References

1. Adams, J.I., and Radhakrishna, H.S., "The lateral Capacity of Deep Augered Footings", Proceedings, Eight Internatl. Conf. on Soil Mechanics and Foundation Engrg.,Vol.II, Moscow, 1973, pp. 1 - 8.

2. Bergfelt, A., "The Axial and Lateral Load Bearing Capacity, and Failure by Buckling of Piles in Soft Clay", Proceedings, Fourth Internatl. Conf. on Soil Mechanics and Foundation Engrg., Vol. II, London, England 1957, pp. 8 - 13.

3. Biot, A.M., "Bending of an Infinite Beam on an Elastic Foundation", Journal of Applied Mechanics, Vol. 4, No. 1, A1 - A7, 1937.

4. Botea, E., Manoliu, I., and Abramescu, T., "Large Diameter Piles under Axial and Lateral Loads", Proceedings, Eight Internatl. Conf. on Soil Mechanics and Foundation Engrg., Vol. II, Moscow, 1973, pp. 27 - 38.

5. Bowles, J.E., "Foundation Analysis and Design", First International Student Edition, Kogakusha Company, Ltd., Tokyo, 1968.

6. Bowles, J.E., "Analytical and Computer Methods in Foundation Engineering", McGraw Hill, Inc., New York, N.Y., 1974.

7. Brand, E.W., Muktabhant, C. and Akrapongpisai, S., "Comparative Study of Undrained Strength Measurements of a Soft Clay", Proceedings, Third S.E. Asian Conf. Soil Eng., Hong Kong, Nov. 1972.

8. Brinch-Hansan, J., "The Stabilizing Effect of Piles in Clay", C.N. Post, November, 1948. (Published by Christiani and Nielsen, Copenhagen, Denmark).

9. Broms, B.B. "Lateral Resistance of Piles in Cohesive Soils," Journal of the Soil Mechanics and Foundations Division, ASCE, Vol. 90, SM2, 1964(a), pp. 27 - 63

10. Broms, B.B. "Lateral Resistance of Piles in Cohesionless Soils", Journal of the Soil Mechanics and Foundations Division, ASCE, Vol. 90, No. SM3, 1964b, pp. 123 - 156.

11. Chang, Y.L., Discussion of "Lateral Pile-Loading Tests", by Lawrence B. Feagin, Transactions, ASCE, Vol. 102, 1937, pp. 272 - 278.

12. Dastidar, A.G., "Pilot Tests to Determine the Effect of Piles in Restraining Shear Failure in Clay", Princeton Univ., Princeton, N.J., 1956 (unpublished).

13. Davisson, M.T., and Gill, H.L., "Laterally Loaded Piles in a Layered System", Journal of the Soil Mechanics and Foundations Division, ASCE, Vol. 89, No. SM3, Proc. Paper 3509, May, 1963, pp. 63 - 94.

14. DeBeer, E.E., "Computation of Beams Resting on Soil", Proceedings, Second Internatl. Conf. on Soil Mechanics and Foundation Engrg., Vol. 1, 1948, Rotterdam, Holland, pp. 119 - 121.

15. Donovan, N.C., "Analysis of Pile Groups", thesis presented to Ohio State University, at Columbus, Ohio, in 1959, in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

16. Ellison, R.D., D'Appolonia, E. and Thiers, G.R., "Load-Deformation Mechanism for Bore Piles", Journal of the Soil Mechanics and Foundations Division, ASCE, Vol. 97, pp. 661 - 678.

17. Evans, L.T., "Bearing Piles Subjected to Horizontal Loads", Symposium on Lateral Load Tests on Piles, ASTM Special Technical Publication, No. 154, 1953, pp. 30 - 35.

18. Franke, E., "Principles for Test-Loadings of Large Bored Piles by Horizontal Loads", Proceedings of the Eighth International Conference on Soil Mechanics and Foundation Engineering, Vol. II, Moscow, 1973, pp. 97 - 104.

19. Fellenius, B.H., "Test Loading of Piles and New Proof Testing Procedure", Journal of the Geotechnical Engineering Division, ASCE, Vol. 101, No. GT9, September, 1975, pp. 855 - 869.

20. Fuller, F.M., and Hoy, H.E., "Pile Load Tests Including Quick-Load Test Method, Conventional Methods, and Interpretations", Highway Research Board No. 333, Pile Foundations, 1970, pp. 74 - 86.

21. Gaul, R.D., "Model Study of a Dynamically Laterally Loaded Pile", Journal of the Soil Mechanics and Foundations Division, ASCE, Vol. 84, No. SM1, Proc. Paper 1535, February, 1958.

22. Gleser, S.M., "Lateral Load Tests on Vertical Fixed-Head and Free-Head Piles", ASTM Special Publication, No. 154, 1953, pp. 75 - 93.

23. Hetényi, M., "Beams on Elastic Foundation", Univ. of Michigan Press, Ann Arbor, Mich., 1946.

24. Howe, R.J., "A Numerical Method for Predicting the Behavior of Laterally loaded Piling", Shell Oil Co., TS Memorandum 9, Houston, Tex., May, 1955.

25. Khadilkar, B.S., CHANDRASEKARAN, V.S., Rizvi, I.A., "Analysis of Laterally Loaded Piles in Two-Layered Soils", Proceedings, Eight Internatl. Conf. on Soil Mechanics and Foundation Engrg., Vol. II, Moscow, 1973, pp. 155 - 158.

26. Kubo, K., "Experimental Study of the Behaviour of Laterally Loaded Piles", Proceeding, 6th Int. Conf. S.M. and F.E., Vol. 2, 1965, pp. 275 - 279.

27. Lazard, A., and Gallerand, G., "Shallow Foundations", Proceedings, Fifth Internatl. Conf. on Soil Mechanics and Foundation Engrg., Vol. III, Paris, France 1961, pp. 228 - 232.

28. Madhav, M.R., Rao, N.S.V.K., and Madhavan, K., "Laterally Loaded Pile in Elasto-Plastic Soil", Soils and Fndns., Vol. 11, No. 2, 1971, pp. 1 - 15.

29. Matlock, H., and Ripperger, E.A., "Procedures and Instrumentation for Tests on a Laterally Loaded Pile", Proceedings, Eighth Texas Conf. on Soil Mechanics and Foundation Engrg. Research, Univ. of Texas, Austin, Tex., 1956.

30. Matlock, H., and Reese, L.G., "Foundation Analysis of Offshore Pile Supported Structures", Proceeding, 5th Internatl. Conf. on Soil Mechanics and Foundation Engrg., Vol. II, 1961, pp. 91 - 97.

31. McCammon, G.A., and Ascherman, J.C., "Resistance of Long Hollow Piles to Applied Lateral Loads", Symposium on Lateral Load Tests on Piles, ASTM Special Technical Publication, No. 154, 1953, pp. 3 - 9.

32. McClelland, B., and Focht, J.A., Jr., "Soil Modulus for Laterally Loaded Piles", Transactions, ASCE, Vol. 123, 1852, pp. 1049 - 1063.

33. McKenzie, T.R., "Strength of Deadman Anchors in Clay", Thesis presented to Princeton University, at Princeton, N.J., in 1955, in partial fulfilment of the requirements for the degree of Master of Science.

34. McNulty, J.F., "Thrust Loadings on Piles", Journal of the Soil Mechanics and Foundations Division, ASCE, Vol. 82, No. SM2, Proc. Paper 940, April, 1956.

35. Mohan, D., SHRIVASTAVA, S.P., "Nonlinear Behaviour of Single Vertical Pile Under Lateral Loads", Third Annual Offshore Technology Conference, Houston, Paper OTC 1485, II, 1971, pp. 677 - 684.

36. Newmark, N.M., "Numerical Procedure for Computing Deflections. Moments, and Buckling Loads", Transactions, ASCE, Vol. 108, 1943, pp. 1161 - 1188.

37. Parrack, A.L., "An Investigation of Lateral Loads on a Test Pile", Texas A and M Research Foundation, Research Foundation Project No. 31, College Station, Texas August, 1952.

38. Peck, R.B., and Ireland, H.O., "Full-Scale Lateral Load Test of a Retaining Wall Foundation", Proceedings, Fifth Internatl. Conf. on Soil Mechanics and Foundation Engrg., Paris, France, Vol. II, 1961, pp. 453 - 458.

39. Peck, R.B., and Davisson, M.T., discussion of "Design and Stability Considerations for Unique Pier", by James Michalos and David P. Billington, Transactions, ASCE, Vol. 127, Part IV, 1962, pp. 413 - 424.

40. Poulos, H.G., "Behaviour of Laterally Loaded piles: I-Single Piles", Jnl. Soil Mechs. Fndns. Divn, ASCE, Vol. 97, No. SM5, 1971(a), pp. 711 - 731.

41. Poulos, H.G., "Behaviour of Laterally Loaded Piles: II - Pile Groups", Jnl. Soil Mechs, Fndns. Divn. ASCE, Vol. 97, No. SM5, 1971b, pp. 733 - 751.

42. Poulos, H.G., "Load-Deflection Prediction for Laterally Loaded Piles", The University of Sydney Research Report No. R 208, March, 1973.

43. Reese, L.C., discussion of "Soil Modulus for Laterally Loaded Piles", by B. McClelland and J.A. Focht, Jr., Transactions, ASCE, Vol. 123, 1958, pp. 1071 - 1074.

44. Reese, L.G., Lymon, C., and Welch, R.C., "Lateral Loading of Deep Foundations in Stiff Clay", Journal of the Geotechnical Engineering Division, ASCE, Vol. 7, July 1975, pp. 633 - 649.

45. Shilts, W.L., Graves, L.D., and Driscoll, C.G., "A Report of Field and Laboratory Tests on the Stability of Posts Against Lateral Loads", Proceedings, Second Internatl. Conf. on Soil Mechanics and Foundation Engrg., Rotterdam, Holland Vol. V, 1948, p. 107.

46. Skempton, A.W., "The Bearing Capacity of Clays", Building Research Congress, London, England 1951, pp. 180 - 189.

47. Skempton, A.W., and Bjerrum, L., "A Contribution to the Settlement Analysis of Foundations on Clay", Géotechnique, London, England, Vol. VII, 1957, pp. 168 - 178.

48. Spillers, W.R., and Stoll, R.D., "Lateral Response of Piles", Jnl. Soil Mechn, Fndns. Divn. ASCE, Vol. 90, No. SM6, 1964, pp 1 - 9.

49. Terzaghi, K., "Theory Soil Mechanics", John Wiley and Sons, Inc., New York, N.Y., 1943.

50. Terzaghi, K., "Evaluation of Coefficients of Subgrade Reaction", Géotechnique, London, England, Vol. V, 1955, pp. 297 - 326.

51. Terzaghi, K., and Peck, R.B., "Soil Mechanics in Engineering Practice", John Wiley and Sons, Inc., New York, N.Y., 1948.

52. Thoms, R.L., "A Model Analysis of a Laterally Loaded Pile", thesis presented to the University of Texas, at Austin, Tex., in 1957, in partial fulfilment of the requirements for the degree of Master of Science.

53. Timoshenko, S. "Strength of Materials Part 2 Advanced Theory and Problems", Third Edition, Van Nostrand, Second East-West Reprint, New Delhi, 1966.

54. Timoshenko, S. and Goodier, J.N., "Theory of Elasticity", Second Edition, McGraw-Hill Book Co., Inc., New York, N.Y., 1951.

55. Vesić, A.B., "Bending of Beams Resting on Isotropic Elastic Solid", Journal of the Engineering Mechanics Division, ASCE, Vol 87, No. EM2, Proc. Paper 2800, April, 1961(a), pp. 35 - 53.

56. Vesić, A.B. "Beams on Elastic Subgrade and the Winkler's Hypothesis", Proceedings, Fifth Internatl. Conf. on Soil Mechanics and Foundation Engrg., Vol. I, 1961(b), Paris, France pp. 845 - 850.

57. Wagner, A.A., "Lateral Load Tests on Piles for Design Information", Sumposium on Lateral Load Tests on Piles, ASTM Special Publication, No. 154, 1953, pp. 59 - 72.

58. Ward, W.H., Samuels, S.G., and Butler, M.E., "Further Studies of the Properties of London Clay", Géotechnique, London, England, Vol. IX, 1959, pp. 33 - 58.

59. Weissmann, G.F., and White, S.R., "Small Angular Deflections of Rigid Foundations", Géotechnique, London, England, Vol. XI, No. 3, September, 1961, pp. 186 - 202.

60. Whitaker, T., "The Constant Rate of Penetration Test for the Determination of the Ultimate Bearing Capacity of a Pile", Proc. Inst. Civ. Engrs., Vol. 26, 1963, pp. 119 - 123.

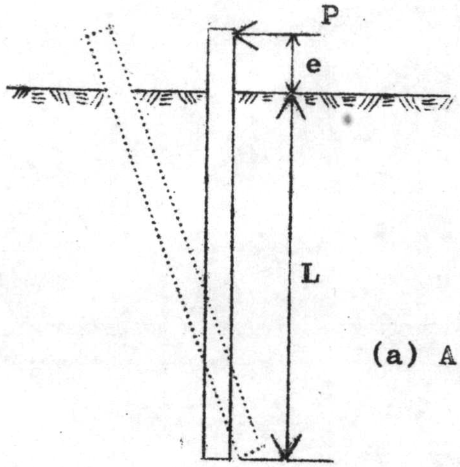
61. Winkler, E., Die Lehre Vonder Elastizität und Festigkeit (Prag, 1867), pp. 182 - 184; and Zimmermann, op. cit., (Prague, Dominious.)

APPENDIX A

Derivation of Deflection Equations for Short and Long Piles

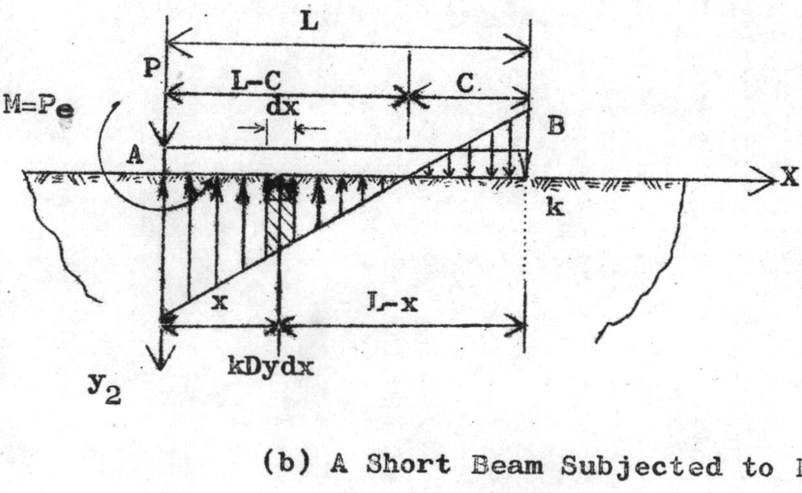
A Short Free-Headed Pile

For $\beta L < 1.5$ (The pile is infinitely stiff)



(a) A Short Free-Headed Pile

In the following analysis the pile is treated as a rigid short beam resting on the surface of a semi-infinite, ideal elastic medium as shown in Fig. A-1b.



(b) A Short Beam Subjected to Edge Forces on Elastic Foundation

Fig. A-1 - Analysis of a Short Free-Headed Pile

Applying the static equation considering of vertical forces $\Sigma F_y = 0$ we have

$$\int_0^L Dkydx = P$$

$$\int_0^L ydx = \frac{P}{kD}. \quad \text{.......................(A-1)}$$

Substituting the straight line equation

$$y_{(x)} = A + BX \quad \text{.......................(A-2)}$$

into Eq. (A-1) leads to

$$AL + \frac{BL^2}{2} = \frac{P}{kD} \quad \text{.......................(A-3)}$$

By taking the moments of the forces about point B (Fig. A-1b) one obtains

$$\int_0^L kDy(L - x)\, dx - P(e + L) = 0 \quad .$$

Substituting Eq. (A-2) and simplifying yields

$$AL + \frac{BL^2}{3} = \frac{2P(e + L)}{LkD}. \quad \text{..................(A-4)}$$

Substituting constant A & B into Eq. (A-2) and simplifying yields

$$y_{(x)} = \frac{2P}{kDL}\left[(2 + \frac{3e}{L}) - \frac{3x}{L}(1 + \frac{2e}{L})\right] \text{....(A-5)}$$

$$y_A = y_o = \frac{4P}{kDL}(1 + \frac{1.5e}{L}) \quad \text{...............(A-6)}$$

$$y_B = \frac{-2P}{kDL}(1 + \frac{3e}{L}). \quad \text{................(A-7)}$$

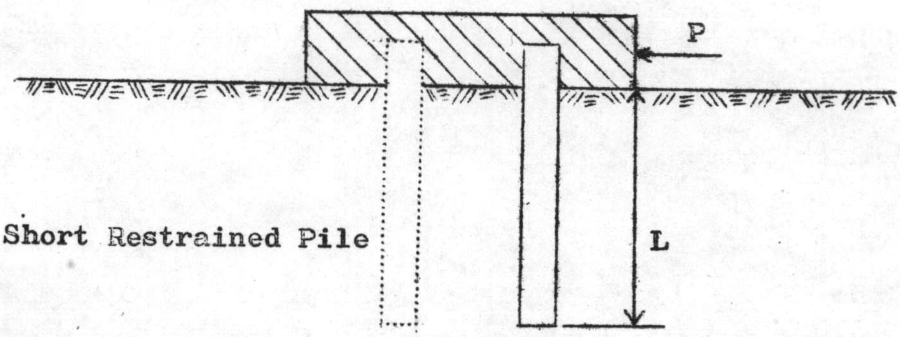
The moment at any point in the pile can be calculated from

$$M_{(x)} = \int_{o}^{x} kDy(L - x)\ dx - P\ (e + x)$$

$$= \frac{2P}{L}\int_{o}^{x}\left[\left(2 + \frac{3e}{L}\right) - \frac{3x}{L}\left(1 + \frac{2e}{L}\right)\right](L-x)\,dx - P(e+x).$$

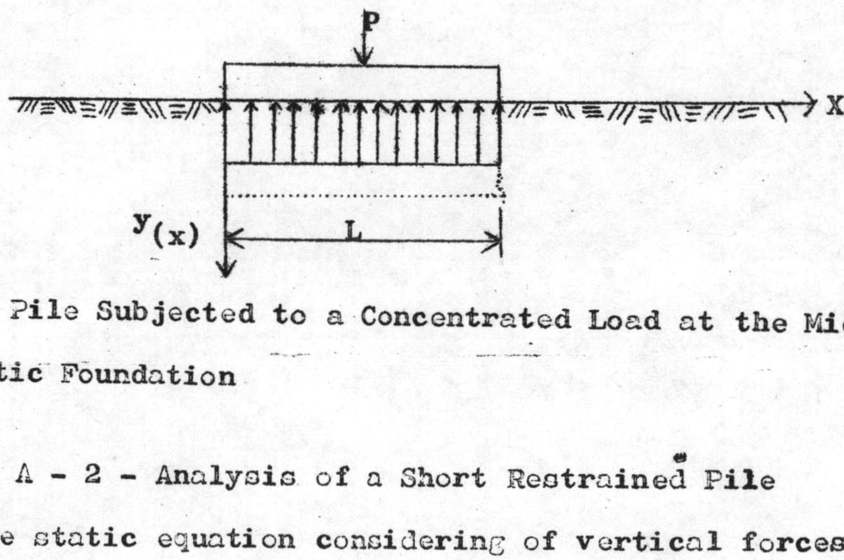
........(A-8)

A Short Restrained Pile



(a) A Short Restrained Pile

In the following analysis, the pile is treated as a rigid short beam resting on the surface of semi-infinite, ideal elastic medium as shown in Fig. A - 2b.



(b) A Short Pile Subjected to a Concentrated Load at the Middle on Elastic Foundation

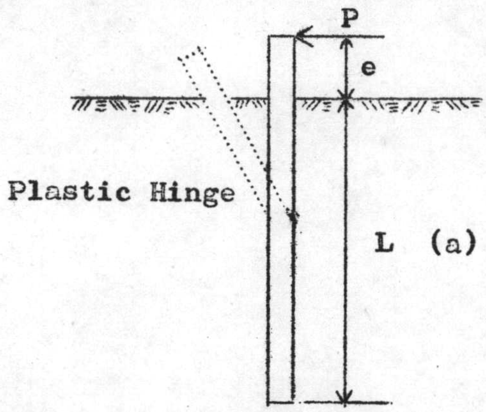
Fig. A - 2 - Analysis of a Short Restrained Pile

Applying the static equation considering of vertical forces $\Sigma F_y = 0$ we have

$$kDyL = P$$

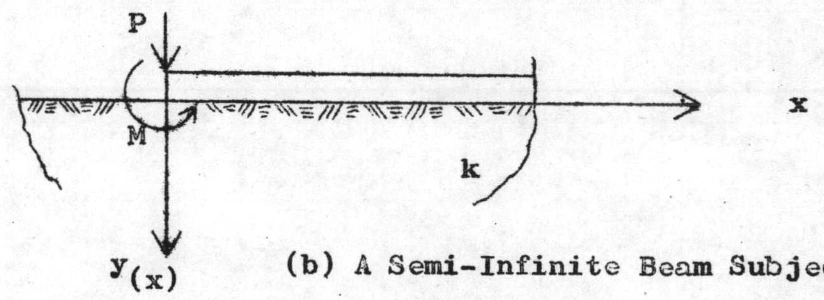
$$y_o = \frac{P}{kDL} \quad \text{.........................(A-9)}$$

A Long Free-Headed Pile ($\beta L > 2.5$)



(a) A Long Free-Headed Pile

In the following analysis, the pile is treated as a semi-infinite beam resting on the surface of a semi-infinite, ideal elastic medium as shown in Fig. A - 3b.



(b) A Semi-Infinite Beam Subjected to Edge Forces on Elastic Foundation

Fig. A-3 - Analysis of a Long Free-Headed Pile

For Semi-Infinite Beam Subjected to Edge Forces

General Solution :

$$y_{(x)} = e^{-\beta x}(C \cos\beta x + D \sin\beta x) \quad \text{..............(A-10a)}$$

$$y'_{(x)} = -\beta e^{-\beta x}\{\cos\beta x\,(C - D) + \sin\beta x\,(D + C)\} \quad \text{.....(A-10b)}$$

$$M_{(x)} = -2EI\beta^2 e^{-\beta x}(C\sin \beta x - D \cos \beta x) \quad \text{...........(A-10c)}$$

$$V_{(x)} = -2EI\,\beta^3 e^{-\beta x}\{C(\cos\beta x - \sin\beta x) + D(\cos\beta x + \sin\beta x)\} \quad \text{.......(A-10d)}$$

Boundary Conditions :

$$\left.\begin{aligned} y''\Big]_{x=0} &= \frac{M}{EI} \\ y'''\Big]_{x=0} &= \frac{P}{EI} \end{aligned}\right\} \quad \text{..........................(A-11)}$$

and

$$y_{(x)} = e^{-\beta x}(C\cos\beta x + D\sin\beta x) \qquad \text{...(A-12a)}$$

$$y'_{(x)} = \beta e^{-\beta x}(D\cos\beta x - C\sin\beta x) - \beta e^{-\beta x}(C\cos\beta x + D\sin\beta x) \text{...(A-12b)}$$

$$y''_{(x)} = -2\beta^2 e^{-\beta x}(D\cos\beta x - C\sin\beta x) \qquad \text{...(A-12c)}$$

$$y'''_{(x)} = 2\beta^3 e^{-\beta x}(D\cos\beta x - C\sin\beta x) + 2\beta^3 e^{-\beta x}(C\cos\beta x + D\sin\beta x) \qquad \text{...(A-12d)}$$

Substituting Eq. (A-12) into Eq. (A-11) yields

$$-2\beta^2 D = \frac{M}{EI} \quad , \; D = -\frac{M}{2\beta^2 EI}$$

$$2\beta^3 D + 2\beta^3 C = \frac{P}{EI} \quad , \; C = \frac{(P + \beta M)}{2\beta^3 EI}$$

Substituting C & D into Eq. (A-10) yields

$$y_{(x)} = \frac{e^{-\beta x}}{2\beta^3 EI}\left[P\cos\beta x + \beta M(\cos\beta x - \sin\beta x)\right] \qquad \text{...(A-13a)}$$

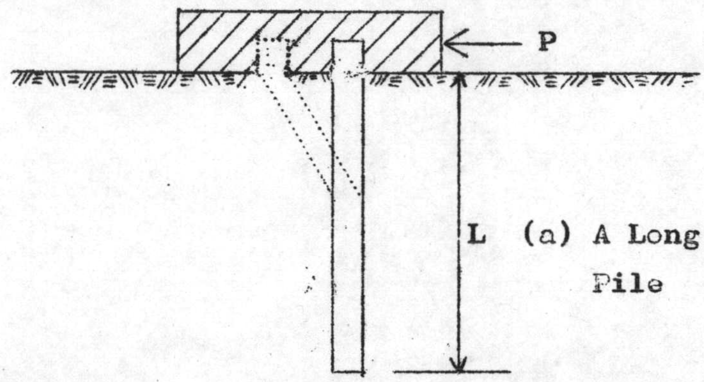
$$y'_{(x)} = -\frac{P}{2\beta^2 EI} e^{-\beta x}(\cos\beta x + \sin\beta x) - \frac{M}{\beta EI} e^{-\beta x}\cos\beta x \quad \text{...(A-13b)}$$

$$M_{(x)} = -EI\,y'' = -\frac{e^{-\beta x}}{\beta} \quad P\sin\beta x + \beta M(\cos\beta x + \sin\beta x) \qquad \text{...(A-13c)}$$

$$V_{(x)} = -EI\,y''' = -P e^{-\beta x}(\cos\beta x - \sin\beta x) + \beta M e^{-\beta x}\sin\beta x \qquad \text{...(A-13d)}$$

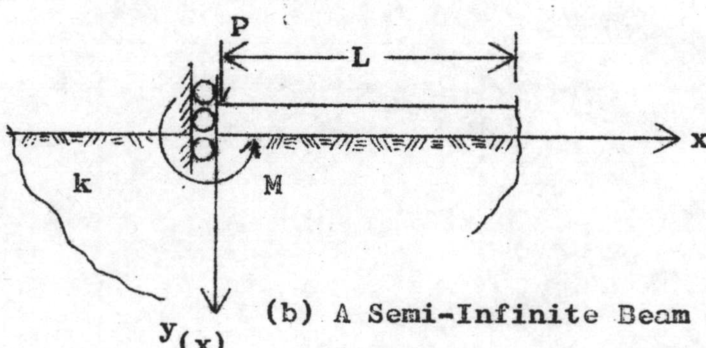
$$y_o = \frac{2\beta P}{k_\infty D}(1 + \beta e) \qquad \text{..................(A-14)}$$

A Long Restrained Pile



(a) A Long Restrained Pile

In the following analysis, the pile is treated as a semi-infinite beam resting on the surface of a semi-infinite, ideal elastic medium as shown in Fig. A-4b.



(b) A Semi-Infinite Beam Subjected to Edge Forces on Elastic Foundation

Fig. A-4 - Analysis of a Long Restrained Pile

Boundary Conditions:-

$$\left.\begin{aligned} y'_{(o)} &= 0 \\ y'''_{(o)} &= \frac{P}{EI} \end{aligned}\right\} \quad \text{..........................(A-15)}$$

Substituting Eq. (A-12) into Eq. (A-15) yields

$$\beta D - \beta C = 0, \quad C = D$$

$$2\beta^3 D + 2\beta^3 C = \frac{P}{EI}, \quad C = D = \frac{P}{4\beta^3 EI}.$$

Substituting C & D into Eq. (A-10) yields

$$y_{(x)} = \frac{P\beta}{k_\infty D} e^{-\beta x}(\cos\beta x + \sin\beta x) \quad \text{.......(A-16a)}$$

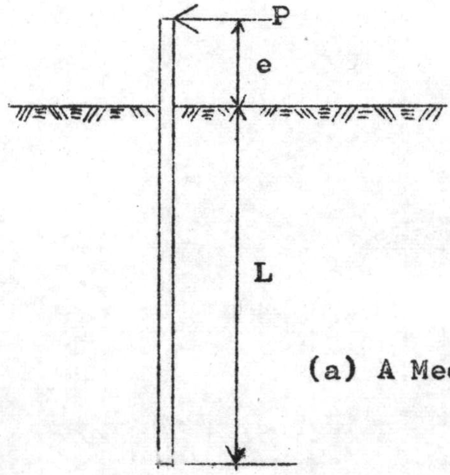
$$y'_{(x)} = \frac{-P}{2\beta^2 EI} e^{-\beta x}\sin\beta x \quad \text{.......(A-16b)}$$

$$M_{(x)} = \frac{P}{2\beta} e^{-\beta x}(\cos\beta x - \sin\beta x) \quad \text{.......(A-16c)}$$

$$V_{(x)} = -Pe^{-\beta x}\cos\beta x \quad \text{.......(A-16d)}$$

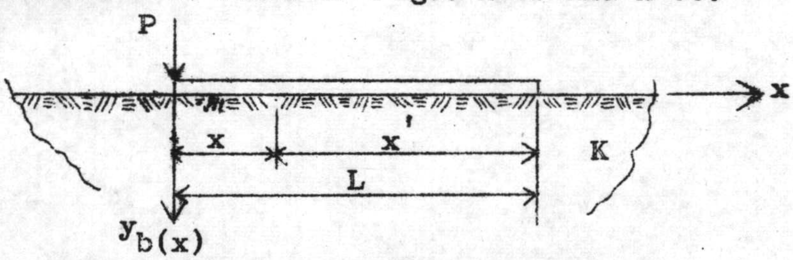
$$y_o = \frac{P\beta}{k_\infty D} \quad . \quad \text{.........................(A-17)}$$

A Medium Free Headed Pile

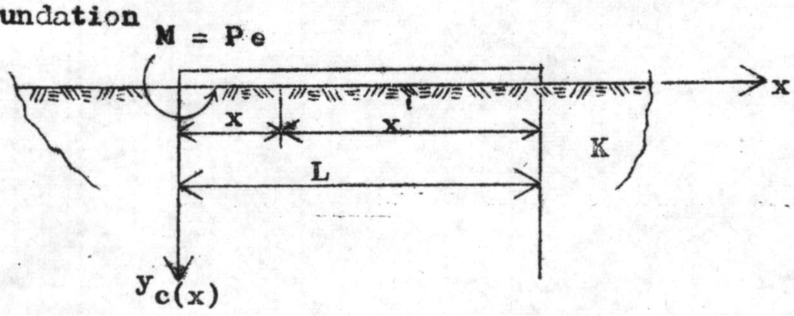


(a) A Medium Free-Headed Pile

In the following analysis, the pile is treated as a finite beam resting on the surface of a semi-infinite, ideal elastic medium as shown in Figs. A-5b and A-5c.



(b) A Finite Beam Subjected to Concentrated Load on Elastic Foundation



(c) A Finite Beam Subjected to Concentrated Moment on Elastic Foundation

Fig. A-5 - Analysis of a Medium Free-Headed Pile

Using the following symbols:

$$A(x) = e^{-\beta x}(\cos \beta x + \sin \beta x)$$

$$B(x) = e^{-\beta x}\sin \beta x$$

$$C(x) = e^{-\beta x}(\cos \beta x - \sin \beta x)$$

$$D(x) = e^{-\beta x}\cos \beta x$$

$$E_I = \frac{1}{2\left[1 - D^2(L)\right] - \left[1 + C(L)\right]\left[1 - A(L)\right]} = \frac{e^{\beta L}}{2(\sinh \beta L + \sin \beta L)}$$

$$E_{II} = \frac{1}{2\left[1 - D^2(L)\right] - \left[1 - C(L)\right]\left[1 + A(L)\right]} = \frac{e^{\beta L}}{2(\sinh \beta L - \sin \beta L)}$$

$$x' = L - x \quad .$$

The governing equation of the problem of beam on elastic foundation is

$$\frac{d^4y}{dx^4} + \frac{K\,y}{EI} = \frac{P_{(x)}}{EI} . \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (A\text{-}18)$$

General solutions of infinite beam subjected to a concentrated load (Fig. A-6) are

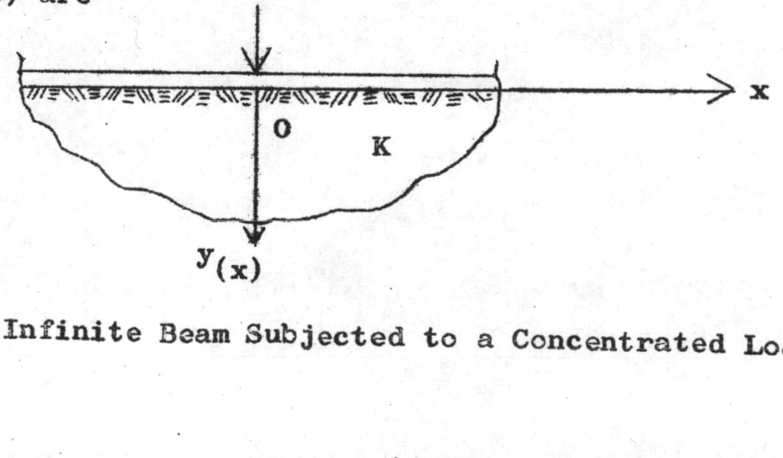


Fig. A-6 - Infinite Beam Subjected to a Concentrated Load

$$y_{(x)} = \frac{P}{8\beta^3 EI} A(x) \qquad \text{.................(A-19a)}$$

$$y'_{(x)} = \frac{-P}{4\beta^2 EI} B(x) \qquad \text{.................(A-19b)}$$

$$M_{(x)} = \frac{P}{4\beta} C(x) \qquad \text{.................(A-19c)}$$

$$D_{(x)} = \frac{-P}{2} D(x) \, . \qquad \text{.................(A-19d)}$$

General solutions of infinite beam subjected to a concentrated Moment (Fig, A-7) are

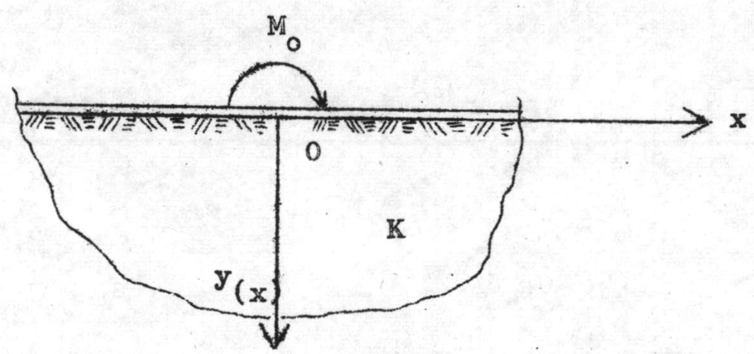


Fig. A-7 - Infinite Beam Subjected to a Concentrated Moment

$$y_{(x)} = \frac{M_o}{4\beta^2 EI} B(x) \qquad \text{.................(A-20a)}$$

$$y'_{(x)} = \frac{M_o}{4\beta EI} C(x) \qquad \text{.................(A-20b)}$$

$$M_{(x)} = \frac{M_o}{2} D(x) \qquad \text{.................(A-20c)}$$

$$V_{(x)} = \frac{-M_o\beta}{2} A(x) \, . \qquad \text{.................(A-20d)}$$

From Fig. A-5b we get

$$y_{b(x)} = \frac{P}{8\beta^3 EI} A(x) + \frac{P}{16\beta^3 EI} E_I \left\{ \left[1+C(L)\right]\left[1-A(L)\right] + 2\left[1+D(L)\right]^2 \right\} \left[A(x)+A(L-x)\right]$$

$$+ \frac{P}{16\beta^3 EI} E_{II} \left\{ \left[1-C(L)\right]\left[1+A(L)\right] + 2\left[1-D(L)\right]^2 \right\} \left[A(x)-A(L-x)\right]$$

$$\frac{-P}{4\beta^3 EI} \left\{ E_I \left[1+C(L)\right]\left[B(x)+B(L-x)\right] + E_{II}\left[1-C(L)\right]\left[B(x)-B(L-x)\right] \right\}$$

................(A-21a)

$$M_{b(x)} = \frac{P}{4\beta} C(x) + \frac{P}{8\beta} E_{II} \left\{ \left[1+C(L)\right]\left[1-A(L)\right] + 2\left[1+D(L)\right]^2 \right\} \left[C(x)+C(L-x)\right]$$

$$- \frac{P}{2\beta} E_{II} \left[1+C(L)\right]\left[D(x)+D(L-x)\right]$$

$$+ \frac{P}{8\beta} E_I \left\{ \left[1-C(L)\right]\left[1+A(L)\right] + 2\left[1-D(L)\right]^2 \right\} \left[C(x)-C(L-x)\right]$$

$$- \frac{P}{2\beta} E_I \left[1-C(L)\right]\left[D(x)-D(L-x)\right],$$ ....(A-21b)

$$y_{b(o)} = \frac{P}{8\beta^3 EI} + \frac{P}{16\beta^3 EI} E_I \left\{ \left[1+C(L)\right]\left[1-A(L)\right] + 2\left[1+D(L)\right]^2 \right\} \left[1+A(L)\right]$$

$$+ \frac{P}{16\beta^3 EI} E_{II} \left\{ \left[1-C(L)\right]\left[1+A(L)\right] + 2\left[1-D(L)\right]^2 \right\} \left[1-A(L)\right]$$

$$- \frac{P\,B(L)}{4\beta^3 EI} \left\{ E_I\left[1+C(L)\right] - E_{II}\left[1-C(L)\right] \right\}.$$ ....(A-21c)

HETÉNYI (1946) simplified these equations into the forms:

$$y_{b(x)} = \frac{2P\beta}{K} \left(\frac{\operatorname{Sinh}\beta L \cos\beta x \operatorname{Cosh}\beta x' - \sin\beta L \operatorname{Cosh}\beta x \cos\beta x'}{\operatorname{Sinh}^2\beta L - \sin^2\beta L} \right)$$

........(A-22a)

$$M_{b(x)} = \frac{-P}{\beta} \left(\frac{\operatorname{Sinh}\beta L \sin\beta x \operatorname{Sinh}\beta x' - \sin\beta L \operatorname{Sinh}\beta x \sin\beta x'}{\operatorname{Sinh}^2\beta L - \sin^2\beta L} \right)$$

.....(A-22b)

$$y_{b(o)} = \frac{2P\beta}{K}\left(\frac{\operatorname{Sinh}\beta L \operatorname{Cosh}\beta L - \sin\beta L \cos\beta L}{\operatorname{Sinh}^2\beta L - \sin^2\beta L}\right) \quad \text{........(A-22c)}$$

From Fig. A-5c, we get

$$\begin{aligned} y_{c(x)} = & \frac{-M}{4\beta^2 EI} B(x) + \frac{M}{4\beta^2 EI} E_I \left[1-A(L)\right]\left[A(x) + A(L-x)\right] \\ & \frac{-M}{8\beta^2 EI} E_I \left\{\left[1+C(L)\right]\left[1-A(L)\right] + 2\left[1-D(L)\right]^2\right\}\left[B(x)+B(L-x)\right] \\ & \frac{+M}{4\beta^2 EI} E_{II}\left[1+A(L)\right]\left[A(x)-A(L-x)\right] \\ & \frac{-M}{8\beta^2 EI} E_{II}\left\{\left[1-C(L)\right]\left[1+A(L)\right] + 2\left[1+D(L)\right]^2\right\}\left[B(x)-B(L-x)\right], \end{aligned}$$

..........(A-23a)

$$\begin{aligned} M_{c(x)} = & -\frac{M}{4}\left[D(x)+D(L-x)\right] + \frac{M}{2} E_I\left[1-A(L)\right]\left[C(x)+C(L-x)\right] \\ & -\frac{M}{4} E_I\left\{\left[1+C(L)\right]\left[1-A(L)\right] + 2\left[1-D(L)\right]^2\right\}\left[D(x)+D(L-x)\right] \\ & -\frac{M}{4}\left[D(x)-D(L-x)\right] + \frac{M}{2} E_{II}\left[1+A(L)\right]\left[C(x)-C(L-x)\right] \\ & -\frac{M}{4} E_{II}\left\{\left[1-C(L)\right]\left[1+A(L)\right] + 2\left[1+D(L)\right]^2\right\}\left[D(x)-D(L-x)\right], \quad \text{....(A-23b)} \end{aligned}$$

$$\begin{aligned} y_{c(o)} = & \frac{M}{4\beta^2 EI} E_I\left[1-A^2(L)\right] - \frac{MB(L)E_I}{8\beta^2 EI}\left\{\left[1+C(L)\right]\left[1-A(L)\right] + 2\left[1-D(L)\right]^2\right\} \\ & \frac{+M}{4\beta^2 EI} E_{II}\left[1-A^2(L)\right] + \frac{M\,B(L)}{8\beta^2 EI} E_{II}\left\{\left[1-C(L)\right]\left[1+A(L)\right] + 2\left[1+D(L)\right]^2\right\}. \end{aligned}$$

..........(A-23c)

HETÉNYI (1946) simplified these equations into the forms:

$$y_{c(x)} = \frac{-2M\beta^2}{K}\left\{\frac{\sinh\beta L(\cosh\beta x'\sin\beta x - \sinh\beta x'\cos\beta x) + \sin\beta L}{\sinh^2\beta L - \sin^2\beta L}\right.$$

$$\left.\frac{(\sinh\beta x\cos\beta x' - \cosh\beta x\sin\beta x')}{}\right\} \qquad \ldots\ldots\ldots\ldots(A\text{-}24a)$$

$$M_{c(x)} = -M\left\{\frac{\sinh\beta L(\sinh\beta x'\cos\beta x + \cosh\beta x'\sin\beta x) - \sin\beta L}{\sinh^2\beta L - \sin^2\beta L}\right.$$

$$\left.\frac{(\sinh\beta x\cos\beta x' + \cosh\beta x\sin\beta x')}{}\right\} \qquad \ldots\ldots\ldots(A\text{-}24b)$$

$$y_{c(o)} = \frac{2M\beta^2}{K}\left(\frac{\sinh^2\beta L + \sin^2\beta L}{\sinh^2\beta L - \sin^2\beta L}\right) \qquad \ldots\ldots\ldots\ldots\ldots(A\text{-}24C)$$

<u>Superpositions</u>:-

$$y_{a(x)} = y_{b(x)} + y_{c(x)}$$

$$M_{a(x)} = M_{b(x)} + M_{c(x)}$$

$$y_{a(o)} = y_o = y_{b(o)} + y_{c(o)}$$

By superposition method, we get

$$y_{a(x)} = \frac{2P\beta}{K}\left[\frac{\sinh\beta L\cos\beta x\cosh\beta x' - \sin\beta L\cosh\beta x\cos\beta x'}{\sinh^2\beta L - \sin^2\beta L}\right]$$

$$- \frac{2M\beta^2}{K}\left\{\frac{\sinh\beta L(\cosh\beta x'\sin\beta x - \sinh\beta x'\cos\beta x) + \sin\beta L}{\sinh^2\beta L - \sin^2\beta L}\right.$$

$$\left.\frac{(\sinh\beta x\cos\beta x' - \cosh\beta x\sin\beta x')}{}\right\} \qquad \ldots\ldots\ldots\ldots(A\text{-}25a)$$

$$M_{a(x)} = -\frac{P}{\beta}\left[\frac{\sinh\beta L\sin\beta x\sinh\beta x' - \sin\beta L\sinh\beta x\sin\beta x'}{\sinh^2\beta L - \sin^2\beta L}\right]$$

$$- M\left\{\frac{\sinh\beta L(\sinh\beta x'\cos\beta x + \cosh\beta x'\sin\beta x) - \sin\beta L}{\sinh^2\beta L - \sin^2\beta L}\right.$$

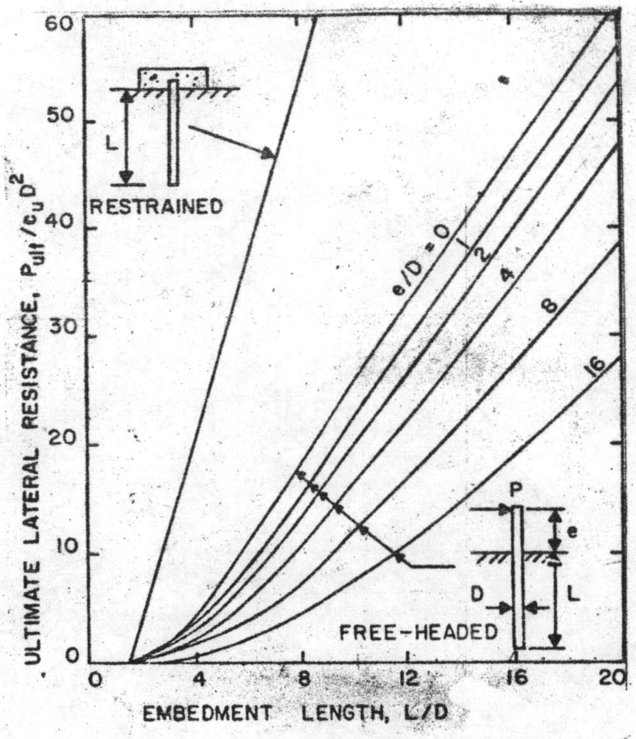
$$\left.\frac{(\sinh\beta x\cos\beta x' + \cosh\beta x\sin\beta x')}{}\right\} \qquad \ldots\ldots\ldots\ldots(A\text{-}25b)$$

$$y_o = \frac{2P\beta}{K}\left(\frac{\text{Sinh}\,\beta L\ \text{Cosh}\,\beta L - \sin\beta L\ \cos\beta L}{\text{Sinh}^2\beta L - \sin^2\beta L}\right) + \frac{2M\beta^2}{K}\left(\frac{\text{Sinh}^2\beta L + \sin^2\beta L}{\text{Sinh}^2\beta L - \sin^2\beta L}\right).$$

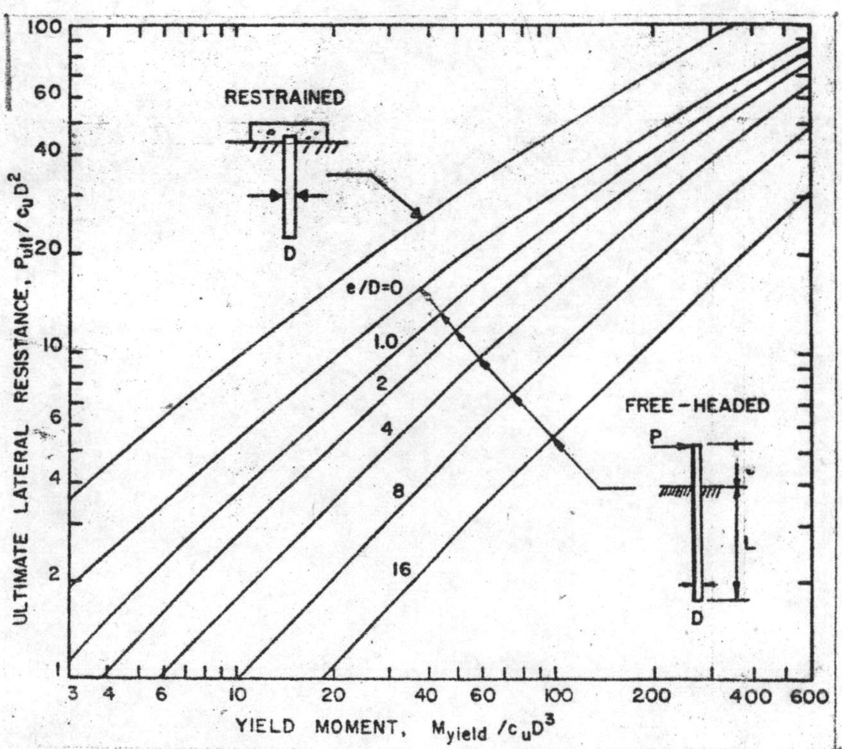
.........(A-25c)

APPENDIX B

Ultimate Lateral Resistance of Cohesive Soils



B - 1 Shert Pile (After BROMS, 1964a)



B - 2 Leng Pile (After BROMS, 1964a)

Fig. B - Cahesive Seils-Ultimate Lateral Resistance

APPENDIX C

Displacement Influence Factor for Horizontal and Moment Loads

(AFTER POULOS, 1973)

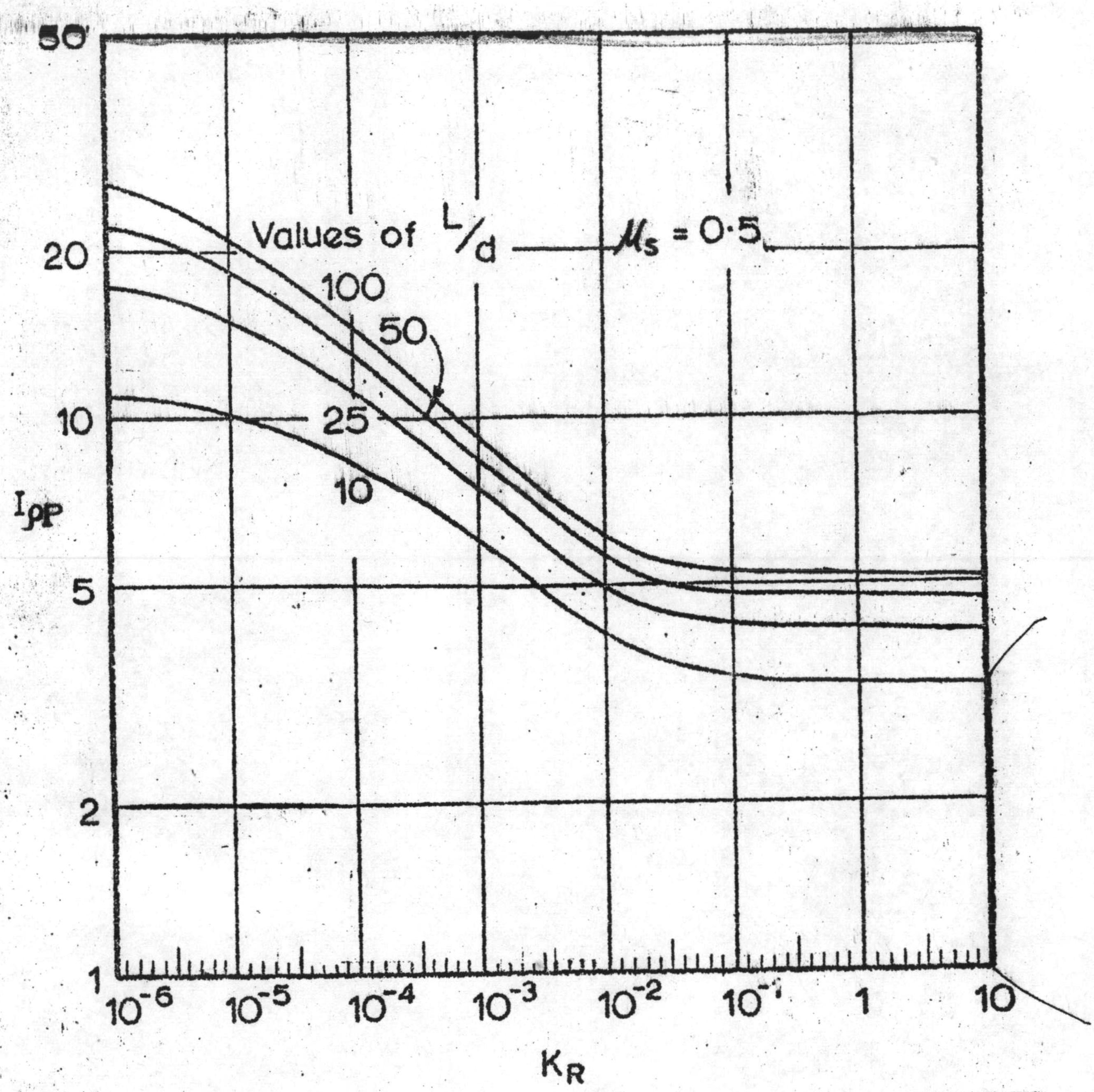


Fig. C-1 Values of $I_{\rho P}$-Free Head Pile. Constant Soil Modulus.

(AFTER POULOS, 1973)

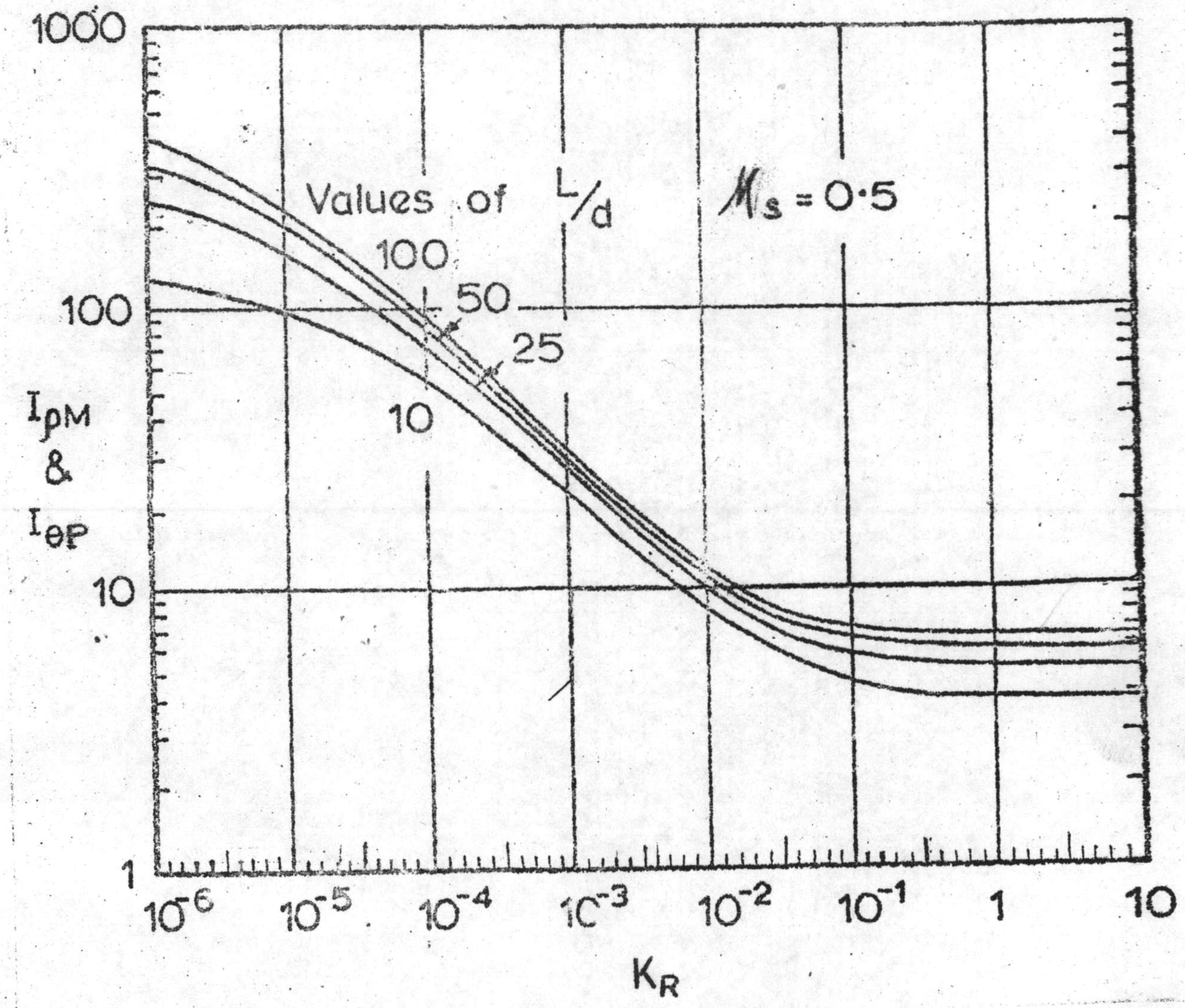
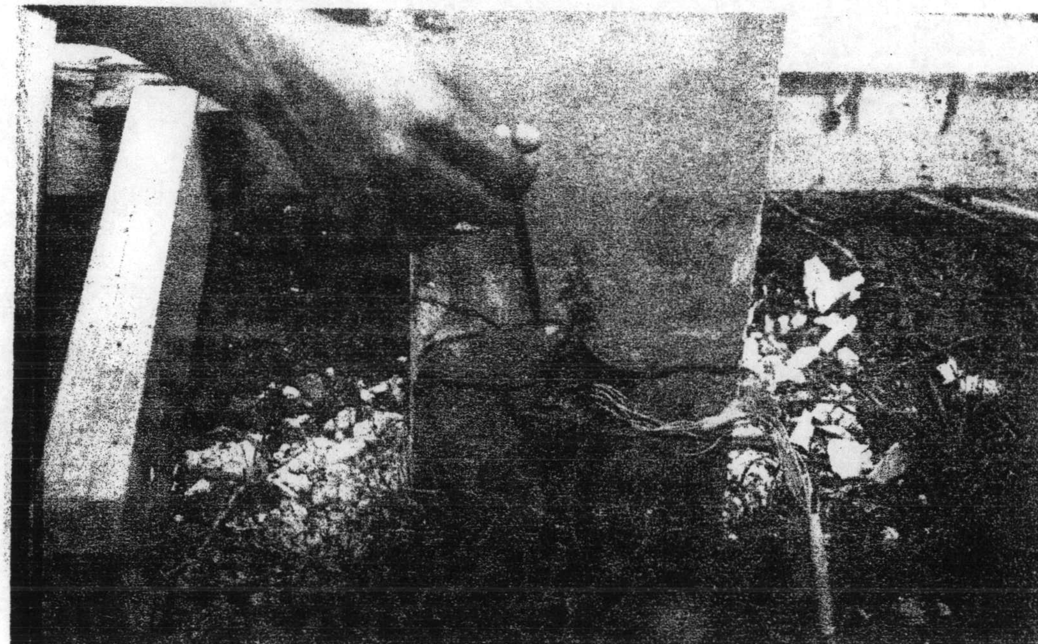


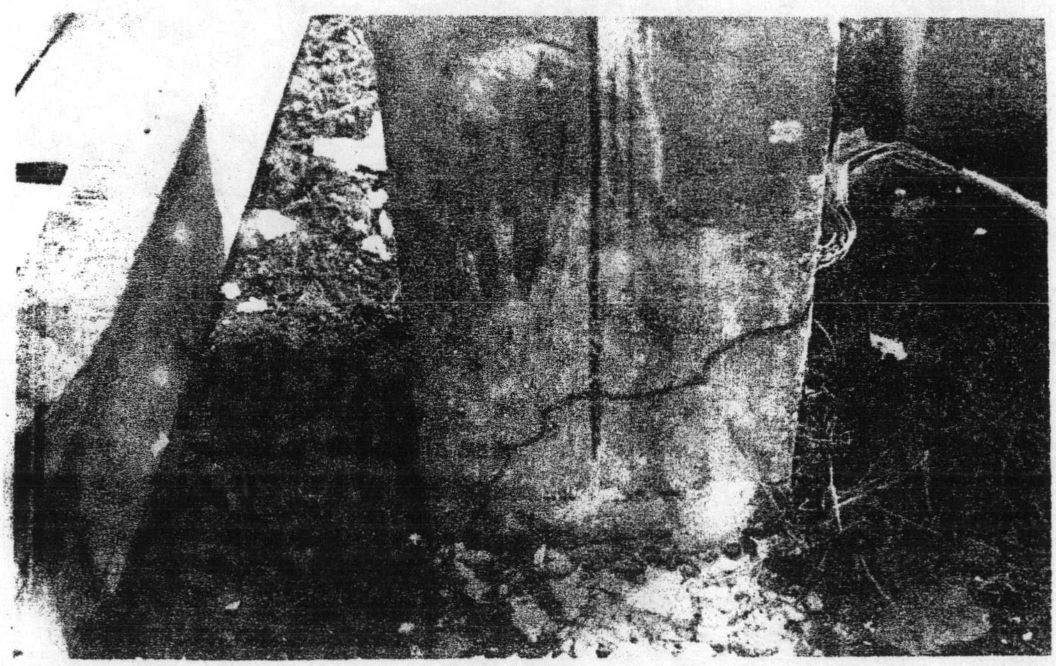
Fig. C-2 Values of $I_{\rho M}$ and $I_{\theta P}$ - Free Head Pile. Constant Soil Modulus.

APPENDIX D

Cracking Characteristic and Position of a Long Pile



(D-1) Cracking in the front of the Pile



(D-2) Cracking in the Side of the Pile

Fig. D - Showing Cracking of Pile No. 5

VITA

Mr. Suphachai Sithilertprasit

B. Eng. Khon Kaen University, 1969.

He joined the Faculty of Engineering, Khon Kaen University after graduation as a University lecturer up to now.