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Deep Tillage Plough down to 600 mm for Improvement of Salt-affected Soils*

-Part 2: Draught and Vertical Force Induced on Plough by Brittle Fracture-

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Abstract

A method is proposed for soil improvement of salt-affected soils. Large soil clods are produced in subsoil by deep tillage to cut off capillarity from groundwater and to prevent the rise of salts to the soil surface. In this paper, the draught and vertical force induced on this plough body by brittle fracture (not by shear failure) was analysed to get the large soil clods in an indoor soil bin with a soil with cement. The results showed that the normal mean peak draught was about 1 kN, and the downward vertical peak force was about 10 kN at 200 mm in the operating depth. When the blade length was short (50 mm or 80 mm) and huge soil clods were produced, the peak draught and vertical force increased to about 2 kN and 20 kN respectively. When the blade length was long (200 and 250 mm) and the operating depth was deep (150 and 200 mm), the peak draught increased abnormally to 4-5 kN. The peak vertical force also increased abnormally to 30-40 kN. The proper length of the plough blade was determined to be 130 mm because of the smallest draught and downward vertical force.

[Keywords] salt-affected soils (solonchak and solonetz), soil improvement, subsoil, large soil clods, draught, vertical force

I Introduction

Salt-affected soils are formed in arid areas in the world. In the previous paper (Guo *et al*., 2006), a method of soil improvement was discussed for salt-affected soils with sufficient rainfall to percolate into subsoil in summer; a coarse layer was provided below the subsoil (B horizon). It was demonstrated that the capillary water from groundwater could be cut off at the coarse layer, thus preventing the rise of dissolved salts to the soil surface. The salts normally accumulating in the topsoil (Ap horizon) are leached out by every rainfall, which then makes pH values to decrease.

In order to cut the capillarity, deep ploughing has been previously performed. However, such ploughing was performed by a back-hoe (Cairns, 1962) or a single mouldboard plough (Bowser & Cairns, 1967), and so every soil horizon was evenly mixed. The Ap horizon contains a

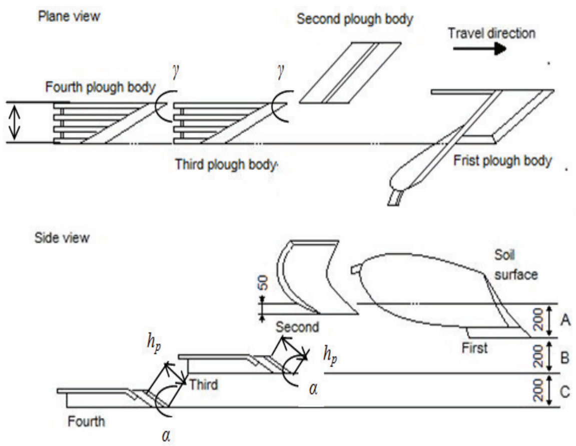

Fig. 1 Schematic diagram of plough bodies of a four-stage subsoil plough for improvement of salt-affected soils. The third and fourth plough bodies are identical. A, B and C are soil horizons (Araya *et al*., 2012).

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fair amount of organic matter and is fertile, so it should not be mixed into the lower infertile horizons (Guo *et al*., 2002). Antipov & Pak (1965) and Cairns (1976) also reported that the Ap horizon should be retained on the surface during ploughing.

We developed a four-stage subsoil plough (Fig. 1, Araya *et al*., 1996a; 1996b; 1996c; Guo *et al*., 2002), which tilles the layers down to 600 mm (to the C horizon) and retains the topsoil (Ap horizon).

The purpose of tillage is generally for preparation of seedbeds, and an aggregate clod size range of 1-5 mm is required (Ojeniyi & Dexter, 1979). For this purpose, shearing failure in soil should be induced by tillage tools to cause soil to crumble into small pieces. However, tensile failure (brittle fracture) should take place here in the soil to obtain the desired soil clods of 100-140 mm (Araya *et al*., 2010). The size of clods produced by brittle fracture is much larger than those by shear failure, and there is negligible deformation in the soil clods (Aluko & Seig, 2000). For this purpose, in preceding paper (Araya *et al*., 2012), the configuration of the third or fourth plough body in Fig. 1 (rake angle, length of plough blade, and operating depth) to induce brittle fracture and to produce soil clods was analysed.

In this paper, the draught and vertical force induced on this plough body when the soil is broken by the brittle fracture (tensile failure) is analysed.

The salt-affected soils in this study are located in dry areas and are generally dry except in rainy seasons, and the measured soil water content of the subsoil is generally about 10% d.b. [dry base, =100 g kg^{-1}(dry soil)], which is much less than the plastic limit, so soil tends to cohere (Sun *et al*., 2007; Zhu *et al*., 2007).

II Materials and Methods

1. Soils in this study

The test site was in Japan. The previous paper (Guo *et al*., 2004) reported that the subsoils of salt-affected soils

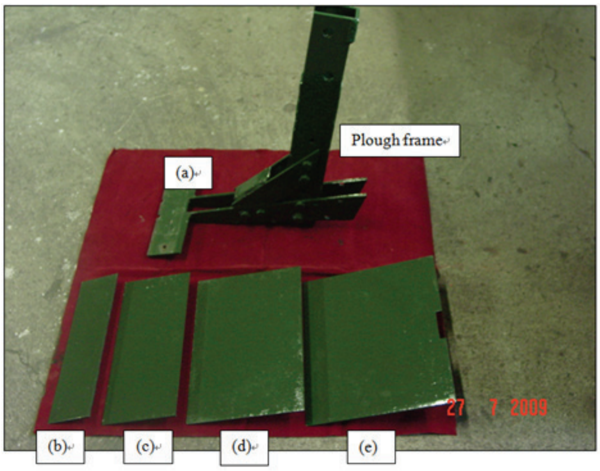

Fig. 2 Model blades of deep tillage plough (plough shares). (a) Blade length h_p=50 mm; (b) h_p=80 mm; (c) h_p=130 mm; (d) h_p=200 mm; (e) h_p=250 mm; rake angle α can be adjusted by the plough frame (Araya *et al*., 2011).

[saline soil (slonchak) and sodic soil (solonetz)] are heavy clay soil, and the distribution of their soil particle-size is similar to that of Japanese pseudogley soil (Table 1), which is a typical Japanese clay and is not a salt-affected soil but an acidic soil (pH 5.9). Therefore, the pseudogley soil was used in this study because it could be easily prepared in large amounts at the test site.

The soil water content of the pseudogley soil was initially adjusted to about 100% d.b., and Portland cement was mixed at a ratio of soil 10 kg and cement 1 kg, and then this mixture was charged into the experimental soil bin. After 14 days, the soil hardened with the cement. After confirming that the soil water content was less than 50% d.b. and the soil penetration resistance was more than 5 MPa (cone penetrometer, 30° cone angle and 13 mm base diameter), we started the experiments. This hardened pseudogley soil with

Table 1 Physical properties of soils in this study (Araya *et al*., 2012).

	Saline soil (solonchak)			Sodic soil (solonetz)				Pseudogley soil+cement
	Ap	Bca	C	Ana	A	B	C	-
Particle density ρ, kg m^{-3}	2615(21)	2583(34)	2598(29)	2490(41)	2340(21)	2500(19)	2500(23)	2540(31)
Bulk density ρ_b, kg m^{-3}	1614(12)	1610(17)	1580(14)	1720(19)	1541(11)	1613(10)	1670(11)	1656(17)
Tensile strength σ_t, kPa	50(6)	250(12)	150(8)	128(9)	314(16)	301(11)	329(12)	357(13)
Cohesion c, kPa	10(3)	10(4)	10(3)	80(9)	250(12)	250(14)	250(13)	250(14)
Angle of internal friction φ, °	50	55	10	0	0	0	0	0
Adhesion a, kPa	4	4	4	1	2.2	1.3	1	1.3
Angle of soil-metal friction δ, °	20	25	17	15.1	9.7	13.8	11.9	12.4
Texture (USDA)	silty clay	clay	clay	sandy clay	clay	clay	clay	silty clay

( ), standard deviation