



Laboratory Equipment for

Soil Mechanical Measurements

Eijkelkamp Agrisearch Equipment

All it takes for **environmental** research

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Introduction

In many land use systems worldwide, soil deformation is a major problem because of increasing land use intensity. On arable soils machine traffic increases in load and wheeling frequency, leading to (sub)soil compaction and deeper soil degradation in terms of hydrologic or pneumatic functions. Altered soil functions, in particular reduced hydraulic conductivities and impeded aeration, may decrease crop growth and productivity as well as the filtering and buffering capacity of soils. Prevented gas exchange and longer-lasting anoxia in soils due to the reduced pore continuity and pore functioning also affects global change processes. To evaluate potential risks for irreversible soil deformation, it is necessary to quantify the mechanical stability. A commonly applied method is determining the pre-compression stress, commonly under static loading conditions in oedometer tests. Conducting agricultural scientific research such as repeated cyclic/dynamic loading studies e.g. wheel passes or animal trampling, can also be a scope of interest.

Theory

Soil formation, including aggregate development, involves changes in physical, mechanical and physical-chemical properties, and therefore requires exact definition of the limits within which properties are quantified. This is true, because in situ soil formation processes have to be linked to internal and external conditions (climatic, mechanical, thermal, hydrological or chemical aspects) for a particular situation. Thus all properties such as soil strength, stress attenuation, changes in soil structure or pore distribution, water fluxes or gas exchange, are material functions with well-defined and quantified limits. In order to deal with soil properties, stress, strain and strength definitions are therefore initially required to define the limits of the material functions later with respect to the application of external stresses.

Force: applied to a soil-per-unit area is defined as stress.

Stresses: working along the surface will also induce stresses in the soil, which may result in a three-dimensional deformation of the soil volume or it will be transmitted as a rigid body. The mechanical behaviour of a soil (volume change and shear strength) can be described in terms of the soil stress state. The number of stress state variables required to define the stress state depends primarily upon the number of phases involved.

Compression: refers to a process that describes the increase in soil mass-per-unit volume (increase in bulk density) under an externally-applied load or under changes of internal pore water pressure. Examples of externally-applied static or dynamic loads are vibration, rolling, trampling, etc. while internal forces-per-unit area includes such factors as pore water pressure or matric potential caused by a hydraulic gradient. In saturated soils, compression is called **consolidation**, while in unsaturated soils, it is called **compaction**. Consolidation therefore depends on the drainage of excess soil water determined by hydraulic conductivity and gradient. However during compaction less compressible air will be expelled as a function of air permeability, pore continuity and water saturation in the profile. Consolidation tests are mainly used in civil engineering (e.g. road construction).
Soil compressibility described by the shape of the stress strain curve is defined as a resistance to a volume decrease, when the soil is subjected to a mechanical load. Compaction tests are used both for laboratory and for field soil compression characterisations. **Compactability** is the difference between the initial and maximum densities to which a soil can be compacted by a given amount of energy at defined water content.

Practice

Traditional odeometers do not measure soil water matrix during compression tests. With our newly-developed compression test apparatus and shear strength test apparatus you can perform all these measurements concurrently, making the results of the tests much more valuable. The air permeameter and water permeameter for soil samples create a full set of instruments for all research involving soil deformation and its consequences.

Taking soil samples

To determine the characteristic of a specific soil, undisturbed core samples must be collected. This is because of the major influences of both pore size distribution and soil structure on all kinds of physical and mechanical soil properties. There is no explicit prescription in literature for recommended sample sizes. Optimal sizes for soil sample rings are determined by the size of structural elements in the soil. In the procedures for soil analyses of the International Soil Reference and Information Centre (ISRIC), sample rings with a diameter of 5 cm and a volume of 100 cm^3 are recommended for permeability tests. Scientists in soil mechanical research want to have samples with a diameter at least three times the height of the sample. For the equipment described in this brochure Eijkelkamp Agrisearch Equipment recommend the following soil sample ring kits:

07.10.SZ
Sample ring kit for surface sampling and in profile pits, for soil sample rings with a diameter of 100x103 mm and a height of 30 mm.

07.53.SC
Sample ring kit for surface sampling and in deeper soil layers (in boreholes up to a depth of 2 metres) for soil sample rings with a diameter of 50x53 mm and a height of 51 mm.

07.60.SC
Sample ring kit for surface sampling and in deeper soil layers (in boreholes up to a depth of 2 metres) for soil sample rings with a diameter of 60x56 mm and a height of 40.5 mm.

The equipment for soil mechanical measurements described here is developed in close co-operation with the Institute for Plant Nutrition and Soil Science of the Christian Albrechts University zu Kiel, Germany.

Applications User groups

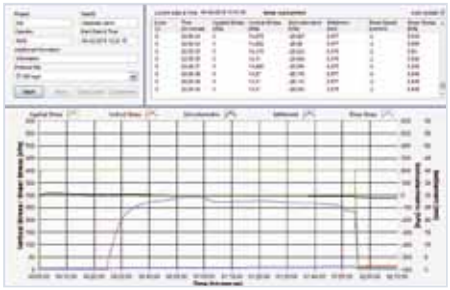
- Soil science
- Soil mechanics
- Soil erosion
- Environmental research
- Basic material research

- Laboratories
- Research institutes
- Educational institutes
- Universities
- Consultants

08.68 Shear test apparatus

for soil, for measuring soil shear strength under compression and simultaneous measuring of soil matric potential with tensiometer in soil samples

The shear test apparatus measures the shear stress of an undisturbed soil sample. During shearing at a constant shear velocity and under 1) consolidated drained (CD), 2) unconsolidated, undrained (UU) or (3) unconsolidated drained (UD) conditions the matric potential and shear forces at a given vertical stress are measured simultaneously. The apparatus operates under computer control using multifunctional software for executing measurement protocols and visualised data presentation.



Features

- User-friendly and easy operation
- Accurate measurement principles
- All in one shear and compression measurements
- Sample diameter 100 mm, height 30 mm
- Software-controlled measurement protocols
- Simultaneous operation of up to 8 instruments
- Graphical instrument overview and data zoom functions
- Calibration functions
- Data file export i.e. Excel
- Upgradable for dynamic multistep operation with advanced sensor-based experiment control
- Excellent price-quality-functionality ratio

Technical specifications

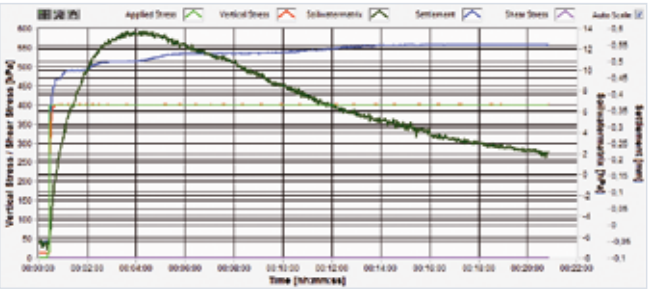
	Range	Resolution	Accuracy
Stress vertical	0-600 kPa	0.1 kPa	2 kPa
Response speed	<10 sec. @1% end-value (adaptable by PID controller parameters)		
Stress horizontal	0-400 kPa	0.1 kPa	2 kPa
Shear speed	0-2 mm/min	0.01 mm/min	0.1 mm/min
Shear stroke	20 mm		
Matric potential	-1000…+1000 hPa	0.1 hPa	2 hPa
Compression	0-30 mm	0.001 mm	0.1 mm
Sample log rate	0.1…60 sec.		
Soil sample diam.	100 mm		
Pressure in max.	0.7 Mpa/7 bar		
Force max.	5 kN		
Stress out max.	600 kPa		
Mains supply	100-250 volts AC		
Mains frequency	47-63 Hz		
Power consumption	0.8 W		

Environmental conditions:	
Temperature	15-35 °C
Humidity	20-80% RH (non-condensing)
Dimensions	45 x 75 x 125 cm
Software language	English
PC connection	USB

08.67 Compression test apparatus

for soil, for soil compression test and simultaneous measuring of soil matric potential with tensiometer in soil samples

The compression test apparatus measures the impact of vertical stress on an undisturbed soil sample. During the measurement the matric potential, compression stress and vertical displacement are measured simultaneously as a function of the vertical applied stress and time. The apparatus operates under computer control using multifunctional software for executing measurement protocols and both numerical and graphical visualised data presentation.



Features

- User-friendly and easy operation
- Accurate measurement principles
- All-in-one compression measurements
- Sample diameter 100 mm, height 30 mm
- Software-controlled measurement protocols
- Simultaneous operation of up to 8 instruments
- Graphical instrument overview and data zoom functions
- Calibration functions
- Excellent price/quality/performance ratio
- Data file export i.e. Excel
- Upgradable for dynamic operation

Technical specifications

	Range	Resolution	Accuracy
Stress vertical	0-600 kPa	0.1 kPa	2 kPa
Response speed	10 sec. @1% end-value (adaptable by PID controller parameters)		
Soil matric potential	-1000...+1000 hPa	0.1 hPa	2 hPa
Compression	0-30 mm	0.001 mm	0.1 mm
Sample log rate	0.1…60 sec.		
Soil sample diam.	100 mm		
Pressure-in max.	0.7 Mpa/7 bar		
Load max.	5 kN		
Stress out max.	600 kPa		
Mains supply	100-250 volts AC		
Mains frequency	47-63 Hz		
Power consumption	0.8 W		

Environmental conditions:	
Temperature	15-35 °C
Humidity	20-80% RH (non-condensing)
Dimension	45 x 45 x 125 cm
Software language	English
PC connection	USB

08.66 Surface shear test apparatus
for soil, suitable for soil samples

The determination of very thin soil layers like soil crusts requires very sensitive and very accurate equipment which also allows very small vertical stress application during measurement. Many different shear test devices are available for measuring shear strength, including direct shear apparatus, shear vane or cone penetrometer, but for example the construction of the frame shear test requires a sample thickness of at least 3 cm, which excludes such test devices for soil crust strength determination.

Features

- Easy manual operation
- Accurate measurement principle, digital read-out
- Excellent price-quality ratio

Technical specifications

Soil sample	diameter 100 mm
Shear container	diameter 68 mm
Weight container	40 g
Weight 1	50 g
Weight 2	100 g
Weight 3	200 g
Weight 4	500 g
Weight 5	1000 g
Weight 6	2000 g
Shear speed	manual
Shear force	0 – 5000 g (resolution 5 g peak value and hold function)
Dimensions	80 x 30 x 35 cm (length x width x height)

08.65 Air permeameter

for soil with three flow meters for laboratory measurement.

Instationary method. Laboratory device suitable for soil samples.

The air permeability apparatus measures the permeability or conductance of an undisturbed soil sample. Air permeability is the property of the soil pore system that allows air to flow through it. Generally the pore sizes and their connectivity determine whether soil has high or low permeability. Air will flow easily through soil with large pores with good connectivity between them. Small pores with the same degree of connectivity would have lower permeability. As soon as pores are water-filled, air permeability is reduced considerably.

Air permeability also depends on texture, structure, bulk density and water saturation, because the higher the degree of water saturation the smaller the connected flow paths. With increasing mechanical stress application, these macropores are increasingly reduced in diameter and become water-saturated, which results in an intense decline in air permeability and therefore also in gas exchange.

Determination of the air permeability is required if quantified data and interpretation about the pore continuity and its dependency on the matric potential as well as the effect of mechanical stress application on e.g. anisotropy of pore structure, are considered.

Features

- Easy manual operation
- Proven accurate measurement principle
- Multi-sample sizes using the fast-exchange sample holder
- Sample diameter 50, 56 and 100 mm (height 51, 40.5, 30 mm respectively)
- Excellent price-quality ratio

Technical specifications

	Range	Accuracy	Remarks
Air input pressure max.	1 bar		External pressure regulator must be applied
Restricted air pressure scale	600 hPa	1.6%	
Sample pressure scale	15 hPa/cmWK	0.1 hPa/cmWK	Scale zero mechanism
Temperature	0-60 °C	2%	Restricted air temperature
Flowmeter 1 range	0.1- 0.6 l/m	1.25%	
Flowmeter 2 range	0.2- 2.0 l/m	1.25%	
Flowmeter 3 range	1.0- 10 l/m	1.25%	
Environmental conditions:			
Temperature	15-35 °C		Stable room temperature is required
Dimensions instrument	50 x 50 x 28 cm		Width x height x depth

09.03 Hauben water permeameter

for soil, for saturated hydraulic conductivity determination.

Instationary method. Laboratory device suitable for soil samples.

The Hauben water permeability apparatus measures saturated hydraulic conductivity of water-saturated soil samples. The water flow depends primarily on the pore sizes, the larger they are the more rapid the water transport, while the finer the pores the more retarded the water flow.

Features

- Easy manual operation
- Proven measurement principle
- Efficient multi-sample handling using the fast-exchange sample holder
- Up to 15 samples per container
- Sample diameter 50 or 56 mm (height 51, 40.5 mm respectively)
- Excellent price-quality ratio

Technical specifications

Container volume	3 litres
Burette height	300 mm
Burette scale interval	5 mm
Burette 1	3 mm
Burette 2	4 mm
Burette 3	5 mm
Sample diameter standard	50 mm (height 51 mm) and 56 mm (height 40.5 mm)
Environmental conditions:	
Operating temperature	15-35 °C (constant temperature is required to avoid viscosity effects on fluxes)
Dimensions:	
Instrument	35 x 35 x 95 cm
Measurement container	60 x 40 x 30 cm (15 samples)

08.01 Sandbox for pF-determination (pF 0 - 2.0)

The sandbox for pF-determination is used to prepare the soil samples up to pF 1.8 just before placing them in other apparatuses like the one previously mentioned.
The samples are saturated and subsequently balanced with respect to the increasing values of the moisture tension. The moisture tensions are obtained by creating a series of under-pressures and over-pressures. Weighing the sample after each balance adjustment yields the moisture content for each moisture tension.

The standard set for pF-determination pF 0 - 2.0 (0 - 0.1 bar) consists of the sandbox with control panel, suction levelling stand, water supply bottle with stand, filter cloth (140-150 micron), a number of containers of synthetic sand, grain size approximately 73 micron and various accessories.
A maximum of 40 soil sample rings can be placed on the sandbox. The samples measured are taken using soil sample rings.

These rings usually have a content of 100 cc. In addition to the standard set a soil sample ring kit must be available as well as cases with soil sample rings and aluminium soil sample boxes. For determination of the pF the laboratory should also be equipped with a balance and a drying oven.

Features

- Shapes the pF curve for the wettest part
- Uses undisturbed samples 53 or 60 mm
- 40 samples allow large-scale research
- Number of samples allows effective averaging
- Set-up can be used repeatedly for years
- Comprehensive photo manual for easy set-up

Technical specifications

Soil sample rings (Ø 53mm)	Max. 40
Dimensions of the box on its stand (excl. supply bottle etc.)	55.0 x 33.5 x 37.5 cm (l x w x h)
Operating range	(0 hPa - 100 hPa); (0 bar - 0.1 bar); (pF 0 – pF 2.0)

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