Undrained shear strength of soft offshore sediments measured by free fall CPT from the Gulf of Finland

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Introduction

Due to the green energy transition, construction of wind energy to offshore areas in Finland is rapidly increasing. Detailed knowledge of seafloor geotechnical properties is needed for the construction of offshore structures. Undrained shear strength is one of the most important properties related to the stability and evaluation of bearing capacity. Tests by a free-fall cone penetrometer (FF-CPT), as a part of the FINMARI research infrastructure, provide a fast and cost-effective method to investigate offshore undrained shear strength.

Offshore sediments of the Inkoo study area in the Gulf of Finland were investigated by the FF-CPT (*Fig. 1*). In addition, site characterization included seismoacoustic survey and sediment coring. The FF-CPT was used for ground-truthing the interpretation of seismoacoustic profiles, as well as, for the measurement of undrained shear strength profiles of the subsurface.

Methods

Site investigations included seismoacoustic surveys and sediment coring, using a Kullenberg-type long piston corer, at two locations onboard the R/V Geomari of GTK (Fig. 1). At the coring locations, FF-CPT tests were carried out by a dotOcean Graviprobe 2.0 FF-CPT (*Fig. 2*). The instrument accelerates in free fall and penetrates soft sediments while recording pressure and acceleration, which are then used for deriving cone resistance and undrained shear strength of the sediment.

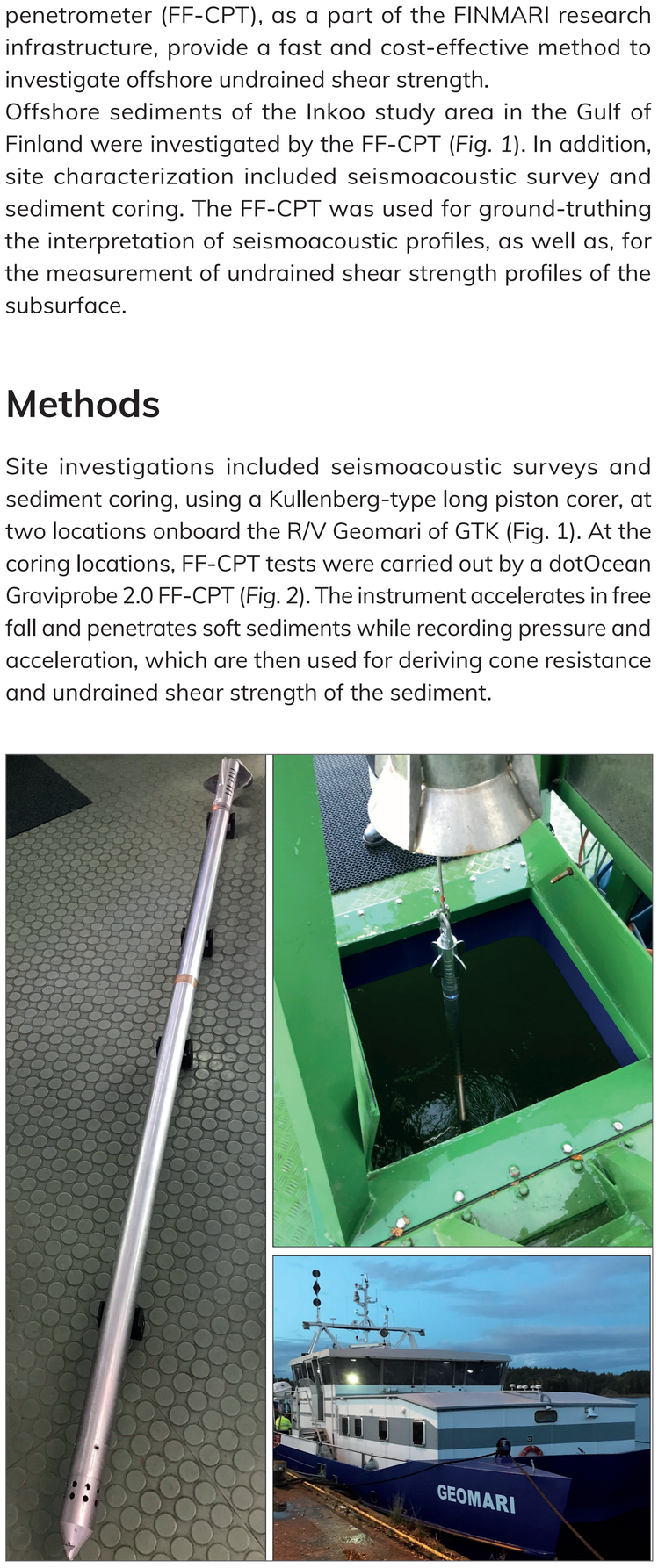

Fig. 2. Graviprobe FF-CPT instrument onboard R/V Geomari is part of the FINMARI research infrastructure.

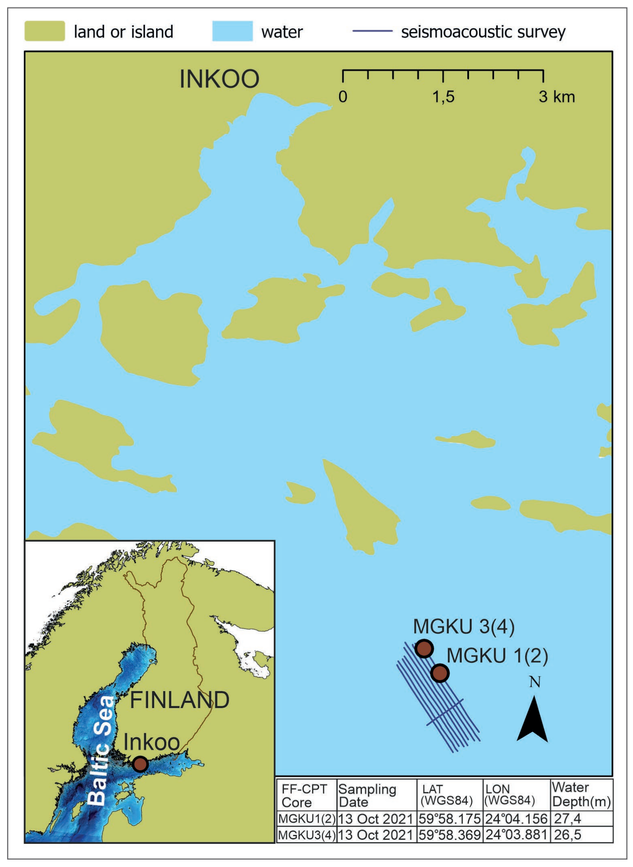

Fig. 1. Inkoo study area in the Gulf of Finland. Sediment cores were collected, and FF-CPT tests carried out at the MGKU 1(2) and MGKU 3(4) sites.

Acoustic survey and sediment coring

The fine-grained sediments of Inkoo study area include brackish-water mud, post-glacial lacustrine silty clay and glaciolacustrine varved silt and clay based on seismoacoustic profiles and sediment coring (*Fig 3*). Both cores MGKU 1(2) and MGKU 3(4) consist of thin sandy brackish-water mud layer on top underlain by organic-rich brackish-water mud. MGKU 1(2) has brackish-water mud to the depth of 2.1 m and MGKU 3(4) to the depth of 0.4 m. At both locations the brackish-water mud is underlain by a sandy erosional layer and post-glacial lacustrine silty clay with sulphide-banded intervals. MGKU 1(2) has post-glacial lacustrine sediment to the depth of 3.8 m and MGKU 3(4) to the depth of 2.1 m. The post-glacial sediment gradates to glaciolacustrine sediment which continues to the core bottom at 4.7 m (MGKU 1(2) and (MGKU 3(4)).

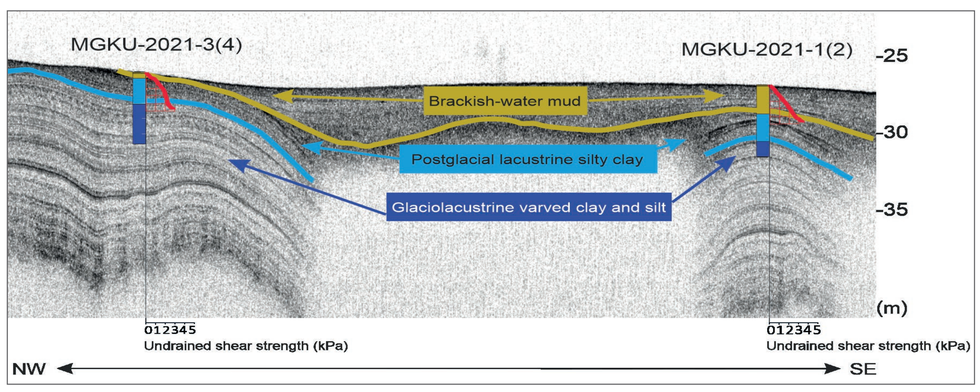

Fig. 3. Seismoacoustic profile and cores MGKU 1(2)-MGKU 3(4) of the Inkoo study site. Brackish-water mud, post-glacial lacustrine silty clay and glaciolacustrine varved silt and clay are indicated, as well as the basal contacts of the brackish-wated mud (yellow line) and the post-glacial lacustrine silty clay(light blue line). Profiles of undrained shear strength, calculated as the mean of three repeat FF-CPT tests, are indicated by red graphs (units in kPa).

FF-CPT tests

Multiple FF-CPT drops were repeated at study locations MGKU 1(2) and MGKU 3(4) (*Fig. 4*), and a mean undrained shear strength was calculated (*Fig. 3*). The undrained shear strength increases almost linearly in the brackish-water mud. FF-CPT penetrates into the post-glacial lacustrine sediment and stops at the depth of ca. 2.4 m at MGKU 1(2). The maximum undrained shear strength at MGKU 1(2) is on average 3.4 kPa. At MGKU 3(4), FF-CPT penetrates through post-glacial lacustrine sediment with a steeper gradient of undrained shear strength to the glaciolacustrine silt and clay, where it stops with the maximum undrained shear strength on average 2.8 kPa at the depth of ca. 2.4 m.

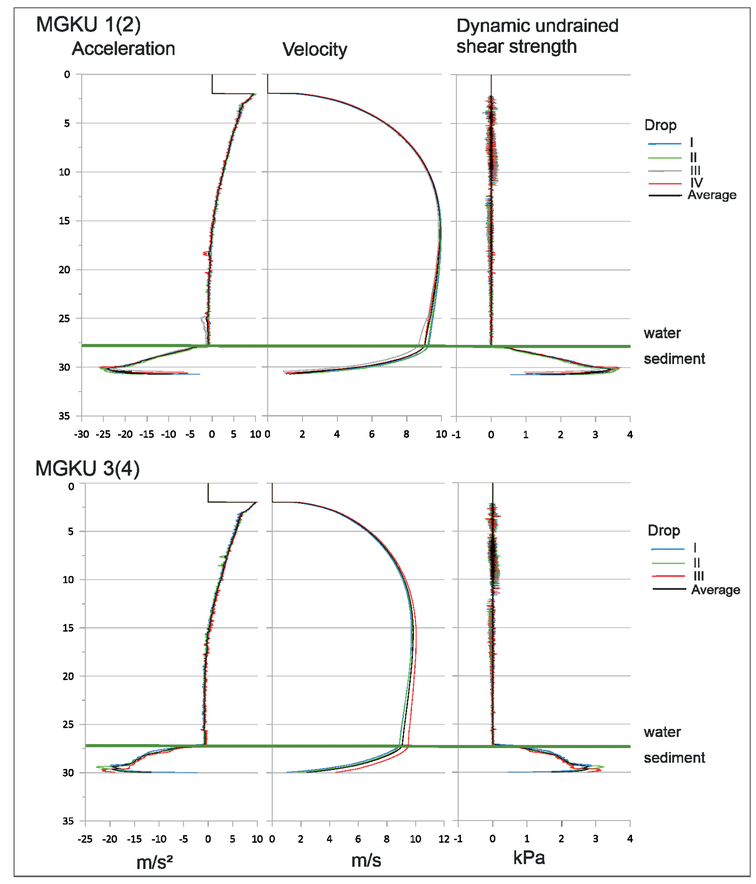

Fig. 4. For MGKU 1(2) four drops and MGKU 3(4) three drops by FF-CPT was repeated. Acceleration, velocity and dynamic undrained shear strength were recorded.

Conclusion

FF-CPT results show that fine-grained sediments of Inkoo study site at MGKU 1(2)-MGKU 3(4) are generally very soft, and the undrained shear strength increases towards bottom. The inclination of the measured shear strength profiles changes at the sediment unit contacts (as indicated by yellow and light blue lines in *Fig. 3*). The different inclinations between brackish-water and post-glacial lacustrine sediments demonstrate their different depositional environments and consequently different geotechnical properties, which needs to be considered when planning the construction of offshore infrastructure.

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