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CONTRIBUTION TO DETERMINING THE LOAD BEARING CAPACITY OF FRANKI PILES

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Abstract

The results of Static Pile Load Tests on Franki piles carried out in Hungary over nearly five decades have been assembled into a comprehensive database to examine the behaviour of Franki piles in different soils. The aim is to better understand the relationship between bearing capacity and variations in sub soils below the pile toe.

Keywords: Franki Piles, bearing capacity, settlement.

1. Introduction

In the last several decades it became common practice to use locally fabricated driven Franki piles with approx. 60 cm trunk-diameter, and 80 to 100 cm bulb-diameter as the foundation of major bridges. Their use is effective when loose soil near the ground surface is followed by a soil-profile of, say 8 to 17 m depth, composed of non-compressible granular layers (sand, gravel, or their mixture) that are several metres thick and of good bearing capacity.

A number of researchers (BOWLES [1], DAS [2], DAY [3]FANG [5] FLEMING [6], SMOLTCZYK[7], Tomlinson [8] etc.) pointed out that a correlation exists between the driving effort and the failure load, but nobody went so far as to include the relevant soil conditions in the calculation.

Several long and heavily loaded bridges and other bridges for auto routes and motorways were built in Hungary in the past decades. During this period carrying out static load tests was not only customary, but obligatory.

482 reports prepared on Franki piles contained at least minimal information in the attached documents about local soil conditions, and/or presented meaningful soil mechanical data. From among these, closer examination took place only with respect to those at which the failure value was attained or approached. In this sense only 43 test results, i.e. 9 per cent of the total were included in the analysis.

Using varying data points, the driving effort, pile length, failure load have been used as parameters and plotted, but unfortunately this has not revealed any significant outcome in comparison with previous findings. Still, no one in Hungary has previously attempted to study and apply the contents of the locally registered piling note (volume of the bulb and progress for the last three blows) and use these along with the surrounding soil parameters to determine the failure load. In this manner the following data have been derived**:** the average progress of the last three blows ($\overline{s_3}$) relative to the ratio of the proportion of the limit load over the bulb's volumetric unit, ($\beta = \frac{F_{D/100}}{V_{bulb}}$) and classifying results based on the soil type in which the bulb rested. The results are graphed in *Fig. 1*.

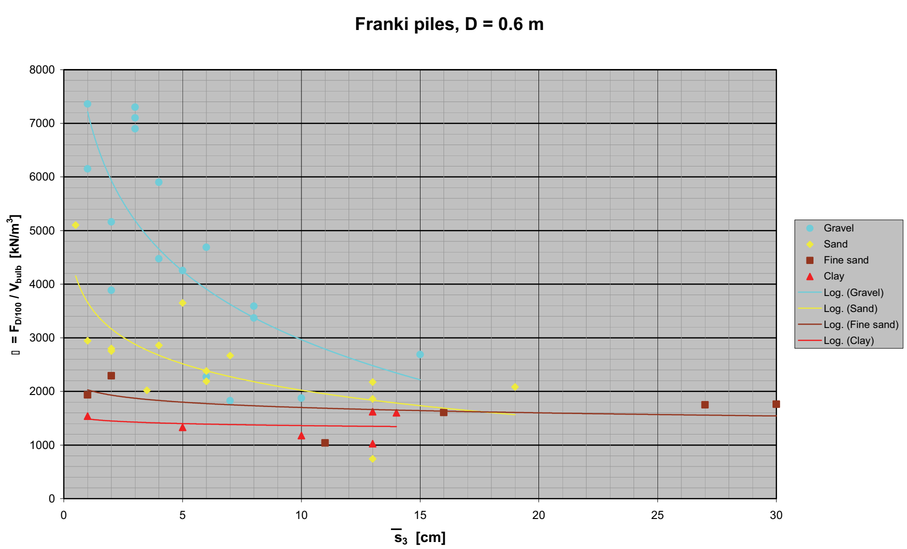

Fig. 1. Limit load of Franki piles

The numerical results of the curves (above) are as follows:

Gravel: $\beta = 7215 - 1846 \ln(\overline{s_3})$ $r = -0.78$
Sand: $\beta = 3660 - 711 \ln(\overline{s_3})$ $r = -0.69$
Fine sand: $\beta = 2030 - 143 \ln(\overline{s_3})$ $r = -0.18$
Clay: $\beta = 1486 - 54 \ln(\overline{s_3})$ $r = -0.14$

(Explanation of terms used in *Fig. 1* is given beneath *Fig. 2*.)

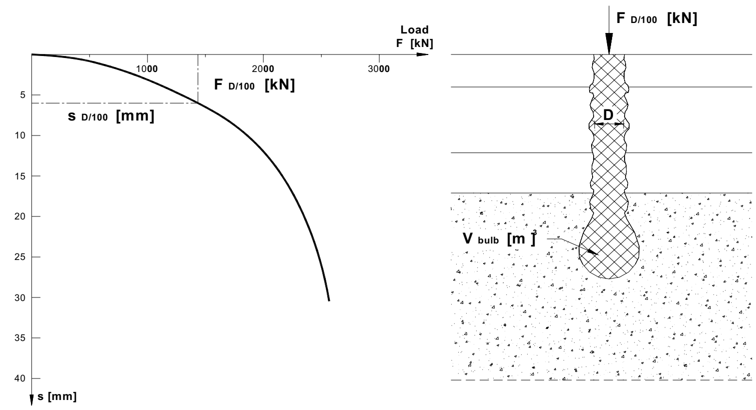

Fig. 2. Explanation of terms used in *Fig. 1*

$F_{D/100}$	= Force (kN) read from the static load trial curve at $s = D/100$ mm displacement (equals approx. 6 mm) that – according to experience – coincides with the limit load.
D	= Nominal diameter of the pile trunk (approx. 60 cm).
V_{bulb}	= Volume of concrete (m^3) used for the bulb, as registered in the Piling Note.
$\overline{s_3}$	= Average progress of the last three blows (cm), as registered in the Piling Note.
$\beta = \frac{F_{D/100}}{V_{\text{bulb}}}$	= Ratio of the proportion of limit load over the bulb's volumetric unit.

From the *in situ* measured force versus settlement curve – and by knowing the soil type at the bulb, the volume of the bulb (V_{bulb}), and the average progress of the last three blows ($\overline{s_3}$) – one will be able to predict immediately the limit load of the pile on the spot of the pile driving.

Fig. 1 suggests that the Franki (driven) piles should only be used in granular soil.

For about 70 per cent of the studied individual Franki piles of 4 to 13 m length, the failure loads were between 2300 and 4300 kN, while loads to 6 mm ($D/100$) settlement were between 1200 and 2500 kN.

In *Fig. 3* the bearing capacities ($F_{D/100}$) of the 43 individual Franki piles at $D/100$ = 6 mm settlement have been plotted versus the pile length (L). Various colours and dots identify the piles of which the bulb rested in different soil types (gravel, sand, fine sand and clay).

Dashed lines represent the boundary lines of the minimum and maximum load bearing capacities. The relevant equations are:

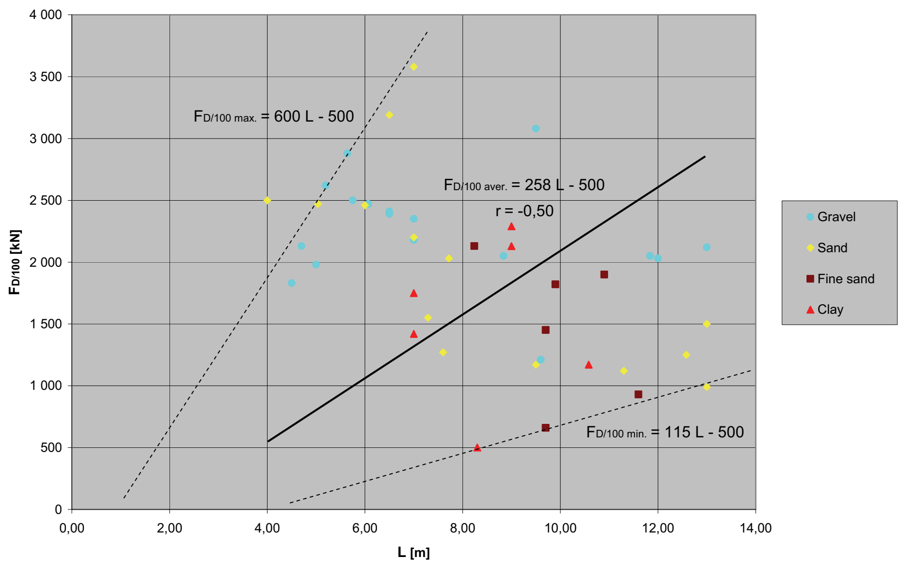

Fig. 3. Bearing capacity of Franki piles installed in different soils

$$F_{\frac{D}{100}\ \mathrm{min}} = 115 \cdot L - 500[\mathrm{kN}],$$

$$F_{\frac{D}{100}\ \mathrm{max}} = 600 \cdot L - 500[\mathrm{kN}].$$

The average bearing capacity is shown with a solid line. The relevant equation is:

$$F_{\frac{D}{100}\ aver.} = 258 \cdot L - 500\ [\mathrm{kN}]; \qquad r = -0,50.$$

From the data the author derived the forces (F_i) that belong to $i \cdot 0.01 \cdot D$ settlement, as well as the failure force (F_t). Based on that data, the corresponding value pairs $F_i\ /\ F_t$ are presented in the following table, as a function of the soil type at the bulb.

On basis of the values shown in *Table 1* one can conclude that for Franki piles the failure below the bulb occurs after smaller settlements than for bored piles with $s_t \approx 0.1 \cdot D$ on average. This means:

- with the bulb in cohesive soils $s_t \approx 0.03 - 0.04 \cdot D$.
  (that is for D = 60 cm diameter piles 1.8 – 2.4 cm).
- while characteristically with the bulb driven into granular soils $s_t \approx 0.015 - 0.03 \cdot D$,
  (that is for D = 60 cm diameter piles, 0.9 – 1.8 cm).

Table 1. Results of Static Pile Load Tests

Location	Soil type below the bulb	F_i / F_t					
		$0.01 \cdot D$	$0.015 \cdot D$	$0.02 \cdot D$	$0.03 \cdot D$	$0.04 \cdot D$	$0.05 \cdot D$
M1 ap./Concó creek bridge	Clay	0.50	0.62	0.73	0.93	1.00	1.00
M3 ap./B 6 (ap=motorway)	Clay	0.69	0.80	0.89	0.94	1.00	1.00
M3 ap./B 11	Clay	0.66	0.79	0.87	0.98	1.00	1.00
M7 ap./13	Clay	0.49	0.60	0.68	0.79	1.00	1.00
M3 ap./H 29	Clay	0.74	0.92	0.99	1.00	1.00	1.00
Dunaújváros	Fine sand	0.60	0.73	0.79	0.93	1.00	1.00
Hódmezővásárhely, Hód tó	Fine sand	0.83	0.94	0.98	1.00	1.00	1.00
Hajdúböszörmény	Fine sand	0.63	0.74	0.85	1.00	1.00	1.00
Dunaújváros	Fine sand	0.69	0.79	0.87	0.98	1.00	1.00
Kaposvár	Fine sand	0.69	0.73	0.92	0.99	1.00	1.00
M70 ap./3a	Sand	0.84	1.00	1.00	1.00	1.00	1.00
M3 ap./H 30	Sand	0.67	0.80	0.88	1.00	1.00	1.00
M3 ap./B 9	Sand	0.73	0.81	0.89	1.00	1.00	1.00
M7 ap./1	Sand	0.65	0.79	1.00	1.00	1.00	1.00
M70 ap./9	Sand	0.80	1.00	1.00	1.00	1.00	1.00
Pécs PÉTÁV yard	Sand	0.89	0.96	0.99	1.00	1.00	1.00
Tokaj ártéri híd	Sand	0.55	0.69	0.78	0.93	1.00	1.00
Tokaj Aranyos bridge	Sand	0.62	0.74	0.85	0.98	1.00	1.00
M7 ap./3	Sand	0.84	1.00	1.00	1.00	1.00	1.00
Zalalövő /W	Sand	0.42	0.57	0.70	0.84	1.00	1.00
M30 ap./4	Sand	0.82	1.00	1.00	1.00	1.00	1.00
M7 ap./5	Sand	0.67	1.00	1.00	1.00	1.00	1.00
M7 ap./14	Sand	0.87	1.00	1.00	1.00	1.00	1.00
M3 ap./B 3	Gravel	0.53	0.64	0.72	1.00	1.00	1.00
M70 ap./4	Gravel	0.57	1.00	1.00	1.00	1.00	1.00
Zalalövő /T	Gravel	0.42	0.59	0.64	0.79	1.00	1.00
Bp. XXII. Leányka u	Gravel	0.92	0.99	1.00	1.00	1.00	1.00
M70 ap./3	Gravel	0.80	1.00	1.00	1.00	1.00	1.00
M30 ap./1	Gravel	0.68	0.73	1.00	1.00	1.00	1.00
M70 ap./8	Gravel	0.79	1.00	1.00	1.00	1.00	1.00
M70 ap./13	Gravel	0.60	1.00	1.00	1.00	1.00	1.00
M70 ap./12	Gravel	0.69	1.00	1.00	1.00	1.00	1.00
M70 ap./14	Gravel	0.74	1.00	1.00	1.00	1.00	1.00
Bp. III. Békásmegyer	Gravel	0.98	1.00	1.00	1.00	1.00	1.00
Bp. III. Bojtár u	Gravel	0.56	0.67	0.76	0.82	1.00	1.00
M7 ap./6	Gravel	0.72	1.00	1.00	1.00	1.00	1.00
M70 ap./2	Gravel	0.69	1.00	1.00	1.00	1.00	1.00
M70 ap./2b	Gravel	0.71	1.00	1.00	1.00	1.00	1.00
M70 ap./11	Gravel	0.56	1.00	1.00	1.00	1.00	1.00

2. Conclusions

The presented study and the derived results demonstrate how the approximate bearing capacity of Franki piles varies as a function of different underground conditions and on the basis of the observed data during their fabrication.

The presented results suggest that Franki (driven) piles should only be used in granular soils.

The data also demonstrate that failure below the bulbs of the Franki piles (depending on the given soil type) occurs at smaller settlements than for bored piles ($D/10$), at which $D = 60$ cm diameter piles the settlement is between 0.9 and 2.4 cm.

The presented results help in the determination of the adequacy of piles already in the course of fabrication and in better assessment of anticipated settlements (for example, at an extended working area where the number of necessary blows can vary within wide ranges).

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