The experience of piling tests on Astana LRT construction site

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ABSTRACT

The article considers the project a light rail LRT on problematical soils of Astana. This article includes a summary of Champ integrity and also static tests of bored piles. As an example of these methods, the results of the Champ integrity test of teamwork and piles of soil carried out on the construction site. Bored piles which have diameter 1200 mm and 8 and 11 m depths have been executed at the for construction site LRT. Some of the requirements of the designer of piled foundations and to what extent the accessible testing methods comply with these requirements are considered. Finally, some recommendations are made for testing methods suitable for problematical ground conditions of Kazakhstan are introduced. This paper presented a short description of changes to the concept of Kazakhstan pile foundation design and to use Champ integrity pile test and static load tests. Design bearing capacity of piles is 4500÷9500 kN. The results can be used to interpret real site data. Finally, some recommendations are made for testing methods suitable for problematical ground conditions of Kazakhstan are introduced.

Keywords: pile, SLT, Cross Hole Analyzer, LRT, Champ

1 INTRODUCTION

Astana LRT Phase I Project starts from Astana International Airport and ends at the new train station, the viaducts in the section are 21.572km long, and the length of viaducts at entrance access is 537.313m in total and 18 elevated stations are set (see Figure 1). The line starts from International Airport 101 Station and is laid northwest along the south side of Section A of Qabanbay Batyr Ave. (green belt). It turns to north in the Astana Star Monument, crosses Qabanbay Batyr Ave. to the east side of its Section B and then subjects to continuous laying northwards along this road, passing Nazarbayev University , Expo Park, Skiing Gymnasium, Astana General Hospital, etc. successively (Zhussupbekov, A., et al. 2017,).

Fig. 1. Planned Astana LRT network.

2 ENGINEERING AND HYDROGEOLOGY

Astana City is located on the hilly Puliyexi'er Plain with an altitude of 340-360m and an area of 300km2.The proposed site is located in the south of Astana city and the middle-upper part of diluvia plain of Ishim River. It is flat in general, but low in southwest and slightly high in northeast. The ground elevation is about 345~360m.

In Astana the climate there is typical temperate continental climate with cold, long and less-snowy winter; Generally , it starts to snow in mid-November , the snow cover period lasts 130~140 days, and 5~5.5 months in winter, 245 days in same years, the average temperature in January is -17, the absolute temperature in the coldest winter ever was -52℃ . The average snow thickness in many years is 30cm. Astana has burning hot, drought and rainless summers with an average temperature of 20.4 in July, the maximum temperature ever was 42 ℃ , and the average temperature in many years is about 1.8℃.

The river flowing through the field of Astana city is 170 km in length and 7400 km^2 in drainage area. Ishim River in the field of Astana city has two branches. Vyacheslav reservoir was built at 70 km on the upstream. Ishim River is seasonal river and snowmelt is the main supply source. Generally, the snow water starts melting from early April and quickly flows into watercourse, with the annual runoff of 87-92%. The interval of exceeding warning water level is 10-12 years and generally the time exceeding the warning water level by 0.4-0.6 m is 2-3 days. The maximum flow rate of the river water reached 1200m^3/s (1948 year). The average low flow of upstream reservoir is 0.29 m^3/s. In flood period, the minimum flow rate is 0.03-0.76 m/sand the average flow rate is 0.05-1.5 m/s.

The artificial filling layer, which is relatively poor and uneven in mechanical property , low in bearing capacity and high in compressibility , cannot be directly adopted as supporting layer of natural foundation prior to treatment. The (③) major layer of quaternary deposit is uniform and compact in soil texture and ordinary in engineering property. Completely-weathered argillaceous sandstone (⑤ 1) layer: the sound is hoarse with hammering identification in the open air, it is free from spring back and can be crumbed with hand, the structure construction has been completely damaged and disintegrated or decomposed into loose soil, the mother rock mineral has weathered and alternated into secondary mineral, it contains high volume sticky clay lumps, its physical and mechanical property is similar with that of sandy soil. When it is used for the soil layer of pile foundation side wall, the side friction is superior to that of sandy soil of quaternary deposit, and may be adopted as supporting layer of pile side. Strongly-weathered sandstone (⑥) layer: the rock is cataclastic, the protolith structure construction is damaged mostly, the rock fissure is extremely developed, the fissure surface is poor in associativity, the structural surface contains quantity of iron oxide, and the rock cementation is poor and regarded as argillaceous cementation. When it is adopted as the soil layer of pile foundation side wall, the side friction is superior to that of gravel soil of Quaternary deposit, and may be adopted as supporting layer of pile side. Moderately- Strongly-weathered argillaceous sandstone (⑥1) layer: the rock is cataclastic, the protolith structure construction is damaged mostly, the rock fissure is extremely developed, the fissure surface is poor in associativity, the structural surface contains quantity of iron oxide, and the rock cementation is poor and regarded as argillaceous filling. When it is adopted as the soil layer of pile foundation side wall, the side friction is superior to that of gravel soil of Quaternary deposit, and may be adopted as supporting layer of pile side. Moderately-and slightly-weathered sandstone (⑦) layer: the rock is relatively complete, the protolith structure is damaged partly, the rock mass is relatively complete and the fissure is argillaceous filling. This layer is favourable supporting layer of pile tip on pile foundation. Moderately-weathered argillaceous sandstone (⑦1) layer: the rock is relatively cataclastic, the protolith structure is damaged partly , the rock fissure is relatively developed, the fissure surface is relatively poor in associativity , the structural surface contains a small amount of iron oxide, the rock mass is relatively broken and regarded as argillaceous cementation. It may be adopted as the supporting layer of pile tip on pile foundation due to its rich argillaceous components; the mechanical property is greatly poorer than moderately- and slightly-weathered sandstone (⑦) layer, comprehensive consideration shall be made when it is adopted as supporting layer of pile tip on rock-socketed pile.

3 VERTICAL COMPRESSION PILE LOAD TEST

Static Load Testing in construction site Light Railway Transport (LRT) in Astana, Kazakhstan

This test is used to measure the axial deflection of a vertical deep foundation when loaded in static axial compression. This vertical compression pile maintained load test is usually carried out to ensure the structural and geotechnical soundness of the pile and also to predict settlement of other piles. Static Load Test (further SLT) one of the more reliable field tests in analyzing pile bearing capacity. SLTs carried out for four piles on the construction site (see Figure 3). The measured relationships between the pile head load, L, and the head settlement, S, of the test piles are shown in Figure 4. The bored piles which have diameters (diameter or D) of from 1000 mm to 1200 mm and from 23.6 to 29 m depths in construction site LRT, Astana (see Table 1) (Zhussupbekov, A., et al. 2016,).

Table 1. Characteristic of bored piles.

#	Pile #	Pile L, m	Pile D, mm
1	Pile-1 (PR3-3)	27.5	1200
2	Pile-2 (A-B/5-2)	24.6	1200
3	Pile 3 (GR18-2)	29.0	1200
4	Pile 4 (CR18-2)	23.6	1000

Testing platform presented itself system from steel, which consists of metallic beam and 2 platforms located on equidistant distances from the centre main beams (see Figure 2).

Fig. 2. Static load test in construction site LRT-Astana.

Standard – SNiP RK 5.01-03-2002 – ultimate value of settlement of the tested pile is determined as and depending on category of construction is equal to 16 or 24 mm. The last argument shows conditional character of SLT method. According to Kazakhstan Standard 1%

of constructed piles on construction site must be tested by SLT, but at least 2 SLTs in a site must be done. Field soil testing with piles on the territory of Kazakhstan and CIS countries is carried out in accordance with the requirements of GOST 5686-94. Static soil testing for bored piles begin after reaching the strength of concrete more than 80% of the project. According to the professional standard "Code for Durability Design on Concrete Structure of Railway" (TB 10005-2010), the environment of concrete structure is classified into 6 types, i.e. carbonized environment, chloride environment, chemical corrosion environment, sulfate physical attack environment, freezing-thawing environment and abrasion environment. The effect grades of various types of environment are classified according to the conditions of the Project and in combination with the design conditions. According to SLT results, the load - settlement diagrams were drawing (see Figure 3).

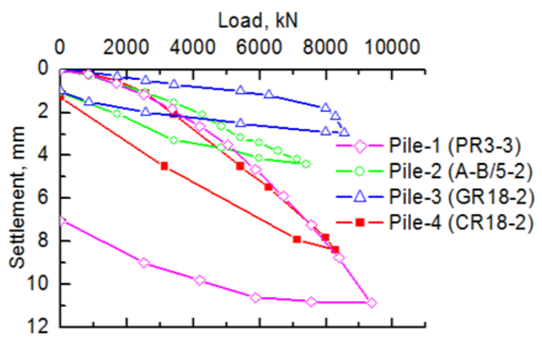

Fig. 3. Results of Static Load Tests by GOST.

In the composition of installation for soil testing with static compression load should include equipment such as (Omarov, A., et al. 2016):

- device for pile loading(jack);
- Support structure or platform for perception reaction forces (cargo platform);
- device for measuring the displacement of the pile during the test (the reference system with measuring instruments);

A device for loading piles must provide coaxial and central transfer loads to the pile, the possibility of transferring loads to feet, the constancy of pressure at each loading step. The distance from the axis, the full-scale pile test to anchor the pile must be at least 3d, but not less than one and a half meters.

For criterion conditional deformation stabilization tests of full-scale pile takes speed sediment piles on a given loading level not exceeding 0.1 mm in the last 60 minutes of observation, if at the lower end of the pile lie sandy soil or clay soils from hard consistency to low-plastic consistency, as if under the lower end of the pile lie clay soils from high-plastic to fluid consistency, then two o'clock observation. Test load full-scale pile should be brought to the point where the total sediment pile is not less than forty mm. At the lower ends of the full-scale burial piles in coarse dense sand and clay soils of hard consistency load must be reduced to the value provided by the test program, but not less than one and a half the value of pile carrying capacity determined by calculation or calculated resistance of the pile on the material (Zhussupbekov A., et al. 2016).

Table 2 presents a comparative analysis of the bearing capacity of piles, obtained by different methods in this research.

Table 2. Results of complex of field piling static loading tests.

#	Pile #	Pile L, m	Pile D, mm	Load, kN	S, mm
Static Compression Pile Load Test					
1	Pile-1 (PR3-3)	27.5	1200	9372	10.8
2	Pile-2 (A-B/5-2)	24.6	1200	7411	4.18
3	Pile-3 (GR18-2)	29.0	1200	8561	2.94
4	Pile-4 (CR18-2)	23.6	1000	8275	8.4

4 CROSS HOLE SONIC LOGGING TEST

"Crosshole Sonic Logging" (CSL) is a testing method for the determination of pile integrity in accordance with relative change of such acoustic parameters as sonic time, frequency and amplitude attenuation when actual measured sound wave transmitted in the concrete media, shooting and receiving sound waves among pre-buried sonic-testing tubes of the pile (ASTM D6760 – 08. (2008)).

By sending ultrasonic pulses through concrete from one probe to another (probes located in parallel tubes), the CSL procedure inspects the drilled shaft's concrete homogeneity, and extent and location of defects, if any. At the receiver probe, pulse arrival time and signal strength are affected by the concrete, or lack thereof. For equidistant tubes, uniform concrete yields consistent arrival times with reasonable pulse wave speed and signal strengths. Non uniformities such as contamination, soft concrete, and honeycombing, voids, or inclusions exhibit delayed arrival times with reduced signal strength (Recommendations on piling (2013).

The CSL testing should initially be performed with the transmitter and receiver probes in the same horizontal plane in parallel tubes unless test results indicate potential defects, in which case the questionable zone may be further evaluated with offset tests (source and receiver vertically offset in the tubes). Using the labeling established for the tubes, perform CSL testing between all adjacent perimeter access tube pairs and across at least the major diagonals within the drilled shaft. In the event defects are detected in drilled shafts with more than four tubes, additional logs in other diagonal tube pairs may be required to estimate the extent of the defect. Offset tests are generally only helpful for the perimeter profiles.

The ultrasonic integrity tests have been carried out on June 20th 2017 using Cross-Hole-Analyzer, Model CHAMP, made by Pile Dynamics Inc. Cleveland Ohio, USA. The field computer contains an A/D-board, conditioner and amplifier for the measurement control as well as a permanent storage of digitized data. Piles PR4-4 and PR6-2 have been tested. The diameter of the test piles was given to 1.2 m, the concrete nominal strength to B45. The test piles have been installed with reinforcement cages containing steel measurement tubes of diameter 42 mm for cross-hole-sonic-logging.

Ultrasonic measurements were executed at all distances available between the access tubes with a vertical resolution of 5 cm. In figure 4 the test situation at site and the location of the test pile is shown.

Fig. 4. «Cross-Hole-Sonic-Logging» - at LRT site.

The following figures show the results of the ultrasonic integrity tests (See Figure 5).

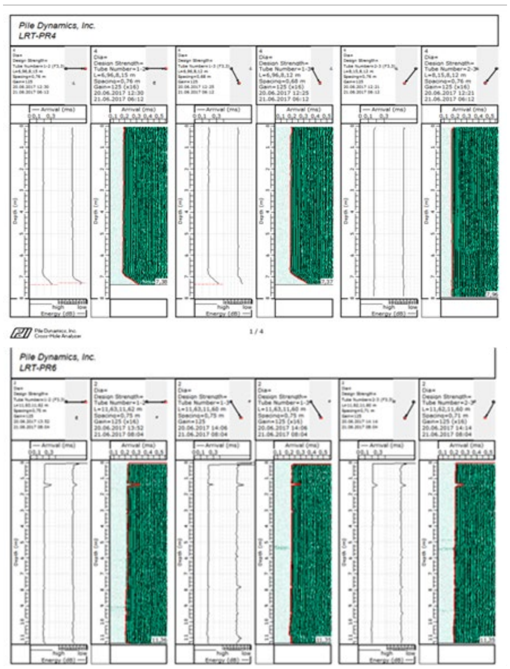

Fig. 5. Results of Champ integrity tests piles PR4-4 and PR6-2.

CONCLUSIONS

Static pile load test is the most reliable method to obtain the load-settlement relation of piles. Most of the static pile load tests are performed using reaction systems. The number of pile load tests in construction site is limited to 2 piles in usual of construction site in Kazakhstan.

Measurement results have been assessed according to ASTM D6760 and German Recommendations on Piling (EA-Pfähle 2013). The measurement method determines deviations from a homogeneous material by changes in the propagation of ultrasonic mechanical waves. These deviations are denoted as anomalies. Defect zones are defined by an increase in arrival time of the ultrasonic wave of more than 20 percent relative to the arrival time in a nearby zone of good concrete, indicating a slower wave speed. With the distance L between the measurement tubes, taken at the pile top, the measured arrival time T of the ultrasonic wave the wave speed c can be obtained by c = L/c. The measured depth is a result of the free accessible tube length less the length of the measurement probe (transmitter and receiver).

The bearing capacity of boring piles according to the results of shown table 2 amounted to be maximal load 9372 kN, maximal settlement from 10.87 mm.

These investigations are important for understanding of behavior of piles on problematical soil ground of Astana, Kazakhstan.

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