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Comparison of bearing capacities of model drilled micro piles using DDS and CFA technologies

Abstract. *Drilled piles installed using CFA (Continuous Flight Auger) and DDS (Drilled displacement system) technologies are relatively new construction products in the market of Kazakhstan for the last 15 years, but already today the technology has a significant practical value in the construction of the cities of Astana, Almaty and other regions. This article presents model tests of bored piles installed using Drilled Displacement System (DDS) and Continuous Flight Auger (CFA) technologies on a volumetric bench. For testing we used 1:20 scale, piles diameter was 20 mm, length was 300 mm. Drilling was performed using augers that were prepared in advance through a 3D printer. The load on the model piles was applied in steps of 39 N up to the ultimate load of 391 N. Based on the results of the study, the «settlement-load» plots of the DDS and CFA model piles were obtained, as well as a comparison of the bearing capacity of these piles by static test method. Based on the study, it was found that the DDS piles exhibit good bearing capacity performance compared to the CFA piles. Overall, the results of the study provide valuable information on the performance behavior of DDS and CFA piles, which can be used to optimize their design and installation in different soil types.*
Keywords: *scaled model tests, model piles, bearing capacity, static load test.*

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1. Introduction

CFA (continuous flight auger) and DDS (Drilled displacement system) technologies were mastered in Kazakhstan about twenty years ago, when constructing bases and foundations of buildings and structures erected on weak soils. During the CFA and DDS pile construction in the new capital city the equipment of Italian company «SoilMec» and German company «Bauer» were used. The borehole for the piles is developed with the help of a continuous through auger drilling, which results in the excavation of the soils. The technology of CFA piles using continuous through auger, includes the following steps [1, 2, 3]:

1. Installation of drilling equipment at the drilling site (Figure 1 a);
2. Drilling the borehole with auger string to the design grade (Figure 1 b);
3. Gradual extraction of the auger string with simultaneous filling of the borehole with concrete mixture (Figure 1 c);
4. Moving the drilling equipment to another drilling location (Figure 1 d);
5. Installation of the reinforcement cage by vibratory dipping using a crane (Figure 1 e);
6. Formation of the pile head for connection to the pile pedestal (Figure 1 f).

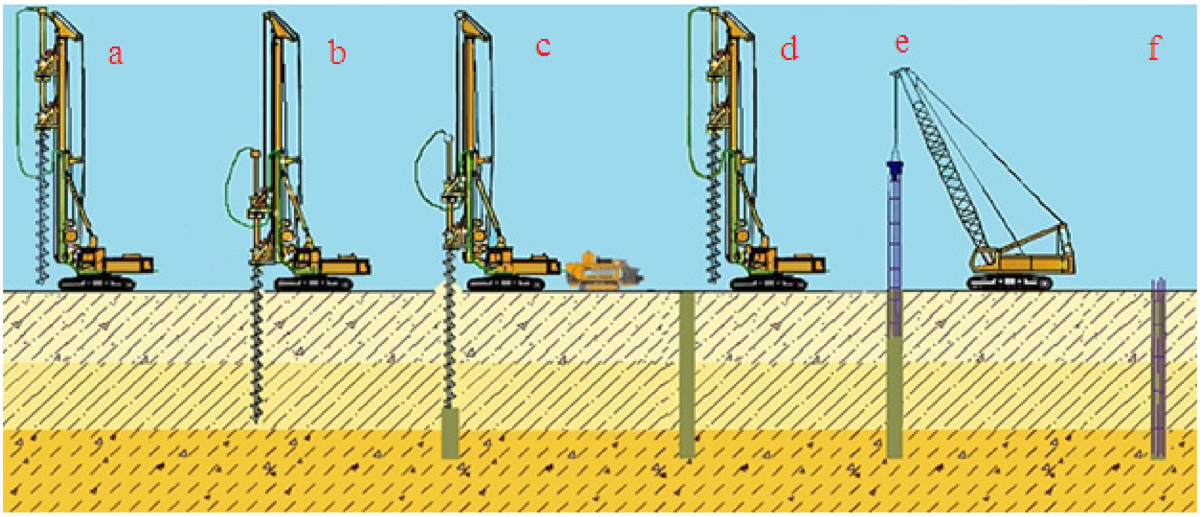


Figure 1. Diagram of pile fabrication using CFA technology

The diameter of the borehole is equal to the diameter of the drill tip of the auger string, which can be 400, 450, 500, 600, 600, 700, 800, 900, 1000, and 1200 mm. CFA bored piles have the following advantages [3, 4, 5]:

- Automated control of the pile device, through which it is possible to obtain data of auger immersion depth, drill rotation parameters, parameters of injected concrete;
- Possibility to use the technology in sandy soils and tight plastic loamy soils, as well as the soils with a significant difference in the strength of the layers;
- the possibility of piling near existing buildings, because as a result of excavation of the ground surface is not dislodged, and the use of small-sized drilling rigs in confined spaces have insignificant vibration effects on existing buildings and structures;
- High productivity of CFA piles. The productivity of CFA piles is 3 times higher than the productivity of traditional technology of bored piles under protective casing in the ground conditions of Astana;
- Automated drilling tool cleaning system.

The disadvantage of CFA technology can be attributed to the high consumption of concrete when piling on water-saturated dusty-clay soils as a result of overpressure and high compressibility of weak soils.

The DDS (Drilled Displacement System) or FDP (Full Displacement Pile) technology was developed by the same German company «Bauer» and represents the drilling of a pile without excavation and with full displacement of the soil with the help of a special drilling element - a packer. The packer is a series of conical rollers successively mounted on the shaft, the axes of which are displaced relative to the common axis of the shaft to the sides. Thus, when rotating the shaft, the rollers rotate in a helical line, realizing the feed of the reamer, which allows to carry out penetration in the ground due to the torque applied to the shaft of the reamer. The use of the reamer provides drilling of a borehole with smooth and strong walls of significant diameter.

The design of the roller allows the concrete to be delivered during the upward stroke of the roller. The DDS technology, which allows piles to be made at a fairly high speed, without vibration and noise, has a number of undeniable advantages:

- High productivity of piling (up to 30 piles per shift);
- Application of the technology reduces the cost of works by saving on the cost of soil removal;
- High quality of concrete filling of the borehole, as a result of its delivery under pressure;
- High bearing capacity of piles due to soil compaction and pressurized concrete mixture supply;

- high accuracy of pile arrangement controlled by on-board computer [6, 7, 8].

The use of special drilling tools makes it possible to install piles through dense sand layers, and in the presence of obstacles in the form of rocks, it is possible to continue drilling by replacing the drilling tool with a boring tool.

Despite the above-mentioned qualities, DDS technology has the following disadvantage:

- Increased attention to work order, as it may affect the foundations of adjacent buildings and structures, as in the case of other compaction technologies.

The investigated DDS technology has long been internationally recognized, but in the difficult ground conditions of Kazakhstan, the operation of DDS piles is still not fully understood [9, 10, 11].

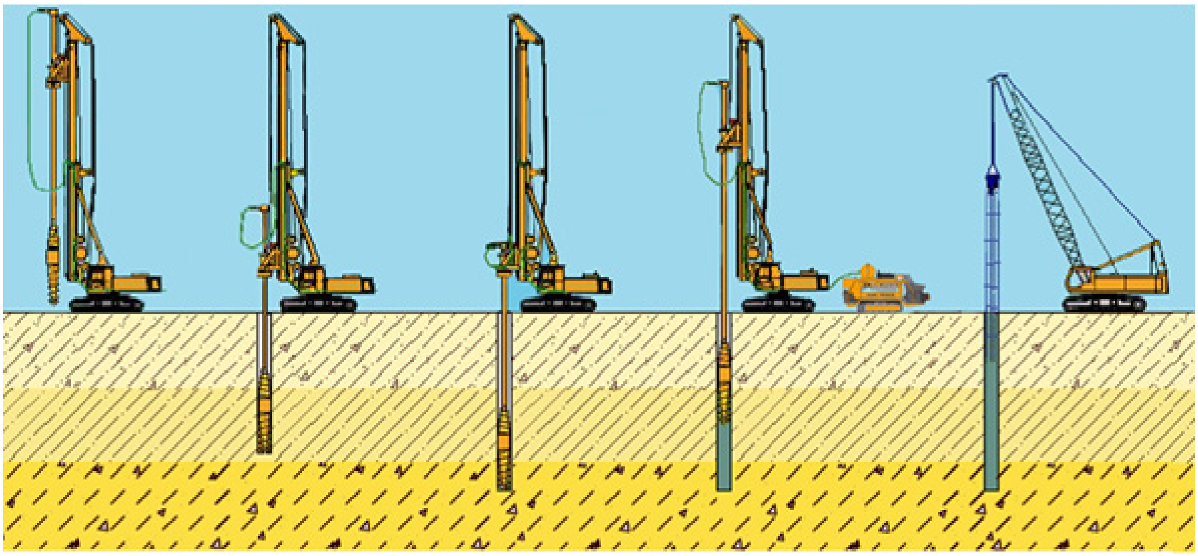


Figure 2. Diagram of pile production using DDS technology

The purpose of this study is to conduct model tests on a volume bench installed using DDS and CFA technologies and to compare their load carrying capabilities.

2. Laboratory scaled model study

Model tests were carried out on a volumetric stand, the design of which was developed and implemented under the guidance of Professor A.Zh. Zhussupbekov at the Geotechnical Institute of the Eurasian National University named after L.N. Gumilev.

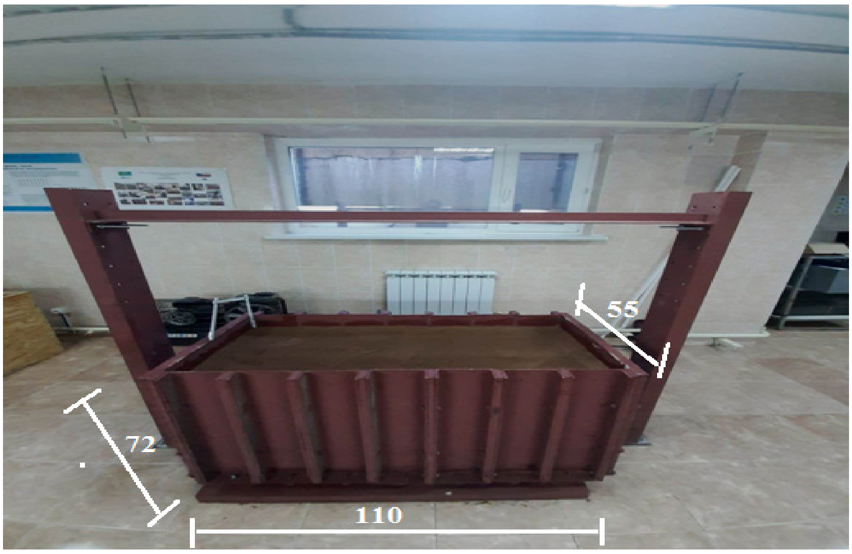


Figure 3. Volumetric stand

An equivalent material (97% fine silica sand and 3% spindle oil) was used as a base, the physical and mechanical characteristics of which are summarized in Table 1.

Table 1. Physical and mechanical characteristics of natural soil and equivalent material

Name of soils of full-scale and model material	Specific gravity, γ, кN/м^3	Clutch, C, kPa	Angle of internal friction, φ, deg.	Modulus of deformation, E, MPa	Poisson's ratio, μ
Loam	20,5	40,0	29	-	-
model material	17,0	0,9	37	0,24	0,25

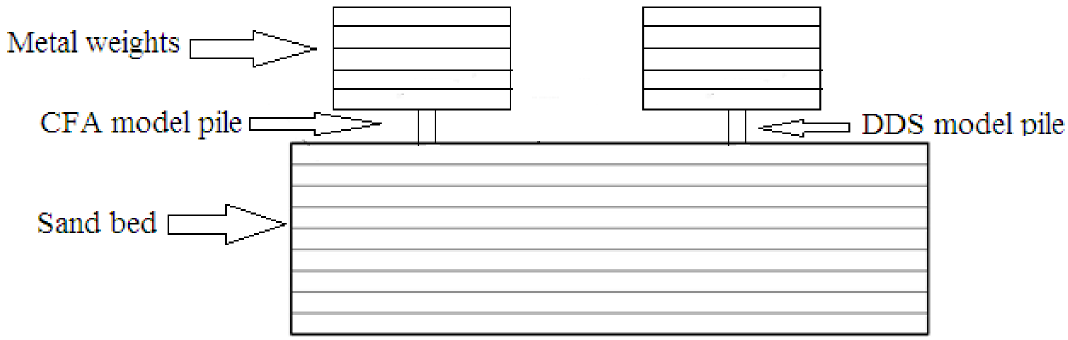
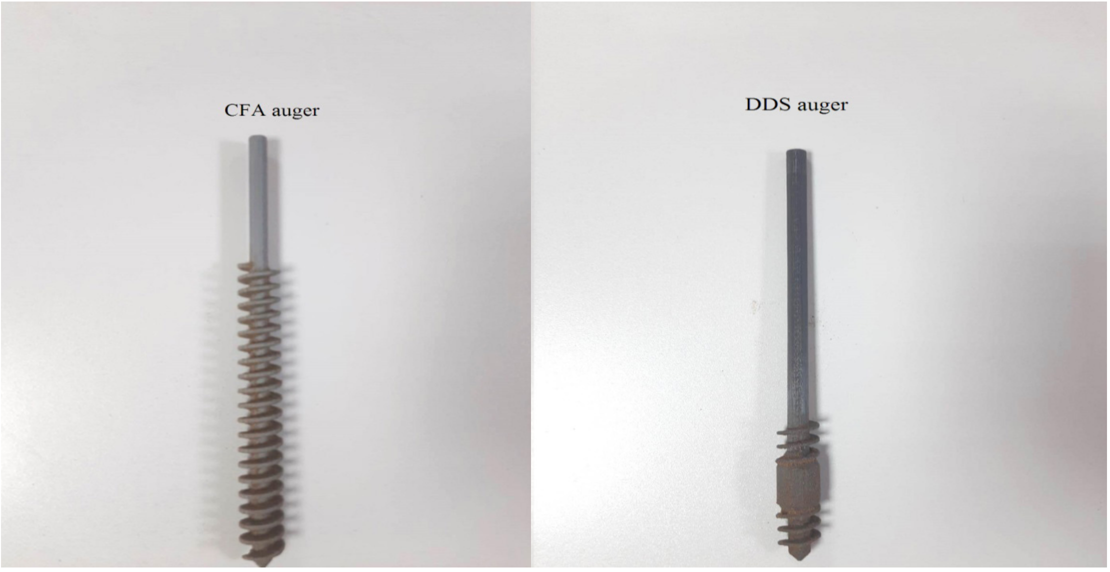


Figure 4. Schematic of horizontal loads acting on model piles of DDS and CFA technologies

Soil drilling was performed using simulated augers. Drilled Displacement System (DDS) and Continuous Flight Auger (CFA) augers were designed in 1:20 scale and printed on a 3D printer. The augers were 20 mm in diameter and 300 mm in length.



a) b)

Figure 5. Model pile augers (a) DDS and (b) CFA

Static testing of model piles was performed using metal weights that were loaded on the piles. The weight of one weight was 4 kg. The load on the model piles was applied in steps of 39 N up to the ultimate load of 391 N.

Figure 6. Static Load Tests of DDS model pile and CFA model pile

After drilling, the borehole was filled with concrete. Fine sand and cement of M300 grade were used for concrete. Figure 7 shows photos of model piles after static loading.

Figure 7: Model piles after static testing

3. Results and discussion

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 settlement was 16.03 mm, and the one corresponding to CFA model pile was 17.49 mm.

The CFA technology piles at a load of 313 N were completely submerged. The test results show that the bearing capacity of the DDS model pile is higher than the CFA piles. It is observed that the auger influence of the model pile is significant to the test results.

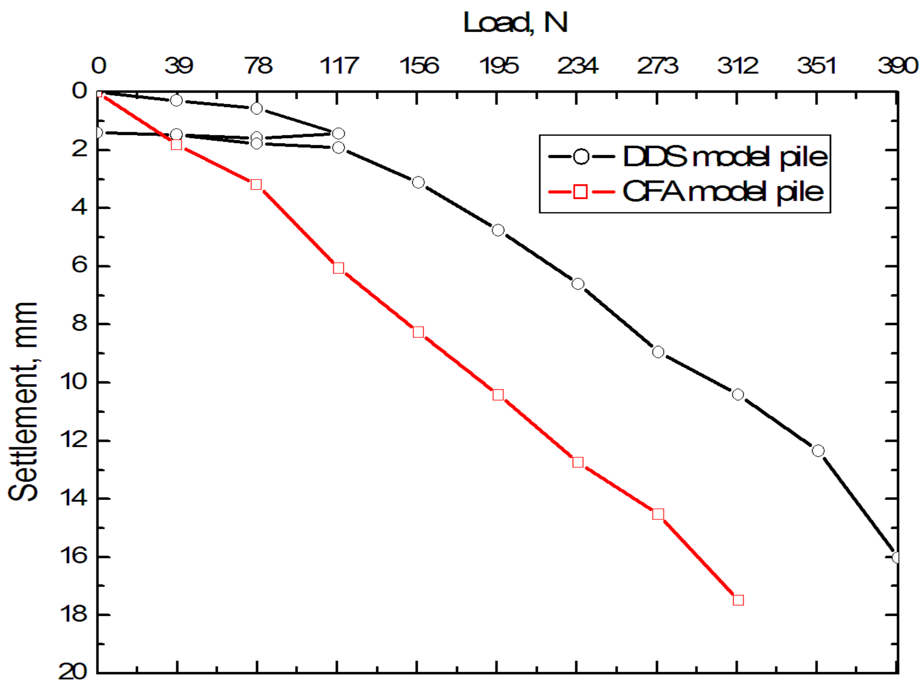


Figure 8. Load – settlement response of the DDS and CFA model piles

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. At a load of 391 N, the settlement of the DDS model pile was 16.03 mm. The CFA model pile was loaded to 313 N and its settlement was 17.03 mm. The preliminary results showed that the load-bearing capacity of model piles using DDS technology is higher than CFA piles.

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References

1. Bazarbayev D.O., Researching of bored FDP pile in a problematical soil ground // A dissertation submitted in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY (Ph.D.) - Астана: ЕНУ им Л.Н. Гумилева, 2009. – 82с.

2. Rad S.H., Ghareh S., Eslami A. Experimental and feld studies on the behavior of drilled displacement piles // Innovative Infrastructure Solutions 6, №188 – Springer Nature Switzerland, 2021. – P. 1-11.doi.org/10.1007/s41062-021-00557-2.

3. Basu P., Prezzi M., Basu D. Drilled Displacement Piles – Current Practice and Design // DFI Journal The Journal of the Deep Foundations Institute . Hawthorne, USA, 2010. – P. 3-20.

4. Issakulov, A., Omarov, A., Zhussupbekov, A., Mussakhanova, S., Issakulov, B. Investigation of the interaction of the bored micro pile by DDS (FDP) technology with the soil ground. International Journal of GEOMATE, Vol. 24, Issue 105, 2023, pp. 11–17.

5. Yergen ASHKEY, Interaction of CFA bored piles with soil condition in Astana // A dissertation submitted in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY (Ph.D.) – Astana.: L.N. Gymileva ENU. -2008. – 52p.

6. Zhussupbekov A., Omarov A., Shakirova N., and Razueva D., Complex analysis of bored piles on LRT construction site in Astana. Lecture Notes in Civil Engineering, Vol. 49, 2020, pp.461–471.

7. A. Zh. Zhusupbekov and Y. Ashkey, T.Zh. Seidmarova, R.K. Bazilov, D.O. Bazarbayev, A.A. Zhusupbekov. "Geotechnical and Geodisaster problems in Kazakhstan". Proceedings 4th International Conference on Disaster Prevention and Rehabilitation, 2007, (Indonesia, Semarang), 28-40 pp.

8. Zhusupbekov A. Zh., Ashkey Y., Geotekhnicheskij monitoring i razrabotka peredovyh tekhnologij ustrojstva svajnyh osnovanij zdanij i sooruzhenij v slozhnyh gruntovyh usloviyah Kazahstana s uchetom trebovanij inzhenerno-geologicheskih izyskanij. Zaklyuchitel'nyj otchet o nauchno-issledovatel'skoj rabote. NC NTI RK.- Astana, 2007.-62 s.- Inv. №0208RK0039.

9. Decourt, L. Behaviour of a CFA Pile in a Lateric Clay.Proceedings of the 4th International Geotechnical Seminar on Deep Foundations on Bored and Auger Piles // BAP IV. Ghent, Belgium, 1993. - pp. 301-308.

10. A. B. Isakulov, A. Zh. Zhusupbekov, B. R. Isakulov, S. B. Iskakov. Topyrak massivinin DDS tekhnologiyasy bojynsha ornatylgan byrgylanyp toltyrylgan қadalarymen ozara arekettesuin zertteu. Vestnik evrazijskogo nacional'nogo universiteta imeni L.N.Gumileva. Seriya tekhnicheskie nauki i tekhnologii, Vol. №4, Issue 141, 2022, pp.19-29.

11. Omarov A., Kuderin M., Zhussupbekov A., Kaliakin N., and Iskakov S., Vibration measurements at a new monument in Nursultan city. International Journal of GEOMATE, Vol. 21, Issue 85, 2021, pp.24–31

DDS және CFA технологиялары бойынша жасалған бұрғыланып толтырылған модельдік микро қадалардың жүк көтергіштігін салыстыру

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Аннотация. CFA (үздіксіз әрекет ететін шнек) және DDS (бұрғылау орнын ығыстыру жүйесі) технологияларын пайдалана отырып жасалған бұрғыланып толтырылған қадалары соңғы 15 жылда Қазақстан нарығында салыстырмалы түрде жаңа құрылыс өнімдері болып табылады. Дегенмен бүгінгі таңда аталған технологиялар Астана, Алматы қалаларында және басқа өңірлерді ғимараттар салу кезінде айтарлықтай практикалық құндылыққа ие. Бұл мақалада көлемді стендте Drilled Displacement system (DDS) және Continuous Flight Auger (CFA) технологияларын қолдана отырып жасалған бұрғыланып толтырылған қадаларының модельдік сынақтары ұсынылған. Тестілеу үшін біз 1:20 масштабты қолдандық, қадалардың диаметрі 20 мм, ұзындығы 300 мм. Бұрғылау 3D принтердің көмегімен алдын-ала дайындалған шнектермен жүргізілді. Модельдік қадаларға жүктеме 39 N қадаммен 391 N шекті жүктемеге дейін қолданылды. Зерттеу нәтижелері бойынша DDS және CFA модельдік қадалары үшін «шөгу-жүктеме» графиктері алынды, сондай-ақ осы қадалардың жүк көтергіштігі статикалық сынақ әдісі бойынша салыстырылды. Зерттеу негізінде DDS қадаларының CFA қадаларымен салыстырғанда жүк көтергіштігі жоғары екендігі анықталды. Тұтастай алғанда, зерттеу нәтижелері DDS және CFA қадаларының өнімділігі туралы құнды ақпарат береді, оларды әртүрлі топырақ түрлерінде жобалау мен орнатуды оңтайландыру үшін пайдалануға болады.

Кілт сөздер: масштабталған модельді қада, модельді сынақ, көтергіш қабілеті, статикалық жүктемелік сынақ.

Сравнение несущей способности модельных микросвай с использованием технологий DDS и CFA

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Аннотация. Буронабивные сваи, установленные с использованием технологий CFA (шнек непрерывного действия) и DDS (система бурового вытеснения), являются относительно новыми строительными продуктами на рынке Казахстана за последние 15 лет, но уже сегодня технология имеет значительную практическую ценность при строительстве городов Астана, Алматы и других регионов. В данной статье представлены модельные испытания буронабивных свай, установленных с использованием технологий Drilled Displacement System (DDS) и Continuous Flight Auger (CFA) на объемном стенде. Для тестирования мы использовали масштаб 1:20, диаметр свай составлял 20 мм, длина - 300 мм. Бурение производилось с помощью шнеков, которые были заранее подготовлены с помощью 3D-принтера. Нагрузка на модельные сваи прикладывалась с шагом 39 Н до предельной нагрузки 391 Н. На основании результатов исследования были получены графики «осадка-нагрузка» для модельных свай DDS и CFA, а также сравнение несущей способности этих свай по статическому испытанию. На основании проведенного исследования было установлено, что сваи DDS обладают хорошей несущей способностью по сравнению со сваями CFA. В целом, результаты исследования предоставляют ценную информацию о эксплуатационных характеристиках свай DDS и CFA, которая может быть использована для оптимизации их конструкции и установки в различных типах грунтов.

Ключевые слова: масштабные модельные испытания, модельные сваи, несущая способность, испытание статической нагрузкой.

References

1. Bazarbayev D.O., Researching of bored FDP pile in a problematical soil ground // A dissertation submitted in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY (Ph.D.) - Астана: ЕНУ им Л.Н. Гумилева, 2009. – 82с.

2. Rad S.H., Ghareh S., Eslami A. Experimental and feld studies on the behavior of drilled displacement piles // Innovative Infrastructure Solutions 6, №188 – Springer Nature Switzerland, 2021. – P. 1-11.doi.org/10.1007/s41062-021-00557-2.

3. Basu P., Prezzi M., Basu D. Drilled Displacement Piles – Current Practice and Design // DFI Journal The Journal of the Deep Foundations Institute . Hawthorne, USA, 2010. – P. 3-20.

4. ssakulov, A., Omarov, A., Zhussupbekov, A., Mussakhanova, S., Issakulov, B. Investigation of the interaction of the bored micro pile by DDS (FDP) technology with the soil ground. International Journal of GEOMATE, Vol. 24, Issue 105, 2023, pp. 11–17.

5. Yergen ASHKEY, Interaction of CFA bored piles with soil condition in Astana // A dissertation submitted in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY (Ph.D.) – Astana.: L.N. Gymileva ENU. -2008. – 52p.

6. Zhussupbekov A., Omarov A., Shakirova N., and Razueva D., Complex analysis of bored piles on LRT construction site in Astana. Lecture Notes in Civil Engineering, Vol. 49, 2020, pp.461–471.

7. A. Zh. Zhusupbekov and Y. Ashkey, T.Zh. Seidmarova, R.K. Bazilov, D.O. Bazarbayev, A.A. Zhusupbekov. "Geotechnical and Geodisaster problems in Kazakhstan". Proceedings 4th International Conference on Disaster Prevention and Rehabilitation, 2007, (Indonesia, Semarang), 28-40 pp.

8. Zhusupbekov A. Zh., Ashkey Y., Geotekhnicheskij monitoring i razrabotka peredovyh tekhnologij ustrojstva svajnyh osnovanij zdanij i sooruzhenij v slozhnyh gruntovyh usloviyah Kazahstana s uchetom trebovanij inzhenerno-geologicheskih izyskanij. Zaklyuchitel'nyj otchet o nauchno-issledovatel'skoj rabote. NC NTI RK.- Astana, 2007.-62 s.- Inv. №0208RK0039.

9. Decourt, L. Behaviour of a CFA Pile in a Lateric Clay.Proceedings of the 4th International Geotechnical Seminar on Deep Foundations on Bored and Auger Piles // BAP IV. Ghent, Belgium, 1993. - pp. 301-308.

10. A. B. Isakulov, A. Zh. Zhusupbekov, B. R. Isakulov, S. B. Iskakov. Topyrak massivinin DDS tekhnologiyasy bojynsha ornatylgan byrgylanyp toltyrylgan қadalarymen ozara arekettesuin zertteu. Vestnik evrazijskogo nacional'nogo universiteta imeni L.N.Gumileva. Seriya tekhnicheskie nauki i tekhnologii, Vol. №4, Issue 141, 2022, pp.19-29.

11. Omarov A., Kuderin M., Zhussupbekov A., Kaliakin N., and Iskakov S., Vibration measurements at a new monument in Nursultan city. International Journal of GEOMATE, Vol. 21, Issue 85, 2021, pp.24–31

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