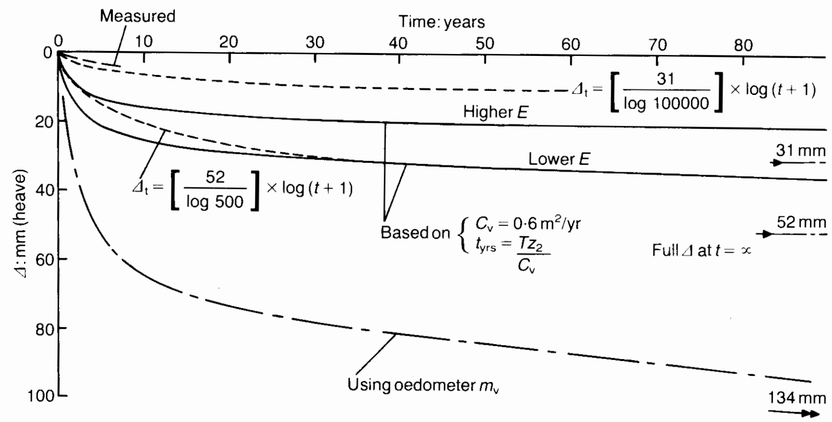

Fig. 11. Long-term heave of basement slab, Δ–time relationship

graph of the right shape. Fitting such a graph to the observations taken so far would predict the heave of the slab towards the end of the building's design life, of about 11 mm.

Mr C. A. Raison, *GKN Keller Foundations Ltd*

The data on ground movements for the QE II Conference Centre can be compared with data measured at the new British Library during construction of basements to a similar depth. The new British Library comprises two different areas. To the south a four level basement excavation 25 m deep is still under construction (early 1987). To the north, because of the underlying tube tunnels of the Victoria Line, the basements were restricted to one and two levels, up to 15 m in depth.

73. Construction of the shallower basements started in 1982 with bulk excavation removing the upper 5 m of the soil. More localized excavation started in February 1985 to allow construction of the B1 raft. Later excavation down to 3 mOD, that is 15 m below street level, allowed construction of the B2 raft. These basements were completed in 1986, including construction of the overlying floor slabs to ground level.

74. During construction, vertical and horizontal ground movements were recorded using inclinometers and magnetic tape extensometers, and vertical movements of the underlying tunnels were measured using traditional level surveys. Heave of the tunnel crown up to 20 mm has been recorded. Fig. 12(a) shows an east–west section through the site showing the progress of the excavations. Fig. 12(b) shows the heave profile along the line of the tunnel crown, maximum heave being measured beneath the B2 excavation areas. Of interest is the rate at which heave occurred, shown in Fig. 13, which follows closely the progress of excavation. This rate of heave was also confirmed by the magnetic tape extensometers installed in the shallow basement area.

75. Borehole extensometer movements are summarized in Fig. 14(a) for excavations in the shallow basement area to 13·5 mOD, an unload of about 100 kN/m^2. Fig. 14(b) shows a similar plot for excavation to 3 mOD, an unload of about

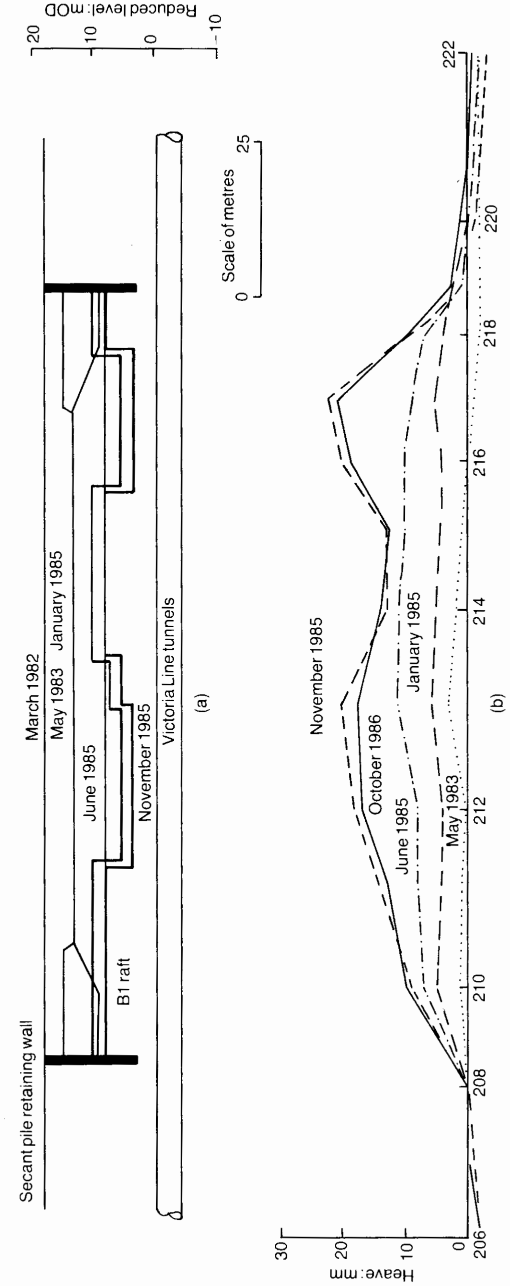

Fig. 12. Tunnel movements: (a) east-west section; (b) heave profile along line of tunnel

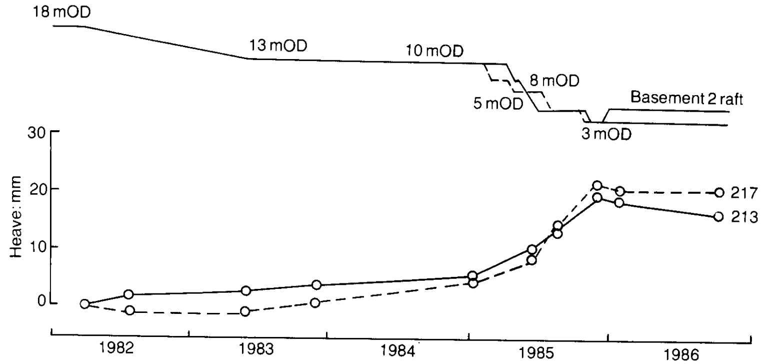

Fig. 13. Rate of heave in tunnel

300 kN/m², comparable to that at the QE II Conference Centre excavation. The magnitude of the heave is similar for the two different dig depths and is not dissimilar to that recorded at the conference centre. These plots also confirm the accuracy of the extensometer measurements which agree well with the heave measured in the tunnel. They show that heave is not local to the excavation surface but occurs to significant depths. For the British Library, the assumption that the Woolwich and Reading beds form a rigid base could not be justified as about 15 mm of heave occurred in the Woolwich and Reading clay.

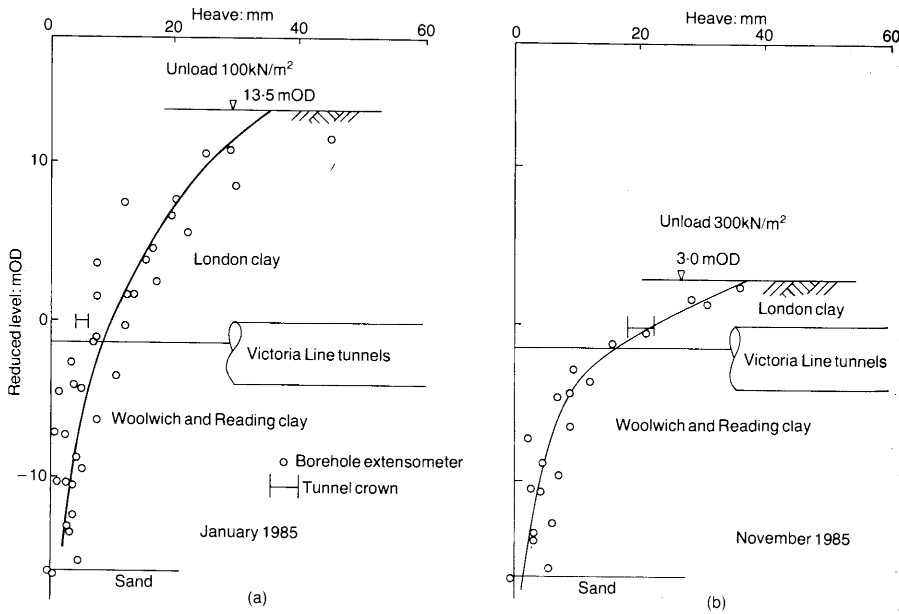

Fig. 14. Borehole extensometer movements: (a) excavations to 13·5 mOD; (b) excavations to 3·0 mOD

76. A particularly important observation is that the heave has been rapid but has not taken place at constant volume as is normally assumed for short-term unloading. The measurements recorded were not accompanied by the large horizontal retaining wall movements that would be expected. These would have to be of the order of 50 mm or more to account for the 25 mm to 40 mm of heave recorded. More importantly, there is no ready source of free water to allow swelling. It is thought that this heave may be due to cavitation, the dissolved air in the pore water coming out of solution in the form of bubbles during the reduction of pore pressures resulting from removal of overburden. This effect may account for some apparent low stiffness profiles obtained by back analysis, possibly such as the one used by Professor Burland.

Mr S. Thorburn, *Thorburn Associates*

Burland *et al.*[4] in 1977 stated that, under certain circumstances, the settlement of raft foundations in clay could be reduced to an acceptable level by employing relatively few piles. In § 25 of Paper 9138 the Authors state,

> 'Such piles were called settlement reducing piles and their use is confined to conditions in which no significant reductions in load carrying capacity occur with settlements in excess of those required to mobilize fully the shaft resistance (i.e., ductile settlement characteristics).'

78. In 1978 Thorburn Associates adopted this design philosophy and constructed three storage tanks of 2000 t capacity and one tank of 4000 t capacity within a site underlain by at least 100 m of normally consolidated very silty clays. Ninety-seven 250 mm square precast reinforced concrete piles were driven to depths of 32 m beneath the 4000 t tank. Load tests revealed a loss of pile resistance due to strain softening and the residual resistances ranged from 73% to 85% of the peak pile resistances.

79. The performances of the tanks have been most satisfactory and the settlements at equilibrium do not exceed 32 mm. The loading intensity imposed by the molasses storage tanks was about 160 kN/m², which was twice the limit stress on the soft silty clays. Professor Burland considers that we were pushing the frontiers of knowledge too far by using settlement reducing piles in such soft ground.

Mr Williams

Several foundations consisting of stiff rafts assisted by a foundation cylinder under each column were constructed in London in the early 1960s and their progress has been kept under general observation since then. Notably the tower of the Shell Centre[12,13] is supported by a raft approximately 23 m × 50 m × 1350 mm thick at a level of 15 m below ground surface. The main columns are on a grid of 7 m × 7 m and under each the raft is assisted by a cylinder of 1·8 m diameter and about 24 m deep with the base enlarged to 4·5 m diameter. The average settlement of this raft is about 25 mm and the average load on it is some 400 kN/m². These observations suggest that about 45% of the load is now supported by the base of the raft, and most of the remainder is on the pile shafts.

81. At the same period some very accurate field measurements of the modulus and the macro-shear-strength of London clay were made at a site in Great Saint Helens.[14] A trial shaft 1·8 m diameter was sunk by hand to a depth of 32 m, lined with grouted, precast concrete segments, and at intervals the base was loaded to failure. Sections of the shaft lining were also loaded to determine the maximum