Laboratory measurement techniques

FILE II

WRF

Laboratory of Soil Hydrology

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THEORY I

Soil water content, θ

Volumetric water content, θ_v

$$\theta_v = \frac{V_w}{V_{tot}} = \frac{M_w / \rho_w}{V_{tot}} = \frac{M_w}{V_{tot}}$$

Gravimetric water content, θ_g

$$\theta_g = \frac{M_w}{M_d}$$

Conversion from θ_g to θ_v

$$\theta_v = \theta_g \rho_b$$

Where soil bulk density, ρ_b

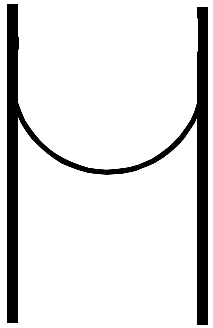
$$\rho_b = \frac{M_d}{V_{tot}}$$

Where *V* and *M* signify volume and mass, respectively whereas the subscripts *w*, *d* and *tot* denote water, dry soil and total, respectively

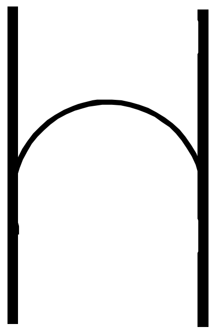
THEORY II

Soil matric potential, h

Definition of capillarity is related to water surface tension that is caused by the disequilibrium of two different non-miscible fluids (air and water) in contact with a solid wall.

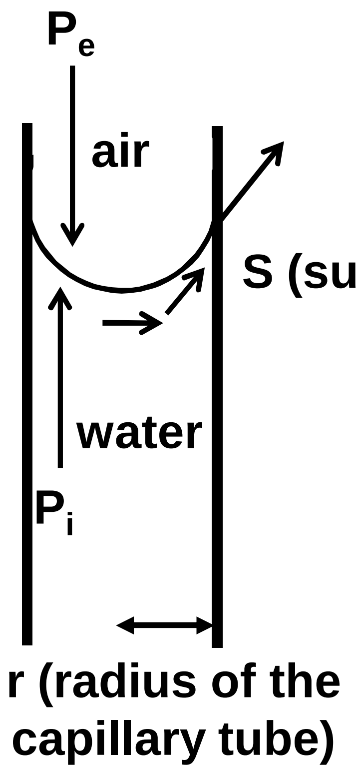


Adhesion: tendency of dissimilar particles to cling to one another (water and solid particles)



Cohesion: tendency of similar particles to cling to one another (mercury)

THEORY III



Soil matric potential, h

Hydrostatic equilibrium

$$\sum \vec{F} = 0$$

$$p_i A - p_e A = sC$$

where C is the girth of the water bend in contact to the wall of the solid capillary tube

$$p_i \pi r^2 - p_{atm} \pi r^2 = S \cos\alpha \, 2\pi r$$

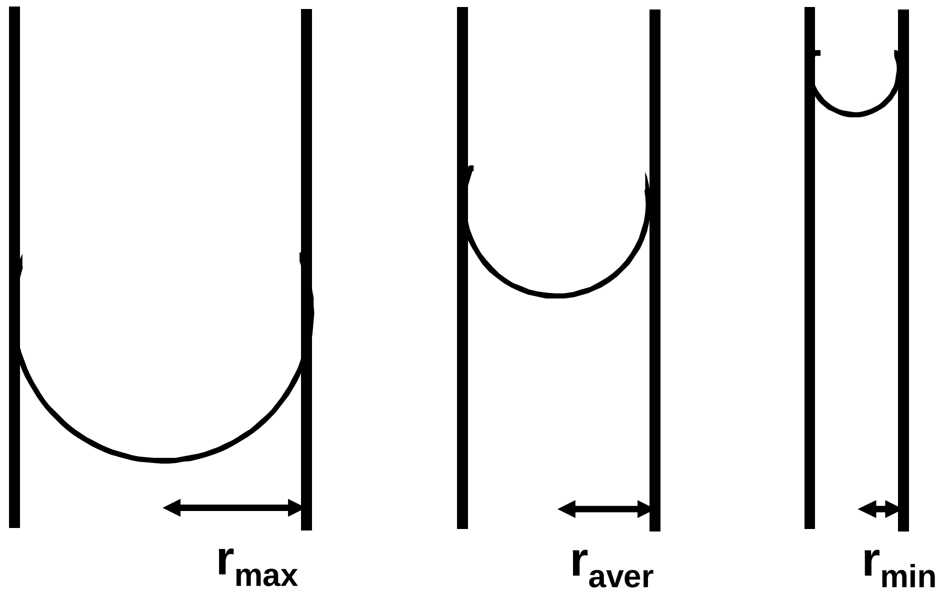
"Scosα" is the vertical component of S

$$p_i = p_{atm} - 2\frac{S\cos\alpha}{r}$$

hence units of S are N/m and p_i is a pressure head in N/m²

THEORY IV
Water retention function (WRF)

WRF relates soil water content to the energy status of the soil which depends on the capillary force



p_{small}= -2scosα/r_{max}

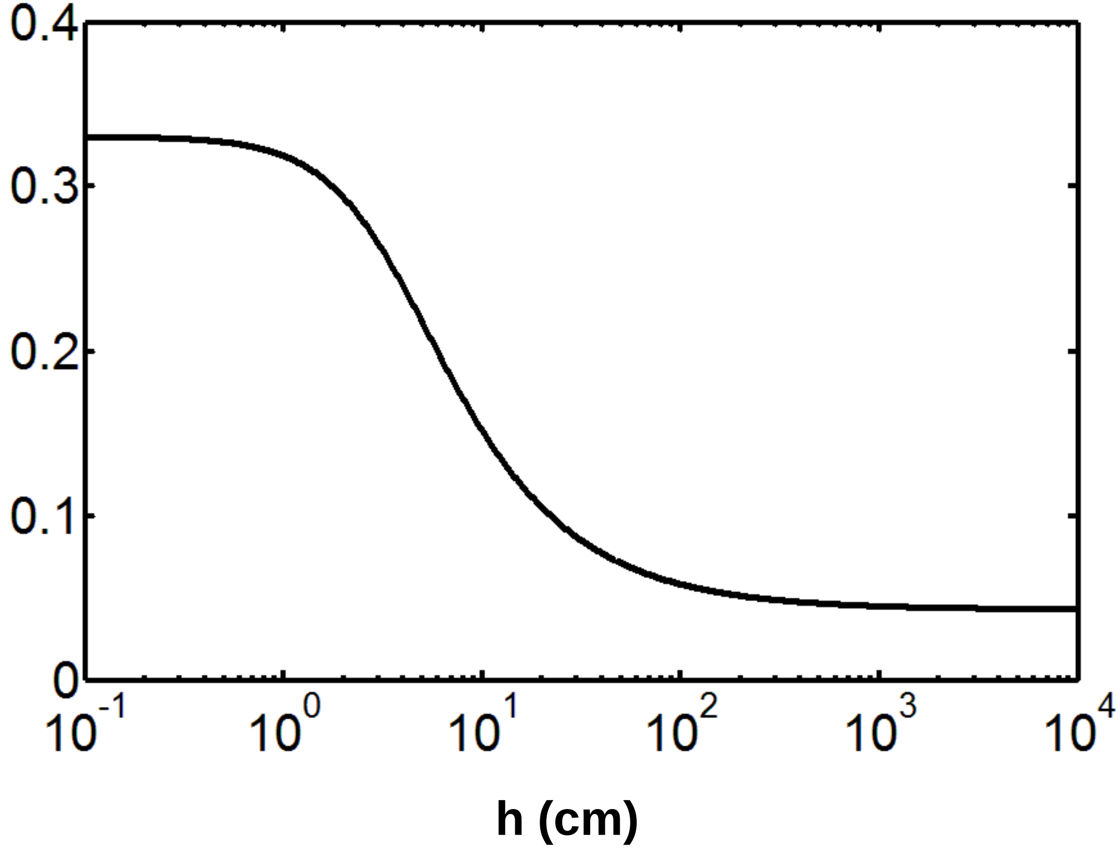
p_{aver}= -2scosα/r_{aver}

p_{large}= -2scosα/r_{min}

h=p/γ to express matric potential in length units (L)

THEORY V
Water retention function (WRF)

WRF relates soil water content to the matric potential

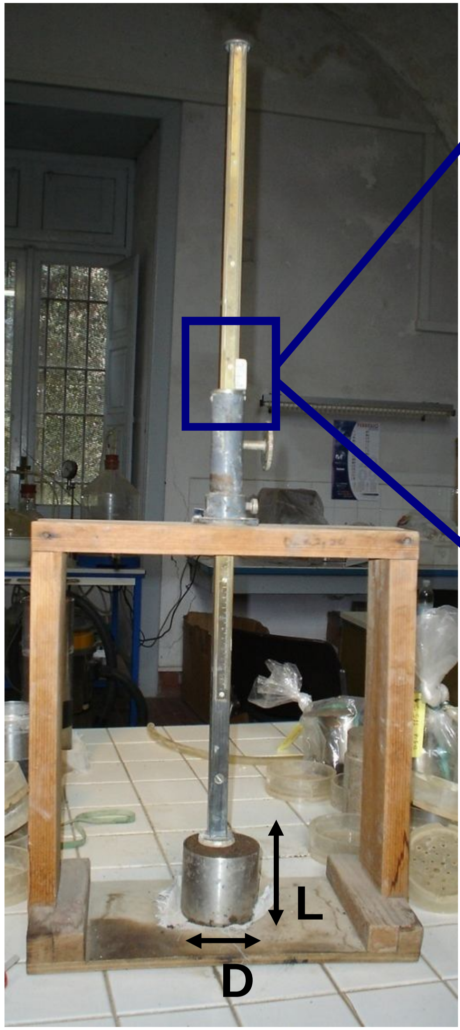


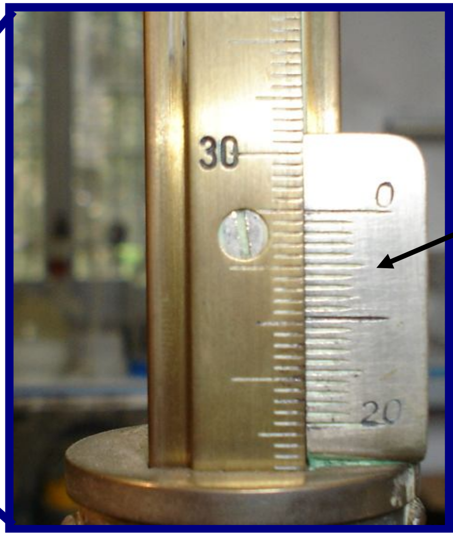
Suction table

Preparation of undisturbed soil cores

Soil core preparation for the K_s measurement

measuring height (L, in cm) of the soil core





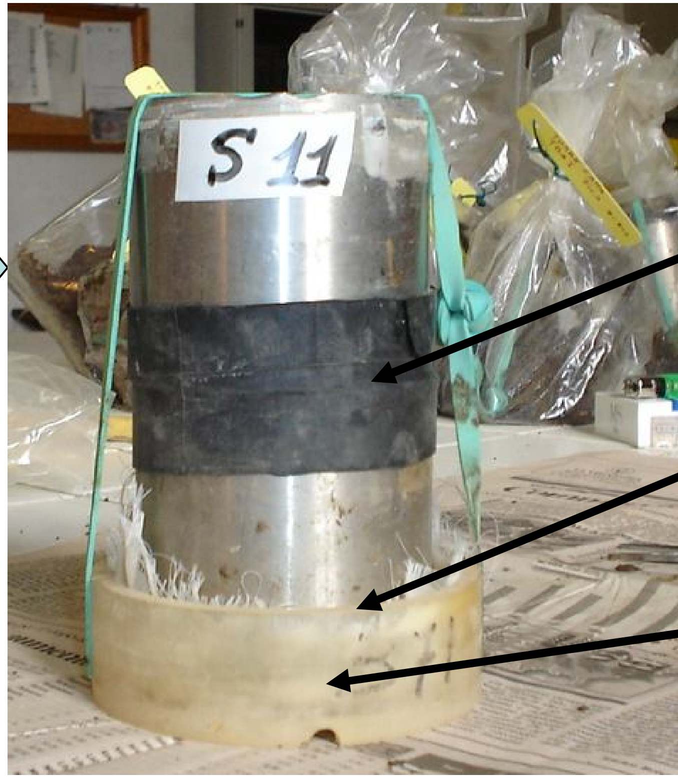
vernier scale

$L = 7.10$ cm

$D = 7.20$ cm

$A = 40.715$ cm^2

$V_t = A \times L = 289.077$ cm^3

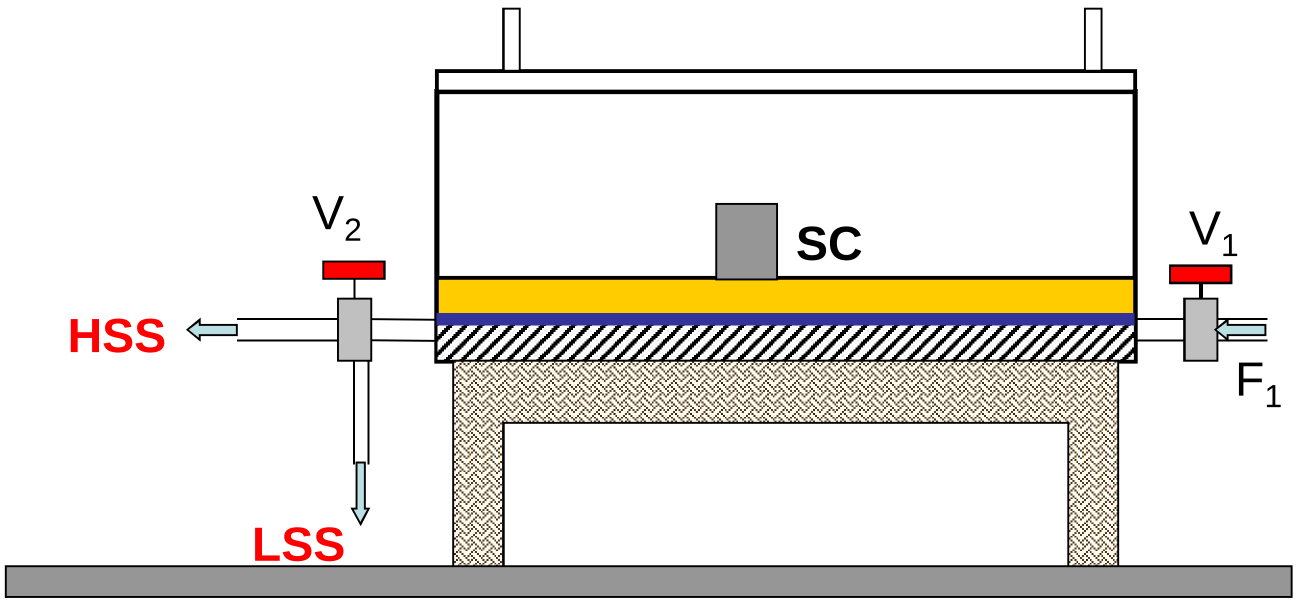


rubber gasket

cheesecloth to avoid loss of soil particles

plexiglass underpinning

Suction table



The water retention characteristics is determined from saturation to a minimum matric head of about -2.0 m. Water-saturated soil samples are placed on a porous barrier subjected to suctions, (or negative pressures). The porous barrier consists of one or more layers of fine materials (mix of kaolin and clay) and the maximum allowable suction depends on the air-entry characteristics of the material placed in the suction table apparatus.

LSS = low suction system

HSS = high suction system

V_1= two-way stopcock valve

V_2= three-way stopcock valve

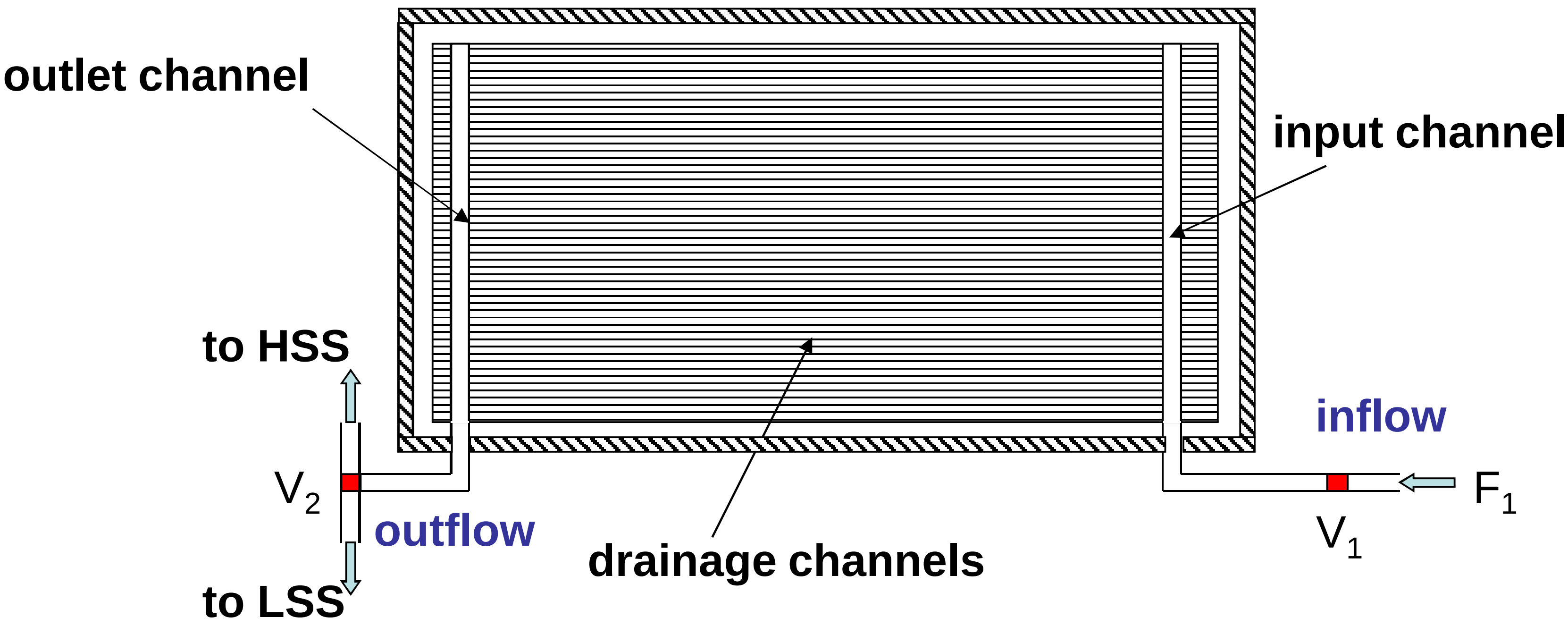
F_1= water refill flask

SC = soil core

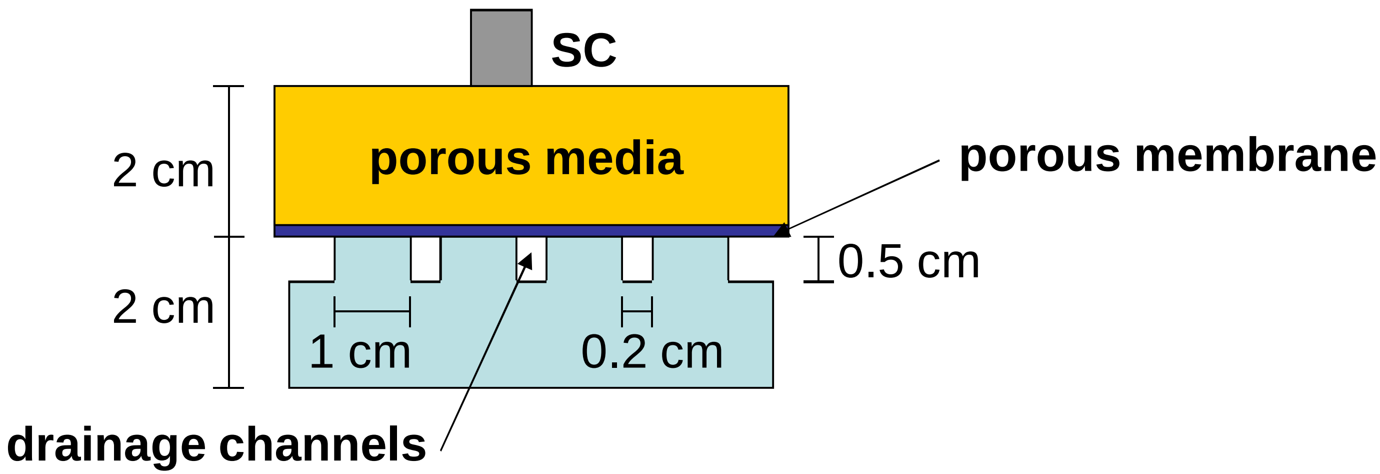
A series of static equilibria is imposed between the water in the soil samples and a free body of water contained in a suction control system at known suction. The volumetric soil water content, θ, is thus determined at each suction step (after hydraulic equilibrium is reached). These pairs of measured θ and h values represent data points of the soil water retention curve.

Romano, N., Hopmans J.W., Dane J.H., 2002. Suction tables. In: Dane, J.H., Topp, G.C. (Eds.), Methods of Soil Analysis, Physical Methods, Part 4, SSSA, Madison, WI.

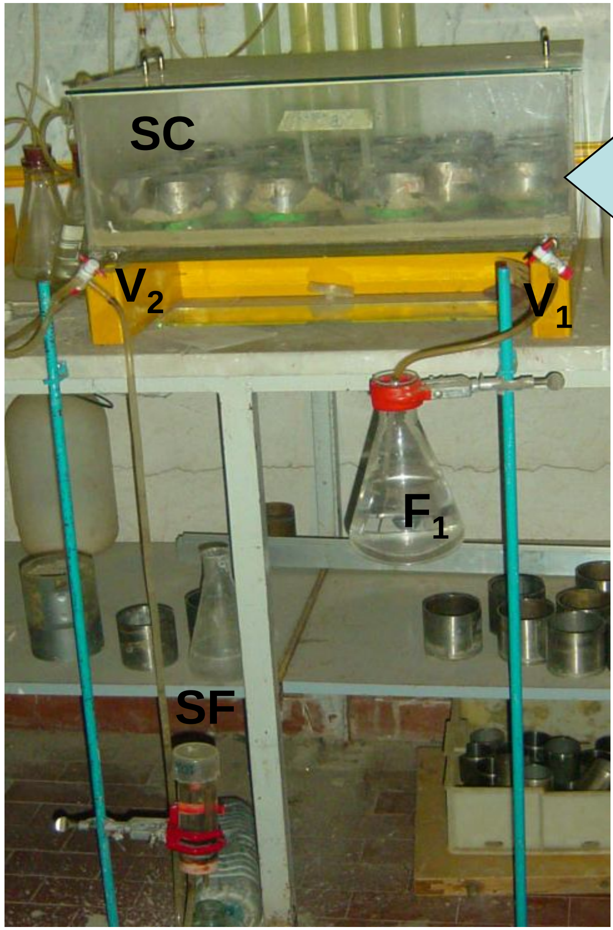
View of the base of the suction table



Transversal section of the base of the suction table



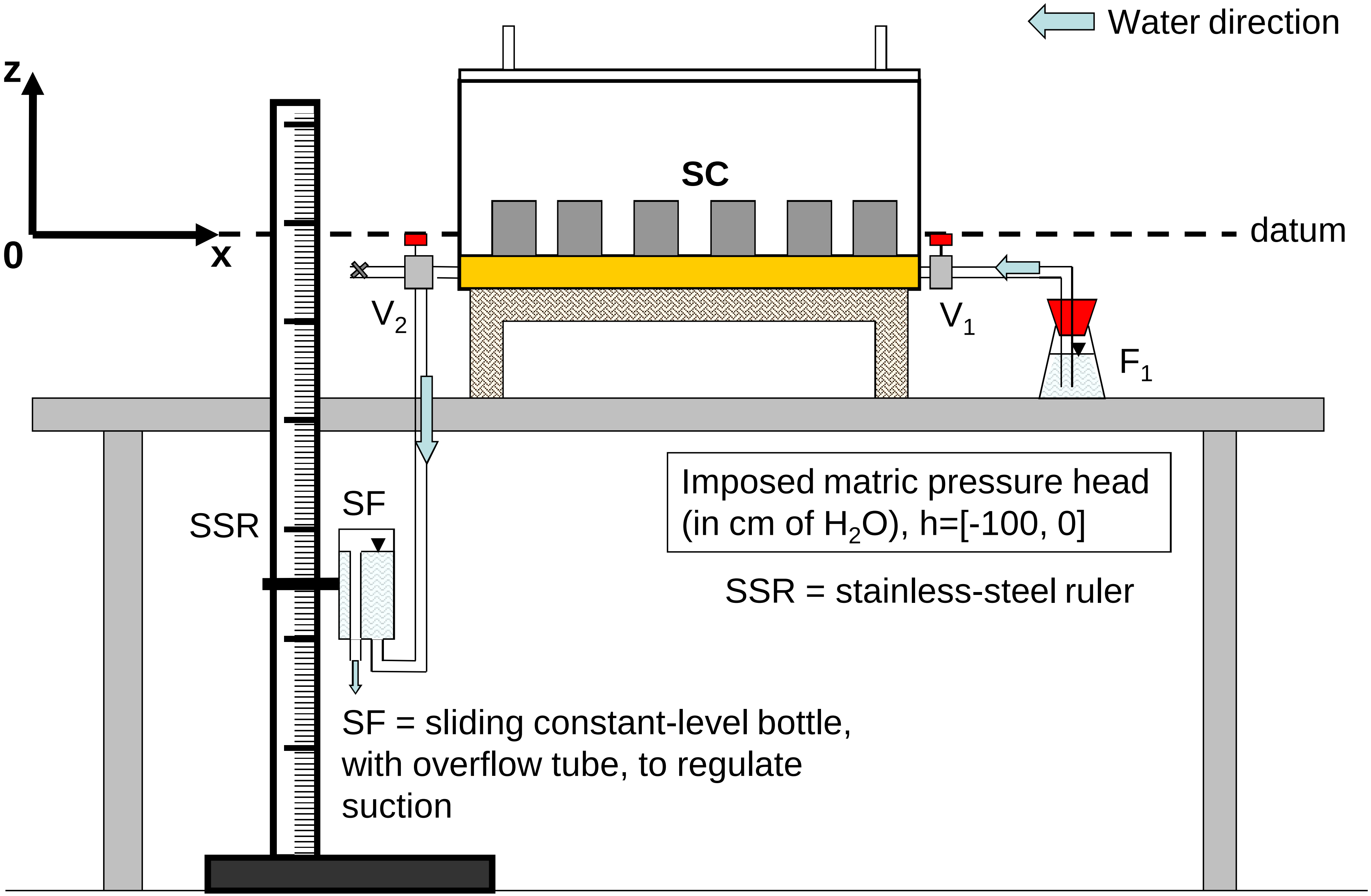
Low suction system (LSS)



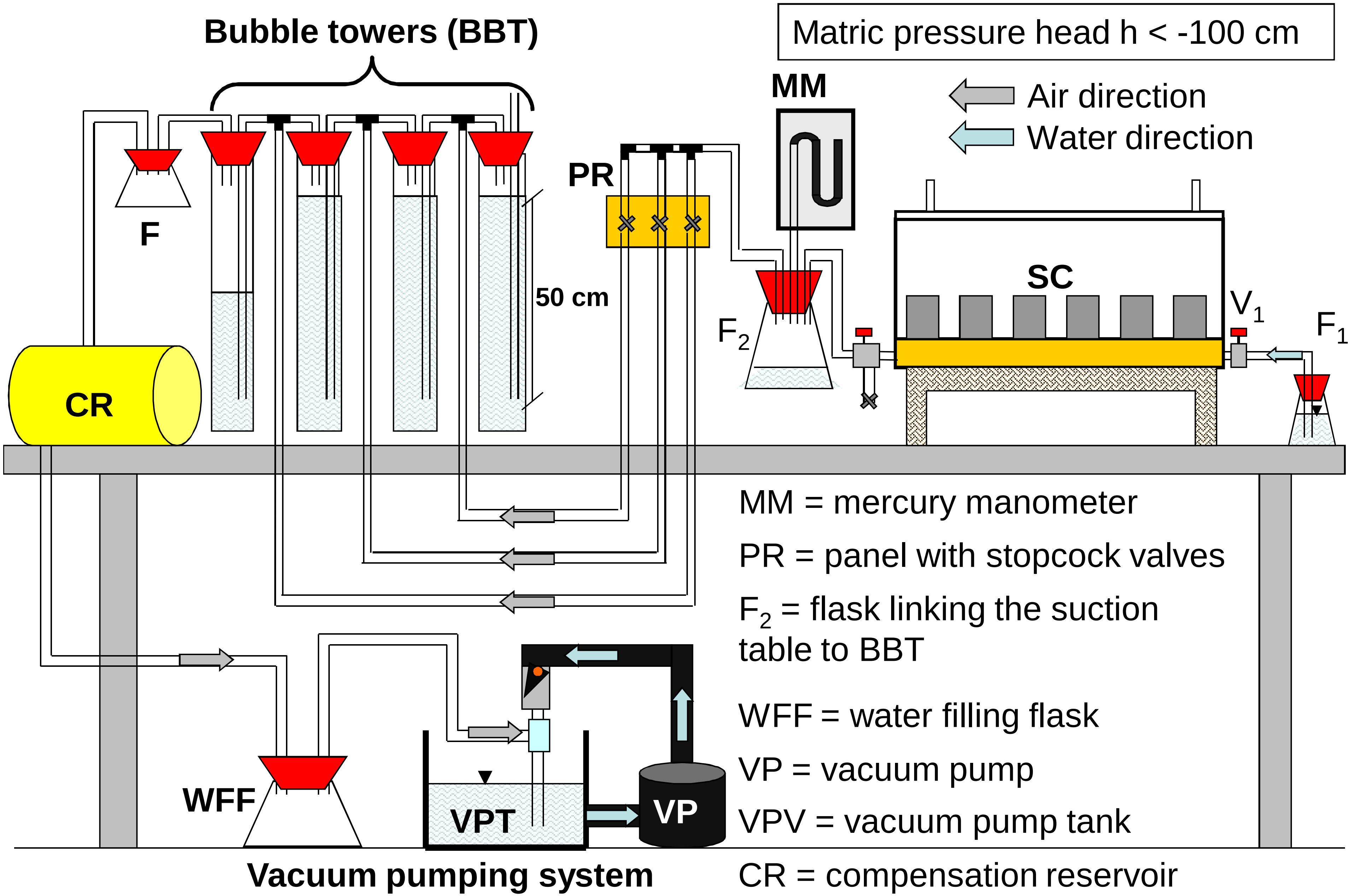
Soil samples are saturated with a deaerated 0.005 M $CaS0_4$ solution

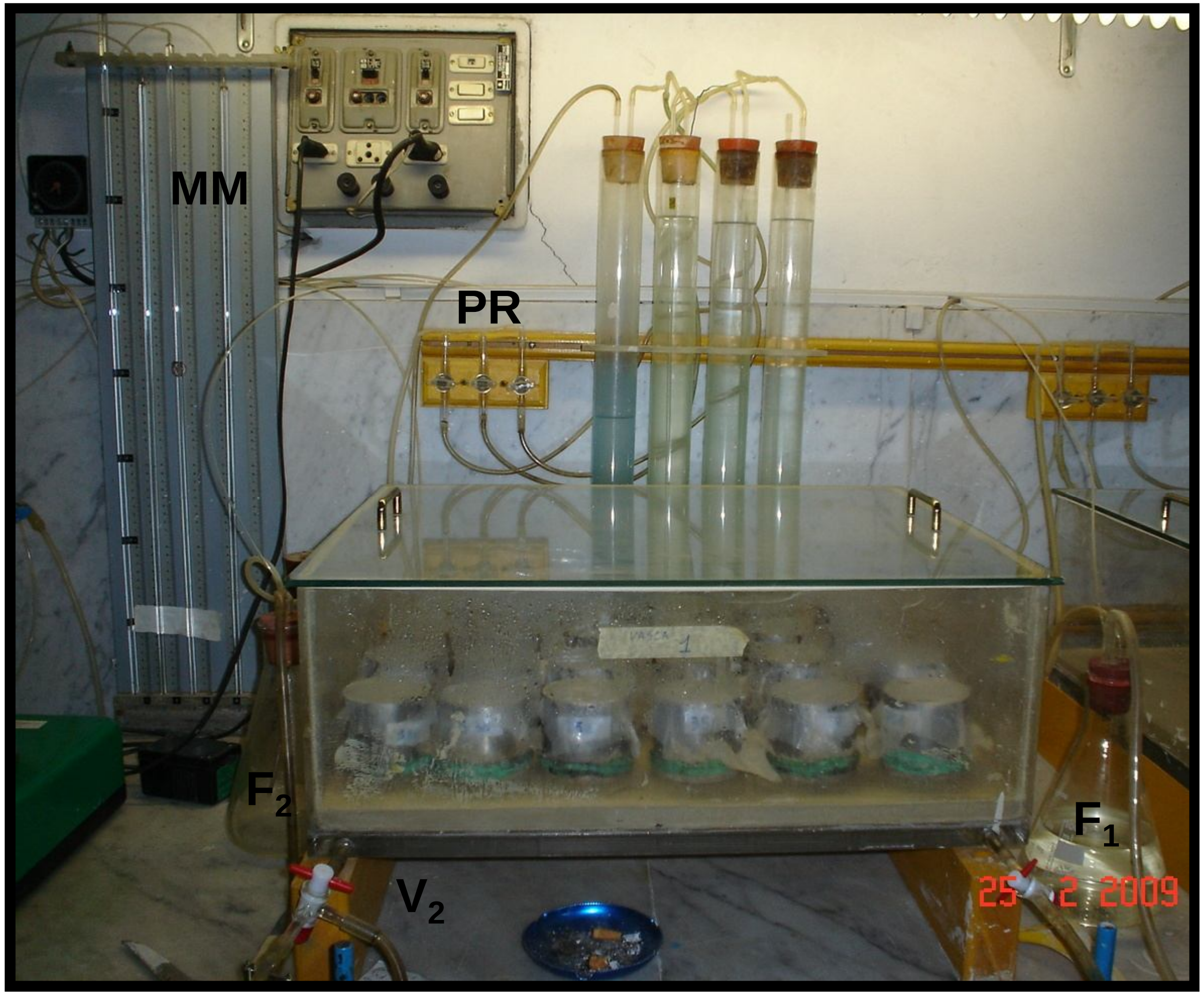
Generally 24 samples are weighed to obtain the mass of the saturated samples and then placed on the suction table by pressing them slightly to guarantee hydraulic contact between the soil and the porous bed material

Low suction system (LSS)



High suction system (HSS) - bubble towers + vacuum pumping system





Bubble towers system

A constant-head cylinder system now controls the applied suction. This device is comprised of a number of Mariotte clear plastic or glass cylinders placed in series to form bubble towers. Each cylinder is about 5.0 cm in diameter and has a two-hole rubber stopper at the top. A bubble tube, about 2 to 3 mm inside diameter, is inserted in one hole of the rubber stopper, whereas the other hole is used to receive a short glass tube for the connection to the adjacent cylinder via plastic tubing and a T-shaped connector.

Vacuum pumping system

One end of each T-shaped connector is linked to a two-way glass stopcock valve placed on a panel. These stopcock valves control the sequential operation of the constant-head cylinders. The lower end of each cylinder also has a rubber stopper. Depending on the length of the bubble tubes and the number of the cylinders in use, different constant water suctions can be obtained up to approximately 2.0 m.

Bulk density measurement (ρ_b)

Once the sample masses have been recorded for the final suction level, the soil samples are placed in an oven and dried at 105°C for 24 to 48 hours. Upon removal from the oven, the samples are transferred to a desicator with an active desiccant, and weighed again after they have cooled to room temperature to obtain the dry mass (M_s).

M_s **= 332.27 g**

$$\rho_b = \frac{M_s}{V_t}$$

$\boxed{\rho_b = 332.27\ \mathrm{g} / 289.077\ \mathrm{cm}^3 = 1.15\ \mathrm{g\ cm}^{-3}}$

Water content values, θ, at all applied suctions are calculated with the following equations:

h (cm)	M_t (g)	θ ($cm^3\ cm^{-3}$)
0	541.50	0.506
-3	536.75	0.478
-5	534.79	0.467
-7	532.77	0.456
-9	530.95	0.445
-13	527.96	0.428
-20	524.31	0.408
-30	522.07	0.395
-50	519.93	0.383
-70	518.41	0.374
-104	517.55	0.369
-155	516.26	0.362
-188	515.65	0.358

θ_s

LSS

HSS

$$M_w = M_t - \text{Tare} - M_s$$

$$V_w = M_w / \rho_w$$

$$\theta = \frac{V_w}{V_t}$$

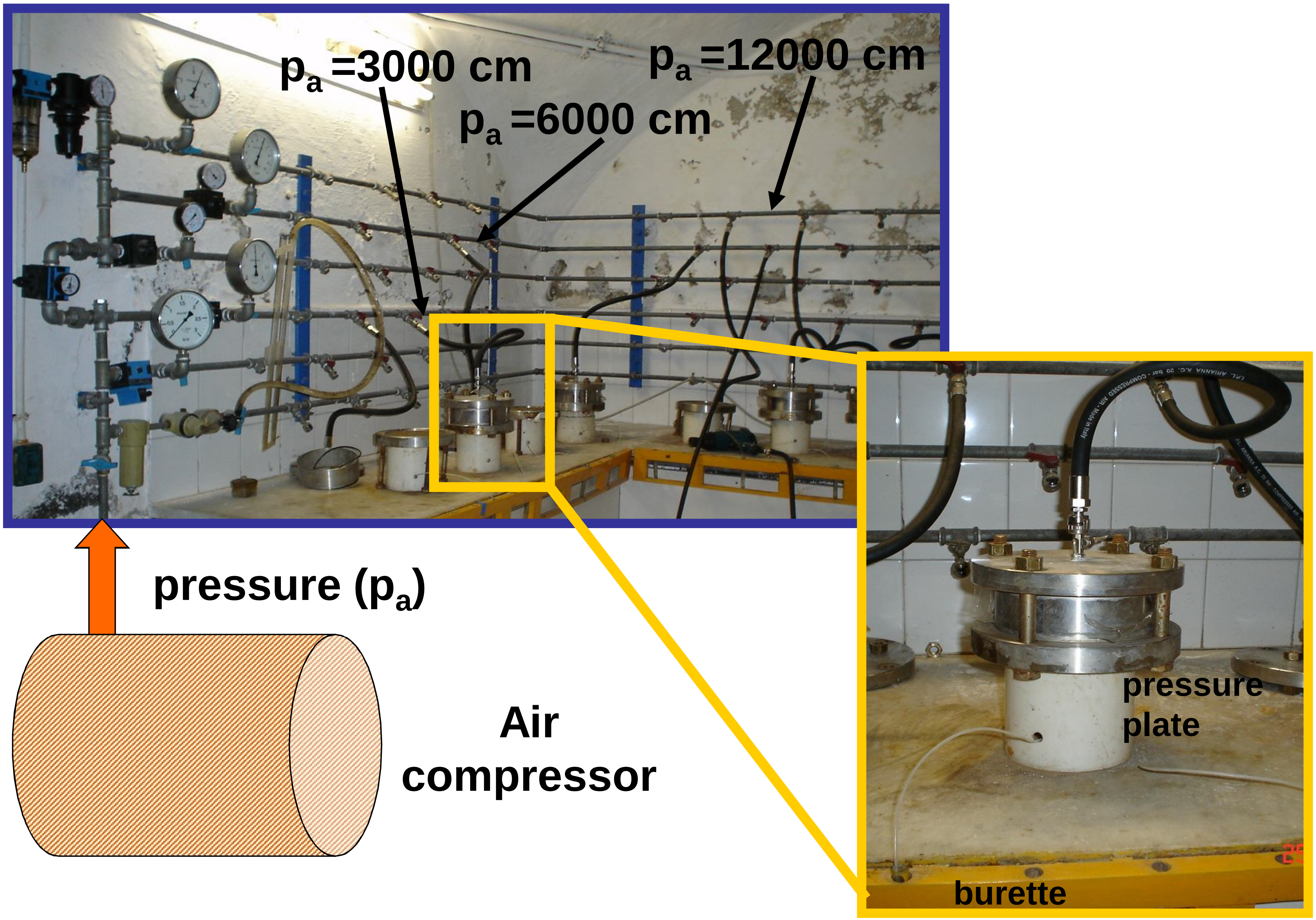
Tare = 9.23 g (elastic bands, cheesecloth) + 112.51 g (steel sampler)

Pressure plate apparatus

Disturbed soil cores collected in field

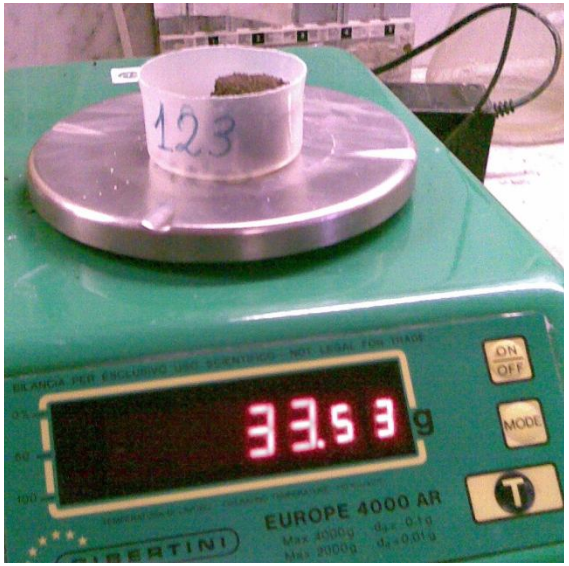
Mechanical grinder

Pressure plate apparatus



Soil cores are weighted after the pressure plates measurements (M_w) and after the oven-desiccation at 105 °C for 24 hours (M_s)

Tare



M_w + Tare

Permeable cellulose membrane

M_s + Tare

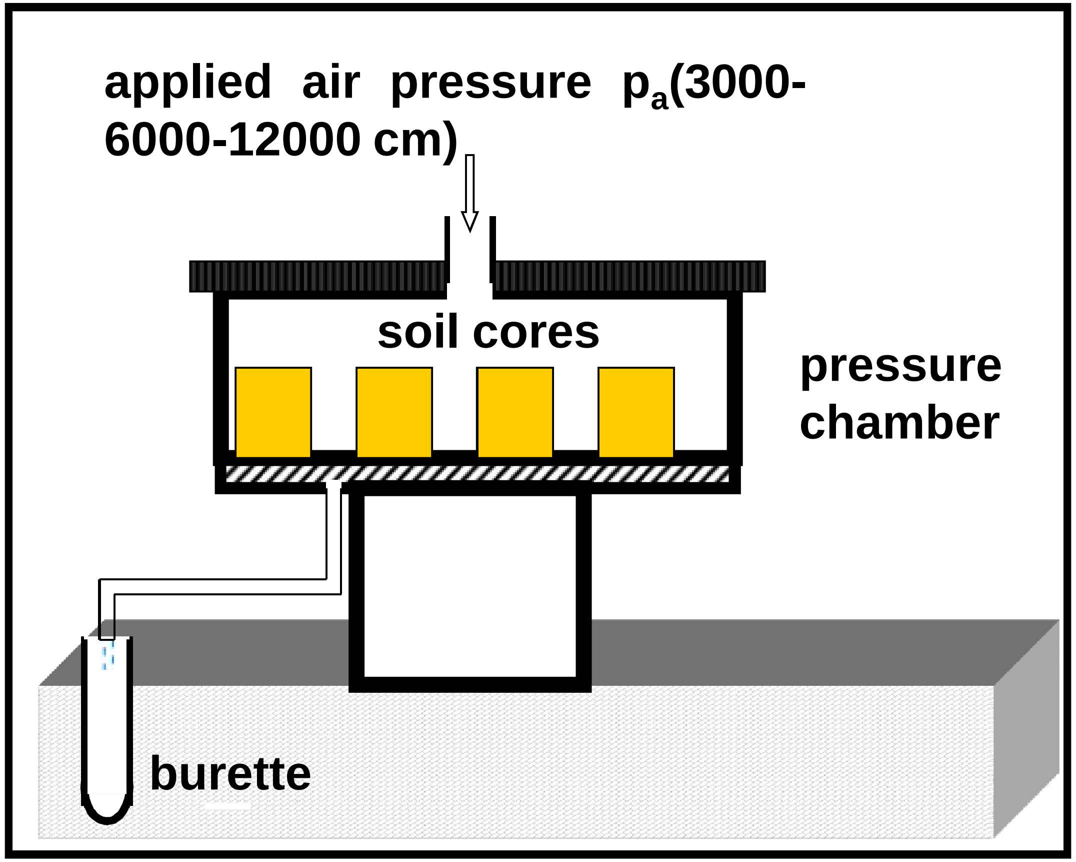
Pressure plates system scheme

h (cm)	M_w (g)	M_s (g)	Tara (g)	w (%)	θ (cm^3 cm^{-3})
-3000	31.05	26.46	9.37	0.269	0.309
-6000	30.76	26.38	8.86	0.250	0.288
-12000	29.51	25.65	8.94	0.231	0.266

M_w = disturbed soil core mass at the end of the measurement + Tare

M_s = disturbed soil core dry mass + Tare

Tare = sampler mass



$$w = \frac{(M_w - M_s)}{(M_s - Tare)}$$

$$\theta = w \frac{\rho_b}{\rho_w}$$

h (cm)	θ (cm^3 cm^{-3})
-3000	0.309
-6000	0.288
-12000	0.266

Measured points in the WRC