HEDRA alert to geotechnical and civil engineers.

Dear colleagues,

Recently, I have had an opportunity to compare the Shrink/Swell test (S/S) with the Conditioned Core Shrink test (CCS) as part of my PhD. While doing so an improved test method was devised with the help from the Swinburne University soil laboratory and JM Field work. The formulas for these tests are (a) and (b) below.

$$\textbf{Shrink/swell: Iss\%} = \frac{(\varepsilon_{sh} + \varepsilon_{sw}/2)}{1.8} \ldots\ldots (a)$$

The Shrink/Swell test (S/S) has formula (a) as proposed by Thorne C. in the 1980's and has been in AS1289 together with other similar tests to calculate soil Ips. The S/S test samples are undisturbed and collected in 50 mm minimum diameter tubes. One part of the sample is reduced to 38 mm ø x 60 mm minimum length to carry out a shrink test and a 20 mm thick slice is cut from the 50 mm ø sample and placed in an odometer and immersed in de-ionised water to test swell. This test was developed when WP4C chilled mirror psychrometers were not available and measuring soil suction was difficult and slow.

$$\textbf{Conditioned core/shrink: Iccs\%} = \frac{\varepsilon_{sh}}{\Delta u} \ldots\ldots (b)$$

ε_{sh} : Shrink, ε_{sw} : Swell, Δu: Suction interval.

The formula for the CCS test (b) is a shrink test measured against the suction interval required. The sample is collected in a 40 mm ø Shelby tube and pushed hydraulically into a bore hole. One 150 mm long sample is conditioned in the laboratory to a suction of 3.2 - 3.5pF. After conditioning the sample is cut into 2 similar samples A & B. The 'A' sample is used to measure shrink and moisture and the 'B' sample to measure suction. This combination allows the calculation of the soil Ips and drawing the Soil Water Characteristic Curve.

The following are some of the problems with the S/S test:

1. In droughts or late summer, the 50 mm ø samples are difficult to drive in the highly reactive clays hydraulically with the small drilling rigs that are normally used for residential testing.

2. Both the shrink and swell tests are commenced at field moisture/suction conditions; therefore, the results differ when sampled in different climatic conditions and seasons.

3. The S/S test is a two-part test – shrink and swell – each is tested separately using different size samples and the results are difficult to join as reliable continuous graph.

4. If the sample is collected dry, the swell test is very time consuming. If collected wet there will be little or no swell and test will be a shrink test only.

5. The S/S formula (a) has a 1.8 denominator which attempts to include the full range of seasonal suctions in Australian conditions in pF terms and assumes a linear strain/suction relationship. However, several researchers have shown that this relationship is much closer to a sigmoidal curve.

6. Fredlund D. et al have shown that the strain/suction relationship is a modified 'S' curve and is approximately linear from 3 - 4pF and almost linear at the very ends of the 'S' shape. Hence, a linear relationship can only be justified in the wetter climates.

7. In formula (a) the swell value is halved to allow for the confinement effect of the sample ring in the swell part of the test.

8. Fityus S. suggests placing an annulus over the sample ring to prevent a 'muffin-top' forming during the swell test. This modification is rarely used.

8. International researchers have shown the difficulty of 'joining' the swell phase with the shrink phase to make a continuous graph.

The Conditioned Core Shrink (CCS) test solves the above problems:

1. The WPC4 psychrometer reads the actual suction while testing rather than assuming a range of suctions.

2. The test is simplified by only testing shrinkage over the range of expected field suctions and does not need to 'join' the swell part of the S/S test to the shrink part of the curve. (often problematic)

3. Field moisture does not affect the result since each sample is conditioned to a narrow suction range.

4. The strain V suction graphs can easily be drawn to fit the data by using Microsoft polynomial orders.

5. This test confirms Fredlund et al's work which shows that the total strain/suction relationship is a sigmoidal curve which is approximately linear from 3 - 4 pF and a curve from 4-5pF. (Refer figure 1)

6. The WPC4 psychrometer is suitably accurate and reliable at suction ranges from 3 to 6 pF and therefore is within all the suctions ranges for 'deemed-to-comply' designs in the AS2870 climate zones.

7. The time required carry out the CCS test is about ½ the time required for the S/S test.

8. The CCS test simplifies the test procedure to one form of strain and does not attempt to 'join' the swell part of the S/S test to the shrink part of the curve. (Which has shown to be difficult)

9. It is often not possible to drive sample tubes in late summer, autumn and in drought with the types of drill rigs being used for residential testing. The Shelby tube samples are much easier to use.

At 3-4pF, Ips V Suction is linear therefore, it has the same Ips. However, at 4–5 pF the relationship is a curve, therefore, has a different Ips.In fact, in this suction interval there are a number of Ips which can be simplified into two. At 3 – 4pF can be one Ips and at 4 – 5 pF can be simplified to the other Ips. Hence, even after simplifying the linear and curve, each climate model will have a minimum of two Ips for each soil layer. (Refer figure 2)

Example: 1

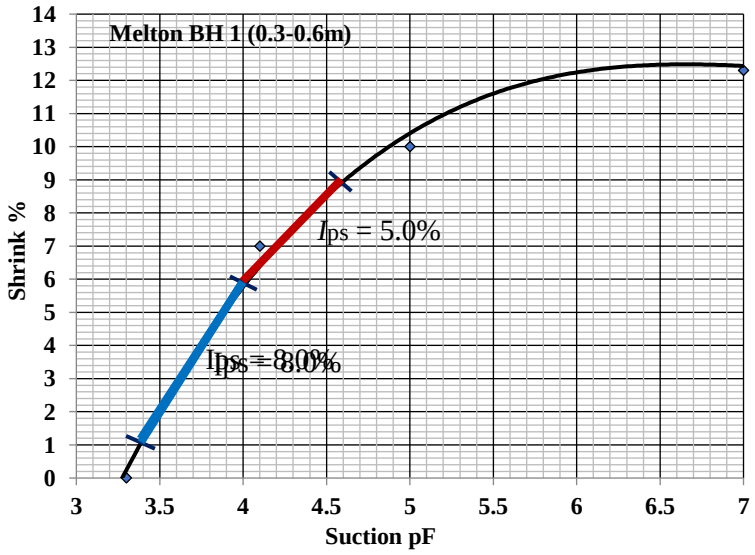

Figure 1

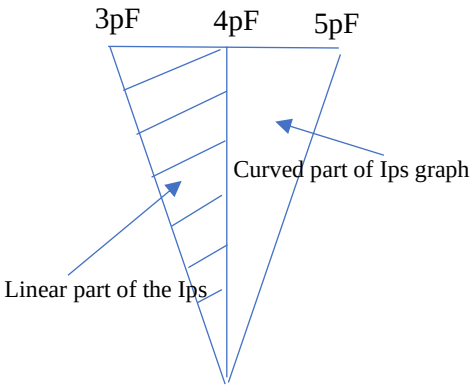

Figure 2

Example 2: Comparing Ips for S/S and CCS tests.

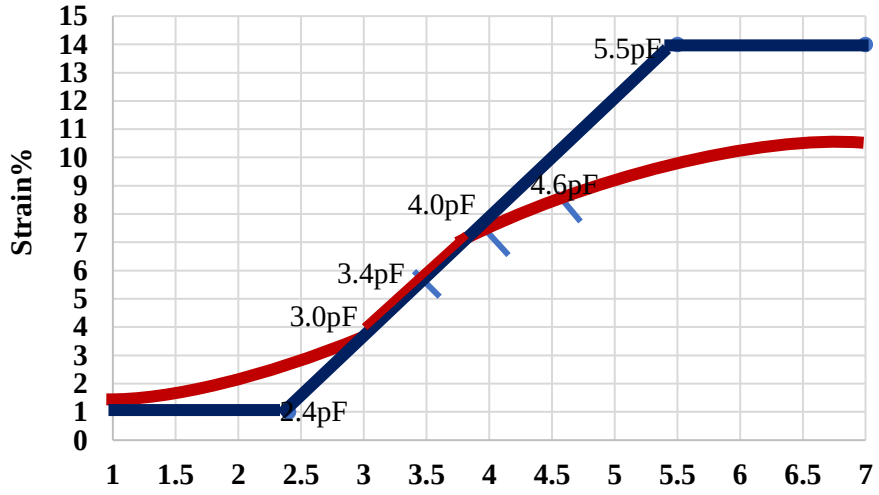

Figure 3

Note: Ips for shrink/swell test follows blue line in figure 3 at any chosen 1.8pF interval from 2.4 to 5.5pF. (Only one Ips value). Ips for shrink test follows A1 and A2 the surface suction intervals of 3.4 to 4.0 and 4.0 to 4.6pF which is the range for Victorian climate zone 3. (Giving two different Ips values)

The Conditioned Core Shrink (CCS) test solves the above problems:

10. The WPC4 psychrometer reads the actual suction while testing rather than assuming a range of suctions.

11. The test is simplified by only testing shrinkage over the range of expected field suctions and does not need to 'join' the swell part of the S/S test to the shrink part of the curve. (often problematic)

12. Field moisture does not affect this test since each sample is conditioned to a narrow suction range.

13. The strain V suction 'best-fit' graphs are easily drawn using Microsoft polynomial orders of magnitude.

14. This test confirms Fredlund et al's work that has found that the total strain/suction relationship is a sigmoidal curve which is approximately linear from 3 - 4 pF and a curve from 4 – 6 pF which can be simplified with a separate linear one. (Refer figure 2)

15. The WPC4 psychrometer is suitably accurate at suction ranges from 3 - 6 pF and therefore is within all the suctions ranges for 'deemed-to-comply' designs in the Australian climate zones in AS2870.

16. The time required carry out the CCS test is about ½ the time required for the S/S test.

17. The CCS test simplifies the test procedure to one form of strain and does not attempt to 'join' the swell part of the S/S test to the shrink part of the curve. (Which has shown to be difficult)

18. In the field it is often not possible to drive sample tubes in late summer and autumn with the types of rigs being used for residential testing. (particularly in the drier climate zones).

19. The S/S tests requires samples with a minimum diameter of 50 mm while the CCS test is carried out on 38 mm diameter samples collected with standard Shelby tubes.

20. While carrying out CCS tests the samples can be weighed to calculate moisture and draw a SWCC curve.

Note: In wet climates where the relationship is in the linear range of the CCS curve only one the Ips is needs to be calculated. Therefore the calculation of the Characteristic Surface Movement is simpler. For more information phone Dominic Lopes at 0418 349 078 or email contact@uslgroup.com.au