The applications of dynamic and static piling tests of Astana

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ABSTRACT

This paper includes the short summary about dynamic and static tests by driven piles (cross-section 30×30 cm and length of 12 m). The definitions methodologies of the pile bearing capacity by aforementioned methods were also given. As an example for those methods, paper describes the results of the dynamic, static and the new in Astana PDA (Pile Dynamic Analyzer) tests of soils by piles performed in the construction site of the “New Railway Station” (Fig. 1). The possible depth of penetration and piles bearing capacity were determined according to the results of tests, as well as the recommendations for the device of working piles of construction project were issued.

Keywords: Foundation pile, static and dynamic vertical load tests, load-displacement curve, PDA test

1 INTRODUCTION

The new train station of Astana capable of servicing 12,000 passengers a day will be located near Mynzhyl'dyk alley west of Khan Shatyr shopping mall and Kabanbai batyr street. The construction is going to be finished before the international exhibition EXPO-2017 to be held in Astana in summer. The building presented by reinforced concrete structures. Totally building area is 84000m². The railway station will be built using green technologies, for example, it will have energy-saving lifts and escalators, heat exchangers as well as solar batteries and geothermal power generators, which is very relevant given the fact that the theme of the upcoming EXPO-2017 in Astana is Future Energy.

2 SITE DESCRIPTION

Fig. 1 shows the plan of the building, locations of the boreholes, positions of CPTs and the tested piles. The building presented by reinforced concrete structures. Totally building area is 84000m².

Field tests carried out in accordance with requirements of GOST 5686 "Soils. methods of the field tests by piles" and definitions of bearing capacity of the piles in accordance with requirements of SNIP RK 5.01-03-2002 "Pile foundations", ASTM D4945-89 – Standard test method for high-strain dynamic testing of piles and Eurocode 7.- Designing bases, foundations and underground structures.

Fig. 1. a) Master plan of Railway station, b) Cross section of station

3 SOIL PROFILE, RESULTS OF SOIL TESTS AND CPT

Fig. 2 shows the results of the oedometer tests, axial stress σ_a versus axial strain ε_a . The one-dimensional deformation modulus, $E_c = \Delta\sigma_a / \Delta\varepsilon_a$, was estimated from the stress range from 0.1 to 0.3 MPa.

Fig. 3 shows soil profile, distributions of the natural water content (w_n), and the natural void ratio (e_n). The results of CPTs, the cone tip resistance (q_c), and the sleeve friction (f_s) are also indicated in the Fig. 4.

Fig. 2. Results of oedometer tests

Fig. 3. Distribution vertical stress, water contents and void ratio through the depth.

Fig. 4. Results of CPT 1

3.1 Rigid Plate Load Test (Soil testing by vertical static loading).

Totally 2 tests (1 test in BR04 (303-14) and 1 test in BR17 (306-14) at a depth of 12 m) had been made. Diameter of the plate $D = 276.4$ mm and area $A = 600\text{mm}^2$.

Fig. 5 shows the result of RPLT tests of BR 04 and BR 17.

Fig. 5. Load-settlement diagram from RPLT results

Modulus deformation of soils in BR04 - 20MPa and BR17 - 22MPa.

4 METHODOLOGIES OF THE PILED FIELD TESTS

4.1 Dynamic load test (DLT)

All the reinforced concrete piles having a width $b = 0.3\text{m}$, area cross-section $A = 0.09\text{ m}^2$, length $L = 12\text{m}$, weight - 2730 kg, modulus of elasticity $E_p = 27500\text{ MPa}$, and density $\rho_p = 2500\text{kg/m}^3$.

In Kazakhstan, DLT is carried out by using different types of pile driving machines and hammers. Before starting the test, pile surface along the whole length had been painted through each 1 m by marks; last one meter is painted through each 0.1 m.

For our project pile driving was performed by using the driving machine "Junttan PM-25" with hydraulic

hammer HHK-7A. The weight of the hammer is 7000kg and the headband weight is 990 kg.

During the pile driving process (Fig. 5) the number of blows of the each 1 meter of pile penetration into the soil ground and of the last one meter in each 0.1 meter were counted. The falling heights of blowing part of the hammer were recorded at the same time. Pile driving was continuing till the design refusals - 0.5cm (cm/blow).

The highest average refusal received during the re-driving of piles after their "rest". These values of refusals had been used for determination of bearing capacity of piles. According to SNIP RK 5.01-03-2002. "Pile foundations", the rest time for the piles immersed into clayey soils should be 6 days.

Re-driving of test piles was carried out sequentially by three and five hammer' blows. The strain gauges with the length of 10 cm were attached on top of the piles before starting re-driving. Strain gauges had been fixed on 60 cm from the pile head.

It is common practice to use the following driving equation to estimate the driving resistance (ultimate pile capacity), F_u , in Kazakhstan (GOST 20176):

$$F_u = \frac{\eta AM}{2} \left[\sqrt{1 + \frac{4Ed(m_1 + \varepsilon^2(m_2 + m_3))}{\eta AS(m_1 + m_2 + m_3)}} - 1 \right] \quad (1)$$

where η - coefficient dependent on the concrete strength of the piles 1500 kPa, A - cross sectional area of pile, M - coefficient (1.0 for hammer impact), E_d -potential energy of hammer-WH-hammer weight, H -fall height of hammer, $h=0.7$, S -set per blow, ε -coefficient of restitution, m_1 -total mass of hammer device, m_2 - total mass of pile and pile cap, and m_3 -mass placed between pile head and pile cap.

Allowable bearing capacity of the piles with an allowance for safety factor (FS=1.4) equal to 540 kN.

4.2 Pile Dynamic Analyzer (PDA)

Fig. 6 presents the monitoring results of PDA test showing pile dynamic compression and tension stresses, static pile capacity and blow counts versus pile penetration depth. CAPWAP analysis results (Fig. 6) that include plots of measured pile head data obtained under the hammer blows from the end of driving and associated simulated pile head and toe static load-movement relationships are presented in the Fig.7.

Allowable bearing capacity of the piles with an allowance for safety factor (FS=1.4) equal to 714 kN.

Fig. 6. Load-settlement diagrams for the determination of bearing capacity of the piles in PDA

4.3 Results of static load tests (SLT)

Static load tests carried out for two piles on the construction site. The measured relationships between the pile head load, P_h , and the head displacement, S_h , of the test piles are shown in Fig. 7. It is seen from Fig. 7 that the load-displacement curves of piles No.3 and No.24 are almost identical, having an ultimate shaft capacity of 920 kN (No.3) and 825kN (No.24).

In Kazakhstan, a safety factor of SLT is 1.2. Therefore, the design value of the allowable piles capacity, Q_d , was estimated to be $Q_d = 920/1.2 = 767$ kN (No.3) and $825/1.2 = 687.5$ kN (No.24).

According to SLT result, the load-settlement diagrams were drawing (Fig. 7) and compared with PDA results (Fig. 8).

Fig. 7. Load-settlement diagram from SLT results

For the comparative criteria of SLT and PDA results fixes settlement of 4.6mm had been taken.

Fig. 8. Comparisons of SLT and PDA load-settlement diagrams

Table 1 presents a comparative analysis of the bearing capacity of piles, obtained by different methods in this research.

Table 1. Different tests

No	Name of methods	The value of the bearing capacity of piles, Q_d (kN)	Conditional criteria of comparison, %
1	PDA	714,3	100
2	DLT	540	75,6
3	SLT 1 (No.3)	767	107,4
4	SLT 2 (No.24)	687,5	96,2

5 CONCLUSIONS

1. According to the results of DLT of driven piles (30 × 30 cm and length of 12 m) the bearing capacity of the piles amounted to be 540 kN.

2. The bearing capacity of driven piles according to the results of SLT1 and SLT2 amounted to be 767kN and 687.5kN.

3. According to the results of PDA bearing capacity of the piles are equal to 714.3kN.

4. PDA dynamic test shown more coincide with SLT result than traditional DLT test.

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