Soil strength development in loamy sand soils: effects of compactive forces and multiple wetting and drying cycles

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Yellow loamy sand soils are widely distributed throughout the dryland cereal growing areas of the north and central Western Australian wheatbelt. These light soils are very susceptible to the development of high-strength soil layers following agricultural traffic (1), they show a marked reduction in root growth in such zones (2) and respond to deep tillage with substantial increases in yield (1,3). This paper examines firstly, the dynamics of the physical deformation (i.e., volumetric strain) occurring under compaction and its role in strength development, and secondly, the effects of time dependent inter-particle bonding in producing a gain in strength (i.e., age hardening).

Methods

The soils used were from the 0-20 cm layers of loamy sands from the W.A. wheatbelt (1). Air dry soil samples were passed through a 2 mm sieve and compacted in plastic columns of 67 mm diameter and 96 mm height, under a range of dynamic and static loads. The samples were then allowed to equilibrate at specific water contents (0-15% w/w). Bulk density profiles of the soil columns were obtained by vertical linear gamma-scanning. Soil strength profiles were measured with an automatic continuous recording laboratory penetrometer. Vertical stress (resistance to compression) was measured using the laboratory penetrometer in a uniaxial confined compression test at constant rate of compression. Replicate soil columns were then taken through one to four wetting and drying cycles before being subjected to strength and stress measurements as above.

Results and discussion

The initial dry bulk density following packing of the columns was 1.30 $Mg \cdot m^{-3}$, and the maximum produced by the compactive treatments was 1.45 $Mg \cdot m^{-3}$. For soils subjected to compaction levels below 0.45 MPa the stress – strain relationship data resulting from the compression tests could be fitted to simple third-degree polynomials but not when subjected to higher compaction levels.

Peak soil strengths (resistance to penetration) were far in excess of reported field data from loamy sands (1), ranging between 6-10 MPa depending on water content and the number of Wetting/drying cycles. Compressibility increased significantly with water content and decreased with increasing numbers of wetting/drying cycles. Although only a small amount of strain was required to overcome the cohesive resistance of cemented inter-particle bonds, the corresponding vertical stress increased significantly up to the fourth wetting/drying cycle.

Results showed that applied stress – compaction (bulk density) relationships are crucial to the definition of excessive soil compaction.Water contents and applied stresses below which the soils are not susceptible to excessive compaction, can be estimated from values of the critical penetration resistance and these ranged from 1.5-2.5 MPa, depending upon the extent of the age hardening process.

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