Experimental evaluation of the bearing capacity of a tension pile
Détermination expérimentale de la force portante d'un pieu à tension

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ABSTRACT: High tension poles of a thermal power station have to be founded in a fly ash deposit. The poles stand on pile foundations. The latter consist of reinforced concrete piles of 30 × 30 cm cross section and 10 m length, driven in fly ash. According to the design a tensile force appears in some of the piles under different loading conditions. This paper considers only the carrying of the tensile forces. They were determined by *CPT* and by the extraction of two piles - one from wet and the other from drained ash. The ultimate tensile forces measured amount from Q_L = 180 ÷ 285 kN respectively. The extraction skin friction of the reinforced concrete pile amounts from wet to drained ash to R_f = 16,7 ÷ 26,4 kPa. The coincidence with *CPT* is relatively good.

RESUME: Mâts de haute tension d'une central thermoélectrique devaient être fondés dans un dépôt de cendre. Les mâts reposent sur une fondation de pieux. Ils sont en béton armé d'une section 30 × 30 cm, une longueur de 10 m, enfoncés dans le cendre. D'après le project les differentes combinaisons des charges provoquent des forces de tension dans quelques pieux. Cet article ne considère que la force portante de tension des pieux. Elle était déterminée par *CPT* et par l'extraction de deux pieux - l'un du cendre saturé en eau et l'autre du cendre drainé. Les forces limites de tension sont Q_L = 180 kN et 285 kN respectivement. La friction d'extraction des pieux en béton armé est R_f = 16,7 kPa et 26,4 kPa respectivement. La coïncidence avec le *CPT* est relativement bonne.

1. INTRODUCTION

A high tension transmission line (400 kV) of a thermoelectric power station runs through fertile land and menaces the health of people working there. For this reason it was decided to move the transmission line on the fly ash deposit of the power station. Every mast of the transmission line is to be founded on 4 footings, each of which by means of 4 - 7 reinforced concrete piles. These have a cross section of 30×30 cm and a length of 10 m (Fig.1).

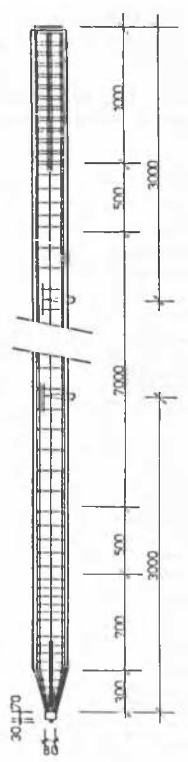

Figure 1. Reinforced concrete driving pile

Some of the piles are tension piles with the respective combination of loadings. The problem consists in evaluating the bearing capacity of a single pile, driven in fly ash. The investigations in this paper concern only this question.

As is known, there are tables of empirical values for the skin friction of piles with relation of the type of soil and the depth of driving. But they do not refer to:

- tension piles;
- artificial soils, such as fly ash.

This case is more complicated, because part of the fly ash deposit is not drained and is under water.

The skin friction between reinforced concrete pile and fly ash was determined by:

- Cone penetration test (*CPT*) and
- the extraction of test piles.

2. PROPERTIES OF THE FLY ASH - AVARAGE VALUES

According to the grain size distribution (Fig. 2) this fly ash is a *fine to silty sand* (*SM*)

Uniformity coefficient	C_u	= 2
Density of solid particles	ρ_s	= 2,32 g/cm^3
Dry density of ash in loosest state	$\rho_{d.min}$	= 0,60 g/cm^3
Dry density of ash in densest state	$\rho_{d.max}$	= 0,80 g/cm^3
Density index	I_d	= 0,56
Angle of internal friction	φ	= 21° ÷ 26°

The local side friction for 9 m depth was determined by *CPT* (20 t dutch cone, base of cone 10 cm^2, angle of the top 60°)

under water	f_c'	= 11,4 kPa
drained	f_c	= 21,4 kPa

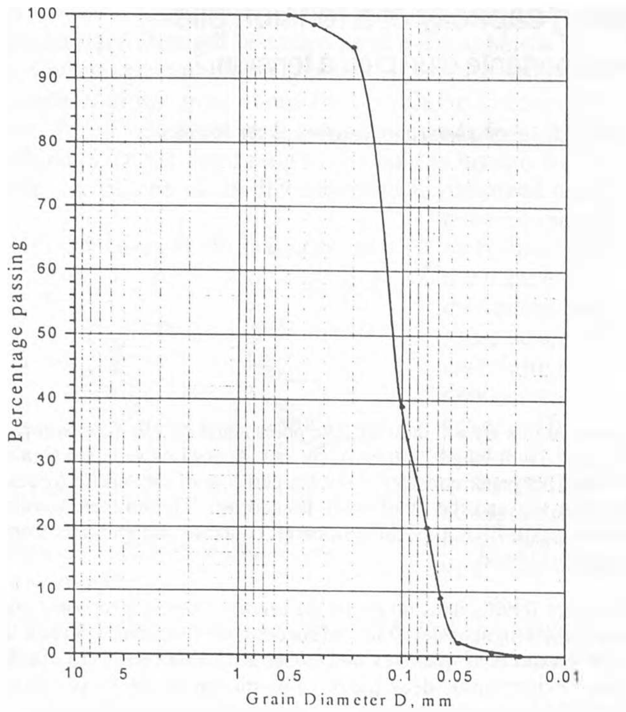

Figure 2. Grain size distribution of the fly ash

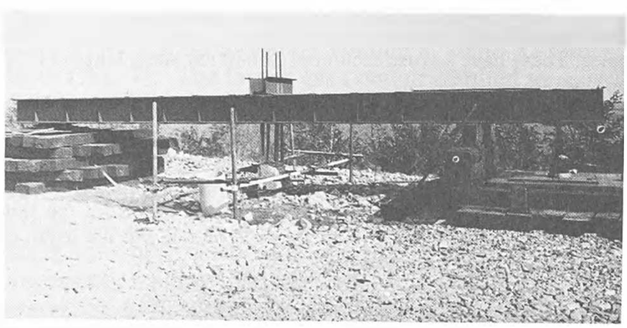

Figure 3. General view of the testing site

3. EXTRACTION OF PILES

The requirements of ASTM standard D 3689-90 "Standard Test Method for Individual Piles Under Static Axial Tensile Load" (Annual Book of ASTM Standards, 1996) were observed. After three weeks of repose following the driving, two piles were tested - one in wet fly ash and the other in drained fly ash.

The testing area is shown on figure 3 and figure 4.

The extraction failure of the two test piles occurs at the pulling out of the pile from the ash, i.e. by skidding between pile and ash. No uplift of a block of ash containing the pile was observed. This phenomenon could be explained by the relatively large angle of internal friction φ compared to the friction between pile and ash. For this reason calculations for this failure mechanism were not performed.

4. TEST RESULTS

The curves obtained

$$h = f(Q)$$

are shown in figure 5, where

h is heave (negative settlement) of pile,

Q - tensile load.

The ultimate limit tension load Q_L is determined after Eurocode 7, Part 1, Chapter 7 "Pile Foundation" (Eurocode 7, 1991) for gross heave equal to 10% from the equivalent diameter of the cross section of the pile, in this case 0,1 × 338 = 33,8 mm. The design bearing capacity Q_k is obtained after table 7.1 from the same EC-7 with a factor to reduce from Q_L to Q_k equal to 1,5 because only one test was carried out

$$Q_k = Q_L : 1{,}5.$$

The skin friction R_f is calculated for Q_L very near to the failure load. The values of Q_L, R_f, f_c and Q_k are given in table 1.

The values of the skin friction R_f are 1,46 respectively 1,23 times larger than f_c obtained by *CPT*. This is logical, while the friction between concrete and ash is evidently higher than the friction between steel and ash.

Since the investor did not present a requirement for cerviceability about Q_k, the design bearing capacity shown in table 1 could be recommended.

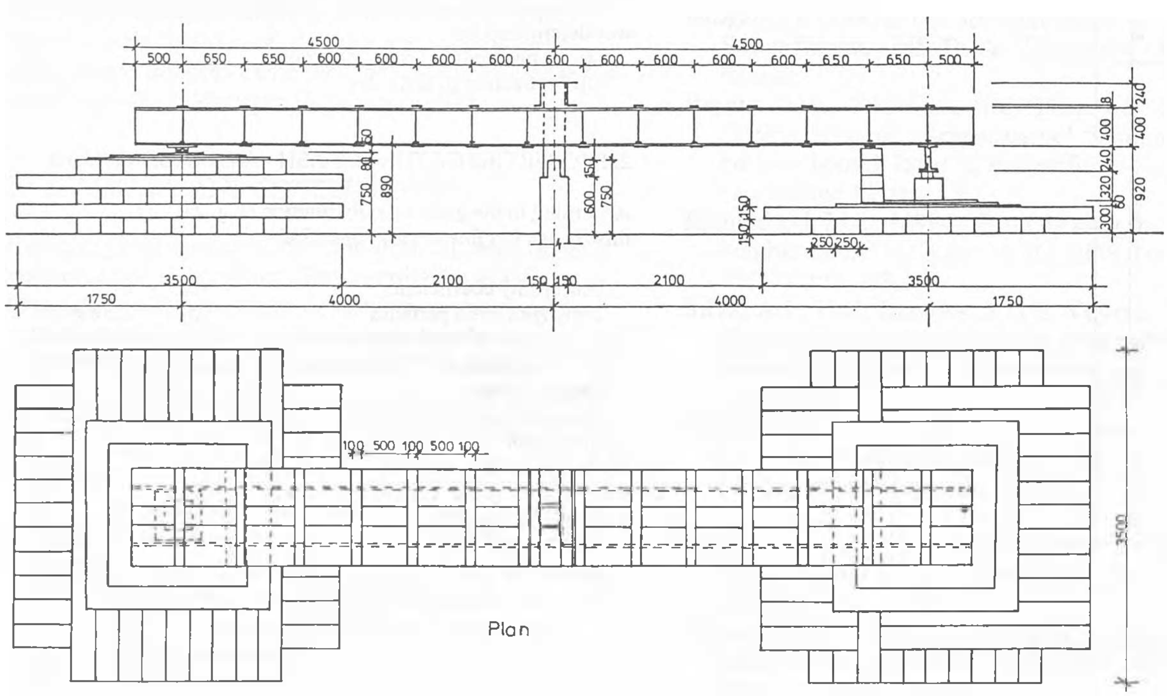

Figure 4. Scheme of the testing equipment for determining of bearing capacity of a tension pile

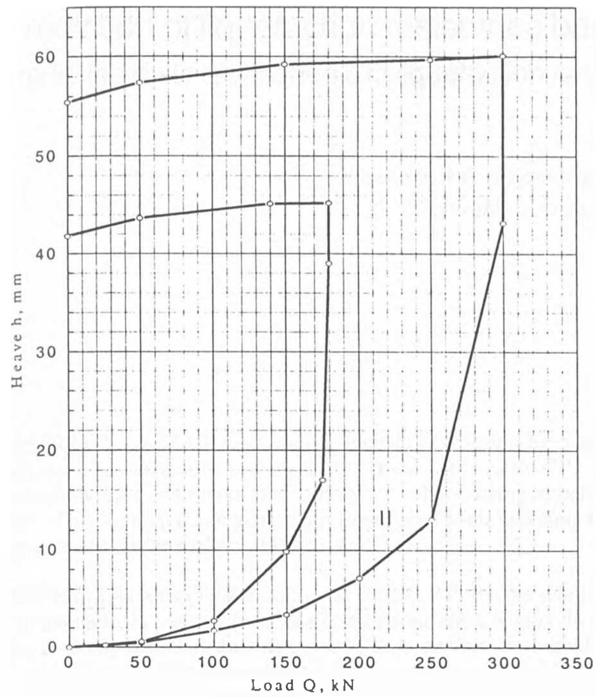

Figure 5. Load(Q) - heave(h) - relation of tension piles
I - pile driven in ash under water
II - pile driven in drained ash

Table 1. Testing Results

Pile driven in ash	Q_L	R_f	f_c (CPT)	$\frac{R_f}{f_c}$	Q_k
	kN	kPa	kPa	-	kN
wet	180	16,7	11,4	1,46	120
drained	285	26,4	21,4	1,23	190

As is well known, there are many methods for determining Q_L from the curve $h = f(Q)$, for instance (Grundbau-Taschenbuch, 1992). The checking established that by some of them the values of Q_L, and from here also of Q_k, are up to 40% lower.

REFERENCES

Annual Book of ASTM Standards, 1996; Vol. 04.08; D 3689-90 *Standard Test Method for Individual Piles Under Static Axial Tensile Load*, pp. 404 - 414

Eurocode 7, Part 1, Chapter 7 - *Pile Foundations*, 1991, Geotechnik, Jahrgang 15 (1992), H.1, S. 32 - 43

Grundbau-Taschenbuch, 1992; Teil 3, 3.3 *Pfähle*, Vierte Auflage, Ernst & Sohn Berlin, S. 243