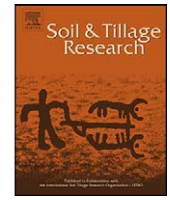
Soil & Tillage Research 105 (2009) 122–127

Contents lists available at ScienceDirect

Soil & Tillage Research

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



Strength attributes and compaction susceptibility of Brazilian Latosols

Ayodele Ebenezer Ajayi [a,b], Moacir de Souza Dias Junior [b,*], Nilton Curi [b], Cezar Francisco Araujo Junior [b], Thiago Tadeu Teixeira Souza [b], Alberto Vasconcellos Inda Junior [c]

[a] *Department of Agricultural Engineering, Federal University of Technology, PMB 704, Akure, Ondo State, Nigeria*
[b] *Federal University of Lavras, Department of Soil Science, CEP 37200-000, Lavras, MG, Brazil*
[c] *Federal University of Rio Grande do Sul, Agronomy School, Department of Soil, CEP 90001-970, Porto Alegre, RS, Brazil*

ARTICLE INFO

Article history:
Received 15 October 2008
Received in revised form 9 June 2009
Accepted 22 June 2009

Keywords:
Precompression stress
Compression index
Water potential
Water retention curve
Soil structure
Load bearing capacity

ABSTRACT

In this study, strength attributes and compaction susceptibility of the main classes of Brazilian Latosols (Oxisols), under native vegetation, were studied using the load bearing capacity models relating precompression stress, compression index and water potential through statistical regression models. These models were developed based on the results of the analysis of undisturbed soil samples collected at the B horizon at the different sites. The results showed that the maximum value of the compression index was 0.53 for the Acric Red Latosol, indicating its higher susceptibility to soil compaction. The Dystrocohesive Yellow Latosol had the highest load bearing capacity, while the Acric Red Latosol had the lowest one. The Dystrocohesive Yellow Latosol due to its high load bearing capacity and bulk density (mechanical resistance) behave similarly to hardsetting soil, in which the plants root system has severe physical restrictions to explore deeper horizons during the dry periods. Differences in the load bearing capacity and compaction susceptibility were found to be influenced by soil structure which is associated with clay mineralogy in these very weathered-leached soils and water potential. The study also showed that soil compression index is influenced by water potential and clay mineralogy also. Our work has laid a foundation for estimation of compaction susceptibility of Latosols.

1. Introduction

The geographical extent of the soil order Latosols (Oxisols—*U.S. Soil Taxonomy*, Sols ferralitiques—*French classification,* and Ferralsols—*World Reference Base for Soil Resources*) has been established in several studies in Brazil. It is found in almost all states of the country (associated with different parent materials) in spite of the varied climatic conditions (Ker, 1997). According to the distribution map of the various classes of soils in the study by Camargo et al. (1987), Latosols cover about 65% of the land mass in Brazil.

Latosols represent by far the major soils under mechanized agriculture and forestry operations in Brazil. Latosols have good potential in response to chemical correction (lime, gypsum and fertilizer application) and exhibit good drainage attributes (Marques et al., 2004). They are highly weathered, strongly leached and friable, dominated by 1:1 clay minerals, Fe-and Al-oxides (in this paper, this general term includes oxides, hydroxides and oxihydroxides), quartz and other highly resistant minerals (Curi, 1983)

The structure of the Brazilian Latosols is mainly associated with the kaolinite and gibbsite minerals content. Whereas kaolinitic Latosols tends to exhibit blocky structure and higher bulk density, the gibbsitic Latosols present granular structure and lower bulk density (Embrapa, 2006; Ferreira et al., 1999a,b). The horizons are poorly differentiated, because differences in properties with depth are so minimal (Curi, 1983).

In mechanized agriculture and forestry harvesting prevalent in Brazil, there are growing concerns on the possible damage to the soil structure in view of increasing mass of machineries and equipment used in field operations (Larson et al., 1980; Peng et al., 2004; Dias Junior et al., 2007; Veiga et al., 2007). The ability of soil to withstand pressure exerted by applied loads depends on its strength, which influences the resistance of soil to compaction. It has been linked to several intrinsic attributes of the soil including texture, clay mineralogy, structure, bulk density, porosity, pore-size-distribution and pore-shape (Ohu et al., 1986; Horn, 1988).

Soil strength (mechanical resistance) and compaction susceptibility may be assessed by different parameters from soil compression curves (bulk density plotted versus log applied pressure), as discussed in some scientific articles (Larson et al., 1980; Horn, 1988; Dias Junior and Pierce, 1996; Alakukku et al., 2003; Imhoff et al., 2004; Gregory et al., 2006; Veiga et al., 2007). The compression curve is composed of two regions: a region of

* Corresponding author at: Department of Soil Science, Federal University of Lavras, P.O. Box 3037, CEP 37200-000, Lavras, MG, Brazil. Tel.: +55 35 3829 1634; fax: +35 3829 1251.
E-mail address: msouzadj@ufla.br (M.d.S. Dias Junior).

0167-1987/$ – see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.still.2009.06.004

plastic and unrecoverable deformation called the virgin compression curve, and a region of small, elastic and recoverable deformation called the secondary compression curve (Larson et al., 1980; Dias Junior and Pierce, 1995; Gregory et al., 2006). The slope of the virgin compression line is called the compression index (CI). The point that separates these two regions in a compression curve is the precompression stress (σ_p). These parameters define the soil compression curve and may change with soil type, initial moisture content or water potential and management history (Culley and Larson, 1987; Larson et al., 1988; Alakukku et al., 2003). The precompression stress have been used as an indicator of the load bearing capacity and mechanical strength of a soil, to estimate quantitatively the compaction risk (Alakukku et al., 2003) in a specific soil condition at given moisture content or water potential (Oliveira et al., 2003; Peng et al., 2004; Dias Junior et al., 2007).

The precompression stress might be derived from a confined compression test, shear strength derived from a triaxial or a direct shear test, and penetration resistance measurements among other methods (Horn and Lebert, 1994; Arvidsson, 2001; Zhang et al., 2001; Horn and Fleige, 2003; Arvidsson and Keller, 2004; Dias Junior et al., 2005, 2007; Veiga et al., 2007). The various soils present mechanical strength values which can be quantified from precompression stress (Dias Junior et al., 2007; Veiga et al., 2007), being this a dynamic attribute influenced by structure, texture, water suction and bulk density (Horn, 1988), besides pedogenetic processes, anthropogenic effects, or hydraulic site-specific conditions (Horn et al., 2004). The soils would also be submitted to an additional soil compaction as long as their internal strength is smaller than the applied pressure (Veiga et al., 2007).

Precompression stress also gives an indication of the maximum pressure that should be applied to a soil in order to avoid soil compaction (Défossez and Richard, 2002; Dias Junior et al., 2005) and it is a useful indicator of the soil's load bearing capacity (Dias Junior et al., 2005; Rücknagel et al., 2007). If the applied pressure to a soil does not exceed the precompression stress value the soil reacts elastically. However, if it exceeds, there would be plastic deformation in the soil (Horn and Lebert, 1994).

Load bearing capacity is a relationship between precompression stress and moisture content (Dias Junior and Pierce, 1996) or water potential (Oliveira et al., 2003) and it means the capability of a soil to withstand stress induced by field traffic without changes in the three-dimensional arrangement of its constituent soil particles (Alakukku et al., 2003). Likewise, these authors suggested that the risk of subsoil compaction is high when the exerted stresses are higher than the load bearing capacity of the subsoil and that the wetness decreases the load bearing capacity. Several studies in tropical and temperate soils showed that the load bearing capacity exponentially decreases as a function of increasing moisture content (Dias Junior and Pierce, 1996; Silva et al., 2002; Peng et al., 2004; Assis and Lanças, 2005; Dias Junior et al., 2007; Gontijo et al., 2008) or increases as a function of increasing water potential (Oliveira et al., 2003; Ajayi et al., 2009).

The soil compression index is an attribute estimated from compression curves and it is an indicator of susceptibility of soil to compaction (Larson et al., 1980; Imhoff et al., 2004; Gregory et al., 2006).

Keeping in mind the above considerations, the objectives of this study were: (1) to determine the values for the precompression stress and the compression index of the various classes of Brazilian Latosols under native vegetation, and (2) to assess the load bearing capacity of these Latosol classes through statistical regression models.

2. Materials and methods

2.1. Site description and sampling protocol

Undisturbed soil samples were collected from four representative sites under native vegetation in Brazil. The selected sites represent geographically distinct sub-regions, wide ranges of ecological conditions and cultivation practices, beyond differential clay mineralogy. They also present the ranges of Latosols that had been associated with different types of parent materials in Brazilian conditions (Table 1).

Ten undisturbed samples were collected in the B horizons at all the sites using aluminium rings with 6.5 cm diameter and 2.5 cm height. The sampling device was pushed carefully into the soil using a falling weight. The sampling pits (1 m width × 2 m length × 1 m depth) were dug very carefully to guard against self-compaction of the soil. They were collected randomly in each pit to ensure good representation. The samples were collected between 80 and 100 cm depth at the sites, because in the B horizon the structure is truly expressed once in the A horizon the granules behave as blocks due to higher swelling-shrinking characteristics. As these Latosols are very much homogeneous in morphology, we decided to collect the samples in the "clean B horizon" in order to avoid as much as possible the organic matter influence on soil attributes. In this way, our data can be extrapolated to the B horizon top where possible damage due to traffic can occur. Also in some Brazilian regions having dry periods, the cohesive Latosols are being prepared up to 120 cm depth using ripper subsoilers aiming to favor an adequate root distribution of perennial plants, such as *eucalyptus* sp. In addition to that, with the mechanical resistance breakdown by the subsoiler, the precompression stress of the soil is much reduced (Gontijo et al., 2008). At each point of sample collection, the ring filled with soil was removed from the Uhland sampler, and wrapped with plastic materials and paraffin wax until compressibility and other tests were performed.

2.2. Laboratory experimental procedure

In the laboratory, the soil samples were carefully trimmed to the size of their respective rings, whose inner diameter, height and weight had been pre-measured. The disturbed soil samples scraped near the intact soil cores were collected, air-dried, sieved

Table 1
Sampling sites and soil descriptions.

Label and location	Geographical coordinate and altitude	Climatic description	Brazilian soil classification	Parent material	Native vegetation
(DRL1) Lavras county, Minas Gerais State	21°13′47″S; 44°58′6″W 918 m	Gentle temperate with dry winter and rainy summer	Dystroferric Red Latosol	Gabbro	Forest
(ARL) Uberlândia county, Minas Gerais State	18°58′37″S; 48°12′05″W 866 m	Tropical monsoonal with dry winter and rainy summer	Acric Red Latosol	Tertiary detritic cover sediments	Cerrado
(DYL) Aracruz county, Espírito Santo State	19°47′10″S; 40°16′29″W 81 m	Moisty tropical with dry winter and rainy summer	Dystrocohesive Yellow Latosol	Barreiras group sediments	Forest
(DRL2) Santo Ângelo county, Rio Grande do Sul State	28°16′16″S; 54°13′11″W 290 m	Moisty tropical without long dry period	Dystroferric Red Latosol	Basalt	Forest