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Quantification of Transmission of Vertical stress and Soil Structure under Partially Confined Uniaxial Compression using X-ray CT

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Soil compaction can seriously damage soil-pore architecture. Accurate estimation of stress transmission through soil is therefore utmost important for efficient soil use and management. Continuous mechanics has been applied for agricultural soils so far, even if their structure is regularly disrupted by tillage. The main objective of the study was to quantify the transmission of vertical stress through topsoil with various initial soil-pore architecture. Partially confined uniaxial compression tests were carried out on intact topsoil columns (20cm diameter and 20cm height) placed on separately sampled subsoil columns in order to simulate field conditions. Stress transmission patterns within the top soil columns were quantified using X-ray CT, while a tactile sensor mat was employed for measuring stresses at the interface of the top and subsoil columns. Resulting soil-pore architecture under applied stresses was quantified using X-ray CT and air permeability measurements. Compression index (Cc) was linearly correlated with initial void ratio of the soils. Discrete stress transmission patterns through top soil were observed at 275 kPa applied stress, whereas elastic stress transmission patterns were observed at 625 kPa applied stress. This means at lower applied stress most of the load is transmitted through aggregates and with increasing applied stresses aggregated soil were deformed toward a more isotropic soil. This reflects that models following the elasticity theory are not able to predict stress transmission through aggregated soil particularly at lower applied stresses. Soil-pore architecture was greatly damaged with increasing applied stresses. X-ray CT analyzed macroporosity, macropore connectivity, and width of macropore size distribution was greatly reduced with increasing applied stresses. Air permeability was tremendously reduced under applied stresses, and all soils showed similar air permeability under 620 kPa stress irrespective of their initial/in-situ values. A regularly tilled topsoil should be considered as a collection of discrete aggregates rather than a continuum for accurate description of stress-strain relationship.