Proceedings of the XVIII ECSMGE 2024
GEOTECHNICAL ENGINEERING CHALLENGES
TO MEET CURRENT AND EMERGING NEEDS OF SOCIETY
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ISBN 978-1-032-54816-6
DOI 10.1201/9781003431749-459
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ECSMGE 24
XVIII EUROPEAN CONFERENCE ON SOIL MECHANICS AND GEOTECHNICAL ENGINEERING

New concept of drilling auger for displacement pile installation

Nouveau concept de tarière pour la mis en œuvre de pieux déplacés

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ABSTRACT: In 2020, a new version of the screw displacement auger for pile installation in soil was developed and patented in Poland. It was named DPDT (Displacement Pile Drilling Tool). The general aim of its development was to reduce the soil resistances to the auger during screwing into the ground while maintaning a good load-bearing capacity for the screw displacement piles. The "DPDT-Auger" prototype was tested as a scaled-down model in the laboratory as well as in full-scale in the field. Its efficiency was compared with an ordinary SDP auger in two ways: by assessing soil resistances during screwing into the ground and by assessing the bearing capacity of completed piles. This paper presents the field tests and their results. Over 80 piles were tested in six test sites. Among them, 24 piles were instrumented and subjected to static load tests. The test results were generally positive and showed that the DPDT auger generates less torque than the SDP auger but requires more rotations and a slightly longer pile installation time. When it comes to the bearing capacity of the compression load, both DPDT and SDP piles showed similar characteristics.

RÉSUMÉ: En 2020, une nouvelle version de la tarière à vis pour l'installation de pieux dans le sol a été développée et brevetée en Pologne. Il a été nommé DPDT (Displacement Pile Drilling Tool). L'objectif général de son développement était de réduire les résistances du sol à la tarière lors du vissage dans le sol tout en conservant une bonne capacité portante aux pieux vissés. Le prototype "DPDT-Auger" a été testé en modèle réduit en laboratoire ainsi qu'en vraie grandeur sur le terrain. Son efficacité a été comparée à celle d'une tarière SDP ordinaire de deux manières: en évaluant les résistances du sol lors du vissage dans le sol et en évaluant la capacité portante des pieux terminés. Cet article présente les tests sur le terrain et leurs résultats. Plus de 80 pieux ont été testés sur six sites d'essai. Parmi eux, 24 pieux ont été instrumentés et soumis à des essais de chargement statique. Les résultats des tests ont été globalement positifs et ont montré que la tarière DPDT génère moins de couple que la tarière SDP mais nécessite plus de rotations et un temps d'installation des pieux légèrement plus long. En ce qui concerne la capacité portante de la charge de compression, les pieux DPDT et SDP présentent des caractéristiques similaires.

Keywords: Screw displacement pile; pile drilling tool; pile installation; bearing capacity of pile.

1 INTRODUCTION

Screw displacement piles and columns are currently one of the most popular technologies for piling and subsoils improvement. They are characterized by several technical and economic advantages, such as: quick construction, no excavation, no shocks and noise, and relatively good load-bearing capacity and stiffness in the ground (Bottiau, 2006; Basu & Prezzi, 2009). However, the disadvantage of this technology is the high resistance during the screwing of pile augers (drills, tools), especially in non-cohesive soils. These resistances require the use of piling machines (drilling rigs) with high rotational power and make it difficult to pass through dense intermediate layers and to create longer piles in the bearing layers.

The high screwing resistance was primarily the reason for the development of various varieties and shapes of displacement drills (SDP, "Omega", FDP, CMC, "DeWaal", APGD and others). Also, the author of this article, who has been dealing with the subject of screw displacement piles at the Gdansk University of Technology for years (habilitation thesis - Krasiński, 2013), has developed his own prototype version of the DPDT (Displacement Pile Drilling Tool) pile auger. It was patented in Poland (Krasiński, 2020, patent No PL 235442 B1). The scheme of the DPDT auger is shown in Figure 1.

In the DPDT auger, the disc helix, which is in the lower part of the typical SDP or CMC augers, has been replaced with a less prominent bar helix (round or square). The main reason for this was to reduce the torque M_T value when screwing the augur into the soil and to reduce or eliminate the loosening of non-cohesive soil around the pile base. A side effect of the change is the slightly conical shape of the pile base which, however, according to research (Krasiński et al., 2022a,b), does not significantly reduce soil resistance under the pile base. An additional advantage of the DPDT drill is its simple design, which reduces the costs of its production and regeneration.

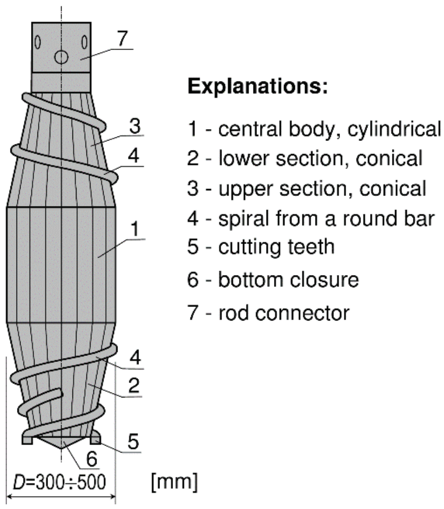

Figure 1. Scheme of new DPDT pile auger (Krasiński, 2020).

2 RESEARCH PROJECT

The development of the DPDT auger became an inspiration to launch the 2019-2022 "DPDT-Auger" research project by the consortium of Gdansk University of Technology and the Polish geotechnical contracting company Budokop Geotechnika Sp. z o. o. (Consortium Leader).

The research project examined the effectiveness of the DPDT auger by comparing it with other drills, first in the laboratory and then in situ in full-scale. Model-scale studies gave generally positive results as described, e.g., in Krasiński et al. (2022b).

The results of the entire research project, which, in addition to comparative research, also included several other issues regarding the execution, calculation and design of screw displacement piles and columns, were included in the Report (Krasiński et al. 2022a) and briefly characterized in the works of Krasiński et al. (2022b, 2023) and Krasiński (2023).

In a field study of the research project, a prototype DPDT auger was tested against an SDP auger. Figure 2 presents photographs of the tested drill bits, which also shows a modified version of the new DPDT-S auger, with the central cylindrical section (soil displacement body) shortened by half. Field tests were carried out on prepared experimental plots, where drill and pile tests were combined with in-situ and laboratory tests of the subsoil.

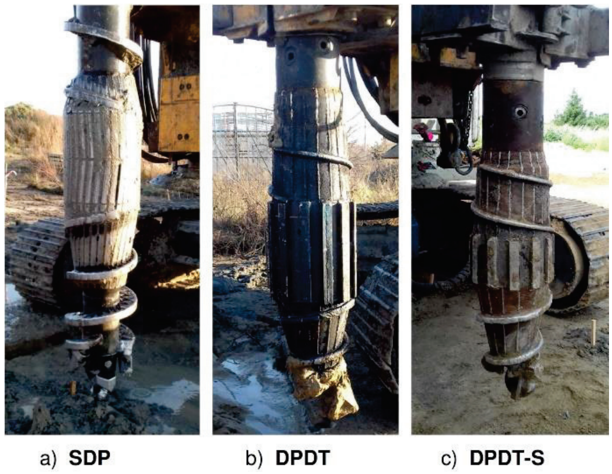

Figure 2. View of pile augers to be tested.

3 FIELD INVESTIGATIONS OF AUGERS AND PILES

As part of the research project, 6 field experimental plots were organized in several places in northern Poland. A total of over 80 screw displacement piles were made and tested by consortium member - Budokop Geotechnika. The given number included 24 research piles, and the rest were anchor piles for test loading stands. The geotechnical structure of the subsoil in the plots was determined using boreholes, CPTU and DMT soundings, and laboratory tests of soil samples. During the field study, first the augers from Figure 2 were tested for resistance and parameters of their drilling into the ground during the installation of research and anchor piles. Then, in each plot, static load tests were performed on 4 test piles, instrumented by a chain of vibrating wire extensometers.

4 TEST RESULTS

The complete results of field tests of the augers and piles are included in the Report (Krasiński et al., 2022a). This article presents only sample results regarding auger screwing resistance and pile settlement characteristics (Q-s) from load tests. All the results are characterized only qualitatively. A detailed quantitative and statistical analysis of the discussed results has been omitted in this article due to space limitations.

4.1 Test results of auger screw-in resistances

The resistance of the augers when screwing into the ground was defined by three basic parameters: torque M_T, specific number of rotations per unit of penetration

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n_R and total time of pile hole drilling t_D. Other parameters were omitted as less important derivatives of the three above parameters (Krasiński, 2014). The SDP, DPDT and DPDT-S augers are compared in terms of M_T, n_R and t_D in Figure 3, 5, 7 and 9. They concern three selected research plots (No. II, IIIab and IV). In order to connect screwing resistances with the soil conditions, the auger resistance graphs appear alongside geotechnical profiles and q_c cone resistance charts from CPTu soundings. The research plots were specially selected due to their non-cohesive soils in load-bearing layers.

The aim of the pile tests and measurements was to determine the load-bearing capacity and *Q-s* characteristics of the piles, divided into the shaft (Q_s) resistances and the base (Q_b) resistances in the lower load-bearing soil layers. Comparative charts from static tests of piles in selected experimental plots No. II, III and IV are presented in Figure 4, 6 and 8. Both these results and those from the remaining experimental plots showed that piles made with the tested DPDT and DPDT-S augers and SDP auger are characterized by similar parameters of interaction with the soil (bearing capacity and *Q-s* characteristics for compression loads).

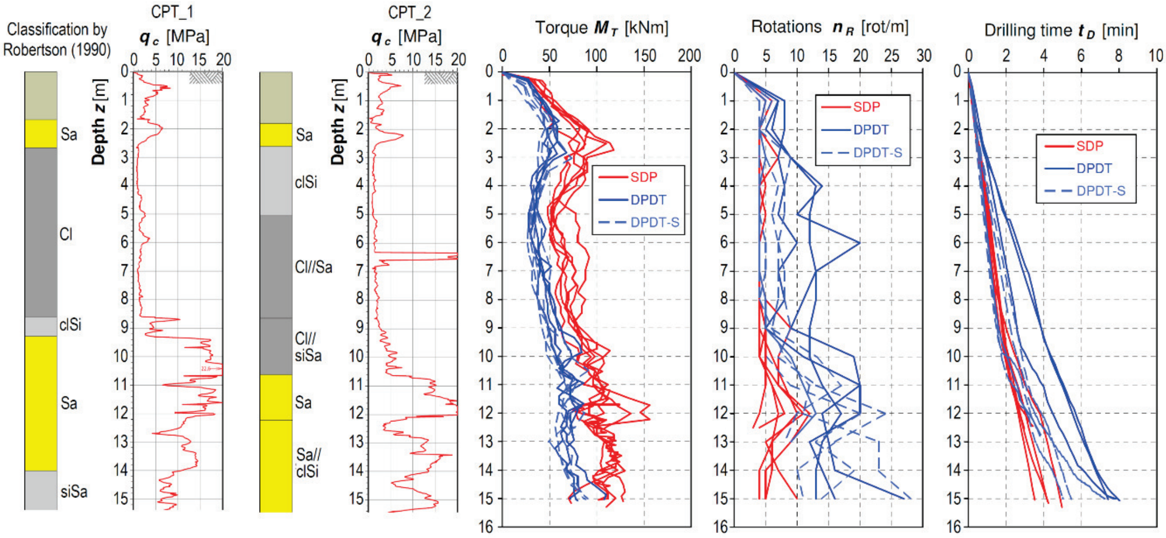

Figure 3. Drilling resistances of pile augers with CPTu diagrams on the experimental plot No. II.

The presented results confirmed observations previously made in the model studies described in Krasiński et al. (2022), and should generally be assessed positively. As expected, the prototype DPDT and DPDT-S augers generated lower values of M_T torques than the SDP auger. However, it was obtained at the expense of a larger number of rotations n_R and a longer pile hole drilling time t_D. The quantitative differences between individual plots are not the same and depend on the geotechnical structure of the subsoil. However, the general patterns in these differences were consistent or similar in all cases.

4.2 Pile load test results

Static pile load tests (SPLT) in field plots were carried out with additional instrumentation of pile shafts using a chain of vibrating wire extensometers Geokon - model 1300 (A9) (Geokon, 2023).

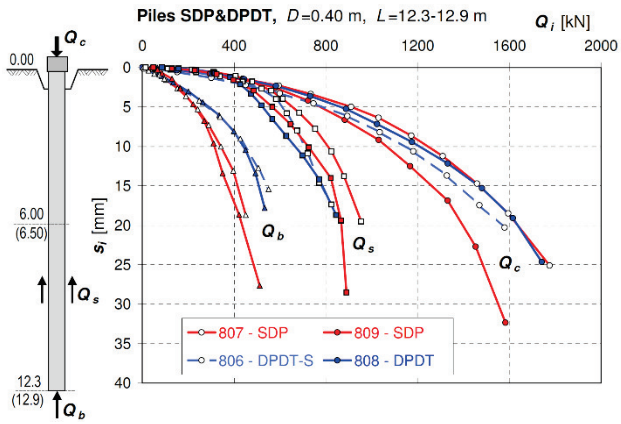

Figure 4. SPLT results of piles on the field experimental plot No. II.

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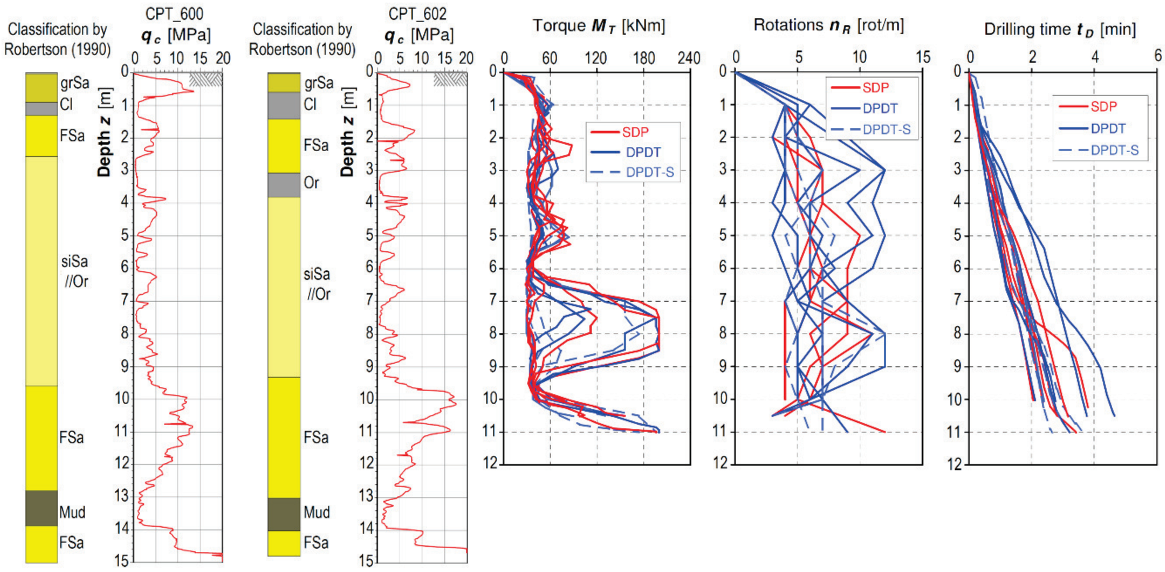

Figure 5. Drilling resistances of pile augers with CPTu diagrams on the field experimental plot No. IIIa.

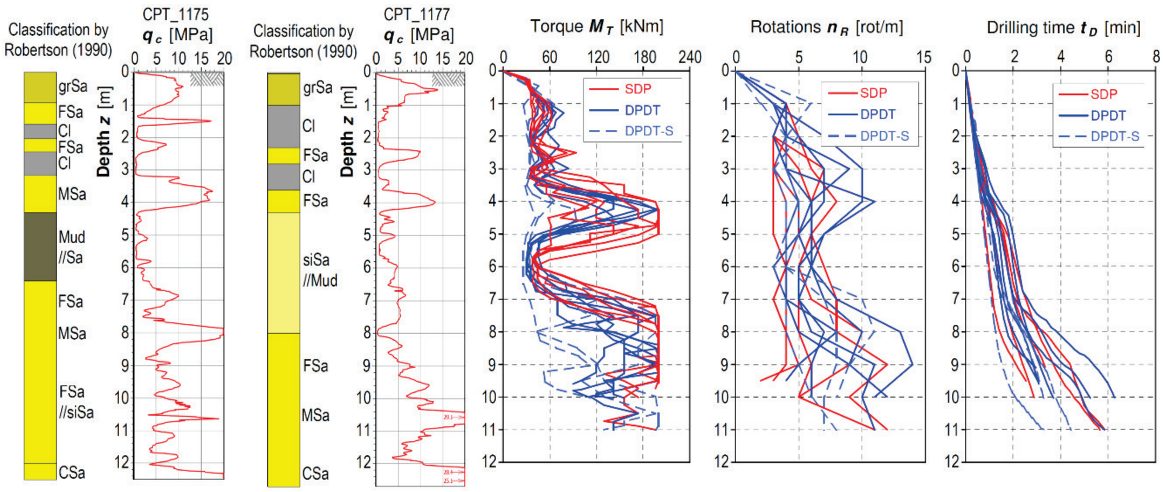

Figure 6. Drilling resistances of pile augers with CPTu diagrams on the field experimental plot No. IIIb.

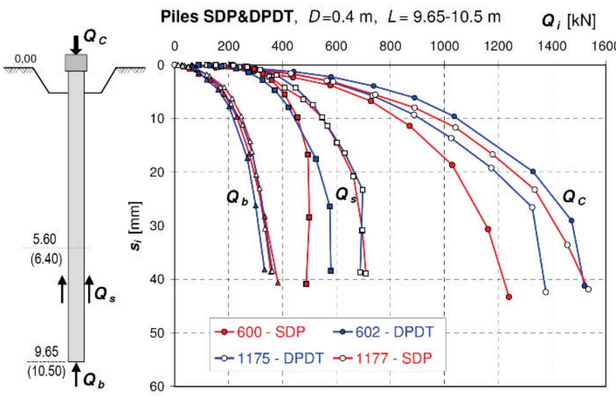

Figure 7. SPLT results of piles on the field experimental plot No. III.

To sum up, the performance of the prototype DPDT and DPDT-S drill bits should once again be positively assessed, mainly due to the fact that they generate a lower M_T torque value than the SDP drill bit. This advantage is crucial and outweighs the disadvantage of increased n_R and t_D parameter values. A lower value of M_T makes it possible to achieve greater auger penetration depths, and thus create longer piles with greater load-bearing capacities. It also provides a greater guarantee of successfully overcoming stronger interlayers in the subsoil and creating piles of desired lengths. At the same time, the shapes of the DPDT and DPDT-S drill bits do not deteriorate the load-bearing capacity or Q-s characteristics of the thus constructed piles.

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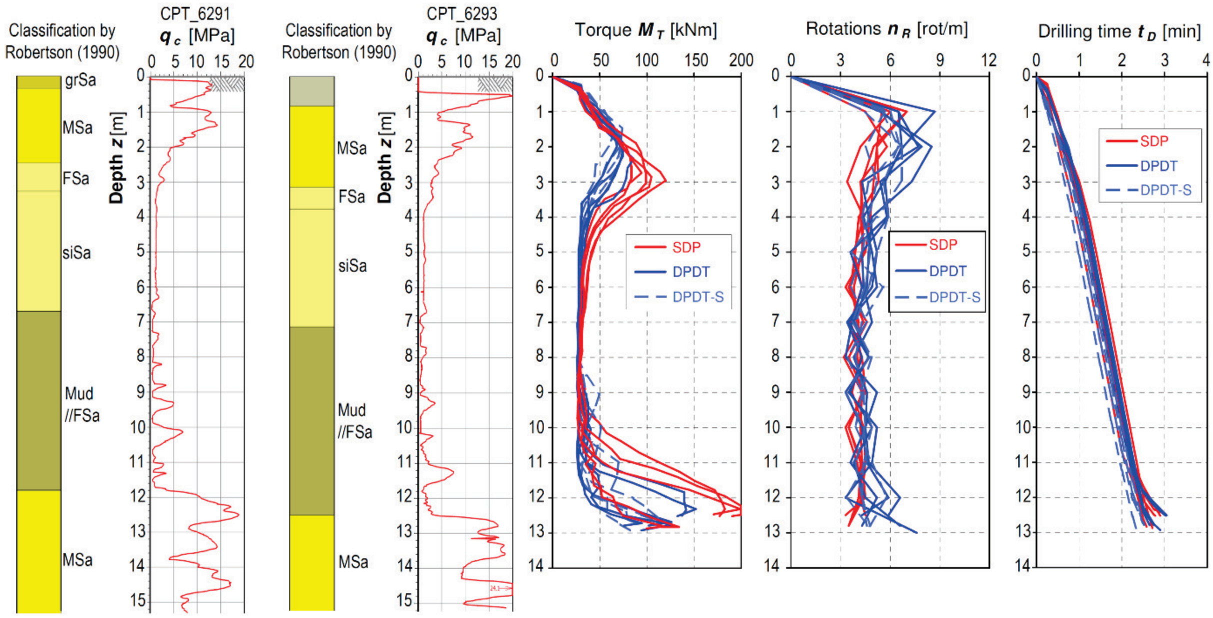

Figure 8. Drilling resistances of pile augers with CPTu diagrams on the experimental plot No. IV.

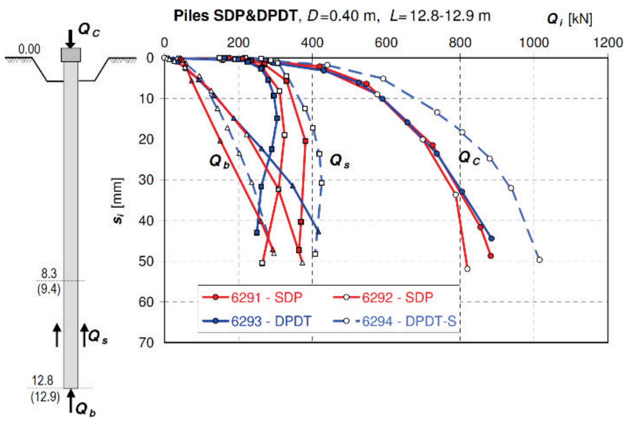

Figure 9. SPLT results of piles on the experimental plot No. IV.

5 CONCLUSIONS

i) Comparative analyses showed that the DPDT and DPDT-S auger indeed required lower torque M_T values but a higher number of rotations per depth unit n_R and longer drilling time t_D in comparison with the SDP auger. The middle section of the DPDT-S auger is shortened by half in relation to the DPDT auger. Thanks to this, the value of the torque M_T is additionally reduced. The overall balance of screwing resistance should be considered favorable for the DPDT and DPDT-S augers, because the generation of a lower torque value allows for the achievement of greater drilling depths and pile lengths, and more effectively overcomes stronger soil layers.

ii) Piles made with SDP and DPDT (DPDT-S) augers are characterized by very similar interaction with subsoils of various geotechnical configurations. Statistically, the load-bearing capacity and stiffness of both types of piles are similar.

iii) In practice, the use of DPDT and DPDT-S drills may be of technical and economic benefit without any significant risk of lowering the quality and load-bearing capacity of the piles in comparison to those made by traditional augers, e.g. SDP. On the contrary, piles and columns made with DPDT drills can achieve more favorable shaft shapes with smaller deformations, neckings and soil inclusions, which are observed when using classic drills with disc helix spirals. They are also more advantageous when making piles in contaminated soils and landfill areas.

ACKNOWLEDGEMENTS

The described test and analyses results of augers and piles were obtained from research works conducted in the "DPDT Auger" research project, financially supported by the Polish National Centre for Research and Development (project No. POIR 4.1.4. 0124/18, “Development of a method and tools for the installation of screw displacement columns/piles in various ground conditions in Poland, together with the preparation of a methodology for the design and acceptance of works”). The project was carried out by the consortium of Gdansk University of Technology and the Polish geotechnical company Budokop Geotechnika Sp. z o.o.

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