Laboratory measurement techniques

FILE I

PSD

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Experimental protocol

Laboratory procedure steps are described by the following points:

1) Soil core preparation and pre-treatment

2) Hydrometer measurement

3) Sieve analysis

4) Calculation of particle size

Gee, G.W., Or, D., 2002. Particle-size analysis: hydrometer method. In: Dane, J.H., Topp, G.C. (Eds.), Methods of Soil Analysis: Part 4 – Physical Methods. SSSA Book Series 5, Soil Science Society of America, Madison, USA.

Preparation of the dispersing solution

35.70 g of sodium polyphosphate ($NaPO_3$)

7.94 g of sodium carbonate anhydre (Na_2CO_3)

1000 mL of deionized water

Dispersing solution is agitated for about 30 minutes with a mechanic magnetic shaker

Dispersing solution concentration is 5%.

Disturbed soil cores collected in field

The soil sample is placed in the oven and dried at 40°C for 24 hours. After removal from the oven, the samples are milled with a mechanical grinder. Therefore the shattered material is sieved in a 2 mm diameter square mesh and it is ready for the hydrometer measurement.

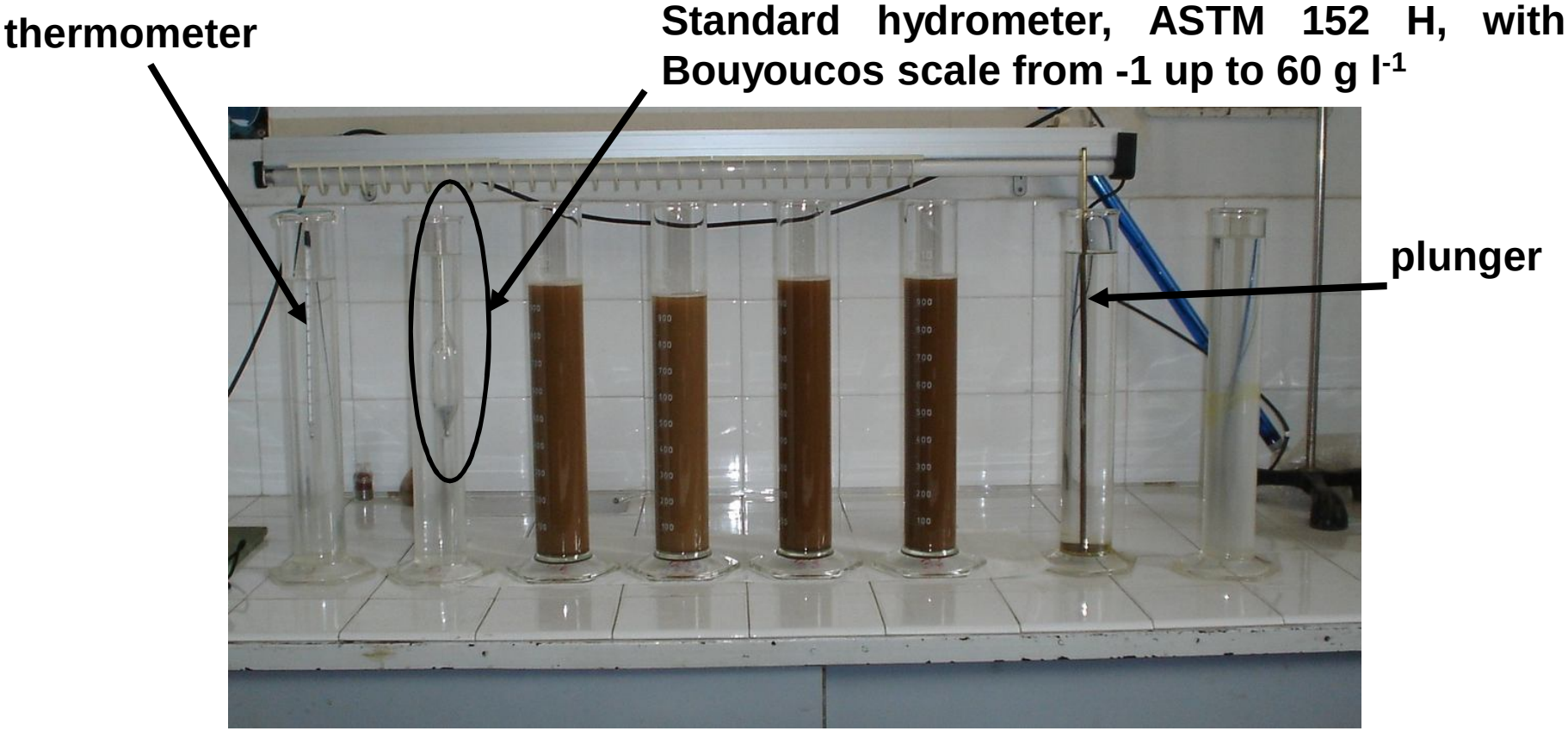
Mechanical grinder

Dispersion of soil: weigh 40.0 g of oven-dried soil (SW) at T = 105 °C, put it into a beaker, add 100 mL of dispersing solution, and allow the sample to soak overnight.

blade electric mixer with a speed of 10,000 rpm

Transfer the dispersed-treated sample into a cup and mix for 5 minutes with the electric mixer, then transfer the suspension to the sedimentation cylinder and add further deionized water to bring the volume to 1000 mL

The resulting suspension needs to equilibrate thermally and temperature has to be recorded. Insert the plunger into the cylinder and mix the content thoroughly. Hold the bottom of the cylinder to prevent tipping. Dislodge sediment from the bottom using strong upward strokes of the plunger. Finish stirring with two or three slow, smooth strokes. Add a drop of amyl alcohol if the surface of the suspension is covered with foam. As soon as mixing is completed, lower the hydrometer into the suspension and take readings after 30 seconds and again at the end of 1 minute. Remove the hydrometer, rinse, and wipe it dry. Reinsert the hydrometer carefully about 10 seconds before each reading and take readings at 3, 10, 30, 100, 210, and 1440 minutes.



Hydrometer

The hydrometer is used to measure the solution density of a suspended soil solution during a sedimentation process

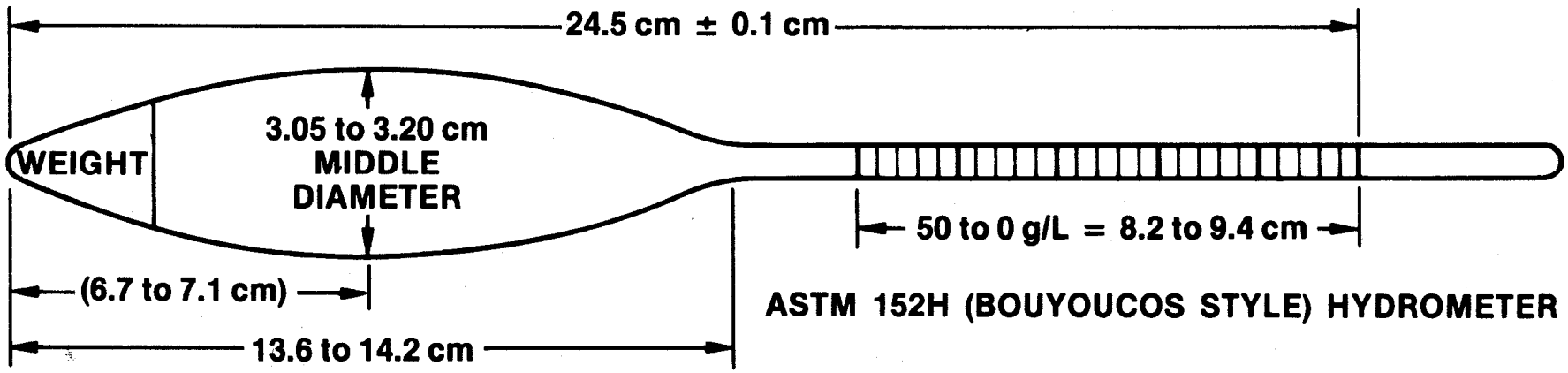
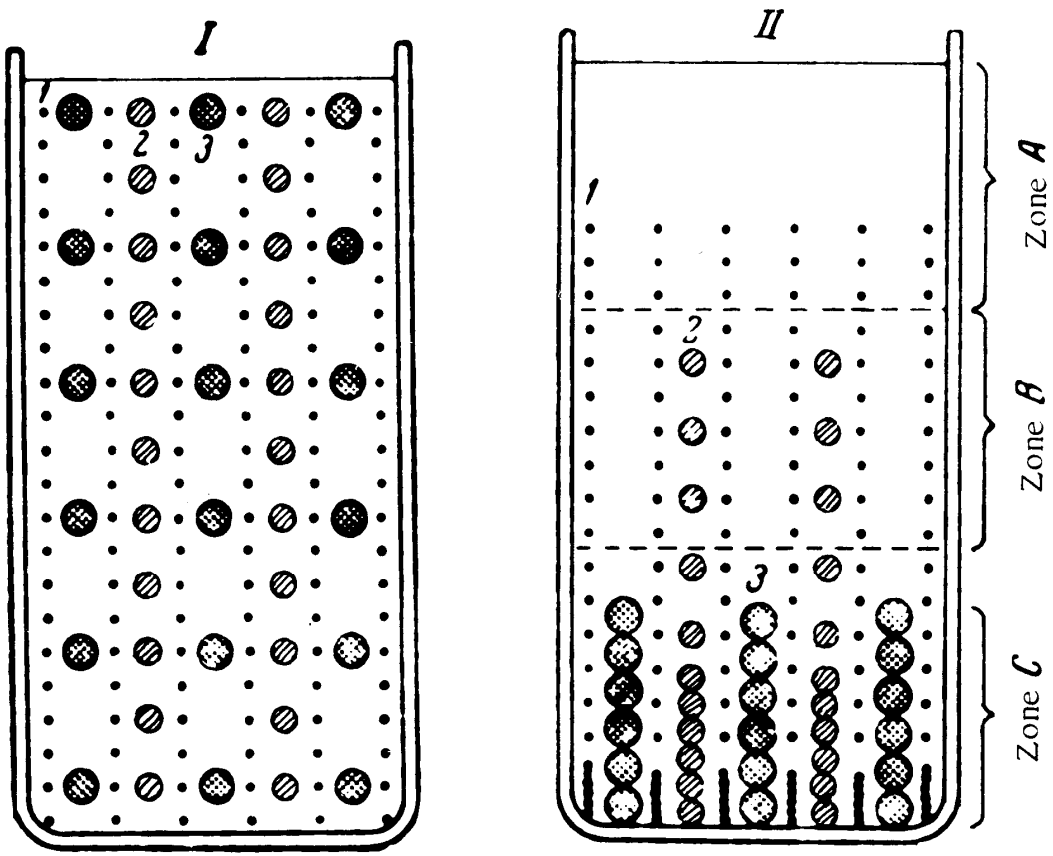


Fig. 15–6. Schematic diagram of ASTM 152 H-type hydrometer.

Sedimentation method

This method is based on Stokes' law (1851) relating particle settling velocity in the suspension to the particle diameter

$$V = \frac{g}{18}\frac{\rho_s - \rho_w}{\eta}d^2$$



Assumptions:

1 - Spherical and smooth particles

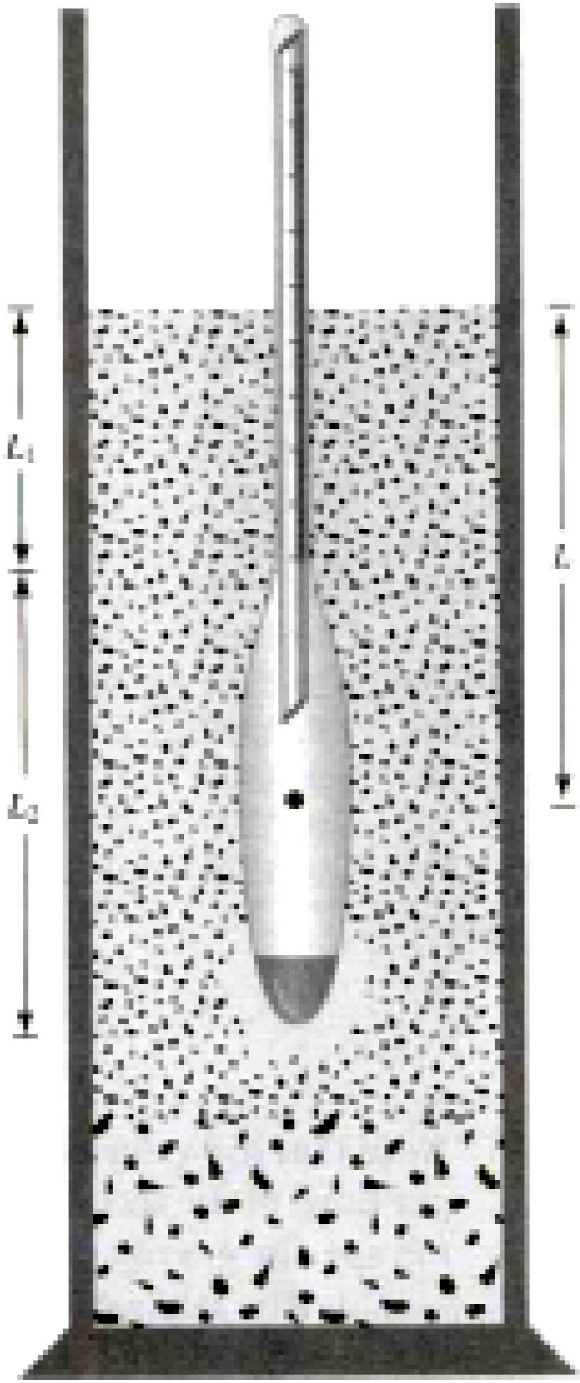
2 - Absence of particle interactions

3 – Settling velocity is due only to viscosity

The hydrometer sinks into the soil solution as smaller particles settle.

The density measurements (R expressed in g/L of solution) are measured on the stem of the hydrometer and are referred to the height of sedimentation (h) according to the following relation:

h (cm) = -0.164*R (g/L) +16.3 (units????)



Density measurements are associated to the suspended particle diameter *d* (μm) at height *h* (cm) through the Stokes' law:

$$d = \frac{\theta}{\sqrt{t}}$$

$$\theta = 10000\sqrt{\frac{30\eta h}{g(\rho_s - \rho_l)}}$$

For every reading it is possible to determine suspended solid material concentration and the relative maximum diameter

***t* is cumulated time in seconds**

T (°C)	ρ_w (g/cm^3)
0	0.99984
1	0.99990
2	0.99994
3	0.99997
4	0.99997
5	0.99997
6	0.99994
7	0.99990
8	0.99985
9	0.99978
10	0.99970
11	0.99961
12	0.99950
13	0.99938
14	0.99924
15	0.99910
16	0.99894
17	0.99877
18	0.99860
19	0.99841
20	0.99820
21	0.99799
22	0.99777
23	0.99754
24	0.99730
25	0.99704
26	0.99678
27	0.99651
28	0.99623
29	0.99594
30	0.99565

Read the hydrometer after placing it in the blank solution (containing no soil), and record the blank reading as RL and the temperature at each time. This is necessary to correct each reading (R) from the dispersing agent and temperature effects which influence density suspension (ρ_w) and dispersing solution viscosity (η).

T (°C)	η (g/ cm*s)
0	0.0182
5	0.0155
10	0.0133
20	0.0102
30	0.0081
40	0.0067
50	0.0056
60	0.0048
70	0.0041
80	0.0036
90	0.0032
100	0.0029

Compute concentration of soil in suspension at time t:

$$C(t) = R(t) - RL$$

Compute the summation percentage for each diameter class:

$$P = C/C_0 * 100$$

where C_0 is the oven dried weight of soil sample divided by volume of liquid (40 g/L)

Example: according to each calculated diameter, P(%) is calculated

sedimentation data	
d (mm)	**P (%)**
0.0297	77.5
0.0145	72.5
0.0082	62.5
0.0046	52.5
0.0030	48.75
0.0014	36.25

Quantitatively transfer the sediment and suspension from the sedimentation cylinder through a *50* μm sieve. The sediment is washed using a wash bottle or gentle stream of water. The *50* μm screen can be dipped in a soap solution to improve the wettability of the screen and speed the flow. Transfer the sand to a tared beaker or aluminum weighing dish, dry (105°C), and weigh.

The sandy fraction is transferred into the oven and dried for about 24 hours

Transfer the dried sand to the nest of sieves arranged from top to bottom in the following order: 1000, 500, 250, 100, and 50 μm. Shake on a sieve shaker for 5 min. Weigh each sand fraction and the residual silt and clay that has passed through the 50-μm diameter square mesh woven bronze wire cloth.

Sieving data: particle fractions are cumulatively weighted by decreasing diameter square mesh woven bronze wire cloth

Sieving data

Example:

hold P (%) = cW/SW*100 = cW/40 *100

where SW is soil weight (40 g)

P (%) = 100 – hold P

sieve diameter	cumulated weight (cW)	hold P	P
mm	g	%	%
2.00	0	0	100
1.00	0.84	2.10	97.9
0.50	1.84	4.60	95.4
0.25	3.23	8.08	91.9
0.10	5.26	13.15	86.9
0.05	6.76	16.90	83.1

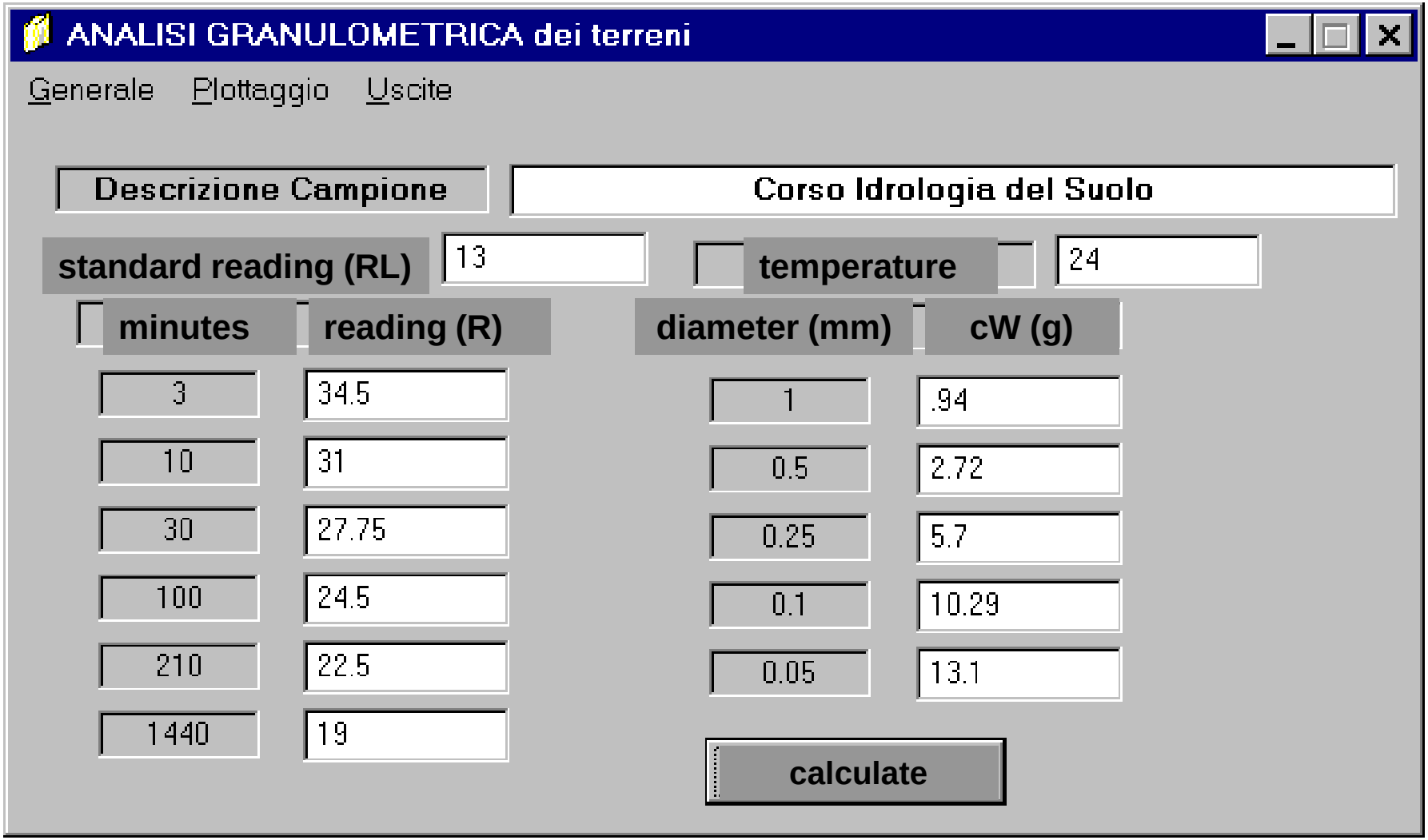
SEDIMENTATION DATA				SIEVING DATA	
time	Hydrometer R	W R	T	sieve diameter	cumulated weight
min	g l^{-1}	g l^{-1}	°C	mm	g
3	40	9	28	2.00	/
10	38	9	28	1.00	0.84
30	34	9	28	0.50	1.84
100	30	9	28	0.25	3.23
210	28.5	9	28	0.10	5.26
1440	23.5	9	28	0.05	6.76

Data sheet for the readings

At the end of the measurement, 11 measured points are calculated to obtain the particle-size distribution (PSD)

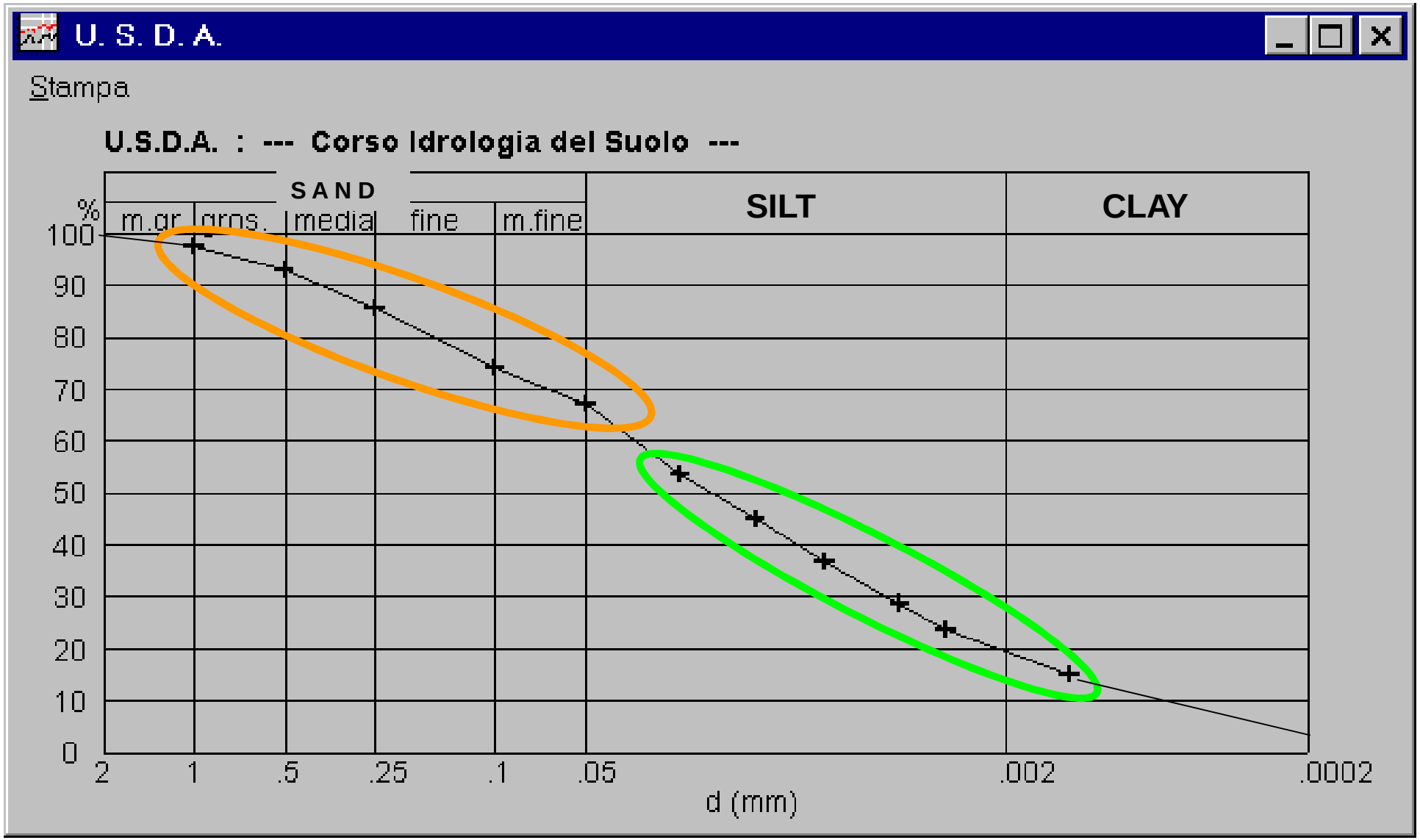
TOTAL	
diameter (mm)	P (%)
2.00	100
1.00	97.9
0.50	95.4
0.25	91.9
0.10	86.9
0.05	83.1
0.0297	77.5
0.0145	72.5
0.0082	62.5
0.0046	52.5
0.0030	48.8
0.0014	36.3

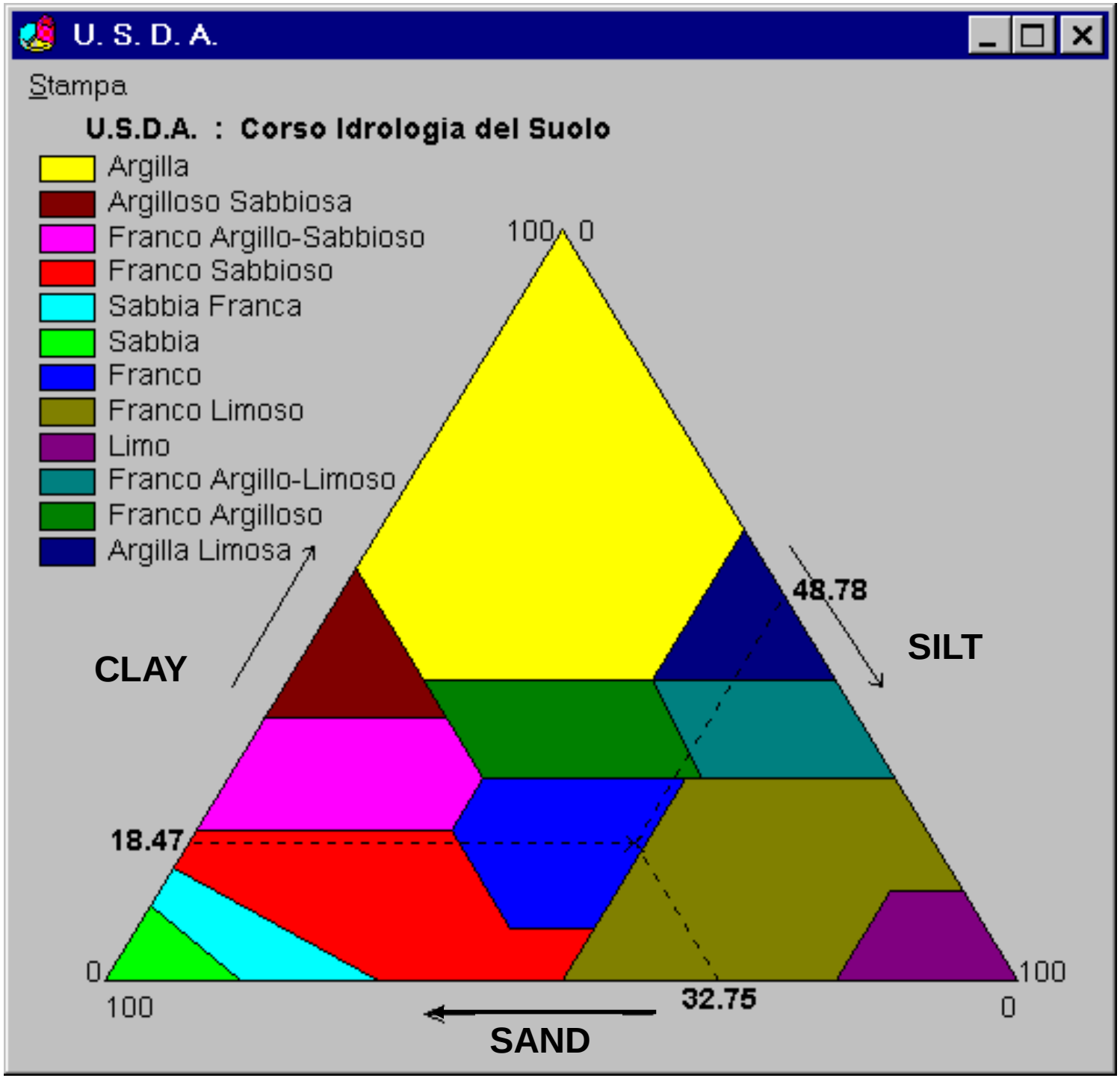
AGT software for determining the PSD curve and texture classes according to USDA or ISSS



sieving data

sedimentation data




U. S. D. A.
Stampa
U.S.D.A. : Corso Idrologia del Suolo
Argilla
Argilloso Sabbiosa
Franco Argillo-Sabbioso
Franco Sabbioso
Sabbia Franca
Sabbia
Franco
Franco Limoso
Limo
Franco Argillo-Limoso
Franco Argilloso
Argilla Limosa
100
0
48.78
SILT
CLAY
18.47
0
100
100
32.75
0
SAND

Example of a USDA texture classification for a dataset of 88 soil cores