Burland, J.B., B.Simpson and H.D.StJohn (1979)
Movements around excavations in London Clay. Proc. 7th European Conf. SMFE. Vol.1.
A brief extract illustrating that Ko is a function of stress history.

waling slab was then cast on the exposed clay surface. Excavation then took place beneath the waling slab to the −16 m level leaving a berm around the perimeter of the excavation to stabilize the toe of the wall. After the basement slab was cast over the central area, the perimeter berm was removed in short lengths with the basement slab being completed rapidly along each length.

Figure 7 shows the observed movements of the wall at one section. Following casting of the waling slab, the wall rotated about this level. It can be seen that quite large movements occurred during removal of the perimeter berm and that the movements continued during the two weeks preceding completing the slab at the −16 m level. It is evident that the weight of a berm can be very effective in controlling the softening and hence the movements and stability of the toe of a wall embedded in clay.

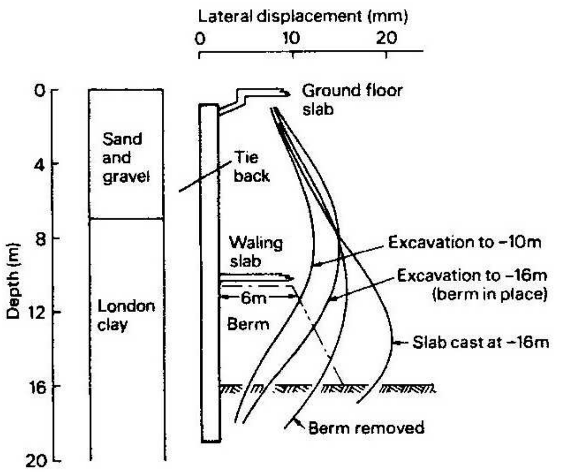

Fig. 7 Central YMCA: Influence of perimeter berm on wall movement.

3. HORIZONTAL EARTH PRESSURE AT REST

It is usually accepted that the vertical stress in an undisturbed soil deposit may be deduced from self-weight alone. Pore pressure variation with depth can be measured directly so that the variation of vertical effective stress with depth can be evaluated. In order to make predictions of ground movement and earth pressure around excavations the initial in-situ horizontal stresses must also be evaluated. In the past this has always been done by indirect methods.

The commonest method is to measure the suction p_k of undisturbed samples usually by determining the swelling pressure in the triaxial machine or oedometer. The coefficient of earth pressure at rest K_o is then calculated from the expression:

$$K_o = \frac{\sigma'_h}{\sigma'_v} = \frac{p_k/\sigma'_v - A_s}{1 - A_s}$$

where A_s is the pore pressure coefficient $\Delta u/\Delta(\sigma_1 - \sigma_3)$ corresponding to the removal of the deviator stress when

$$\sigma_1 = \sigma_2 > \sigma_3.$$

Both Skempton (1961) and Bishop et al (1965) assumed $A_s = 0.3$ and give values of K_o at various depths in London Clay at Bradwell and Ashford Common respectively.

Frequently the values of K_o for London Clay given by Skempton and Bishop et al are used as a basis for calculations on other sites. Indeed there is a danger that the deposit may come to be regarded as having a fairly unique distribution of K_o with depth. Such an assumption can give rise to very significant errors unless account is taken of the influence of stress history due to such factors as groundwater lowering or the presence of alluvium overlying the surface of the clay.

Figure 8 is a diagramatic representation of the relationship between the vertical effective stress σ'_v and the horizontal effective stress σ'_h acting on a layer of clay:

(a) during initial deposition of the overlying sediments (path OA) when K_o is assumed equal to 0.55;

(b) during subsequent erosion of the overlying sediments (path AB) when σ'_h becomes larger than σ'_v; and

(c) during a further phase when σ'_v is increased by some cause (path BC).

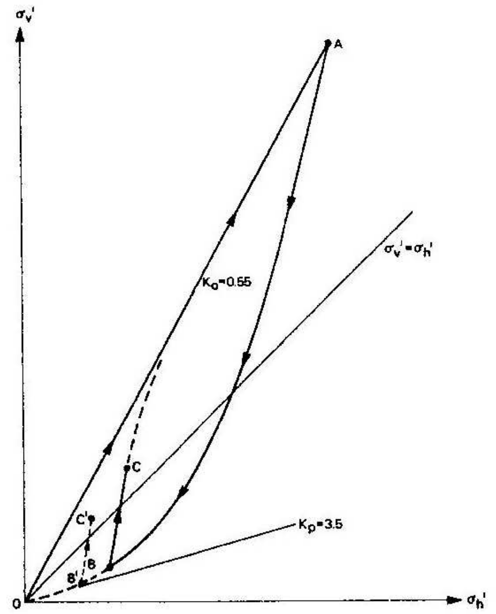

Fig. 8

It will be noted that the re-loading path BC is much steeper than the unloading path AB at B. It is very probable that initially during the re-loading cycle the clay behaves elastically such that:

$$\frac{\Delta \sigma'_h}{\Delta \sigma'_v} = \frac{\nu'}{1 - \nu'}$$

where ν' is Poisson's ratio for the soil skeleton.

Wroth (1972) has deduced that ν' for London Clay is equal to about 0.15 giving $\Delta\sigma'_h/\Delta\sigma'_v = 0.18$. Of course, as the point C approaches the virgin consolidation line OA the re-loading path will eventually merge with OA. At high overconsolidation ratios reload curves BC, B'C' etc will be parallel.

The idealised curves shown in Fig 8 may be used to study the influence of re-loading on the in-situ effective stresses within a heavily overconsolidated clay stratum. The full lines in Fig 9(a) show the distributions with depth of the effective horizontal and vertical effective stresses in a clay layer which has had 170 m of overlying sediment removed. The water table is at the surface and the pore pressures are hydrostatic with depth. Figure 9(b) shows the corresponding distribution of K_o with depth. It should be noted that in the top four metres the clay is in a state of passive failure with K_p assumed equal to 3.5.

The chain dotted lines in Fig 9 represent the stress conditions corresponding to an effective surcharge of 100 kN/m^2 applied to the surface and allowed to come to equilibrium. This might correspond to the deposition of a surficial layer of gravel or alluvium - a situation which is quite usual in London. It will be seen that whereas σ'_v increases by 100 kN/m^2 uniformly with depth the corresponding increase in σ'_h is only 18 kN/m^2, except very near the surface where the soil lies on the virgin consolidation line OA in Fig 8. It can be seen from Fig 9(b) that the corresponding values of K_o have been reduced dramatically.

Another common situation in the London area is that pumping from the underlying chalk has reduced the pore water pressures in the overlying clay. The effect of reducing the pore water pressures to half the hydrostatic value is shown by the broken lines in Fig 9. This has the effect of increasing σ'_v in proportion to the depth. The horizontal effective stresses only show slight increase, but once again the values of K_o reduce by a substantial amount. The dotted lines in Fig 9 show the effects of combining both a surcharge and underdrainage.

It is clear from Fig 9 that the distribution of K_o with depth is far from unique and is very sensitive to stress history. On the other hand the distribution of σ'_h with depth below the surface of the clay is relatively insensitive to stress change and it seems probable that it is this rather than values of K_o which might be regarded as fairly unique for a given heavily overconsolidated deposit. Field evidence supporting this conclusion is provided by the well defined relationship between average shaft friction and average depth below the surface of the London Clay for bored piles from a variety of sites (Burland, 1973). It is the horizontal effective stress acting on the pile shaft which primarily determines the shaft friction in a given clay.

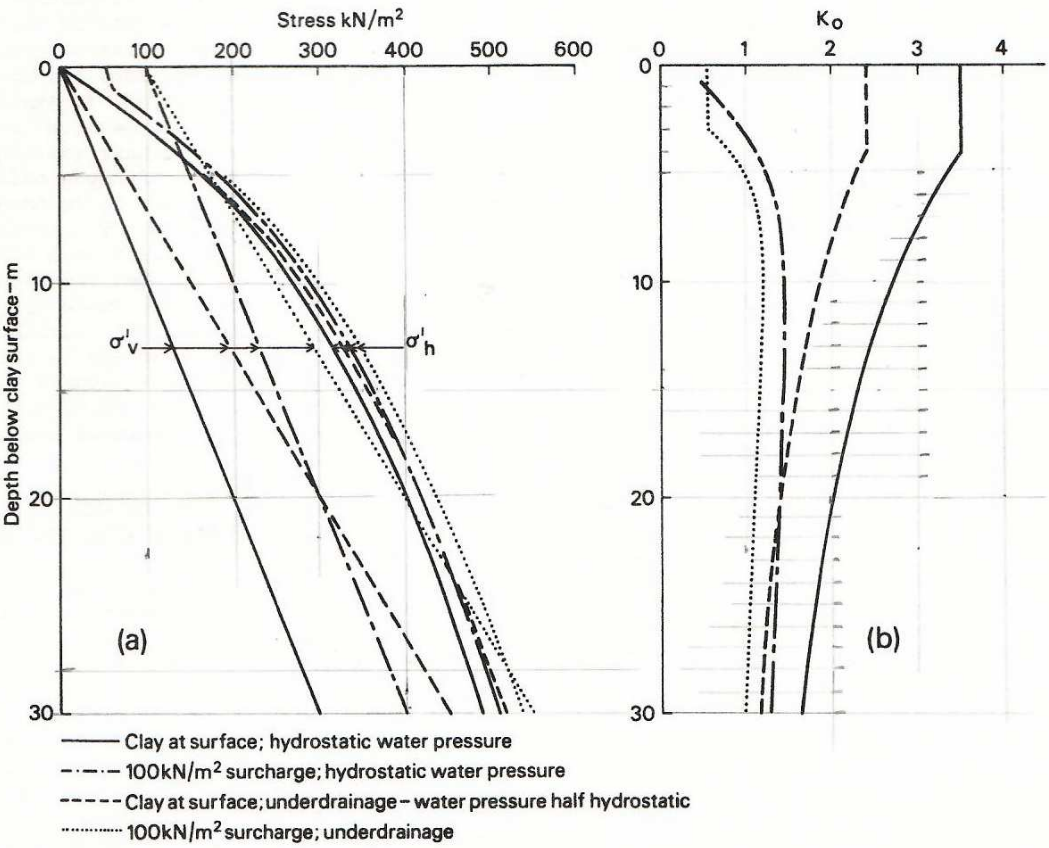

Fig. 9 Influence of stress history on K_o and σ'_h in a heavily overconsolidated clay.