LOAD DISTRIBUTION ON SOIL PROFILE AS GENERATED BY FARM MACHINERY TIRES.

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ABSTRACT

Soil compaction is considered as a major agricultural problem which is close associated to agricultural productivity. This way, the sources of soil compaction should be identified and conveniently studied, so the interacting factors can be considered to propose a future mathematical model. Great part of Brazilian tractors is equipped with tires, which are recognized to generate soil compaction. This research work proposes the application of the *shadow Moiré* technique to map strain distribution on soil profile as well as density increase due to the action of loads generated by tractor tires. Iso-strain curves generated from *more* fringes.

KEYWORDS: Tires, Moiré, Soil Compaction.

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RESUMO

A compactação do solo é considerada como um dos maiores problemas para a produtividade agrícola. As origens da compactação do solo devem ser estudadas e identificadas convenientemente, assim como os fatores a ela atrelados, pois somente desta forma é possível propor modelos matemáticos coerente. Grande parte dos tratores brasileiros são equipados por pneus, que são reconhecidos grandes compactadores. Esta pesquisa propões a aplicação da técnica de moiré de sombra para mapear a distribuição de deformações em um perfil de solo, assim como, identificar o aumento de densidade do solo devido a ação de cargas geradas por pneus de tratores.

PALAVRAS-CHAVES: Pneus, Moiré de Sombra, Compactação do Solo.

INTRODUCTION

Soil compaction is a phenomenon identified as density increase and, consequently, voids decrease. Such a situation is created by dynamic and generally periodic loads as farm machinery traffic, generating dense and hard layers which are incompatible with roots penetration as well as water diffusion. The correlation of crop yielding and soil resistance to root penetration has been demonstrated by [18]. Soil compaction is followed by the decrease of macro and micro pores, as well as availability of water and nutrients and gas diffusion [17] HAKANSSON et al. [8] also state that compaction causes less soil volume for root development which is associated to lower water and nutrients absorption. GILL & VANDEN BERG [7] observe that excessive soil compaction lowers down water penetration water, increases erosion as well as runoff. The application of penetrometer is considered very practical in measuring soil compaction in field conditions, allowing the survey of several points at different depths. However, the presence of roots, stones and variation of soil moisture content is viewed as a disadvantage of the method [3].

Tire type and dimensions, together with machine velocity and traffic periodicity, are considered highly influencing factors affecting soil compaction. Hillel [9] states that the pressure value applied by the tire onto the soil surface is close to the tire inflating pressure. . In general the pressure applied for the tires over a surface of support it is approached equal at pressure of tire inflation [9].

SOEHNE [15], emphasizes that pressure distribution on soil will depend on the vehicle weight which, in turn, will determine the total applied force, on the tire-surface contact area, on the soil initial density and moisture content.

The normal pressure at compress surface of the soil it has a tendency of the to concentrate around of vertical axis in center of applied load. This tendency is so much greater as the soil plasticity due the increase of moisture of soil, soil cohesion and percent of clay . Due this tendency the value of pressure at 30 centimeter below of surface can to be 50 percent greater for a loose and plastic soil e 35 percent for a hard and resistance soil if compared with a normal soil [15]

The stress distribution of compaction is a important project's parameter, and use of tillage machines, and it isn't trivial [7]. The equation that they describe this distribution they are known like Boussinesq Equations [9]. The use of Boussinesq Equations for the prediction of soil stress under whells of tractor must to be done with caution for the fact this equations they have been developed for the use in homogeneous material, isotropic and elastic, characteristics that aren't applied at agricultural soils, this form they are necessary corrections, that they are done adding "factors of concentration" dependents of soil [18].

The basics Boussinesq Equations are:

$$\sigma_r = \left(\frac{3*Q}{2*\pi*r^2} \right) * \cos(\theta) \qquad (1)$$

$$\sigma_z = \left(\frac{3*Q}{2*\pi*r^2} \right) * \cos^3(\theta) \qquad (2)$$

Where the variables seen on Fig. 1, are:

σ_r is the radial stress (principal stress);

Q is the punctual vertical load on soil surface;

r is the ratio of point of surface until the point in which the stress it is applied;

θ it is the angle between the vertical plane and the radius r;

σ_z is the vertical stress in the volume element at ratio r.

UPADHYAYA et al. [18] states that by including the "correction factor" the equations 1 and 2 take the form:

$$\sigma_r = \left(\frac{\nu*Q}{2*\pi*r^2} \right) * \cos^{(\nu-2)}(\theta) \qquad (3)$$

0

$$\sigma_r = \left(\frac{\nu*Q}{2*\pi*r^2} \right) * \cos^{\nu}(\theta) \qquad (4)$$

Where υ is named "concentrated factor" which varies from 3 at 6.

The equations above refer to the application of a punctual load on the soil surface. Stress-lines are showed on Fig. 2 [15]. Loads applied by tires do not exhibit punctual form, but distributed over the surface as showed on Fig. 3 [15].

Considering tires, the punctual loads aren't, but distributed over a surface, being the geometry differ, showed in Fig. [15].

GAMEDA et al. (1984) affirms this values they varies as the rigidity of soil, being õ = 3 for the isotropic materials; õ = 4 for the hard material, just elastic deformation; õ = 5 for agricultural soils with normal moistures and densities; õ = 6 for soils very moistures.

ALBIERO et al. [1] describe a shadow *moiré* technique with appropriate processing to obtain the iso-strain mapping of a soil surface under compressive loading, obtaining the corresponding deformation in a orthogonal direction on the surface under consideration.

The shadow moiré technique consists in generating interference patterns between a grid and its own shade projected onto an object surface. *Moiré* techniques are suitable to generate contour lines onto surfaces, obtaining, that way, its topography and geometry. These phenomena are well understood and described by the wave theory, discarding the quantum as well as electromagnetic theories.

The wave function describes the light propagation as waves [14]. When two waves of same frequency and amplitude exist simultaneously in the same space region, the total wave function is the summation of theses waves and their phase relationship will generate fringe patterns of different light intensities [14].When two grids or screens are superimposed, fringes are generated as a result of the these grids line combinations. These fringes are named *moiré* patterns or *moiré* fringes and the phenomena called *moiré* effect. CLOUD [2] mentioned that in 1945 these fringes were recognized to exhibit displacement magnifying abilities. HU [10] reports that projecting and shadow *moiré* are the mostly employed shape surveying techniques due their simplicity and quickness. *Moiré* fringes can be sought as a superposition of two plane waves which keeps an angle between their traveling directions. In the regions where the waves are on phase, a constructive interference is generated, showing clear patterns and in the case of destructive interference, dark patterns are formed[11]. Such an approximation is derived from the interference between fringe patterns by means of the relations so called initial transition model [12]. TAKASAKI [16] employed the superposition of a grid onto its own shade to measure the contour of some objects. By employing the whole field subtracting method as defined by POST[13], an isostrain field could be defined which would indicate the occurrence of stress concentration.

Moiré fringes are generated by points of equal height similar to contour lines of topographic maps. POST [13] states that sharp fringes are obtained when bar width are equal to the space between them and the grid is well defined at the edges of the bars.

The objective this work is to apply a methodology based in the shadow *moiré* technique as described by ALBIERO et. al.[1] to determine the spatial distribution of radial stress (principal stress) of the compacted soil volume generated by agricultural tire.

METHODOLOGY

The experimental phase of this work was carried on the experimental field at the Faculty of Agricultural Engineering in the State University of Campinas, São Paulo, Brazil. The experimental setup to generate *moiré* fringes as it is shown on Fig. 4, was constituted by a light source of 500 W Sawyers Grand Prix 730RI, one digital camera Sony Mavica with 800 kpixels, and one Ronchi grid with a period of 0.4 bar/mm, a tractor tire - Goodyear 9.00-16-F2, with inflating pressure of 220 kPa, mounted on the forward axis of a Massey Fergunson MF290 tractor, having a total weight of the 4000 kg, being the weight over the forward axis of 1660 kgf. The experimental setup for load application on the soil is showed on Fig. 5.

The selected soil for experimental tests represents a red distroferric latossol [4], constituted by 57% of clay, 11% of silt, 22% of sand and 10% of organic matter, having an apparent density of 1.27 g/cm^3, 24.9 % of moisture content and a cone index of 1500 kPa.

TAKASAKI [16] employed the superposition of a grid over it own shade to gerate the topographic of objects. In this case the *moiré* fringes were constituted of a set of points even level. POST[13] state that *moiré* fringes can be generated with good visibility when: the bars space between them are of equal width; the bars contours are well defined; the intersection of angle between the light source and the observer line of vision is small; the ratio between spaces and bars is less than 1,05:1.

The selected Ronchi grid, had a period of 0.4 mm, keeping the ratio between reference grid/ specimen grid as 1:1, the angel between light source and the observer vision line fixed in 25^{o}.

The pictures were gotten in JPEG format, and converted through the software IRFANVIEW 3.58 [10] to gray scale in BMP format, where the 0 level stands for black color and 255 level for white color.

Each set of pictures of experimental tests was processed through specific filters (gaussian and arithmetical median with array 3 x 3).

Whole field subtraction method was employed as defined by POST [13], by subtracting pixel to pixel of a picture referring to X_i loading from a picture at X_{i+1} loading level. That method allows determining the deformation experienced by a testing specimen between two loading level situations by means of both image superposition.

RESULTS AND DISCUSSION

The obtained results are shown in Fig. 6 and 7. It is noticed that the stress distribution showed in iso-strain maps, mainly for the format of onion. Fig. 3 exhibits the soil stress distribution under loading, which confirms the efficiency of the shadow *Moiré* technique in generating the presented data.

It should be understood that the presented map is qualitative and the scale refers to a relative strain intensity. It is noticed on Fig. 6 and 7 that iso-strain maps follows the stress line geometry as predicted by the Boussinesq theory. Showed results evidence stress concentration around the vertical axis normal to the compressed surface as described by SOEHNE [15].

POST [13] states that the shadow *moiré* techinique is able to capture out-of-plane strains in a loaded object. Referring to anisotropic materials, out-of-plane strain are captured generating different patterns for each type of soil structure, physical-mechanical characteristics and respective compactation condition, besides organic matter content, micro and macro structure and moisture content.

ALBIERO et al. [1] emphasizes that color scales displayed together with processed images in shadow *moiré* technique, defines iso-strain maps of soil samples under compressive loading, referring to pixel to pixel subtraction generating the image matrix. Each pixel of that image is defined as light intensity referenced in a 0 to 255 gray scale, in such a way that the subtraction of a pixel of unloaded soil image from a pixel of loaded soil image, generates a pixel of relative strain values, informing how the pixel exposes the deformation of the whole region.

Scales indicate the relative strain distribution in the region and the algebraic sign (+ or -) should not be understood as positive or negative strain strain, but just as greater or smaller strain.

CONCLUSIONS

The above results allow to conclude that proposed methodology generates satisfactory results in determining radial stress compaction on soils by means of iso-strains maps.

The shadow moiré technique showed to be practical, of the easy and fast execution.

Future studies should be devoted to quantify the sacles.

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FIGURES CAPTIONS

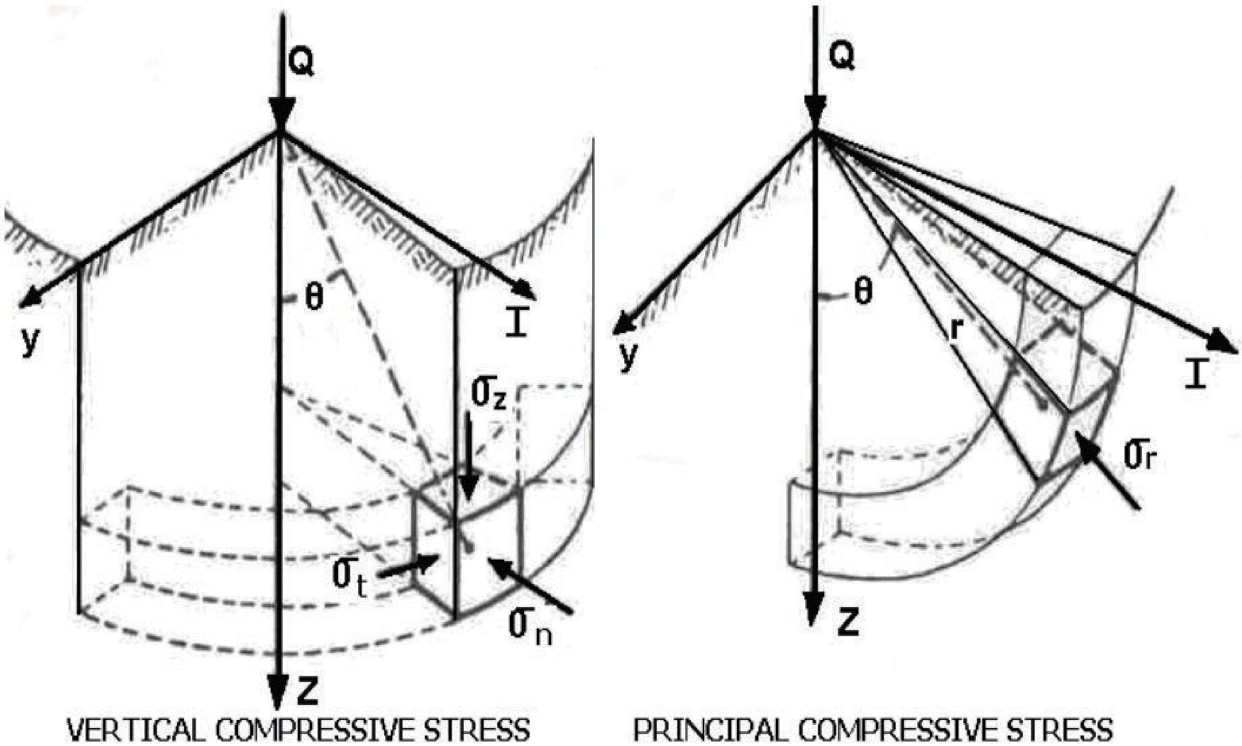

Fig. 1. Variables used in equations (1), (2) , (3) e (4), (SOEHNE, 1958).

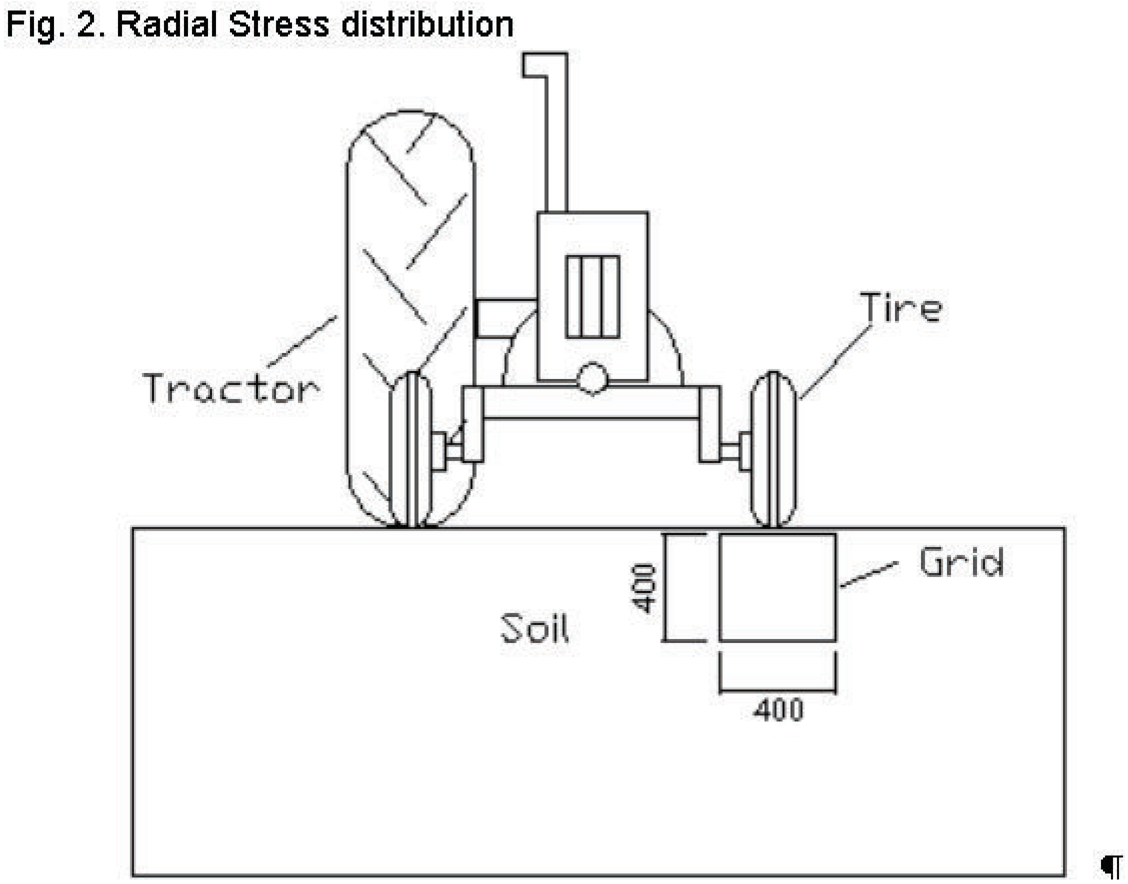

Fig. 2. Radial Stress distribution σ_r , (SOEHNE, 1958).

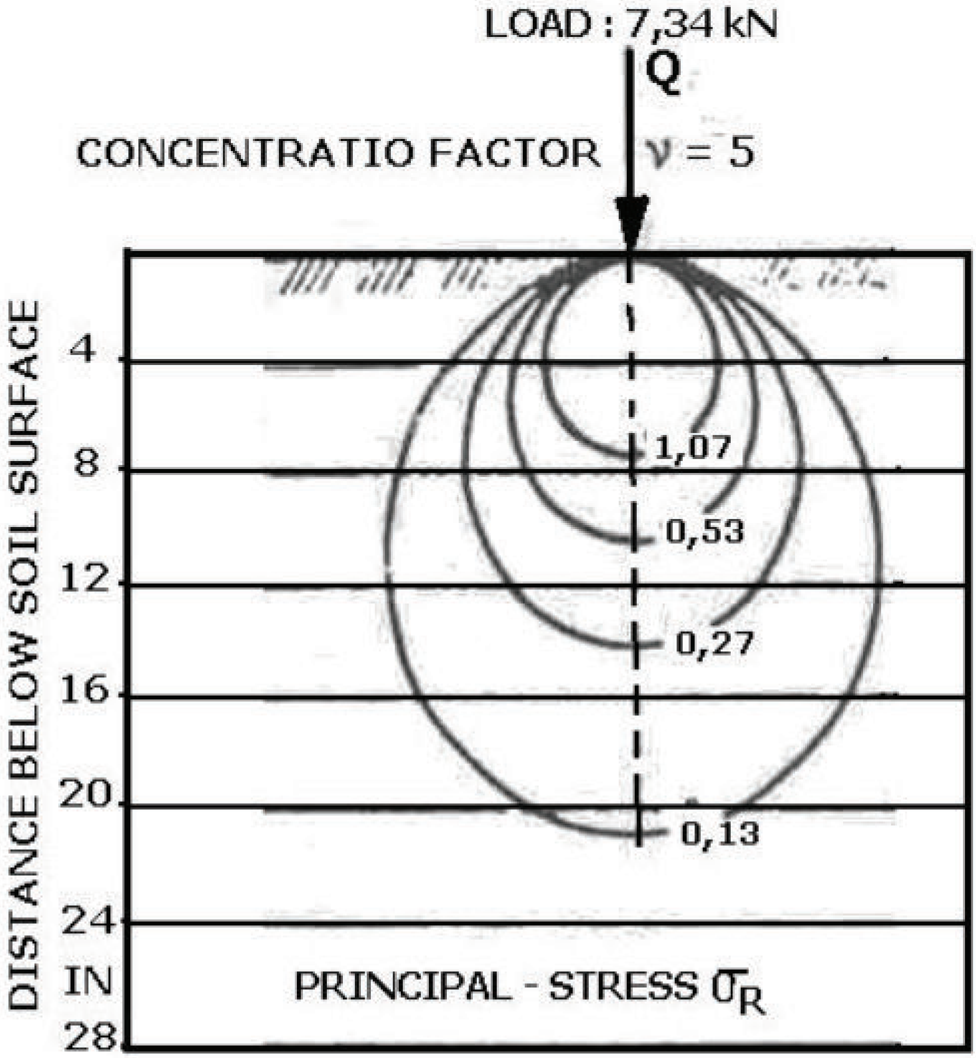

Fig. 3. Vertical Stress over tires and tractors in Boussinesq Theory, concentration factor $\upsilon = 5$, Tire type = 9 – 24 ; load= 4,9 kN ; Pressure tyre = 82,7kPa, (SOEHNE, 1958).

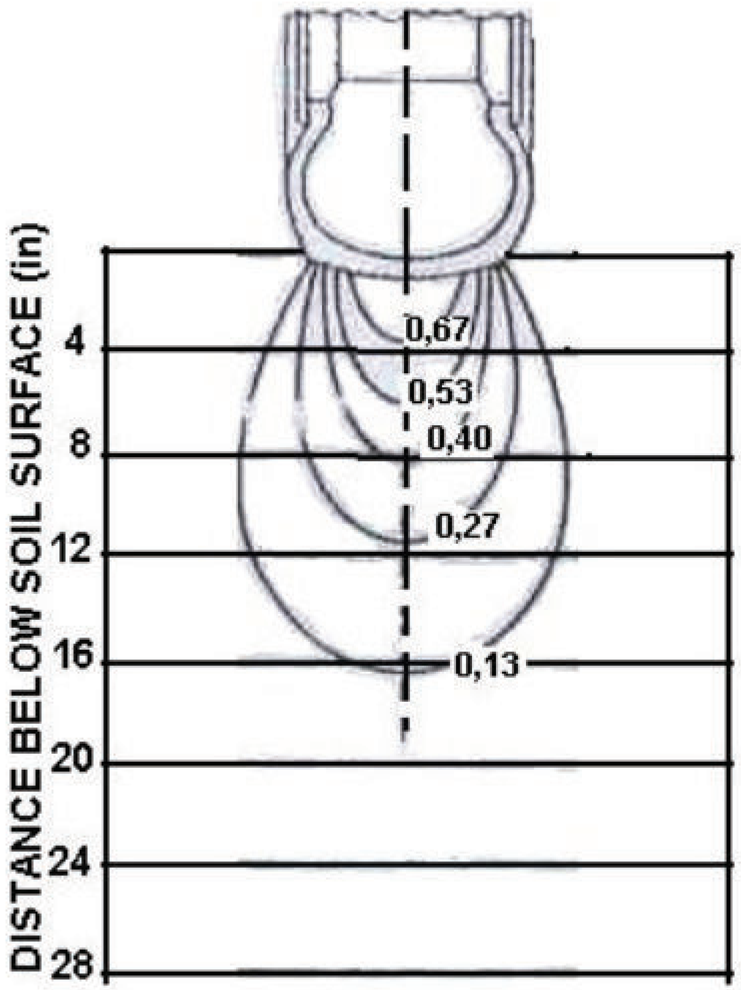

Fig. 4. Experimental setup for to get the moiré fringes.

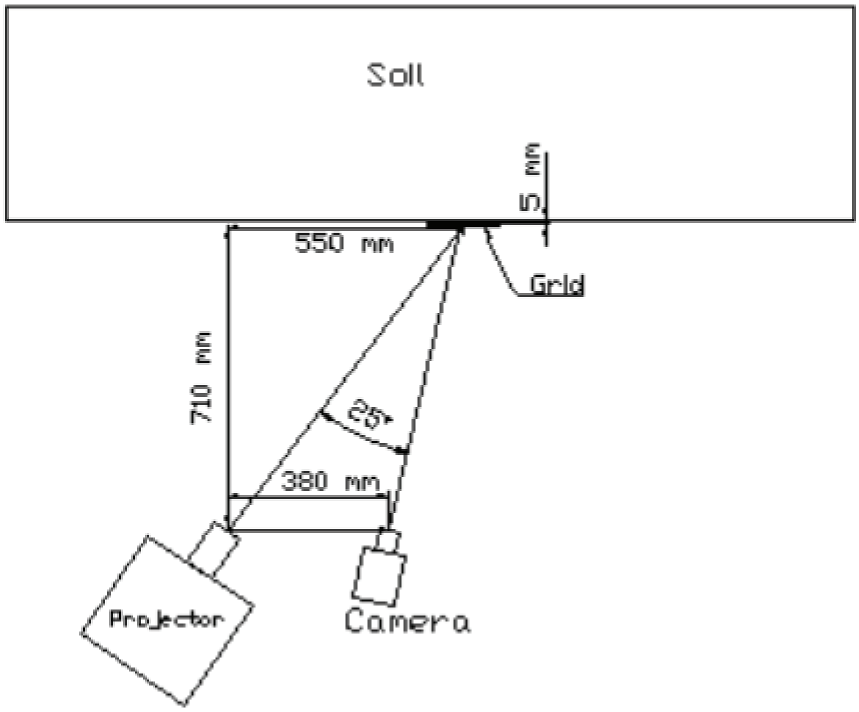

Fig. 5. Experimental setup for load application in soil.

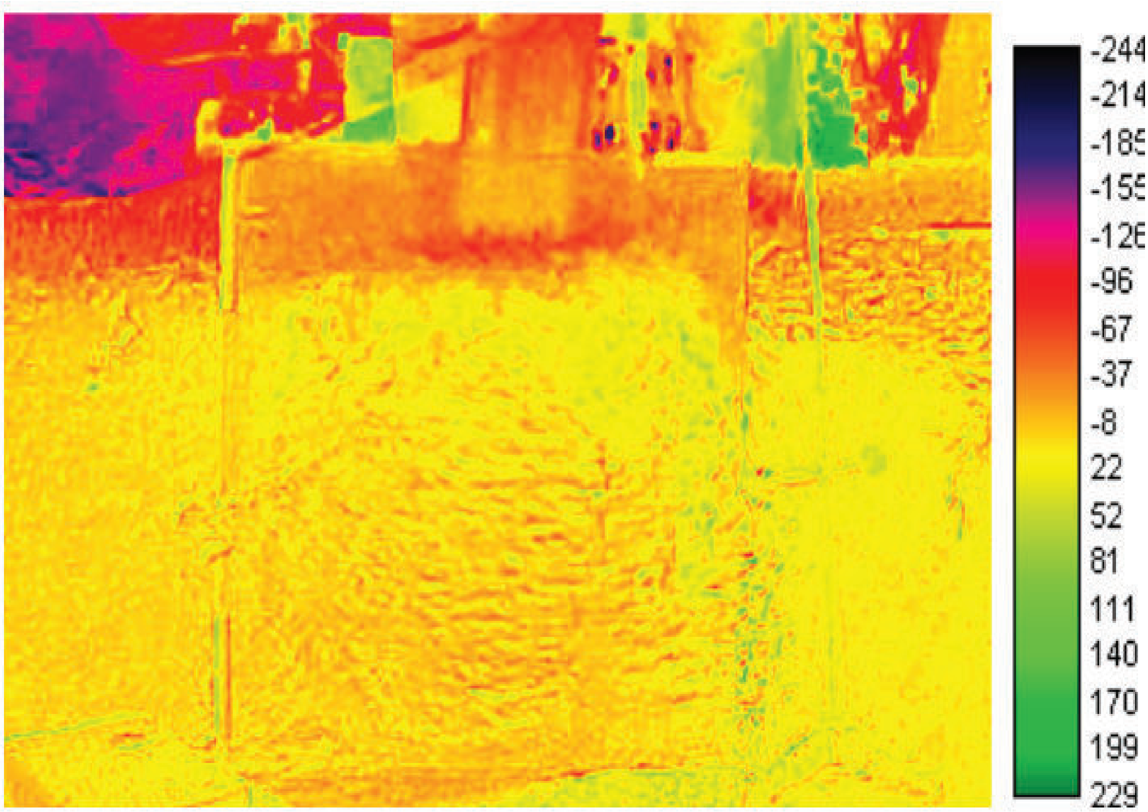

Fig 6. Iso-deformation map showed even region stress.

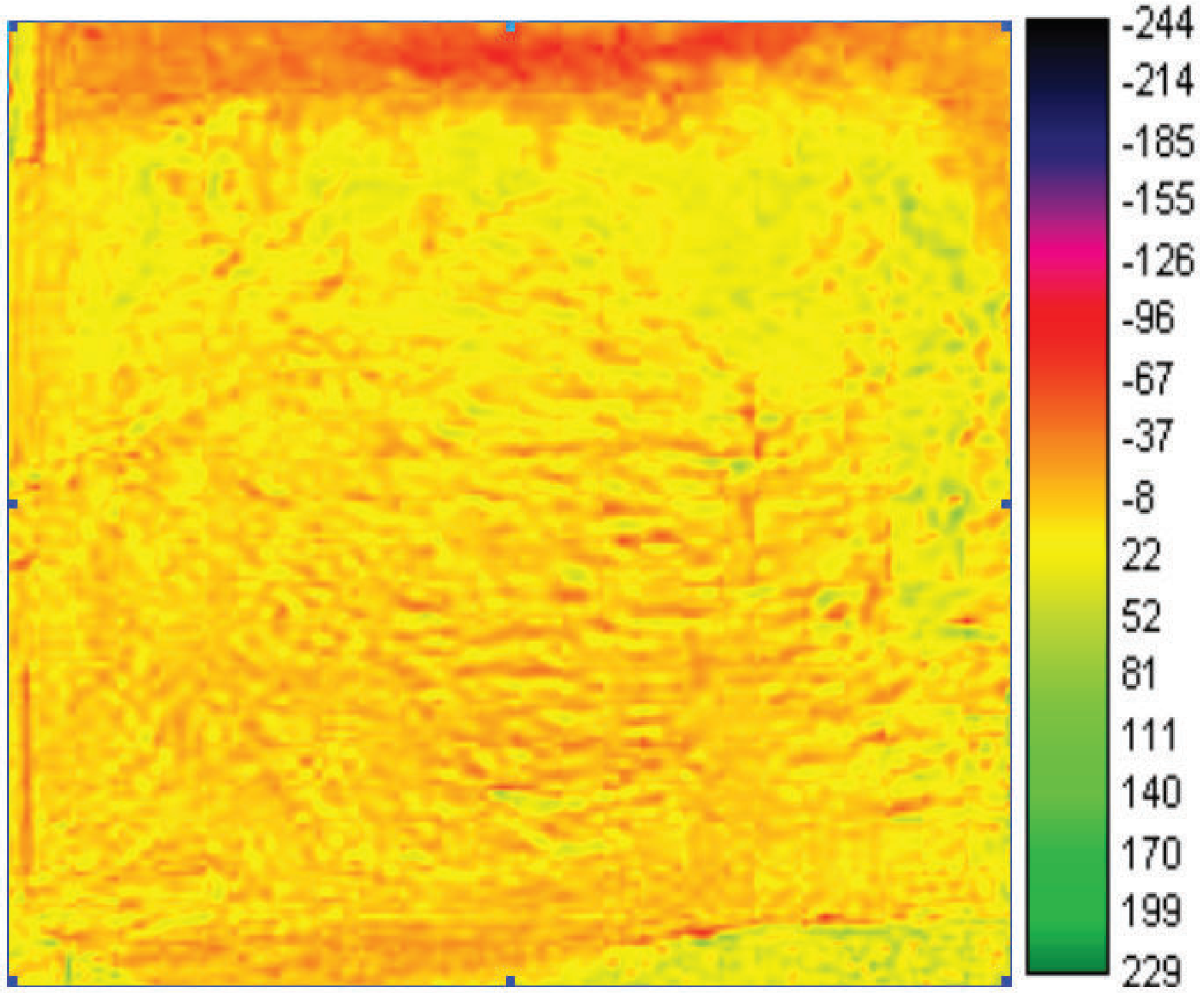

Fig. 7. Iso-deformation map (zoom of 3 times).

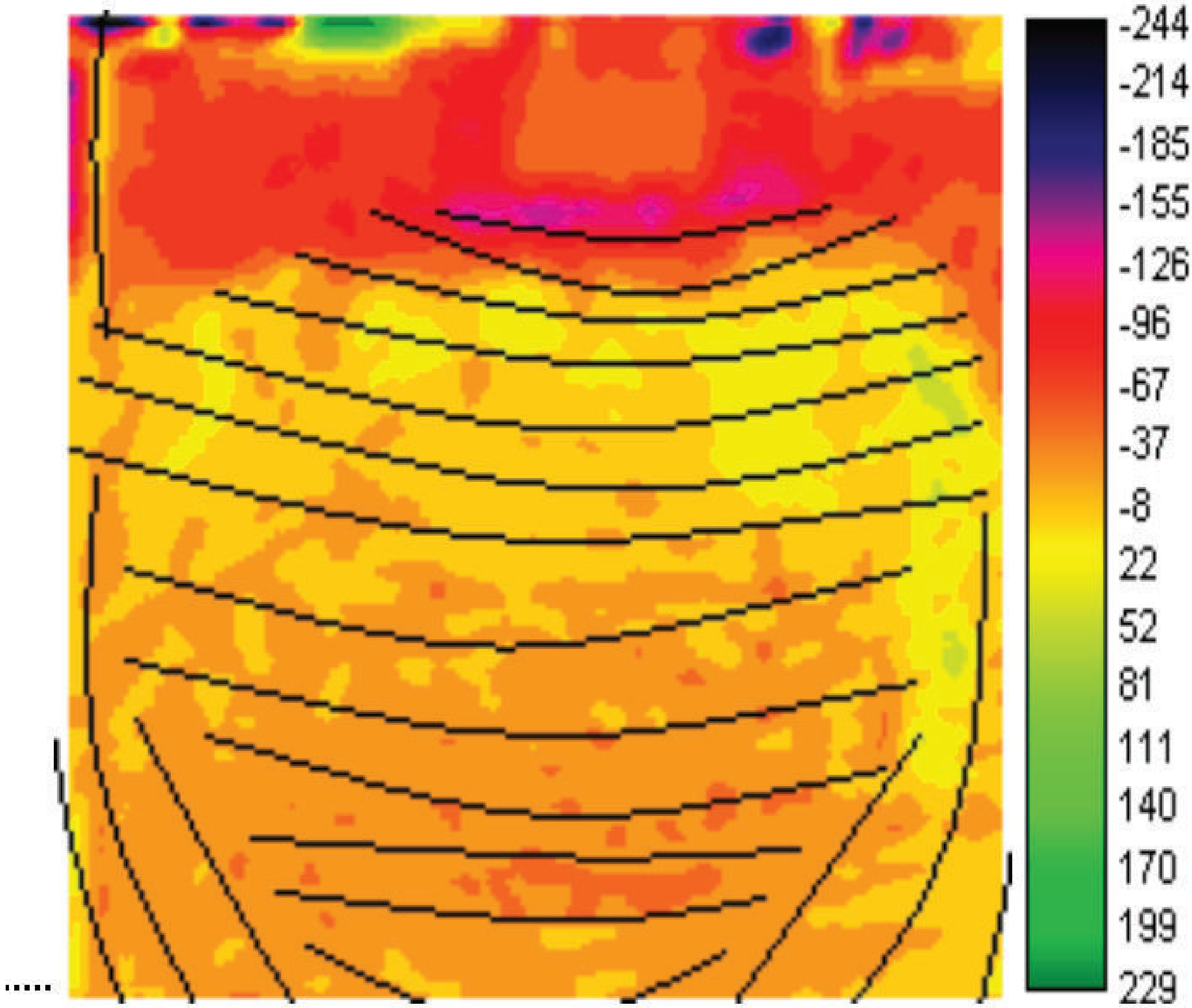

Fig. 8. Iso-deformation after filter treatments of noise.