Comparison of two methods for aggregate stability measurement – a review

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ABSTRACT

Soil structure is a very important soil property, which influences many processes in the soil. There are many methods for aggregate stability measurement varying in the energy applied in the treatment. The aim of this paper is to compare two aggregate stability measurement methods on a set of reclaimed dumpsite soils. Method proposed by Le Bissonnias (1996) is composed of three tests, which allow distinguishing the particular aggregate breakdown mechanisms. Results can be expressed by a coefficient of vulnerability (*Kv*). Results of the second method, assessment of water stable aggregates, can be expressed by WSA index. WSA indexes mainly correspond to the results of the first test, which qualify the aggregate breakdown during the fast wetting. A strong statistically significant relationship was found between WSA and *Kv* for each test. Correlation coefficients were –0.767, –0.806, and –0.741 for linear models. Our conclusion is that results of both methods are comparable.

Keywords: soil structure; aggregate stability; soil reclamation; soil analysis

Soil structure represents a very important soil property. Its stability expressed by the stability of soil aggregates, directly or indirectly influences other physical and chemical properties of the soil and can be used as an indicator of soil degradation (Cerda 2000).

The measurement of soil aggregate stability becomes important because it can give general information about soil conditions. The aggregate stability is the ability of the bonds of the aggregates to resist when exposed to stresses causing their disintegration (e.g. tillage, swelling and shrinking processes, kinetic energy of raindrops, etc.).

Each method of soil aggregate stability measurement simulates a specific mechanism of aggregate breakdown. Le Bissonnais (1996) reported four main mechanisms of aggregate breakdown: (a) slaking due to compression of entrapped air during wetting, (b) microcracing due to differential swelling, (c) mechanical breakdown, and (d) physico-chemical dispersion due to osmotic stress. A short overview of methods used for aggregate stability measurement can be found e.g. in Le Bissonnais (1996) or in Diaz-Zorita et al. (2002). Selection of the methods and interpretation of its results depends on the purpose of the measurement. The most common method used for aggregate stability measurement is wet sieving. Other methods are based, for example, on the simulation of raindrop energy impact, ultrasonic dispersion, or breakdown of aggregates after sudden immersion in water. In the Czech Republic, a method according to Novák (cit. Drbal 1971) is being commonly used. This method is based on the comparison of dry sieving with wet sieving after slow capillary wetting and fast wetting. The standard DIN 19683-16 suggests a method of aggregate stability measurement, which should be used because of the possibility of the comparison results. The principle of this method is used in the methodology for the determination of water stable aggregates supplemented by the company Ejkelkamp with a Wet Sieving Apparatus. Therefore, we made a comparison of water stable aggregates assessment (method mentioned above) and the method proposed by Le Bissonnais (1996).

MATERIAL AND METHODS

A set of 46 soil samples from the reclaimed dumpsites of North Bohemia Mining Company was used for aggregate stability measurement. The soil samples were collected from dumpsites of different age and different management, usually from the top 20 cm.

For aggregate stability measurement the method proposed by Le Bissonnais (1996) was used, which allow distinguishing the different destruction mechanisms causing aggregate breakdown. The

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method is composed of three tests (fast wetting, slow wetting, and shaking after pre-wetting). Because of using Wet Sieving Apparatus, this method had to be modified. Weight of 4.0 g of 2–5 mm air-dried aggregates was pre-treated according to each test methodology, sieved in ethanol for 6 minutes and dried in an oven at 110°C to a constant weight. Then the distribution of particular aggregate size fractions (< 0.25, 0.25–0.5, 0.5–1.0, 1.0–2.0 and 2.0–5.0 mm) was determined. The aggregate stability was expressed as a coefficient of vulnerability, which qualifies how many times the size of aggregates decreased due to the examined breakdown mechanism (Valla et al. 2000). It is calculated as follows (equation 1):

$$Kv = x/\mathrm{MWD} \quad (1)$$

where: Kv is the coefficient of vulnerability, x is the mean weight diameter of aggregates taken to the analysis (in this case 3.5 mm), and MWD is the mean weight diameter of aggregates after their disintegration (mm).

The content of Water Stable Aggregates (WSA) was also measured. Its measurement was done according to the methodology for the Wet Sieving Apparatus, which is similar to that proposed by Kemper and Rosenau (1986, cit. Diaz-Zorita et al. 2002) and standard DIN 19683-16. Weight of 4.0 g of 2–5 mm air-dried aggregates were placed on the sieves of Wet Sieving Apparatus and washed in cans with distilled water for 3 minutes. Then these cans were replaced with cans with a dispersing solution (containing 2 g sodium hexametaphosphate/l for soils with pH > 7 and 2 g sodium hydroxide/l for soils with pH < 7) and the sieving continued until only the sand particles (and root fragments) were left on the sieves. Both sets of cans were placed in an oven and dried at 110°C. After drying, the weight of materials of unstable and stable aggregates was determined. Dividing the weight of the stable aggregates over the total aggregate weight (without sand particles > 0.25 mm) gives an index for the aggregate stability (equation 2):

$$\mathrm{WSA} = Wds/(Wds + Wdw) \quad (2)$$

where: WSA is the index of water stable aggregates, Wds is the weight of aggregates dispersed in dispersing solution (g), and Wdw is the weight of aggregate dispersed in distilled water (g).

Both analyses were done in two repetitions for each sample. All data were statistically analysed in statistical software Statgraphics plus for Windows 4.0 (Manugistic 1997).

RESULTS AND DISCUSSION

Six samples had to be excluded from statistical analyses because of their high content of very coarse particles and coal residues, which would behave as almost stable aggregates and would distort the results. The average value of vulnerability coefficient for the first test (*Kv* I) was 2.75, for the second test (*Kv* II) 2.49, and for the third test (*Kv* III) 2.36. The average index of water stable aggregates was 0.75. Summary statistics for all variables is in the Table 1. For comparison of the vulnerability coefficients (*Kv*) with the index of water stable aggregates (WSA), all *Kv* were converted to a similar index. In this conversion we assumed aggregates left on the sieves of the Wet Sieving Apparatus to be stable (even if they were disintegrated into the smaller fragments) and aggregates that passed through the sieves (< 0.25 mm) to be unstable. Then the weight of stable aggregates was divided by the weight of sample taken to the analysis; however the weight of sand particles was not excluded (equation 3). The value 0.25 mm is also meant to be a limit between micro and macroaggregates (Le Bissonnais 1996):

converted Kv = weight of aggregates > 0.25 mm (g)/ weight of sample taken to analysis (g) (3)

To get a normal distribution for all data, partially logarithmic transformation (for coefficients of vulnerability for each treatment; i.e. *Kv* I, *Kv* II, and

Table 1. Summary statistics for variable *Kv* I, *Kv* II, *Kv* III, WSA, converted *Kv* I, converted *Kv* II, and converted *Kv* III

	Kv I	*Kv* II	*Kv* III	WSA	Converted *Kv* I	Converted *Kv* II	Converted *Kv* III
Average	2.75	2.49	2.36	0.75	0.75	0.81	0.82
Median	2.17	2.05	1.83	0.83	0.79	0.88	0.88
Variance	2.83	1.79	1.32	0.07	0.04	0.03	0.03
Minimum	1.24	1.19	1.14	0.06	0.30	0.24	0.37
Maximum	9.02	6.65	5.13	1.00	1.00	1.00	1.00

Table 2. Paired-sample comparison for determination of differences between WSA and converted *Kv* for each test (exponential transformation)

	t-test	*P*-value
WSA – *Kv* I	–1.878	0.068
WSA – *Kv* II	3.348	0.002
WSA – *Kv* III	2.101	0.040

Kv III) and partially exponential transformation (for WSA and converted *Kv*) were done.

The results of paired-sample comparison (Table 2) have shown that there is no statistically significant difference between converted *Kv* I and WSA at confidence level $\alpha < 0.01$. Between converted *Kv* II and WSA and converted *Kv* III and WSA, there is a statistically significant difference at the confidence level $\alpha < 0.05$. The same mechanism of aggregate breakdown acts in the first test of Le Bissonnais's method and water stable aggregates assessment, because aggregates are suddenly immersed into water in both cases. Therefore, these results are best comparable. Breakdown by differential swelling and mechanical breakdown is not so concerned in assessment of water stable aggregates, however it also depends on the soil nature.

Regression analysis was done for further comparison of results (Figures 1–3). It can be seen that there is a strong statistically significant relationship between WSA and all *Kv*'s. The strongest correlation was found between WSA and *Kv* II, which expresses aggregates breakdown, by differential swelling. This can be due to the deposition of clay material on dumpsites, which usually occurs in north Bohemia region.

We conclude that the results of these two methods are comparable. Of course, both methods have their advantages and disadvantages. The disadvantage of the method proposed by Le Bissonnais (1996) is that aggregate stability is increased by sand particles that are not excluded from the calculation of *Kv*. On the other hand, a big advantage of this method is distinguishing the particular mechanisms of aggregate breakdown. Therefore, it can be used within a large range of soils. In the assessment of WSA, only hexametaphosphate as a dispersing solution was used, because sodium hydroxide was too aggressive to the aluminum cans. An advantage of this method is that sand particles are excluded from the calculation of WSA index and its methodology is similar to that in standard DIN 19683-16.

The Le Bissonnais's method is more suitable for soil structure stability investigation of reclaimed dumpsite soils. The reclaimed dumpsite soils contain very compact fossil aggregates that originate from dumped earth in the top layer. These fossil aggregates behave as sand particles but they disintegrate quite early due to a change of thermodynamic conditions.

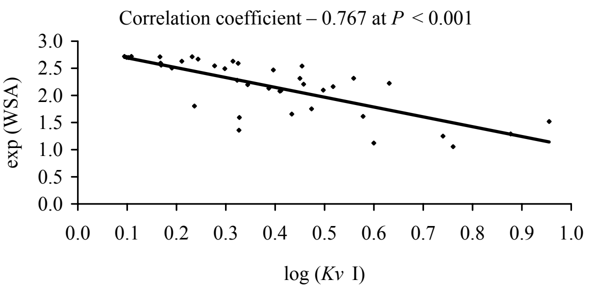

Figure 1. Dependence of exp (WSA) on log (*Kv* I)

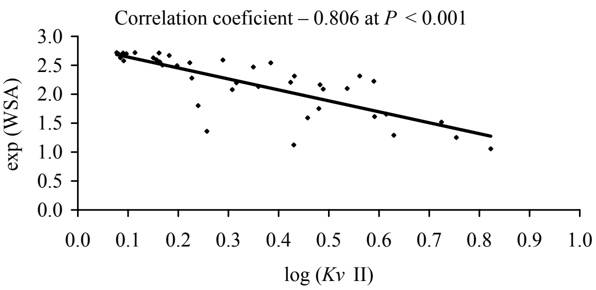

Figure 2. Dependence of exp (WSA) on log (*Kv* II)

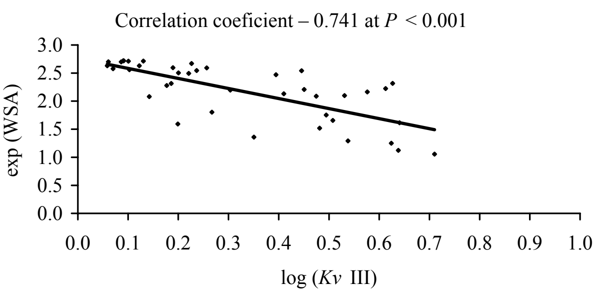

Figure 3. Dependence of exp (WSA) on log (*Kv* III)

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ABSTRAKT

Porovnání dvou metod stanovení stability půdních agregátů – studie

Půdní struktura je důležitou půdní vlastností, která ovlivňuje mnoho procesů probíhajících v půdě. Existuje mnoho metod stanovení stability agregátů, které se liší množstvím energie aplikovaným na rozbor vzorku. Cílem příspěvku je porovnání dvou metod stanovení stability agregátů. Metoda navržená autorem Le Bissonnais (1996) se skládá ze tří testů a dovoluje jednoznačně oddělit působení jednotlivých dezagregačních mechanismů. Výsledek je vyjádřen koeficientem vulnerability (*Kv*). Výsledek druhé metody, stanovení množství ve vodě stabilních agregátů, je vyjádřen indexem WSA. WSA nejvíce odpovídal výsledkům prvního testu, jímž je hodnocen rozpad agregátů při prudkém ovlhčení. Byly zjištěny silné, statisticky průkazné závislosti mezi WSA a *Kv* pro všechny testy. Korelační koeficienty lineárních modelů nabývaly hodnot –0,767; –0,806 a –0,741. Výsledky obou metod jsou tudíž srovnatelné.

Klíčová slova: struktura půdy; stabilita agregátů; rekultivace půdy; rozbory půdy

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