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Bearing Capacity of Small Diameter Timber Piles in Sand

P.J. YTTRUP
Lecturer, Deakin University, and Principal, P.J. Yttrup & Associates, Victoria
and
A.S. MINER
Post Graduate Student, Deakin University, Victoria

SUMMARY The results of 31 load tests on driven timber piles of diameter 75 mm to 200 mm are presented. The piles had driven lengths of 500 mm, 1000 mm and 1500 mm. The comparison of the predicted capacity of the piles with measured capacity suggests that pile driving formula such as the Hiley and Janbu consistently overestimates pile capacity by about 60%. A simple pile driving formula is shown to give excellent correlation with the experimental results.

1 INTRODUCTION

The engineering use of small diameter piles is not new; their use in Australia and New Zealand is however relatively recent. The increased availability of preservative treated softwood poles suitable for in-ground use is a factor in their increased use.

Correctly treated natural round softwood poles have adequate durability for in-ground structural applications. McQuire (1971) has estimated a service life of the order of 100 years for treated softwood in ground contact.

The ready availability and low cost of treated natural round softwood poles has led to their significant use in domestic scale construction. Their use as embedded piles to replace concrete and hardwood is well developed in New Zealand, Walker (1981).

The installation of piles by driving with a drop hammer and lightweight rig has not been as readily accepted as poles used for embedded piles. In Australia there are only a few contractors who install small diameter timber piles for domestic and light industrial scale construction. The use of driven small diameter timber piles holds some promise in reactive clay sites, Cameron (1981). Piling with a nominal diameter of 150 mm and from treated pinus radiata poles have been installed in many filled sites around Melbourne, Stuart (1983). These piles have a safe working load of about 60 kN and driven depths of 2 m to 4 m.

The load test results for piles in sand presented in the following sections, is from the early stages of an on-going research and development project into foundation systems for domestic scale construction. For such small scale construction, often without engineering input, simple procedures are in order; pile driving formula for bearing capacity calculation for example.

2 PILE LOAD TESTING PROGRAM

2.1 The Test Site

The site chosen for the pile tests was near Ocean Grove in Victoria. The site consists of loose to medium dune sands to a significant depth. The geotechnical profile is shown in Figure 1.

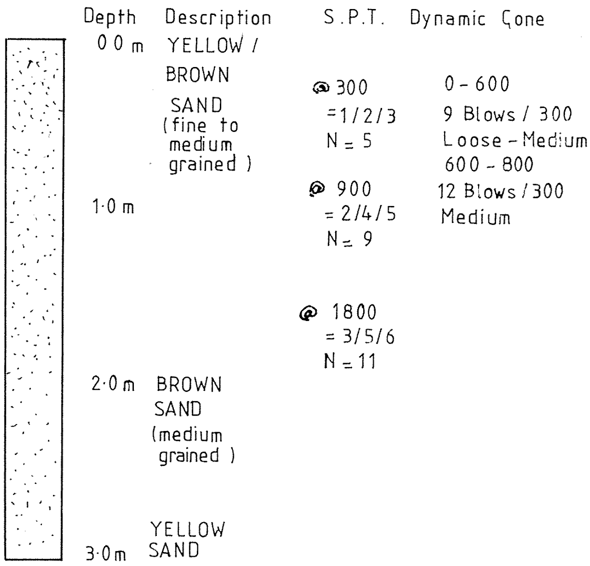

Figure 1 Geotechnical profile at test site

2.2 Installation of Piles

The piles were installed by three different contractors using three different rigs; all used drop hammers. The description of the rigs is given in Table 1.

During pile driving the hammer was raised to a nominal maximum height of 1500 mm, as suggested in the SAA Piling Code (1978). A dynamic analysis reported by the authors, Yttrup and Miner (1983), also suggests that hammer fall height should not exceed 1500 mm if dynamic stresses in the pile are to be within the allowable limits specified in the SAA Timber Engineering Code (1975).

At the desired depth the 'pile set' was measured, this being the pile penetration per hammer blow; an average obtained from five blows. The fall height of the hammer was kept constant during set measurement, but was different for the three rigs as summarised in Table 1.

The driving data for the 31 piles tested is summarised in Table II; also summarised are the ultimate loads and pile displacement at ultimate load.

TABLE 1

DETAILS OF PILE DRIVING RIGS USED

CONTRACTOR	RIG MANUFACTURER AND HAMMER LIFTING SYSTEM	WEIGHT OF HAMMER W. (kN)	HAMMER FALL DURING SET MEASUREMENT H.mm
Stratumpile (RIG 1)	Modified Massey-Ferguson (Truline) Cable & Winch	2.94	810
Foreshore (RIG 2)	Moorehouse-Gyro Friction Wheels No Cable	1.15	1500
Marshall (RIG 3)	Massey Ferguson (Truline)	1.86	1200

TABLE II

PILE DRIVING DATA AND MEASURED ULTIMATE LOADS

PILE NO	DRIVEN DEPTH (mm)	PILE DIAMETER (mm)	DRIVING RIG USED	SET. S. mm/blow	ULTIMATE LOAD kN	DISPLACEMENT AT ULTIMATE LOAD (mm)
1	1000	131	1	37.6	36.3	2.0
2	1000	147	1	26.0	46.1	3.6
3	500	151	1	21.6	30.4	2.7
4	1000	136	1	29.6	29.8	1.8
5	1500	142	1	15.4	66.7	3.0
6	500	156	1	21.4	42.4	3.5
7	500	148	1	30.2	38.5	3.5
8	1500	140	1	13.6	71.1	3.6
9	1500	132	1	18.4	53.4	3.0
10	1030	118	2	15.0	28.9	1.6
11	1030	134	2	20.0	33.8	2.3
12	1390	121	2	19.6	43.7	3.20
13	1020	137	2	18.8	39.2	1.60
14	710	118	2	31.4	21.6	2.20
15	1270	124	2	22.8	38.3	3.30
16	690	131	2	28.6	10.6	1.90
17	610	127	2	24.0	28.5	3.10
18	1500	155	3	33.4	24.5	1.70
19	1500	90	3	33.4	27.5	2.50
20	500	100	3	59.0	16.2	2.60
21	1000	90	3	35.8	33.8	2.70
22	500	120	3	61.0	34.2	3.1
23	1000	90	3	49.2	23.5	3.5
24	500	100	3	92.0	13.7	2.6
25	1000	135	3	19.8	39.2	3.8
26	1500	125	3	22.8	39.7	0.90
27	1000	140	3	21.4	31.9	1.50
28	500	145	3	40.0	26.5	2.40
29	500	200	3	18.6	41.2	0.50
30	1000	210	3	10.0	83.4	2.50
31	1500	175	3	10.8	77.5	1.0

2.3 Pile Test Loading Arrangement

The test piles were loaded using a hand pumped hydraulic jack system reacting against a steel universal beam anchored by two or four reaction piles. Loads were measured with a hydraulic load cell and pile deformation measured by precise level set up about 5 m from the test pile. The pile loading arrangement is shown in Figure 2.

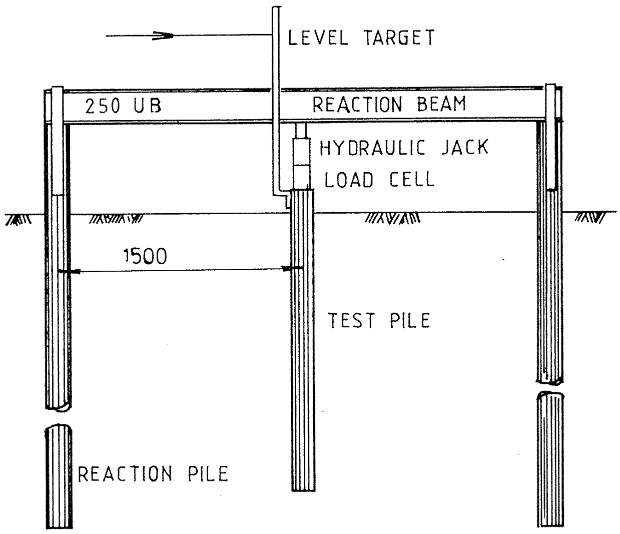

Figure 2 Pile Loading Arrangement

3 PILE LOAD TEST RESULTS

The load was applied in increments of about 5 kN, with pile displacement measured at each increment. The ultimate load was reached in approximately 15 minutes. A typical load-displacement curve is shown in Figure 3 for pile No 9. Also shown is the method of defining the ultimate load.

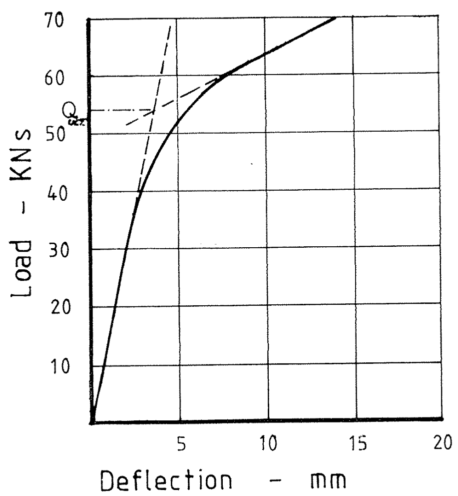

Figure 3 Load-Displacement curve for pile No 9

The ultimate load and pile displacement at ultimate load is tabulated in Table II.

4 DISCUSSION OF RESULTS

4.1 Static Analysis

The capacity of the piles can be estimated using the 'Recommended Methods of Calculation' in the SAA Piling Code; this being a conventional static analysis. The difficulty is to establish the relative density of the sand if SPT values are used, overburden correction arises and there is little agreement as to which correction should be applied.

The static analysis capacity predictions are compared with actual test results in Figure 5. Good agreement can be achieved, particularly in a back-analysis situation.

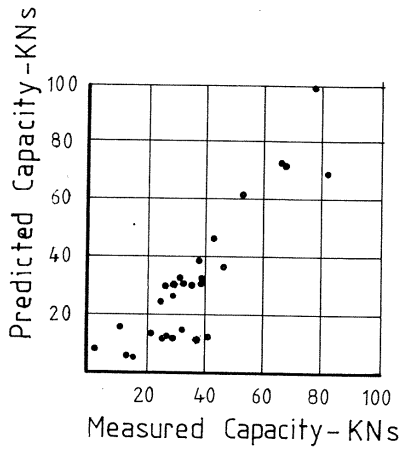

Figure 5 Comparison of static analysis with actual pile capacity

4.2 Pile Driving Formulae

The use of pile driving formulae such as the Hiley or Janbu, is not favoured by many geotechnical engineers. However, for small 'un-engineered' pile installations which occur in domestic scale construction, the relative simplicity of pile driving formula is attractive. Prescribed minimum driven depths for piles plus a minimum load capacity calculated from a suitable pile driving formula appears acceptable for domestic scale construction.

The ultimate capacity predicted by the Hiley and Janbu formula are plotted in Figure 6 and Figure 7 respectively, against the measured pile capacities. The efficiency factor used in the pile driving formula was taken from Poulos and Davis (1982). The pile capacities predicted by the formula are about 60% higher than the measured capacity; the ratio

$$\frac{\text{Predicted Capacity}}{\text{Measured Capacity}}$$

is about 1.6 throughout the range of the test results.

Because the Hiley and Janbu formula both give linear results in Figures 6 and 7 a simple 'correction factor' (ie, a 'small timber pile correction factor') could be applied. The normally published efficiency factors used in pile driving formula are probably much too high, this is also suggested from the results by Balfe (1983) for dynamic testing of large piles in South Melbourne where only 40% to 60% of the hammer energy reached the pile, even under near ideal conditions.

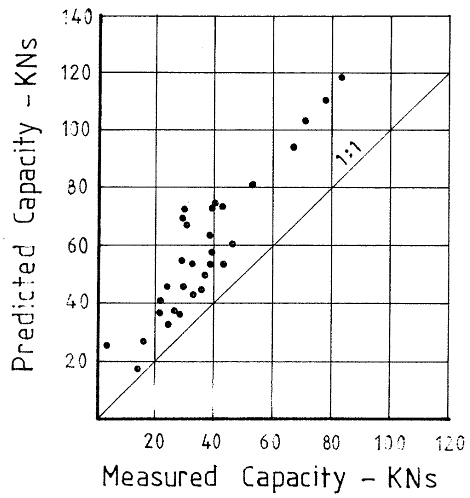

Figure 6 Hiley formula predictions versus measured capacity.

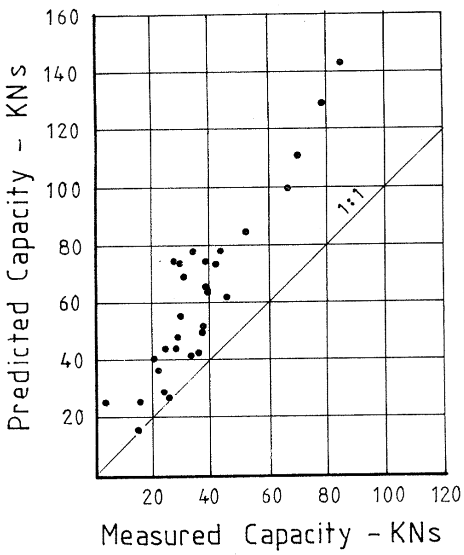

Figure 7 Janbu formula predictions versus measured capacity.

The measured pile capacity and driving sets are plotted in Figure 8 as

$$Q_{ULT} \text{ versus } \frac{WH}{S}.$$

It can be seen that the data points plot around the line

$$Q_{ULT} = 0.4 \frac{WH}{S}$$

with a good quality fit. This expression is similar to the Sanders pile driving formula but with the addition of the 0.4 'efficiency factor'. That is, only 40% of the hammer energy is available to cause pile penetration.

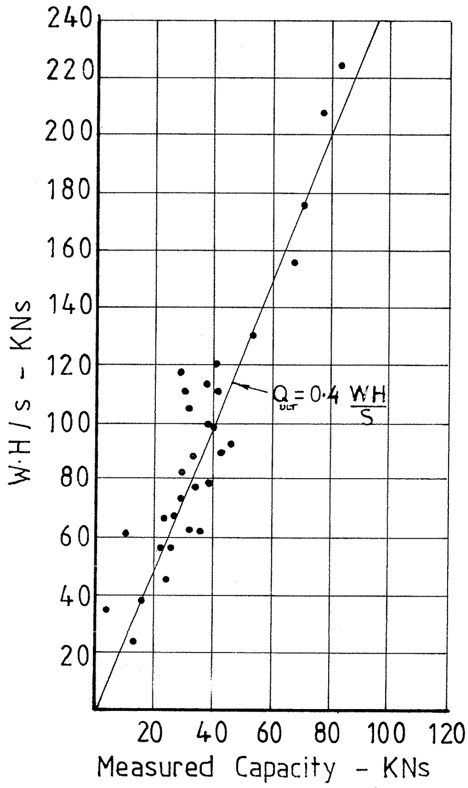

Figure 8 Measured pile capacity Q_{ULT} plotted against $\frac{WH}{S}$

For short piles the mobilisation of shaft skin friction and end bearing resistance occur almost simultaneously. This differs from long piles where shaft resistance is mobilised progressively and ahead of end resistance by the compressional wave travelling down the pile. A pile driving forumla evolved for, or from, long piles is, therefore, not necessarily applicable to short piles. Also the weight of the piling hammer is relatively heavy compared with the weight of the pile for small piles, which also differs from large scale piling.

4.3 Other Results

The pile load test results reported by Lapish (1975) conducted on treated softwood piles in New Zealand are plotted with the Ocean Grove results in Figure 9. The Lapish results are in good agreement with Ocean Grove results, even though the Lapish tests were conducted in a range of soil types, not only sand.

5 CONCLUSIONS

The bearing capacity of small diameter preservative treated softwood piles can be predicted by a simple pile driving formula as proposed. Alternatively, the more commonly used Hiley or Janbu formula could be used if multiplied by a factor of approximately 0.6; that is, these formulæ overestimate the pile bearing capacity.

6 ACKNOWLEDGEMENTS

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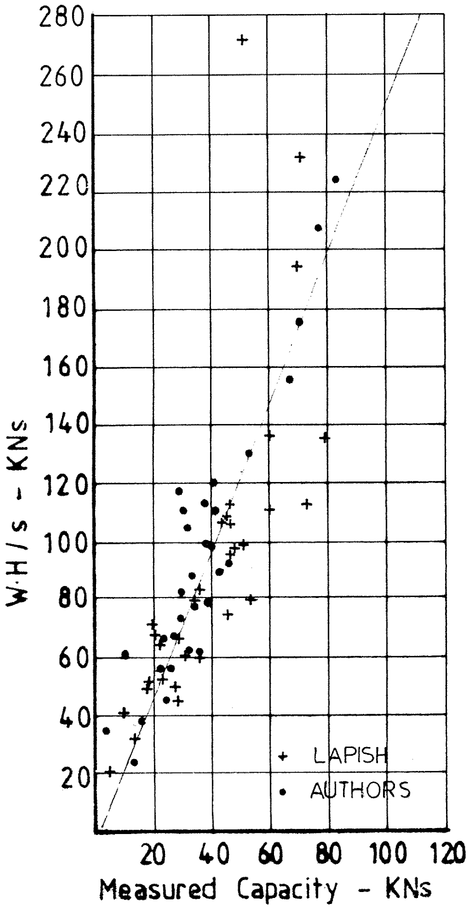

Figure 9 Lapish pile load results from New Zealand plotted with the authors results.

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