residual factor or whether they used the progressive failure model to obtain the average shear strength along the slip surface whence the residual factor could be obtained on the basis of

$$R = \frac{S_t - S}{S_t - S_r}$$

giving a value consistent with the physical model. This approach is similar to that suggested by Bishop (1971b) who represented the shear strength mobilized in terms of a local residual factor, similar to that defined by Skempton (1964) but varying along the slip surface.

Authors' reply to B. K. Menzies

We should like to clarify the use of the residual factor in the Paper. The residual factor R , as introduced by Skempton (1964) in the Fourth Rankine Lecture, is a quantitative measure of the amount by which the average shear strength has fallen off from the peak to the residual value at the instant of slope failure. In physical terms, R is the proportion of the total slip surface in the clay along which its strength has fallen to the value. Hence, for a factor of safety $F=1.0$, it corresponds to the expression D/L used in the Paper. For two long-term failures in London Clay, namely, the Northolt slide and the Sudbury Hill slide, the values of R obtained by Skempton are respectively 0.56 and 0.83 at the instant of slide. The corresponding values from stress analysis are 0.57 and 0.85. The small difference is apparently due to the fact that Skempton has been working in terms of average stresses along the slip surface, whereas a point by point treatment has been used in the stress analysis.

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Rigid circular plate resting on a non-homogenous elastic half-space

CARRIER, W. D., III & CHRISTIAN, J. T. (1973). *Géotechnique* **23**, No. 1, 67–84.

L. Belloni, Dr Eng. D.I.C. Studio Geotecnico Italiano, Milano and M. Jamiolkowski, Dr Eng. Politecnico di Torino

The Authors have presented the results of an excellent parametric study by means of the finite element method. They evaluate the displacements and stresses under a rigid circular plate resting on a heterogeneous elastic half-space.

Particularly valuable are the Authors' remarks regarding the applicability of such a foundation model in practice for settlement calculations and soil structures interaction studies.

We should like to compare the results of the vertical surface displacement w_c , evaluated beneath a centre of a flexible, uniformly loaded rectangular area, obtained by means of an approximate method (Klein, 1956, Klein and Durajev, 1971), with those given by Carrier III and Christian.

- (b) For $\beta < 0.001$, the settlements calculated by means of the numerical evaluation of the integral in equation 2 are a little underestimated, as the rigorous solution for $\nu < 0.5$ and $E_0 = 0$ gives $w(x, y, 0)$ equal to ∞ , as shown by Gibson (1967), Gibson and Sills (1971), Awojobi and Gibson (1973) and Brown and Gibson (1972).
- (c) The I' values we obtained for $\beta = 0.001$ agree quite well with the limiting values given by the Authors (Fig. 4). However, we believe that the $\beta = 0.001$ represents the upper

Fig. 2. I as a function of β for $\alpha = b/c = 1$ and for $\nu = 0; 0.25; 0.33; 0.4$

Fig. 3. I' as a function of β for $\alpha = b/c = 1$ and for $\nu = 0; 0.25; 0.33; 0.4$

Fig. 4. I' as a function of ν for $\beta = \text{constant}$

Fig. 5. Settlement under a rectangular area uniformly loaded for $\beta = 0.001$ and $\nu = 0; 0.33$

limit of the possible heterogeneity of real soil deposits. This makes the solution obtained applicable for all practical cases, except for the calculation of the immediate settlements.

(d) The variation of I and I' with the degree of the heterogeneity β confirms that for $\beta \geq 10$, the settlement calculations and soil-interaction studies may be referred to the Boussinesq half-space, for $\beta \leq 0.01$ and $\nu < 0.5$ the soil behaviour does not follow exactly the Winkler type spring model as shown by Gibson (1967) for $\nu = 0.5$. However, even for $\nu < 0.5$ nearly almost all the surface settlement is confined under the loaded area (Fig. 5) and the Winkler hypothesis may represent a good approximate solution for settlement and interaction problems when $\beta < 0.01$.

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Correlation between Atterberg plasticity limits and residual shear strength of natural soils

VOIGHT, B. (1973). *Géotechnique* **23**, No. 2, 265–267.

P. K. De and B. Furdas, Sir William Halcrow and Partners, Aberaman, Aberdare, Glamorgan

We welcome Voight's Note as a contribution to a better understanding of the physical properties of natural soils in relation to the residual shear strength.

During the investigation of active spoil tips in South Wales, attempts were made to relate shear strengths of soil samples to their Atterberg limits. Most of the available drained shear box test results were on colliery spoil and boulder clay, a few on silty-sandy clay, one on Keuper marl and one on peaty clay.

The following graphs were plotted:

- (a) ratio of residual shear strength to normal pressure (τ'_r/σ) against plasticity index for the colliery spoil and natural soils separately;
- (b) (τ'_r/σ) against the ratio of plastic limit to liquid limit for the colliery spoil and natural soils separately;
- (c) brittleness index $(\tau'_f - \tau'_r)/\tau'_f$ against plasticity index and against PL/LL for colliery spoil and the natural soils separately and combined.

Little or no correlation was obtained with the plots involving colliery spoil, which is not surprising as Voight pointed out in his Note that in non-natural soils the trend of increasing I_p for decreasing μ'_r is not observed in all cases. Also, no correlation was obtained with the plots involving brittleness index as expected, as the brittleness index is a function of peak and residual shear strengths. The former is dependent on many factors, such as stress history and initial moisture contents.

The plots of (τ'_r/σ) against I_p and PL/LL showed that there seems to be a definite statistical relationship between these properties. The amount of scatter was, however, quite large. The curve obtained for (τ'_r/σ) plotted against I_p was similar to that shown by Voight, the curve obtained for (τ'_r/σ) plotted against PL/LL is shown in Fig. 1. (As the residual cohesion always approaches zero, (τ'_r/σ) can be written as $\tan \phi'_r$.)

It can be seen from Fig. 1 that for each PL/LL point, three values of $\tan \phi'_r$ are plotted. This is due to the fact that three shear box tests were carried out from one U4 sample, whereas index properties were obtained for the whole sample. It was observed, whilst plotting Fig. 1, that for most samples $\tan \phi'_r$ tends to decrease with increasing normal pressure, resulting in a