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Second edition of ISO 19901-8 standard for marine soil investigations

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ABSTRACT: The second edition of the ISO standard "Marine Soil Investigations", ISO 19901-8, was published October 2023 by the ISO committee TC67/SC7 as prepared by the geotechnical working group SC7/WG10. The new edition has adopted a title and scope change to also include the lower carbon industries. All clauses of the standard have undergone thorough technical revisions following feedback from industry stakeholders, addressing aspects such as the uncertainty of depth measurements and cone penetration tests (CPTs). The second edition introduces changes to enhance clarity of reporting requirements, redefines roles and responsibilities, and updates the calibration and verification procedures for cone penetrometers, with reference to the second edition of ISO 22476-1. The document optimises the referencing to project specifications, and emphasizes a focus on data accuracy, uncertainty analysis, and the interaction between geotechnical and geophysical disciplines. Furthermore, it promotes the application of best practices for laboratory testing, aligning closely with other related ISO standards, including ISO 19901-10 for marine geophysical investigations with respect to an integrated site characterisation approach. The paper discusses the motivation and scope of the new inclusions and amendments of the second edition and how this revision ensures that the standard remains relevant and robust in supporting safe and effective offshore infrastructure development.

Keywords: ISO standard; marine soil investigation; in-situ testing; deployment, drilling and sampling; laboratory testing.

1 INTRODUCTION

The ISO subcommittee SC7 for offshore structures develops standards for Technical Committee TC67 on materials, equipment and offshore structures for the petroleum, petrochemical, natural gas industries and now also the lower carbon energy industries. TC67/SC7 is organised in several working groups (WG), each dedicated to different types of structures. WG10 is responsible for preparing the geotechnical design standard ISO 19901-4 as well as for providing geotechnical input to all other working groups. Technical panels TP1 and TP2 within WG10 are responsible for the preparation of the Marine Soil

Investigations (MSI) standard, ISO 19901-8, and the Marine Geophysical Investigations standard, ISO 19901-10, respectively.

The first edition of the MSI standard was introduced in 2014, building on the NORSOK G-001 standard for marine soil investigations. Since then, the standard has undergone a comprehensive technical revision, resulting in the publication of its second edition in 2023. The MSI focuses on investigations of sandy and clayey soils, while also providing guidance, with less detail, for investigations of chalk, calcareous soils, cemented soils and weak rock. The document is designed to offer flexibility in the choice of MSI techniques without hindering innovation.

2 MAIN AMENDMENTS TO THE SECOND EDITION OF ISO 19901-8

2.1 General

The primary motivation for initiating the revision of the first edition of ISO 19901-8 (2014) came from the industry feedback to the original document. In the first edition, both depth accuracy and CPT application classes defaulted to the lowest quality unless explicitly specified in the project specifications. In practice, this approach required a well-informed and experienced client to prepare appropriate and fit-for-purpose specifications. Additionally, the industry was challenged in aligning on expectations for e.g. CPT accuracy class 1, which in practice was specified and expected to be achieved in firmer clays, denser sands and more variable soil conditions than the soft soil that class 1 accuracy class originally was intended for.

Feedback was also received on the reporting structure, which was now informative and no longer normative with reference to the NORSOK G-001. The clause addressing reporting of CPT results read unclearly and led to confusion with respect to the specific reporting requirements. Clients also expressed concerns about the lack of a sufficiently structured reporting framework, particularity when multiple contractors were involved in a single campaign.

The first edition of the MSI held many references to the project specifications, including requirements for details, which were neither practical nor relevant in practice, for instance with respect to untimely specifications of consolidation stresses for e.g. oedometer and triaxial testing. Clients also raised concerns about the exclusion of certain requirements present in the NORSOK G-001, opening for equal referencing of both ASTM and ISO laboratory testing standards. In many cases, the ASTM and ISO standards present conflicting requirements, such as e.g., height-to-diameter ratios for triaxial testing.

In addition to the industry feedback mentioned above, the first edition of the MSI frequently assigned responsibilities to either the client or the contractor. However, in practice, it is found more efficient and appropriate, when these responsibilities are addressed separately in project specifications, allowing the second edition of the MSI to focus primarily on *what* needs to be done, rather than *who* should do it.

The following sections highlight the main changes introduced to the specific clauses of the ISO MSI and the rationale behind with key changes as follows:

- Application classes for in situ testing tools have been removed and replaced by an assessment of documented calibration results and uncertainty analyses;
- New procedures for calibration and verification of cone penetrometers are introduced with reference to the latest edition of ISO 22476-1;
- References to project specifications for technical details have been reduced where possible and roles and responsibilities have been further clarified;
- Title and scope change adopted as per Technical Management Board Resolution 53/2022.

Where relevant and practical, the second edition of the MSI has partly adopted the supplementary specifications of IOGP (2020).

3 CLAUSE 5: OBJECTIVES, PLANNING AND REQUIREMENTS

Clause 5 now includes a number of general changes made to improve the clarity and readability, and to coordinate to an extent with the now published ISO 19901-10 for Marine Geophysical Investigations. Moreover, a new sub-clause 5.2.2. “Integrated geoscience studies” have been included to discuss the benefits of performing integrated geoscience studies, with significant informative text in the accompanying annex sub-clause A.5.2.2. Sub-clause 5.4 “Health, safety and environmental requirements for marine operations” has been amended so that some of the previous recommendations (i.e. in the first edition of MSI), such as that of having an HSE plan and appropriate staff competencies, are now mandatory.

With numerous references made to “project specifications” in the first edition of the MSI, it was found that in practice these statements created ambiguity in how and when these requirements or

recommendations should be specified and adopted, and the responsibility (i.e. client or contractor) for ensuring such information is shared in a timely manner. Therefore, a new sub-clause was added to the second edition to more explicitly identify roles and responsibilities for dealing with all project specification statements in the standard. This includes 5.3.1 "Responsibility and development of project specifications", which serves as an umbrella statement on this topic for all clauses of the MSI.

Finally, two new sub-clauses have also been introduced, including 1) a new sub-clause 5.4.3 "Hazardous substances and acoustic noise" that comprises text that was in the first edition MSI, and 2) a new sub-clause 5.4.4 "Shallow gas", introduced to emphasize the severity that this hazard poses. It is accompanied by informative guidance in annex sub-clause A.5.4.4 on responsibilities and performance of shallow gas risk assessments.

4 CLAUSE 6: DEPLOYMENT OF INVESTIGATION EQUIPMENT

Amendments to Clause 6 primarily concern the borehole depth accuracy. Where applicable, the term "accuracy" is now replaced by "uncertainty" for consistency with the ISO international vocabulary of metrology (ISO/IEC GUIDE 99:2007). Quantitatively, the term "accuracy" should be avoided, as it implies inherently that a perfectly "true value" can be defined and measured. Hence, the terms "borehole depth accuracy" and "depth accuracy classes" are now replaced by "vertical depth uncertainty" and "depth uncertainty classes", respectively. The depth uncertainty (as per Table 1 of MSI) shall be estimated as combined standard uncertainty according to ISO/IEC GUIDE 99:2007.

In key factors affecting the uncertainty of vertical depth measurements, the second edition emphasizes focus on the uncertainties of the measurement system as well as the uncertainties of estimation of a sample data point within a sampling tool. For example, it is critical to understand the capacity of a selected drilling system to measure and monitor the base elevation of the equipment relative to the seafloor (i.e., borehole reference datum), including any settlement into the seabed or change of equipment base elevation during sampling operation, as well as the curvature and tilt of the drill string with the sampling/in-situ tool inside it. It is clear from the extensive discussions within TP1, that the industry does not currently have enough data and information available to support a change of the existing default depth uncertainty class. It is important that the MSI offer the flexibility in order to prevent clients inadvertently specifying (and therefore paying for) requirements tighter than needed. The discussions resulted in additional requirements to reporting of sampler information and assessments of other key factors affecting vertical depth uncertainty, and the selection and use of the depth uncertainty classes is expected to be revisited for the next revision of the MSI.

Finally, the second edition now also emphasizes that data reporting shall include an assessment of the interaction of the deployed investigation equipment with the upper seabed, and whether this can have adversely affected the acquired data, including any measurements of elevation changes of the investigation equipment and any corrections applied to the acquired data. It also clarifies the need of reviewing detailed bathymetry information to assess seafloor hazards, e.g. slopes or obstacles, in order to ensure safe operation of the investigation equipment, optimize landing speed and minimise upper seabed disturbance during landing or prior to sampling operation.

5 CLAUSE 7: DRILLING AND LOGGING

In response to industry feedback, TP1 considered whether Clause 7 should remain a standalone clause or have its components migrated to other sections of the MSI. However, consensus held that drilling operation is often underappreciated or poorly understood by geotechnical engineers, despite being critical to the success of a marine soil investigation. Therefore, the structure was preserved to underscore its importance.

Sub-clauses 7.1 and 7.2 were subject to minor editorial changes to improve clarity and reduce ambiguity. Sub-clause 7.3 removed sections relating to shallow gas and pilot hole drilling as part of a wider effort to increase the awareness and guidance around the hazards posed by shallow gas to geotechnical operations. As part of this effort, sections of the previous informative Annex on Drilling and Logging were transferred into the normative section of Clause 5 "Objectives, planning and requirements" (see Section 3).

In Clause 7.4, the previous recommendation to develop a drilling operations plan or include relevant details in the Project Execution Plan (PEP) is now a requirement, with minor editorial updates. Clause 7.5 now mandates documenting drilling parameters, with an expanded list of parameters based on IOGP (2020) and clarified reporting units. Clause 7.6 on "Borehole Geophysical Logging," incorporates content from the former informative annex, offering clearer guidelines

on project specifications and reporting of geophysical logging results.

In the informative Annex (A.7) major amendments include 1) incorporating IOGP (2020) documentation guidance for the drilling operations plan; 2) moving certain shallow gas guidance to the normative Clause 5; and 3) expanding the geophysical logging section with examples of tools to cover a wide variety of techniques and configurations.

6 CLAUSE 8: IN SITU TESTING

Amendments to Clause 8 aim to reduce uncertainty of in-situ testing results and improve quality control. First, stricter tolerances for cone penetrometer friction sleeve diameters have been introduced (referencing ISO 22476-1:2023) to enhance the repeatability of sleeve friction measurements across manufacturers, addressing concerns raised by various studies (Soage Santos et al., 2014; Powell et al., 2020).

Secondly, the previous "application class" scheme has been replaced with a detailed classification procedure for cones and test results. Previous versions of ISO 22476-1 and the MSI lacked procedural guidance, making practical application difficult (e.g., Lunne et al., 2017; Peuchen & Terwindt, 2014; Soage Santos, 2022). The revised Clause 8 introduces a two-step, performance-based approach; classifying devices into “cone classes” and test results into “test categories”.

The new cone classification scheme provides comprehensive calibration and verification procedures, including uncertainty analysis. Penetrometers are now assigned to specific cone classes (1+, 1, or 2), facilitating comparison across manufacturers and ensuring appropriate cone selection for projects. The second step classifies tests into test categories (A, B, or C), based on reference readings and diagnostic checks. While these categories do not quantify test uncertainty, they help identify potential issues, such as equipment malfunction or procedural error. Measures to avoid potential conflicts caused by interpretation are made by linking the soil categories to prescribed ranges of cone resistance (q_c), for example profiles showing q_c < 1 MPa can be used instead of using terms like “Very soft to firm clays”.

Thirdly, the standard addresses measurement uncertainties arising from cone-soil interaction, particularly due to temperature variations and bending moments (e.g., Peuchen et al., 2020; Soage Santos, 2022). Temperature fluctuations of more than 10°C (e.g., in dense sands) can cause q_c drifts of up to 300 kPa, leading to significant errors when characterizing underlying clay. The revised Clause 8 now requires temperature and bending moment stability within the cone classification scheme, with optional corrections for temperature effects on q_c, sleeve friction (f_s), and pore pressure (u) data. It encourages the use of temperature sensor for corrections.

Additionally, new normative requirements address common operational errors, such as temperature stabilization before taking reference readings. Reporting requirements have also been revised to ensure sufficient information for quality control. Calibration and verification reports, along with field quality control checks, allow independent verification of “cone class” and ‘test category’ assignments. All data corrections must be reported alongside uncorrected data to maintain transparency.

7 CLAUSE 9: SAMPLING

The revision of Clause 9 has mainly focused on amendments to terminology and the inclusion of new requirements for reporting of sampler information. The term “quality class” is now removed and the previously undefined term “sample quality” is now defined in sub-clause 3.32. A note is now included with a reference to the sample quality criteria for low to medium OCR clays provided by Lunne et al. (2006). Moreover, the term “undisturbed sample” is now replaced by “intact sample” to improve clarity and provide an appropriate and consistent use of terminology throughout the MSI.

In sub-clause 9.3, Tables 6 and 7 are elevated from the previously informative annex (Tables E.2 and E.4) to the normative section of the standard to ensure the reporting of appropriate information on drilling and non-drilling mode samplers, respectively. New requirements include reporting sample tube penetration, stroke, hammer blows, and hammer weight for drilling mode samplers, while safety measures are introduced to prevent early triggering of box core and piston core samplers during non-drilling mode operations. Further, sub-clause 9.5 on “Handling, transport and storage of samples“ now states that for non-drilling mode samplers, all observations providing information on penetration depth shall be reported. It also now explicitly requires that offshore storage of intact samples shall avoid exposure to high temperatures, freezing, chemical and moisture changes, and minimise vibration or impact/shock. Moreover, all intact samples, which have not been extruded in the field, are now required to be stored vertically and it is recommended that all intact tube samples are stored in a temperature-controlled environment targeting in situ temperature, with a temperature in the range of 5°C to 25 °C.

Finally, a reference to ISO 22475-1 is included for guidance on handling, transport, onshore storage of samples and sampling records.

8 CLAUSE 10: LABORATORY TESTING

Clause 10 primarily covers general overview statements on laboratory testing while Annex B now details test procedures. Key updates in the second edition of the MSI include: 1) reference to twelve new ISO standards for laboratory testing of soils, 2) new language on project specifications, and 3) three new tests and detailed guidance on preparation of specimens for coarse soils. Additionally, technical wording has been refined throughout.

The first edition of MSI primarily referenced ASTM standards for laboratory soil testing, as only two relevant ISO standards, ISO 14688-1 (soil description) and ISO 14688-2 (soil classification), were available at the time. Country-specific laboratory standards were intentionally excluded. Although several ISO Technical Specifications (TS) existed in 2014, they were not formal standards and would expire; however, they were still referenced in the original MSI. By 2023, the 12-part ISO 17892 series was published, offering appropriate standards for classification and advanced laboratory tests, all of which are included in the second edition of MSI, where now both ASTM standards and the ISO 17892 series are referenced in Annex B. Extensive discussions in TP1 concluded a preference for maintaining reference to ASTM standards alongside the ISO series, acknowledging their continued use in practice. However, since ISO rules prohibit dual referencing of standards with a mandatory "shall" statement, TP1 had to accept a compromise, where the standards are called out with a “should” recommendation instead. Consensus was thus reached for leaving it to individual project specifications to state preference for a given standard and whether it shall be a requirement to follow that standard.

Three new test procedures were introduced in the second edition of MSI: 1) miniature penetration tests (e.g., T-bar, ball) which are primarily used for testing box core samples offshore (sub-clause B.2.15.8); 2) needle penetration resistance, which is a strength index test for weak/soft rock (B.2.17); and 3) new procedures for determining the maximum and minimum index dry densities of clean sands, which uses significantly less soil than the ASTM test(s) with reference to Knudsen et al. (2020) (sub-clause B.2.9).

Sub-clause 10.5 on laboratory preparation of reconsolidated samples or specimens of sands for advanced laboratory testing has been significantly expanded to include advantages and disadvantages of the various coarse soil reconstitution techniques, and specification of acceptable dry density uncertainty values.

9 CLAUSE 11: REPORTING

The main update addresses the example reporting format detailed in Table A.8 of the MSI. The first edition MSI stated that if the reporting format was not given in the project specifications, then the “contractor’s practice shall apply”. In the second edition this statement has been modified to “if the reporting format is not given in the project specifications, then the format given in Table A.8 shall be used”. This change was introduced for bringing further consistency to the reporting format, as also significant variations were observed between reporting practices as adapted by the different contractors. Further, terminology and definitions of characteristic, derived, measured, nominal and representative values were aligned with ISO 19900:2018. Consequently, sub-clause 11.3 was renamed from “Data interpretation and evaluation of representative geotechnical parameters” to “Data interpretation and soil parameters”. Also, to better differentiate between reporting of factual and interpreted data and parameters, titles of sub-clauses 11.2 and A.11.2 were both revised from “Presentation of field operations and measured and derived geotechnical parameters” to “Presentation of field operations and factual data”. Sources of factual data listed in sub-clause 11.2 now also include: 1) details confirming measurement uncertainties of the positioning system for each investigation point, and 2) observations during testing which can affect the results or interpretation. Small strain shear modulus, G_{max}, is now also included in the list of soil properties and geotechnical parameters typically presented in sub-clause A.11.2.2. Finally, a new paragraph at the end of sub-clause 11.3 addresses integrated geoscience studies and ground model principles, referencing ISO 19901-10 and SUT OSIG (2022). This addition aims to encourage data integration and enhance understanding of the ground conditions across the site.

10 SUMMARY AND CONCLUSION

The revision of the MSI has been carried out with due consideration to the valuable feedback provided from industry to the first edition MSI, appreciating and honouring that this edition in general has been received well by the industry. Throughout the document, content has also been updated to

incorporate the significant experience gained from offshore wind projects, aligning with the title and scope change for including the lower carbon energy industry. The main changes involve a two-step procedure for calibration and verification of cone penetrometers as well as an increased focus on uncertainty analyses with a replacement of the former depth accuracy and CPT application classes. Roles and responsibilities have been clarified, and the excessive referencing to project specifications for technical details has been reduced. The second edition ensures that the ISO 19901-8 standard remains relevant and robust in supporting safe and effective offshore infrastructure development.

AUTHOR CONTRIBUTION STATEMENT

L. Krogh: Conceptualization and Supervision, Writing- Original draft. **Ø. Blaker**: Writing- Original draft, Writing – review & editing. **T. Carrington, H. Nguyen, P. Taylor, R.S. Santos, T.I. Yetginer-Tjelta, D.J. DeGroot** and **G. Yetginer**: Writing- Original draft.

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REFERENCES

International Association of Oil & Gas Producers (2020). Supplementary Specification for Marine Soil Investigations. JIP35.

ISO/IEC Guide 99:2007 International vocabulary of metrology – Basic and general concepts and associated terms (VIM).

ISO 19900 Petroleum and natural gas industries – General requirements for offshore structures.

ISO 19901-8 Oil and gas industries including lower carbon energy – Offshore structures – Part 8: Marine soil investigations.

ISO 19901-10 Petroleum and natural gas industries – Specific requirements for offshore structures – Part 10: Marine geophysical investigations.

ISO 14688-1 Geotechnical investigation and testing – Identification and classification of soil – Part 1: Identification and description.

ISO 14688-2 Geotechnical investigation and testing – Identification and classification of soil – Part 2: Principles for a classification.

ISO 22475-1 Geotechnical investigation and testing – Sampling methods and groundwater measurements – Part 1: Technical principles for the sampling of soil, rock and groundwater.

ISO 22476-1 Geotechnical investigation and testing – Field testing – Part 1: Electrical cone and piezocone penetration test.

Knudsen S., Powell J.J.M., Lunne T., Thomsen N., Krogh L., Barwise A. (2020). Development of new robust procedures for determination of maximum and minimum dry densities of sand, *In* Proc. 4th ISFOG 2020, Austin, Texas.

Lunne T., Berre T., Andersen K.H., Strandvik S., Sjursen M. (2006). Effects of sample disturbance and consolidation procedures on measured shear strength of soft marine Norwegian clays. *Can. Geotech. J*. 2006, 43 pp. 726–750.

Lunne, T., Santos, R. Brink Clausen, J. & Powell, J.J.M. (2017). Guidelines for Use of CPTU Application Classes According to ISO 19901-8: (2014). *In* Proc. 8th SUT OSIG, London, UK.

NORSOK G-001 Marine soil investigations. Rev. 2, Oct. 2004, Standards Norway (withdrawn).

Peuchen, J. & Terwindt, J., (2014). Introduction to CPT accuracy. *In* Proc. 3rd CPT'14, Las Vegas, Nevada.

Peuchen, J., Santos, R., Yetginer, A.G., Eckart, W.S., Carrington, T.M. & Lunne, T. (2020). CPT data showing anomalies – assessment and potential postprocessing. *In* Proc. 4th ISFOG 2020, Austin, Texas.

Powell JJM and Dhimitri L. and Ward, D. (2021). The friction sleeve measurement in CPTU-Does size matters? – A new study. *In* Proc. 6th ISC, Budapest, Hungary.

Soage Santos. R, Barwise. A, Alexander M. (2014) Improved CPT sleeve friction sensitivity in soft soils. *In* Proc. 3rd CPT'14, Las Vegas, Nevada.

Soage Santos. R. (2022). Uncertainties associated with CPT data acquisition. *In* Proc. 5th CPT'22, Bologna, Italy.

SUT OSIG (2022). Guidance notes for the planning and execution of geophysical and geotechnical ground investigations for offshore renewable energy developments. SUT, London.