Soil & Tillage Research 102 (2009) 138–143

Contents lists available at ScienceDirect

Soil & Tillage Research

journal homepage: www.elsevier.com/locate/still

q value for calculation of pressure propagation in arable soils taking topsoil stability into account

H.M. Bastgen, E. Diserens *

Agroscope Reckenholz-Tänikon Research Station ART, CH-8356 Ettenhausen, Switzerland

ARTICLE INFO

Article history:
Received 31 January 2008
Received in revised form 15 August 2008
Accepted 19 August 2008

Keywords:
Machine load
Soil compaction
Topsoil stability
Pressure propagation
Concentration factor
q value

ABSTRACT

Reliable recommendations for practice are required, to enable farmers themselves to decide whether or not it is acceptable to drive over the soil under the prevailing conditions. To this end, the pressure propagation has to be calculated by means of easily recorded parameters. The TASC program (Tyres/Track And Soil Compaction) makes a contribution to this.

The risk of soil compaction may be evaluated with reference to six parameters (tyre size, wheel load, tyre inflation pressure, topsoil stability, soil type and maximum tillage depth).

The program uses these parameters to evaluate the soil stress caused by tyres and tracks.

The aim of the study is on the basis of field measurements to derive a regression equation for calculation of the *q* value (as a measurement of soil hardness when calculating the pressure propagation in the soil) as a function of the penetration resistance. The topsoil stability can then be taken into account when calculating the compressive stress. Locations ranging from high (ley on dry clay soil) to very low soil stability (shortly after ploughing) were selected for the purpose of the study. Soil pressure measurements were made at plough pan level at a total of nine sites (cropland and pasture) with light to heavy soils. Different machine weights were used, producing wheel loads varying from the empty slurry tanker (wheel load 1432 daN) to the 6-row sugar beet harvester (wheel load 10,678 daN).

The *q* value is a measure of topsoil stability (penetration resistance). The *q* value is determined by the compressive stress at a particular depth, by the depth itself, by the contact area and by the wheel load. The so-called equivalent contact pressure can be recalculated on the basis of the compressive stress values measured at a depth of 20 cm. The ratio of the equivalent contact area pressure to the measured contact area pressure (wheel load/measured contact area) gives the *q* value. This value increases as the soil stability decreases.

For the purpose of the regression calculation a logarithmic function was derived for mineral soils from the upper quartiles on the one hand and from the medians of the *q* value and the medians of the penetration resistance on the other.

The coefficient of determination is 0.71. The function applies to mineral soils. First measurements on organic soils indicate that mineral and organic soils react differently to pressure propagation.

No direct correlation was found here between penetration resistance and soil moisture.

© 2008 Elsevier B.V. All rights reserved.

1. Introduction

As a result of market economy pressures, ever-heavier and ever-larger machines are being used in agriculture for efficient plant production with the minimum possible manpower hours per hectare. Excessive soil stress often impairs the supply of water, air, nutrients and heat (Alaoui and Helbling, 2006). Structural changes occur in the form of compaction (Boizard et al., 2000) or plastic deformation extending down to the subsoil (Arvidsson et al., 2002; Tobias et al., 2001). When working fields with heavy machinery it has become essential to monitor the stresses according to the soil conditions in order to preserve soil fertility for the long term (BMVL, 2002; Heinonen et al., 2002).

Forecasting of the compaction risk is based on a characterisation of the topsoil stability (Lebert, 1989) on the one hand and a calculation of the pressure propagation in the soil (Gupta and Raper, 1994) on the other. The pressure propagation calculation is generally based on Boussinesq's theory, according to which the soil is considered to be elastic, homogenous, isotropic, stress-free and an infinite weightless half-space (Boussinesq, 1885; Lang and Huder, 1982). Fröhlich (1934) introduces an exponent *vk*, an

* Corresponding author. Tel.: +41 52 368 33 53; fax: +41 52 365 11 90.
E-mail addresses: Hellen.Bastgen@gmx.de (H.M. Bastgen), etienne.diserens@art.admin.ch (E. Diserens).

0167-1987/$ – see front matter © 2008 Elsevier B.V. All rights reserved.
doi:10.1016/j.still.2008.08.005

ordinal or concentration factor which varies with soil stability and being a dependency of the stress σ_r on the depth z. This allows a series of statically possible stress distributions in a medium having no tensile strength to be represented. Söhne (1953) establishes three different cases when calculating the pressure propagation under an agricultural tyre: (i) an even, circular surface pressure on a hard, dry soil which deforms elastically with a concentration factor of 4, (ii) a surface pressure according to a fourth power parabola for a soil of normal moisture and compactness with a concentration factor of 5, (iii) a parabolic distribution of the surface pressure for an elastic, moist soil with a concentration factor of 6. Other concentration factors are proposed according to the main soil types, equivalent radius of the tyre contact area, contact pressure and pre-compression stress at pF 2.5. This varies from 2.1 (for low stress on consolidated silty soil) to 5 (for high stress on soft loamy soil) (Horn and Lebert, 1994; DVWK, 1995). The SOCOMO model (soil compaction model) is based on these data (van den Akker, 2004). The measured values were compared with calculated values from various model approaches on the basis of field measurements made over several years of compressive stresses under wheels on soils with marked plough pans. To describe the stress state under the wheel axis measured by means of Bolling probes in the subsoil, the best fit with Newmark's equation ($vk = 2$, pressure constant and distributed over the soil surface in a circular pattern, soil elastic) was established (DVWK, 1995). A q value was introduced into Newmark's equation for the most accurate possible calculation of the compressive stress at a soil depth of 20 cm, near the plough pan (Diserens and Steinmann, 2002; Diserens et al., 2003). This q value equals the quotient of the equivalent and the measured contact pressure. Soft soil deforms plastically under the tyres. This causes lateral yielding of the soil at the edge of the load area and leads to a concentration of stresses under the load axis. The equivalent contact area decreases, the equivalent contract pressure increases and the q value rises. The quotient depends on the topsoil stability. Experiments to date have produced topsoil stability values between 4.3 and 8.3 daN, giving a q value between 1.92 and 0.73 for the calculation of the compressive stress (Diserens and Steinmann, 2002).

The aim of the study is also to derive the q value for very soft and very hard soil conditions with reference to additional field measurements. In this context the linearity hitherto assumed (Diserens and Steinmann, 2002; Diserens, 2005) between the penetration resistance in the topsoil and the q value will be verified. It is hoped to enable the compaction risk to be predicted as practically as possible, even under extreme soil conditions, with reference to easily recordable soil parameters such as the penetration resistance in particular.

2. Material and methods

2.1. Soils, machines, contact area, Bolling probes measurements

The plant cover and soil properties at the nine different experimental sites are shown in Table 1. The organic soils are distinguished from the mineral soils by a higher proportion of organic matter (Table 1, nos. 21–23). The mineral sites have an organic carbon content between 1.4 and 3.4%, whereas the organic soils have a content between 9.4 and 10.1%.

The nine field trials involved a total of 23 machines or load situations (Table 2). The machine with the smallest wheel load (1432 daN) was a slurry tanker, while the fully laden 235 kW self-propelled sugar beet harvester had the highest wheel load at 10,678 daN.

Before travelling over the ground, the penetration resistance of the chosen lanes was determined. This was done using penetrometers devised specially by Agroscope Tänikon. A set of Pesola scales was converted and fitted with a screwdriver head (tip width: 6×10^{-3} m). Instead of tractive force this records compressive force. To measure the penetration resistance at the very hard site (Table 1, nos. 7–10) the penetrometer with the larger measuring range up to 50 daN had to be used. The penetrometer with the measuring range up to 20 daN sufficed for the other field measurements. Five representative zones with

Table 1
Experimental sites and soil types

Case no.	Plant cover/crop	Soil type clay/silt/sand content (%)	C org. (%)	Penetration resistance max. 0–0.1 m (daN)	Water potential (hPa)
1	Ploughed, harrowed	Sandy loam (15/26/59)	1.4	2.96	−463
2	Ploughed, harrowed	Sandy loam (15/26/59)	1.4	2.96	−501
3	Ploughed, harrowed	Sandy loam (15/26/59)	1.4	3.24	−485
4	Barley stubble	Sandy loam (15/26/59)	1.4	9.65	−421
5	Barley stubble	Sandy loam (15/26/59)	1.4	9.65	−401
6	Barley stubble	Sandy loam (15/26/59)	1.4	7.91	−380
7	Temporary ley (mown)	Loamy clay (48/32/20)	3.4	26.95	−555
8	Temporary ley (mown)	Loamy clay (48/32/20)	3.4	26.95	−527
9	Temporary ley (mown)	Loamy clay (48/32/20)	3.4	25.52	−382
10	Temporary ley (mown)	Loamy clay (48/32/20)	3.4	25.52	−494
11	Wheat stubble	Sandy loam (19/41/40)	1.4	5.4	−21
12	Rape stubble	Loamy clay (48/32/20)	3.3	4.32	−78
13	Rape stubble	Loamy clay (48/32/20)	3.7	4.32	−51
14	Temporary ley (mown)	Loamy silt (27/53/20)	1.6	7.98	7
15	Temporary ley (mown)	Loamy silt (27/53/20)	1.7	7.98	7
16	Maize stubble	Sand (7/8/85)	2.0	9.94	−26
17	Maize stubble	Sand (7/9/84)	1.4	9.94	−26
18	Permanent meadow	Loam (32/32/36)	1.9	9.06	−46
19	Permanent meadow	Loam (33/34/33)	1.9	9.06	−46
20	Permanent meadow	Loam (32/32/36)	1.9	9.06	−46
21	Oats	Clay loam (org. soil) (52/28/20)	10.1	4.04	−18
22	Oats	Clay loam (org. soil) (52/28/20)	9.4	4.04	−18
23	Oats	Clay loam (org. soil) (52/28/20)	9.8	4.04	−18

Download English Version:

https://daneshyari.com/en/article/306452

Download Persian Version:

https://daneshyari.com/article/306452

Daneshyari.com