RESEARCHES ON MECHANICAL POLLUTION OF AGRICULTURAL SOIL

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The soil compaction is seeing like a mechanical pollution produce by the farm machinery traffic on the farm land. The authors expose the main results obtained during the investigation of the soil compaction problem. For solve the soil compaction problem the authors have applied two different ways. First way use the analytical solving (using the calculus of variation, for an equation system) for soil compaction phenomena and obtain solution which given the possibility to estimate the influence of some process parameter about the compaction degree. The second consist in the structural solving, which use the finite elements modeling for the soil and using different loads.

Keywords: soil, compaction, modeling, mechanical pollution

1. Introduction

The soil compaction, named also soil mechanical pollution, is a very complex problem because the soil modeling with a continuum media body must reflect the changes in the soil structure produced by the traffic, and on other hand, because the stress state in the soil is considered only a measure for the compaction.

The soil compaction is defined as the soil bulk density increasing. Then, the soil compaction phenomenon must reflect the increasing of the density, but the structural software program, generally cannot reflect this aspect. There are few model which can give the measure of the soil bulk density, and these models are complicated, many times using nonlinear formulae. Really the compaction phenomenon is profound non linear because of the soil non linear structure. A mathematical model which reflects the soil bulk density is given in chapter 1.

The structural solution results evaluate the soil compaction in term of the state stress in the soil, and the state stress in the soil is accepted only as a measure of the soil compaction. The compaction structural solution must take account about the non-linear soil structure, but not only this aspect, in plus, generally, the initial soil bulk density distribution is not constant. A good structural solution

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must reflect the residual changes in the soil bulk density distribution. After our knowledge, thus solution there is not until now.

Some structural solutions appear in the chapter two.

2. A model of the soil compaction with soil bulk density modification

This model is 1-dimensional model and using the model of the unsteady quality materials, defined in [1]. The parameters significations are the next: u is the displacement, x is the coordinate on the vertical direction (figure 1, a)), t is the time, ε is the strain, ρ_0 is the initial soil density (the density of the initial soil configuration), ρ is the soil density in the current configuration, ρ_0 is the soil density in the initial configuration (at t=0), f is the inertial load deliver by the soil mass (inertial force density), S is the Piolla – Kirchoff stress of first species in the soil, ε is the soil strain, l is the length of the soil column (or the soil depth), M is the wheel mass specific load, m is the mass of the soil column situated under the contact zone between the wheel and the soil, R is the wheel dynamic radius, V is the vehicle velocity, L and b are the length and the width of the contact zone between the wheel and the soil. Φ is a function which gives the mechanical behavior of the soil material.

The equations of this model are the next (Cuchy equation, geometrical equation, mass continuity equation, and material equation):

$$\begin{aligned} &\frac{\partial S}{\partial x}+\rho f=\rho_0\frac{\partial^2 u}{\partial t^2}, \\ &\varepsilon=\frac{\partial u}{\partial x}, \\ &\rho_0=(1+\varepsilon)\rho, \\ &S=\Phi(h,\varepsilon) \end{aligned} \qquad (1)$$

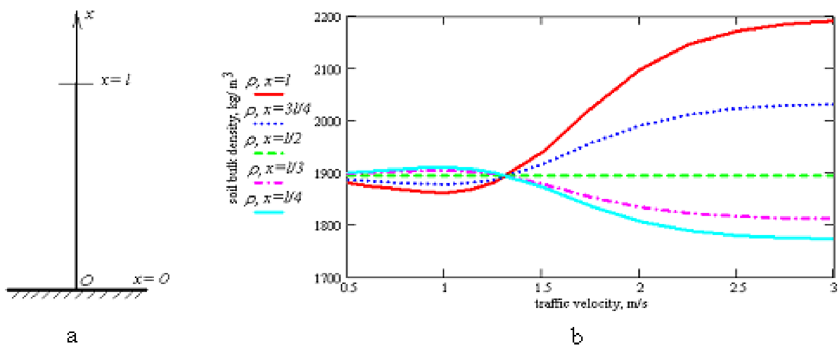


Fig.1. Scheme of the model: a) the geometry and b) soil bulk density dependence on the traffic velocity.

In [1] is given a elementary approximate solution for the model (1). These solution can be use for obtain the a solution for the soil compaction. This solution provides the curve of variation of the soil bulk density in report with some parameters:

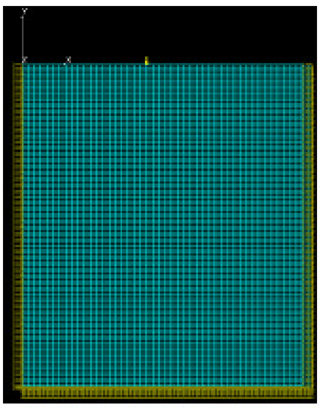
$$\rho(t,x) = \psi(\rho_0(x), M, m, R, V, L, l, t, x)\,. \tag{2}$$

Some graphical representation of the soil bulk density in report with the traffic velocity, for example, is shown in figure 1, b. These curves show the measure of the soil compaction is affected by the traffic velocity at different depths in the soil. The small traffic velocity affects more the surface soil, and the big traffic velocity affect more the depth soil. The information obtained about the traffic velocity on the soil compaction is possible only using models which can consider the impact by the vehicle wheel and the soil. This solution is given entirely in [2].

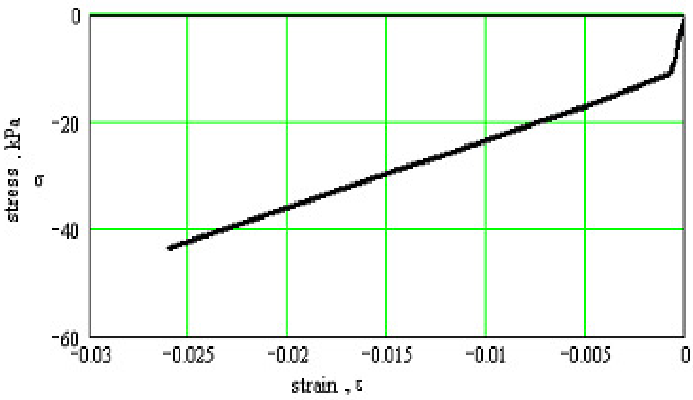
3. Structural solutions

In the last years a lot of soil compaction simulation is based on the mathematical models which use the method of finite elements, or other numerical methods for the continuum body. From the start we avoid the linear – elastic models, and, more generally, the elastic models. The soil elasticity can be neglected in the process of the soil compaction assessment. An elementary structural model is necessary to be nonlinear and to consider the soil plasticity. For the next example, is considers an elastic-plastic material (bilinear material).

The material curve is shown in the figure 2, b. The elements finite network is shown in the figure 1, a.



a



b

Fig.2. The model, based on the method of finite elements (a) and the material characteristic, (b).

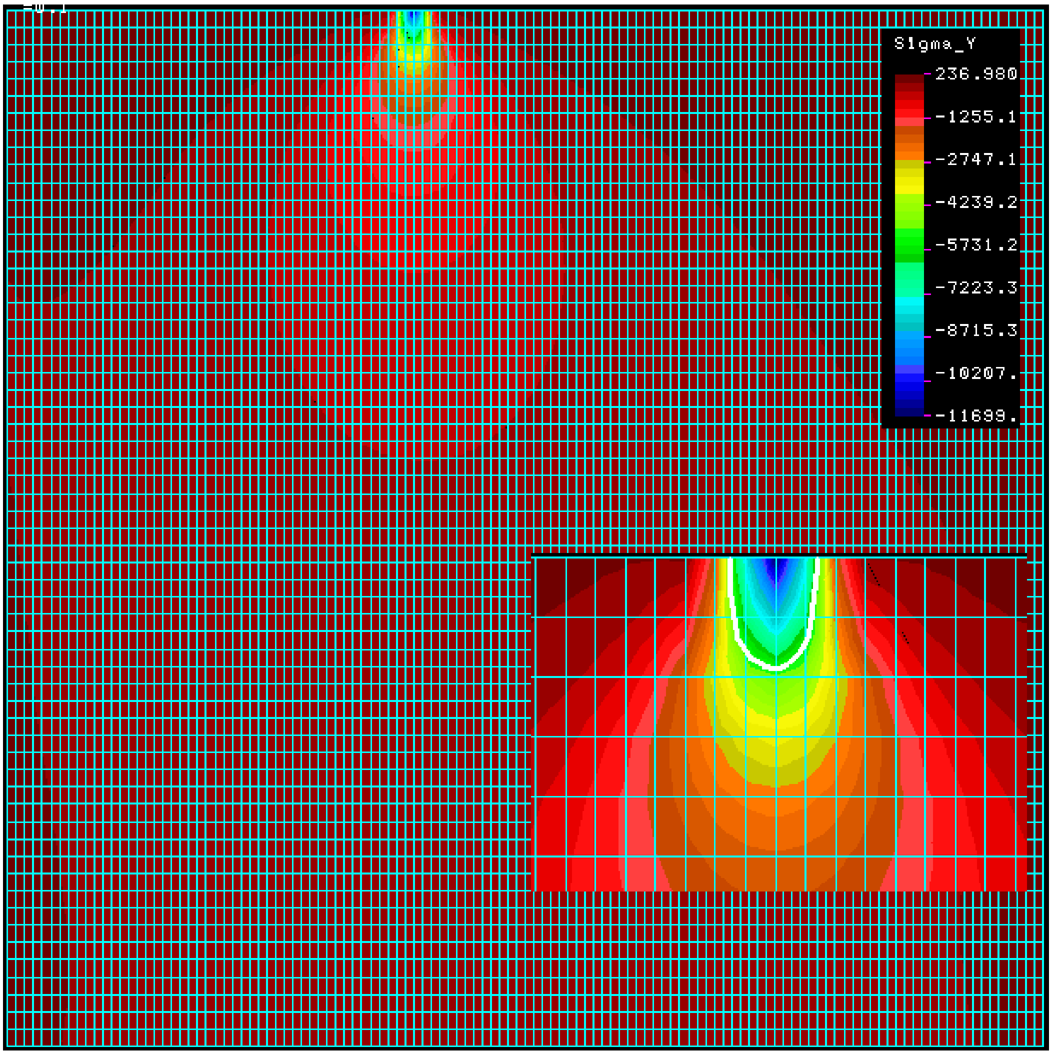


Fig. 3. Vertical stress in the plan MEF model for the soil which is load by a distribute force. The stress is given in Pa. In detail is shown the compaction zone.

For example, we consider, in the solutions with the result given in the figure 3, a soil modeled as a elastic-plastic bi-linear material. The main parameters of this model are: elastic modulus, E= 100000 N/m^2, Poisson ratio, ν= 0.4, soil bulk density, ρ= 1400 kg/m^3, the yield stress limit, σ_Y= 5000 N/m^2, and tangent modulus, E_T= 98100 N/m^2.

We consider many types of loads. For example in the figure 3, is considered a load given by a vehicle wheel. The wheel load is 1000 kg, then the force which is applied on the soil is 9810 N. The force is applied in three successive nods of the network, each force heaving value 3270 N. In the figure 3, these forces are applied by the un-deformed shape. In these conditions, the vertical stress has values included between 236.98 and 11699 N/m^2. If we consider that the compaction zone is characterized by the vertical stress which over the yield limit of the material (zone of residual strain and stresses), then a delineation of these zone is shown in detail of the figure 3. In figure 4, the compacted zone is shown using the plastic vertical strain and the vertical plastic strain. Using these map, the depth of the compacted zone is assess to be 20 cm, and the width at the surface of the soil, 20 cm.

The map of the displacement in the soil is shown in the figure 5. The maximum value of the displacement field is 4.92 cm and its location is the soil which under the wheel. For other appreciations we precise that the distance between two succeeding nods in horizontal direction (Ox), is 5 cm, and on the vertical direction is 10 cm.

This elastic-plastic model is not influenced by the change of the soil bulk density value. Changing the soil bulk density, for example at the value 1000 kg/m3, the maximum value of the displacement, strain, and stress fields remain same.

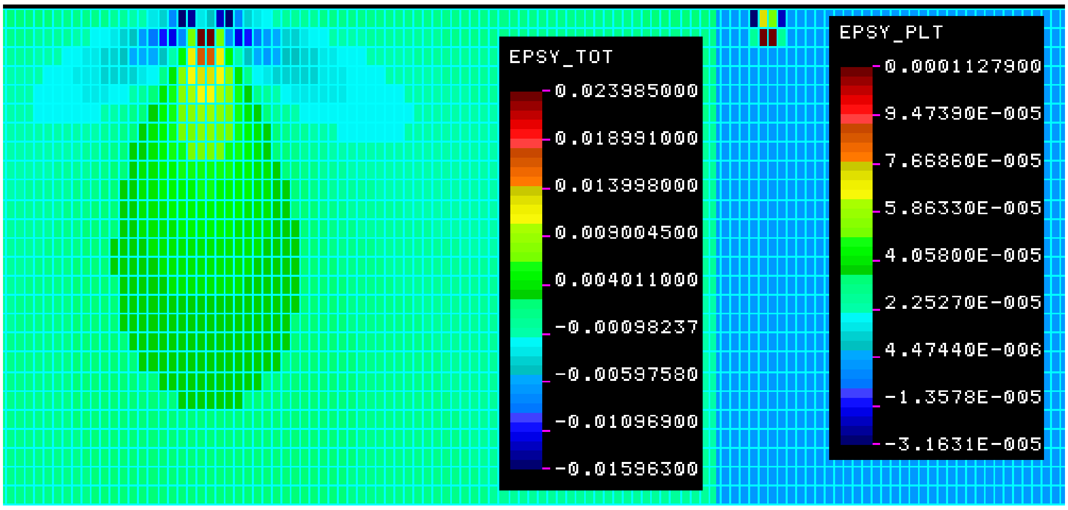


Fig.4. The compacted and the un-compacted zones in the soil loaded by vehicle wheel, in the term of totao vertical strain and plastic vertical strain.

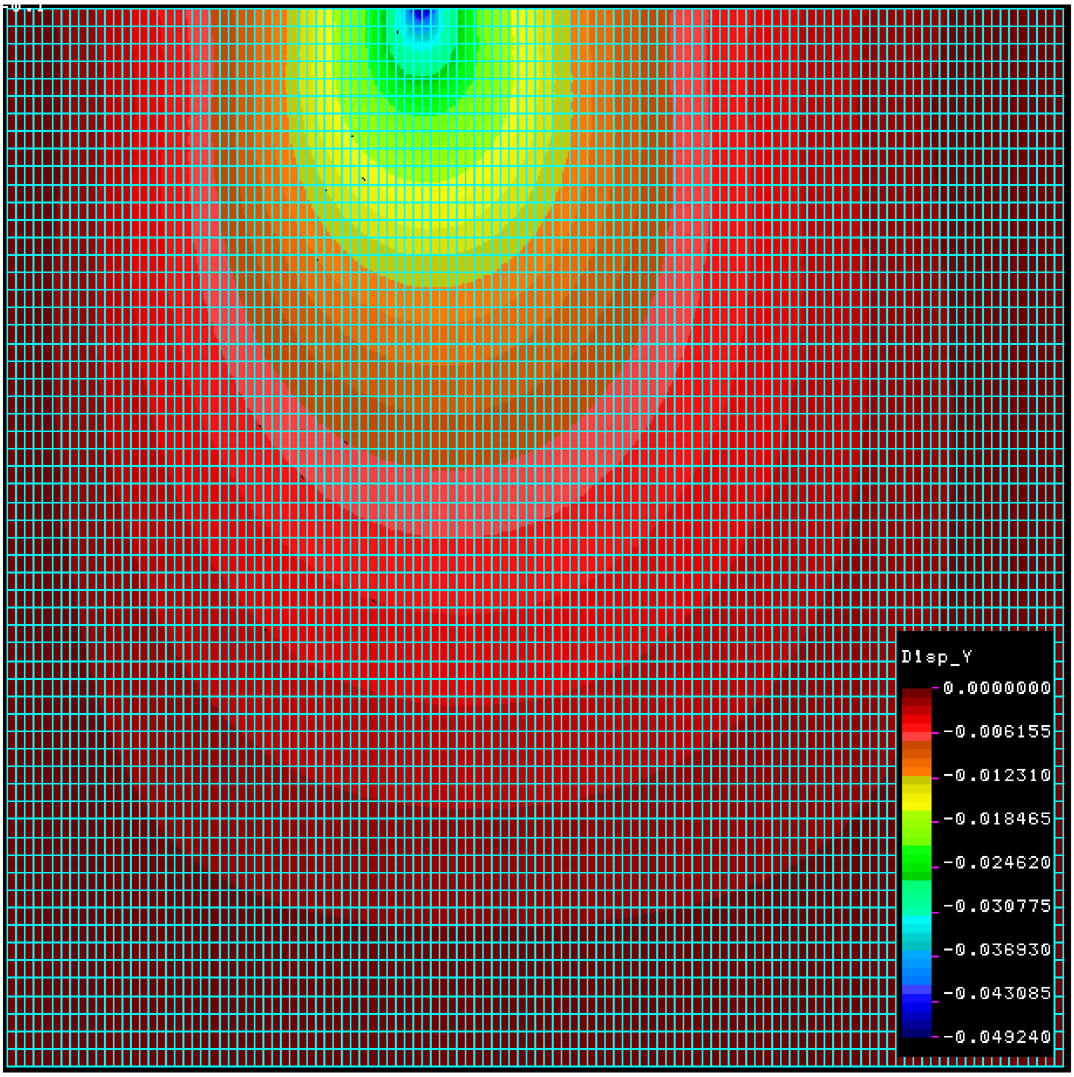


Fig.5. The displacement state in the soil, in m.

However, there is some way to approximate the compaction degree. If the report between the soil bulk density after and before the load action is considered equal with 1+ plastic strain, then, the maximum value of the compaction degree is 1.00011279. For the assess of the compaction degree we can made the hypothesis that the soil mass variation in the compacted zone is neglected. In this case a elementary calculus, using the maximum value of the soil displacement, give for the maximum value of compaction degree, 1.14.

Now, for assessment of the effects of another load (another vehicle wheel), is necessary, at least, to modify the structural soil propriety in the compacted zone which is delineate in the figure 3. For this mathematical model the change of the soil bulk density cannot produce effects. Therefore, the way to find the effects of another load of the same soil, is to consider a pre-stress state in the compacted zone, for example, but, we recommend to consider to the residual deformation of the soil, for a good estimation of the new value of the residual displacement. These changes of the model are the minimum required for obtain some soil compaction phenomenon.

4. Conclusions

The soil compaction definition is based to the soil bulk density, which is considers the main characteristic of the soil compaction. Generally, this characteristic is, not given by the classical structural solution, and many others solutions don't give the soil bulk density space-time variation.

The use of the hand solving for the compaction problem has the next advantages:

- it is possible to obtain soil bulk density formulae which give the influence of each parameter considered about the compaction phenomenon (for example vehicle velocity influence);
- it is possible to consider many types of equations which describe the soil material behavior;
- the formulae obtained by this way can provide different optimal solution for the soil compacting problem, for example, we find the influence of the velocity traffic about the compacting phenomenon;
- using the explicit formulae we have obtained on this way it is possible to formulate some farm management principle, which lead to the diminution of the compaction intensity;
- it is possible to precise a soil bulk density formula, which include the model parameters;
- it is possible to precise the depth of the compacting zone.

The using of the hand solving for the compaction problem has the next disadvantages:

- the solution is usually 1-dimensional because the 3-dimensional solutions are difficult to obtain.

The structural solving for the compaction problem has the next advantages:

- the solutions are 2 or 3 – dimensional and give the space-time variation of the stress, strain;
- by the way of structural analysis is possible to visualize the compacted zone of the soil in 3-dimensional space.

The structural solving for the compaction problem has the next disadvantages:

- generally, this way don't give the soil bulk density space-time variation;

- the structural analysis programs cannot consider whatever material equation for describe the soil behavior;
- for finding the influence of the parameters compacting problem about the compacting degree (with a exactly definition), we need many numerical solving and supplementary general studies.

In the article we comment some aspects of the two proposed way for modeling the compaction phenomenon. We refer to the material laws which we are using to the soil body, the boundary condition and, especially, the calculus of the loads of the soil, generated by the contact between the vehicle wheel and the soil. The structural models will be 2 dimensional (figure 1, b, d, f, h) or 3 dimensional. Also, we comment the result which a structural way can be provide and which result, usually not include the bulk soil density space variation. The presented results in the article will try to assess the density space variation in the compacting soil.

Using the obtained results we can evaluate the time period that which is necessary a deep tillage for the soil compaction amelioration.

R E F E R E N C E S

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