

The effects of wetting rate on aggregate stability in three soils

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1. Abstract

Aggregate stability is a crucial factor of soil erosion and crust. Disintegration of aggregates is affected by wetting rate. At wetting rates of 2(slow), 10(middle) and 50 mm h⁻¹(fast), three soils (Loess, Red and Black soils, or Typic Haplustalfs, Typic Hapludults and Pachic Udic Argiborolls respectively) of main arable lands in China were taken to investigate the effects of wetting rate on aggregate stability. The aggregate stability was found to be in the order of red soil > black soil > loess. Except slow and middle wetting rate for loess and red soil, there was significant difference among different wetting rate with different soils.

Keywords: wetting rate, aggregate stability, mean weight diameter

2. Introduction

Aggregate breakdown influences several aspects of soil's physical behavior, such as infiltration, crusting, and erosion (Farres, 1987). Aggregate disintegration is main influenced by aggregate stability and wetting rate (Shainberg et al., 2003). The extent of aggregate disintegration by wetting depends on aggregate stability which is related to organic matter, sesquioxides and clay content (Kemper and Koch, 1966; Kay and Angers, 1999).

According to Le Bissonnais (1996), four main mechanisms can be identified that cause aggregate breakdown: (1) slaking, i.e., breakdown caused by the compression of entrapped air during wetting; (2) breakdown by differential swelling; (3) breakdown by raindrop impact; (4) physicochemical dispersion due to osmotic stress.

There are numerous methods for determining aggregate stability, the most widely used ones being wet sieving (Kemper and Koch, 1966; Kemper and Rosenau, 1986), the drop test technique (Farres, 1980) and application of ultrasonic energy (North, 1976).

These mechanisms differ in the type of energy involved in aggregate disruption. For instance, swelling can overcome attractive pressures in the magnitude of Mpa (Rengasamy and Olsson, 1991) while slaking can overcome attractive pressures in the range of kPa only. Slaking and swelling is determined by the wetting rate of the soil.

The objectives of this study are to determine the aggregate stability and the effect of wetting rate on aggregate disintegration of three important Chinese soils.

3. Materials and Methods

Soil Samples

Three soils, representing main arable soils in Northeast, Northwest and South of China were used in this study. These soils were loess (Typic Haplustalfs, according to the U.S. Soil Taxonomy) from Shaanxi Province in the Northwest, red soils (Typic Hapludults) from Hubei Province in the South and black soils (Pachic Udic Argiborolls) from Heilongjiang Province in the Northeast. The soil materials were taken from the top layer (0 to 200 mm) of cultivated fields. Soil physical and chemical properties were determined by standard methods (ISSAS, 1978). A few of the soil properties are presented in Table 1.

Table 1 Some physical and chemical properties of the soils used in the study

Soil	Texture □ USDA □			CEC mmol/kg	ESP □	OM g/kg
	sand g/kg	silt g/kg	clay g/kg			
Loess	82	586	332	185	0.73	15.1
Red soil	47	712	241	173	0.51	16.2
Black soil	192	570	238	394	0.48	42.6

CEC = cation exchange capacity; ESP = exchangeable sodium percentage; OM = organic matter

Aggregate Stability Study

Macro-aggregate stabilities were measured with the routine dry and wet-sieving method (Bin and Horn, 2001). In the routine method, the air-dried soil samples were sieved by hand on a column of six sieves: 5, 3, 2, 1, 0.5 and 0.25 mm. The mass percentage of each size fraction was calculated. Based on these percentages, composite soil samples were made for wet sieving. The soils were wetted slowly by adding water up to saturation and, after corking, were agitated end over end 10 times in water. Finally, the soil samples were placed on the same column of sieves, which were raised and lowered 3-4 cm under water surface. The material remaining on the sieves was oven dried and weighted to give the stable aggregate mass.

Aggregate stability was expressed using the mean weight diameter (MWD) and the percentage of aggregate destruction (PAD) (Zhang and Horn, 2001).

$$MWD = \sum_{i=1}^{n+1} \frac{r_{i-1} + r_i}{2} \times m_i$$

Where r_i = aperture of the i th mesh (mm), $r_0 = r_1$ and $r_n = r_{n+1}$; m_i = mass fraction of aggregates remaining on i th sieve; n = number of the sieves.

$$PAD = \frac{m_d - m_w}{m_d} \times 100$$

where m_d = mass fraction of aggregates > 0.25 mm after dry sieving; and m_w = mass fraction of aggregates > 0.25 mm after wet sieving.

The effect of different Wetting Rates on aggregate stability was measured after dry-sieving method. Samples of aggregates 2 to 5 mm in size were put in the oven at 40°C for 24 h, and 5 g of the oven-dry aggregates were wetted with three wetting rates: 2, 10 and 50 mm h⁻¹ in deionized water used the same method of crust Strength Study. The aggregates were immersed in ethanol for 5 min after saturated for 10 min, and then the samples were oven dried at 40°C for 24 h. Their size distribution was measured by the dry-sieving method.

4. Results and discussion

The results of the aggregate size distribution and aggregate stability parameters of the loess, red and black soils, as determined by dry and wet sieving method, are presented in Table 2. The soils were ranked differently according to the parameters of soil aggregate stability. According to MWD and PAD, The red soil was most stable while the loess was the least stable.

Table 2 The aggregate size distribution and aggregate stability parameters determined by dry-sieving and wet-sieving

Soil	Method determined	Content of aggregates in various levels □ % □					MWD (mm)	PAD (%) >0.25 mm
		5-2	2-1	1-0.5	0.5-0.25	<0.25		
Loess	Dry-sieving	22.32	37.01	25.55	10.45	4.67	1.57	94.56
	Wet-sieving	0	0.31	4.81	7.58	85.90	0.20	
Red soil	Dry-sieving	14.57	27.53	24.94	17.97	15.00	1.20	31.08
	Wet-sieving	2.46	13.03	21.88	21.21	41.42	0.58	
Black soil	Dry-sieving	30.89	47.97	15.71	4.65	0.77	1.94	30.57
	Wet-sieving	0.3	9.9	17.0	41.8	31.1	0.48	

Table 3 presents the comparison of mean weight diameter (MWD) of the experimental samples during different treatment. The MWD_{dry} and MWD_2 of different soils had significant difference and was found to be in the order of black soil > red soil > loess. All of three soils have the order of $MWD_{dry} > MWD_2 > MWD_{10} > MWD_{50} > MWD_{wet}$. The reason for this result was the slaking of aggregate increased with the augment of wetting rate.

Table 3 Comparison of mean weight diameter (MWD) of the experimental samples during different treatment

Soil	Loess	Red soil	Black soil
MWD_{dry}^{\dagger}	1.57b [‡]	1.20c	1.94a
MWD_2	1.33b	1.07c	1.56a
MWD_{10}	1.14ab	1.00b	1.23a
MWD_{50}	0.85b	0.90b	1.09a
MWD_{wet}	0.20b	0.58a	0.48a

[†]Footnote of MWD indicate dry-sieving, wetting rate and wet-sieving; [‡]Letters followed the values indicate the significance at the 0.05 probability level.

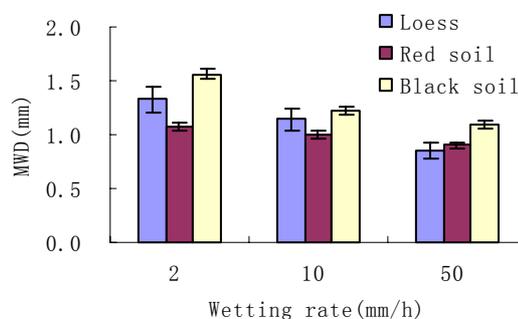


Figure 1 Mean weight diameter (MWD) of the experimental samples during different wetting rates

MWD of the experimental samples during different wetting rates are presented in Fig. 1. Except slow and middle wetting rate for loess and red soil, there was significant difference among different wetting rate with different soils.

The results of the aggregate size distribution and aggregate stability parameters of the experimental samples (Table 2) indicated that the aggregates of red soils and black soils were more stable than those of the loess soils, and the reason were much higher content of soil oxides, especially iron and aluminum oxides and organic matters in red soils and black soils, respectively. Muggler et al. (1990) revealed that translocation of Fe and its recrystallization in the presence of clay play important action for aggregation. Goldberg et al. (1990) founded that amorphous and crystalline aluminum and iron oxides play an important role in stabilizing soil structure. The results of other researchers illuminated that the iron and aluminum oxides content of red soils in the same research field reached 30–50 g kg⁻¹. Levy and Mamedov (2002) showed that for coarse- and medium-textured soils (<25% clay), with low organic matter, aggregate stability was relatively low. Kemper and Koch (1966) founded that the clay and organic matter act as cementing and binding agents in the soil. In all three-soil samples we studied, the organic matter in black soil is much higher than those of other two soils.

The effect of wetting rate to aggregate stability could be explained by the clay mineralogy. Kaolinitic and illitic soils with no smectite are stable, whereas smectitic soils and soils with some smectite content are unstable and have a strong swelling during immersed in water (Stern et al., 1991). The dominant mineral of red soil was Kaolinite and the most mineral of loess was illite and kaolinite. So with low degree slaking and swelling, there wasn't significant difference in slow and middle wetting rate for loess and red soil. The smectite content is only less than the illite in black soil, so with strong swelling, it has significant difference in all three wetting rate for black soil.

5. References

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