Chapter 13
AXIALLY LOADED PILES

13.1 Single Incompressible Floating Pile

This problem has been considered by Poulos and Davis (1968).

The distribution of shear stress along the pile shaft is shown in Fig.13.1 for various *L/d* values while the proportion of applied load transferred to the base is shown in Fig.13.2.

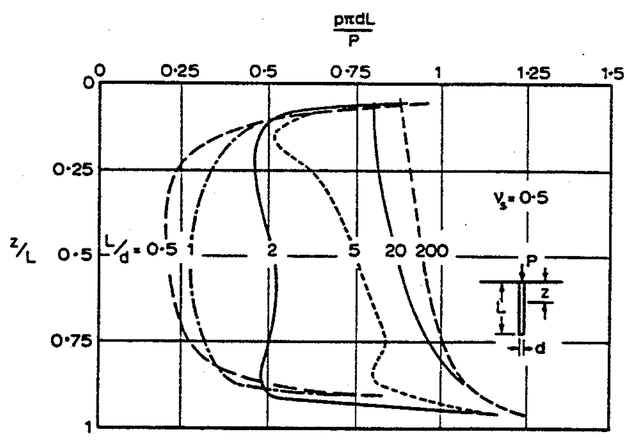


FIG.13.1 Distribution of shear stress along incompressible pile.

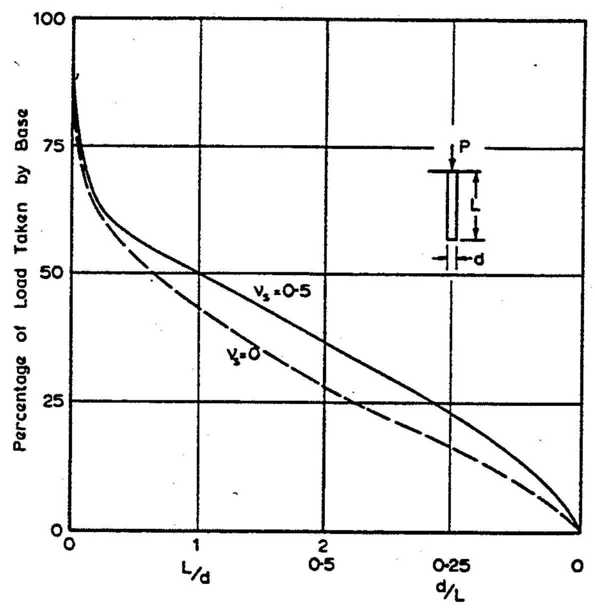


FIG.13.2 Proportion of applied load transferred to base of incompressible pile.

Influence factors for the vertical displacement are shown in Figs.13.3 to 13.6 for a pile in a finite layer and for four values of ν_s (Poisson's ratio of mass).

The effect of having an enlarged base, diameter d_b, on the pile is shown in Fig.13.7 for base load, and Fig.13.8 for displacement.

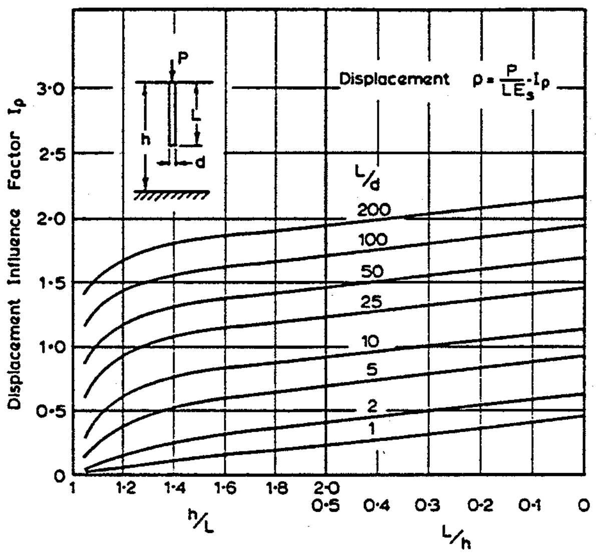


FIG.13.3 Displacement of incompressible pile in finite layer. $\nu_s = 0$.

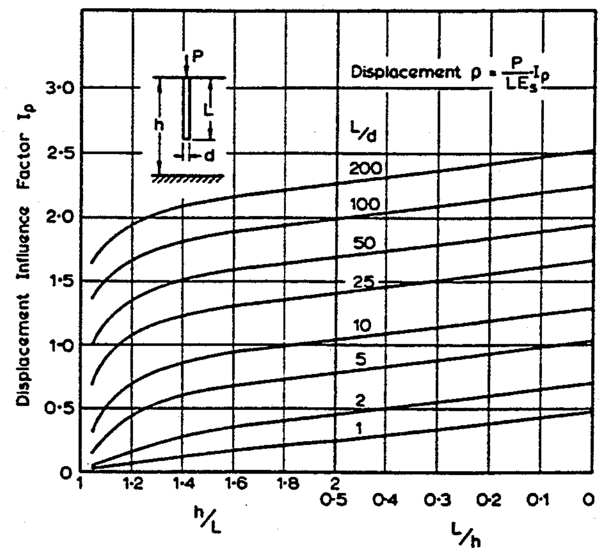


FIG.13.4 Displacement of incompressible pile in finite layer. $\nu_s = 0.2$.

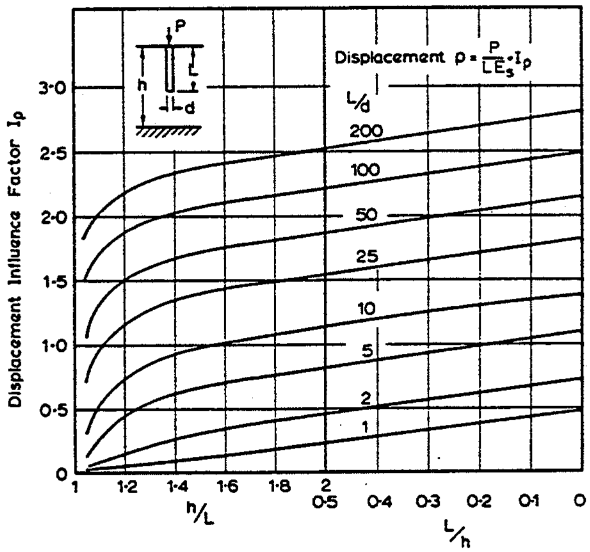


FIG.13.5 Displacement of incompressible pile in finite layer. $\nu_s = 0.4$.

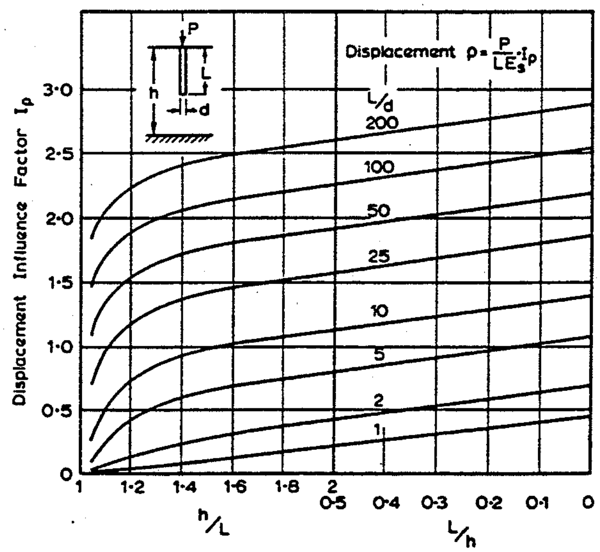


FIG.13.6 Displacement of incompressible pile in finite layer. $\nu_s = 0.5$.

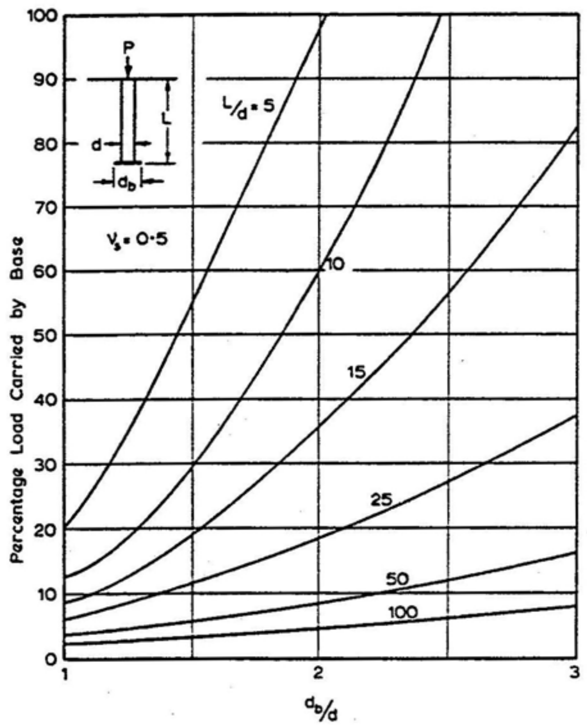


FIG.13.7 Effect of enlarged base on proportion of load transferred to pile base.

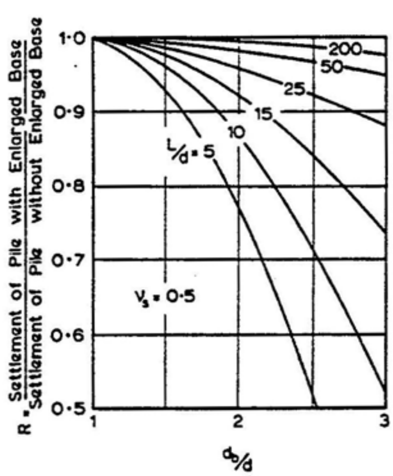


FIG.13.8 Effect of enlarged base on pile displacement.

The behaviour of piles of non-uniform cross-section is considered by Poulos (1969) while the behaviour of piles having a rigid cap resting on the surface is examined by Poulos (1968b).

13.2 Single Compressible Floating Pile

The compressibility of the pile in relation to the soil is expressed by a pile stiffness factor K where

$$K = \frac{E_p}{E_s} R_A \qquad \ldots (13.1)$$

where E_p = Young's modulus of pile

E_s = Young's modulus of soil mass

R_A = area of pile section/$\frac{\pi d^2}{4}$

The influence of K on the shear stress distribution along the pile is shown in Fig.13.9 while the proportion of load transferred to the base is shown in Fig.13.10. The difference between the top and tip displacement of a pile having $L/d=25$ is shown in Fig.13.11. Influence factors for displacement of the pile top are shown in Fig.13.12. In all the above cases, the layer is of infinite depth. The influence of finite layer depth is shown in Fig.13.13.

Influence factors for the vertical displacement of a point within a semi-infinite mass, at depth H below the surface and radial distance r from the axis, due to a pile are shown in Figs.13.14 to 13.27 for various values of L/d and K. These factors have been obtained by Poulos and Mattes (1971a).

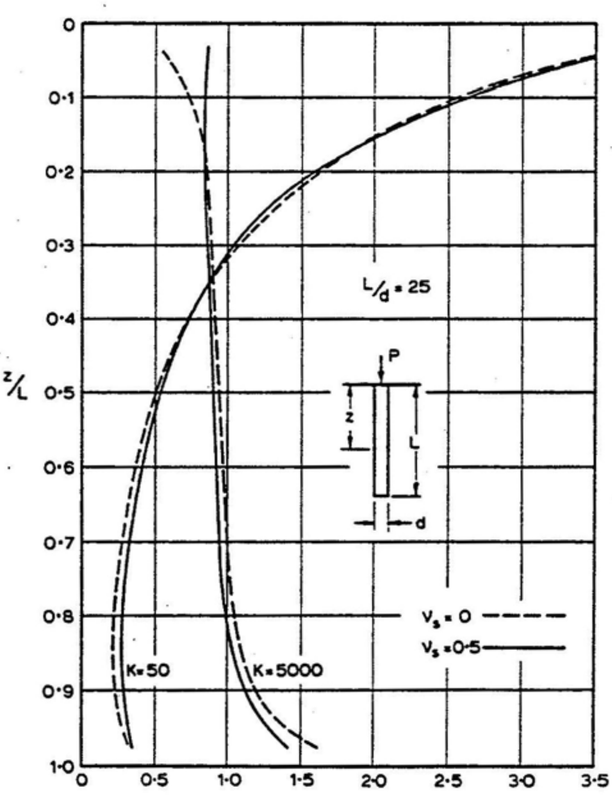


FIG.13.9 Effect of pile compressibility on shear stress distribution (Mattes and Poulos, 1969).

The displacement ρ is given by

$$\rho = \frac{P}{L\,E_s} I_\rho \qquad \text{... (13.2)}$$

The solutions are for $\nu_s = 0.5$, but ν_s generally has a relatively small effect on I_ρ. For $r/L > 0.5$, the displacement due to the pile, is within ±3% of the value due to a point load P acting on the axis at a distance $2L/3$ below the surface.

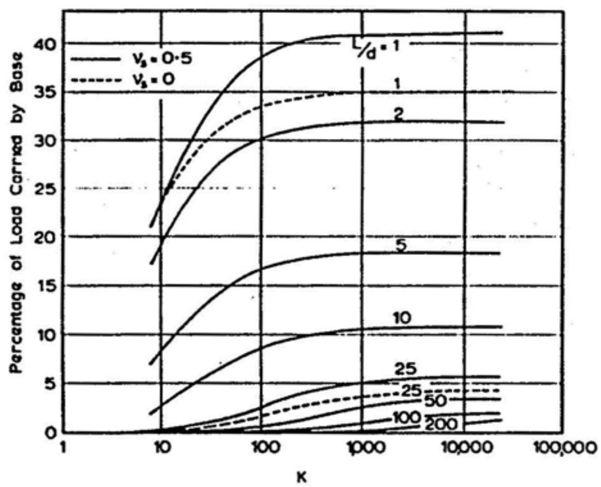


FIG.13.10 Effect of pile compressibility on load transferred to pile base (Mattes and Poulos, 1969).

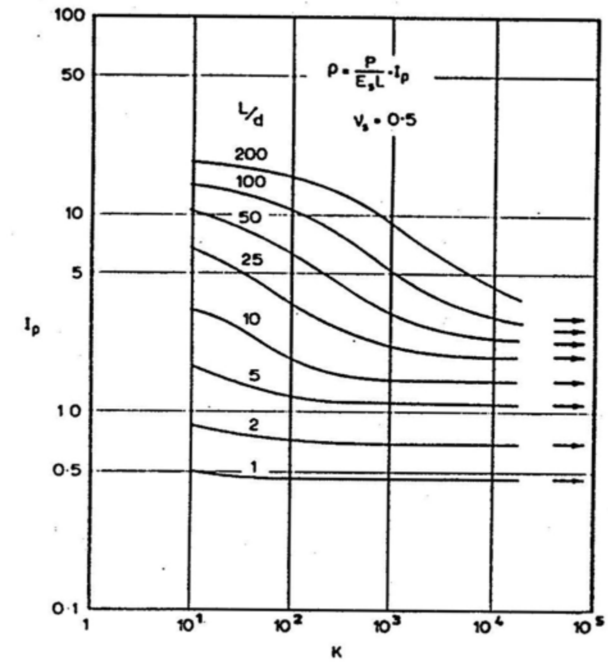


FIG.13.12 Displacement influence factors for compressible floating pile (Mattes and Poulos, 1969).

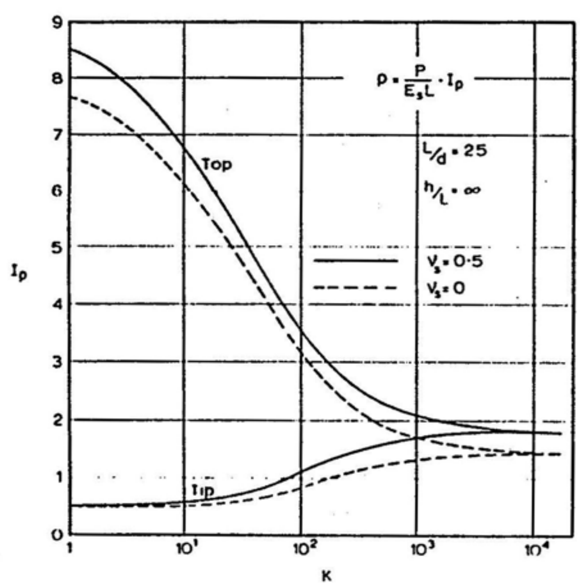


FIG.13.11 Top and tip displacements of compressible floating pile (Mattes and Poulos, 1969).

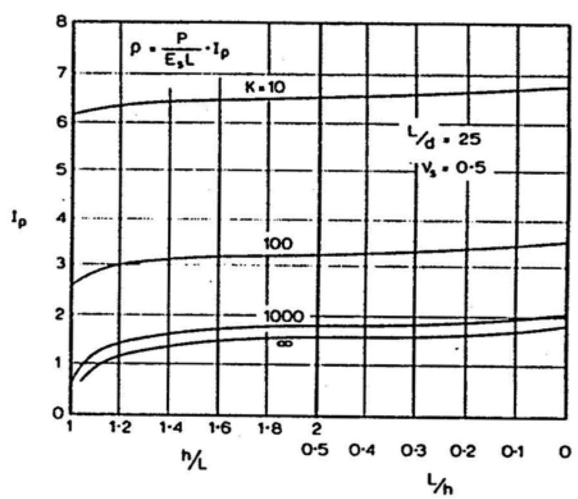


FIG.13.13 Effect of finite layer depth on pile displacement (Mattes and Poulos, 1969)

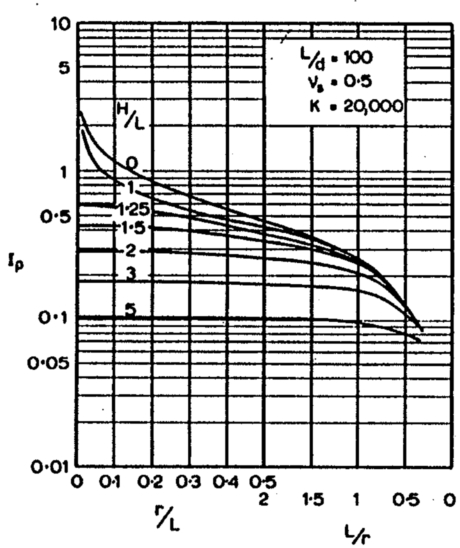


FIG.13.14 Factors for displacement due to pile. L/d = 100, K=20000.

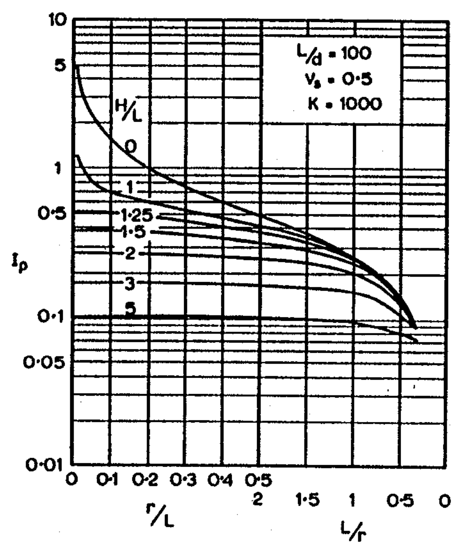


FIG.13.15 Factors for displacement due to pile. L/d = 100, K=1000.

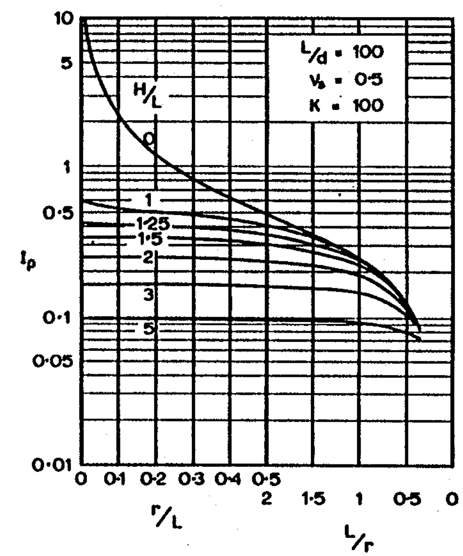


FIG.13.16 Factors for displacement due to pile. L/d = 100, K=100.

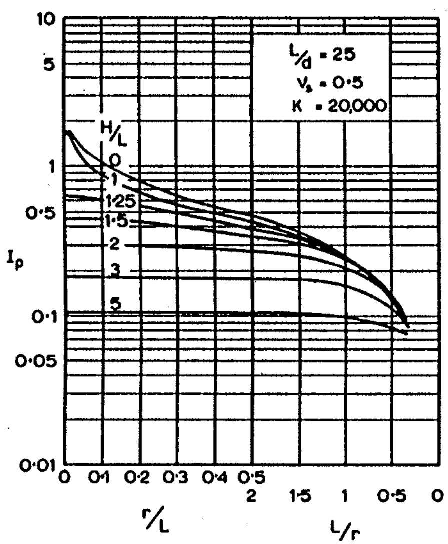


FIG.13.17 Factors for displacement due to pile. L/d = 25, K=20000.

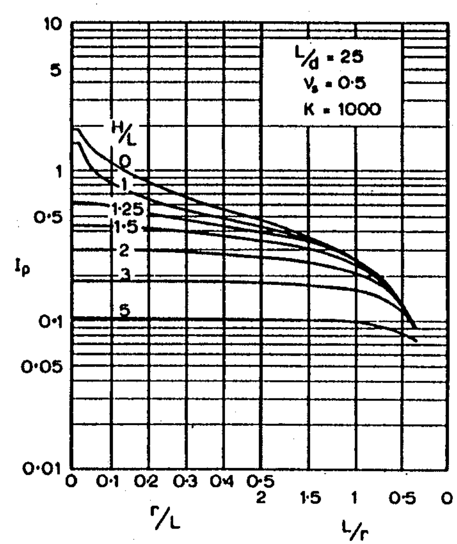


FIG.13.18 Factors for displacement due to pile. L/d = 25, K=1000.

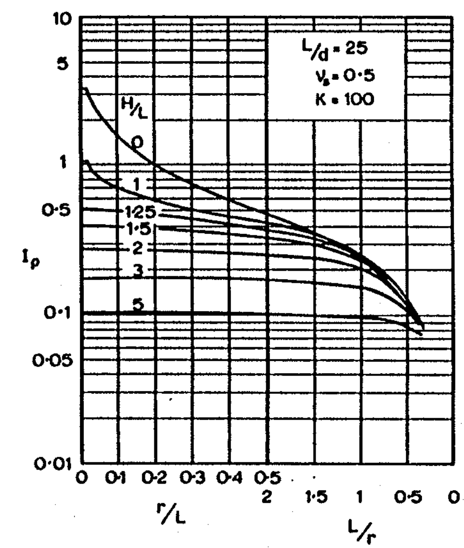


FIG.13.19 Factors for displacement due to pile. L/d = 25, K=100.

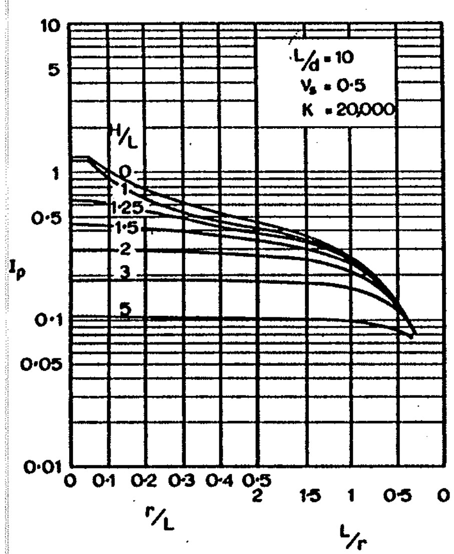


FIG.13.20 Factors for displacement due to pile. L/d = 10, K=20000.

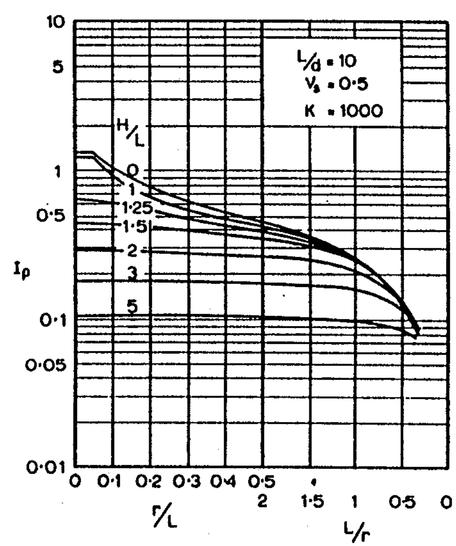


FIG.13.21 Factors for displacement due to pile. L/d = 10, K=1000.

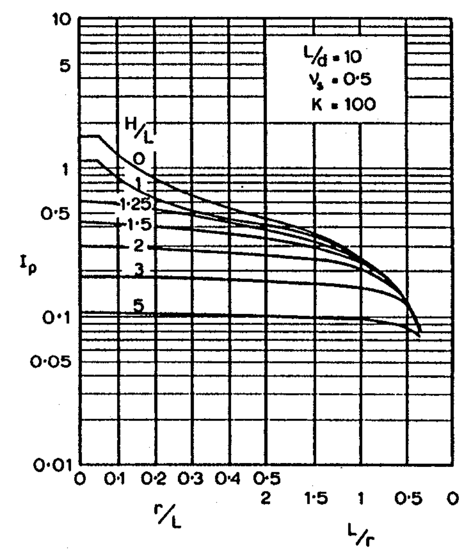


FIG.13.22 Factors for displacement due to pile. L/d = 10, K=100.

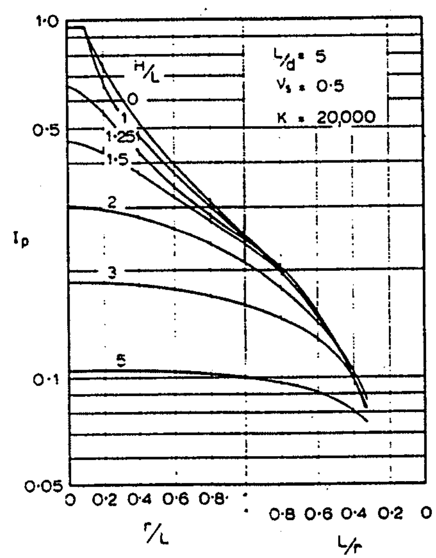


FIG.13.23 Factors for displacement due to pile. L/d = 5, K=20000.

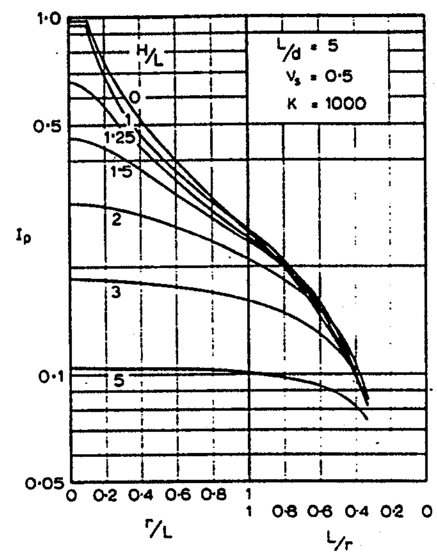


FIG.13.24 Factors for displacement due to pile. L/d = 5, K=1000.

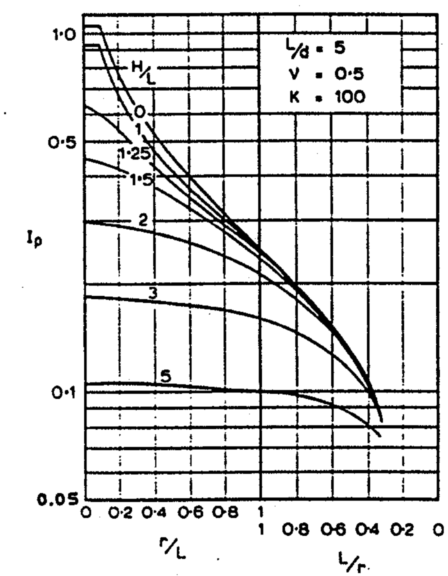


FIG.13.25 Factors for displacement due to pile. L/d = 5, K=100.

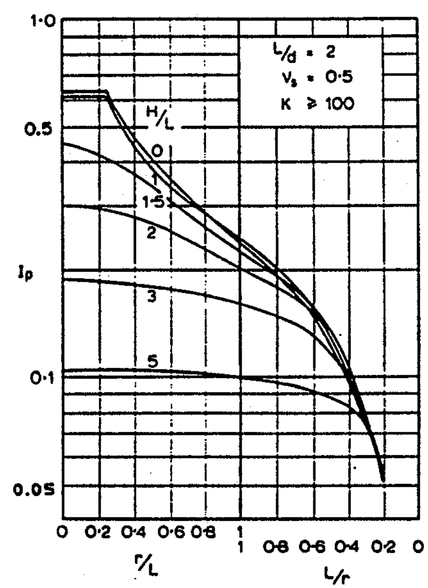


FIG.13.26 Factors for displacement due to pile. L/d = 2, K ≥ 100.

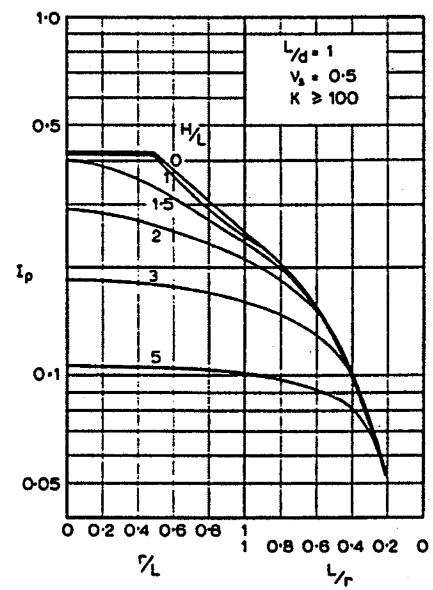


FIG.13.27 Factors for displacement due to pile. L/d = 1, K ≥ 100.

13.3 Single Compressible End-Bearing Pile

This problem has been considered by Poulos and Mattes (1969a).

For a rigid bearing layer, the distribution of axial load within the pile with depth is shown in Fig.13.28 while the proportion of load transferred to the pile base is shown in Fig.13.29. The displacement of the top of the pile is shown in Fig.13.30.

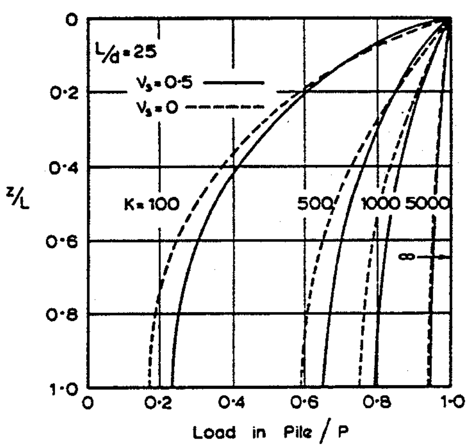


FIG.13.28 Load distribution in end-bearing pile.

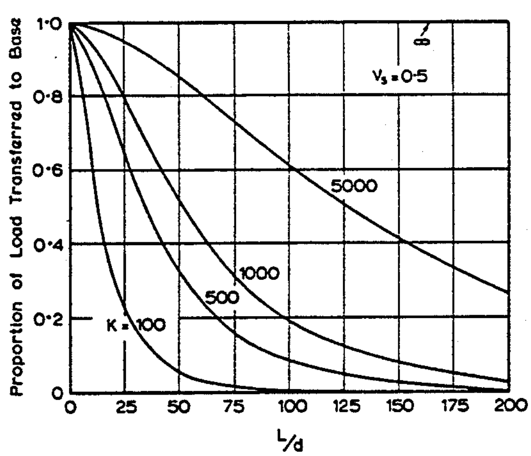


FIG.13.29 Proportion of load transferred to base of end-bearing pile.

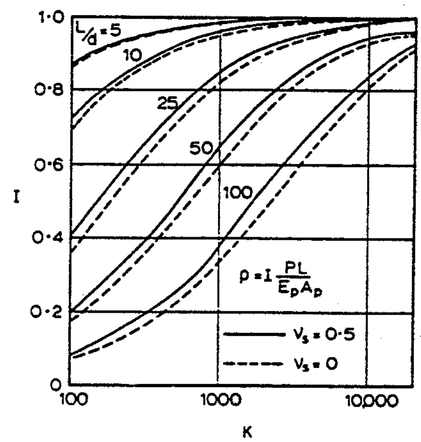


FIG.13.30 Displacement at top of end-bearing pile.

13.4 Negative Friction in a Single End-Bearing Pile

This problem has been considered by Poulos and Mattes (1969b).

For a layer underlain by a rigid base which is subject to a vertical displacement which varies linearly from S_0 at the surface to zero at the base $(z=L)$. Influence factors for the maximum load P_N induced in a pile (at the tip) are shown in Fig.13.31.

Distributions of load along the pile are shown in Fig.13.32.

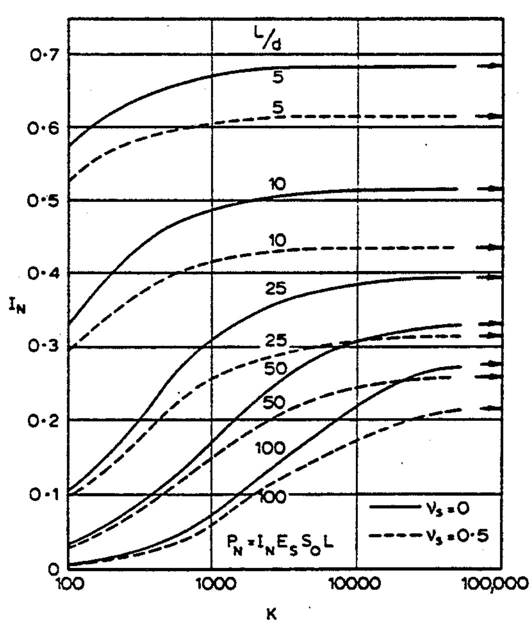


FIG.13.31 Influence factors for downdrag load at pile tip.

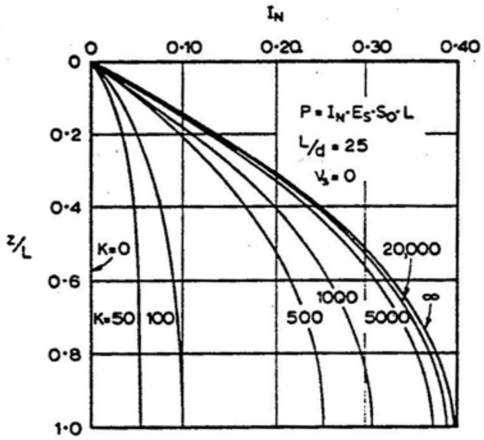


FIG.13.32 Distribution of downdrag load along pile.

13.5 Floating Pile Groups

13.5.1 INTERACTION BETWEEN TWO IDENTICAL PILES

The increase in vertical displacement of a pile due to an adjacent identical pile has been considered by Poulos (1968c) and Poulos and Mattes (1971b) in terms of an interaction factor α where

α = ratio of increase in displacement due to adjacent pile to displacement of single pile only.

The variation of α with centre-to-centre pile spacing s/d is shown in Fig.13.33 for two incompressible piles in a finite layer. An example of the effect of ν_s on α is shown in Fig.13.34. Curves of α *vs.* s/d for two compressible piles in a semi-infinite mass having $\nu_s = 0.5$ are shown in Figs. 13.35 (a) to (c) three values of L/d.

For compressible piles with a rigid circular cap resting on the surface, interaction curves are given by Davis and Poulos (1972).

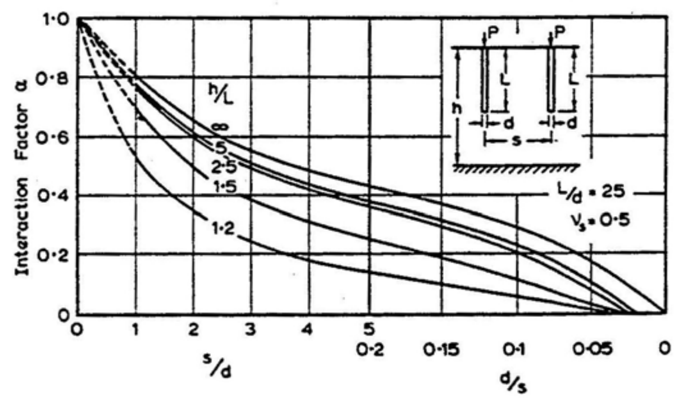


FIG.13.33 Interaction factors for two incompressible piles in a finite layer.

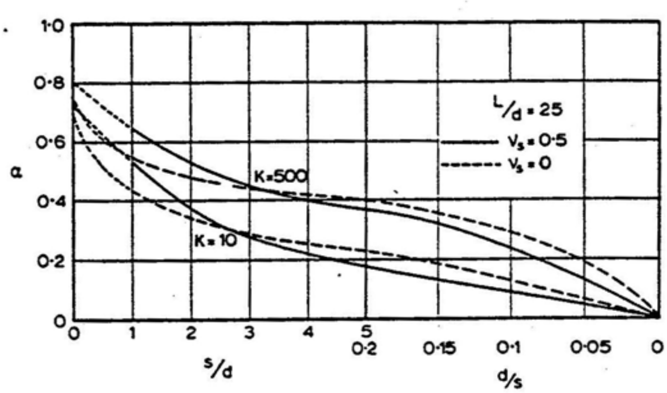
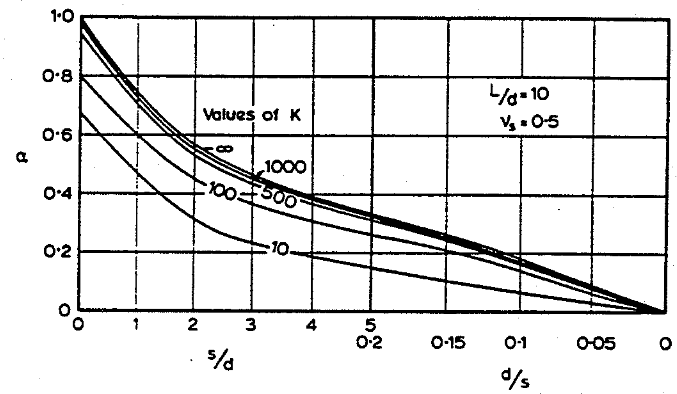
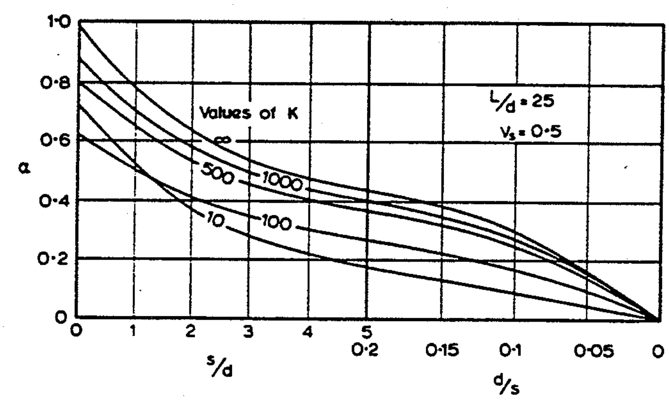


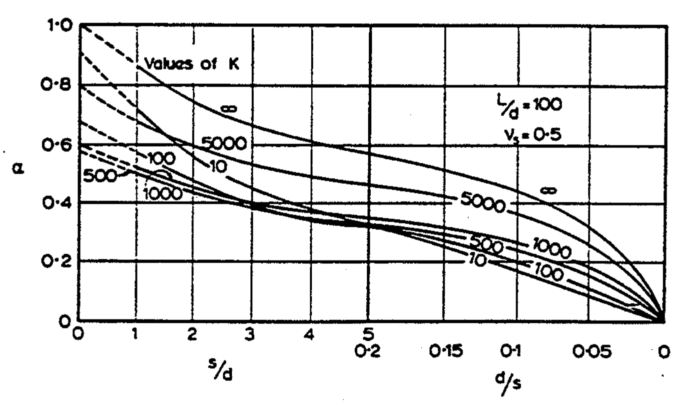
FIG.13.34 Effect of ν_s on interaction factors for two floating piles in a semi-infinite mass.



(a) L/d = 10



(b) L/d = 25



(c) L/d = 100

FIG.13.35 Interaction factors for two floating piles in a semi-infinite mass.

13.5.2 ANALYSIS OF GENERAL PILE GROUPS

The two-pile interaction factors in Figs.13.33 and 13.34 may be used to analyze the displacement and load distribution in any general pile group by using the principle of superposition, which has been found to apply closely for pile groups.

For any pile i in a group of k piles, the displacement is

$$\rho_i = \rho_1 \Big(\sum_{\substack{j=1 \\ j \neq i}}^{k} P_j \, \alpha_{ij} + P_i \Big) \qquad \ldots (13.3)$$

where ρ_1 = displacement of single pile under unit load

α_{ij} = interaction factor for spacing between piles i and j

P_j = load in pile j.

If the above equation is written for all the piles in the group, and use is made of the equilibrium equation

$$P_G = \sum_{j=1}^{k} P_j \qquad \ldots (13.4)$$

where P_G = total group load,

the resulting equations may be solved for two limiting cases:

(i) equal displacement of all piles. This corresponds to a rigid pile cap, and the distribution of load and the uniform displacement of the group may be computed.

(ii) equal load in all piles. This corresponds to a uniformly-loaded flexible pile cap, and the distribution of displacement in the group may be computed.

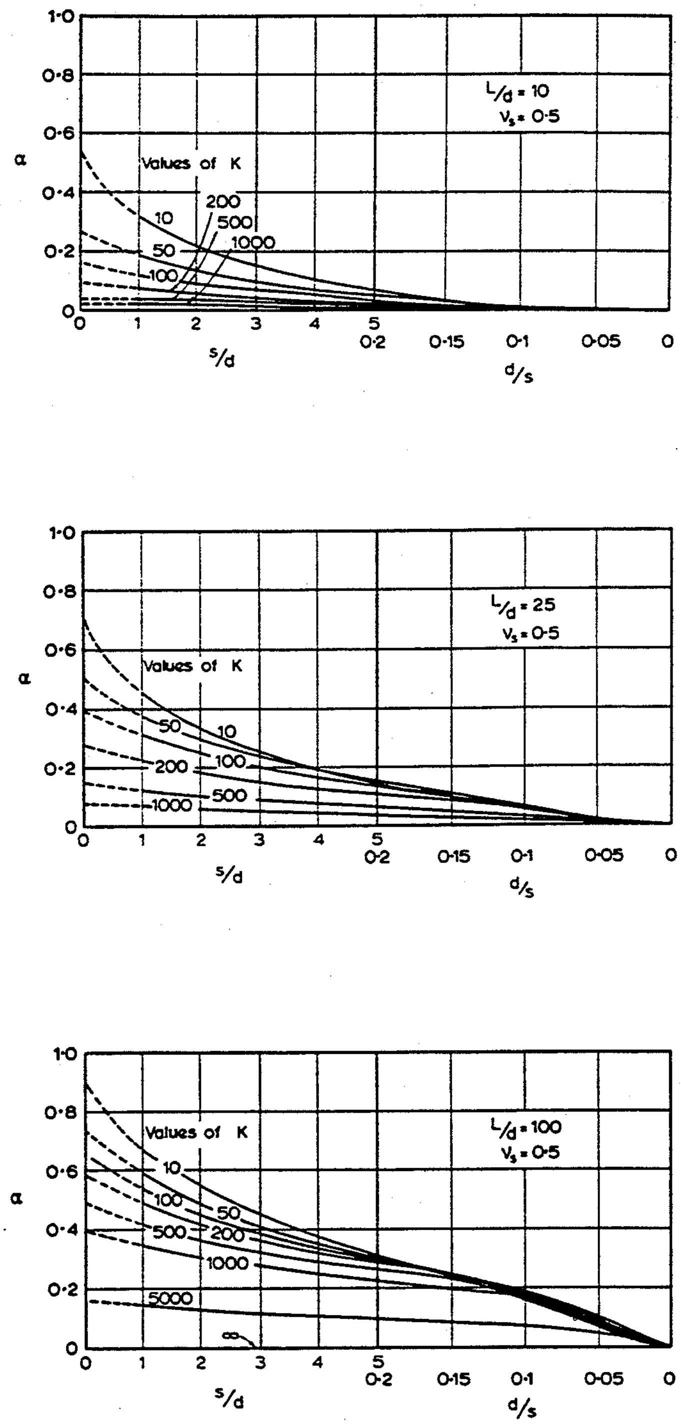
Typical solutions for the settlement and load distribution in various pile groups are given by Poulos (1968c) and Poulos and Mattes (1971b).

Similar solutions for pile groups having a pile cap resting on the surface are given by Davis and Poulos (1972).

13.6 End-Bearing Pile Groups

For two identical piles resting on a rigid base, interaction factors α are plotted against centre-to-centre spacing in Figs. 13.36(a) to (c).

As for floating pile groups, superposition may be used to analyze any general pile group. Typical solutions for the displacement of load distribution within groups of end-bearing piles are presented by Poulos and Mattes(1971b).



(a) L/d = 10

(b) L/d = 25

(c) L/d = 100

FIG.13.36 Interaction factors for two end-bearing piles resting on a rigid bearing stratum.