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Modification of Davisson's method

Modification de la methode de Davisson

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ABSTRACT

Davisson's method (Offset Limit Method) is probably the best-known and most widely used method for predicting the ultimate pile load from load test results. This method when applied to the load-settlement curve of a tested pile, usually fails, unless the pile is loaded close to failure. Results of eighty static axial load tests on different types of piles carried out in Egypt were analyzed according to Davisson's method to obtain the ultimate load. Only four out of the eighty tests satisfied the method and predicted the ultimate load.

Elastic and plastic settlements were measured for each pile load test at test load. These values were compared with those obtained from their relevant parts in Davisson's equation. Davisson's equation, when applied at test load equal to either one and a half or twice the working load, gives values higher than those measured for both the elastic and plastic parts.

Davisson's equation was modified to accommodate the difference between the calculated and the measured values at the test load. The suggested form of Davisson's equation allows the prediction of the pile ultimate load using the pile test load without having to extrapolate the load-settlement curve.

RÉSUMÉ

La méthode de Davisson une des plus propagé méthode pour prédire le poids le plus grand charge ultime pour les pieux et cette méthode quand elle faite sur le courbe du poids et la rupture du pieu examiné toujours ne reussi pas sauf si que le pieu se met presque au poids détructeur. Les résultats de 80 expériences pour les poids verticales sur plusieurs genres des pieux ont étaient faite en Egypte et elles étaient calculées par la méthode du Davisson pour produire la charge ultime du poids du pieu , il'ya4 expériences seulement des 80 expériences satisfées la méthode et la prédiction de la charge ultime.

Le tassement de l'élastic et le plastic sont mesurés pour chaque expérience a une poids expériencelle . Ces valeurs sont compares avec ceux qui sont calcules de la équation de Davisson . L'équation de Davisson quand elle applique au poids expériencelle une fois et demi ou deux fois donne des résultats plus grand que les mesures de l'expérience de l'élastic et le plastic.

L'équation de Davisson était modifiée pour accommoder le difference entre la valeur qui était calculée et la valeur qui était mesurée au poids expériencelle. La forme proposé du méthode de Davisson permit la prédiction du charge la plus grand ultime pour le pieu par utiliser le poids experiencelle a l'allongement du poids et du tassement du pieu .

1 INTRODUCTION

The working load or design load is the load a pile is designed to carry safely within a limited range of settlement; this limited settlement range depends on the nature of the building, its importance and also the properties of soil in which the pile is installed. Design load is pre-calculated using field and laboratory test results. Load tests are performed to prove the design load and check the pre-chosen factor of safety.

A method to insure the above was proposed by Davisson (1972); which is easy to apply and has gained wide acceptance. The Offset Method defines failure as the intersection of the elastic stiffness of the pile drawn through an offset on the abscissa that depends on the pile diameter. Since the offset is defined by the pile diameter, the capacity is dependent on the pile diameter.

The proposed modified method estimates the ultimate pile load from the axial pile load test by using a reduction factor for Davisson equation. For the purpose of this study, results of seventy six field axial load tests database on different pile types were compiled. The tested piles included driven, bored, and continuous flight auger piles with different diameters. The tests were carried out at various locations in different Egyptian soils. The soils for all the sites consisted of different layers of silty clay to fine sand along the pile length and the pile tip ended in medium to graded sand.

2 THE DAVISSON OFFSET LIMIT LOAD

The method was proposed by Davisson (1972) as the load corresponding to the movement that exceeds the elastic compression of the pile (taken as a free standing column) by a value of 3.8 mm plus a factor equal to the diameter of the pile (in cm) divided by 10.

The method is based on the assumption that ultimate capacity is reached at a certain small toe movement. It was primarily intended for test results from driven piles, but when applied to bored piles, it becomes impractically conservative. The offset limit criterion is intended for interpretation of quick testing, in which each load increment is held for periods not exceeding one hour. It can also be used when interpreting results from slow methods. This method also gained widespread use in phase with the increasing popularity of wave equation analysis of driven piles and dynamic testing.

The load settlement curve is plotted to a convenient scale, so that the line OO_1 makes an angle of about 20 degrees with the load axis, (Figure1). The line OO_1 represents the relationship between the load and shortening of an elastic free axially loaded column which equals QL/AE. The line CC_1 is drawn parallel to OO_1 at an offset distance OC, where: D is in cm and OC equals (3.8+ 0.08 D) in mm. The intersection of CC_1 with the load-settlement curve gives the ultimate pile load Q_{ult} or 0.9 Q_{ult} according to Egyptian code of practice [4], as shown by the following equation:

S_{ult} = (0.08 *D+3.8) + (Q_{ult}L/AE) (1)

Where: S_{ult}: settlement (mm) of pile at ultimate load, D: diameter of the pile at the pile tip (cm), Q_{ult}: ultimate load (ton), A: base area of the pile (mm^2), E: modulus of elasticity of the pile material (2 ton/mm^2) and L: length of the pile shaft (mm).

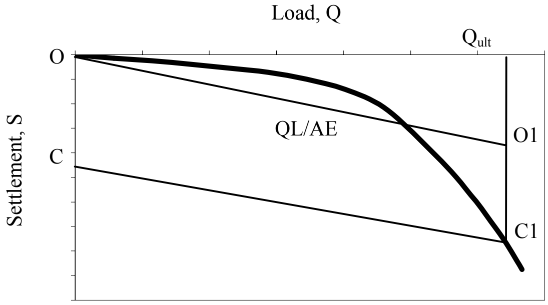

Figure 1. The Offset Limit Method (after Davisson 1972).

In Davisson's Offset Limit Method, the predicted failure load value tends to be conservative [3]. The actual limit line can be drawn on the load-settlement curve already before starting the test. The ultimate load can, therefore, be used as an acceptance criterion to proof tested piles in contract specifications. This method is not suitable for tests that involve loading and unloading cycles.

3 PROPOSED DAVISSON MODIFICATION

Davisson's method can not be applied unless the pile is loaded close to failure. The problem is that in most static load tests where the pile is loaded to one and a half or twice the design load, failure rarely occurs. For this reason it was found necessary to modify Davisson's method so as to estimate the ultimate pile load from the test load.

For the purpose of this study, results of seventy six axial load tests on different pile types (driven, bored and augered), lengths and diameters were considered as shown in table (1) for one and half the working load and table (2) for twice the working load.

Brinch-Hansen, (1961, 1963) considered that the shape of the pile load-settlement curve is a parabolic curve which can be calculated by using the following equation:

$$S = a\,Q^2 \qquad (2)$$

$$a = 1/\,(C_1\,S + C_2)^2 \qquad (3)$$

Where S is pile settlement at pile load Q, C_1 and C_2 are constants, for the same pile load test. At test load equation (2) can be written as follows:

$$S_{TL} = a\,Q_{TL}^2 \qquad (4)$$

Where S_{TL} is pile settlement at pile load test, and Q_{TL} is the test pile load.

By dividing equation (2) at ultimate load by equation (4) the following relation was obtained:

$$Q_{ult}^2 = Q_{TL}^2\,[S_{ult} / S_{TL}] \qquad (5)$$

Ultimate pile settlement, S_{ult}, was taken according to Davisson (1972), as in equation (1) and pile settlement at test load, S_{TL}, can be written in a similar form:

$$S_{TL} = (0.08\,D + 3.8) + (Q_{TL}\,L\,/A\,E) \qquad (6)$$

Table 1: Results of Axial Load Tests for One and Half the Working Load

Test No	L m	D mm	Test load (ton) 1.5 W.L	Measured settlement at Test Load (mm)		
				Elastic Sett.	Plastic Sett.	Total Sett.
D_r1	13	450	67.5	1.85	0.38	2.23
D_r2	17.5	500	67.5	4.00	0.41	4.40
D_r3	14.75	530	120	2.43	0.33	2.75
D_r4	22.25	430	75	2.68	0.12	2.80
D_r5	19.3	400	60	2.18	1.62	3.80
D_r6	15	400	60	1.98	0.40	2.38
D_r7	26.5	600	195	4.37	0.67	5.04
D_r8	13	400	80	2.98	1.30	4.28
B9	22.85	800	262.5	0.94	1.13	2.06
B10	13.1	500	105	2.09	1.19	3.27
B11	11	500	75	1.02	0.97	1.99
B12	12	500	85	1.59	2.57	4.16
B13	14.55	600	90	0.49	0.26	0.75
B14	13.35	450	52.5	0.62	0.32	0.94
B15	13.5	800	187.5	1.48	4.25	5.73
B16	17.25	600	150	2.19	2.37	4.56
B17	12.5	800	240	2.62	7.78	10.40
B18	13	600	153.75	5.23	5.04	10.27
B19	22.5	600	120	0.90	0.58	1.48
B20	21	600	75	1.15	0.33	1.48
B21	14.8	400	45	1.21	0.20	1.41
B22	20	600	150	0.96	1.63	2.58
B23	20	600	157.5	2.45	1.56	4.01
B24	13.35	450	52.5	0.56	0.32	0.88
F25	18	650	210	2.48	1.33	3.81
F26	18	600	180	2.95	1.29	4.24
F27	18	600	180	3.22	1.65	4.87
F28	14	600	120	1.33	0.75	2.08
F29	14	600	120	1.24	0.28	1.52
F30	14	600	120	0.99	0.66	1.65
F31	13.6	400	45	1.78	2.22	4
F32	13.6	400	45	1.22	1.65	2.87
F33	12	600	90	0.63	0.54	1.17
F34	13.2	400	30	0.48	0.26	0.74
F35	12.2	400	30	0.46	0.23	0.69
F36	12.2	400	30	0.49	0.26	0.75
F37	15	400	30	0.41	0.21	0.62
F38	12.2	400	30	0.35	0.37	0.72
F39	21	500	97.5	0.79	0.57	1.36
F40	21	500	97.5	1.77	0.57	2.34
F41	15	600	150	2.95	3.3	6.25
F42	25	400	55.5	0.81	0.37	1.18

Table 2: Results of Axial Load Tests for Twice the Working Load

Test No	L m	D mm	Test load (ton) 2 W.L	Measured settlement at Test Load (mm) Elastic Sett.	Plastic Sett.	Total Sett.
D_r1	23	500	120	1.79	0.55	2.33
D_r2	17	430	80	2.65	0.79	3.44
D_r3	13.6	500	95	2.00	0.56	2.56
D_r4	20	400	50	2.30	0.59	2.89
D_r5	26	450	90	2.26	1.65	3.91
D_r6	19.7	400	60	1.30	0.12	1.41
D_r7	11.75	400	70	0.92	0.71	1.63
D_r8	23.75	400	70	2.82	0.29	3.11
D_r9	12	500	34	0.91	0.36	1.26
D_r10	14.75	400	70	1.68	0.63	2.31
D_r11	17.2	400	128	1.17	0.39	1.56
D_r12	19.5	400	80	5.27	2.30	7.57
D_r13	12	400	80	1.16	0.25	1.41
D_r14	19.5	450	50	0.49	0.09	0.58
D_r15	23.5	450	90	3.06	1.20	4.26
B16	25.2	800	350	2.72	2.27	4.99
B17	13.5	500	120	2.16	4.10	6.26
B18	14	600	130	2.68	2.82	5.50
B19	14	600	130	2.57	3.10	5.67
B20	15.5	600	120	3.21	1.49	4.70
B21	17.5	800	350	8.65	5.74	14.39
B22	12.8	800	350	5.88	9.30	15.18
B23	17	800	120	6.65	10.74	17.39
B24	18	800	340	6.35	5.27	11.62
B25	20	800	350	3.55	1.81	5.36
B26	16.5	600	147	1.67	2.155	3.82
F27	19.6	600	210	3.27	0.42	3.69
F28	19.6	600	210	2.10	0.47	2.57
F29	19.6	600	210	4.14	0.905	5.047
F30	19.6	600	210	3.46	6.15	9.61
F31	19.6	600	210	2.09	0.52	2.61
F32	19.6	600	210	3.34	0.24	3.58
F33	19.6	600	210	3.38	0.22	3.6
F34	13.6	400	60	0.81	1.1	1.91

D_r: driven pile cast in situ.
B: bored pile.
F: continuous flight augered pile.
L: pile length.
D: pile diameter.

Comparing separately the two terms of equation (6) at test load to the measured plastic and elastic settlement at test load, the results are shown in Figures (2 to 5). It can be seen that the plastic part presented in Figure (2) and the elastic part presented in Figure (3) for test load at one and half the working load, and similarly in Figures (4) and (5) for the case where the test load is twice the working load, equation (6) over estimates the plastic and elastic pile behavior. In order to predict the modified Davisson's equation using pile test load, $Q_{T.L}$, in case of the test load one and half, and twice the working load, the following equations were suggested respectively:

$$S_{TL} = (0.06\,D - 1.9) + 0.5\,(Q_{T.L}L/EA) \qquad \text{(mm)} \qquad (7)$$

$$S_{TL} = (0.12\,D - 4) + 0.85\,((Q_{T.L}L/EA) - 2) \qquad \text{(mm)} \qquad (8)$$

Where: D = pile diameter (cm), $Q_{T.L}$= pile load test at one and half the working load (ton) L = pile length (mm), E = pile Young's modulus (2 ton/mm^2), and A = pile cross section area (mm^2).

By substituting in equation (5) in case the test load is one and half the working load the ultimate pile load Q_{ult} may be calculated using pile test load, Q_{TL}, as follows:

$$Q_{ult}^{\ 2} = Q_{TL}^{\ 2}\,\frac{[0.08D + 3.8] + \dfrac{Q_{ult}L}{EA}}{[0.06D - 1.9] + \dfrac{Q_{TL}L}{2EA}} \qquad (9)$$

Similarly, if the test load is twice the working load the ultimate pile load Q_{ult} may be calculated using pile test load, Q_{TL}, as follows:

$$Q_{ult}^{\ 2} = Q_{TL}^{\ 2}\,\frac{[0.08D + 3.8] + \dfrac{Q_{ult}L}{EA}}{[0.12D - 4] + 0.85[\dfrac{Q_{TL}L}{EA} - 2]} \qquad (10)$$

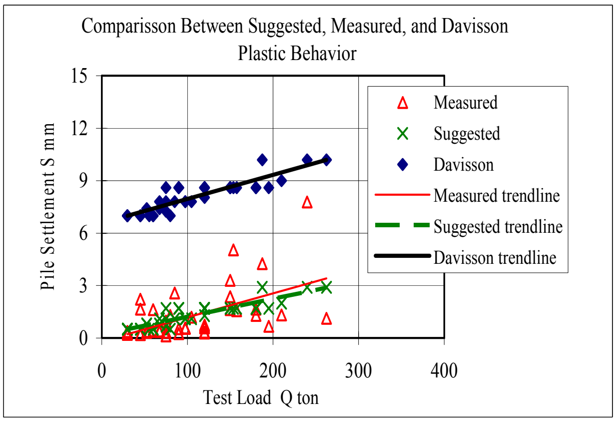

Figure 2. Plastic behavior for test load one and half the working load.

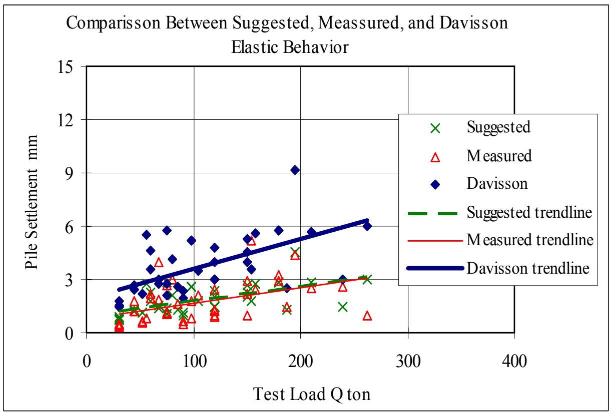

Figure 3. Elastic behavior for test load one and half the working load.

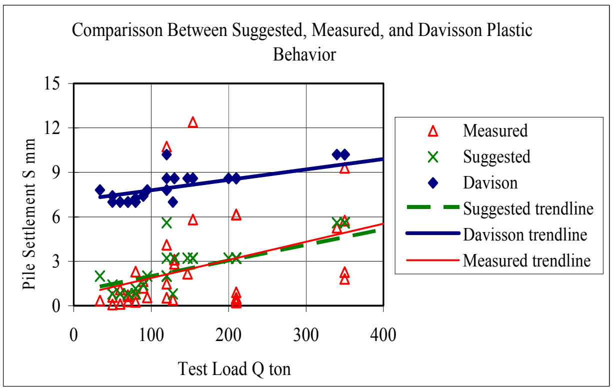

Figure 4. Plastic behavior for test load twice the working load.

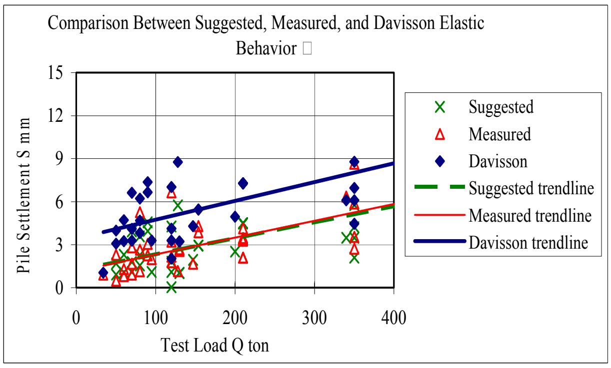

Figure 5. Elastic behavior for test loads twice the working load.

A comparison was carried out between measured and suggested elastic and plastic pile settlements as shown in Figure (6) in case the test load is one and half the working load and Figure (7) in case the test load is twice the working load.

4 SUMMARY AND CONCLUSIONS

Davisson's method needs the pile to be loaded near to failure to be applicable. Davisson's equation when applied for test load it highly over estimated the elastic and plastic settlements.

The suggested form of Davisson's equation allows the prediction of the pile ultimate load using the pile test load without having to extrapolate the load-settlement curve. Since equations (9 and 10) are equations of the second degree in Q_{ult} they can be easily solved to obtain the ultimate pile load.

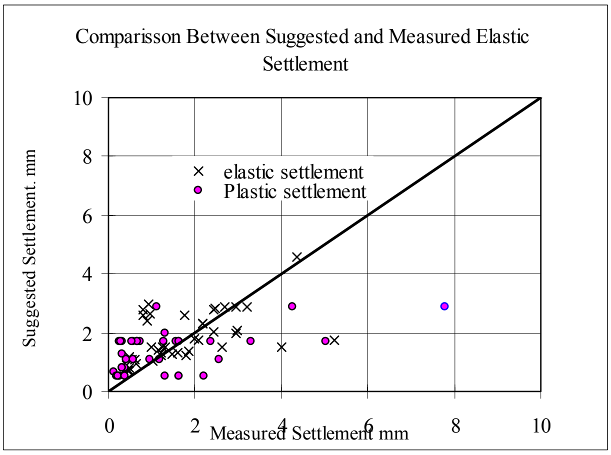

Figure 6. Measured and suggested elastic and plastic pile settlement in case the test load is one and half the working load.

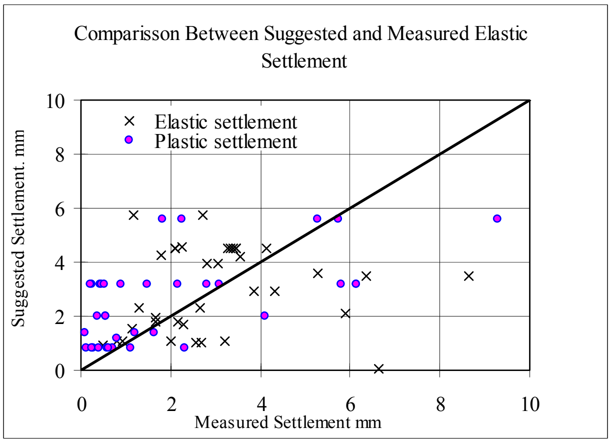

Figure 7. Measured and suggested elastic and plastic pile settlement in case the test load is twice the working load.

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