STUDY ON THE MEASURING EQUIPMENT OF STRESS IN AGRICULTURAL SOIL

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Abstract: *Worldwide, the degradation of soil structure is a subject of great interest, both in terms of agronomic and environmental impact. One of the main causes of soil degradation is the artificial compaction, specific to intensive agriculture. Among the negative effects of soil compaction, there are: decreased soil permeability to air and water, the occurrence of marks on soil surface, increasing resistance to penetration, inhibition of the development of plant roots, reduced crop yields, increased resistance to plowing and high fuel consumption. The main factors influencing artificial compaction are: soil type, soil moisture, and number of passes of agricultural vehicles on the soil, size of external load applied by the rolling body, size and shape of the contact surface.*

Soil stress state occurs as a result of external load applied on soil surface at the passage of agricultural vehicles. With the increase of external load, stress is distributed deeper in the soil. Knowledge of soil stress state can provide information about the degree of soil compaction.

This paper presents various models of experimental equipment for the assessment of stress and strains in soil, as indicators of soil compaction.

Key words: *Soil compaction, Agricultural soil, Soil stress, Sensors, Wheel, Tire.*

INTRODUCTION

Compaction of agricultural soils represents a form of degradation, manifested by the decrease of porosity and increase of bulk density of soils subjected to loads, limited water and air permeability, and reduced root penetration.

Compaction affects both superficial layer and the depth of soil. After its origins, there are two forms of soil compaction:

-*Natural compaction*, induced by the factors and processes leading to soil formation itself, being specific to certain types of soils. Among the causes of natural compaction, literature specifies: freeze–thaw cycles, precipitation, soil drying, tree roots. These causes, however, are not as harmful as the artificial ones [8].

-*Artificial (anthropic) compaction*, induced by the technological errors in the farming system, such as excessive traffic on the soil during agricultural works, especially in inadequate conditions of soil moisture. This phenomenon is mainly aggravated by the increase of the weight of agricultural equipments, intensity and frequency of soil works and by tire inflation pressure [12].

The most important *factors with a significant influence on the artificial compaction* of agricultural soils are: soil moisture content, soil type, intensity of external load, area of the contact surface between soil and tire, shape of the contact surface, and the number of passages of agricultural vehicles on the soil [3].

According to literature, in Europe, compaction has caused the degradation of about 33 million ha of soil. The European Union acknowledges that subsoil compaction is a major form of soil degradation, especially in the developed countries [11].

After [4], in Romania approximately 2,8 million ha of arable soils are affected by natural compaction, while artificial compaction affects 6,7 million ha. Regarding the degree of compaction of arable soils, 38% are moderately compacted, 22% strongly compacted, and 6% excessively compacted.

Hamza M.A. and Anderson W. K. (2003) consider that soil compaction affects 4 million ha in Australia, 18 million ha in Africa and 10 million ha in Asia [7].

By assessing various parameters, such as soil type and texture (registered in European soil database), depth at which plant roots encounter obstacles, the impermeable layer of soil, it was possible to draw the map of the European soils that could become compacted when exposed to the risk of compaction [13].

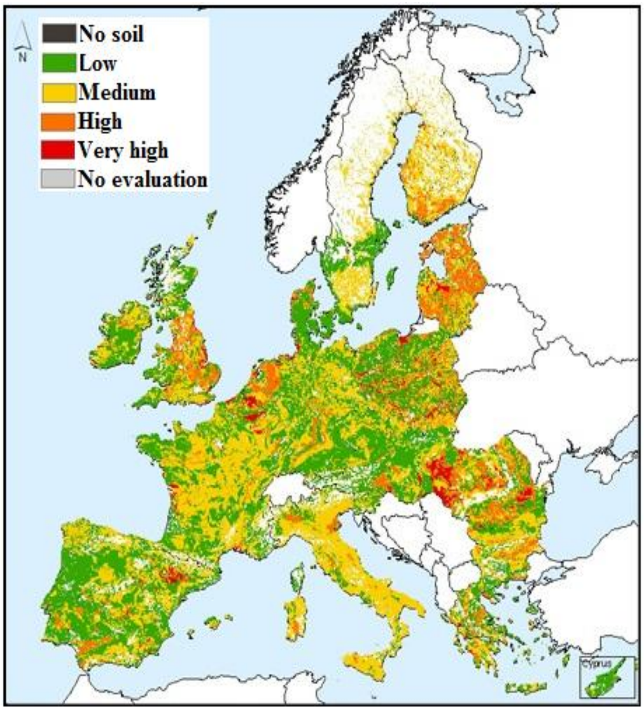

Fig.1. Distribution of soils predisposed to the risk of natural compaction in Europe [3; 13]

In addition, literature also indicates the type of rolling body (wheels with tires, metallic or rubber tracks), tire inflation pressure, and even trampling caused by grazing animals [8].

Most agricultural machinery generate soil pressures above the recommended limits. Wheels and tracks have a distinct influence on pressure distribution on the contact surface. In comparison with tracks, pressure exerted by the wheel on the soil is higher, as the weight of vehicle is concentrated on a smaller surface.

Pressure exerted by tracks has more uniform distribution, with smaller average values, since the contact surface is larger. High values of tire inflation pressure generate smaller contact surface and large soil deformation, and stress will propagate to greater depths. At lower tire inflation pressures, tire deforms more, the contact surface is larger, soil deformation is smaller, and stress will propagate at smaller depths.

MODELS OF EXPERIMENTAL STANDS AND EQUIPMENT USED FOR THE STUDY OF SOIL COMPACTION

Several models of stands and equipments are used to determine soil compaction.

A common indicator of soil compaction is cone index or penetration strength, and it can be measured directly using various forms of static or dynamic penetrometers [10]. Penetration strength is influenced by soil moisture and bulk density, and by soil compressibility and structure.

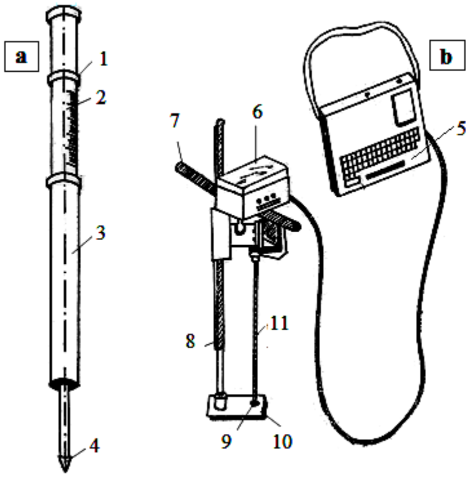

Fig. 2. Field penetrometers (a – static; b – dynamic, electronic type Bush) [4]
1- indicator ring; 2 – calibrated inner tube; 3 – outer tube with inner arc;
4 – penetration cone; 5 – portable computer; 6 – electronic pressure recorder;
7 – lever; 8 – socket support; 9 – penetration cone; 10 – support; 11 – penetration rod

The action of rolling bodies on the soil can be simulated using bevameters, developed by Bekker M.G. (1969). Compression bevameter uses a working body with square, rectangular or circular section, on which a compressive force F acts, whose value increases monotonically from zero, recording the variation of normal stress σ depending on soil deformation h. Shear bevameter simulates the action of tracks and driving wheels on the soil. The working body is a circular sector with radially edges of adhesion [9].

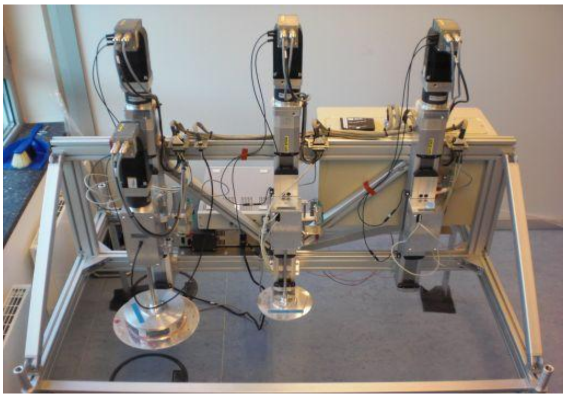

Fig. 3. Bevameter with loading plates of various size (applied force of 500 N) [14]

Stress state in agricultural soil can be measured in real time by means of SST pressure transducers (Fig. 4), which were described by Nichols et al (1987). These transducers can measure the pressure in six planes and the recorded values are used to calculate main stress, normal stress and shear stress in octahedral plane [2,10].

The AgTech transducer (Fig. 5), presented by Turner et al. (2001), indicates the pressure variation over time and hence, the shape of pressure distribution at the passage of agricultural vehicle on the soil, maximum pressure and residual pressure in soil after the passage. Effects of contact surface geometry, vehicle type and vehicle load can also be estimated using AgTech transducers [10].

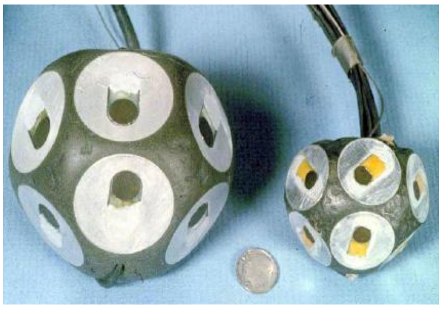

Fig. 4. SST pressure transducer [10]   Fig. 5. AgTech pressure transducer [10]

Gysi et al. (2000) measured the pressure distribution under the tires of agricultural vehicles using a MODULAS pressure cell containing 32 quartz sensors. This sensor is suitable only for measurements in dynamic regime. The authors have placed the sensor on a hard surface using a mortar made of quartz sand and epoxy resin [6].

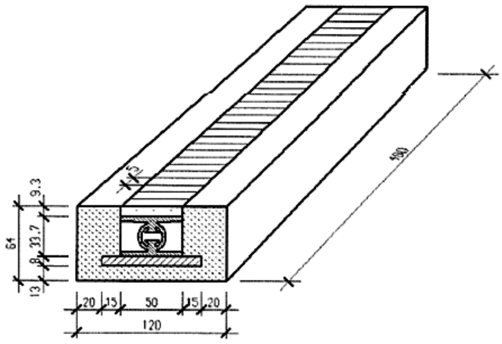

Fig. 6. MODULAS pressure transducer (size in mm) [6]

The distribution of both normal and tangential stress in soil-tire interface is also important, since they are used as input data for models of estimating compaction.

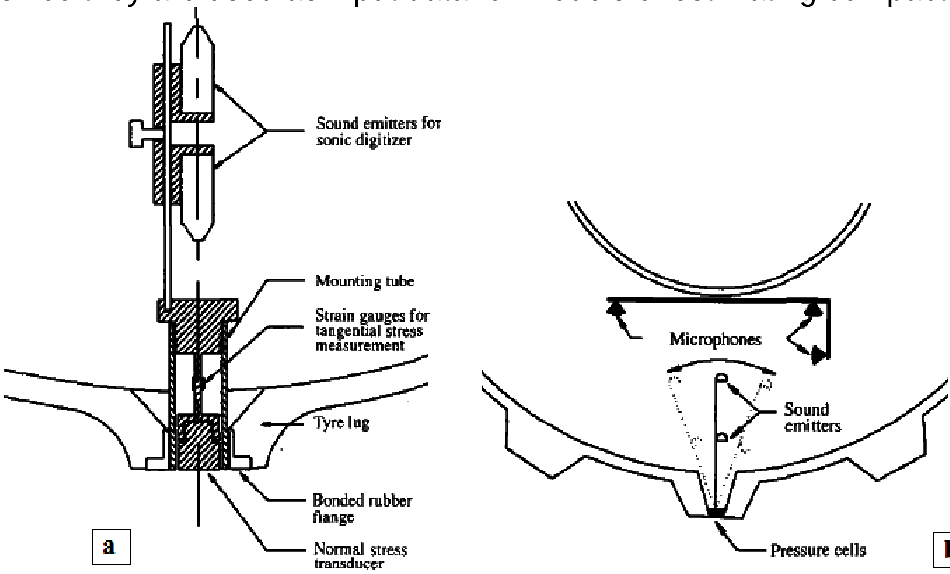

Fig. 7. Transducer for the measurement of normal and tangential stress in soil-tire interface (a) and the position of measuring system inside the tire (b) [2]

VandenBerg and Gill (1962) measured the distribution of normal stress across the width of a smooth tire, by embedding pressure transducers in the tire and in soil surface. It was found that the shape and size of pressure distribution varied with soil type. Burt et al. (1987) developed a system for measuring the size, location and direction of stress at the interface between soil and tire with lugs. The bidirectional transducer uses a small pressure sensor mounted on the end of a cantilevered beam (Fig. 7a) [2]. Normal stress is measured by the pressure sensor, while strain gauge mounted on the beam measures the strain due to the moment of bending given by the tangential force on the pressure sensor. Using a sonic digitizer, mounted in the tire, the location and orientation of each transducer were measured, with respect to a known point on the wheel rim (Fig. 7b). The horizontal and vertical components of the interface stress were than computed and integrated into thrust and vertical forces [2].

In laboratory conditions, using soil bins, authors Stranks (2006) and Godwin et al. (2009) studied the effects of tire size, tire inflation pressure and size of external load on the depth of wheel track and the depth at which stress propagates in soil profile.

Fig. 8. Laboratory soil bin. Rubber track (left) and harvester tire (right) [1, 5]

CONCLUSIONS AND FUTURE WORK

Soil compaction represents a serious concern not only for farmers, but also for the specialists in agriculture, environment and civil constructions. Understanding what causes soil compaction facilitates the development of practical management strategies to avoid or to remedy the negative effects of this phenomenon.

The distribution of stress in soil depends on the area of the contact surface, soil moisture, tire inflation pressure, and the design of the tire. For the future, we intend to conduct experimental research on the influence of these parameters on stress distribution in various types of agricultural soils.

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