DSPACE

https://dspace.org/

Behaviour of a model MV pile in sand bearing capacity implications

Guy, John Evelyn

2015-01-23
http://hdl.handle.net/10539/16709

Downloaded from a DSpace repository. https://dspace.org/

For both the immediate post-installation test and the submerged sand tests, qv, the effective overburden pressure at the pile toe was about 5,0 kPa. By substituting this value into equation (7-4), the Nq values applicable to each test can be estimated as Nqa = 134 and and Nqb = 120, respectively. Triaxial tests carried out on specimens of the test sand at densities ranging from 16,4 kN/m^3 to 16,3 kN/m^3 (Figures 7.2a and 7.2b) indicated that the internal friction angle of the undisturbed soil was of the order of 38^o. For a soil with this friction angle, the Skempton et al (1953) Nq factor has a value of about Nq = 160. Although somewhat high, this agrees reasonably well with the calculated model test values given above. The Coyle and Castello (1981, p.979) Nq value for a pile installed to a depth with an L/d ratio of 12,5 in a sand with a friction angle of 38^o is about Nq = 75. Coyle and Castello's data was obtained mostly from driven pipe piles. This, and scale effects (de Beer [1963], Meyerhof [1983]) as noted above, may have contributed to the discrepancy between the model test Nq, and Coyle and Castello's empirical Nq. Meyerhof (1983) presents a method of calculating ultimate unit point resistances for piles in sand. Using this method, and various pile load test data, he defines a "reduction factor" Rb, where Rb is the ratio of observed ultimate unit point resistance, qpo, to the calculated ultimate unit point resistance, qpt. Thus:

$$Rb = qpo/qpt$$

In investigating scale effects in piles, he then presents a diagram (op. cit., Figure 4, p.802) relating the reduction factor to pile base diameter. The diagram shows that with decreasing pile base diameter the reduction factor increases. By extrapolating the data in Meyerhof's diagram to a pile toe diameter of 0,06m a reduction factor of between 1,5 and 2,0, say 1,75, can be estimated. Most of the piles used by Coyle and Castello (op.cit.) for their empirical design correlation for Nq had a toe diameter of about 0,5m. Pile base diameters of 0,5m obtain on Meyerhof's diagram a reduction factor value of 1. In order to correlate Nq from the model pile test with Coyle and Castello's proposed Nq, it is therefore suggested that the model test results should be modified by a reduction factor of 1,75. When this is applied to the previously noted model test Nq values of Nqa = 134 and Nqb = 120, the revised Nq values become Nqa = 77 and Nqb = 69.

Due to possible lateral stress relief which may have occurred when draining the sand box of water before carrying out the "drained" static load test (see Section 6.3.5), it is considered that comparison of a calculated Nq for this test with Coyle and Castello's data is not valid.

Until an improved theoretical model for calculating pile and bearing resistance is developed, it is suggested

that empirical design correlations for Nq, modified by Meyerhof's reduction factor may constitute the most reliable approach to the estimation of pile end bearing capacity. The model pile test results support this suggestion.

7.4 Comparison with Field Data

All the factors affecting the bearing capacity of the model MV pile noted in 7.2 and 7.3 cannot at this stage be compared with the bearing capacity characteristics of full-scale MV piles as no suitably instrumented tests have been carried out. A rough indication of the development of high skin friction capacities may be obtained by reference to the results of a number of pile load tests. Table 7.4 presents a summary of some load test results. The estimated quantities given in this table were obtained as follows:

1 Toe capacity in sand estimated using Coyle and Castello's (1981, Figure 6) empirical correlations for Nq and L/d.

2 Toe capacity in clay estimated from the undrained cohesion of the soil, "C", and the bearing capacity factor Nc, where Nc = 9.

Table 7.4 Summary of some MV pile test load data.

Compression tests

Locality	Durban City	Durban Bayhead 1	Durban Bayhead 2	DUBAI U.A.R.	Durban Wentworth
Shaft length m	8,7	14,1	11,5	6,0	19,5
Lateral dimensions mm	3000	2270	4000	4000	3000
Failure load kN	800	+2000	+2200	1700	1500
Estimated toe capacity kPa	1800	750	5100	8600	5300
Estimated toe load kN	127	39	651	1080	375
Estimated shaft load kN	673	+2000	+1548	620	1125
Average shaft friction kPa	82	+156	+107	82	126
Average grout pressure kPa (γd = 20 kN/m^3 γsub = 10 kN/m^3)	43,5	70,5	57,5	30	100
Estimated average shaft friction angle ($\delta = \phi$)	34°	38°	37°	40°	35°
Estimated Ks	2,8	+2,8	+2,7	3,3	1,8
Ratio of Ks/Kp	0,79	+0,67	+0,67	0,71	0,49
Average soil profile	Loose	Medium dense	Medium dense	Dense	Loose/ medium dense
Assumed average dry density of soil kN/m^3	14	15	15	16	15

3 Soil friction angles obtained from Meyerhofs (1976, Figure 2) correlation with static cone penetrometer resistance.

4 Soil densities were estimated using data from Bowles (1982 p.100), Tables 3-2 and 3-3.

For the calculation of skin friction capacities, it was assumed that the correct average overburden pressure to use was that due to the hydrostatic pressure of the grout column.

Meyerhof (1956, Figure 4) presents data relating average unit skin friction capacities of driven piles to static cone penetration resistance. Comparison of the data in Table 7.4 to Meyerhof's data indicates that the average unit skin friction capacity of MV piles is of the order of 2X to 3X that of preformed driven piles. The shaft friction stresses in Table 7.21 are similar to those given by Jelinek (1962).

On the basis of the data in table 7.4 a preliminary recommendation can be made for the design of MV piles in relatively uniform cohesionless sands. It is recommended that average shaft capacity can be estimated conservatively from the equation:

$$fs = \overline{qv}.Ks.\tan \emptyset$$

where $\overline{qv}$ is the average hydrostatic pressure of the

uncured grout column, Ks is half the possible lateral earth pressure coefficient, Kp, and Ø is the average internal friction angle of the soil obtained using the correlation diagram given by Meyerhof's (1976, p.200) Figure 2. Due to possible lateral stress relief and soil creep with time it is suggested that Ks should not exceed the proposed value. For determination of pile end bearing capacity, it is recommended that Coyle and Castellos (1981, p.979) Figure 6 be used to obtain the Nq bearing capacity factor. Meyerhof's (op.cit.) Figure 2 may also be used to estimate Ø at the pile toe. Since MV pile toe diameters typically lie within the range 0,3 to 0,5m, Nq does not need to be adjusted by a reduction factor.

7.5 Summary

1 The shaft friction capacity of the model pile has been investigated. It was found that high lateral earth pressures were developed which were close to passive lateral earth pressures at failure in a soil mass.

2 A possible explanation for the phenomenon of "arching" near the pile toe reducing the skin friction capacity in this region, was obtained. The "arching" may be due to interference of stress fields originating against the pile shaft and at the pile toe.

3 The slip-line field around the toe of the model pile does not resemble any of the conventional slip-line fields developed from limiting equilibrium principles. It is approximately similar, however, to the slip-line field developed around an expanding cavity in an elastic solid.

4 Slip on the surface of the pile may not occur on a plane of maximum stress obliquity.

5 Preliminary design recommendations for MV piles in relatively uniform cohesionless soils were made.

8 SUMMARY AND RECOMMENDATIONS FOR FURTHER WORK

8.1 Summary

An overview of piling in general with brief comments on pile design approaches has been presented along with notes on the history and details of the MV pile type. Test equipment for the installation and loading of a model MV pile in the laboratory has been described. A major feature of this equipment was the use of a semi-circular half pile installed against a glass panel which formed one side of a box containing the test sand. The equipment was used to provide a visual record of the displacement of sand particles around the model on an approximate plane of symmetry, as well as information on the response of the pile to both static and dynamic loading. Results of one of the tests have ben reported in detail and discussed.

In this test, the model pile was installed to a depth with a penetration ratio of about L/d = 12,5, and into a sand with an average dry density of 1673 kg/m^3 and a friction angle of ϕ = 38^o. Four types of load test were carried out, most of the testing being done in submerged sand. These included: (a) Measurement of impact loads during pile installation; (b) measurement of static toe load immediately following installation; (c) measurement of load distribution in the pile during

loading in submerged sand, and (d) a repeat of test (c) after draining the water from the sand box. Due to frictional contact between the half pile and the glass side of the sand box, loads measured in the pile shaft had to be corrected to obtain an estimate of the loads due to pile/soil interaction only. Draining the sand box of water prior to conducting the final load test apparently resulted in significant stress relief. Loads measured during this test are therefore thought to have little practical value.

Soil displacements were obtained using a photogrammetric technique. Measurements of the horiz and vertical displacement components at discre etration incre-ments of the pile, of a large number of individual sand grains located near the pile toe, were presented in the form of contour diagrams. The accuracy of the displace-ment measurements wa limited to about 25 microns. Contour diagrams of various soil strain components, calculated from the displacement data, have also been presented. The data suggests that there may be loss of axial symmetry conditions near the point of the pile shoe.

Analysis of the model test data leads to the following observations:

1 The "wave equation" could be used to predict pile "set", but not shaft stress or the scale of the model pile.

2 The lateral radius of the zone of soil disturbed by pile movement during both pile installation and static load testing was about 3,6 pile diameters. Disturbance below the pile toe occurred to a depth of about 4 pile diameters during pile installation, but to about 2,5 pile diameters during static loading.

3 Contours of principal strains indicated a correlation with the geometry of the pile shoe. The volumetric strain diagrams showed that in general 3 zones of similar volumetric changes can be identified around the pile toe. These include an outer compressive zone, a central dilatant zone and an inner zone of complex volume changes.

4 Unit shaft friction stresses were found to follow a triangular distribution pattern along the pile shaft. The estimated stresses indicated that high lateral earth pressures were developed against the pile shaft. The calculated lateral earth pressure coefficients approached the value of the passive lateral earth pressure coefficient. It was

suggested that the preservation of high lateral stresses was probably due to the method of pile manufacture.

5 A diagram of a possible slip-line field around the lower region of the pile was presented using calculated principal strain direction data. The proposed shear pattern differed considerably from "conventional" slip-line field patterns assumed in the determination of the Nq bearing capacity factor, but approximately resembled the pattern developed around an expanding cavity in an elastic solid. Interference of slip-lines originating at the pile shaft with slip-lines originating at the pile toe was observed. Slip on the pile surface may not occur on a plane of maximum stress obliquity.

6 A preliminary design method for MV piles was proposed on the basis of the model test results and selected field test data.

8.2 Recommendations for Further Work

Despite the known limitations of model tests, it is believed that further investigations of a similar type to that described here would prove worthwhile. A minimum supplement to the work reported here would

be to install the same pile into the same sand at a depth given by an embedment ratio of about L/d = 20. Further, in order to obtain more accurate data on the load distribution down the pile shaft, it is suggested that for each half pile test a complementary and duplicate circular pile test be conducted in the centre of a proportionately larger sand box. It has been shown that when the water was drained from the sand box stress relief occurred in the soil influencing the pile load capacity. This method of attempting to investigate the pile capacity at greater confining pressures is therefore to be discouraged. A more efficient method of measuring sand grain displacements needs to be developed in order to improve the resolution of displacement measurements in areas of high displacement gradients.

9 REFERENCES

A.S.C.E. (1941) Pile Driving Formulas. Progress report of the Committee on the bearing capacity of pile foundation. Proceedings American Society of Civil Engineers, vol.67, no.5, (May), pp.853-866.

A.S.C.E. (1946) Pile Foundations and Pile Structures. American Society of Civil Engineers Manual of Practice, no.27, 72pgs, (reprinted 1959).

A.S.C.E. (1975) In-Situ Measurement of Soil Properties. Speciality Conference, Geotechnical Engineering Division, American Society of Civil Engineers, Raleigh, N.C., June 1975.

A.S.C.E. (1981) Cone Penetration Testing and Experience. Proceedings Session, Geotechnical Engineering Division, American Society of Civil Engineers, National Convention, St. Louis, Missouri. October 26-30, 1981, eds. Morris G.M. and Holtz R.D.

Acar, Y.B. and Tumay, M.T. (1986) Strain Field Around Cones in Steady Penetration. Proceedings American Society of Civil Engineers, Journal Geotechnical Engineering Division, vol.112, no.2 (February), pp.207-213.

Acker, W.L. III, (1974) Basic Procedures for Soil Sampling and Core Drilling. Distributed by Acker Drill Co. Inc., Seronton, Pa., USA.

Andrawes, K.Z. (1976) The use of stereo-photogrammetry for measuring displacement fields. A report submitted to the U.K. Science Research Council, February 1976.

Arthur, J.R.F., Dunstan, T., A-Ani, Q.A.J.L., Assadi, A. (1977) Plastic deformation and failure in granular media. Geotechnique, vol.27, no.1, March 1977, pp.53-74.

Arthur, J.R.F., Chua, K.S. Dunstan, T., Rodriguez del C., J.I. (1980) Principal stress rotation : a missing parameter. American Society of Civil Engineers, Journal of the Geotechnical Engineering Division, vol.106, no.GT4, April, pp.419-433.

Arthur, J.R.F. and Roscoe, K.H. (1965) An examination of the edge effects in plane-strain model earth pressure tests. Proceedings 6th International Conference Soil Mechanics and Foundation Engineering, Montreal vol.2, pp.363-367.

Atkinson, J.H., and Bransby, P.L. (1978) The mechanics of soils - An introduction to Critical State soil mechanics. University series in Civil Engineering, McGraw-Hill Book Company (U.K.) Ltd., Berkshire, England.

Azzouz, A.S. and Lutz, D.G. (1986) Shaft Behaviour of a Model Pile in Plastic Empire Clays. Proceedings American Society of Civil Engineers, Journal Geotechnical Engineering Division, vol.112, no.4 (April), pp.389-406.

B.S.I. (1981) Code of Practice for Site Investigations, BS 5930. British Standards Institute, London.

Baligh, M.M. (1985) Strain Path Method. Proceedings American Society of Civil Engineers, Journal Geotechnical Engineering Division, vol.111, no.9 (September), pp.1108-1136.

Baligh, M.M. and Levadoux, J.-N. (1986) Consolidation after Undrained Piezocone Penetration. II : Interpretation. Proceedings American Society of Civil Engineers, Journal Geotechnical Engineering Division, vol.112, no.7, (July), pp.727-745.

Bassett, R.H. (1980) General Reporter. Session 9 : The Use of Physical Models in Design. Proceedings VIIth European Conference, Geotechnical Engineering. "Design Parameters in Geotechnical Engineering". Brighton, England (September), 4, pp.315-326.

Bazant, Z. (1979) Methods of Foundation Engineering. Developments in Geotechnical Engineering, 24, Elsevier Scientific Publishing Company, Amsterdam, N.Y.

Begemann, H.K.S. Ph. (1965) The Friction Jacket Cone as an Aid in Determining the Soil Profile. Proceedings 6th International Conference Soil Mechanics and Foundation Engineering (Montreal), 1, pp.17-20.

Bennett, D.H., and Gisbourne, R. (1971) The penetration resistance of dry sand. In "Stress/Strain Behaviour of Soils". Roscoe Memorial Symposium, Cambridge University, March 1971.

Bieganousky, W.A., and Marcuson, W.F. (1976) Uniform placement of sand. Journal of Geotechnical Engineering Division, Proceedings American Society of Civil Engineers, 102, no. GT-3, (March), pp.229-234.

Bowles, J.E. (1974) Analytical and Computer Methods in Foundation Engineering. McGraw-Hill Inc., U.S.A. ISBN 0-07-006753-8.

Bowles, J.E. (1977) Foundation Analysis and Design. 2nd ed. International Student Edition. McGraw-Hill Kogakusha Limited, Tokyo.

Bowles, J.E. (1982) Foundation Analysis and Design. 3rd ed. International Student Edition. McGraw-Hill Kogakusha Limited, Tokyo.

Braatvedt, I.H. (1980) Introductory Address to Piling Panorama 1980. Piling Panorama (1980), Concrete Society of South Africa, March 1980, Johannesburg.

Bredenburg, H. (1981) Editor. Applications of Stress-Wave Theory on Piles. Proceedings International Seminar on Application of Stress-Wave Theory on Piles, Stockholm, June 1980. A.A. Balkema, Rotterdam (1981).

Bridgmann, P.W. (1931) Dimensional Analysis. Yale University Press, Connecticut, USA.

Brink, A.B.A., Partridge, T.C. and Williams, A.A.B. (1982) Soil Survey for Engineering. Clarendon Press, Oxford.

Buckingham, E. (1914) On Physically Similar Systems. Physics Review, vol.4, no.3, pp.354-376.

Buckingham, E. (1915) Model Experiments and the Forms of Empirical Equations. Transactions American Society of Mechanical Engineers, vol.37, no.2, pp.263-285.

Butterfield, R., and Andrawes, R.Z. (1978) An air activated sand spreader for forming uniform sand beds. Geotechnique 28, 3, pp.97-100. (Technical Notes)

Butterfield, R., Harkness, R.N., and Andrawes, K.Z. (1970) A stereophotogrammetric method for measuring displacement fields. Geotechnique, 20, no.3, pp.308-314.

Butterfield, R., Harkness, R.N. and Andrawes, K.Z. (1972) A note on the measurement of planar velocity fields by stereophotogrammetry. International Journal of Hydraulic Research. Dâft, vol.10, no.1, pp.15-26.

Chellis, R.D. (1961) Pile Foundations. Foundation Engineering. McGraw-Hill Book Company Inc., New York.

Chong, C.V.Y. (1977) Properties of materials. The M & E Handbook Series, MacDonald and Evans, Plymouth, U.K.

Clemence, S.P. and Brumund, W.F. (1975) Large Scale Model Test of Drilled Pier in Sand. Proceedings A.S.C.E., Journal Geotechnical Engineering Division, 101, GT6, (June), pp.537-550.

Clough, R.W. (1965) The finite element in structural mechanics in "Stress Analysis". Publishers: John Wiley and Sons Limited, Chichester, U.K.

Coyle, H.M. and Castello, R.R. (1981) New Design Correlations for Piles in Sand. Proceedings A.S.C.E., Journal Geotechnical Engineering Division, 107, no.GT7 (July), pp.965-986.

Cummings, A.E. (1940) Dynamic Pile Driving Formulas. Journal Boston Society of Civil Engineers, vol.27, no.1 (January), pp.6-27.

Cumming, J.D. (1956) Diamond Drill Handbook. J.K. Smit and Sons, Colwyn Bay, U.K.

Dally, J.W., and Riley, W.F. (1965) Experimental Stress Analysis. McGraw-Hill International Book Company, Tokyo.

Das, B.M. and Seeley, G.R. (1976) Uplift Capacity of Model Piles Under Oblique Loads. Proceedings A.S.C.E., Journal Geotechnical Engineering Division, 102, GT9, (September), pp.1009-1013.

Davis, H.E., and Woodward, R.J. (1949) Some laboratory studies of factors pertaining to the bearing capacity of soils. Proceedings of the Highway Research Board, vol.29, pp.467-476.

De Beer, E.E. (1963) The Scale Effect in the Transposition of the Results of Deep Sounding Tests on the Ultimate Bearing Capacity of Piles and Caisson Foundations. Geotechnique, 13, no.1, (March), pp.39-75.

De Beer, E.E. (1965) The Scale Effect on the Phenomenon of Progressive Rupture in Cohesionless Soils. Proceedings 6th International Conference Soil Mechanics and Foundation Engineering. 3/3, vol.II, pp.13-17. Montreal, Canada.

E.A.U. (1975) Emphelungen des Arbeitsausschusses Ufereinfassungen. (EAU) 1975/hrsg, vom, Arbeitsansschuss "Ufereinfasungen" d. Hafenbautechn. Ges. e.v.u.d. Dt. Ges. fur Erdu. Grundbau, e.v. 5 Aufl. W. Ernst, Berlin, Munchen, Dusseldorf, 1976. ISBN 3-433-00717-9.

E.S.O.P.T. (1974 +) Conference Proceedings. European Society on Penetration Testing.

Forehand, P.W. and Reese, J.L. Jr. (1964). Prediction of Pile Capacity by the Wave Equation. Journal Soil Mechanics and Foundation Division, Proceedings American Society of Civil Engineers, SM2, (March), pp.1-25.

Forster, K. (1956) Anwendung von MV-Pfahlen im Hamburger Hafen. Baumaschine und Bautechnik, 7. Jahrgang, Heft 5, (May).

Gerber, E. (1929) Untersuchungen ueber die Druckverteilung im Oertlich Belasten ten Sand. Dissertation, Technische Hochschule, Zurich.

Gieck, K. (1982) A collection of technical formulae. 5th ed. Publishers, Gieck-Verlag, Heilbronn/N, West Germany.

Glanville, W.H., Grime, G., Fox, E.N. and Davies, W.W. (1938) An Investigation of the Stresses in Reinforced Concrete Piles During Driving. British Building, Research Station, Technical Paper no.20.

Goble, G.G., Kovacs, W.D., and Rausche, F. (1972) Field demonstration : Response of instrumented piles to driving and testing. Proceedings American Society of Civil Engineers. Speciality Conference on "Performance of Earth and Earth-supported Structures". Purdue University, Indiana. (June), vol. 2 , pp.3-38.

Goble, G.G., Likens, Jr. G and Rausche, F. (1975) Bearing Capacity of Piles from Dynamic Measurements. Final Report, Department of Civil Engineering, Case Western Reserve University, March 1975.

Goble, G.G., Rausche, F. and Likins, Jr. G.E. (1980) The Analysis of Pile Driving - A State-of-the-Art. In Proceedings International Seminar on the "Application of Stress-Wave Theory on Piles". Stockholm, 4-5 June 1980, ed. H. Bredenburg. Publisher: A.A. Balkema, Rotterdam, 1981.

Grundbau Taschenbuch (1966) Grundbau Taschenbuch, vol.1, 2nd ed, 1966. Verlag von Wilhelm Ernst & Sohn, Berlin, Munchen.

Hanna, T.H. and Tan, R.J.S. (1973) The Behaviour of Long Piles Under Compressive Loads in Sands. Canadian Geotechnical Journal, 10, no.3, (August), p.311-340.

Hammond, R. (1967) Modern Foundation Methods. MacLaren & Sons Limited, London.

Handford, S.A. (1951) The Conquest of Gaul. Translation of "De Bello Gallico IV-2" Caesar.

Hecht, F. (1961) Moderner Ausbau des Hafens Köln-Niehl 1. Schift und Hafen, Jahrgang 13, Heft 14, April.

Hunter, A.H., and Davisson, M.T. (1969) Measurements of pile load transfer. Performance of Deep Foundations. ASTM STP 444. American Society. Testing and Materials, pp.106-117.

Hvorslev, M.J. (1949) Subsurface Exploration and Sampling of Soils for Civil Engineering Purposes. Report by Committee on Sampling and Testing. Soil Mechanics and Foundations Division, American Society of Civil Engineering, United Engineering Centre, New York, USA.

Isaacs, D.V. (1931) Reinforced Concrete Pile Formulae. Transactions of the Institution of Engineers, Australia, vol.XII, pp.305-323.

Jelinek, L. (1962) Tragfahigkeit von MV und SBV - Pfahlen. Contract report by Prof. Dr-Ing R. Jelinek, Direktor de Institutes f. Grundbau u. Bodenmechanik an der Technischen Hochschule München.

Jelinek, R. and Ostermayer, H. (1964) Zur Tragfähigkeit von Zugpfahlen Rechnerische Grenzbetastung und Versuchsergebnisse bei MV-Phählen. Felsmechanik und Ingenieur geologie, vol.II/1.

Jennings, J.E., Brink, A.B.A. and Williams, A.A.B. (1973) Revised guide to soil profiling for civil engineering purposes in Southern Africa. Civil Engineering in South Africa, 15, no.1, January, pp.3-12.

Jeske, G. and Hamann, A. (1962) Das Stutzbouwerk Rognitzstrasse im Zuge der Stadtautobahn Berlin. Baumaschine und Bautechnik, Jahrgang 9, Heft 6, June.

Joyce, M.D. (1982) Site Investigation Practice. E. & F.N. Spon Ltd, London.

Kerisel, J. (1961) Foundations profondes en milieu sableux. Proceedings 5th International Conference Soil Mechanics and Foundation Engineering, Paris, vol.2, pp.73-83.

Kerisel, J. (1964) Deep foundations, basic experimental facts. Conference on Deep Foundations. Mexican Society for Soil Mechanics, Mexico, 1, pp.5-44.

Kezdi, A. (1975) Pile Foundations in "Foundation Engineering Handbook", eds. Winterkorn, H.F. and Fang, H.Y. (1975), pp.556-600. Van Nostrand Reinhold Company, New York.

Kiessling, G. (1960) Gründung des Absetzbelkens der Klaranlage Bonn. Baumaschine und Bautechnik, May 1960, Heft 5.

Knabe, W. (1971) An experimental study of bearing capacity of strip foundation on sand supported by short friction piles. Archiwum Hydrotechniki, 18, no.2, pp.185-209.

Köhling, E. (1962) Der Bau einer Tiefstrasse swischen sichtbar ver bleibenden stahlspondwonder. Baumaschine und Bautechnik, Jahrgang 9, Heft 10, October, Seite 425 ff.

Kulhawy, F.H., Kozeras, D.W. and Withian, J.L. (1979) Uplift testing of model drilled shafts in sand. American Society of Civil Engineers, Journal Geotechnical Engineering Division, GT1 (January), pp.31-47.

Langhaar, H.L. (1951) Dimensional Analysis and Theory of Models. John Wiley and Sons, New York.

Larssen-Handbuch (1960) Larssen-Handbuch. Dortmund-Hoerder, Huttenunion, Artiengesellschaft, Dortmund.

Lee, I.K., Ingles, O.C. and White, W. (1983) Geotechnical Engineering. Pitman Publishing Inc., Massachusetts, USA.

Levadoux, J.-M. and Baligh, M.M. (1986) Consolidation after undrained piezocone penetration. I : Prediction. Proceedings American Society of Civil Engineers, Journal Geotechnical Engineering Division, vol.112, no.7, (July), pp.707-726.

Little, A.L. (1961) Foundations. Edward Arnold (Publishers) Limited, London.

Lowery, L.L. Jr., Edwards, T.C. and Hirsch, T.J. (1968) Use of the move equation to predict soil resistance on a pile during driving. Texas Transportation Institute, Research Report 33-10, August 1968.

Luker, I. (1984) The use of stereophotogrammetry to measure movements. Transactions of the S.A.I.C.E. The Civil Engineer in South Africa, vol.26, no.8, (August), pp.371-381.

Maddocks, D.V. (1978) The behaviour of model ground anchors installed in sand and subjected to pull-out and repeated loading. Ph.D. thesis, University of Bristol, England.

Mansur, C.I., and Kaufman, J.M. (1956) Pile tests, bow-sill structure, Old River, Louisiana. Proceedings American Society of Civil Engineers, Journal of Soil Mechanics and Foundations Division, 123, Prac. Paper 1079.

Mazurkiewicz, B.K. (1968). Skin friction on model piles in sand. Danish Geotechnical Institute, Copenhagen, Denmark. Bulletin no.25, pp.13-47.

Menard, L. (1975) The interpretation of pressuremeter test results. Sols-Soils, 7, no.26, pp.7-43.

Meterhof, G.G. (1959) Compaction of sands and bearing capacity of piles. Proceedings American Society of Civil Engineers, Soil Mechanics and Foundation Engineering Division, vol.85, no.SM6, pp.1-29.

Meterhof, G.G. (1983) Scale effects of ultimate pile capacity. Journal Geotechnical Engineering, vol.109, no.6, (June), pp.797-806.

Meyerhof, G.G. (1956) Penetration tests and bearing capacity of cohesionless soils. Journal Soil Mechanics and Foundations Division, Proceedings American Society of Civil Engineers, 82, SM-1, pp.866-885.

Meyerhof, G.G. (1976) Bearing capacity and settlement of pile foundations. Journal Geotechnical Engineering Division, American Society of Civil Engineers, GT-3, 102, pp.197-228. (11th Terzaghi Lecture.)

Michigan State Highway Commission (1965) A performance investigation of pile driving hammers and piles. Lansing, Michigan, 338p.

Müller, A. (1961) Der MV-Pfahl. Schweizerische Bauseitung, vol.79, Heft 33, pp.577-580.

Müller, A. (1965) Pieux d'ancrage systeme MV. "L'Enterprise" Revue Suisse des Entrepreneurs et des Maitres Charpentiers, Zurich, no.47, du 19 November 1965. Buchdruckerei a/d Sihl AG, Zurich.

Olson, R.E. and Flaate, K.S. (1967) Pile driving formulas for friction piles in sand. Journal Soil Mechanics and Foundations Division, Proceedings American Society of Civil Engineers, SM-6, Paper no.5604, pp.279-296.

O'Neill, M.W. (1983) Side load transfer in driven and drilled piles. Journal Geotechnical Engineering, vol. 109, no.10, (October), pp.1259-1266. Auger Piles, P-Augered, P-Bored, P-Driven Dispt, P-Load Transfer, P-Precast, P-Skin Friction, Skin Friction, Stress-Hand P, Stress Distribution P.

O'Neill, M.W., Hawkins, R.A., and Mahar, L.J. (1982) Load transfer mechanisms in piles and pile groups. Proceedings American Society of Civil Engineers. Journal Geotechnical Engineering Division, vol.108, no.GT12, (December), pp.1605-1623.

Ormondroyd, J., Allnutt, R.B., Mintz, F., and Specht, R.D. (1957) Motion Measurements in Hetenyi, M., (1950). See cp8, pp.301-339.

Peck, R.B. (1942) Discussion on "Pile driving Formulas". Proceedings American Society of Civil Engineers, 68, no.2, (February), pp.323-324.

Peck, R.B., Hansen, W.E. and Thorburn, T.H. (1974) Foundation Engineering. John Wiley, New York, USA.

Peekel, C.H.R. (1971) Do we measure strain when we measure strain? Automation Industries, B.V., Peckel Division, Rotterdam, Holland.

Poulos, H.G. and Davis, E.H. (1980) Pile Foundation Analysis and Design. John Wiley and Sons, New York.

Przedecki, T. (1975) Model test of a pile driven into a cohesionless medium. Proceedings 1st Baltic Conference, Soil Mechanics and Foundation Engineering, September 1975, Gdansk, Poland, vol.3, Section III, p.165-173.

Ralston, A., and Rabinowitz, P. (1978) A first course in numerical analysis. International student edition. McGraw-Hill Kogakusha Limited, Tokyo.

Ramey, G.E. and Hudgins, A.P. (1977) Sensitivity and accuracy of the pile wave equation. Ground Engineering, 10. no.7, pp.45-47 (October).

Rausche, F., Moses, F. and Goble, G.G. (1972) Soil resistance predictions from pile dynamics. American Society of Civil Engineers, Journal Soil Mechanics and Foundations Division, 98, SM9, (September), Paper no.9220, pp.917-413.

Robinsky, E.I. and Morrison, C.F. (1964) Sand displacement and compaction around model friction piles. Canadian Geotechnical Journal, 1, no.2, (March), pp.81-93.

Robinsky, E.I., Sagar, W.L. and Morrison C.F. (1964) Effect of shape and volume on the capacity of model piles in sand. Canadian Geotechnical Journal, 1, no.4, (November), pp.189-204.

Roscoe, K.H. (1970) The influence of strains in Soil Mechanics. Geotechnique, Vol. 20, No. 2, pp.129-170.

Roscoe, K.H., Arthur, J.R.F., and James, R.G. (1963) Strains in soils by an X-ray method : Part I. Civil Engineering and Public Works. Review, vol.58, no.684, (July), pp.873-876.

Roscoe, K.H., Arthur, J.R.F., and James, R.G. (1963) Strains in soils by an X-ray method : Part II. Civil Engineering and Public Works. Review, vol.58, no.685, (August), pp.1009-1012.

SABS 088 (1972) Code of Practice for Pile Foundations. South African Bureau of Standards, Pretoria.

Samson, C.H., Hirsch, T.J., and Lowery, L.L. (1963) Computer study of dynamic behaviour of piling. Journal of Struct. Division, Proceedings American Society of Civil Engineers, ST4, (August), Paper no.3608, pp.413-449.

Sanglerat, G. (1972) The Penetrometer and Soil Exploration. Developments in Geotechnical Engineering, vol.1. Elsevier Publishing Company, Amsterdam.

Sanglerat, G. (1979) The Penetrometer and Soil Exploration. Developments in Geotechnical Engineering, vol.1, 2nd ed. Elsevier Scientific Publishing Company, Amsterdam.

Scott, C.R. (1974) An Introduction to Soil Mechanics and Foundations. 2nd ed. Applied Science Publishing Limited, Essex, England. (First published in 1969.)

Scott, C.R. (1980) An Introduction to Soil Mechanics and Foundations. 3rd ed. Applied Science Publishers Limited, London.

Sheingold, D.H. (1980) "Transducer Interfacing Handbook". Analog Devices Inc., Norwood, Massachusetts, USA.

Simons, N.E. and Menzies, B.K. (1975) A Short Course in Foundation Engineering. IPC Science and Technology Press. 2nd impression and revision 1976. Reprinted 1977.

Skempton, A.W., Yassim, A.A., and Gibson, R.E. (1953) Theorie de la force portante des pieux. Annales de l'Institut Technique du Bâtiment et des Travanx Publics, vol.6, no.63-64, pp.285-290.

Smith E.A.L. (1955) Impact and longitudinal wave transmission. Transactions American Society of Mechanical Engineers, (August), pp.963-973.

Smith, E.A.L. (1960) Pile-driving analysis by the wave equation. Journal Soil Mechanics and Foundations Division, Proceedings American Society of Civil Engineers, SM-4, (August), Paper no.2574, pp.35-61.

Smith, G.N. (1971) An Introduction to Matrix and Finite Element Methods in Civil Engineering. Applied Science Publishers Limited, London.

Smith, G.N. and Pole, E.L. (1980) Elements of Foundation Design. Granada Publishing Limited, Technical Books Division, London.

Spencer, J.R. (1965), Ed. Treatise on Architecture; being the treatise by Antonio di Piero Averlino, known as Filarete. Published in Florence between 1461 and 1464 for Piero de Medici. Translated with introduction and notes by John R. Spence, New Haven, Yale University Press, Yale Publications, in the History of Art, No. 16.

Tavenas, F.A. and Audibert, J.M.E. (1977) Application of the wave equation analysis to friction piles in sand. Canadian Geotechnical Journal (CDN), vol.14, no.1, February 1977, pp.34-51.

Tayl D.W. (1948) Fundamentals of Soil Mechanics. John Wiley and Sons Inc., New York.

Tejchman, A. (1971) Skin friction of a model pile driven in sand. Bull. Geotekn. Institute, Copenhagen, no.29, p.5-26.

Tejchman, A. (1971) Point resistance of a model pile driven in sand. Bull. Geotekn. Institute, Copenhagen, no.29, p.27-37.

Terzaghi, K. (1943) Theoretical Soil Mechanics. John Wiley, New York, USA.

Terzaghi, K. and Peck, R.B. (1967) Soil Mechanics in Engineering Practice. 2nd ed, Wiley International Edition, John Wiley and Sons, Inc., New York.

Tomlinson, M.J. (1963) Foundation Design and Construction. Pitman Publishing Company SA (Pty) Ltd, Johannesburg. 2nd ed. (1969), 3rd ed. (1975).

Tomlinson, M.J. (1977) Pile Design and Construction Practice. Cement and Concrete Association, Viewpoint Publications, 52 Grosvenor Gardens, London SW1W OAQ.

Tumay, M.T., Acar, Y.B., Cekirge, M.H. and Ramesh, N. (1985) Flow field around Cones in steady penetration. Proceedings Americal Society of Civil Engineers, Journal Geotechnical Engineering Division, vol.III, no.2, (February), pp.193-204.

Van der Veen, C. and Boersma, L. (1957) The bearing capacity of a pile predetermined by a cone penetration test. International Conference on Soil Mechanics and Foundation Engineering, 3b/15, pp.72-75.

Vaughan, J. (1975) Application of B & K equipment to Strain Measurements. Publishers: Brüel and Kjaer.

Vesic, A. (1963) Bearing capacity of deep foundations in sand. National Academy of Sciences, National Research Council, Highway Research, Record 38, pp.112-153.

Vesic, A.S. (1964) Model testing of deep foundations and scaling laws. Proceedings Conference on Deep Foundations, Mexican Society of Soil Mechanics, vol.II, Mexico City, Mexico, pp.525-533.

Vesic, A.S. (1965) Ultimate loads and settlements of deep foundations in sand. Proceedings Symposium on "Bearing Capacity and Settlement of Foundations", April 1965, held at Duke University, Durham, M.C., p.53-68.

Vesic, A.S. (1967) A study of bearing capacity of deep foundations. Georgia Institute of Technology, Atlanta, Ga. (March), Project B-189, Final Report Engineering Export Station.

Vesic, A.S. (1970) Tests on instrumented piles, Ogeechee River Site. Journal Soil Mechanics and Foundation Engineering, American Society of Civil Engineers, SM-2, (March), pp.561-584, Paper no.1170.

Vesic, A.S. (1977) Design of Pile Foundations. Report for : Transportation Research Board, National Research Council, USA, Synthesis of Highway Practice, no.42.

Walker, B.P., and Whitaker, T. (1967) An apparatus for forming uniform beds of sand for model foundation tests. Geotechnique, vol.17, no.2, (June), pp.161-167

Wild Heerbrugg (1957) Wild A7 Autograph. Operating instructions. Publishers: Wild Heerbrugg Ltd, Heerbrugg, Switzerland.

Wood, D.M. (1981), Discussion of Arthur et al (1980). American Society of Civil Engineers, Journal of the Geotechnical Engineering Division, vol.107, no.GT5, May, pp.704-707.

APPENDIX A

A.1 Measurement of Grain Displacements

The principles of the method used for measuring the displacements of the sand particles around the model MV pile have been given in section 4.7. This appendix provides further details of the method.

The reference grid drawn onto the external face of the glass panel of the sandbox (see Figures 4.2 and 4.9), was 270mm square with grid lines at 30mm intervals dividing the region around the pile toe into 81 squares. Letraset members were placed at the intersection of the grid lines. When viewed in the stereoplotter, certain positions on these numbers were selected as stationary control points to which the displaced sand could be referred (see Figure A.2). The camera used to record the sand patterns around the model pile was a Super Cambo III with a Voigtlander Braunschweig Apu-Skopa 1:9/21cm lens. An extension was added to the rear of the camera to enable it to accept 230 X 240mm sheets of Kodak Plus X film. The model pile and surrounding soil, were illuminated during exposure of the film, by two flash units placed either side of the camera lens and inclined at 45° to the camera axis. The entire area lying between the horizontal bracing supporting the glass panel of the sand box and between the pile axis

and the side of the sand box (see Figure 4.2), some 340mm x 232mm, was recorded on the plate film.

The Butterfield et al (1970) stereophotogrammetric method for measuring planar displacement fields, requires stereo superposition of photo-pairs to express the displacements as height in the stereo image. Where the trajectory of the soil displacement has components of movement along both the x and y axes of the stereo plotter, corrections discussed by Luker (1984) may have to be applied if removal of, for example, the y parallax, interferes with measurement of the x parallxx.

The method used here, however, does not rely on stereo superposition of the photo-pairs. Instead the Wild A7 Autograph (Wild Heerburgg [1957]) was used simply as a rather sophisticated optical micrometer to measure the co-ordinates of the control points and selected sand grains in each photograph. (The technique was originally applied by Roscoe et al [1963a] who used an "Orthogonal displacement meter" to obtain displacement components on X-ray plates of discrete lead shot markers embedded in the test soil.) Accordingly both left and right plotter cameras of the Wild A7 Autograph were given the same bz, omega and phi settings which remained fixed throughout the series of measurements (see Figure A.1). For convenience the settings selected were the so-called "normal" settings of 100mm, 100 grads and

100 grads respectively. In this position, the picture carriers lie in the same orientation and elevation above, and parallel to, the plane of the x and y carriages. The z axis was nominally set at 300mm, and the focal lengths of the plotting cameras, at 200mm. These settings also remained constant during the measurements, as did the settings of the X and Y carriage counters.

The first exposure in the sequence of photographs (e.g. Plate 1 Dyn) was placed emulsion side down in the left hand plotting camera with the toe of the pile pointing towards the observer so that the axis of the pile was parallel to the axis of the y carriage. The next photograph was placed in a similar position in the right hand plotting camera. Coarse misalignments between the orientation of the photographs as placed in the left and right plotting cameras were removed by applying b'x, b'y and kappa adjustments. Then using the X and Y carriages only and working square by square through the reference grid, the co-ordinates of the 4 control points defining each square were measured a minimum of 3 times, while between 15 and 36 selected sand grains were co-ordinated, once each in both photographs. Control points common to adjacent squares in the reference grid were co-ordinated up to 12 times in this way and about 25 co-ordinate pairs were typically obtained for each square measured on each photograph. All data was

Author Guy John Evelyn
Name of thesis Behaviour Of A Model Mv Pile In Sand Bearing Capacity Implications. 1987

PUBLISHER:

University of the Witwatersrand, Johannesburg
©2013

LEGAL NOTICES:

Copyright Notice: All materials on the University of the Witwatersrand, Johannesburg Library website are protected by South African copyright law and may not be distributed, transmitted, displayed, or otherwise published in any format, without the prior written permission of the copyright owner.

Disclaimer and Terms of Use: Provided that you maintain all copyright and other notices contained therein, you may download material (one machine readable copy and one print copy per page) for your personal and/or educational non-commercial use only.

The University of the Witwatersrand, Johannesburg, is not responsible for any errors or omissions and excludes any and all liability for any errors in or omissions from the information on the Library website.