THE EFFECTS OF WETTING AND DRYING ON SOIL PHYSICAL PROPERTIES

A thesis submitted by

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SUMMARY

Physical factors responsible for aggregate formation and stability, and methods for assessing aggregate water stability are reviewed. The natural factors responsible for developing and controlling soil strength, which is defined as the ability of a soil to withstand an applied stress, and methods of soil strength measurement are also reviewed.

Thixotropic hardening

This topic does not really fall within the subject title of this thesis. However, this study is a precursor to the studies of the effects of wetting and drying cycles because it is necessary to be able to avoid any confounding effects of thixotropic hardening, especially with remoulded and disturbed soil samples.

It is found that some agricultural top soils exhibit appreciable thixotropic behaviour at soil water contents close to that at which tillage is usually performed. This is shown by increases in the strength (shear strength, tensile strength, penetration resistance, and compression resistance) with ageing at constant water content.

The water content at which maximum thixotropic strength regain occurs is influenced by the clay mineral content of the soil. For soil containing kaolinite, the maximum thixotropic strength regain occurs at a water content at about or below the plastic limit. For soil containing illite and montmorillonite (no kaolinite) this maximum value occurs at the water content between the liquid and plastic limits.

Effect of wetting and drying on aggregate formation and stability

Planes of weakness (cracks) formed by unequal swelling and shrinkage resulting from uneven wetting and drying provide the initial faces of

soil aggregates in an initially unaggregated soil. It was found that wetting and drying to water matric potential of -1 kPa and -100 kPa, and of -1 kPa and 60°C oven dried resulted in the greatest aggregation (> 0.25 mm).

For aggregated soil too, wetting and drying influences aggregate water stability. Providing there is an extra energy source for microbial activity (such as in aggregates disturbed by tillage), wetting and drying first increases the proportion of water stable aggregates > 0.5 mm to a maximum value. Further wetting and drying then decreases aggregate water stability. When there is no extra energy sources, wetting and drying steadily decreases aggregate water stability.

Effect of wetting and drying on soil strength

Wetting and drying may influence the strength of a soil. Providing the stresses set up by unequal swelling and shrinkage are able to create cracks, wetting and drying decreases the tensile strength of remoulded aggregates and of the aggregates disturbed by tillage. For larger aggregates (clods) the decrease in the strength was shown by the fact that with the same amount applied energy (by the drop shatter test or by a second implement pass) greater soil break up occurred.

Since soil wetting and drying in the field are usually from one side only, the formation of cracks in larger aggregates occurs much more readily than in smaller aggregates. As a consequence, the decrease in the strength in larger aggregates occurs much more rapidly than that in the smaller aggregates. This phenomenon led to the development of a method for measuring soil friability.

Soil friability is defined as the tendency of an unconfined soil mass to break up and to crumble under applied stress into smaller mechanically stable soil aggregates. A measure of soil friability was developed from the theory of the brittle fracture theory of soil aggregates. Friability was obtained from the slope, k, of plots of the log aggregate tensile strength, σ_T, against the log aggregate volume, V:

$$\log_e \sigma_T = K - k \log_e V.$$

Values of friability ranged from $k < 0.05$ (not friable) to $k > 0.40$ (mechanically unstable).

This measure can be used to predict the water content at which tillage can produce the greatest soil crumbling. The method is also useful in explaining the results of some earlier workers, and may have a very interesting future in the study of soil physical properties.

Application of soil conditioners

Phosphoric acid addition decreases the tensile strength of remoulded and natural aggregates, but increases the penetration resistance of remoulded soil. As a consequence of the decrease of aggregate tensile strength, phosphoric acid application decreases the resistance of beds of these aggregates to compression. Phosphoric acid is also found to increase soil friability.

Calcium sulphate addition increases the tensile strength of remoulded and natural aggregates, but decreases the penetration resistance of remoulded soil. This increase in aggregate tensile strength results in increases in the resistance of beds of these aggregates to compression.

Effect of tillage on soil water behaviour

The amplitude of natural soil water content flucutations (wetting and drying) in the tilled layer of a tilled soil is greater than that at the same depth in an untilled soil. Under South Australian conditions, the cumulative wetting and drying in the tilled soil (0 - 10 cm depth) until 20 days after tillage was greater by a factor of 1.7 - 2.0 than that in untilled soil. For the 0 - 3 cm layer, these values ranged from 3.1 - 5.6 depending on the tillage system.

Meteorological factors influence the rate of drying from a soil when soil water content is high enough to provide the evaporative demand. When soil water content is low (for the Urrbrae soil, lower than about 10%), the rate of drying is mainly controlled by soil water content.

Agricultural implications

Cracks are formed by natural wetting and drying. These make the soil weaker, and at the same time provide initial faces of soil aggregates. This could have some significance in soil management practice. By increasing the amplitude of wetting and drying, by for example stubble management, it is likely that the soil can be tilled more esily and can result in a finer tilth.

Tillage increases the amplitude of wetting and drying, the strength of the clods produced by tillage decreases with wetting and drying, and at the same time aggregation is promoted by wetting and drying. It is therefore suggested that delaying a second implement pass for several days after a first implement pass, can enable soil to be tilled with minimum energy and cost to produce a fine seed bed. In addition, with decreasing clod strength it is possible to reduce the number of implement passes so that compaction damage can be minimized. Compaction damage might also be reduced as a result of the increase in the tensile strength (with a delay of the second implement pass), and hence compression resistance, of aggregates in the deeper part of the tilled layer.

Thixotropic hardening of top soil may influence seed germination and crop growth, either directly through the increase in strength or indirectly through its effect on soil water behaviour.

It is suggested that phosphoric acid should be used in soils of high aggregate tensile strength, because besides increasing aggregate water stability it also reduces aggregate tensile strength and increases friability. Calcium sulphate, on the other hand, should be used in soils of low aggregate tensile strength, so that besides increasing aggregate water stability, the resistance of the soil to compression can be increased.