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Accuracy of determining pile capacity by static and dynamic methods in difficult ground conditions in Astana

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ABSTRACT: The article presents the results of the dynamic (DLT), static (SLT) and a new method of Pile Dynamic Analyze (PDA) tests of the reinforced concrete piles with rectangular section 30 x 30 cm and length 12m driven piles for problematic soil conditions of the "New Mosque" in Astana city. Field test are carry out in accordance with requirements GOST 5686, for definitions of bearing capacity of the piles in accordance with requirements SP RK 5.01-03-2013 and ASTM D4945. The test method is similar to that used on driven piles with the monitoring of hammer blows and subsequently analyzing the pile response to the stress wave propagation. A separate hammer or drop weight is usually brought to site to allow the dynamic load to be applied to driven pile. According to the results of tests were determined the possible depth of penetration and bearing capacity of driven piles. This geotechnical investigation is important for understanding the soil-pile interaction on difficult and problematical soil ground conditions related to the construction site.

1 INSTRUCTIONS

The congregation was built on a land plot of 10 hectares. The total area of the premises is 68,062 m². The total capacity of the mosque is 235 000 people, of which: 30 thousand men and 5 thousand women can pray simultaneously in the halls; 200 000 people can pray in the open air: 170 000 in the mosque yard and 30 000 in the area of the podium and stage. The mosque has four minarets 130 m high (see Figure 1).

Figure 1. Construction site "New Mosque" in new Capital of Kazakhstan.

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Each minaret consists of five parts symbolizing the five pillars of Islam: shahada, namaz, fasting in the month of Ramadan, zakat and hajj. One of the minarets in the left wing is open to visitors and tourists can take an elevator up to the observation deck. The height of the big dome is 83.2 m and the diameter is 62 m. The entrance door of the mosque is 12.4 m high and weighs 1.5 tons and is handmade of hardwood. On the wall on the qiblah side are carved the 99 names of Allah, illuminated with golden light. The mosaic wall is 100 m long and 22.4 m high. The mosaic consists of 25 million glasses of different colors. The total area of the carpet is 15.525m^2, the thickness of the carpet is 15 mm. In the center of the main hall under the dome hangs a crystal chandelier, 27 m in diameter and weighing 20 tons.

The chandelier is made of 1,360,890 crystal fragments. Also in the four corners of the hall hang four chandeliers, each 8m in diameter. The first and second floors of the mosque have classrooms, a conference hall, a wedding hall, a Quranic reading hall, a TV studio, offices, staff rooms, stores, a museum and technical premises in addition to prayer rooms. The underground floor has a banquet hall with 440 seats, a closed parking lot with 405 seats, a lobby, a restroom, technical and ritual services area, sacrificial offering area and other rooms. In terms of mosque capacity, the Republican Chief Mosque in Astana is one of the 10 largest mosques in the world.

2 THE RESULTS OF ENGINEERING AND GEOLOGICAL RESEARCHES OF THE SITE

On the basis of field visual description, confirmed by the results of static sounding and laboratory tests of soils, it was found that to a depth of 17.0-27.0m in the geological structure of the site take part alluvial Quaternary deposits, represented by loam, sand, gravel and gravel soils, as well as eluvial soils of the Lower Carboniferous, represented by loam sands, sands, gravel and rubble soils. According to the drilling data, the groundwater on the survey area is at a depth of 3.00 - 3.60m. Under the conditions of the natural regime, the groundwater level is subject to seasonal fluctuations: the minimum standing is observed in March, the maximum standing is at the beginning of May. The amplitude of level fluctuations in the studied area was 1.0-1.5 m. It is recommended to take the level at 1.3 m higher than the established one for the period of surveying as the predicted one. Groundwater is fed mainly by infiltration of atmospheric precipitation, meltwater and floodwater. The area of aquifer spreading serves as the feeding area.

According to the results of chemical analyses, groundwater is characterized as sodium chloride, very hard, neutral, slightly alkaline, slightly acidic, slightly mineralized, brackish. In relation to steel structures ground water is corrosive. The degree of aggressiveness of ground water in relation to the cable lead sheathing is medium and high, in relation to the cable aluminum sheathing - high.

In relation to concrete of W4 grade, ground water is non-aggressive and slightly aggressive, in well 306-18 highly aggressive on Portland cement, in relation to reinforced concrete structures - moderately aggressive.

3 METHODOLOGY FOR LOAD TESTING OF PILES

3.1 *Static load tests by GOST*

Static load tests carried out for four piles on the construction site (see Figure 2). The measured relationships between the pile head load, L, and the head settlement, S, of the test piles are shown in Figure 3. It is seen from Figure 4 that the load-settlement curves of piles No.4, 9, 13 and No.14 are almost identical, having an ultimate shaft capacity of 1400 kN (Zhussupbekov *et, al* 2015 and Zhussupbekov *et, al* 2017 and Zhussupbekov *et, al* 2019).

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= 1400/1.2=1167kN.

Figure 2. Test piles static loading method SLT by GOST.

According to SLT result, the load-settlement diagrams were drawing (see Figure 3) and compared with PDA results (see Figure 5).

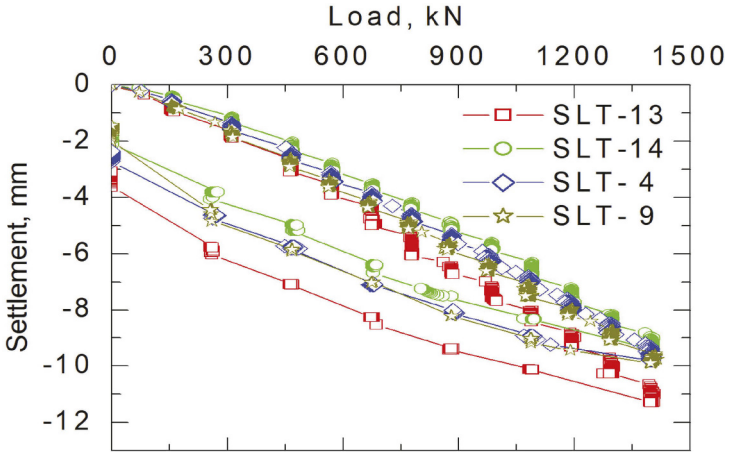

Figure 3. Results of Static load tests by GOST.

3.2 *Dynamic load test by ASTM (DLT - PDA)*

In Kazakhstan carry out dynamic test with using many types of pile driving machine hammers. Before beginning test pile driving on its surface painted whole length of piles through 1 m, but with last meter through each 0.1 m shown.

Pile driving was performed using the piling installation «Junttan PM-25" with hydraulic hammer HHK-7A with a mass of 7000 kg of the hammer and headband weight equal to 990 kg.

Figure 4 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 (Figure 4) 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 Figure 5.

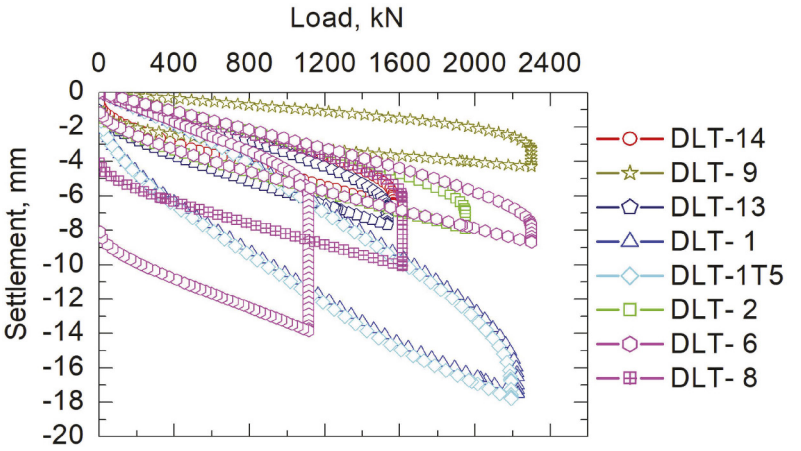

Figure 4. Results of Dynamic load tests by ASTM.

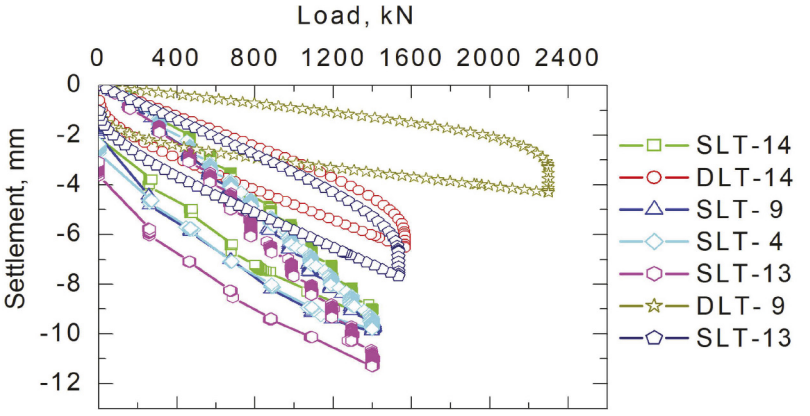

Figure 5. Results of DLT and SLT.

4 CONCLUSIONS

On the construction site of the main mosque hall of the facility "The main mosque for 30,000 places in Astana" static and dynamic tests of driven piles in the amount of 8 pieces were carried out.

The carrying capacity of the piles sunk to a depth of 7.5 m, according to the results of dynamic tests was 1600 kN.

The bearing capacity of the piles sunk to a depth of 7.5 m, according to the results of static tests was 1400 kN.

Allowed load on the pile, taking into account the coefficient of reliability $\gamma_k = 1.2$ in accordance with paragraph 3.10. SNiP RK 5.01.-03-2002 "Pile foundations", should be taken equal to 1176 kN.

DLT (PDA-ASTM) dynamic test shown more coincide with SLT result than traditional DLT test (GOST).

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