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Wet Aggregate Stability Test

Purpose and Justification:

Wet aggregate stability is a measure of the extent to which soil aggregates resist falling apart (i.e., slaking) when wetted and exposed to the force of rain drops. This physical soil property is measured using the Cornell Sprinkle Infiltrometer (the rain simulator), which steadily rains on a sieve containing a known weight of soil aggregates between 0.25-2.0 mm in size for five minutes. Unstable aggregates slake and pass through the sieve and are collected and the fraction of soil remaining on the sieve is used to calculate the percent wet aggregate stability. Soils with high wet aggregate stability are more resistant to water and wind erosion and show better overall soil health (e.g., infiltration, root growth, biological activity, etc.).

Each soil sample is placed on a 20cm diameter soil sieve which receives 1.25cm water depth (as drops) in 5 minutes. About 11,700 drops of 4mm diameter with a total weight of 0.393kg are delivered. These drops reach a velocity of 3.1m/s as they fall the 50cm distance (terminal velocity for this sized drop is 8.8m/s). The total Kinetic Energy (KE) delivered in 5 minutes is:

$$KE = \frac{1}{2} m * v^2$$

$$KE = \frac{1}{2} (0.393kg)(3.1m/s)^2$$

$$KE = 1.9 \text{ Joules}$$

Procedure reference: B.N. Moebius, H.M. van Es, R.R. Schindelbeck, O.J. Idowu**,** J.E. Thies, D.J. Clune. (2007) Evaluation of Laboratory-Measured Soil Physical Properties as Indicators of Soil Quality. Soil Science Vol. 172, No. 11, pp. 895-910.

Poster description of the WAS test used in the Cornell Soil Health Assessment (see Figure 1 below): Wet Aggregate Stability Test of Soil Structure in the Cornell Soil Health Assessment Bob Schindelbeck (rrs3@cornell.edu), Kirsten Kurtz, Joseph Amsili, Harold M. van Es.

Objective:

The Wet Aggregate Stability (WAS) of soil health samples is tested on soil air dried to constant weight, using the aggregate size fraction 0.25mm-2mm. From the total weight of dry aggregates tested, the weight of slaked soil and the weight of stones retained on the wetted sieve are measured and the difference determines the percent of stable soil as aggregates.

NOTE: For quarantined soils, see labeled procedures in italics at the bottom of each section.

Materials and Equipment:

Cornell Rainfall Simulator
Filter Paper
Sixteen 0.25mm sieves
Drying oven at 105° C
Aluminum trays
Aluminum drying cans
Plastic cups
Soil sieve brush
Analytical Balance
Two-tablespoon scoop
4-cone portable platform
Sink with sprinkler hose
Squeeze bottles with water
Reverse osmosis system and water storage tank with pump
Tyler sieve shaker
One 2mm, one 0.25mm sieve and one catch pan: all 20cm diameter

Additionally, for quarantine soils:
Plastic working basin to contain all stray soil material
Two 5-gallon buckets
Bleach
Spray bottle with sterilization solution
Latex or nitrile gloves to protect hands
Large basin to bleach quarantine sieves

Sterilization solutions approved for use with Quarantined soil:
Bleach- 10% bleach solution within a labeled spray bottle must be left on contaminated equipment for 30 minutes before rinsing. Ethanol solution (70%) within a labeled spray bottle must be left on contaminated equipment for 30 minutes before rinsing.

Additional Quarantine Protocols:

1. ***In the event of spilling quarantine soil, the soil should be swept up using a hand broom and dustpan and disposed of in an autoclave bag. The hand broom and dustpan as well as any surfaces contaminated with Q soil should be heavily sprayed down with 70% ethanol. The alcohol should be left on surfaces for 30 minutes.***
2. ***In the event of spilling bleach water, the water should be mopped or sponged up and bleached again with a 10% bleach solution for thirty minutes. The mop head or sponge should be disposed of in an autoclave bag and autoclaved. The surface contaminated should be sprayed down with 70% alcohol. After two hours the bleach water can be disposed of down the drain.***

Procedure:

I. Filter preparation:

1. Weigh 300mm diameter high-capacity filters and group them in rounded tenths of grams. For example, if a filter weighs 9.32 grams, group it under 9.3 grams, if it weighs 9.26 grams, group it under 9.3 grams. Oven dry three of each group at 105°C and retain the mean as the weight for each group. These folded filters can be stored in labeled plastic Ziploc for future use.
2. Fold each filter three times to mimic a fluted filter.
3. Once ready for testing, get out the 4-cone portable platforms and lay them out together on a table.
4. Place the filters into the funnels, noting rounded filter weight on the Aggregate Stability data sheet. Choose all filters with the same weight (from the same Ziploc bag in 1. and 2. above). NOTE: Make sure there are no tears or punctures in the folds of the filter. It may be helpful to squirt a *small* amount of water onto the filters to help position them in the funnels - be careful to not over water, as filters are susceptible to failure.
5. The funnels with filters are now ready to receive sieves.

II. Aggregate preparation:

1. On a Tyler Sieve shaker, stack two 200mm diameter sieves (starting at top) 2mm and 0.25mm, and a 200mm catch pan.
2. Add one half cup of air-dry soil that has been sieved past 8mm.
   Always work from within a plastic bin when handling Quarantined soil samples.
3. Shake for 15 seconds, collect the material on top of the 0.25mm sieve. Hand shake material collected on the 0.25mm sieve to eliminate aggregates smaller than 0.25mm.
4. Return other soil material to labeled sample archive bag.
5. Place the saved material sequentially into a labeled plastic cup in a dedicated 15-sample aggregate stability tray. Record sample identities for each set on data sheet.
   Quarantined samples should be clearly marked with a "Q" on the lid.
6. Repeat procedure until 3/4 of a cup of crumbs < 2mm, >0.25mm is obtained.
7. In each tray, sample 16 should contain Quality Control soil prepared as above.
8. Store samples in aggregate stability trays until ready for analysis.

After using sieve shaker and sieves, sterilize these and plastic work bin with a disinfectant solution and let sit for the required time before rinsing.

III. Moisture Correction Factor (MCF- used to convert air dried soil weight to oven dried soil weight (105C) basis):

1. Place about 10g of air-dry soil sample material from each plastic cup into an aluminum drying can.
2. Record the weight of aluminum can and air-dry soil.
3. Oven dry at 105°C to constant weight.
4. Record the weight of aluminum can and 105°C soil.
5. Calculate moisture correction factor (MCF) used in Table 1 column P.

MCF = ((can + air dry soil wt) – (can + 105°C soil wt)) / ((can + 105°C soil wt) – (can wt))
Units are in g water per g air dry soil

IV. Sieve preparation:

1. Set out the dried, 16 pre-weighed, numbered, 200mm diameter, 0.25mm mesh sieves on a bench near the analytical balance.
2. Confirm that the weights of the sieves match what is labeled on the data sheet.
3. WAS samples should be stored in plastic cups in groups of 15, in labeled trays. Sample number 16 in each set is a Quality Control (QC) sample.
   Quarantined samples should be clearly marked with a "Q" on the lid.
4. Using a 2-tablespoon sized scoop, spread about 25 grams of 0.25-2.0mm aggregates in a single layer onto the surface of the 0.25mm sieve, with order of samples corresponding to numbers labeled on each sieve (i.e., sample 1 goes in sieve 1). Spread the soil evenly on the sieve by shaking the soil scoop about six inches above the sieve.
   Spread soil on sieves inside a bin. Discard any leftover soil into an autoclave bag and autoclave as soon as possible. After using scoop and bin, sterilize with a disinfectant solution and let sit for the required time before rinsing.
5. Weigh each sieve and record the total weight of the sieve + aggregates onto the WAS data sheet (Table 1 below- column F "spoon on" heading).
   Weigh sieves on scale, and after using apply sterilizing solution and let sit for the required time before rinsing.
6. Place sieves onto the filters that are resting within the 4-cone portable platforms. NOTE: Make sure that sieves are resting within the cone so that any material falling through the sieve will fall into the filter and not behind it, and that the sieves are resting as parallel to the floor as possible
7. MAKE SURE ALL SIEVES HAVE BEEN WEIGHED BEFORE PLACING THEM UNDER THE SIMULATOR.
8. Do not disturb the soil on top of the sieve. Try to maintain an even distribution of aggregates across the sieve surface. Samples are ready to be placed under the rainfall simulator.

V. Rainfall Simulator Calibration/Preparation:

1. Make sure the rainfall simulator tank contains enough water to run the amount of samples you will prepare.

2. To fill simulator tank, confirm there is enough room temperature, degassed reverse osmosis water in the storage tank.
3. Through the large opening on top of the rainfall simulator tank, insert the clear plastic hose, and flip the pump switch over to turn it on. Water should begin to flow.
4. Fill the rainfall simulator tank as much as possible without completely emptying the storage tank. Turn the pump switch upside down to turn off the pump.
5. Cap rainfall simulator with large rubber stopper.
6. Perform a practice run, record the amount of rainfall delivered in a 5-minute period.
7. DO NOT place samples under the simulator UNTIL AFTER CALIBRATION.
8. Pull out the large rubber stopper and let dripper run for a few minutes. (If you have just filled the tank, this step can be avoided).
9. Prime rain simulator by removing the large rubber stopper for one minute. Replace the large rubber stopper. Now remove the small rubber stopper. Let water flow for a few minutes after bubbles are seen entering under water.
10. Make sure the stopwatch is zeroed and press the start button and simultaneously note the water level on the ruler glued to side of simulator tank. This is measurement one.
11. After 5 minutes, note water level. This is measurement two.
12. Record difference between measurement one and two in the margin on the Wet Aggregate Stability data sheet. This difference should be as close to 1.25cm as possible.
13. If substantially higher or lower than 1.25cm (should be within ±0.1cm), then the rate may be adjusted by sliding the air entry tube inside the tank up or down. Get a faster rate by sliding the tube up, and a slower rate by sliding it down.
14. Minor adjustments are only necessary if there has been an extreme difference in temperature between the last testing and the current testing event.

VI. Wet Aggregate Stability Test:

1. Confirm that all sieves with soil samples have been weighed before placing them onto the filters and funnel apparatus.
   Place catch basin outflow tube into 5 gallon pail to collect all runoff water. When pails have approximately 4 gallons move outflow tube to another pail. To full pails add bleach tablets to obtain a 10% solution. Let pails sit for 30 minutes before discarding treated solution down the drain.
2. With rainfall simulator running, place the first platform of cones, filters, and sieves 0.5m directly under the tank, such that all areas of the sieves are receiving drops.
3. Immediately after placing platform under dripper, start the stopwatch.
4. Throughout a 5-minute period, it is necessary to constantly rotate the tank of the simulator (around its vertical axis) and to allow it to swing very slightly (< 1cm swing) to ensure random delivery of drops to the entire sieve surface. This movement should rotate the simulator ~90 degrees once every 15-30 seconds.
5. At the 5-minute mark, carefully remove the platform from under the dripper and place sieve rack into bin to trap waste water from the draining sieves.
6. Set stopwatch to zero and repeat the test for the other three 4-cone platforms.

Let sieves sit while performing the rest of the tests to allow water in filters to drain, leaving just slaked soil inside the filter.
Spray any water that may have dripped on the floor with an approved Quarantine disinfectant solution and rinse away after the required time.

7. Carefully remove sieves and gently slide filters sideways so retained water drains out of the filter and is not impeded by retained soil. Note that the filters are weakened by the moisture and are easily ripped.
8. The slaked soil particles that failed in the WAS test are now in the filter. To enhance drainage of the water, gently rotate the filter and to shift the soil to a clean area of the filter. Drainage requires 15-30 minutes.

VII. Rinsing the sieve- collecting slaked soil taco and coarse material from sieve top

1. The WAS data sheet should have the pre-experiment sample identity, sample locations and the dry material + sieve weight from the beginning of the test.
2. Identify on data sheet the drying tray and aluminum drying can sets to be used.
3. Place the metal cans in the correct order in a labeled metal tray. Record tray ID.
4. Each sample will require two sequential drying cans – the first (odd numbered) for the moist "soil taco" containing the slaked soil inside the filter paper. The second can (even numbered) will receive the material that would not pass through the washed sieve. This is called the "sand can" on the data sheet.
5. Carefully fold the damp filter paper with the slaked soil sample and place it in the appropriate even numbered can. Do not record the weight before drying.
6. A sink equipped with a tall faucet works best for washing sieves.
7. Set up faucet to deliver a gentle stream of water but avoid splash initiation. Rotate the sieve to expose retained soil to water stream.
   Place bin with a 5-gallon bucket inside it into sink. Catch all water used for sieve rinsing in bucket, add bleach tablets to create a 10% bleach solution and discard after 30 minutes.
8. Wash remaining material THROUGH the sieve such that only clean sand too large for the mesh is left behind (do not lose any sand during washing). Using fingers, rub all stable soil particles less than 0.25 mm through the sieve into sink.
   Catch all water used for sieve rinsing in pail, add 10% bleach and discard after 30 minutes.
9. Using a squeeze bottle with water, starting with a stream of water at one side of the remaining material, slowly move across the sieve, washing the retained material into a tared and labeled aluminum can. This material on the sieve can be rinsed with a squeeze bottle into a temporary staging container. Then rinse all material from the staging container to the target even numbered aluminum can.
10. Before placing aluminum cans into 105°C oven, excess water can be decanted to facilitate drying. Take care not to decant any collected material. Do not record the weight before drying.
    Decant water into 5-gallon pail. Add bleach tablets to create a 10% bleach solution. Discard after 30 minutes. Sterilize any laboratory equipment that encounters quarantined soil.
11. Wash any contaminants out of sieves; shake off excess water and place sieves in 105° C oven for at least 30 minutes or until dry. Allow sieves to cool before cleaning the screen with the sieve brush.
    Disinfect sieves and containers with an appropriate solution for the required time, then rinse and dry in oven.
12. Repeat entire procedure for next batch of sieves.
13. MAKE SURE THAT SIEVES START OUT DRY! Use round sieve brush to clean top and bottom area of dry sieves before beginning another sample set.
14. Place trays into the 105° C oven to dry overnight to constant weight.
    Disinfect any laboratory equipment as well as any surfaces that encounter quarantined soil.

VIII. Weighing rocks and slaked soil:

1. After drying to constant weight in the 105° C oven, remove trays from the oven one at a time.
   Place into bin.
2. The dried, slaked soil and filter (soil taco) and the dried coarse material (sand) are weighed in the aluminum cans.
3. Weigh filter and aluminum can together on the analytical balance, record weight in the "filter and oven dry soil and taco can" column of the Wet Aggregate Stability data sheet (Table 1 below- column G).
4. Weigh aluminum can with stones, record weight in "sand can and oven dry stones" column of the Wet Aggregate Stability data sheet (Table 1 below- column H).
5. Discard filter and stones into compost bucket after they are weighed and recorded.
   Discard sub-samples into autoclave bags and autoclave as soon as possible. Bleach any laboratory equipment as well as any surfaces that encounter quarantined soil.
6. Continue with all filters and cups in tray and repeat for other dried trays.
   Discard sub-samples into autoclave bags and autoclave as soon as possible. Bleach any laboratory equipment as well as any surfaces that encounter quarantined soil.

IX. Data Collection Sheet and Calculations:

An example Wet Aggregate Stability data sheet for use in the laboratory is given in Table 2 below After all data for 16 samples is recorded in the laboratory, it is transcribed into an Excel spreadsheet. In Table 1 below we see the EXCEL spreadsheet column headings where the data is entered.

Table 1. First row of sample data sheet (columns A-L) used in the laboratory. Details shown in columns M-P are only seen in the EXCEL spreadsheet.

DATE:				WET AGGREGATE STABILITY Data Sheet											
Operator:				(2 - 0.25mm diameter crumbs)											
												These columns in yellow are not printed			
column A	column B	column C	column D	column E	column F	column G	column H	column I	column J	column K	column L	column M	column N	column O	column P
					spoon on	dry taco	dry sand								
sample ID	Sample number	dry crumb **TRAY**	Sieve ID	Sieve tare Wt (g)	Sieve+ Dry Soil wt (g)	filter + oven dry soil + **taco can** (g)	**sand can** + oven dry stones (g)	**filter wt.**	**drying tray ID**	**z can taco can ID**	**z can sand can ID**	**z can taco can wt. (g)**	**z can sand can wt. (g)**	**% wet aggregate stability**	**Moisture correction to 105C**
1	**1**	x	1	354.00					U	U1	U2	22.65	22.77	=(((F7-E7)/(1+P7))-(H7-N7)-(G7-I7-M7))/(((F7-E7)/(1+P7))-(H7-N7))*100	

1. In each set of 16 samples that are run, sample 16 is a soil Quality Control (QC) standard which is run as a check.
2. Record the collected laboratory data into the blank cells (columns F-I) in each row.
3. Record ID of aluminum tray and drying can sets in columns J-L.
4. Columns M and N are completed during the data analysis stage from a saved file of tare weights of the aluminum cans.
5. In Column P, enter the Moisture content Correction Factor (MCF- to correct data from air-dry soil weight basis to oven dry soil weight basis). See section *III* above.
6. When all the data are entered, highlighting the cell in column O of each row in an Excel table would reveal the formula used in the calculation of WAS.

Equations 1 and 2 below describe the calculation of wet aggregate stability % from the collected data.

Equation 1. Percent Stability of Aggregates (all weights in grams) =
(((initial dry material on sieve - sieve wt) / (1+MCF)) - (dry sand and organic material in can - can wt)) - (dry filter and failed soil - filter wt - can wt)) / (((initial dry material on sieve - sieve wt) / (1+MCF)) - (dry sand and organic material in can - can wt)) * 100

Equation 2. Percent Stability of Aggregates =
(((column F- column E) / (1+column P)) - (column H - column N) - (column G - column I - column M)) / (((column F – column E) / (1+ column P)) - (column H - column N)) * 100

Table 2. Wet Aggregate Stability datasheet

DATE:		**WET AGGREGATE STABILITY Data Sheet**									
Operator:		**(2 - 0.25mm diameter crumbs)**									
column A	column E	column C	column D	column E	column F	column G	column H	column I	column J	column K	column L
					spoon on	dry taco	dry sand				
sample ID	Sample number	dry crumb **TRAY**	Sieve ID	Sieve tare Wt (g)	Sieve+ Dry Soil wt (g)	filter + oven dry soil + **taco can** (g)	**sand can** + oven dry stones (g)	**filter wt.**	**drying tray ID**	**z can taco can ID**	**z can sand can ID**
	1		1								
	2		2								
	3		3								
	4		4								
	5		5								
	6		6								
	7		7								
	8		8								
	9		9								
	10		10								
	11		11								
	12		12								
	13		13								
	14		14								
	15		15								
QC	**16**		16								

Figure 1. Wet Aggregate Stability Test of Soil Structure in the Cornell Soil Health Assessment. Bob Schindelbeck (rrs3@cornell.edu), Kirsten Kurtz, Joseph Amsili, Harold van Es.