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Designing of the pile tip level at bridge foundation in loose and soft deposits

Desseinant du niveau de pointe d'un pieu à un fondation du pont dans des dépôts lâches et tendres

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SYNOPSIS Bearing capacity of the piles at the bridge foundations in loose and soft deposits under rivers on great plains is, in general, less than that given in publications. Short piles give great settlements in the clay layers. Relatively long piles are convenient to apply to prevent the movement of the foundations. The settlement of the piles is less and the bearing capacity is greater if the lower part of the pile embedded in the sandy layers.

1. INTRODUCTION

Rivers on great plains change their beds frequently and below the river relatively young deposits are to be found to a considerable depth. Mostly this is the case at such plains where the surface, settled in geological ages, are filled up by river and sea deposits. Under such soil conditions pile-foundations are made mostly, as usually in the recent period. In connection with the piled foundations the following three interrelated problems are encountered:

1/ Design of the piling depth, that of the required pile length

2/ Estimation of the piles' diameter and the bearing capacity

3/ Calculation of the expected settlement of the pile foundation.

Deposits under the river bed are loose, easy to compress the layers. Foundations near the surface involve, generally, considerable settlement, deformation and displacement of the foundation. In case of several bridges structural defects were encountered because of the piers'movements, due to the settlement, tilting and movement of foundation, elimination of which required considerable maintenance work.

2. LOOSE SEDIMENT UNDER THE RIVER BED

Five bridges were constructed in the last decades to span the River Tisza/Hungary. In connection significant exploration work was carried out. The exploration have revealed clayey layers of varying softness and medium stiffness and sandy layers of different composition, laying under each other from the surface to the depth of the exploration. Majority of the granular layers is fine sand. The void ratio of the clay is relatively high, it varies between

$$e = 0{,}8\text{-}1{,}17 \qquad /1/$$

Their plasticity index is

$$I_p = 46\text{-}52\ \% \qquad /2/$$

Smaller than the above value has been encountered only at some thinner layers. The angle of internal friction of the clay is:

$$\emptyset\ 5\text{-}13^{\circ}$$

Angle of internal friction of the granular layers is 20-25°. Coefficient of uniformity

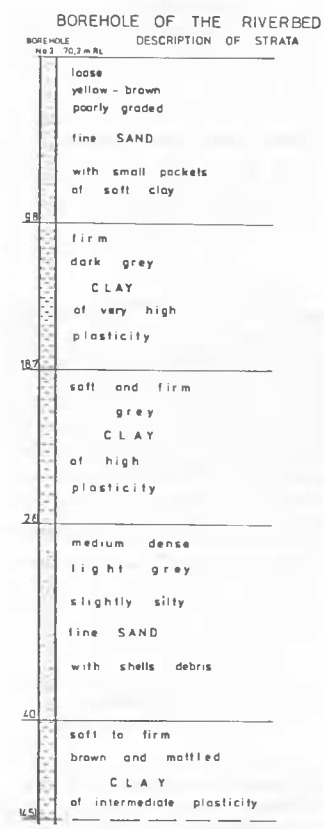

Figure 1/a

Characteristic borehole
Boring on the site of the highway-bridge spanning the River Tisza at Szeged

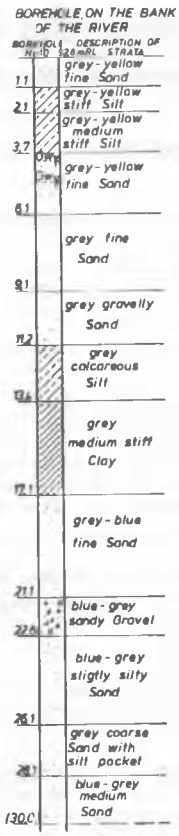

Figure 1/b
Characteristic borehole
Boring on the site of the motorway at
Tiszapalkonya

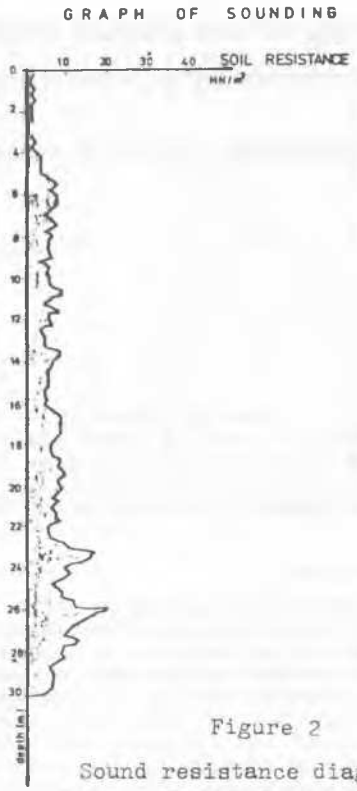

Figure 2
Sound resistance diagram
Tiszapalkonya

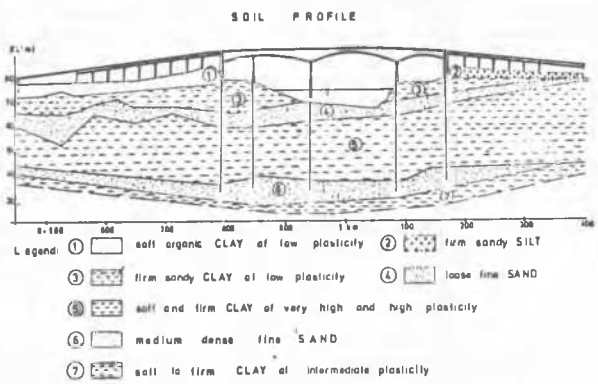

Figure 3
Cross-section of the bridge
over the River Tisza
at the bridge of Szeged-North

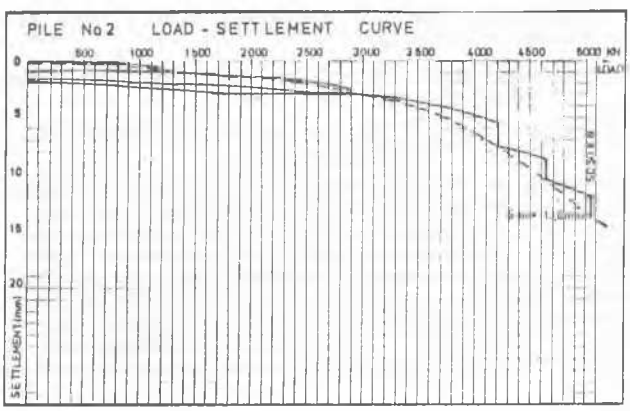

Figure 4/a
Load-settlement curve
bored pile with dia. of o,8o m
/Bridge at Csongrád/

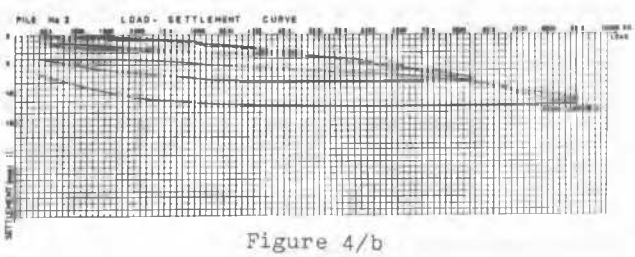

Figure 4/b
Load-settlement curve pile with
dia of 1,2 m/Bridge at Csongrád/

is U = 2-6. The water content of the cohesive layers is near the plastic limit, only some layers have higher water content

The natural water content of the granular layers is about 25 to 30 %
Characteristic boring profiles is shown in Figure 1/a and 1/b.

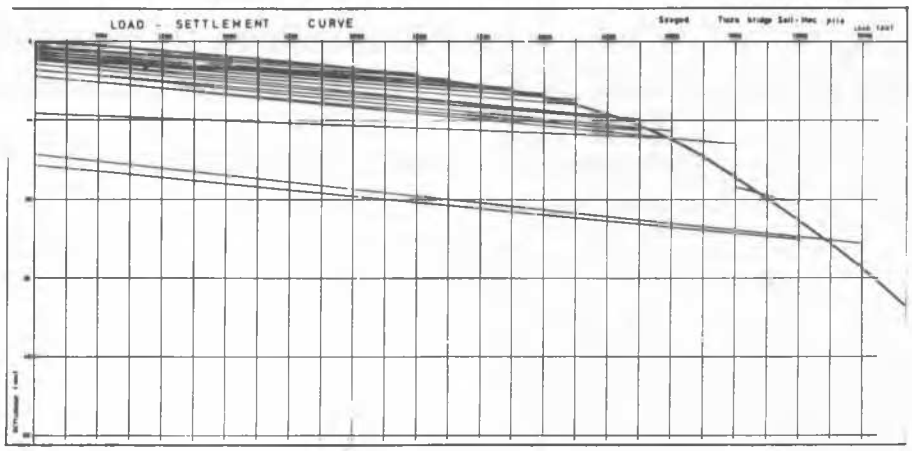

Figure 4/c

Load-settlement curve Soil-Mec type bored pile with dia of 1,2 m at the bridge of Szeged-North

At other exploration the loose granular layers are prevalent. Sounding of the granular layers showed relatively low soil resistance although it was not possible to eliminate the skin friction entirely at these probes /Fig.2/

Scouring-outs are also to be considered because of the considerable flow regime of the river, as a consequence of which the level of the bed bottom can not be considered as an exact line. The scouring-outs and the deposits change their places quite frequently /Fig.3./

3. PILE-SKIN FRICTION IN LOOSE, GRANULAR DEPOSIT

Pile foundations made in relatively young loose deposits are to be generally considered as friction piles, i.e. the skin friction has basic role in the bearing capacity. The performed different tests, test piling, sounding and loading, equally have shown that the load acting on the piles, serving as bridge foundations, is basically carried by the skin friction.

4. TEST PILING

The loading tests in the course of design were carried out mostly on the bank. To eliminate the skin friction of the layers above the bed bottom we enclosed the upper part of the piles with pipes thus limiting the acting of the skin friction only from the depth of the bed bottom. It was a simulation of the work of the river piles. Of the performed loading tests /Fig. 4a/ a shorter and a longer piles have been chosen for this paper /Fig. 4b/. Loading tests were made at the actual sites of piling during construction.

These tests also justified the above-explained facts. When performing loading-tests on Soil-Mec piles with dia. of 1,2 we obtained bearing capacity of 13,000 k/N and settlement of 28 mm. For load-settlement curve see Fig. 4/c.

The ultimate load capacity of the shorter Ø 0,80 m pile - 26 m - was 5050 kN, while that of the longer Ø 1,20 m pile,-33 m,-was as much as 9477 kN. The acting skin friction was the same at both piles, because at the longer pile on the upper part the friction was eliminated by casing tube.
The loading tests at other bridges have shown that the compression under the shorter piles was several times more than under the longer ones.
The experiences of constructed bridges have shown that the foundations on long bored piles suffered no remarkable settlement and there was no tilting or movement.

5. EVALUATION OF THE PILE LOADING

The loading tests carried out for different bridge foundations have not, of course, scientific aims, they have been intended to serve practical goal, checking of the designed bearing capacity of the pile. The general lesson that can be drawn from the numerous loading tests performed in loose sediments is that the load acting on the piles is mostly carried by the skin friction. If we attribute the results obtained for bearing capacity by loading tests solely to the skin friction and if we calculate the friction coefficient from the acting load based on the well-known formula of the skin friction

$$P = \frac{q}{2} K.f \qquad /3/$$

where q - is the geostatical pressure kPa
K - is the skin surface sq.m., and
f - is the friction coefficient
and take the $f = tg\ \emptyset$ value into account we obtain for the value of Ø angle is in good coordination with the average friction angle of the penetrable layers.

6. SELECTION OF THE FOUNDATION LEVEL

When selecting the foundation level the problems connected with movement are to be necessarily taken into account. The experiences gained with formerly built bridges have shown that at bridges with shallow foundations considerable settlement, tilting and movement have been encountered. Such phenomena were observed at several bridges spanning the River Tisza and Danube. Especially big movements were observed at the road-bridge built over the River Tisza at Szeged toward the end of the last century and founded in the soft clay layers relatively near the bed bottom by caisson method. The test has revealed that the movements were caused by the soft clay layer interchanged by uniform sized quick-sand to be found under the river bed. The colloid content of the clay is very high.
Thick and unfavourable from the foundation-aspect layers lying under the riverbed require long bored piles with big diameter /o,8 m and over/ for bridge foundation. Such long piles prevent settlement and movement of pile foundations.