Strength and compression properties of a range of cotton soils and relevance to soil management.

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Summary

This paper summarises a large number of strength and compression tests on a range of cotton soils. The soils were sampled at a number of locations from Warren to Emerald and varied considerably in their characteristics. They were tested over a wide range of moisture contents, densities and saturations.

The results show that by incorporating liquid and plastic limits, a single set of management rules may be developed for all the soil types. Moisture content measurements will then be sufficient to apply management rules. However, the measured parameters displayed considerable statistical variation and management rules will need to be set at appropriate levels of risk.

Materials and Methods

The soils and testing procedures are described in detail elsewhere (Kirby, 1990), but a brief outline is given here. 18 different soils were sampled and were mainly grey and black cracking clays (Vertisols) with one duplex soil (Transitional Red Brown Earth) from the Trangie area.

The basic objective in the testing program was to see how well strength and compressibility were related to simpler measures such as moisture content, density, liquid and plastic limits.

While various strength and compressibility parameters were measured it will be sufficient here to discuss just one of the measures of strength, called the pre-consolidation stress (P_c). As shown in Fig. 1, when soil is compressed the reduction in void ratio is slight for pressures below P_c, but increases markedly once P_c is exceeded. (Note: void ratio is inversely related to density.) In terms of compaction by vehicles, this means that if the ground pressure exerted by the vehicle is less than P_c then compaction will be limited, but will become progressively more severe as the ground pressure exceeds P_c. (This is a simplified explanation that leaves out the influence of shearing in the soil, as described by Kirby, 1988, but the same principles apply to the more general situation in which shearing is accounted for.)

Results

As expected, soils become stronger and the pre-consolidation stress, P_c, increases as they become drier and denser (decreased void ratio). However, not all soils had the same strength at the same moisture content. Heavier clays, which have higher liquid and plastic limits, were stronger at any given moisture content than lighter clays. It was found that instead of relating strength directly to moisture content it was better to use the fractional distance between the liquid and plastic limits. This is called the liquidity index, LI, and is defined by

$$LI = (MC - PL) / (LL - PL) \qquad (1)$$

(MC is the moisture content, LL and PL are the liquid and plastic limits). LI thus gives a moisture content normalised according to the distance between the liquid and plastic limits, a value of 0 being the plastic limit, negative values drier than that and positive values wetter than that.

The best relationship among P_c, LI and void ratio was given by following

$$P_c = \exp (5.69 - 3.23\ LI - 1.02\ e) \qquad (2)$$

where e is the void ratio. This equation had an R^2 of 0.682. Figure 2 shows the data of P_c as a function of liquidity index.

Relevance to soil management

The results show that by incorporating liquid and plastic limits, a single set of management rules may be developed for all the soil types. This prospect will be described using as an example the pre-consolidation stress roughly to assess when compaction will occur. It will be understood, however, that further work is required to develop more refined management rules for incorporation into SOILPAK.

Once the liquid and plastic limits are known for a particular soil then a measurement of the moisture content is sufficient to calculate the liquidity index. This done, the pre-consolidation stress may be calculated from equation (2) providing the density is assumed. Figure 2 shows the regression line for the average value of density. It will be noted that at the plastic limit (LI = 0) the line is at a value of P_c of about 100 kPa. This is in the usual range of ground contact pressures for vehicles used in the cotton industry. As stated previously, compaction will be limited if P_c is higher than the ground contact pressure. The implication is that, for averagely dense soils and middle of the range vehicles, compaction will be limited when the soil is much drier than the plastic limit.

This rough example has in fact substantiated earlier evidence (e.g. Kirby, 1988) that soils drier than the plastic limit are not likely to be compacted badly. However, the extensive data that has been collected in this study allow a more sophisticated analysis, including some assessment of the statistical variability of predicted compaction. Thus the level of risk of damage associated with trafficking soil under a range of conditions (of moisture content, density, type of vehicle and so on) can be assessed. This is now being done and the results will be presented to SOILPAK in due course.

References

KIRBY, J.M., 1988. Degradation of cotton soils beneath vehicles. *The Australian Cotton Grower* **Feb-Apr**, 33-38.

KIRBY J.M., (in preparation). Critical state soil mechanics parameters and their variation for Vertisols in eastern Australia. For submission to *Journal of Soil Science.*

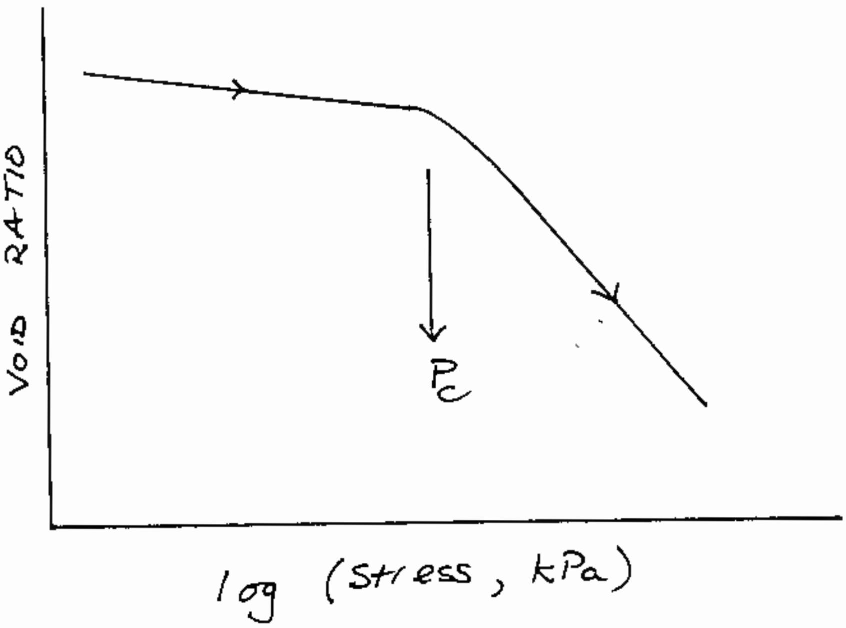

Fig. 1 Compression curve for soil showing the pre-consolidation stress, P_c, which divides limited compression behaviour at low stress from increased compression at high stress.

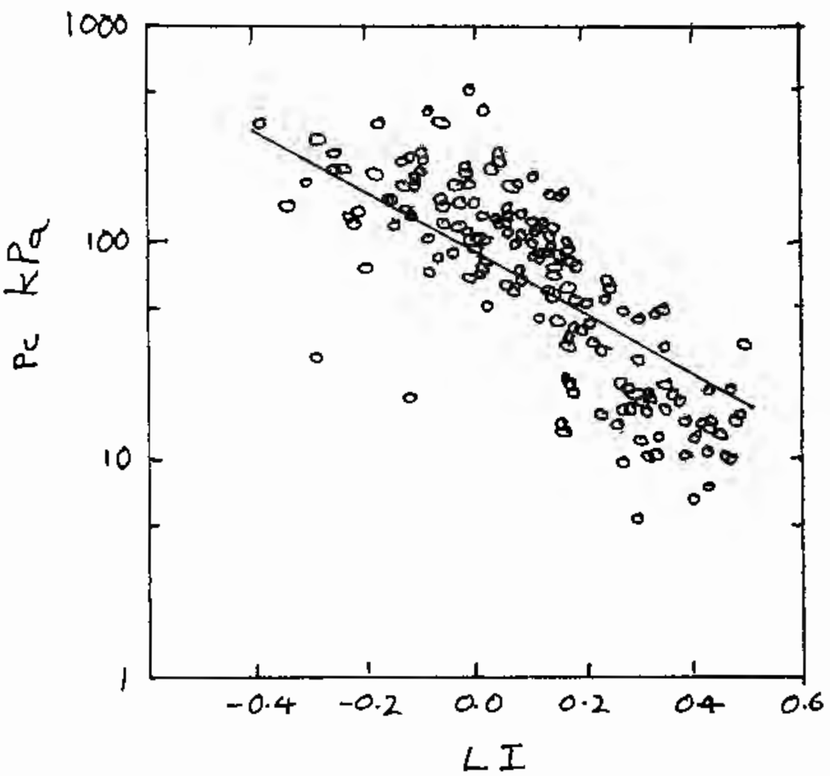

Fig. 2 Pre-consolidation stress as a function of liquidity index. The line shows the regression equation at the average value of void ratio.