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Experimental Researches Regarding Determination of Soil Cone Index in a Soil-Tyre Interaction Process

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Abstract. Soil compaction mainly occurs in occasions related with agricultural traffic, when the soil is subjected to various applied loads by different types of agricultural implements. Soil surface compaction and deep soil compaction occurs because of soil-tyre interaction process that will modify the initial stress state. This will alter the initial soil physical properties, so it is possible to evaluate the soil compaction by measuring their variation. This paper presents a tool and a method for experimental determination, in laboratory conditions, of soil cone index at soil-tyre interface layer and on soil profile, being focused only on data related with soil cone index influenced by wheel load and number of passes.

The analysis of measured data showed that the analyzed method for experimental determination of soil cone index can be used also in field conditions, for studies related with spatial variation of soil cone index due to agricultural traffic.

Keywords: soil cone index, soil compaction, agricultural tyre, traffic

INTRODUCTION

In today agriculture, and especially in the actual concept of sustainable agriculture, it's a very important to predict soil compaction risk moments, being possible for the farmers to choose to till or traffic the soil when it is not in a highly compactable state or it's very important to estimate the damage being done to the soil structure by the agricultural traffic.

From mechanical point of view the soil compaction can be defined as being the change in soil mass per unit volume under external applied forces.

The cause of the mentioned phenomenon consists in the displacement of soil particles with the respect of six degrees of freedom. Also the initial stress state in the soil will be changed under the external applied forces or stresses. So, the initial soil physical properties will be altered being possible to record their variation in order to evaluate the new stress state in soil and its relation with soil compaction.

The evaluation of soil compaction can be done by studying soil particles movements and stresses during the soil-tyre interaction process and, based on measured data, to develop indexes that can characterize the new soil stress state with implications on soil compaction.

From practical point of view it is also important to use indexes that are "user friendly", respectively easy to use and easy to measure (e.g. using devices for "in situ" measurement), such as soil cone index.

MATERIALS AND METHODS

The research has been carried out at Department of Agricultural Engineering within University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca.

For experiments was developed an experimental device that was used to measure soil particles movements under external applied loads and to measure soil cone index for several loading cases.

The above mentioned loading cases are characterized through established wheel load, tyre air pressure and number of passes on the same path.

The experimental device was mounted on the U-650 tractor and has the following main parts (fig.1): frame, loading wheel, loading device (hydraulic cylinder and hydraulic circuit) and a soil bin (with size by 3000 x 800 x 800 mm).

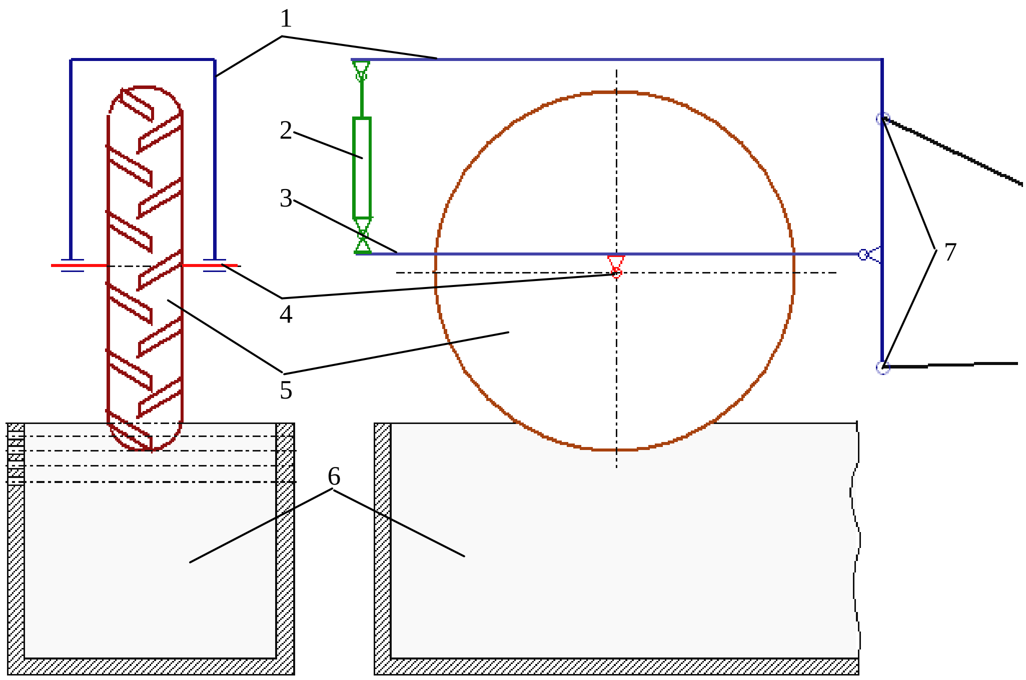


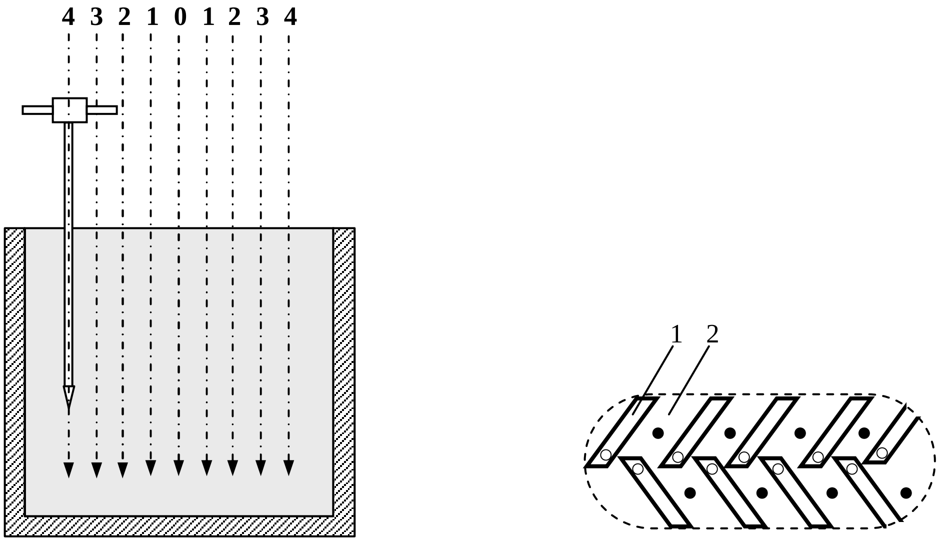
Fig.1 Experimental device set-up
1-frame; 2-hydraulic cylinder; 3-mobile frame; 4-whell spindle; 5-loading wheel; 6-soil bin; 7-mounting triangle for tractor

For in situ measuring of soil cone index, depending on loading cases, was used an electronic penetrometer FIELDSCOUT SC-900 and for in situ measuring of moisture content was used an electronic umidometer AQUATERR T-300.

The soil cone index has been measured on soil profile in vertical-transverse plane and in vertical-longitudinal plain in relation with loading wheel moving direction.

Also, the soil cone index has been measured on the contact surface between loaded wheel and the soil (on the soil-tyre interaction surface), after the wheel pass on the soil.

In Fig. 2 is showed a sketch after which the measurements (in order to get the variation of soil cone index on the soil profile) were carried out.



Legend:
0 – measuring position located on the wheel median plain
1÷4 – measuring positions located at 5 cm, 10 cm, 15 cm și 20 cm in relation with 0 position

a)

Legend:
○ – measuring point located on the contact surface between tyre tread and soil (1)
●– measuring point located on the contact surface between tyre tread and soil (2)

b)

Fig.2 Experimental set-up for soil cone index measurement
a) on soil profile (in vertical-transverse plain in relation with wheel moving direction)
b) on the soil-tyre contact surface (in vertical-longitudinal plain)

RESULTS AND DISCUSSIONS

The study was made for several loading cases that were characterized through number of passes on the same path, loads values and air pressure in the tyre.

a) Study on soil cone index depending on number of passes

In order to show the influence of number of passes on soil cone index, because of several passes of the loaded wheel on the same path, in fig.3 is showed the soil cone index variation graph on the soil profile, depending on number of passes (initial soil state, before loading and after three successive wheel passes). The measurements were made according fig.2a.

According fig.3 is showed a gradual increase of soil cone index depending on number of passes, the maximum values being measured in the center of the contact surface between soil and tyre and the minimum values are located at the edge of the soil-tyre contact surface. The width of soil-tyre contact surface, on which soil cone index varies from maximum values to the minimum values, is about 30 cm being influenced by tyre width.

On the soil profile, in depth, because of the passes of the loaded wheel, the soil cone index gradually decreases starting with the soil surface to the depth of about 6 cm, after which the soil cone index equalize the initial values (before loading).

According above considerations was showed that de soil is gradually pressed (compacted) from the surface to deeper soil layers, beginning with the soil layer located very near to loaded wheel. The soil cone index gradually changes in deeper soil layer because of repeated wheel passes.

In this way it is possible to assert that the soil cone index can still increase, at higher number of wheel passes, but only if the air and water in macropores can be removed as a result of soil particle reorganization in a more compacted state

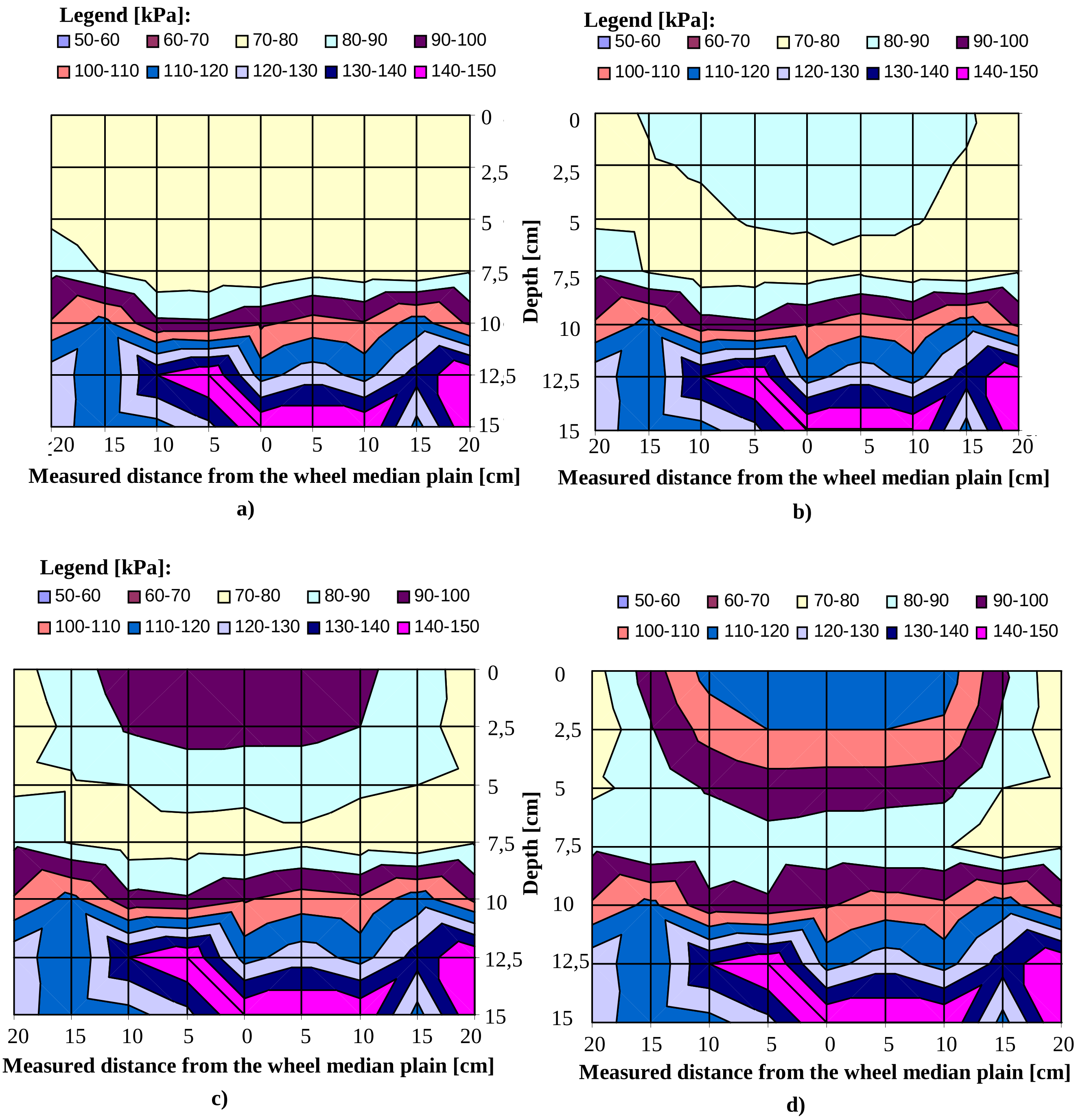


Fig.3 Variation of soil cone index on soil profile for several passes
(wheel load 8500 N; tyre air pressure 50 kPa)
a) initial; b) 1 pass; c) 2 passes; d) 3 passes

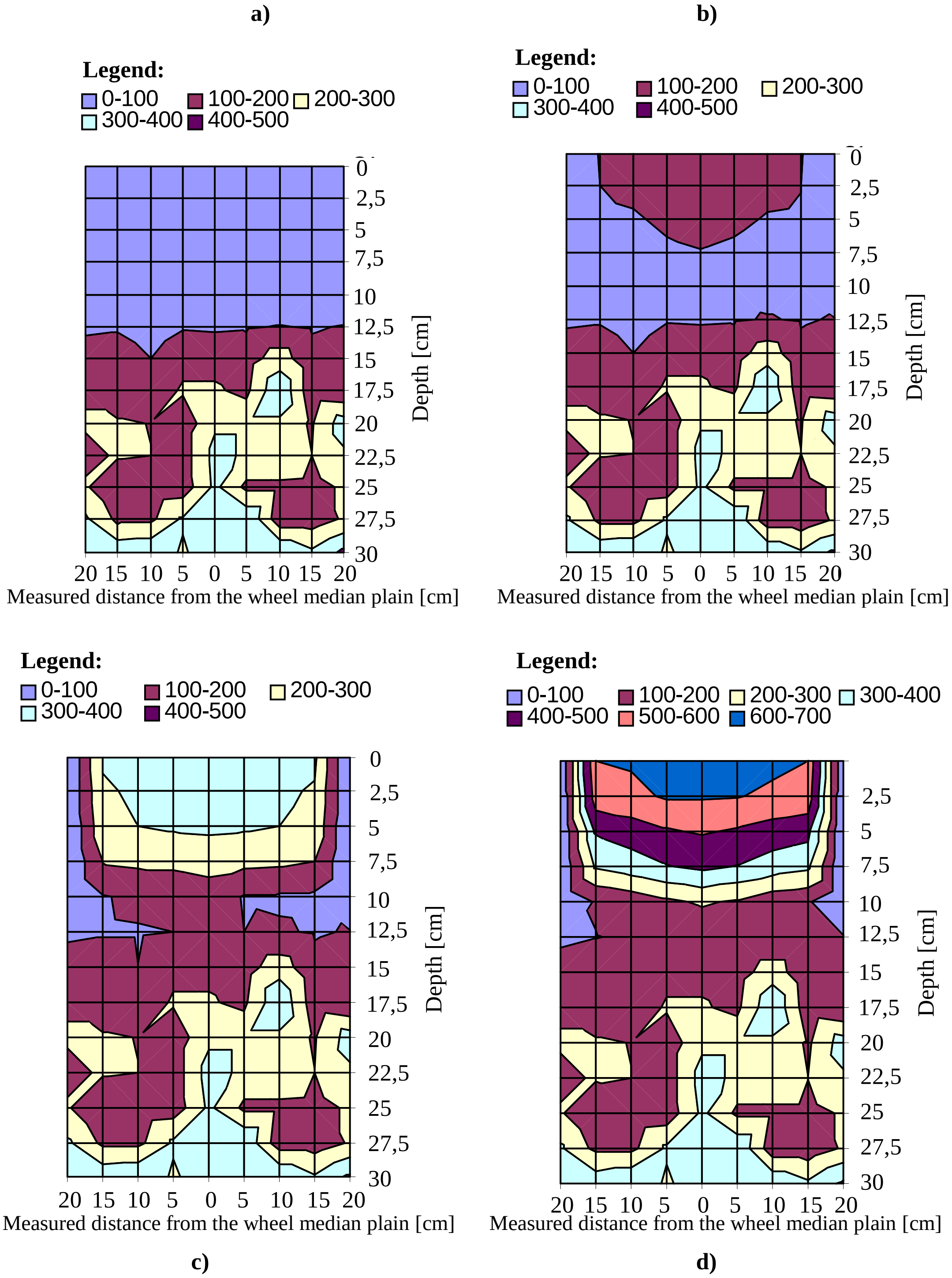


Fig. 4 Variation of soil cone index on soil profile depending on wheel load
(tyre air pressure 150 kPa)
a) initial; b) 8500 N; c) 13600 N; d) 17000 N

On the width of the soil-tyre contact surface is showed a decrease of soil cone index values according the measured distance to the center of contact surface, the maximum values being on the soil strip with minimum 20 cm in width, directly proportional mainly to wheel load and dependent on the width of the contact surface. From this point of view, for a certain wheel load, with the prescribed requirement of minimum pressure on the ground surface, it is recommended to promote tyres with the highest soil-tyre contact surface, in order to keep up the effect of soil-tyre interaction process on soil cone index to upper layers.

By analyzing the measured data was showed that the variation on soil cone index, on the soil profile, in the center of the soil-tyre contact surface, depending on wheel load, takes place after a order two polynomial curve.

According mentioned observation or according Fig.4 it is possible to see that for higher wheel loads the soil cone index will gradually increase, also at soil-tyre interface level but also in depth, because of proportional increase of the medium pressure on the ground surface.

CONCLUSIONS

In this paper was developed a methodology for experimental determination, in laboratory conditions, of soil cone index at soil-tyre interface layer and on soil profile, depending on wheel load and number of passes. The measured data showed a strong correlation between the mentioned parameters and the measured soil cone index, being required to survey and to record these parameters in a framework of a management tool for soil compaction control.

For an extensive study to the above mentioned parameters can be added other parameters like tyre air pressure, wheel speed, tyre type, tyre size etc.

The analysis of measured data shows that the analyzed method for experimental determination of soil cone index can be used also in field conditions, for studies related with spatial variation of soil cone index due to agricultural traffic.

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