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In-situ test campaign of vibrodriven sheet piles

Campagne d’essais in situ : vibrofonçage de palplanches

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ABSTRACT: An experimental test campaign was recently performed in the facilities of the BBRI to compare the dynamic behavior and the performances of different vibrodriven sheet piles. Within the framework of this in-situ test campaign, three types of sheet pile were instrumented and vibrodriven in homogeneous soil strata involving refusal conditions at a reachable depth. A continuous monitoring was conducted during the vibrodriving of all the sheet piles. The present paper describes the geotechnical context of the site, the preparation of the sheet piles, transducers and acquisition material, the vibratory hammer, the installation of the sheet piles and a summary of the results obtained during the test campaign. As a result of the test campaign, no fundamental difference was observed between the three types of sheet piles in terms of cumulative driving time and driving velocity curves. Moreover, as observed during the vibrodriving, irregularities in the measurements (deformations and accelerations) can often be explained by the monitoring of the holding back force applied by the crane operator to the head of the sheet pile. The influence of this parameter should always be regarded when comparing different vibrodriven sheet piles.

RÉSUMÉ : Une campagne d’essai *in situ* a récemment été réalisée au sein des installations du CSTC. L’objectif était de comparer le comportement dynamique et les performances de différents types de palplanches vibrofoncées. Dans le cadre de cette campagne d’essais, trois types de palplanches furent instrumentées et vibrofoncées dans un sol stratifié homogène impliquant l’obtention d’un refus à une profondeur atteignable. Un monitoring continu fut réalisé durant le vibrofonçage des palplanches. Le présent article décrit la géologie du site, la préparation des palplanches, des capteurs et du matériel d’acquisition, le vibrateur, l’installation des palplanches ainsi qu’un résumé des résultats obtenus durant la campagne d’essais. Comme observé durant celle-ci, aucune différence fondamentale ne fut constatée entre les différents types de palplanches testées en termes de courbes d’enfoncement en fonction du temps et de vitesse de pénétration. De plus, les irrégularités observées au niveau des mesures de déformation et d’accélération peuvent souvent être expliquées par le monitoring de la force de retenue appliquée par l’opérateur en tête de palplanche. L’influence de ce paramètre devrait toujours être considérée quand on compare les résultats du vibrofonçage de différents types de palplanches.

KEYWORDS: Vibrodriving, sheet piles, real-scale tests, in-situ test campaign, field test comparison, monitoring, holding back force.

1 INTRODUCTION

The first purpose of the present in-situ test campaign was the comparison of the dynamic behavior and performances of three different types of sheet pile (type AZ ArcelorMittal) with regard to their vibrodriveability. The tested sheet piles were the following types: AZ26-700, AZ26-700N and the new developed AZ25-800 model. For these sheet piles, a reference length of 22 m has been defined for the realization of the in-situ test campaign.

It was the aim to organize the test campaign on a field presenting homogeneous soil strata and involving refusal conditions at a reachable depth considering the reference length defined for the sheet piles (= 22 m). The purpose was to simulate the difficult conditions of driveability encountered in practice. For that reason, the test site of the laboratory facilities of BBRI (in Limelette) was chosen for the in-situ test campaign.

For each type of sheet piles (noted types 1, 2 and 3 for the sake of confidentiality), three similar double sheet piles were considered for the analysis and the comparison of their dynamic behavior:

- type 1: double sheet piles B, C and D,
- type 2: double sheet piles F, G and H
- type 3: double sheet piles J, K and L

In total, nine double sheet piles were therefore installed.

The characteristics of the sheet piles are given on the website of ArcelorMittal. The nine double sheet piles were delivered paired. In order to avoid uncoupling, the head of each double sheet pile was welded on two zones of 20 cm and the toe was also welded on 15 cm.

In practice, the installation of the sheet piles was carried out by the Belgian contractor Soetaert nv (of the Jan De Nul Group). The BBRI was in charge of the coordination of the test campaign and it was also responsible for the monitoring, the analysis and the report of the data.

The following paragraphs present the geotechnical context of the test site, the preparation of the sheet piles, transducers and acquisition material, the vibratory hammer, the installation of the sheet piles and a summary of the results obtained during the test campaign.

2 GEOTECHNICAL CONTEXT

As it was foreseen to install three groups of different sheet piles, one electrical CPT was systematically performed in the center of each group (CPT1 for the AZ26-700N, CPT2 for the AZ25-800 and CPT3 for the AZ26-700). Figure 1 presents the results of the CPTs with the stratification of the test site. As illustrated in Fig. 1, beyond 12.5 m, there is an increase of the cone resistance due to the penetration in the tertiary compacted Brusselian sand locally presenting hard quartz concretions. On the site, the water level can be found at great depth (~ 40 m). Additional information concerning the geotechnical context of the site of Limelette can be found in Van Alboom and Whenham (2003).

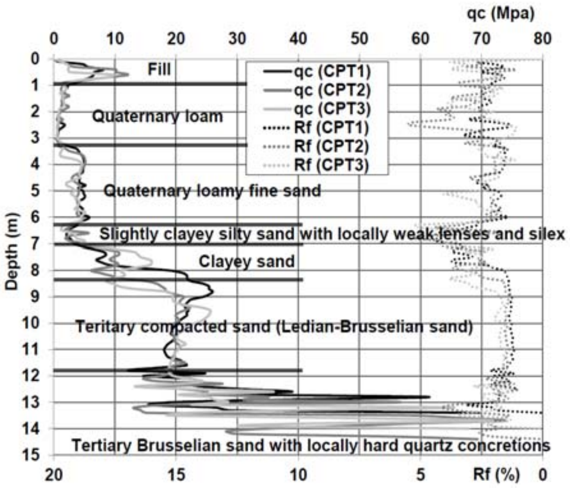

Figure 1. Results of the electrical CPTs 1, 2 and 3 with the description of the stratification encountered on the site of Limelette

3 PREPARATION OF THE SHEET PILES, TRANSDUCERS AND ACQUISITION

As illustrated in Fig. 2, the double sheet piles were marked every 25 cm in order to record their penetration. During the preparation, two accelerometers and two strain gages were fixed to the two elements of the double sheet pile as illustrated in Fig. 3. The strain gages were welded to the sheet piles and protected against humidity with a painted coating. These strain gages were mounted on the neutral axis of the two sheet pile elements to avoid the influence of bending effects on the deformation measurements. The accelerometers were bolted to the sheet piles with the help of threads previously performed in the steel (see Fig. 3). The accelerometers (types Deltatron and Bruël & Kjaer) and the strain gages (type TML) were mounted on the two sheet pile elements at a distance of 2.5 m from the top of the sheet pile. During the vibrodriving, the holding back force exerted by the crane operator on the vibrator was measured by means of a force transducer designed by the BBRI (see Fig. 4).

Figure 2. Marking of the double sheet piles before installation

The sheet pile penetration was manually (with a chronometer) and continuously recorded with a numeric camera focusing on the penetration of the sheet pile at the surface of the soil.

The following acquisition material was used for the measurements:

- accelerometers by means of the NI-SCXI 1100 system: sample rate of 1 kHz
- strain gage transducers by means of the NI-SCXI 1520 system: sample rate of 1 kHz
- TML TC 32K to register the holding back force: sample rate 1 Hz

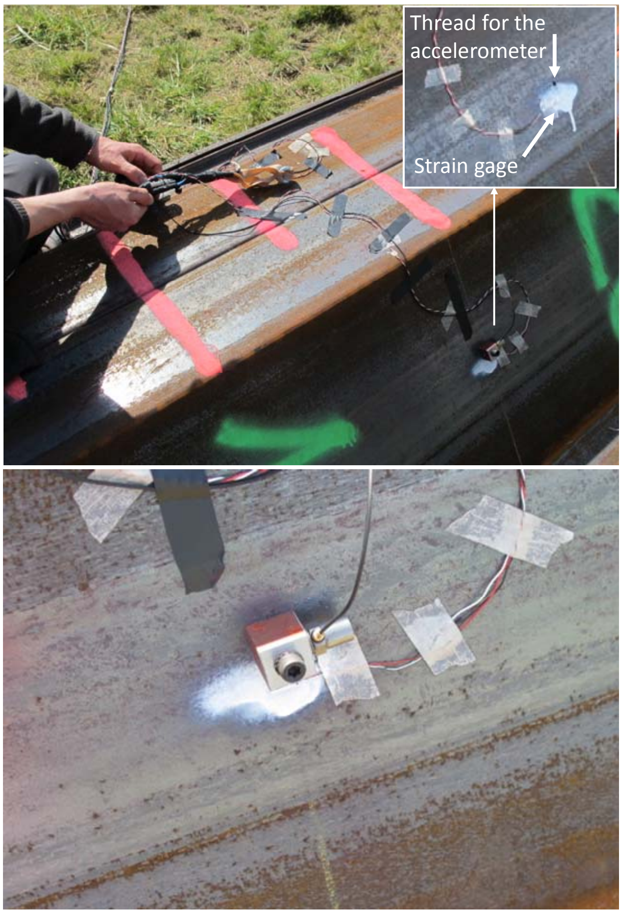

Figure 3. Instrumentation setup on the sheet piles

Figure 4. BBRI holding back force transducer as used during the test campaign

4 INSTALLATION OF THE SHEET PILES

During the in-situ test campaign, the nine double sheet piles were firstly vibrodriven until a refusal depth was reached. Afterwards, they were impact driven with an IHC hydraulic hammer. The nine double sheet piles were finally extracted from the soil by vibro-extraction. In this paper, only the vibrodriving stage is reported.

Vibrodriving was performed by a high frequency vibrator with variable eccentric moment type Dieseko PVE 40VM equipped with two clamps (double clamp option) such as illustrated in Fig. 4 (left). During this operation, the sheet piles were guided into the ground with the help of steel beams (see Fig. 5). During the vibrodriving, the following measurements were recorded for all the double sheet piles:

- the vertical deformations at the head of the double sheet pile by means of the strain gages installed on the two sheet pile elements (see Fig. 3),
- the vertical acceleration of the vibrator by means of an accelerometer vertically mounted on the vibrating part of the vibrator,
- the vertical acceleration of the double sheet pile with two accelerometers installed on the two sheet pile elements (see Fig. 3),
- the holding back force exerted by the crane operator,
- the penetration velocity of the double sheet pile.

Figure 6 illustrates the vibrodriving of the last double sheet pile on the site of the BBRI.

Figure 5. Steel guide used during the vibrodriving phase of the test campaign to guide the sheet piles into the ground

Figure 6. Vibrodriving of the last double sheet pile with the vibrator type Dieseko PVE 40VM on the site of the BBRI

5 SUMMARY OF THE DATA MONITORED DURING THE VIBRODRIVING

This paragraph summarizes the data monitored during the vibrodriving of the nine double sheet piles. Figure 7 gives the penetration logs of the nine vibrodriven double sheet piles. The mean of the point resistances of the electrical CPT's performed on the site is also given for the sake of interpretation. As observed in Fig. 7, the penetration logs are comparable. The variability encountered for one type of sheet pile (see sheet pile type 3) is greater than the variability encountered comparing two different types of sheet piles.

Figure 8 presents the mean values of the penetration logs for the three types of sheet pile. As only monitored from 3m depth, the double sheet pile B is not considered for the computation of the averaged values. Considering the three curves of Fig. 8, no fundamental difference is observed between the three types of sheet piles: the cumulative time curves are comparable. This comparison can be established without any consideration of the frequency influence. Indeed, the frequency monitored (on the vibrator and on the sheet pile itself) during the vibrodriving of the nine double sheet piles was always close to 33 Hz which corresponds to the nominal working frequency of the vibrator Dieseko PVE 40 VM. During the vibrodriving of the nine double sheet piles, the deformations of the steel sheet piles (monitored by means of the strain gages) always remained in the field of elastic strains with a large safety margin.

As observed in Fig. 7, the shape of the penetration logs on the first meters for the sheet piles D and L slightly differs from the other curves. This is the influence of the holding back force applied by the crane operator on the vibrator. That effect is illustrated in Fig. 9 for the double sheet pile D.

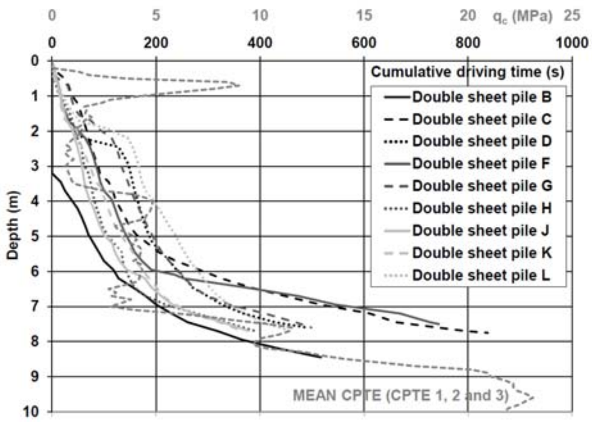

Figure 7. Cumulative vibrodriving time vs. depth for the nine vibrodriven double sheet piles

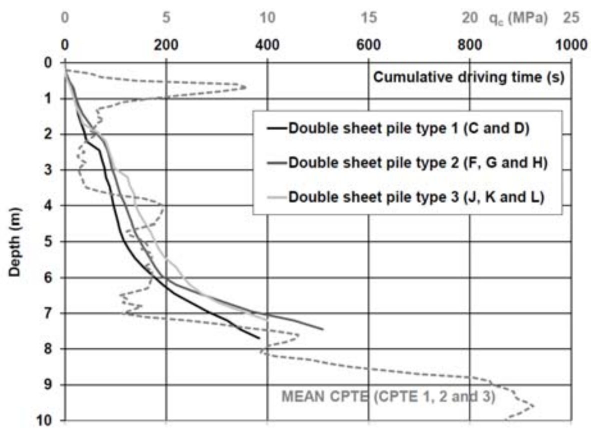

Figure 8. Mean cumulative time vs. depth for the three types of sheet piles vibrodriven on the site of Limelette

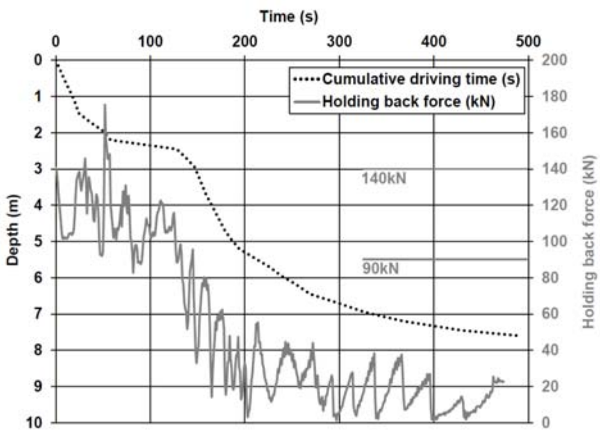

Figure 9. Influence of the holding back force applied by the operator on the vibrator on the shape of the penetration log for the double sheet pile D

In Fig. 9, the limit of 140 kN represents the static weight of the vibrator (including the clamp) and of the double sheet pile. The limit of 90 kN represents the static weight of the vibrator including the clamp. Considering the nine double sheet piles vibrodriven on the site of Limelette, the crane operator generally applied a holding back force greater than 100 kN on the first meter. Once the double sheet pile is installed (generally about 3 m) into the ground, this holding back force decreases and varies but staying smaller than 50 to 60 kN until the end of the vibrodriving process. In the case of the double sheet pile D, one can observe that during the two first meters, the holding back force applied by the operator was close to the static weight of the vibrator and the double sheet pile. The shape of the penetration log is therefore a direct consequence of this high holding back force preventing the free sinking of the double sheet pile in the ground. The irregularities in the other measurements (deformations and accelerations) can often be explained by the monitoring of the holding back force. A shock caused by the sudden application of a large holding back force is directly "felt" by the transducers (accelerometers and strain gages) attached to the double sheet pile.

As observed on other construction sites, another influencing factor is the use of the steel beams (see Fig. 5) to guide the double sheet pile vertically into the ground. An important friction between these steel beams and the sheet piles is sometimes observed during the vibrodriving resulting in a decrease of the penetration velocity. In the present test campaign, the free motion of the sheet piles between the steel guides was continuously verified during the vibrodriving phase.

Figure 10 gives the driving velocity log for the nine vibrodriven double sheet piles. The mean of the point resistances of the electrical CPT's performed on the site is also given for the sake of interpretation. Figure 11 presents the mean values of the driving velocity logs for the three types of sheet pile. Considering the three curves of Fig. 11, no fundamental difference is observed between the three types of sheet piles: the driving velocity curves are comparable.

6 CONCLUSION

As noted during the in-situ test campaign, no fundamental difference was observed between the new developed AZ 25-800 model and the existing AZ 26-700 and 26-700N in terms of penetration logs and driving velocity curves. Moreover, irregularities in the measurements (penetration, deformation and acceleration) can generally be explained by the monitoring of the holding back force applied by the crane operator to the head of the sheet pile. The influence of this parameter should always be regarded when comparing different vibrodriven sheet piles.

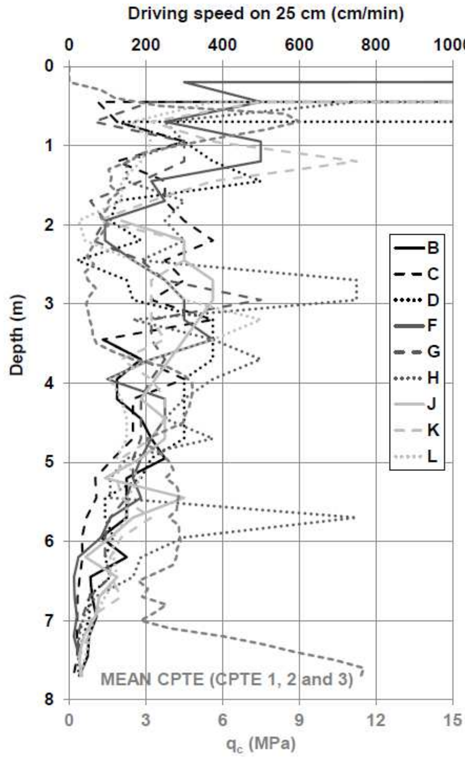

Figure 10. Driving speed on 25 cm vs. depth for the nine vibrodriven double sheet piles

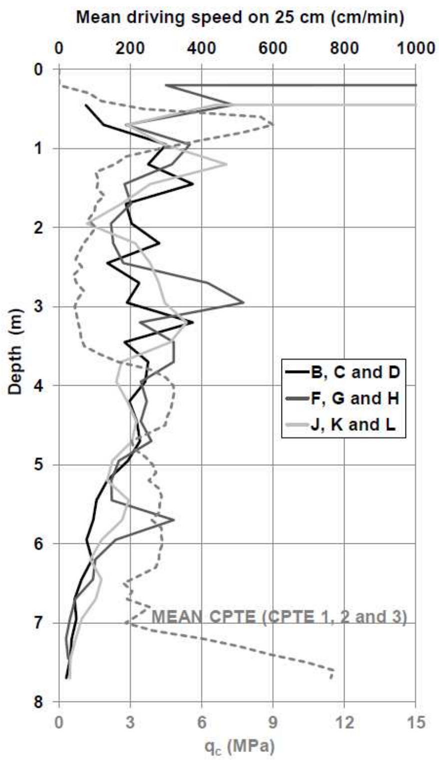

Figure 11. Mean driving speed on 25 cm vs. depth for the three types of sheet pile vibrodriven on the site of Limelette

7 REFERENCES

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