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DETERMINING THE SOIL COMPACTION DEGREE BY MEASURING THE PENETRATION RESISTANCE

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Abstract: *The assessment of soil resistance is carried by determining resistance to penetration. This represents a simple method to assess the state of soil compaction, which is used in attempts regarding the influence of works on soil and highlight the seasonal dynamics of its physical state. The spatial placement of the measuring points and of the measured values allows the elaboration of maps by which a proper management of agricultural technologies can be achieved.*
Resistance to penetration is an important indicator of the quality of physical soil quality, and the 2MPa limit is widely used to characterize the soil physical quality, both in systems without soil processing and in conventional systems.
Keywords*: penetration resistance, compaction degree, physical soil quality, penetrometer.*

1. INTRODUCTION

Knowledge of agricultural soils is a relevant factor for the sustainable development of agricultural activities. The quantification of soil compaction degree consists of measuring penetration resistance that indirectly determines the energy that the plant roots must have to have to penetrate the pores of the soil, respectively its structure.
The penetration resistance is an easy and quick method to assess the soil resistance. This is dependent on the shear force of the soil, the degree of compaction, including the friction between soil and metal.
From experiments, the highest penetration resistance values are obtained on technological paths (both surface and depth), indicating that the penetration resistance is dependent on the agricultural work applied and the traffic of agricultural machinery.
The penetration resistance value depending on the soil is given in the following table:

Table 1: The penetration resistance of soil

Type of soil	Resistance to penetration (KPa)
Light	Under 15
Middle	15.....50
Heavy	50.....150
Very heavy	Over 150

Resistance to soil penetration is related inter alia, by its moisture content and the content of organic matter. The higher the moisture content of the soil, the lower the penetration resistance and hence the carrying capacity.

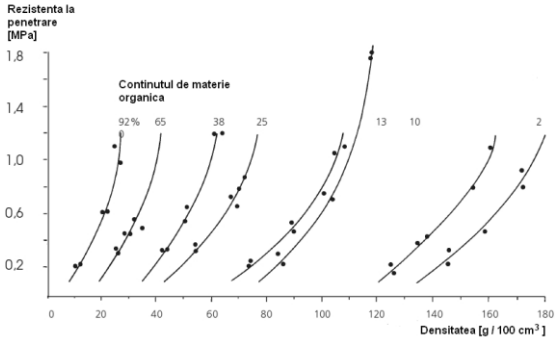

Figure 1: The relationship between penetration resistance and soil density, correlated with the organic matter content.

2. MEASURING DEVICES FOR PENETRATION RESISTANCE

The penetration resistance depends on the degree of soil compaction and is determined by the following methods:

- With sensor devices that penetrate the soil vertically;
- With sensor devices that penetrate the soil horizontally;
- With non-contact devices that use indirect methods.

2.1 MEASURING DEVICES THAT PENETRATE SOIL VERTICALLY

The simplest vertical resistance measurement tool is the cone penetrometer. Over time, various models have been built, the dimensions of which have been standardized.

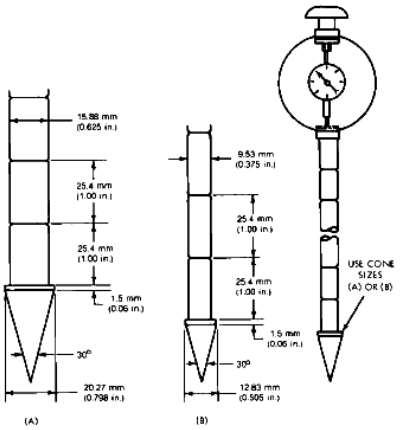

Figure 2: The penetrometer with cone (ASABE, 2004)

Lately, variants of penetrometer with electronic computing techniques began to be used in order to record, acquire and process data regarding the strength and depth of penetration of the cone into the soil. Penetrometers that have a different geometry of the cone have been constructed, which measures both penetration resistance and the electrical conductivity of the soil.

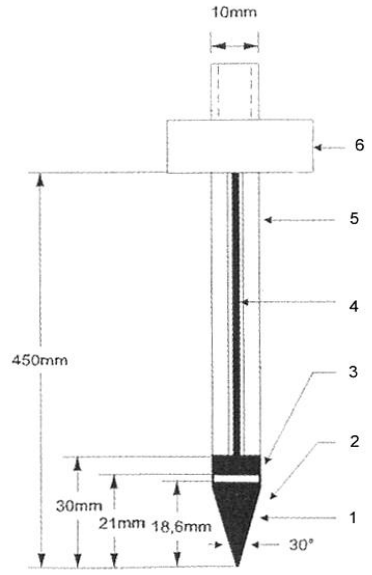

Figure 3: Scheme of an electronic cone penetrometer

Such a device is the digital penetrometer with cone, provided with a screen on which the measurement results are displayed digitally.

Figure 4: Static penetrometer with cone, with digital display

There are also automated instruments for measuring soil resistance such as a penetrometer recorder with GPS.

Figure 5: Penetrometer recorder with GPS

PENETROLOGGER penetrograph is largely used to determine resistance to soil penetration, both in agriculture and in civil constructions.

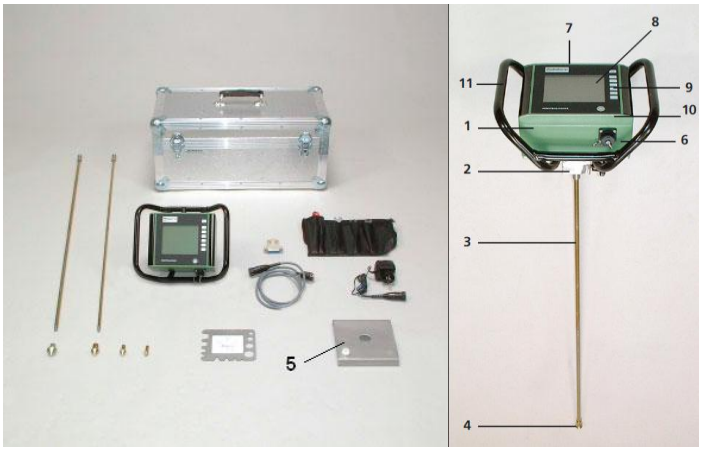

Figure 6: Penetrograph Penetrologger of Eijkelkamp company

2.2 MEASURING DEVICES THAT PENETRATE SOIL HORIZONTALLY

A horizontal measuring system for soil resistance was developed by Hall and Rapper in 2005. The sensor was equipped with a detection peak and a force transducer. Values obtained with this sensor are less influenced by soil moisture than with static penetrometer with cone.
Chung and collaborators (2006) have developed a soil resistance measuring sensor that functions as a horizontal penetrometer, capable to determine soil resistance at several depths. The sensor body is a metal plate. The bending moment produced by the resistance of the soil is detected by the transducers attached to the sensor foot.

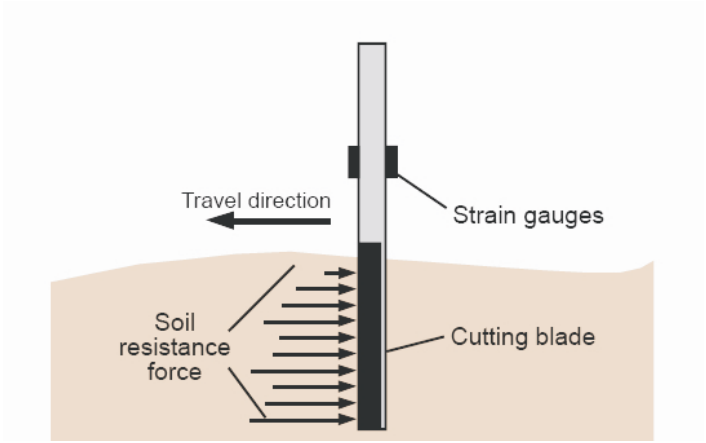

Figure 7: Scheme of the mechanical resistance measuring device in a horizontal plane (Adamchuk and Jasa, 2002)

A more special device for measuring penetration resistance in horizontal plane is the penetrometer with acoustic sensors.

These sensors use soil texture by changing the acoustic signal due to soil particles and / or its compaction. Peak detection of the sensor was equipped with a microphone, which feels the noise caused by the tool's retraction from the soil. However, this method cannot determine soil resistance at different depths and is unusable due to a low signal-to-noise ratio.

Figure 8: Measuring device of soil resistance in horizontal plane with acoustic sensors

In order to simplify the methodology for determining the penetration resistance, specialists in soil mechanics, propose to measure the penetration of soil resistance in the horizontal plane by moving a horizontal penetrometer with cone, at different depths with the help of a mobile measuring device on the frame of a loosening soil machine carried behind a vehicle.

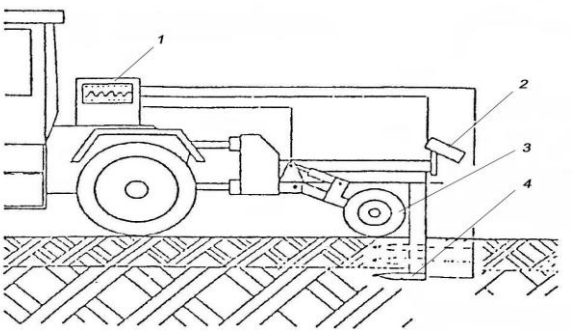

Figure 9. Scheme of mobile device for measuring penetration resistance in a horizontal direction

2.3 MEASURING DEVICES OF RESISTANCE TO INDIRECT PENETRATION (NON CONTACT)

Such a device is provided with sensors that operate in infrared or with a polarized light spectrum. It functions on similar principles of remote sensing, on satellite platforms or a plane.

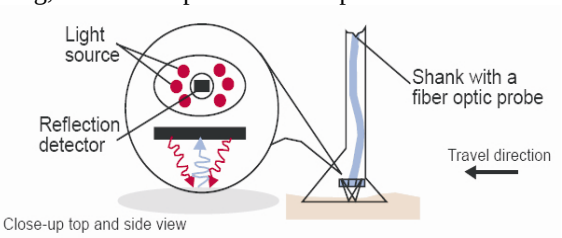

Figure 10: The scheme of an optical sensor (after Adamchuk and Jasa, 2002)

Another device measuring resistance to indirect penetration is the one that penetrates the soil by radar, a device that transmits high-frequency radio waves into the soil.

Figure 11: Soil penetration device with radar (after GeoModel, 2007)

3. CONCLUSIONS

- Determination of soil penetration resistance is a simple method of indirectly estimating the resistance to plowing or other soil works, as well as the development and penetration of the radicular system into the soil. The resemblance between the penetration peak of the penetrometer and roots is obvious. Experimental research shows that at values below 10-15 daN/cm^2, resistance to penetration does not influence the roots entering into the soil, while at values higher than de 35-50 daN/cm^2 this is almost impossible.
- The points in which penetration resistance is measured and the values obtained, allow the elaboration of maps, which may be useful in choosing agricultural technologies.

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