Model and field tests of drilled displacement system piles

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Abstract. Drilled Displacement System (DDS) and Continuous Flight Auger (CFA) piles are two popular techniques used for building pile foundations that offer advantages over traditional pile systems, including improved load-carrying capacity, reduced installation time, and less spoil generation. This article presents laboratory-scaled model tests conducted on model piles installed using the Drilled Displacement System (DDS) and Continuous Flight Auger (CFA) technologies on a test tank setup filled with soil. Model piles considering a scaling factor of 1/20 with a diameter of 20 mm and a length of 300 mm were adopted for the study. Static loading is applied to the model piles and the corresponding displacements are measured during each loading phase. The results of the analysis were compared for load-settlement curves and ultimate bearing capacity estimates for both DDS and CFA piles. Based on the study, the DDS piles were observed to perform well in terms of load-carrying capacity compared to the CFA piles. Further, full-scale field tests under static load conditions were carried out on DDS-drilled piles of diameter 400 mm and length 6 m. The load-settlement response from the field test shows good agreement with the model tests. Overall, the results of the study provide valuable insights into the behavior and performance of DDS piles that can be used to optimize their design and installation in different soil types.

Keywords: scaled model tests, model piles, bearing capacity, static load test

1 Introduction

Pile foundations are the most demanded type of foundations at construction sites on the territory of Kazakhstan. The purpose of the widespread use of pile foundations is explained by the fact that they cover the load-bearing capacity of the pile, which is drilled and filled due to the increase in the load from high-rise buildings and structures. New technologies and devices that have appeared in connection with the installation of drilled-filled pile foundations make it necessary for designers to improve regulatory documents due to the

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lack of current regulatory documents, as well as recommendations for the installation of pile foundations through modern technologies [1-3].

Drilled Displacement System (DDS) and Continuous Flight Auger (CFA) piles are recent techniques used for building pile foundations. DDS pile is a type of displacement pile that is commonly used in urban areas where noise and vibration levels need to be minimized. It involves driving a steel casing into the ground using a hydraulic press, while simultaneously extracting soil and creating a void. The void is then filled with concrete and reinforcing steel, forming a solid foundation for the structure to be built upon. DDS piles are typically used for small to medium-sized structures and can be installed in various soil conditions. The CFA pile on the other hand is a type of auger cast pile that involves drilling a continuous flight auger into the ground to the required depth. The auger is then withdrawn while concrete is pumped through the hollow stem of the auger, filling the void left by the auger as it is withdrawn. This creates a continuous column of concrete and forms a solid foundation for the structure to be built upon. CFA piles are commonly used for large structures and in challenging soil conditions such as soft soil and rock.

DDS technology not only increases the load-bearing capacity of piles, but also saves earthworks time, labor and finances. Installation of drilled-filled piles using DDS technology has become increasingly popular in Europe and the United States over the past decade. The main advantages of this technology: high performance of pile preparation, high economic efficiency, absence of vibration and noise when installing the pile, upper bearing capacity of piles[4-6]. Despite the above advantages, the disadvantage of this technology is the risk of affecting the foundations of existing buildings and structures, so it is not recommended to use this method in conditions of dense urban construction.

The sequence of work on the installation of drilling piles manufactured using DDS technology includes the following operations (Figure 1): installation of drilling equipment at the drilling site; immersion of the drilling tool with a sealing system to the design mark; connection of the concrete pump followed by filling the well with concrete mixture and simultaneous extraction of the drilling tool; immersion in the well with concrete reinforcement frame to the design mark. A distinctive feature of the DDS technology is the drilling tool (Figure 1). When drilling the drilling tool down, simultaneously with drilling, the well is rolled out, because of which the radial compaction of the soil occurs without its excavation, when drilling up, the walls are compacted [7-10]. This technology allows to arrange piles with a diameter of up to 0.6 m to a depth of up to 30 m. When calculating the productivity, the following parameters should be considered: the diameter of the pile, the amount of applied torque and pressing force, density (strength of the soil, compaction of the soil, power of the concrete pump).

The objective of the present study is to carry out scaled model tests on model test piles installed using the DDS and CFA technology and to compare the load-settlement response. Further field investigations were also conducted to validate the laboratory test results and to provide recommendations based on the findings,

https://doi.org/10.1051/e3sconf/202341003024

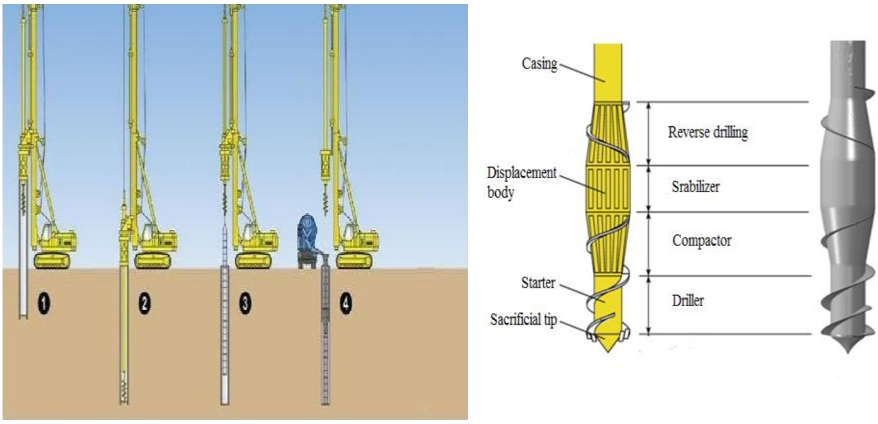


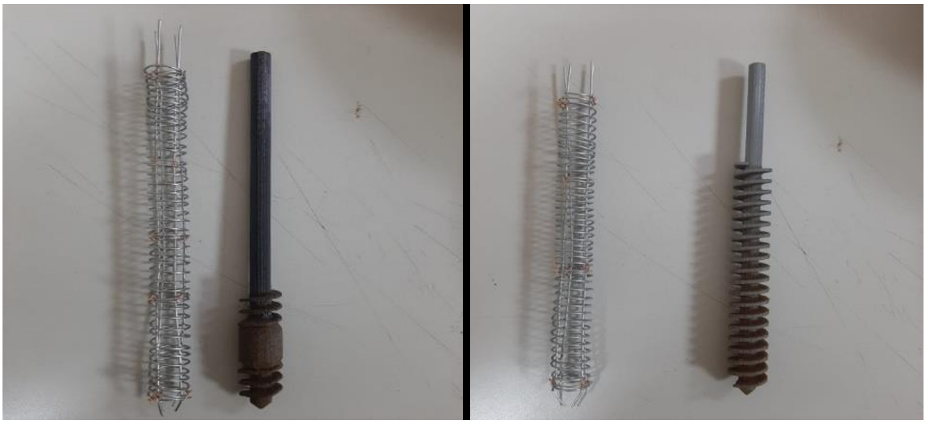
Fig. 1. Installation process of DDS piles and details of drilling shaft

2 Laboratory scaled model study

Model tests of piles was carried out on a test tank setup which was developed and implemented in Geotechnical Institute of the Eurasian National University (Figure. 2). The test material used is poorly graded sand of angular shape with a specific gravity of 2.62 and unit weight of 1.7 g/cc. Based on direct shear test carried out on the test specimen, the sand was found to have an angle of internal friction of 37^{o}. An equivalent material (97% sand and 3% spindle oil) was used as a base to achieve minimal cohesion of 0.9 kPa and elastic modulus of 0.24 MPa. The test bed was prepared in five layers and each layer was compacted using tamping to achieve a relative density of 75%.

Fig. 2. Volumetric stand

The augers were prepared for installation of model piles by DDS and CFA technologies with a diameter of 20 mm and a length of 300 mm considering a scale factor of 1/20. Figure 2 (a) shows the augers used to install the model pile DDS (b) the model pile CFA which performed by technologies.



(a) (b)

Fig. 3. Photographs of test auger a) model DDS auger b) model CFA auger.

Figure 4 shows the static load test setup for the present study. The load on the pile was applied in steps of 39 N to the ultimate 235 N with metal weights of 4 kg. The displacement of the model pile was measured by deflectometer with accuracy class of 0.01 mm, which are attached to the frame of the volumetric stand.

Fig. 4. Static tests of the DDS and CFA model piles

Static tests on the model piles DDS (Drilled displacement system) and CFA (Continuous flight auger) were carried out on the volumetric stand. After the static test, the «settlement-load» graphs of the DDS and CFA piles were obtained. The DDS model pile sag was 8.56 mm, and the CFA model pile was 19.25 mm. The CFA technology piles at a load of 196 N were completely submerged. The test results show that the bearing capacity of the DDS model pile is higher than the CFA piles. Considering the results of our model tests, it was recommended to use DDS technology for bored piles at the «Asyltas» construction site.

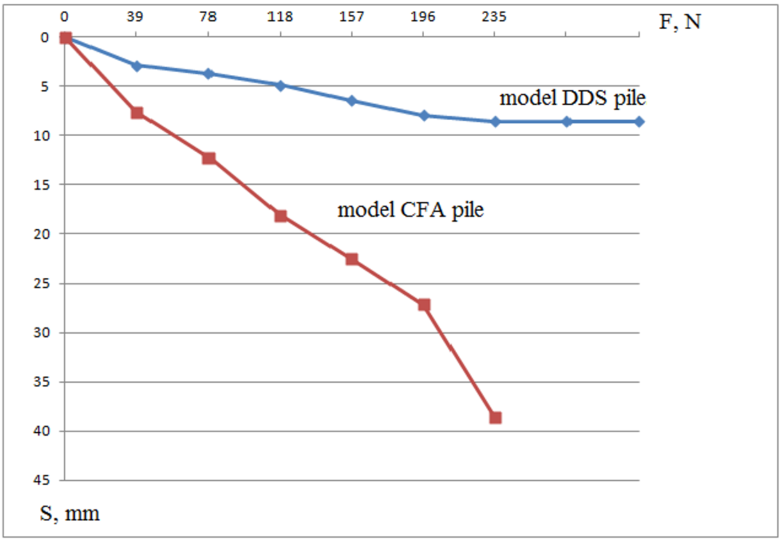


Fig. 5. Load – settlement response of the DDS and CFA model piles

3 Field studies on DDS piles

Based on the recommendation from model studies, field investigation was conducted on 2 test piles with a diameter of 400 mm, length 6 m at a test site in Astana, Kazakhstan using the DDS technology. The soil properties at the test site for different depths are shown in Table 1.

Table 1. Physical and mechanical properties of soils

Layer no.	Soil description	Layer thickness, m	Soil properties		
			E, MPa	C, kPa	φ, deg.
1	top soil, loam	0,4	-	-	-
2	loams	5,1	4,8	17,6	16
3	gravelly sand	5,1	35	-	39
4	silty clay	1,0	4,8	17,6	16-
5	rock debris with silty clay inclusions	4,4	-	-	-

The load on the pile was applied in steps of 180 kN and 90 kN to the limit of 1080 kN by the hydraulic jack DU200P150. The hydraulic jack force is regulated by fluid supply from the pumping station and fixed with a technical manometer. Pile movement is measured by means of displacement transducers with accuracy of 0.01 mm, which are fixed on a bench mark system fixed to the ground. The reference system is independent of the movement of the beam and pile system.

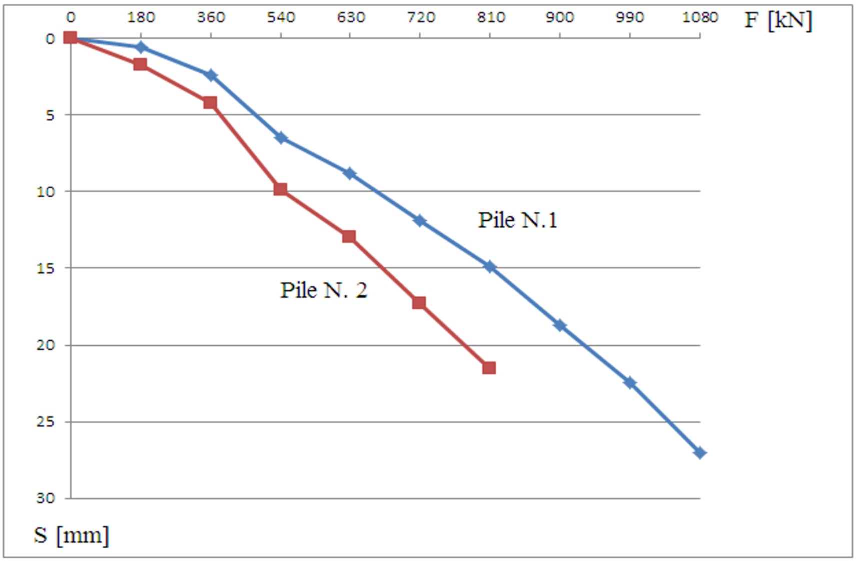


Fig. 7. Field test results of load-settlement response of DDS piles

For the construction of industrial and civil multi-story buildings, the DDS pile technology is taken in accordance with the Construction Norms and Regulations RK 5.01-01-2002 for reinforced concrete structures. This technology offers several advantages, making it particularly attractive for use in dense urban areas. One of the main advantages is the absence of vibration or noise during the construction process. Additionally, there is no need for soil excavation, which reduces the overall cost of the project by eliminating the need for soil removal. The onboard computer controls the entire process, ensuring high accuracy of pile setting in the plan, compliance with the verticality of drilling, immersion depth of the working body, and the pressure of concrete when filling the borehole. As a result, high-quality concreting is achieved with smooth and strong walls after unrolling, and pressurized concrete feeding through the hollow unroller.

4 Conclusion

Based on the results of testing model piles on a volumetric stand, a comparative analysis of the bearing capacities of model piles using DDS and CFA technologies was obtained. The results showed that the load-bearing capacity of model piles using DDS technology is higher than CFA piles. The results obtained served to recommend this technology for use at the Asyltas construction site. The results of the axial compression loading tests performed in soft to firm or stiff clays demonstrated the suitability of DDS technology pile foundations. The results of the loading testing program confirmed that the DDS bored pile is a viable deep pile foundation option for the construction site in Kazakhstan and demonstrated their advantages. The results of the static load tests were satisfactory, as the maximum test load on the pile was 1080 kN. The settlement was 27 mm These investigations are important for the understanding of soil-pile interaction on the problematical soft soils ground of by different technologies (DDS and CFA) in Astana, Kazakhstan.

The authors would like to thank KGS LLP Astana, Kazakhstan for facilitating the field test program at their construction site. This support is gratefully acknowledged.

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