LANDTECHNIK 71(3), 2016, 90–96

DOI:10.15150/lt.2016.3125

LANDTECHNIK
AGRICULTURAL ENGINEERING

Review of evaluations of crushing results for the seedbed preparation

Siegfried Anisch, André Grosa, Tim Bögel, Thomas Herlitzius

For evaluating the work results of tillage operations today only inaccurate parameters are available which cannot be readily measured. Thus, evaluating and comparing the work results of machines and developing suitable sensors are difficult. At the Technical University of Dresden, till 1990, research projects for determining aggregate size composition of soil have been done. Based on this work, this study will show suggestions for measuring, displaying and evaluation of soil crushing results depending on tillage work conditions.

Keywords

Seedbed preparation, soil aggregate size, sieve analysis, aggregate breaking force, point-load index

Crushing of the soil is one of the main targets for seedbed preparation on heavy soils. Commonly machines operate with passive (pulled) and/or active (PTO-driven) tools. The typical method for farmers is a visual check of a sufficient amount of fine soil (for embedding the seed) and aggregates in bigger size (for preventing wind and water erosion) [Diez et. al. 2012].

For machinery testing the evaluation is supported by a sieve analysis with a round-hole swing sieve [Brehm 2009, Schuchmann 2014]. Based on these investigations, under same field conditions, evaluations of the machinery can be done. Disadvantages of this method are higher measurement errors as a result of particle crushing during severing and the considerably high expenditure of time and work. For evaluating particle crushing expenditure of time, crop and field related requirements and comparable soil conditions are essential.

Physical law of the aggregate size composition of soil

For many decades in the processing of basic materials (coal, stones, etc.) the crushing result with the sieve residue R as a mass relationship is displayed as a double exponential regression graph in a double logarithmic diagram (RRSB-diagram after Rosin/Rammler/Sperling/Bennett; Rammler 1937). Based on this method, it was proved for chosen tillage tools that this relationship is also valid for aggregate size composition of different soil types after tillage operation (Hillig 1987, Soucek & Pippig 1990).

Analyses of 79 different tests of shizzle ploughs and disc harrows from 21 DLG test reports (5207F to 5217F; 5897F; 6029F; 6110F; 6151F; 6153F; 6166F; 6255F to 6257F) confirm the physical law of the aggregate size composition for seedbed preparation (Anisch 1990, Brehm 2009) (Figure 1) .

received 9 October 2015 | accepted 14 March 2016| published 10 June 2016

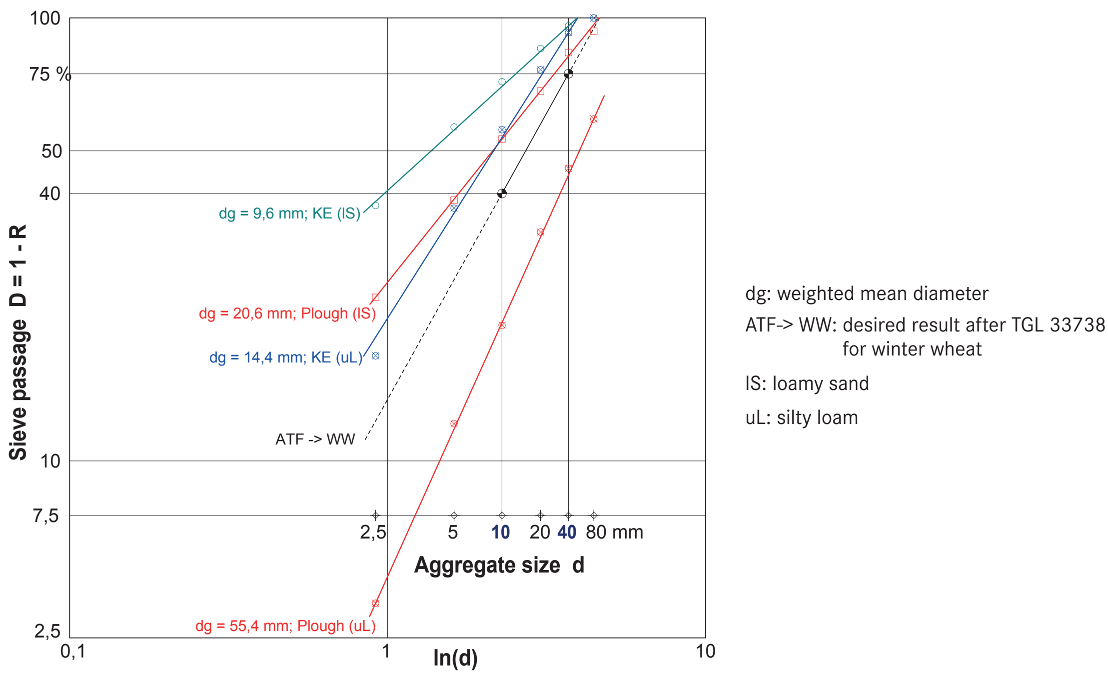

Figure 1: Crushing result of the rotary harrow KE 3000S related to DLG test report 5897F (Brehm 2009) in a double logarithmic plot related to Rammler (1937)

Based on this physical law, just two measurements of the sieve passage or sieve residue are necessary. They can be compared with the former GDR norm TGL 33738 (1984) (Table 1).

Table 1: Soil aggregate size for the seedbed

Sieve passage	Required result after TGL 33738 [%]			Test result DLG 5897F (Brehm 2009) [%]		Soil type
	wheat	rye & barley	rape	plough	rotary harrow	
D10	> 40	> 45	> 75	20.4 53.4	56.3 72.1	uL lS
D40	> 75	> 80	> 90	46.3 84.3	93.3 94.6	uL lS

Determination of the crushing result

For experimental investigations and tests of seedbed preparation machinery the sieve analysis is still used (Anken 1996, Brehm 2009). As mentioned before, this method is time-consuming and error-prone. The weighted mean diameter GMD allows no reference to agricultural requirements.

One possible solution is a portable, easy to handle sieve shovel (Figure 2). Soil samples can be sieved in the two fractionations R > 10mm and R > 40mm and the amount of the soil sample mass can be determined (Anisch 1990). This method allows determining statistically proven results during field tests in less than an hour. Using a digital scale the shares of R10 and R40 can be determined with a simple scraping and sieving device (Figure 3).

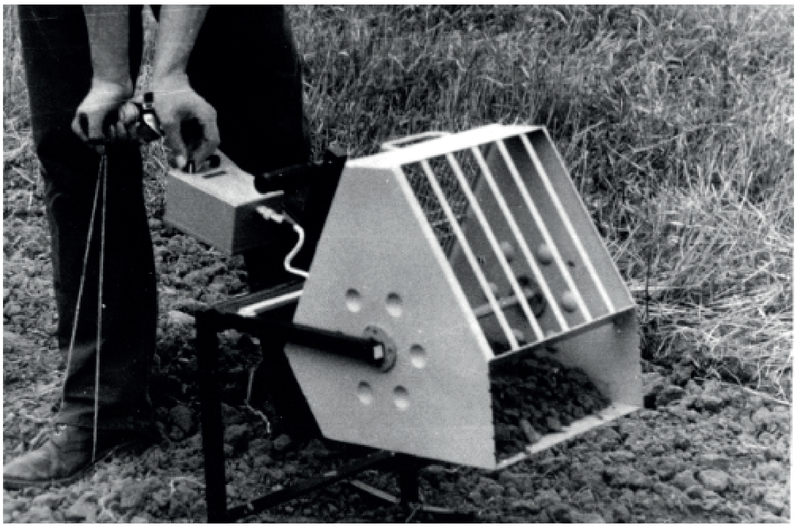

Figure 2: Weighting of a soil sample with a sieve shovel

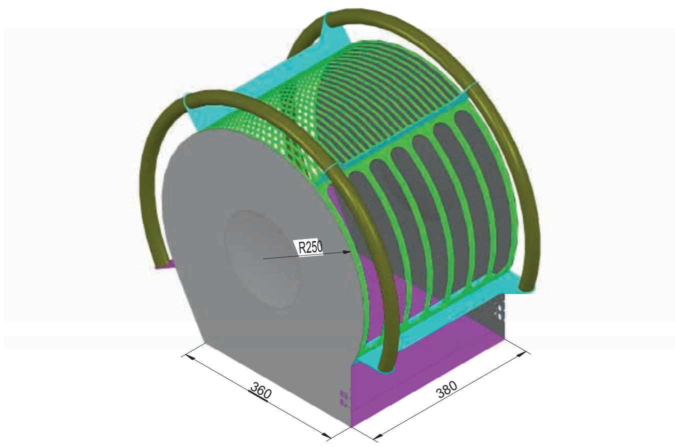

Figure 3: Scraping and sieving device (R10 and R40); units in mm

Determination of the crushing result from parameters of the seedbed surface

The soil aggregates in the upper layer define the visual and geometrical properties of the surface. Rieger et al. (2014) investigated with a stereo-vision-system (SVS) the change of the surface (roughness, e.g.) after different tillage operations. Concerning the crushing results no information was given.

An often use method is investigating specific aggregate sizes (d > 40mm e.g.) to estimate the number of area share (Anken 1996). With a laser profilemeter a measured roughness of the surface can be set in correlation to the sieve results when the tillage operation was done with a tine. R^2 of 64 % can be achieved (Anken 1996).

Better relationship shows a method from the „Eidgenössische Forschungsanstalt für Agrarwirtschaft und Landtechnik (FAT)". Based on digital photo analyses of shadows from the soil aggregates the diameter of the assumed circular aggregates are calculated. The calculated diameter shows a high correlation of 81 % to the weighted mean diameter (GMD) from the sieve analyses (Anken 1996). For evaluation of the seedbed preparation the GMD is not used. However, much better correlations (R^2 = 0,88) result when the proportion of aggregates with d > 40mm is considered.

Displaying the results

If the experimentally obtained results (R10 and R40) are entered in the diagram according to Figure 4 (middle), the results of the soil crushing can be clearly displayed and compared. Based on the desired results from TGL 33738 reproducible results can be achieved. (Anisch 1990).

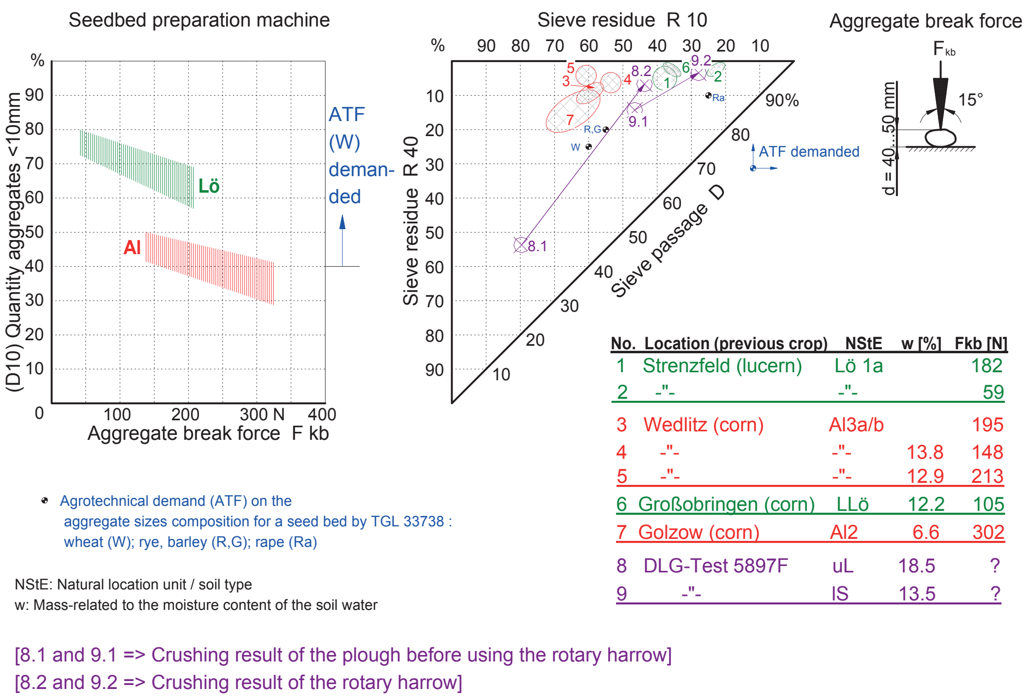

Figure 4: crushing result of a seed bed machine (No. 1–7) and a rotary harrow KE (No. 8 and 9) after ploughing

Marking the field conditions by strength of the soil aggregates

For crushing parts the tensile, bending and shear strength and the tools are essential. For seedbed preparation larger aggregates have to be crushed into smaller parts. This happens depending on soil type, water content, plant material, roots, porosity etc. A reproducible, physical unit to evaluate the amount of mechanical crushing work can not be determined from these parameters.

The used aggregate stability describes the resistance of soil aggregates to environmental influences. With water sieving, the effect of the water content can be investigated (Kolbe 2011). The falling test (Hartge and Horn 1922) for measuring the density level of soil aggregates does not lead to reproducible results. With a penetrometer the penetration resistance of a specific tool can be measured (DIN 19662). Aggregates in the upper layer of the soil can be moved or destroyed by this method. Harder layers of the soil can be determined, but not the absolute strength. In geophysics the method of point-load test is used in laboratory and field tests. The point-load index i_s (PLI) is based on the breaking force F_B between two attacking points from which the cross-section area A is calculated (Thuro 2010):

$$i_s = F_B / A \; [MPa] \qquad \text{(Eq. 1)}$$

Based on this result the one-dimensional compressive strength is determined for the design of construction works.

In field test with seedbed preparation machines on different soil types the strength of soil aggregates were investigated with a similar method, the so called aggregate breaking force F_{kb} . A number of small aggregates from the sieve residue R40 were penetrated on a hard, flat ground by a wedge tool (angle 15°, width 30mm) and the penetrating force F_{kb} was measured (Figure 4). The tension and the cross-section area were not clearly defined, but for different soil types different levels for the mechanical crushing could be observed and compared.

Evaluation of the crushing result

The crushing result can be evaluated with the desired target and the required effort. While the effort (costs, time, etc.) can be measured precisely, no target size is defined for the crushing result at present.

For the comparison of tillage tools and equipment Bosse and Kalk (1988) have proposed the complex evaluation parameter „Comparative Energy“ as the quotient of energy demand (mechanical energy, generated by tractor engine) and result of tillage. They compare the dimensionless weighted work result of the machine, i. e. leveling, crushing, loosening and re-compacting, before and after the tillage with desired targets. This evaluation can only be used for scientific investigations.

On almost every field the desired targets according to TGL 33738 for wheat were achieved after one tillage operation (No. 1 to 6) (Figure 4). These fields were described with an aggregate breaking force F_{kb} < 200N. On “Lö” fields a better seedbed was achieved than on “Al” fields, with equal soil strength. At the dry, hard field “Al-2” (No. 7) the desired share of aggregates < 10mm could not be reached.

The visual check of the seedbed preparation (Brehm 2009) relies on small aggregates d < 10mm. This share (D10 = 1 - R10) can be reproduced and measured (Figure 4, left) and be used as a target for the seedbed preparation in comparison to the field conditions.

Conclusions

By the mechanical crushing of soil the aggregates follow physical laws (Anisch 1990, Hillig 1987, Rammler 1937). For the development of tillage machinery, hence, a fast and easy testing of the work results can be achieved by means of a sieve device measuring the share of aggregates with d > 10mm and d > 40mm reproducibly. If the aggregate breaking force (or point-load index) is used to describe the strength of the specific soil, different field conditions can be compared objectively. For comparison, the desired targets depending on the soil type and the crop must be defined.

Based on the former TGL 33738 suggestions should be made for the share of aggregates d < 10mm and d > 40mm for typical soils. To describe the strength of the soil aggregates the aggregate breaking force (point-load index) has to be determined using digital pressure sensors and defined penetrations tools. For controlling of seedbed preparation machines continuously working sensors are required (Grosa 2014).

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Authors

Dr.-Ing. Siegfried Anisch was scientific assistant and group leader for „tillage operation“ at the chair of Agricultural Construction at the Technical University of Dresden (1971–1991) and chief of development at Eberhardt Maschinenfabrik GmbH, Eberhardt-Mengele productions GmbH and Bohnacker AG/Mengele Agrartechnik (1991–2004)

Dipl.-Ing. André Grosa and **Dipl.-Ing. Tim Bögel** are scientific assistants and **Prof. Dr.-Ing. habil. Thomas Herlitzius** is head of the Chair of Agricultural Systems and Technology at Technical University of Dresden, Bergstraße 120, 01062 Dresden, E-Mail: herlitzius@ast.mw.tu-dresden.de.