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DMT-MEASUREMENTS AROUND PCS-PILES IN BELGIUM

EVALUATION DES PILES PCS EN BELGIQUE BASEE SUR DES ESSAIS DMT

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SYNOPSIS : This paper evaluates the soil stress changes around a Socofonda PCS auger pile using the dilatometer test.
Results of three test sites are reported. The evaluation of the execution parameters and other external influences are gathered through DMT-measurements during installation of the pile. The paper further describes a comparison of the results of soil investigation at different stages before, during and after pile installation.

INTRODUCTION

The bearing capacity, especially the shaft friction, of auger piles is strongly dependent on the execution parameters of the pile. PCS- piles (Pressurized Concrete Screw-piles) installed with a continuous auger are brought to depth causing no or a very limited soil displacement. During casting the concrete, an additional pressure is applied on the fresh concrete. For this type of pile, the execution parameters are the downward force during penetration N_i, the torque M_i, rotation speed (downwards) n_i, downward velocity of the auger v_i, upward velocity v_u, upward force N_u, concrete pressure σ'_b, the ratio diameter auger to diameter stem, the pitch (for alle the discussed piles, p was 45 cm) of screwing down, and the quality of the concrete and the way of casting. This is an important factor governing the arching effect and determining the real fresh concrete pressure in equilibrium with the total horizontal soil stresses. By the use of hyperplastifiers, the W/C ratio can be limited to 0.45 and the cubic strength nowadays reaches 45N/mm^2 and higher.
All of these parameters are continuously measured (each 80 mm) during pile installation.

TYPE OF PILE

Generally the PCS-auger piles are using an inner stem diameter of 100 mm. During casting of the concrete an overpressure of 2 to 4 bar is applied on the fresh concrete, while the auger is regained slowly. This procedure doesn't cause vibrations. After casting the concrete, the reinforcement is brought into the pile using a vibrator. Eventual difficulties can be avoided using a greater inner stem diameter. So the reinforcement can be placed inside before casting the concrete. The outer diameter for such piles ranges between 35 and 45 cm. The high torque (100 kNm) that can be applied avoids excavating too much of soil and allows for penetration in resistant bearing layers. The degree of soil displacement can be deduced out of the overconsumption (occ) of concrete, defined as :

$$occ = \frac{V_b - V_p}{V_p} \times 100 \text{ (in \%)} \qquad (1)$$

in which :
V_b = concrete volume consumption
V_p = theoretical volume of the pile with known nominal dimensions.

This parameter (occ) gives a mean value and hides local effects such as lenses or layers where a higher excavation and/or soil displacement resulting in varying concrete consumption exists. For the discussed piles, the overconsumption was 16 % for the test site at Oudenaarde, 28 % for Dendermonde and 95 % for Doel-test sites. The high overconsumption at Doel is mainly due to the fact that the upper layer (0 to -8.00) is composed of dredged material and to the presence of another very soft layer on the levels from -8,70 to -10.30.

SOIL TEST PROGRAM

For each pile, the following test soil results are gathered : (CPT) electrical cone penetration test before execution of the pile ; (DMT1-A) DMT-test before installation of the pile at 1,5 times pile diameter out of the center of the pile. In addition, during installation of the pile, a DMT1-B test is performed with the DMT-blade installed at a fixed depth. The A-reading of the DMT curve was considered equivalent to an oedometer time-deformation curve. Using Casagrande's log t/fitting method : $t_{100\%}$ was determined before the start of the piles installation. Pile installation started when the decreasing ratio of A-readings became less than 5 kPa/hour. By this, consolidation and relaxation, due to the installation of the DMT blade did only have a neglegeable influence on the measurements lateron during pile installation. Finally a (DMT-1-C) test after installation of the pile at 1,5 times pile diameter out of the center of the pile was performed. The membrane is oriented towards the pile shaft.

For the orientation of the blade, one has two possibilities :

- radial position (membrane towards the pile). The advantage here is the direct measurement of horizontal stress variation. For large soil displacements, arching effect can occur around the blade.
- tangential position : the advantage is a smaller disturbance of the initial stress field around the pile. On the other hand as long as no clear relationship exists between the principle stress changes, the

interpretation of such DMT readings with tangential blade orientation mainly stays difficult.

The aim of this research program was to evaluate the effect of PCS pile installation, in sandy layers, on the surrounding soil stress field.

DISCUSSION OF THE TEST SITES

Doel-test site

The results of this test site, with all of the difficulties linked normally to each new research experience have been discussed in an earlier paper Peiffer et al (1991).

Dendermonde-test site

The results of the field tests are given in Fig. 1 a,b,c and 2.

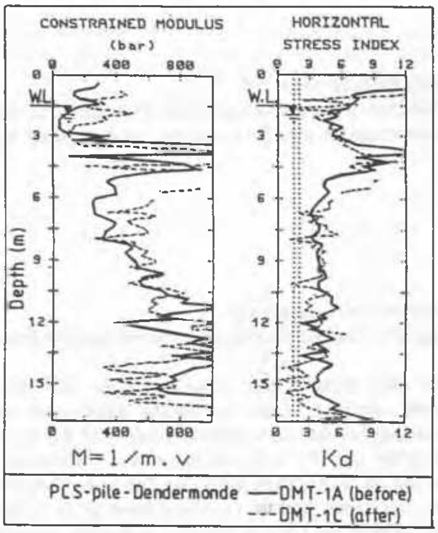

Fig. 1a. DMT-results at Dendermonde

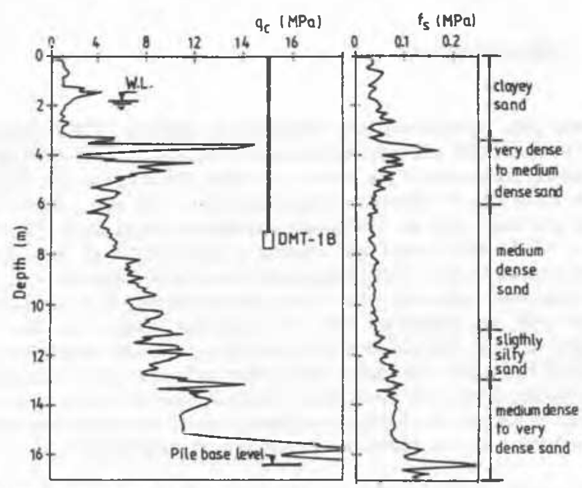

Fig. 1b. Initial CPT at test site

From the linearly increasing CPT in the sandlayers where the DMT (1-B) is installed, it becomes evident the sandlayer was normally consolidated. The starting DMT A-reading is sligthly higher than expected probably due to the local increased stress field around the blade. The DMT-membrane is directed towards the pile centre. The screwing-in energy resulting in

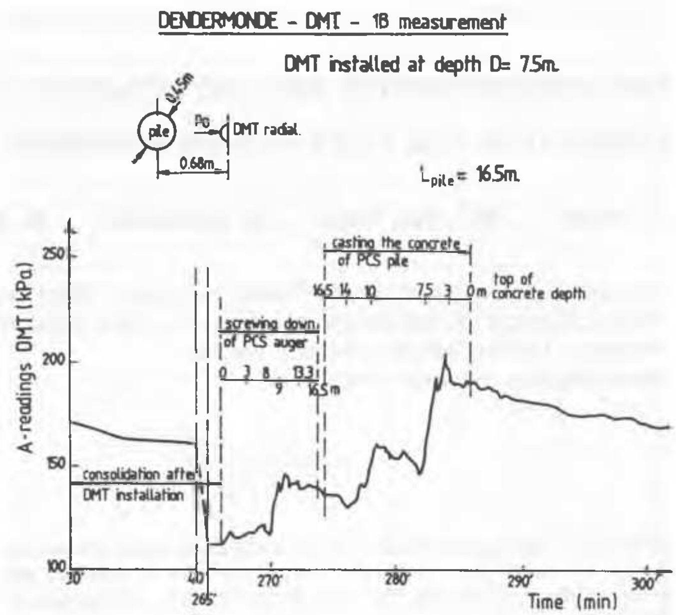

Fig. 1c. DMT-1B result at Dendermonde

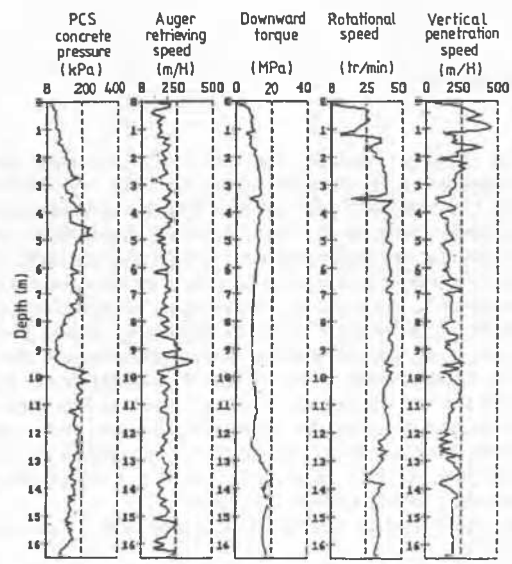

Fig. 2. PCS-pile installation parameters at Dendermonde test site

very high downward penetration in the cohesive top layers, induces excess pore water pressures and "heavy liquid pressures" which compensate a normally expected soil relaxation. When the auger passes by at DMT-level, the whole of the remoulded soil column along the auger being more or less in suspension, induces for the rest of the screwing down movement a remarkable total stress increase (water pressure increase). One so can easily explain an input of total stress increase of order of $\leq$ 30 kPa. Obviously, the water overpressure fades out with time. During the casting process the total stresses, induced by the fresh concrete are detected, expecially again starting at the level of the blade. The final DMT A-reading is apparantly flattening out at about 160 kPa, being almost 50 kPa higher than the starting value. From this point of view this pile system would be somewhat beneficial to the soil-condition. One however must be careful since only DMT A-readings, performed some days after pile installation would indicate reliable more results. In Fig. 2 DMT1-A/1-C one sees such difference between the DMT-test before and after full pile installation indicating that there is almost no change in horizontal stress index and constrained modulus.

Oudenaarde-test site

Two piles were examined at this site ; piles n° 205 and n° 207. The results are gathered in Fig. 3,4 and 5.

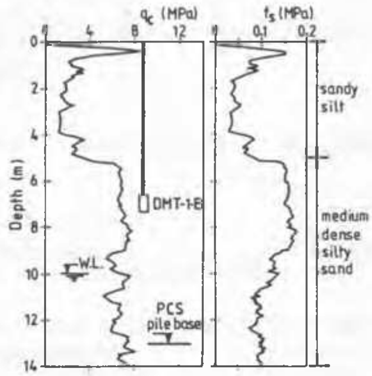

Fig. 3a. DMT-results at Oudenaarde

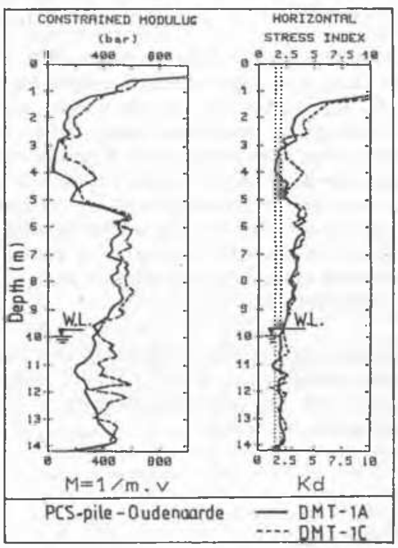

Fig. 3b. Initial CPT results at Oudenaarde

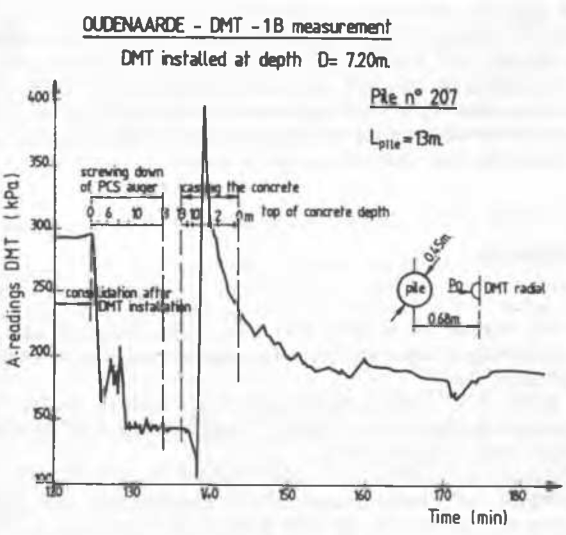

Fig.4a. DMT 1B pile n° 207 result at Oudenaarde

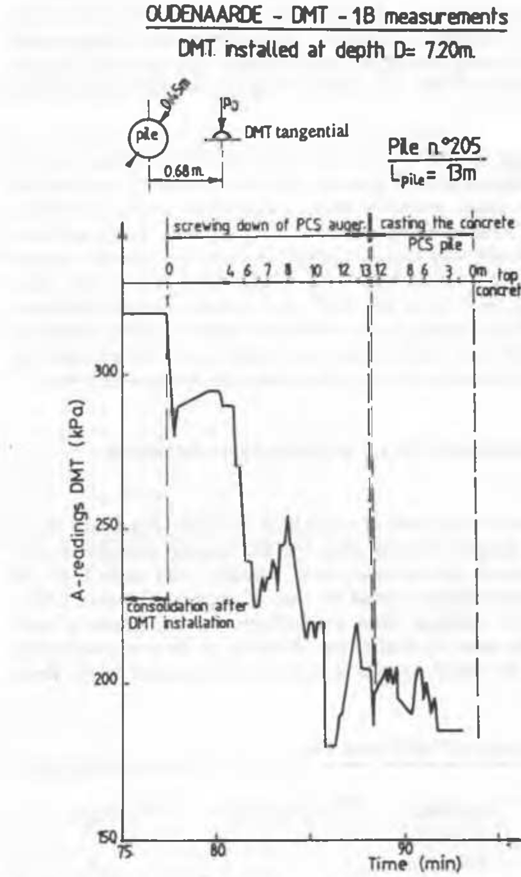

Fig. 4b. DMT 1B pile n° 205 result at Oudenaarde

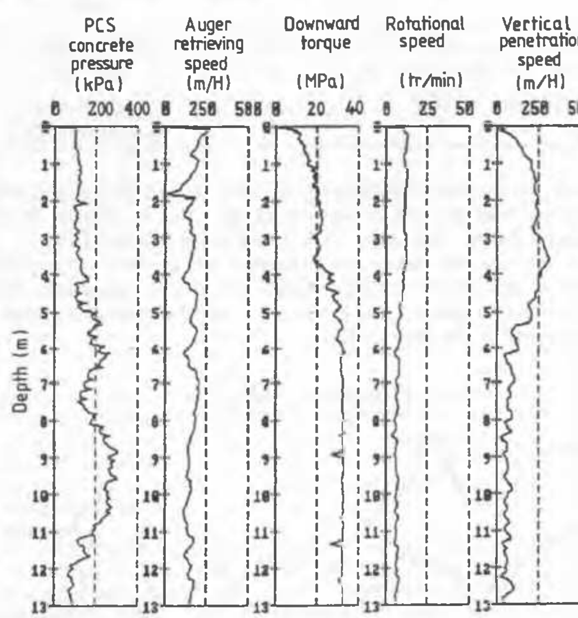

Fig. 5. PCS-pile n° 205 installation parameters recorded at Oudenaarde

From the Fig. 4b, the (tangential) DMT-1B analysis on pile n° 205 indicates that soil arching is built op gradually during screwing down of the auger, resulting in a general overall (gradual) decrease of the A-value with some peaks in between, probably due to collapses of former arches while the auger continues to penetrate. The further general decrease after DMT A-reading during casting the fresh concrete, only shows the gradual outfading influence of the soil arching with increasing fresh concrete weight.

From the readings for pile n° 207, with radial DMT-1B readings, a lot of interesting differences with the previous analysis are shown. Over the first five meters, the auger penetrates with a rather small torque, but with a high downward velocity through the loose silt/silty sand. This results this type of dry and only very slightly cohesive material in a dramatic decrease of the total stress combination felt by the DMT blade. The fresh concrete passing the level of the DMT, the concrete pressure influences tremendously the A-reading of the DMT-total stress in radial direction. Such overpressures are again fading out in time, partly compensated by the increasing fresh concrete weight above the DMT-measurement level.

CONSIDERATIONS ON PILE INSTALLATION EFFECTS

Our main interest in this kind of research is to finally understand much better the shaft capacity of screw piles. For this purpose, the pile installation effects have to be evaluated more carefully with respect to the effective soil stress changes around the shaft. Comparison between DMT-1-A and DMT1-C readings gives an indication for the degree of such stress changes in terms of total stress. Referring to the horizontal stress index (table 1), the results of such comparison are presented for the three test sites.

Table 1. Comparison of DMT-stress index

Site	Measured Concrete Overconsumption	$\frac{K_{D,after\ inst.}}{K_{D,before\ inst.}}$	Soil type
Doel	95 %	1,30	medium dense sand
Oudenaarde	28 %	1,20	medium dense sand (NC)
Dendermonde	16%	1,00	medium dense sand-slightly (OC)

Moreover, the increase of DMT-horizontal total stress in the top layer and the decrease near the pile tip are remarkable. This is dicussed in an earlier paper Peiffer, Van Impe, Cortvrindt, Van den Broeck (1991).
Because also the pile installation parameters are available, a proposal could be to calculate the idealized specific screwing-in energy Esc. The use of this specific energy value in relation to the pile installation parameters is sugested in Van Impe (1988).

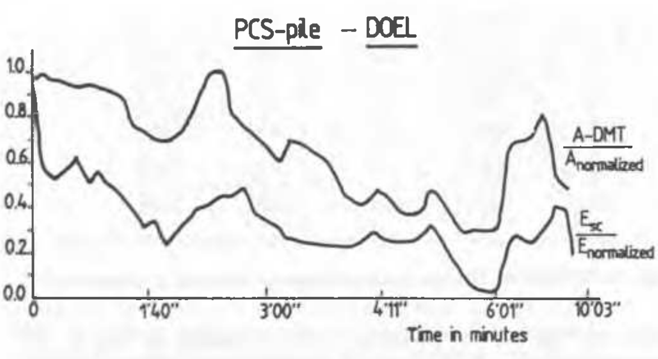

Fig. 6. PCS-installation energy function as compared to DMT A-readings

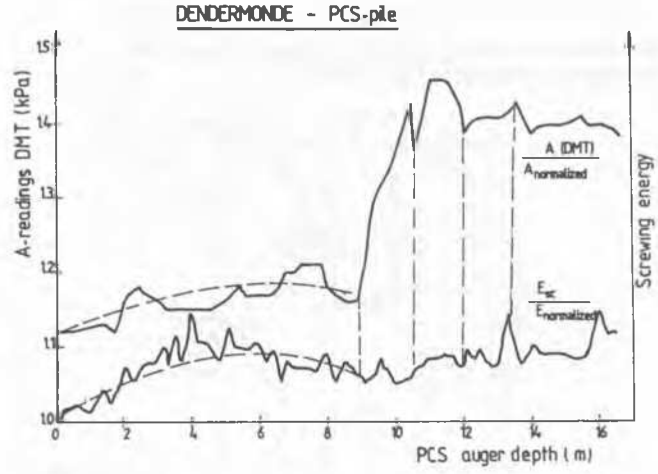

Fig. 7. PCS-pile installation energy and DMT A-readings as a funtion of time

The results of such Esc-data can either be presented in a time related diagram (Fig. 6 - Doel) or an auger peneatration depth diagram (Fig. 7 - Dendermonde). In these figures we can see a quite good agreement between DMT-A-readings and installation energy curves. For Doel, the input energy curve is even quite similar to the A-reading curve. Peaks of energy-input can also be found on the A-reading curve. For Dendermonde one sees clearly the effect of the energy-input on the horizontal stress state when the auger passes. One also can see the influence of execution time and time delays on the final stress-state. A similar analysis for Oudenaarde and also the evaluation of screwing out energy is discussed in Van De Velde, Van Hoye (1992).

The today's analysis in this research program is also going out from continuous pressure measurements at the DMT1-B blade during pile installation. Together with pile installation parameter, a more complete stress field analysis so became available.

CONCLUSIONS

In this paper the dilatometer is described as a tool that could help to evaluate the influence of pile execution parameters on the soil condition around the pile shaft. For PCS-piles some increase of horizontal stress is mainly dependent on the OCR, soil type, dilatant character of the soil, and predominantly on the installation details. It can be deduced that a too low auger penetration velocity and losses of time during installation can affect largely the final stress state around the pile.

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