DISCUSSION

Residual strength of clays and correlation using Atterberg limits

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The author has to be complemented for his contribution on correlations of ϕ'_r with the position of a soil on the plasticity chart. He has discussed well the reasons for such a correlation. However, from Fig. 4 it can be seen that when ΔPI (distance above or below A-line) is ± 5 , the variation in ϕ'_r is of the order of 5° to nearly 25° . The variation in ϕ'_r is very sensitive in this region, and most often the variation in ΔPI would be in this region. Further, according to the author, ΔPI below or above the A-line is the crucial parameter irrespective of the level of w_L . In other words, if ΔPI is the same for two different soils at two different w_L , their ϕ'_r values should be similar. Points A and C (Fig. 1) are classified into the same category. But the ϕ'_r value of soil C is likely to be lower because the w_L is higher.

Table 2 presents $\pm \Delta PI$ and corresponding ϕ'_r for soils other than volcanic ash. Soils with w_L less than 50% have also been considered. It is seen that in most of the cases, for the same value of ΔPI , the ϕ'_r varies significantly. The maximum variation is seen for $\Delta PI = 9$, for which ϕ'_r ranges from 8.1° to 31.2° . However, there are cases where ϕ'_r is in the same range for the same value of ΔPI , even though w_L varies significantly: for example, for $\Delta PI = 4$, ϕ'_r ranges from 9.2 to 12.1 and w_L ranges from 31% to 82%. In view of this, Fig. 4 appears to be a less useful correlation.

Liquid limit is a widely used index property for correlations with engineering properties. For example, several investigators have attempted to correlate liquid limit with the compression index. Fig. 5 shows the correlation of w_L with ϕ'_r for the results presented in Table 1 excluding the results of volcanic ash. Although the correlation is not that good, the trend is very clear.

It has been well brought out by the author that ΔPI is an important parameter. As ΔPI increases, there is a decreasing trend in ϕ'_r . Further, as w_L increases there is a decreasing trend in ϕ'_r . Fig. 6 shows the correlation between ϕ'_r and ($w_L \pm \Delta PI$). Compared with Fig. 5, the correlation is improved.

The clay fraction and the type of clay mineral also play an important role. As most natural soils contain different types of clay mineral in different proportions, it is rather difficult to isolate individual effects. However, there could be a general trend correlating ϕ'_r with clay fraction. Fig. 7 shows the correlation between clay fraction and ϕ'_r . It is seen that the correlation coefficient is substantially increased compared with values in Figs 5 and 6. The discussers believe that, in the absence of any other better correlation, the correlation between clay fraction and ϕ'_r is reasonable. The discussers do feel that there is some merit for considering ΔPI as a parameter.

Author's reply

The author would like to thank the discussers for their interest in his technical note and for their discussion contribution. The points they make are valid, and highlight the limitations of empirical correlations in soil mechanics, especially those made with single parameters such as ΔPI , LL, or PL. They are right in pointing out that there will still be

Table 2. Variation of ϕ'_r for same ΔPI

ΔPI	ϕ'_r	w_L
78	3.1	351
29	6.9	161
23	5.5	113
15	10.8	79
11	6.6	85
11	7.4	118
10	7.1	73
10	14	89
10	22.1	41
9	8.1	129
9	8.4	82
9	30.2	24
9	31.2	22
8	7.0	93
8	7.1	59
8	8.0	66
8	23.8	34
7	9.5	62
7	24.4	42
6	7.1	71
6	7.3	63
6	9.4	95
6	9.4	57
6	12.6	94
6	25.3	29
5	7.8	62
5	8.2	62
5	9.9	72
5	25.6	39
5	28.7	41
4	9.2	63
4	10.7	58
4	11.1	82
4	12.1	31
3	5.4	59
3	8.1	59
3	13.0	64
2	10.1	26
2	28.8	46
1	9.2	59
0	8.7	65
0	13.1	89
-3	10.0	89
-3	25.0	38
-4	20.0	80
-4	27.5	52
-5	15.9	88
-5	19.3	77
-6	9.9	97
-6	13.5	71
-11	8.0	63

variation in ϕ'_r with LL, regardless of constant ΔPI . However, the variation with LL is less dramatic than the variation with ΔPI .

The author's interest in correlations of this type grew out of experience with residual soils, especially those of volcanic origin. With these materials, which are very widespread in

Fig. 5. Variation of ϕ'_r with liquid limit

Fig. 7. Variation of ϕ'_r with percent clay size fraction

Fig. 6. Variation of ϕ'_r with $(w_L \pm \Delta PI)$

some parts of the world, conventional correlations tend to break down. Examining the basis of these correlations in the light of residual soil behaviour led to the conviction that LL or PL on their own were not useful guides to likely geotechnical characteristics, and that the overall position on the plasticity chart was the most important indicator. Position in relation to the A-line seemed to be very significant, and the use of ΔPI was an attempt to better take account of this position.

As indicated in the original note, it is not the author's view that correlations of this type are very useful for actually obtaining the value of ϕ'_r from Atterberg limits for a particular soil. The writer is very wary of equations of the type given by the discussers in their Figs 5–7, as they tend to imply a degree of precision much higher than is actually the case. The usefulness of correlations of this type should be confined to providing 'background' information useful in putting together an overall picture of the behaviour of a soil.