The use of conventional interpretation methods for determining the capacity of piles

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ABSTRACT

The paper presents discussions of the bearing capacities of precast concrete joint piles from construction site of the port of Prorva located in the West Kazakhstan. Kazakhstan is the world's ninth biggest country by size and the largest landlocked country, and it is the essential transportation hub between Russia, Central Asia, China and Europe. According to the design drawings, new Cargo offloading facility (COF) construction site was planned to be installed by precast concrete joint piles (PCJP). PCJPs were composed of two segments with cross-section of 40 cm × 40 cm with the length of bottom segment 16.0 m and upper segments 9.5 and 11.5 m. The conventional interpretation methods were applied to load-settlement curves obtained by static loading tests. The analysis showed the highest pile capacities from the Chin interpretation and Decourt extrapolation methods. The results from De Beer, Davidson and Fuller & Hoy interpretation methods were similar. The result from Butler & Hoy interpretation method was found similar to the ones obtained from pile driving analyzer and APILE analysis. The pile capacity obtained by Kazakhstani standard method was slightly higher, however is still applicable. The consequentially performed procedures described in the paper may serve as practical guideline for assessing capacities of considerable amount of driven piles.

Keywords: pile loading test, interpretation methods, APILE, PDA, pile capacity

1 INTRODUCTION

COF is going to be an essential strategic project for the expansion of oil fields. Its construction started in the second half of 2016 and continues at present time. COF is located along the quay and represents a special reinforced concrete surface supporting the large cranes needed to unload cargo handling bulky and general cargo. Sheet pile walls surrounds COF surface. According to the design drawings, COF construction site was planned to be installed by precast concrete joint piles (PCJP). This was the first experience of installing such type of piles in Kazakhstan. Applying PCJPs for the first time demanded a comprehensive approach. Therefore, it was decided to first conduct their tests in a pilot site.

Geotechnical survey results (field SPT tests and boreholes) showed that the soil conditions at the COF area might result in difficulties with installation of the prefab concrete piles which support the relief decks. Given the soil profile it is expected that pre-augering (or other measures) must be applied to reduce risks on pile damage and delays during pile driving. In this TN the necessity of these measures is determined by pile driveability analysis and the impact of these measures is investigated as well. Result is a stepwise procedure of the pile installation to be undertaken if driveability is found to be difficult.

PCJPs were composed of two segments with cross-section of 40 cm × 40 cm with the length of bottom segment 16.0 m and upper segments 9.5 and 11.5 m. The head of bottom segment and the bottom of upper segment had steel plates, which had jointing and locking mechanisms. Piles were coated by corrosion protection material (bituminous) and marked by cross-lines every 0.25 m. Before driving the bottom segment, the pile top was attached by nylon plate (Emeca) with yield stress of 72 MPa and thickness of 6 cm. The hammer helmet was attached by wooden plate. Both plates were needed to preserve pile head in a good condition (Zhussupbekov et al. 2017; Zhussupbekov et al. 2018).

2 GEOLOGICAL STRUCTURE

Field Standard Penetration (Further - SPT) tests were carried out in Construction site Prorva. SPT 1520, 1523 , 1524, 1526, 1527 and 1528 are used for the pile design calculations, because these are near the relief decks. When SPT blowcounts reach 100 blows (for soft rocks), the test is stopped and reported as refusal. The exact number of blowcounts required to penetrate the soil is therefore unknown at several locations and can easily be higher than reported. This is the case for the SPT's at the COF as well. SPT blowcounts were maximized at 100 blows (N). When transferring blowcounts N to normalized blowcounts (N60), this number is increased up to 122. The location of the

SPT's is presented in Figure 1.

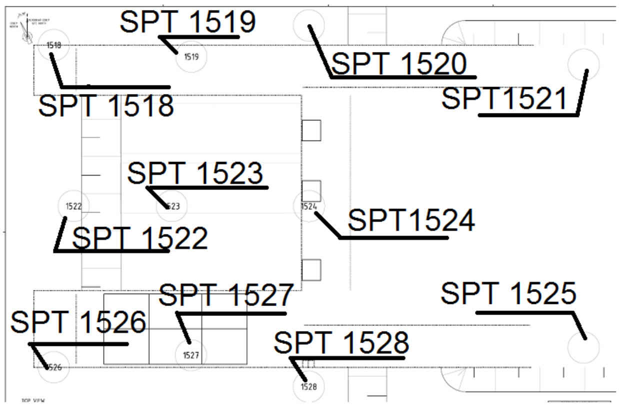

Fig. 1. Location of the SPT's.

Therefore a spliced pile is applied: two sections, one with a length of 6.5 m and one with a length of 16 m long. For practical reasons the blowcount is limited to 100 bl/25cm. If the blowcount is higher than 100 bl/25cm, then the driving process becomes ineffective and pile damage is likely to occur, resulting in the inability to reach target depth. In Figure 2 to Figure 4 the results are presented relative to the penetration depth.

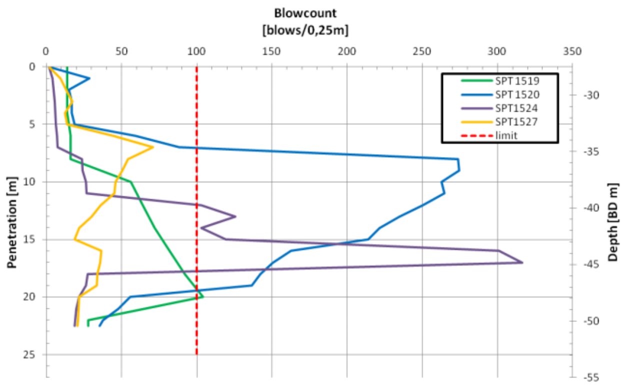

Fig. 2. Blowcounts per SPT.

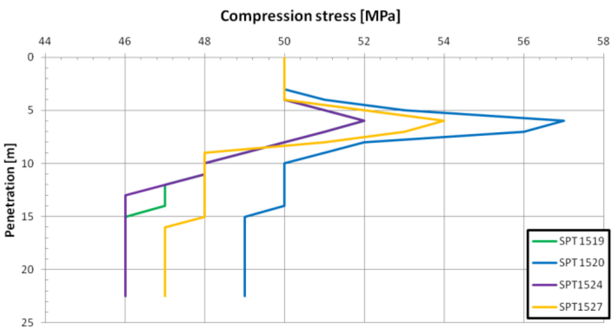

Fig. 3. Compression stress per SPT.

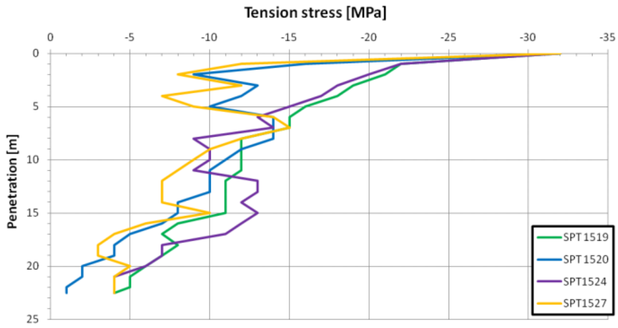

Fig. 4. Tension stress per SPT.

The indicative driveability analysis results in the following findings:

The current pile design will not reach the required depth without exceeding allowable compressive and tensile stresses, therefore an increase of pile reinforcement is required for a feasible design.

Blowcounts are far above 100 with SPT 1520, 1519 and 1524, which shows that for the SPT's which have layers that are maximised at 100 blows the target penetration of the piles can not be reached. Therefore driving the piles till the necessary depth is considered not feasible (Zhussupbekov et al. 2017; Zhussupbekov et al. 2016).

3 PILE DYNAMIC AND STATIC LOAD TESTS

3.1 Dynamic test by Pile Driving Analyzer (PDA by ASTM)

The dynamic tests of PCJPs were carried out by PDA – Model PAX using piling machine JUNTTAN PM25LC that had a hydraulic hammer HHK-9A with a weight of 9 tons and a 990 kg head-cap. The tested PCJPs were attached by pair of accelerometers and strain transducers in a distance of two widths below the pile head. The sensors were connected to PDA via special cables. PDA internally performs all the necessary signal conditioning and processing to obtain output results during driving. For each hammer blow it immediately displays on the monitor screen the measured force at the pile head (Fmeasured(t)) and pile head movement velocity (vmeasured(t)) as a function of time. After accomplishment of dynamic tests, acquired data was analyzed by Case Method & iCAP® in the software PDIPLOT2, Ver 2016.1.56.3 (Zhussupbekov et al. 2015; Zhussupbekov et al. 2016).

3.2 Static loading tests (SLT by ASTM)

SLTs of PCJPs were carried out according to the requirements of ASTM D1143 – Standard Test Methods for Deep Foundations Under Static Axial Compressive Load.

Three SLTs were conducted with maximum load of 3278 kN at construction site Prorva.

Table 1 include test information for construction site Prorva.

Table 1. Pile load test information at construction site.

Pile ID	A1	A2	A3
Cross-section, cm	40x40	40x40	40x40
Length, m	25.5	27.5	25.5
Penetration length	24.25 m	26.25 m	22.5 m
Type of boreholes	Pre-augering diam.330 mm, l=12 m	Pre-augering diam.330 mm, l=12 m	Pre-augering diam.330 mm, l=9 m
Maximum load, kN		3278	
Max. settlement	20.0 mm	34.04 mm	31.53mm

3.3 Pile Bearing Capacities from Interpretation Methods

An estimation of the bearing capacity of tested PCJPs was performed by the following methods: Davisson, Chin, De Beer, Fuller and Hoy, Butler and Hoy, and Decourt Extrapolation.

Figure 5 includes the final analyzed load-settlement curves, acquired by Davisson method. Here, the bearing capacity is defined as the value of load, coincident to the cross-section of the curve with a line that is parallel to the tangent to the curve, and which is in a certain distance – offset limit, or Davisson's limit. Davisson's limit value is defined as a value of load corresponding to the movement, which exceeds the elastic compression of the pile by an offset value of 3.8 mm plus a factor, equal to the diameter of the pile divided by 120. For example, pile with diameter of 566 mm (cross-section 400x400) would have the value of movement, equal to 8.52 mm. Davisson limit was developed in conjunction with the wave equation analysis of driven piles and has gained widespread use in course of time with the increasing popularity of this method of analysis (Zhussupbekov et al. 2016;).

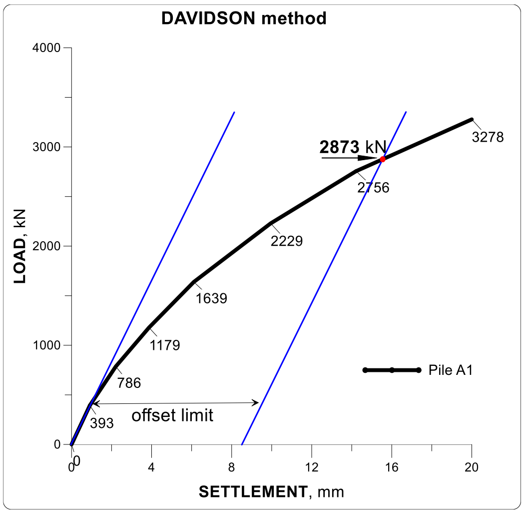

Fig. 5. Pile capacities interpreted by Davidson Method.

In the method of Chin, each settlement value is divided with its corresponding load value. The resulting value is plotted against the settlement and a trend line is drawn on the plot (see Figure 6).

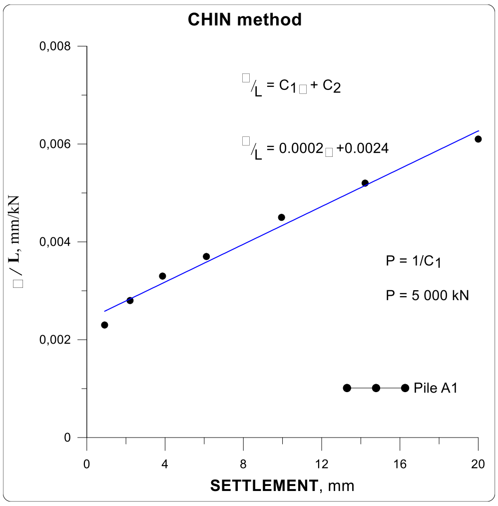

Fig. 6. Pile capacities interpreted by Chin method.

Figure 7 illustrates a simple definition, proposed by Fuller & Hoy (Fellenius, 1980; Fellenius, 2001). The pile capacity is equal to the test load for where the load-settlement curve is sloping 0.14 mm/kN.

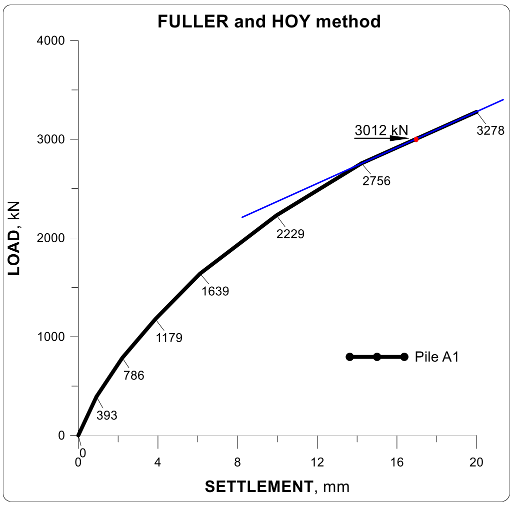

Fig. 7. Pile capacities interpreted by Fuller&Hoy method.

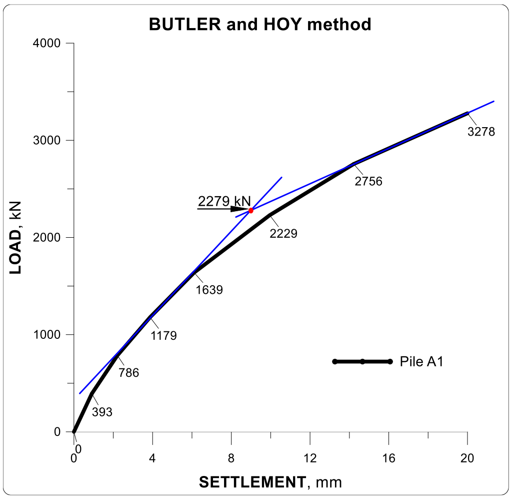

Fig. 8. Pile capacities interpreted by Butler & Hoy method.

Figure 8 also shown a development of the above definition proposed by Butler & Hoy defining the pile capacity as the load at the intersection of the tangent sloping 0.14 mm/kN, and the tangent to the initial straight portion of the curve, or to a line that is parallel to the rebound portion of the curve (Reese et, al. 2007).

3.4 Pile Capacities from APILE Analysis

The physical and mechanical characteristics of soil layers of the construction sites A and B represented an initial data for APILE analysis and were inserted into the APILE Plus software. Table 2 illustrates each PCJPs capacity values acquired from all four APILE analysis methods, as well as their averaged values.

Table 2. Results of ultimate capacity from APILE.

Methods	A1, kN	A2, kN	A3, kN
API	2430	2744	2130
FHWY	2314	2521	2108
Army Corps	2332	2572	2092
Lambda	2088	2337	1848
Average	2291	2544	2045

4. CONCLUSIONS

The bearing capacities of PCJPs under the ultimate and working loads in the COF Project in West Kazakhstan were examined using interpretation methods. Their results were compared to those obtained from PDA, APILE analysis and hand calculations according to Kazakhstani standards.

For the ultimate load, it is found that the Chin and Decourt methods present the highest values for both sites A and B. De Beer, Davidson, and Fuller and Hoy methods were more or less similar in the site A. In the meantime, results from Butler and Hoy method in site A was almost similar to the ones from PDA and APILE analysis, which cannot be said about the site B. Hand calculation presented second highest result for both sites after the Chin and Decourt methods, nevertheless is still rational to apply.

For the yield load, all interpretation methods except Chin and Decourt gave lower predictions. It is reasonable, because the results from PDA, APILE analysis and hand calculation are appropriate for ultimate bearing capacity prediction.

The bearing capacity of precast concrete joint piles was determined from APILE by using engineering-geological data of the object. According to the analysis, we can observe the similarity of the obtained data with the results from the PDA, hand calculation and interpretation methods. There were revealed insignificant differences related to bearing capacity of the piles under the ultimate load 3278 kN.

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