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Medusa SDMT testing at the Onsøy Geo-Test Site, Norway

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ABSTRACT

The Medusa SDMT is the last-generation, fully automated version of the seismic dilatometer (SDMT). An extensive *in situ* testing campaign with the Medusa SDMT was carried out in June 2022 in different soil types at four well-known benchmark test sites in Norway, part of the Geo-Test Sites (NGTS) research infrastructure managed by the Norwegian Geotechnical Institute. The experimental campaign was conducted as part of the Transnational Access project – JELLYFISh funded by H2020-GEOLAB. This paper presents a preliminary assessment of significant results obtained by Medusa SDMT at the Onsøy test site, a soft marine clay. The data is compared to available *in situ* and laboratory data previously published at the Onsøy test site. The results show that the Medusa SDMT data are consistent with traditional (pneumatic) SDMT results. Furthermore, the parameters obtained from the interpretation of Medusa SDMT data, in particular the overconsolidation ratio *OCR*, the coefficient of earth pressure at rest K_0, and the undrained shear strength s_u agree generally well with the corresponding parameters obtained in past investigations from other *in situ* and laboratory tests.

Keywords: SDMT; Medusa DMT; *in situ* testing; Geo-Test Sites.

1. Introduction

The assessment and mitigation of multiple geo-hazards, such as subsidence, seismic liquefaction, and landslides, are of primary importance for protecting communities and reducing damages in densely populated and risk-sensitive areas. In this context, the improved geotechnical characterization of soil deposits commonly encountered in risk-sensitive areas, such as intermediate soils, sands, soft and quick clays, is a key aspect to contribute to mitigate the impact of geo-hazards. At the same time, there is an increasing demand towards the development of innovative 'smart' technology to facilitate *in situ* soil testing in a variety of field conditions.

Among recent advancements of *in situ* testing technology, one significant development is the Medusa DMT, which represents the last-generation, fully automated version of the flat dilatometer (DMT). The Medusa DMT is able to perform dilatometer tests using a standard blade without the pneumatic cable, the control unit and the gas tank required in the traditional DMT configuration. The seismic version of the probe (Medusa SDMT) incorporates additional sensors for the measurement of the shear wave velocity (V_S).

An extensive *in situ* testing campaign with the Medusa SDMT was carried out in June 2022 in different soil types at four well-known benchmark test sites in Norway (Monaco et al. 2023): Halden (silt), Onsøy (soft clay), Tiller-Flotten (quick clay), and Øysand (sand). These benchmark sites are largely documented in previous research and are part of the Geo-Test Sites (NGTS) research infrastructure managed by the Norwegian Geotechnical Institute (NGI) (L'Heureux and Lunne 2020). The experimental campaign was conducted as part of the Transnational Access project – JELLYFISh funded by H2020-GEOLAB.

This paper presents some significant results obtained when testing Medusa SDMT in soft clay at the Onsøy test site and comparisons with the data obtained at the same site from previous *in situ* and laboratory investigation campaigns. Section 2 briefly summarizes the main features of the Medusa SDMT. Section 3 presents the field-testing program carried out at the Onsøy site. The results obtained by Medusa SDMT are compared to those obtained by the traditional seismic dilatometer (SDMT) in Section 4, while comparisons between soil parameters obtained from interpretation of Medusa SDMT and other *in situ* and laboratory tests documented in Gundersen et al. (2019) are discussed in Section 5. Final remarks are summarized in the Conclusions.

2. Medusa SDMT

The Medusa DMT (Marchetti 2018, Marchetti et al. 2019) is a self-contained probe able to autonomously perform dilatometer tests using a blade of standard dimensions without the pneumatic cable, the control unit and the gas tank which are required in the traditional pneumatic DMT configuration (Fig. 1). A motorized syringe, driven by an electronic board powered with rechargeable batteries, hydraulically expands the membrane to obtain the DMT *A*, *B*, *C* pressure readings, which are acquired and stored automatically at each test depth (typically every 0.20 m). The automatic (volume controlled) hydraulic pressurization of the membrane is highly repeatable and permits to impose a programmable timing (i.e., the recommended standard timing, or different timing corresponding to variable pressurization rates) to obtain the pressure readings. The probe can operate in cableless mode, which is a significant practical advantage in the offshore industry and for deep investigations. An optional electric cable may be used to obtain real-time data during test execution.

The Medusa SDMT incorporates additional sensors and components for the measurement of the shear wave velocity V_S in addition to the DMT measurements. The test procedure and interpretation for obtaining V_S measurements using the Medusa SDMT are the same established for the traditional SDMT, as described by Marchetti et al. (2008).

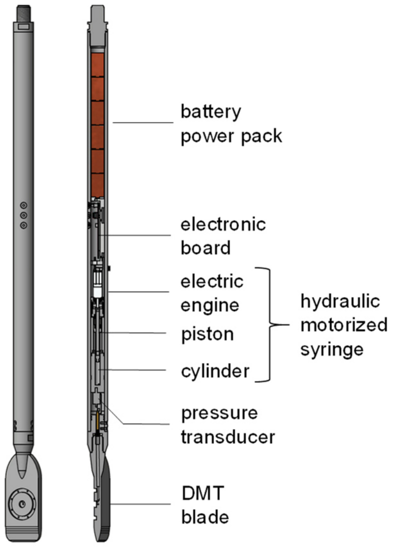

Figure 1. Main components of the Medusa DMT

3. Site conditions and Medusa SDMT campaign

The Onsøy site (Gundersen et al. 2019) is located in southeastern Norway, about 100 km from Oslo, just north of Fredrikstad (Fig. 2). It consists of a 25-35 m thick marine clay deposit which is normally consolidated, but it exhibits overconsolidation due to ageing. The overconsolidation ratio (*OCR*) decreases from about 4 near the surface to 1.2 at 30 m depth.

The natural water content varies between 40% and 70%, and the average plasticity index varies from about 45% in the upper 8 m to about 25-30% below 8 m. The sensitivity (S_t), as measured by fall cone tests, is constant at around 6 down to about 13 m. Beyond this depth it increases to a value of 45 at approximately 19 m, becoming a quick clay just above bedrock.

The salt content of the pore water is an important characteristic of the Onsøy clay. The percolation of freshwater from the surface has caused an almost linear salinity increase from zero at the surface to 30 g/l at about 7.5 m depth. Beyond this depth, the salinity remains constant.

Organic content values, determined by chemical oxidation with nitric acid, show values around 0.8% in the top 9 m and around 0.6% below this depth.

The soils at the Onsøy site are marine clays (Lunne et al. 2003). Such clays were deposited during deglaciation and the early postglacial period (Holocene) at times of higher relative sea level. Marine clays are found extensively in Scandinavia and North America. The Onsøy clay has also many similarities to marine clays in, e.g., Japan and southeast Asia, and is also remarkably similar to clays found offshore at the Troll, Gjøa, Luva and Aasta Hansteen oil and gas fields in the North Sea.

The experimental program at Onsøy, performed on 23-24 June 2022, comprised Medusa (S)DMT tests carried out using both standard and innovative non-standard test procedures (repeated A-readings, A-reading while penetrating), supplemented by one Medusa DMT dissipation test. The field-testing program included:

- one Medusa SDMT sounding (ONSD02) by standard procedure (penetration rate 20 mm/s, *A*-reading 15 s after stop, *B*-reading 15 s after *A*-reading), with *A*, *B*, *C* readings every 0.20 m and V_S measurements every 0.50 m;
- one Medusa DMT sounding (ONSD03**)** by repeated *A*-readings procedure, with *A*, *B*, *C* readings every 0.20 m (no V_S measurement);
- one Medusa DMT sounding (ONSD04) by *A*-reading while penetrating procedure, with continuous A readings, *B* and *C* readings every 1 m (no V_S measurement);
- one DMTA dissipation test (ONSD05) using a stationary probe inserted to the selected depth (6.40 m), run in parallel with the execution of Medusa (S)DMT soundings (also overnight).

The Medusa (S)DMT soundings reached a depth of 20.4-20.6 m below the ground surface. The field-testing program was developed considering the reference data available from NGI. The location of the Medusa (S)DMT soundings within the test site area was established close to one available traditional (pneumatic) SDMT sounding (ONSD01) performed by NGI (Fig. 2).

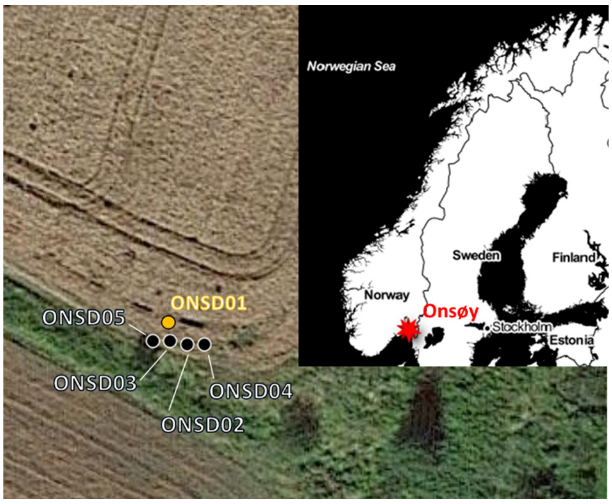

Figure 2. Location of Medusa (S)DMT and traditional SDMT (ONSD01) soundings at the Onsøy test site

Details on the different Medusa DMT test procedures are given in Monaco et al. (2022) and Marchetti et al. (2022). In this paper the attention is focused on the comparison of results obtained by Medusa SDMT vs. traditional SDMT carried out by the same standard procedure, as well as vs. other tests. Therefore, only the results provided by the standard test procedure (ONSD02) will be discussed further.

The standard Medusa DMT test procedure is the same procedure of the traditional pneumatic DMT test. As soon as the test depth is reached, the penetration is stopped and the DMT test cycle starts. The activated motorized syringe gradually increases the hydraulic pressure to the membrane. When the internal oil pressure equals the external soil pressure, the membrane lifts-off from its seat and starts to expand laterally. When the membrane has expanded of 0.05 mm at its centre, the *A*-pressure is recorded. After the *A*-reading, the motorized syringe continues to increase the pressure until the membrane displacement at the centre equals 1.10 mm. At this instant the second pressure reading *B* is recorded. As soon as the *B*-reading is obtained, the motorized syringe starts decreasing the oil pressure. If the *C*-pressure reading is requested, the motorized syringe applies a gradual and controlled depressurization after the *B*-reading and the membrane slowly returns to its initial position against the sensing disc. At the instant in which the contact reactivates, the corresponding pressure is recorded as the *C*-pressure reading.

In the standard procedure the pressurization rate is regulated by the motorized syringe so that the *A*-pressure reading is obtained 15 s after start of pressurization and the *B*-pressure reading 15 s after the *A*-pressure reading, in accordance with existing standards of the pneumatic DMT (ASTM D6635-15, ISO 22476-11:2017(E)).

4. Medusa SDMT vs. traditional SDMT test results in Onsøy clay

Figures 3 and 4 show the comparison of the results obtained by Medusa SDMT (ONSD02) and by traditional SDMT (ONSD01). The depth profiles of the corrected pressure readings p_0, p_1, p_2 (A, B, C corrected with the calibration offsets ΔA, ΔB to account for membrane stiffness) and the measured shear wave velocity V_S are shown in Fig. 3. Figure 4 shows the derived intermediate parameters, i.e., the material index I_D, the pore pressure index U_D, the horizontal stress index K_D, and the dilatometer modulus E_D (see Marchetti et al. 2001 for definitions and details).

The *in situ* u_0 pore pressure profile was established based on available information from piezometer measurements at the site (Gundersen et al. 2019). It shows hydrostatic pore pressure distribution with a groundwater table at a depth of 1 m below the ground surface. The values of the *in situ* vertical effective stress σ'_{v0} were calculated based on an approximate estimate of the depth profile of the soil unit weight (γ) obtained from DMT using available correlations (Marchetti and Crapps 1981). Further refinements will make use of more accurate determinations of γ, in place of the above estimated values.

The profiles of p_0 and p_1 obtained by Medusa SDMT and traditional SDMT (Fig. 3) are very close to each other. However, some difference is more evident when these pressures are combined in terms of intermediate parameters (Fig. 4). In particular, the values of the material index I_D calculated from p_0 and p_1 acquired by traditional SDMT appear significantly lower than the I_D values provided by Medusa SDMT. For low I_D values such inconsistency is amplified by the logarithmic scale. The same trend is also observed, to a lesser extent, in the profiles of the dilatometer modulus E_D, which depends on the difference ($p_1 - p_0$) as I_D, and of the horizontal stress index K_D, which depends only on p_0.

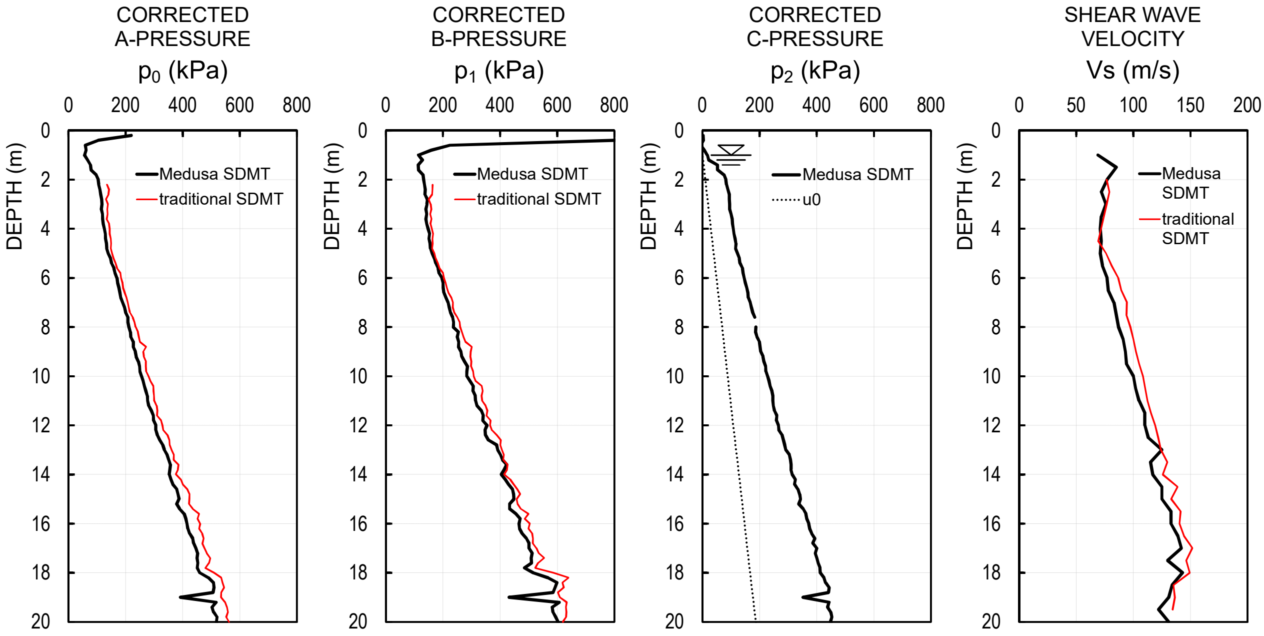

Figure 3. Comparison of the profiles of p_0, p_1, p_2, V_S obtained by Medusa SDMT and traditional SDMT at the NGTS Onsøy site

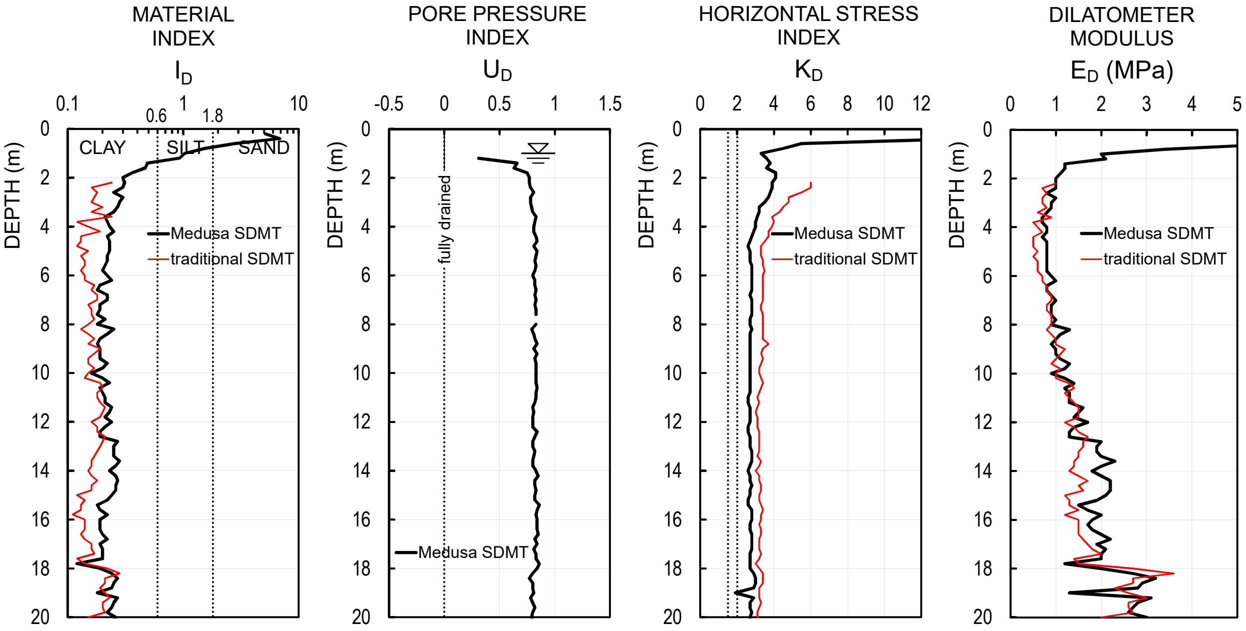

Figure 4. Comparison of intermediate parameters (I_D, U_D, K_D, E_D) obtained by Medusa SDMT and traditional SDMT

Such discrepancy may be attributed to inherently different technical features of the Medusa SDMT and the traditional SDMT equipment, as pointed out by Marchetti et al. (2021) and summarized in the following.

(1) With the traditional equipment the pressure is generated and measured at surface, although it operates on the membrane of the blade at depth. Any pressure equalization difference at the opposite ends of the pneumatic cable introduces an error on the test readings. The Medusa SDMT generates and measures the pressure directly at depth, eliminating any possible pressure equalization problem.

(2) With the traditional equipment it may not be simple for the operator to regulate the gas flow for obtaining the *A*, *B* pressure readings exactly at the timing prescribed by existing standards (*A*-reading 15 s after stop, *B*-reading 15 s after *A*-reading), especially when using long cables and in soft soils, in which the *A*-pressure values are very low and accordingly the pressurization rate should be very slow. If the *A*-pressure is accidentally measured at a time $t << 15$ s, it may result in a higher value due to higher excess pore pressures induced by probe penetration. The motorized syringe of the Medusa SDMT applies the pressure with a liquid (oil), which is incompressible. For this reason, it is possible to calculate and impose the speed of the motorized syringe for obtaining high accuracy in the timing of the DMT pressure readings.

Due to these two major differences, the Medusa SDMT permits to significantly improve the accuracy and repeatability of the measurements. In stiff soils, such improvements may appear as almost negligible when profiling the soil parameters. In very soft soils, however, the technical features of the Medusa SDMT may enable to obtain high quality data even in cases in which this would not be possible using the traditional equipment, as illustrated by Marchetti et al. (2021).

The profiles of p_2 and U_D in Fig. 3 and Fig. 4 refer only to the Medusa SDMT, because p_2 was not measured with the traditional SDMT. The profiles of V_S measured by Medusa SDMT and traditional SDMT (Fig. 3) are quite similar.

5. Medusa SDMT vs. other test results at the Onsøy site

Figures 5-10 show the comparison of the depth profiles for different soil properties obtained at the Onsøy test site from a variety of *in situ* and laboratory tests in past investigations and in the 2022 Medusa SDMT campaign. For a preliminary assessment, in this paper the profiles of the parameters estimated from Medusa SDMT are simply superimposed to the corresponding summary graphs presented by Gundersen et al. (2019). For consistency, the results obtained from Medusa SDMT and traditional SDMT, available from previous investigations, have been processed and interpreted using the same set of common use correlations developed for the pneumatic DMT (Marchetti 1980, see also Marchetti et al. 2001).

Figures 5 and 6 show, respectively, the depth profiles of the *OCR* and of the coefficient of earth pressure at rest K_0 (Gundersen et al. 2019), compared to the corresponding profiles obtained from Medusa SDMT and traditional SDMT according to Marchetti (1980). It can be noted that the *OCR* and K_0 profiles estimated from Medusa SDMT plots very close to the “best estimate” profile established in previous research, while the traditional SDMT appears to overestimate *OCR* and K_0.

Figure 7 shows the comparison of the depth profiles of the undrained shear strength s_u in compression (s_{uC}), in extension (s_{uE}) and in direct simple shear (s_{uDSS}) available at Onsøy with the s_u obtained from the 2022 Medusa SDMT campaign.

Figure 7a shows that the s_u profile estimated from Medusa SDMT plots at the lower bound of the *in situ* s_u profiles determined by CPTU using different cone factors (N_{kt} = 12, $N_{\Delta u}$ = 9) or estimated using correlations established for Norwegian clays (Karlsrud et al. 2005), as well as of the s_{uC} obtained in the laboratory on high quality samples through laboratory triaxial compression tests (CAUC). Also, the s_u values estimated from Medusa SDMT are generally lower than the s_u estimated from traditional SDMT. This result is consistent with the lower *A*-pressure values measured in absence of the pneumatic cable, as previously discussed.

Figure 7b shows that the Medusa SDMT s_u profile fits well with the "best estimate" s_{uDSS} profile at Onsøy. On the other hand, the s_u profile from Medusa SDMT is on average 10-15 kPa higher than the "best estimate" s_{uE} profile at the site.

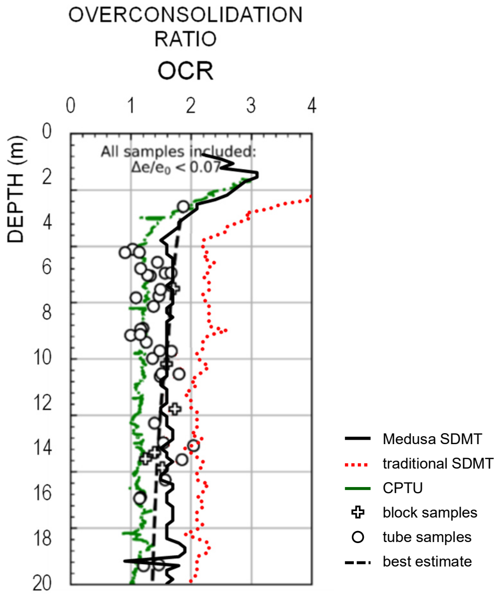

Figure 5. Comparison of profiles of *OCR* obtained from interpretation of Medusa SDMT, traditional SDMT and other tests (modified from Gundersen et al. 2019)

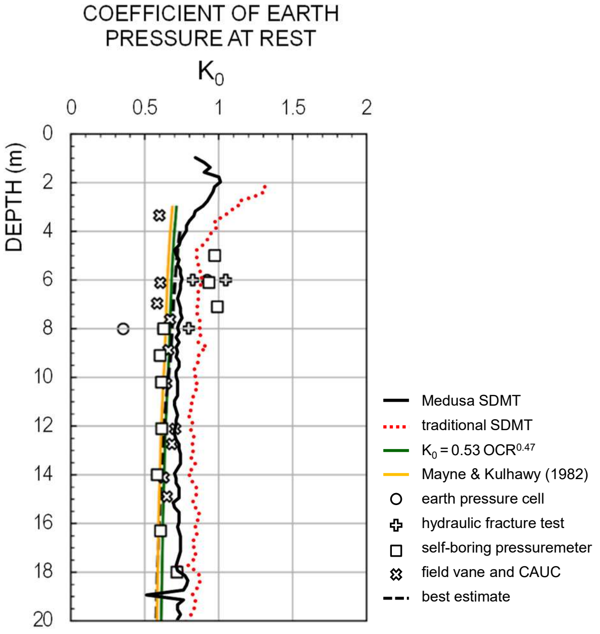

Figure 6. Comparison of profiles of K_0 obtained from interpretation of Medusa SDMT, traditional SDMT and other tests (modified from Gundersen et al. 2019)

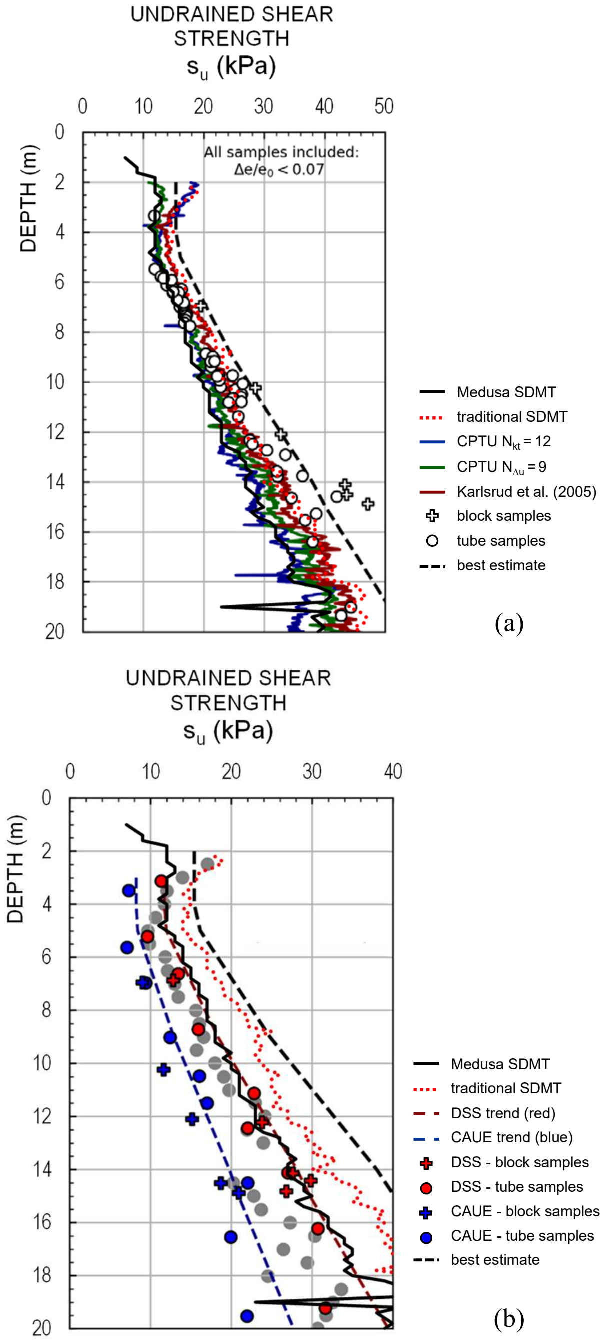

Figure 7. Comparison of profiles of s_u obtained from interpretation of Medusa SDMT, traditional SDMT and other tests: (a) s_u obtained from triaxial compression tests (CAUC) and estimated from CPTU; (b) s_u obtained from triaxial extension tests (CAUE), direct simple shear tests (DSS) and field vane tests (modified from Gundersen et al. 2019)

The reason for the differences observed in the s_u profiles can be simply explained. Norwegian clays show strength anisotropy, and the undrained shear strength is influenced by the loading and shearing directions, so that $s_{uC} > s_{uDSS} > s_{uE}$. The s_u from Medusa SDMT was interpreted using the Marchetti (1980) equation given by:

$$\left(\frac{s_u}{\sigma'_{v0}}\right)_{OC} = \left(\frac{s_u}{\sigma'_{v0}}\right)_{NC} \cdot (0.5K_D)^{1.25} \qquad (1)$$

in which the dependence of the ratio (s_u/σ'_{v0}) on *OCR* is correlated to the horizontal stress index K_D.

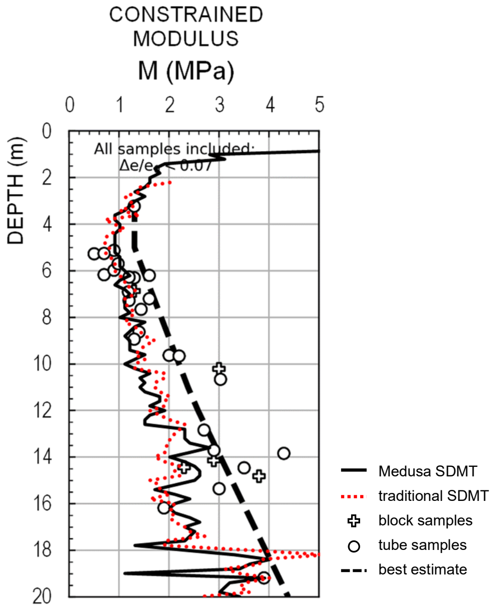

Figure 8. Comparison of profiles of M obtained from interpretation of Medusa SDMT, traditional SDMT and from laboratory oedometer tests in the overconsolidated stress range (modified from Gundersen et al. 2019)

In Marchetti (1980), the normally consolidated strength $(s_u/\sigma'_{v0})_{NC}$ in Eq. (1) is assigned a value of 0.22 based on *in situ* and laboratory tests performed on Italian clays. However, this value will differ for Norwegian clays and vary according to the loading direction (i.e., compression, extension, or direct simple shear). Results herein also seem to differ slightly from the correlations previously established by Lacasse and Lunne (1989). Hence, additional Medusa SDMT data on Norwegian clays should be gathered to establish revised relationships between s_u, OCR and K_D.

Figure 8 compares the profiles of the constrained modulus M obtained from interpretation of Medusa SDMT and traditional SDMT according to Marchetti 1980) with the M values determined from laboratory oedometer tests in the overconsolidated stress range, as reported by Gundersen et al. (2019). For effective stresses exceeding the preconsolidation stress, the comparison with available oedometer test data, expressed in Gundersen et al. (2019) in terms of stress dependent relationships, is not straightforward and requires further elaboration of Medusa SDMT data.

Figure 9a shows an overall agreement between the profiles of the shear wave velocity V_S obtained from different *in situ* and laboratory tests, or estimated according to correlations established by L'Heureux and Long (2017) for Norwegian clays. The V_S measured by Medusa SDMT are very close to the V_S obtained using the traditional SDMT, as well as the seismic cone (SCPT). A similar agreement is observed for the profiles of the small strain shear modulus G_0 (Fig. 9b) derived from V_S or estimated by available correlations (Andersen 2015).

Finally, Fig. 10 compares the horizontal coefficients of permeability and consolidation (k_h and c_h) estimated from the Medusa DMT dissipation test according to the interpretation method proposed by Marchetti and Totani (1989) for the traditional DMTA dissipation (see also Marchetti et al. 2001), with the vertical coefficients of permeability and consolidation (k_v and c_v) obtained from laboratory CRS oedometer tests (Gundersen et al. 2019).

Due to the long duration of the dissipation, only one DMTA dissipation test (ONSD05) was performed during the field-testing campaign at Onsøy using a stationary probe inserted to a depth of 6.40 m, by recording the A-pressure readings for about 32 hours. The values of k_h and c_h estimated from the Medusa DMT dissipation test plot close to the lower bound values of k_v and c_v obtained from CRS oedometer tests and are slightly lower than the "best estimate" profiles determined based on laboratory data, but within the same order of magnitude.

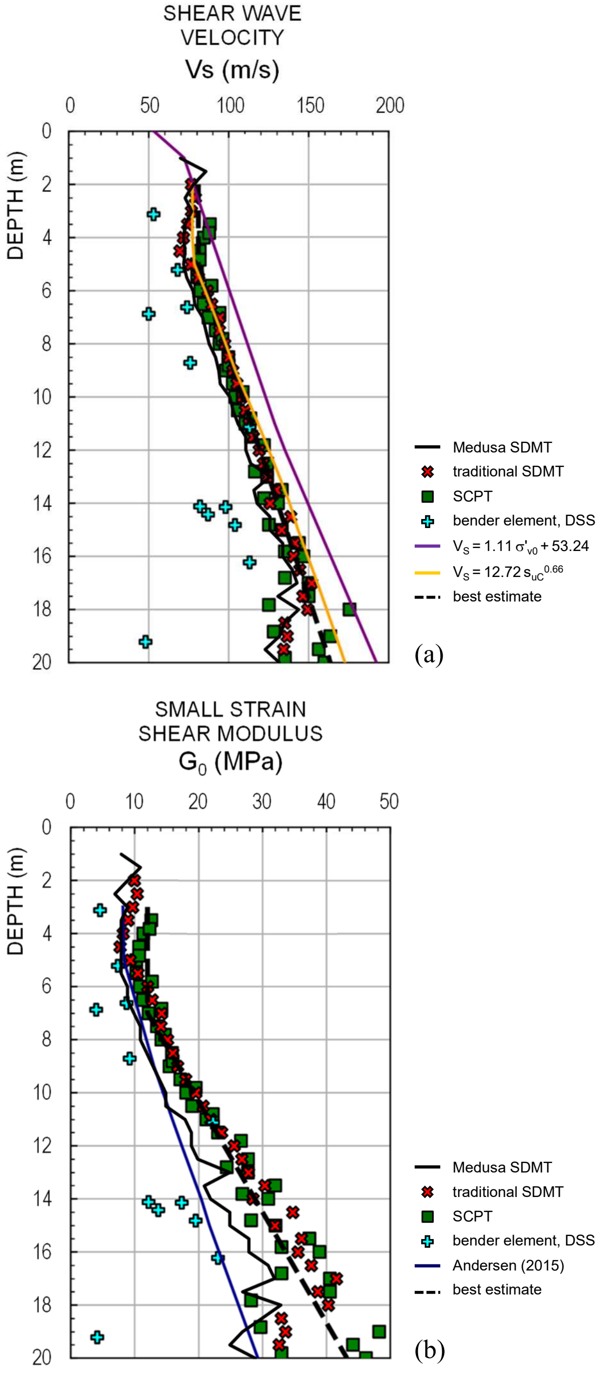

Figure 9. Comparison of profiles of V_S (a) and G_0 (b) obtained from Medusa SDMT, traditional SDMT and other tests (modified from Gundersen et al. 2019)

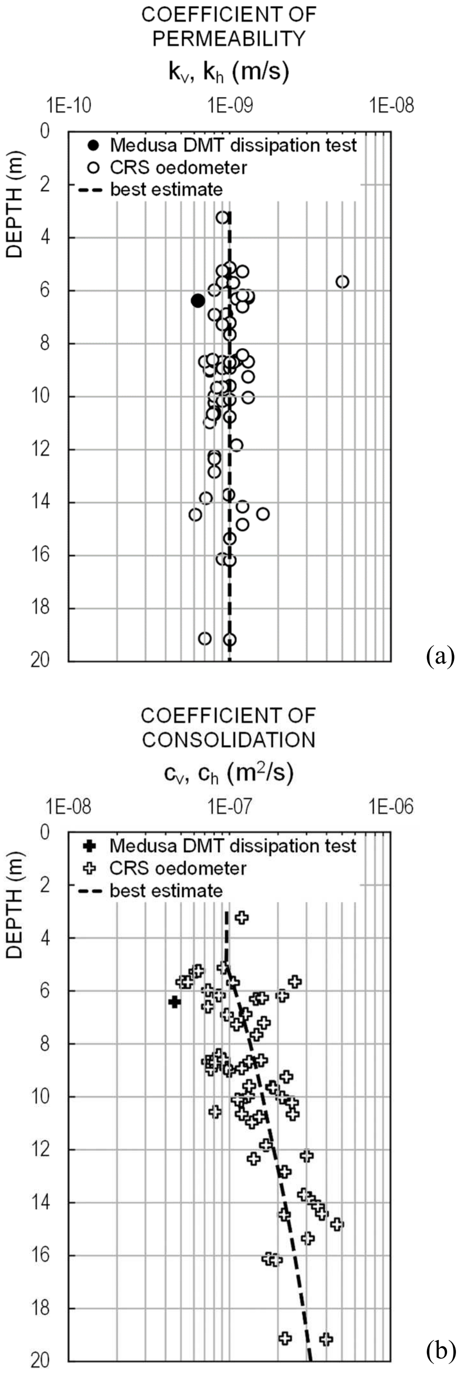

Figure 10. Comparison of coefficients of permeability (a) and consolidation (b) estimated from the Medusa DMT dissipation test (k_h, c_h) and obtained from laboratory CRS oedometer tests (k_v, c_v) (modified from Gundersen et al. 2019)

6. Conclusions

Benchmark GeoTest sites prove to be of paramount importance for testing and validating innovative soil investigation methods. In this respect, the recent experimental program at the NGTS Onsøy soft clay test site with the Medusa SDMT (the last generation, fully automated version of the DMT) could uniquely benefit of the availability of an existing large and consistent data set obtained in past investigations from a variety of high-quality *in situ* and laboratory tests.

The preliminary analysis of the results obtained at the Onsøy test site indicates, overall, a substantial consistency of measurements and interpreted parameters provided by Medusa SDMT, by traditional pneumatic SDMT and by other *in situ* and laboratory tests.

One notable feature emerging from the field-testing campaign at the Onsøy site is the superior accuracy of the results obtained from Medusa SDMT compared to the traditional pneumatic SDMT employed in past investigations. With the Medusa SDMT the pressure is generated and measured in the probe at depth, eliminating any pressure equalization problem at the opposite ends of the pneumatic cable. The automated membrane inflation and the incompressibility of the pressurizing fluid enables the Medusa SDMT to enforce the standard rate of membrane inflation with high precision and repeatability.

The improved accuracy in pressure measurements and controlled pressurization rate provided by the Medusa SDMT makes this instrument particularly useful for testing very soft soils, such as the Onsøy clay, in which the measured pressures are typically very small. This capability turns out to be a significant advantage for a reliable determination of relevant soil parameters depending on such small quantities, in particular the overconsolidation ratio *OCR*, the coefficient of earth pressure at rest K_0, and the undrained shear strength s_u.

Further insights on the data gathered at the Onsøy test site, supplemented by additional Medusa SDMT data in different Norwegian clays, would permit to establish improved relationships for estimating the undrained shear strength s_u and other relevant soil parameters.

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References

Andersen, K. H. 2015. "Cyclic soil parameters for offshore foundation design." In *Frontiers in offshore geotechnics III*, ISFOG 2015, edited by V. Meyer, 5–82. Taylor & Francis.

ASTM D6635-15 2015. "Standard Test Method for Performing the Flat Plate Dilatometer", ASTM International, West Conshohocken, PA, USA.

Gundersen, A. S., Hansen, R. C., Lunne, T., L'Heureux, J-S., and Strandvik, S.O. 2019. "Characterization and engineering properties of the NGTS Onsøy soft clay site." AIMS Geosciences 5, no. 3: 665–703. https://doi.org/10.3934/geosci.2019.3.665

ISO 22476-11:2017(E) 2017. "Geotechnical Investigation and Testing – Field Testing – Part 11: Flat Dilatometer Test", International Organization for Standardization, Geneva, Switzerland.

Karlsrud, K., Lunne, T., Kort, D. A., and Strandvik, S. 2005. "CPTU correlations for clays." In *Proc. 16th ICSMGE*, Osaka, 693–702. Millpress. https://doi.org/10.3233/978-1-61499-656-9-693

Lacasse, S., and Lunne, T. 1989. "Calibration of dilatometer correlations." Norwegian Geotechnical Institute, Publication no. 177.

L'Heureux, J-S., and Long, M. 2017. "Relationship between shear-wave velocity and geotechnical parameters for Norwegian clays." J. Geotech. Geoenviron. Eng. 143, no. 6: 04017013. https://doi.org/10.1061/(ASCE)GT.1943-5606.0001645

L'Heureux, J-S., and Lunne, T. 2020. "Characterization and engineering properties of natural soils used for geotesting." AIMS Geosciences 6, no. 1: 35–53. https://doi.org/10.3934/geosci.2020004

Lunne, T., Long, M., and Forsberg, C. F. 2003. "Characterization and engineering properties of Onsøy clay." In *Characterization and engineering properties of natural soils*, edited by T.S. Tan et al., 395–427. Balkema.

Marchetti, D., Danziger, F., and Jannuzzi, G. M. F. 2021. "Comparison of DMT results using traditional pneumatic equipment and the Medusa DMT in the Sarapuí II soft clay deposit in Brazil." In *Proc. 6th Int. Conf. on Geotechnical and Geophysical Site Characterisation ISC'6*, Budapest. https://doi.org/10.53243/ISC2020-350

Marchetti, D. 2018. "Dilatometer and Seismic Dilatometer Testing Offshore: Available Experience and New Developments." *Geotech. Testing J.* 41, no. 5, 967–977. https://doi.org/10.1520/GTJ20170378

Marchetti, D., Monaco, P., Amoroso, S., and Minarelli, L. 2019. "In situ tests by Medusa DMT." In *Proc. XVII ECSMGE-2019*, Reykjavik. https://doi.org/10.32075/17ECSMGE-2019-0657

Marchetti, D., Monaco, P., Totani, G., Totani, F., and Amoroso, S. 2022. "Comparisons CPT-DMT in soft clay at Fucino-Telespazio GeoTest site." In *Cone Penetration Testing 2022*, edited by G. Gottardi, and L. Tonni, 190–196. CRC Press/Balkema. https://doi.org/10.1201/9781003308829-21

Marchetti, S. 1980. "In Situ Tests by Flat Dilatometer." J. Geotech. Eng. Div. 106, no. GT3: 299–321.

Marchetti, S., and Crapps, D. K. 1981. "Flat Dilatometer Manual." Internal Report G.P.E. Inc., Gainesville, FL, USA.

Marchetti, S., Monaco, P., Totani, G., and Calabrese, M. 2001. "The Flat Dilatometer Test (DMT) in Soil Investigations – A Report by the ISSMGE Committee TC16." In *Proc. Int. Conf. Insitu Measurement of Soil Properties and Case Histories*, Bali, 95–131. Official version approved by ISSMGE TC16 reprinted in *Proc. 2nd Int. Conf. Flat Dilatometer*, Washington, 2006, 7–48.

Marchetti, S., Monaco, P., Totani, G., and Marchetti, D. 2008. "In Situ Tests by Seismic Dilatometer (SDMT)." Geotechnical Special Publication GSP 180, 292–311. https://doi.org/10.1061/40962(325)7

Marchetti, S., and Totani, G. 1989. "C_h Evaluations from DMTA Dissipation Curves." In *Proc. 12th ICSMFE*, Rio de Janeiro, 281–286. Balkema.

Mayne, P., and Kulhawy, F. H. 1982. "K_0-OCR relationships in soil." J. Geotech. Eng. Div. 108, no. GT6: 851–872.

Monaco, P., Chiaradonna, A., Marchetti, D., Amoroso, S., and Le, T. M. H. 2023. "GEOLAB – Transnational Access project JELLYFISh – Field testing of Medusa DMT. " (Version 0) [Data set]. Zenodo. https://doi.org/10.5281/zenodo.7695740

Monaco, P., Marchetti, D., Totani, G., Totani, F., and Amoroso, S. 2022. "Validation of Medusa DMT test procedures in Fucino clay." In *Proc. 20th ICSMGE*, Sydney.