Is soil compaction due to external stresses in central Iran?

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Introduction

Compaction significantly influences soil physical, chemical and biological properties. Soil compaction is traditionally defined as a process of decreasing soil pore space due to compressive and shear stresses under agricultural vehicles. Heavy intensive traffic and improper tillage implements are reported to cause severe soil compaction (Soane and van Ouwerkerk, 1994). But Koolen (1994) believed that compaction may be defined as any negative aspect of soil deformation which is important to crop production. However, natural hardening of soil (hardsetting) is an important process occurring in arid soils with low organic matter and unstable structure. Hardsetting of a cultivated soil usually involves slumping, a compacting process that occurs without the application of an external stress. This phenomenon is sometimes confused with compaction, which is caused by external stresses, whereas the forces causing hardsetting are generated within the soil (Mullins, 2000). Young et al. (1988) showed that bulk density as high as 1.7 Mg m$^{-3}$ was attained in a few months after plowing a hardsetting soil. This provides a clear demonstration that external loading is not always the cause of high bulk density of topsoil. Reducing the wheeling area on such soils, without changing management systems may have little influence on the compaction problem. In central parts of Iran, the soils are low in organic carbon, structurally unstable and intensively and conventionally tilled. They are unique in behavior concerning soil compaction and tillage systems (Hemmat, 1998; Hajabbasi and Hemmat, 2000; Mosaddeghi et al., 2000; Shirani et al., 2002). They are top-crusted (Eghbal et al., 1996) and behave similarly to slaking, crusting and hardsetting soils (Mosaddeghi et al., 2003b). They contain large amounts of palygorskite in their mineral fraction. Other major clay minerals in the region are mica/illite, smectites, and kaolinite. Carbonates and sulfates are also important components of the mineral content in soils of the region. The amount of calcium carbonates in these soils is very high (often 30-50 % or more) (Khademi and Mermut, 1998).
In this paper, information on the compaction and mechanical behavior of soils from central Iran based on studies done by the author and his colleagues at Isfahan University of Technology was gathered to define the important factors affecting soil hardening in the region.

**Materials and Methods**

Compressibility and mechanical tests were carried out on five soil samples. The samples were collected from five important soil series of Isfahan province in central Iran. Also, the mechanical behavior of unsaturated samples of artificial mixtures of palygorskite-calcium carbonate-sand was studied.

**Results and Discussion**

In a field study on a silty clay loam soil, traffic caused high soil sinkage and side-flowing at the plastic limit (PL) whereas little compaction occurred at 0.6PL (Mosaddeghi, 1997; Mosaddeghi et al., 2000). This confirmed the high dependency of soil strength on water status. In a pot experiment using the same soil, effects of internal/matric forces upon drying on soil mechanical properties including pre-compaction stress ($\sigma_{pc}$) were examined. The pots were saturated by flood irrigation and soil physical and mechanical properties were measured during soil drying. The soil $\sigma_{pc}$ was strongly affected by water content. The $\sigma_{pc}$ increased linearly with effective stress ($\sigma'$) generated by matric suction for the range of $0<\sigma'<100$ kPa. Therefore, internal forces are among the major sources of hardening in this structurally unstable soil (Mosaddeghi, 2003; Mosaddeghi et al., 2003a and b). These findings were confirmed by the field study on the same soil (Mosaddeghi et al., 2005b). A laboratory experiment was conducted to investigate the tensile strength of artificial mixtures of sand-palygorskite-calcium carbonate (Mosaddeghi et al., 2005a). The effect of palygorskite on the strength was approximately four times greater than that of carbonate due to the fibrous structure and the higher surface area of palygorskite. The significant linear relation between tensile strength and $\sigma'$ generated by matric suction showed the importance of moisture-mediated strength in palygorskite and/or carbonates-containing soils. In a lab experiment on the five topsoils, it was shown that $\sigma_{pc}$ might not be a real critical stress from the view of soil physical qualities (e.g. air permeability) especially for the soils with unstable structure and at high water contents (Mosaddeghi et al., 2003c and 2005c). This is due to the fact
that the positive pore water pressure homogenizes the soil and reduces the continuity of soil pores. Moreover, the particles of the unstable soils do not have permanent and stable bonds e.g. by organic compounds or cementation in order to resist loading. Drying and wetting processes could significantly affect the soil behavior. Therefore, compressive behavior of soils, especially with unstable structure, could be significantly affected by internal stresses (Mosaddeghi et al., 2003d). Another lab trial was conducted to find an alternative laboratory method (besides the confined compression test) for predicting \( \sigma_{pc} \) of soils with low organic matter and/or high water content. A semi-confined compression test was recommended for precise prediction of \( \sigma_{pc} \) (Mosaddeghi et al., 2003e and 2005d). A field study was carried out in order to assess the capability of a plate sinkage test for in situ measurement of soil compactability. The results showed that the plate test was able to predict the \( \sigma_{pc} \) better than the confined test (Mosaddeghi et al., 2005b). The effects of plate size and surcharge pressure on the shape of stress-strain curves and \( \sigma_{pc} \) values of a silty clay loam soil were investigated. With increasing plate size, the measured \( \sigma_{pc} \) decreased. The effect of surcharge pressure on \( \sigma_{pc} \) value was negligible (Mosaddeghi et al., 2004a). The \( \sigma_{pc} \) of the tractor pre-compacted topsoil was better predicted by the plate test than by the confined test (Mosaddeghi et al., 2004b). Cone penetrometry could be used as a quick method for studying soil deformation under running tires and prediction of \( \sigma_{pc} \) (Mosaddeghi et al., 2004c). It is concluded that, internal stresses (matric suction) are important with respect to soil compaction and pre-compaction stress of the unstable soils in central Iran. Water potential (internal stresses), through effective stress, had a crucial and significant effect in this regard. Therefore, the effects of internal stresses should not be overlooked in arid soils and the best management, wetting manner and irrigation technique need to be investigated and chosen for sustainable management of soil hardening. Changes of soil physical properties during the compaction process imply that bulk properties like void ratio cannot completely describe the soil physical quality state but additional information about pore continuity properties is necessary.

References


