5. Modulus of Rupture Test for Determining Soil Strength of Surface Soils

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BACKGROUND

The cohesion exhibited by soils upon drying is a soil property that relates to surface crusting and clod formation. Soil crust formation has been identified as a major problem for crop production on Luvisolic and on Solonetzic soils on the prairies. The modulus of rupture, a concept relating to the breaking strength of beams and for predicting strength of materials is applied for evaluating the strength and cohesion of dry soil.

"A soil briquet, specially molded to have a rectangular cross section and supported as a simple beam (ends supported with no constraint), is loaded to failure with a concentrated load at the center of the beam span (Fig. 5.1). From the load or force required to break the beam, and from the appropriate dimensions of the sample, the modulus of rupture for the soil briquet is calculated" (Reeve 1976). The modulus of rupture test provides a means for evaluating the effectiveness of soil amelioration techniques on soil crusting strength of Luvisolic and of Solonetzic soils.

MATERIALS AND METHODS

Soil samples were collected from Solonetzic soils located near Kerrobert (SE-13-33-23-W3) and near Oxbow (NE-15-4-2-W2 and SW-32-4-2-W2). Furthermore, samples were used from a Luvisolic soil (near Choiceland) and from three Chernozemic soils; Kernen farm (heavy clay), Goodale farm (very fine sandy loam) and Lanigan (sandy loam). The samples were air-died soil and broken up in order to pass through a 2-mm sieve. Metal molds (69 x 35 x 7 cm) were greased with a thin layer of Vaseline to prevent the soil from sticking to the mold. The molds were placed on a sheet of filter paper on a wire-mesh screen. Soil was poured into the molds to exact volume. Soil and molds were

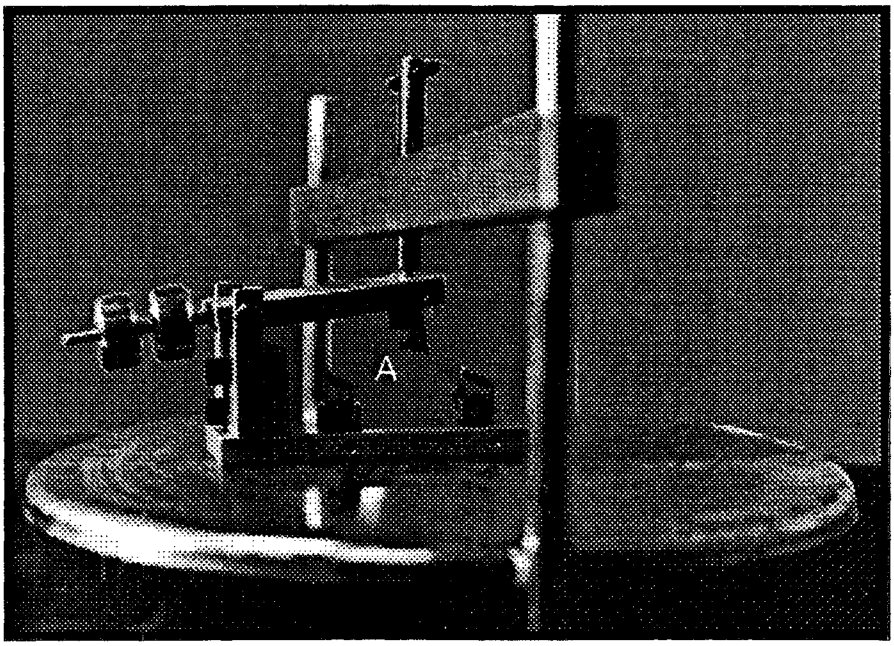

Fig. 5.1 Knife assembly used in the modulus of rupture test (the soil briquet is placed at point "A" between the blades).

wetted for 1 to 2 hours by adding water to just below complete immersion of the sample. The soil samples and molds were dried at 50^{o}C for 24 to 48 hours. Soil briquettes were removed from the molds and their dimensions measured using a set of micro callipers. The briquettes were placed on the knife assembly shown below, care was taken to adjust the top knife to just touch the briquette. A constant volume of water was applied into the flask at the end of the beam balance. The volume of water per minute had been adjusted to result in a force of 1.96 dynes/min.

CALCULATIONS

Modulus of Rupture

For the beam set-up used in this experiment, the modulus of rupture s is given by the equation:

$$s = \frac{3 \times F \times L}{2 \times b \times d^2}$$

F = breaking force applied at the center of the briquet (dynes)

L = distance between briquet end supports (cm)

b = width of the briquet (cm)

d = thickness of the briquet (cm)

for our apparatus:

$$F = 980 \times \frac{1000}{W_1} \times W_2$$

F = the breaking force in dynes

W_1 = counter weight, placed on the weight hanger at the end of the balance, required to balance out 1000 gm on the weighing platform (gm)

W_2= grams of water added to the vessel to break the sample (gm)

The modulus of rupture equation is rearranged by substituting the above:

$$s = \frac{1.47 \times 10^6 \times W_2 \times L}{W_1 \times b \times d^2} \quad \text{in dynes/cm2}$$

Note 1 bar= 10^6 dynes/cm^2= 10^2 kPa= 1023 cm H_2O

<u>*COLE Index*</u>

The Coefficient of Linear Extensibility is determined from:

$$COLE = \frac{Lm - Ld}{Ld} ,$$

L_m = length of sample moist, and L_d= length of sample dry (usually air-dry or oven-dry).

RESULTS

The soil strength values for most of the Chernozemic soils were quite low (Table 5.1) and in some cases replicate briquettes fell apart before the modulus of rupture test could be carried out. The heavy clay Chernozemic soil and the Luvisolic soil resulted in briquettes of considerable greater strength, and thus were well suited for this technique. Similarly, the four Solonetzic soils resulted in briquettes that were easy to handle for this technique. The Solonetzic soils from near Oxbow, had different levels of Sodium Adsorption Ratio's (SAR). The levels were 0.9, 1.6, 5.6 and 6.0, for soils #1, #2, #3, and #4, respectively. The effect of increasing SAR on soil strength is clearly shown in Table 5.1.

Table 5.1 The effect of soil type and texture on soil strength and COLE index.

Soil	texture	Soil strength (kPa)	COLE index
Chernozemic	V.F.Sa. Loam	5	0.017
Chernozemic	Sa Loam	9	0.034
Chernozemic	H. Clay	847	0.127
Luvisolic	C. Loam	262	0.022
Solonetzic-1	C. Loam	19	0.055
Solonetzic-2	C. Loam	254	0.068
Solonetzic-3	C. Loam	807	0.055
Solonetzic-4	C. Loam	977	0.101

The data from the above table indicates an expected range in values of soil strength and soil shrinkage. Richards (1953) listed a modulus of rupture value of 11 kPa for a fine sandy loam and a value of 27 kPa for the same soil with an ESP of 37%. Chenu and Guerif (1991) listed modulus of rupture values of around 600 kPa for kaolinite and around

2.65 x 10^4 kPa for montmorillonite. The COLE index values are in the range of values given for various soils in Saskatchewan by Dasog et al. (1988): COLE values for the surface horizons of fine-textured Chernozemic and Luvisolic soils ranged from 0.015 to 0.104.

In a separate experiment, surface soil samples from a deep tillage project on Solonetzic soils near Kerrobert (Boehm 1991) were used to study the effect of deep plowing and of deep ripping on the surface condition of the soil (Table 5.2).

It was thought that deep plowing had increased the sodium content of the surface soil layers, which would explain the greater soil strength in the deep plowed plots. Obvious visual differences in the surface soil condition amongst the deep tillage plots had been observed in the spring of 1991.

Table 5.2 The effect of deep tillage on the surface condition of a Solonetzic soil.

Block	Tillage	Soil strength		COLE index		Bulk density†	
		(kPa)		(x 10^{-2})		(g cm^{-3})	
West	Control	21	(15)	5.9	(1.2)	1.13	(0.05
West	Plowed	46	(13)	6.5	(0.9)	1.10	(0.03)
West	Ripped	21	(15)	5.6	(0.9)	1.03	(0.01)
Mid	Control	4	(8)	5.3	(0.3)	1.12	(0.10)
Mid	Plowed	46	(9)	6.6	(0.6)	1.16	(0.00)
Mid	Ripped	7	(6)	4.8	(1.0)	1.09	(0.02)
East	Control	57	(11)	5.5	(0.6)	1.12	(0.04)
East	Plowed	125	(28)	6.2	(0.9)	1.14	(0.07)
East	Ripped	78	(41)	7.4	(1.0)	1.20	(0.02)

Standard deviations are shown in brackets
† Bulk density of the briquets based on air-dry soil moisture content (50°C)

SUMMARY

The modulus of rupture technique for determining surface soil strength is a relatively simple and inexpensive technique. It lends itself well for the determination of a limited number of samples, involving only a minimal amount of technician time. The drying stage of this test (24 to 48 hours) is the only time consuming part of this technique. The time required to process large numbers of samples would be considerable unless a large number of sample molds and wire-mesh screens could be obtained. A convenient aspect of this technique is that the COLE index can be determined on the samples at the same time.

The modulus of rupture technique should be used only in soils where soil crusting has been observed or documented. The soil strength of coarse- and medium-textured Chernozemic soils may be too small to produce the briquettes needed for this technique.

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