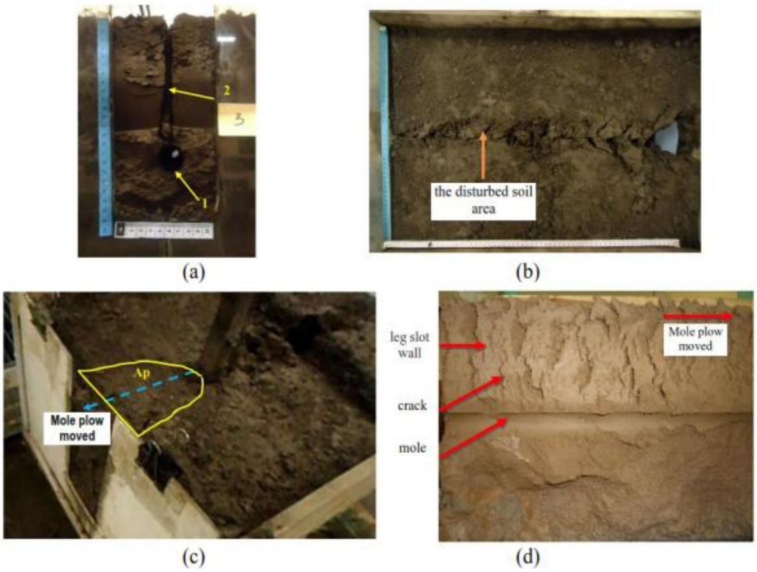

Figure 1: (a) mole drainage formed: 1 mole's hole area (A_l), 2 leg slot (C_l); (b) the disturbed soil area (T_p); (c) the surface area of soil fracture (A_p); (d) cracks in the leg slot wall (P_r).

RESULTS AND DISCUSSION

The force acting on the soil can cause deformation and soil movement or both of them. The tillage force upon the formation of mole drainage causes the deformation of the soil in the form of the mole wall compaction, cracks and fractures around the mole.

The results of geometrically measured mole drainage showed that the mole's hole area (A_l) of the three soil types was the same, but the size of the leg slot (C_l) was not. The mole's hole area of the three soil types was almost the same as the expander area (7,065 cm2). Mole's hole area of T_A soil was 7.03 cm^2, T_B soil was 6.98 cm^2 and T_C soil was 6.95 cm^2 (Table 2). Variance analysis of the effect of soil type on the mole's hole area showed that its treatment difference was said to be non significant at 5% level (Table 3).

Table 2. Mole's hole area (A_l), and leg slot (C_l)

Soil	A_l (cm^2)	C_l (cm)
T_A	7,03	0,33
T_B	6,98	0,35
T_C	6,95	0,88

Table 3. Analysis of variance of time and soil type effect on the mole's hole area

Source of variation	Degree of freedom	Some of square	Mean square	$F_{computed}$	$F_{tabulated}$

					5%	1%
Time	14	0,8676	0,0620	1,3398	2,58	4,79
Soil	2	0,1342	0,0671	1,4504	1,76	2,2
Exp. Error	140	6,4752	0,0463			
Total	156	7,4770				

$F_{tabular} < F_{computed}$: nonsignificant at 5% level

Leg slot of the three types of soil was not the same. The leg slot formed on T_A and T_B soils approached the thickness of the leg of mole plow (0.3 cm) i.e. the leg slot of T_A soil was 0.33 cm and T_B soil was 0.35 cm (Table 2). The leg slot formed on T_C soil was 0.88 cm. It was bigger than the leg slot of T_A and T_B soil and almost three times bigger than the mole plow's leg because there was soil fault around the leg slot.(Figure 2 (c)). The variance analysis also stated that the leg slot of those three different soil types was very significant at 1% level (Table 3). The leg slot of T_A soil was not different from T_B soil leg slot at 5% level, but the leg slot of T_C soil was very different from T_A and T_B soil leg slot at 1% level (the least significant difference test / LSD test, Table 4).

Table 4. Variance Analysis of time and soil type effect on leg slot

Source of variation	Degree of freedom	Some of square	Mean square	$F_{computed}$	$F_{tabulated}$	
					5%	1%
Time	14	0,1024	0,0073	0,1088	2,58	4,79
Soil	2	14,7578	7,3789	109,71**)	1,76	2,2
Experiment error	140	9,4157	0,0673			
Total	156	24,3759				

Note: **) significant at 1 % level

Table 5. Test of BNT (LSD Test) soil type effect on leg slot

Soil	Leg slot	BNT 0.5% = 0.0928	BNT 0.1% = 0.1219
T_A	0,3286	a	a
T_B	0,3486	a	a
T_C	0,8835	b	b

Note: **) significant at 1% level

(a) (b) (c)

Figure 2. The leg slot formed in soil T_A (a), T_B (b) and T_C (c).

The soil with different clay content would give different soil reaction forces on the formation of mole drainage. Visually, seen from the soil surface, soil deformation in the form of soil surface disturbance around the leg slot showed the differences among T_A, T_B and T_C soils (Figure 3). The disturbance of T_A surface soil was smoother than that of T_B and T_C soil. On the T_B and T_C soil, the left and right side of the leg slot formed small clumps of earth. The area measurement of the disturbance of soil surface per unit area (T_p) showed that T_C's soil surface disturbance level (0.0570 cm^2/cm^2) was bigger than which of T_B soil (0,0283 cm^2/cm^2), the disturbance area of T_B's soil surface was bigger than which of soil T_A (0.0087 cm^2/cm^2) (Table 5).

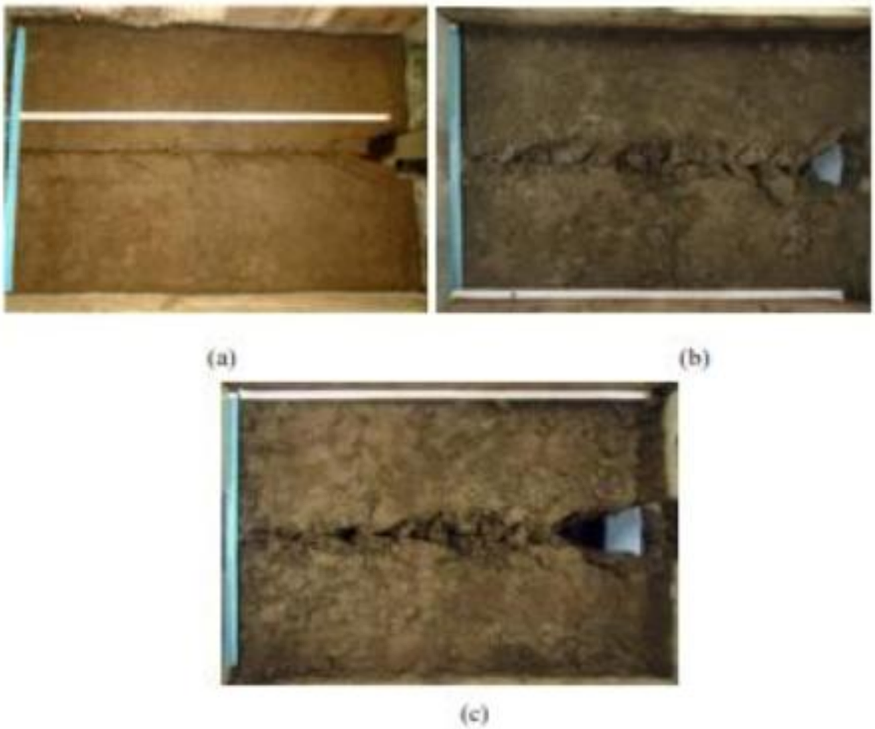

Figure 3. Up view of mole drainage in soil TA (a), TB (b), and (c) TC

Table 5. Disturbed soil area (T_p), surface area of soil fracture (A_p), and cracks in the leg slot wall (P_r).

Soil	T_p (cm^2/cm^2)	A_p (cm^2)	P_r (cm/cm^2)
T_A	0,0087	13,8000	0,5001
T_B	0,0283	24,3467	0,3523
T_C	0,0570	32,2806	0,4147

Based on volume of the soil fracture, the deformation in T_C soil was larger than T_B soil, T_B soil' deformation was larger than T_A soil's deformation. Visually observed, the volume of soil fracture at the end of T_C's soil tillage was larger than T_B soil, the volume of soil transferred by T_B soil was larger than T_A soil, as shown in Figure 4.

Quantitatively the measured surface area of soil fracture volume (A_p) also showed that the surface area of fracture volume of T_C soil (32,2806 cm^2) was larger than T_B soil (24,3467 cm^2), the surface area of fracture volume of T_B soil was larger than T_A soil (13.8000 cm^2) (Table 5).

Figure 4. Soil fracture: (a) soil T_A, (b) soil T_B and (c) soil T_C.

CONCLUSION

1. The shallow mole drainage installed in paddy fields with low clay content (T_A soil, 13.12%), and with high clay content (T_B soil, 41.17% and T_C 53.63%) would have mole channel as wide as the diameter of the mole plow.
2. The higher the clay content the soil had, the greater the soil deformation would be, which was expressed in the level of soil disturbance (T_p) and the surface area of soil fracture volume (A_p) on the mole. T_p of T_A soil = 0.0087 cm^2/cm^2, T_B soil = 0,0283 cm^2/cm^2, T_C soil = 0,057 cm^2/cm^2. A_p of T_A soil = 13.8000 cm^2, T_B soil = 24,3467 cm^2, T_C soil = 32.2806 cm^2.
3. The intensity of the soil cracks on the mole (P_r) on loam soil tended to be larger than the cracks in the clay soil. P_r of T_A soil = 0,5001 cm^2/cm^2, T_B soil = 0.3523 cm^2/ cm2, T_C soil = 0.4147 cm^2/cm^2.

REFERENCES

1. Bennet, D., Richard, G. and Bill, R. (2004). *Mole drainage for increased productivity in the South West Irrigation Area*. State University of Western Australia.

2. Bowler D.G. (1980). *The drainage of wet soils*. Hodder and Stougton. Auckland, New Zealand.

3. Christen, E.W. and Spoor, G. (1999). Improving controlling irrigation water flow to mole drains. *Journals of Irrigation and Drainage Engineering* **125**: 59-63.

4. Gill. W. R. and Berg G.E.V. (1968). Soil Dynamics in Tillage and Traction. Agricultural Hand Book. United States Department Agricultural.

5. Godwin, R.J., Spoor, G., Leeds-Harrison, P. (1981). An experimental investigation into the force mechanics and resulting soil disturbance of mole plough. *Journal of Agricultural Engineering Research*. **26:** 477- 497

6. Hopkins. (2002). Installation of mole drainage by mole plow with floating beam. http://www.tgdrains.com.au/page5.htm [2 Oktober 2014]

7. Kumar M.J. and Koga Kiyoshi. 1995. Mole drainage: Prospective drainage solution to Bangkok clay soils. *Journals of Agricultural Water Management* **28**: 253-270.

8. Kusnadi, K. D. (2010). *Teknik Drainase Bawah Permukaan*. Graha Ilmu. Yogyakarta.

9. Leeds-Harrison P., Spoor, G. and Godwin, R.J. (1982). Water flow to mole drain. *Journal of Agricultural Engineering Research* **27**:81-91

10. Muller, L. (1988). Efficiency of subsoiling and subsurface drainage in heavy alluvial soils of the GDR. *Journal of Soil and Tillage Research.* **12**: 121-134

11. Purwantana, B. (1993). Rancang bangun kaki bajak lorong dan pengaruhnya terhadap laju pengatusan lengas tanah. Research Institute. Universitas Gadjah Mada. Yogyakarta.

12. Purwantana, B. (1994). Pengaruh kandungan lempung terhadap stabilitas lorong pengatus air tanah. *Research Institute*. Universitas Gadjah Mada. Yogyakarta.

13. Rozaq, A. (1992). Identifikasi pola patahan tanah pada pembuatan lorong pengatus air tanah di lahan sawah. *Research Institute*. Universitas Gadjah Mada. Yogyakarta.

14. Rozaq, A., Handoyo, R., Purwantana, B. (1993). Rancang bangun alat pengatus air tanah untuk mempercepat penanaman palawija di lahan sawah. *Research Institute*. Universitas Gadjah Mada. Yogyakarta.

15. Sharma, P.K. and De Datta, S.K. 1986. Physical Properties and Process of Puddled Rice Soil. *Journal of Soil Science*. **5**: 139-178.

16. Song, Si Fu and Zhang Wei. 1985. Subsurface drainage in lowland rice field in china. In *soil physics and rice*. IRRI. Los Banos. 351-366.

17. Spoor, G. Leed-Harrison, P.B., and Godwin, R.J. (1982). Potential role of soil density and clay mineralogy in assessing the suitability of soils for mole drainage. *Journal of Soil Science.* **33**. 427-441.