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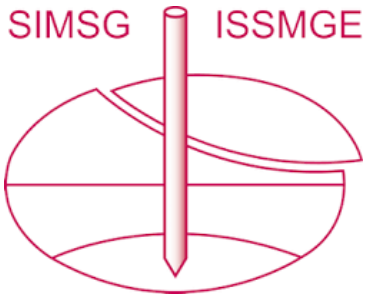

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Pile-Jetting: Discussion of recent developments and possibilities for physical modelling

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ABSTRACT: Jetting as a construction method has been used for many years for applications such as underpinning existing structures, sealing works on construction sites, and earthquake mitigation measures. However, contractors are increasingly seeking to promote this method for the construction of individual piles with controllable pile size and quality. In particular, the use of smaller construction systems – such as self-drilling systems already used for soil nailing – offers new opportunities on space-constrained construction sites, as is typically the case for refurbishment measures on existing structures. This contribution briefly discusses physical modelling approaches that have been used for related problems, with a focus on the parameters relevant to pile-jetting. Finally, an outlook is given on possible initial centrifuge model-test setups for pile-jetting.

1 INTRODUCTION

Jetting is often used for underpinning works due to its relatively fast installation and construction process and because the jetting body provides soil stability from the outset of the underpinning process. The principle of jetting is to inject, at high pressure, a cementitious slurry into the ground. The slurry is then mixed with the adjacent soil. The jetted ground provides stabilised soil once the cement-injection has hardened (e.g. Qin, 2023). Jetting is a viable option for producing pile-like constructions in the soil. A key requirement is to control the quality of the jetted pile in terms of strength, integrity and pile diameter. These parameters depend on soil properties (e.g. grain size distribution), soil state (loose or dense; saturated or unsaturated), and the overburden pressure at the relevant depth, as well as on cement-slurry properties and the applied injection pressure. Therefore, investigating the interdependence of these parameters through physical modelling is crucial for constructing jetted piles with reliably controllable pile diameter.

1.1 Pile-Jetting at prototype conditions

The "Mini-Jetting" technique is employed to carry out injection works with significantly smaller installations than conventional jet-grouting methods. It is based on a direct drilling system using hollow rods and disposable drill crowns, through which the cement suspension is injected during the drilling process (Fig. 1). Nozzles in the crown reduce the outlet cross-section, thereby increasing the pressure to the injected material (Fig. 2).

Figure 1: Self-drilling anchor with continuous thread (Kuechler-Technik, 2025)

Figure 2: Jetting with grout

With a fine cementitious injection material and pressures of up to 200 bar, it is possible to install piles for underpinning or sealing, even in fine-grained soils.

2 PHYSICAL MODELLING OF PILE-JETTING – STATE OF THE ART AND POSSIBILITIES

Shepley & Bolton (2013, 2014) investigated the effects of water injection on pile installation load using centrifuge modelling. They describe aspects of water-pressure development in the centrifuge model, flow rate, and energy losses through the model pile. Particular attention was paid to measuring the pile-toe pressure, as this is an important factor for pile-jetting installation. It is suggested to measure the toe pressure via a pressure transducer located as close as possible to the pile toe. De Brum Passini et al. (2018) discuss the mechanism of pile installation by soil fluidisation in saturated sand. They conducted a series of model tests in the laboratory at 1*g* conditions in both medium-dense and dense sand and showed that the fluidised geometry is not influenced by soil density. Zakeri et al. (2014) conducted a series of centrifuge model tests to investigate the long-term axial capacity of jetted piles, as the bearing capacity of jetted piles in fine-grained soils increases with time due to consolidation and thixotropy.

The brief review of the state-of-the-art shows that little centrifuge modelling work has been carried out on direct pile jetting for onshore foundation systems. Key research questions to promote the "Mini-Jetting" technique - such as (i) injection pressure as a function of soil type, (ii) size control of the jetted pile, and (iii) construction process challenges - require further investigation using centrifuge modelling.

The studies by Shepley & Bolton (2013, 2014) show that the application of high injection pressures, as well as the modelling of the jetting equipment, are of particular interest. De Brum Passini et al. (2018) provide initial insight into the influence of soil density on the jetting procedure. Zakeri et al. (2014) highlight the dependence of pile capacity on consolidation. This knowledge, together with an understanding of scaling laws (e.g. Madabhushi, 2014), may support the development of a draft centrifuge model test program to investigate the performance of this system, as introduced in Section 1.1, with respect to pile integrity.

3 OUTLOOK

A centrifuge test setup for pile jetting may be developed as a next step. The following components need to be modelled according to the scaling laws:

a) A direct drilling system using a hollow rod and a drill crown with nozzles. The capability for in-flight drilling is of great importance. Gaudin et al. (2011) constructed a model spudcan using water jetting, which may be helpful to develop the drilling system.

b) High-pressure cementitious injection appropriate to the surrounding soil. The scaling of the injection to be used will depend on the grain-size distribution of the soil used in the centrifuge. Experience from pile jetting in practice may help to benchmark injection parameters for specific soil conditions. Shepley & Bolton (2013, 2014) provide guidance on applying high pressure at the nozzle of the drilling system. The size control of jetted piles may be assessed by excavating the model pile after testing. More advanced methods, such as Computer Tomography (*CT*), may be evaluated in a later phase (e.g. Arnold et al. 2024).

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REFERENCES

Arnold, A., Portmann, G., Angst, U., Brem, M., Montani, S. and Pedrozzi, G. (2024). Zustandserfassung von bestehenden Mikropfählen und permanenten ungespannten Ankern. Bundesamt für Strassen ASTRA.

De Brum Passini, L., Schnaid, F., Maia Rocha, M. and Möller, S.V. (2018). Mechanism of model pile installation by water jet fluidization in sand. *Ocean Engineering 170(2018)*, pp. 160-170. http://doi.org/10.1016/j.oceaneng.2018.10.017

Gaudin, C., Cassidy, M.J., Bienen, B. and Hossain, M.S. (2011). Recent contributions of geotechnical centrifuge modelling to the understanding of jack-up spudcan behaviour. *Ocean Engineering 38*: 900-914. https://doi.org/10.1016/j.oceaneng.2010.12.001

Kuechler-Technik (2025). https://www.kuechler-technik.ch/geotechnikprodukte/ankertechnik

Madabhushi, G. (2014). *Centrifuge Modelling for Civil Engineers.* Taylor & Francis Group

Qin, X. (2023). Application of High-pressure Jet Grouting Pile in Deep Foundation Pit Excavation and Support Scheme around the Original Natural Foundation. In *Journal of Civil Engineering and Urban Planning.* Clausius Scientific Press, Canada, pp. 24-29. http://doi.org/10.23977/jceup.2023.051204

Shepley, P. and Bolton, M.D. (2013). Water injection aided pile jacking centrifuge experiments in sand. Proceedings of the 18th International Conference on Soil Mechanics and Geotechnical Engineering, Paris, 2013. pp. 957-960.

Shepley, P. and Bolton, M.D. (2014). Water supply to a geotechnical centrifuge for pile jetting in sand. *Proceedings of the 8th ICPMG 2014, Perth, Australia.* pp281-287. http://doi.org/10.1201/b16200-34

Zakeri, A., Liedtke, E., Clukey, E.C. & Jeanjean, P. (2014). Long-term axial capacity of deepwater jetted piles. *Géotechnique* 64(12): 966-980. http://doi.org/10.1680/geot.14.P.014