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DESIGN OF NEW PORTABLE VERTICAL CONE PENETROMETER

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Abstract: *This paper describes new portable vertical penetrometer design for the agricultural soil compaction measuring. The Department of Machine Design and The Department of Electrical Engineering, Automation and Informatics on FoE SUA in Nitra are currently preparing a new measuring system with modern electronic parts as well as application of new measuring principles for depth and force sensors. Design has a new arrangement of the elements in the body. Major innovation is the use of a colour touch screen which one allows real time monitor: the laboratory measurements, the measured data saved on SD card, Excel and formatted data, the ultrasound sensors values for the indirect ground depth measuring, the user friendly setup options of the device parameters and the incorporation of GPS into the device housing. Connection with personal computer remained unchanged from the previous type. In this paper is described the enhanced algorithm for penetration resistance measuring of a soil in dependence on depth and on place of the pushed sensing head.*
Keywords: *soil compaction, portable vertical cone penetrometer, penetration resistance measurement, cone index*

INTRODUCTION

Harvesting, sowing and protection and mechanisms for tillage negatively affect soil compaction despite new design solutions, especially in extreme weather conditions.

There is necessary to have detailed and accurate information about the condition of land and constantly specifies those models of the soil particles spatial arrangement for finding appropriate solutions to minimize soil compaction.

Monitoring of soil compaction is performed mainly by penetrating devices which are mainly used in mapping the immediate condition of the soil.

Soil compaction is most often defined by penetration resistance (Cone Index, CI) when measured cone and sensor, measure the value of the resistive force exerted per unit area at the base of the cone. To ensure comparability and reproducibility of results and objectively assess the changes of soil compaction it is used standard size cone by American standards ASAE S 313.3. This article describes the design of a new penetration device designed at DMD and DEEAI at FE SUA in Nitra (Slovakia) and the first results in the implementation of this device.

MATERIAL AND METHODS

Microprocessor and computer technology and research and development in this sphere influences on the development of penetration devices in positive direction due to which we can make the measurement quickly and results processed into more transparent and comprehensible form. The cooperation of work between DMD and DEEAI at TFE SUA in Nitra (Slovakia) was made 15 years ago penetrometer P-BDH 3A (Figure 1).

This penetrometer was founded on the principle of sensing the force of soil resistance against solid shape (cone) pushed into the soil by capturing incremental value after pressing deeper every centimetre. For measurements were used optoelectronic measurement systems, digitization and record of measured values in memory, which was transported into a computer and processed further. The measuring device was very simple and reliable with over 10,000 possible record data. Through digital indicator can be adjusted input parameters, calibrate the device and check the measured data values. Wide application of penetration method just for its benefits will likely continue in other areas. Increasingly sophisticated *equipment available with electronics and modern processing methods and evaluation techniques can position the field tests keep at the forefront of scientific and agricultural interest.*

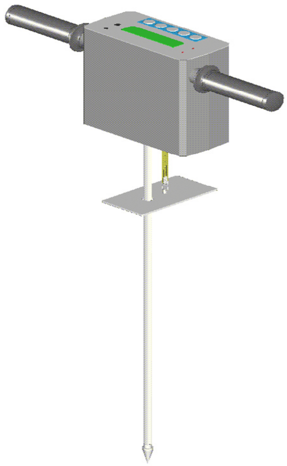


Figure 1. Penetrometer P-BDH 3A

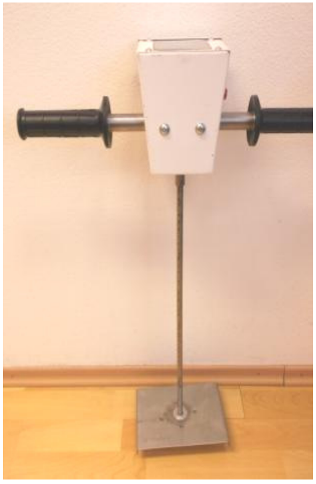


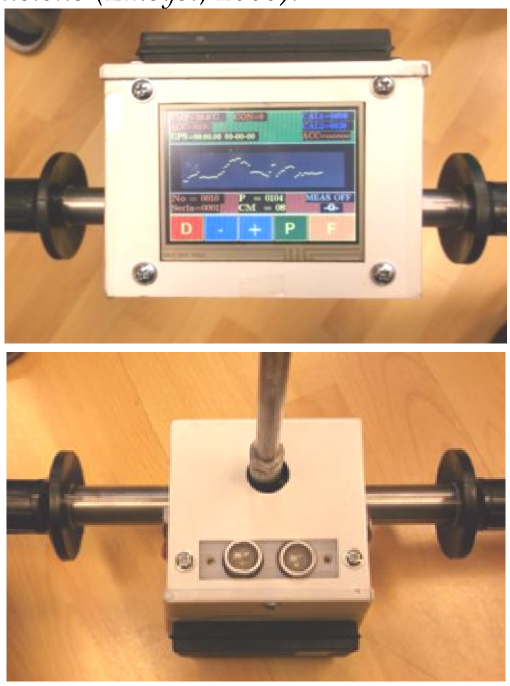
Figure 2. Penetrometer PE 90

Years of experience in the measurement and evaluation of measurement the authors prompted to upgrade the device so as to remove some of the shortcomings of the device in terms of measurement system, as well as increased measurement comfort and control. During the measurement at P-BDH 3A was not possible to follow the course of the measured forces, depending on the depth and it was not able to locate the measurement location by a GPS system.

Finally, the authors decided technical and technological improving to meet the new requirements of the practice. The concept of the new device was based on the requirement of control options during the penetration resistance measurement and so extreme values (errors) can be immediately erased. It was also our aim to prepare a reliable measuring instrument with a low price that was unlike now commercially produced devices cheaper and more accessible for practice (Figure 2). Therefore into this new concept were applied commercially produced force and depth sensors (ultrasonic sensors) modern electronic and microprocessor technology, including the use of a colour touch screen.

RESULTS AND DISCUSSION

Penetrometer marked as PE 90 is new variant of penetration device, which consists of a steel casing, cut out and welded out of sheet metal which one is associated with the metal housing with countersunk screws. To this housing is bolted carrying case with attached handles inside which is fixed force sensor (Líška, 2008), the bottom of the sensor is attached to the rod with cone probe. On the top of the metal cover is placed colour touch screen (Figure 3a). To measure the force of resistance was chosen sensor type EMS 20 with a measuring range up to 5 kN, which has minimal dimensions (Emsyst, 2008).



a)

b)

Figure 3. Device view: a) view on display unit, b) location of ultrasonic probes

At the new concept were used current possibilities of modern electronic and microprocessor technology. The device uses a colour touch screen for entering measuring conditions, parameter setting and control over the measurement on the display screen.

There is mounted ultrasonic sensor for measuring of depth to the bottom of the housing, and is *clamped sliding reflector plate to ensure a correct reflection of the ultrasonic signal to the measuring rod (Figure 3b). The device can be externally connected to a computer to export data and GPS position for their further process. It has the ability to connect to an external power source with controlled charging of battery capacity. Handles, measuring rod and the GPS sensor is removable, which allows better storage-ability and its transfer.*

Measurement algorithm of penetrometer resistance depending on the soil depth should take into account the following aspects:

- *the measuring system have to do the calibration of sensors due to temperature after power on (1),*
- *to determine of the GPS signal activity,*
- *measuring rod speed in the recess have to be max. 0.01 ms^{-1},*
- *device has an audible alarm to warn the possible destruction of the force sensor under strong recess,*
- *in case of the wrong methodology recess irregular movements of measuring rod, for example impact on stone or finding an air gap, attention to the possible incorrect results.*

Built-in temperature sensor is used to calibrate ultrasonic sensor distance covered by the adapted known equation:

$$s=(165.9+0.305.(T_s-273.15)).t \qquad (1)$$

where: s - is sensed soil depth, m
T_s - is air temperature, K
t - is measurement time interval, s

*After the first layout of the components in the new device were resolved other parts like battery, location of some controls, GPS sensor, battery charge and computer connection. It has got GPS sensor with SiRFstar III chip, which in addition to determining the exact position of measurement what also provides information about the current altitude and the time of measurement. Values of ambient and soil temperature is an additional indication of measurement. The measured data are stored on the microSD card format in *.csv file that is readable in MS Excel or other spreadsheets (Géci, 2007).*

Today a new variant of penetration device PE90 shown is designed with the technical characteristics shown in Table 1.

Table 1. Technical characteristics of PE 90

Measuring range	0 - 10 MPa (cone index)
	0 - 600 mm (measurement depth)
Measuring step depth	10 mm
Number of measurements	cca 100 000 on 256 MB microSDcard
File type	.csv (.txt, .bin)
GPS module	SirfStar III
Connectivity	USB, RS232C, SD card
Unit Dimensions	120 x 140x 90 mm (body)
Length of the rod	600 mm
Weight	2.6 kg
Size cone (diameter of base / top angle)	12.8 (20.3) mm/ 30 °
Battery life	min. 10 hours

Nowadays is well known companies Eijkelkamp Penetrologger that has a measuring range up to 10 MPa, measuring the depth in interval 10 or 20 mm, depth measurement is max. 800 mm. Cone used for measuring has got angle of 60° on special request also available with cone according to ASABE. The device can be added with GPS without connection to system memory.

ELE International Company offers Proving Ring penetrometer with ASABE cone, it has analogue pointer without electronic record of the measured resistance and depth and no GPS. A few years ago they offer ELE CCP model with a measurement range up to 600N, depth measurement up to 450mm with a reading offer 15mm, 16 digit display with record up to 600 measurements. Currently, it is not in the catalogue.

Australian company AGRIDRY RIMIK PTY LTD in Toowoomba offers RIMIK CP 40 CONE, which one has advanced electronic components, display unit, strain gauge force transducer with a measuring range up to 5.5 MPa and depth measurements up to 600 mm at the rate 15, respectively 20 mm. It also has a built-in GPS. Measuring capacity is about 2047 measurements. This device appears to be the most advanced on the market.

It may be noted that the PE 90 penetrometer has comparable properties with worldwide manufacturers. However, our penetrometer has improved the intuitive management and has bigger recording memory.

CONCLUSION

The reason for the research and development of new penetrometer equipment is not only to design *lightweight, portable and reliable equipment, but also a consistent device enabling a wider usable and able to obtain data comparable to each other.*

Modern penetrometer devices except the new options (GPS, colour touchscreen, high memory capacity, autocalibration) must take into account the versatility and ease of use in a variety of conditions by affordable price. The new proposal penetration device can meet all these requirements and provide greater comfort and productivity.

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