

DIN EN ISO 19901-8

ICS 75.180.10

Einsprüche bis 2013-06-29

Entwurf

**Erdöl- und Erdgasindustrie –
Spezielle Anforderungen für Offshore-Anlagen –
Teil 8: Meeresbodenuntersuchungen (ISO/DIS 19901-8:2013);
Englische Fassung prEN ISO 19901-8:2013, nur auf CD-ROM**

Petroleum and natural gas industries –
Specific requirements for offshore structures –
Part 8: Marine soil Investigations (ISO/DIS 19901-8:2013);
English version prEN ISO 19901-8:2013, only on CD-ROM

Industries du pétrole et du gaz naturel –
Exigences spécifiques relatives aux structures en mer –
Partie 8: Investigations des sols en mer (ISO/DIS 19901-8:2013);
Version anglaise prEN ISO 19901-8:2013, seulement en CD-ROM

Anwendungswarnvermerk

Dieser Norm-Entwurf mit Erscheinungsdatum 2013-04-29 wird der Öffentlichkeit zur Prüfung und Stellungnahme vorgelegt.

Weil die beabsichtigte Norm von der vorliegenden Fassung abweichen kann, ist die Anwendung dieses Entwurfes besonders zu vereinbaren.

Stellungnahmen werden erbeten

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- oder in Papierform an den Normenausschuss Erdöl- und Erdgasgewinnung (NÖG) im DIN, 10772 Berlin (Hausanschrift: Burggrafenstr. 6, 10787 Berlin).

Die Empfänger dieses Norm-Entwurfs werden gebeten, mit ihren Kommentaren jegliche relevanten Patentrechte, die sie kennen, mitzuteilen und unterstützende Dokumentationen zur Verfügung zu stellen.

Gesamtumfang 157 Seiten

Normenausschuss Erdöl- und Erdgasgewinnung (NÖG) im DIN

Nationales Vorwort

Dieses Dokument (prEN ISO 19901-8:2013) wurde vom Technischen Komitee ISO/TC 67 „Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries“, Subkomitee SC 7 „Offshore structures“ in Zusammenarbeit mit dem Technischen Komitee CEN/TC 12 „Materialien, Ausrüstungen und Offshore-Bauwerke für die Erdöl-, petrochemische und Erdgasindustrie“ (Sekretariat: AFNOR, Frankreich) erarbeitet.

Für Deutschland hat hieran der Arbeitsausschuss NA 109-00-01 AA „Materialien, Ausrüstungen und Offshore-Bauwerke für die Erdöl-, petrochemische und Erdgasindustrie — Spiegelausschuss zu CEN/TC 12 und ISO/TC 67“ im Normenausschuss Erdöl- und Erdgasgewinnung (NÖG) des DIN Deutsches Institut für Normung e. V. mitgearbeitet.

Dieser europäische Norm-Entwurf enthält unter Berücksichtigung des DIN-Präsidialbeschlusses 1/2004 nur die englische Originalfassung der ISO Norm.

Das Ausgabedatum des Europäischen Norm-Entwurfs stand zum Zeitpunkt der Veröffentlichung dieses DIN-EN-ISO-Entwurfs noch nicht fest; der prEN ISO wird jedoch vom CMC unter der angegebenen prEN-Nummer demnächst zur CEN-Umfrage verteilt. Um der deutschen Öffentlichkeit eine möglichst lange Einspruchsfrist einzuräumen, wurde dieser Norm-Entwurf bereits vorab veröffentlicht.

Für die in diesem Dokument zitierten Internationalen Normen wird im Folgenden auf die entsprechenden Deutschen Normen hingewiesen:

ISO 19901-4 siehe DIN EN ISO 19901-4

ISO 22476-1 siehe DIN EN ISO 22476-1

Nationaler Anhang NA (informativ)

Begriffe, Symbole und Abkürzungen

Die Benummerung der folgenden Begriffe, Symbole und Abkürzungen ist identisch mit der Benummerung in der englischen Fassung.

3 Begriffe

Für die Anwendung dieses Dokuments gelten die folgenden Begriffe:

3.1

Genauigkeit

Exaktheit einer Messung im Vergleich mit dem wahren Wert der gemessenen Größe

3.2

Anwendungsklasse

Klassifizierung der Art der Ausrüstung, mit der unterschiedliche Genauigkeiten erreichbar sind

Anmerkung 1 zum Begriff: Anwendungsklassen wurden als Orientierungshilfe für die Auswahl der Arten der technischen Ausrüstung festgelegt; die Auswahl sollte auf der Genauigkeit basieren, die für die Anwendung der Ergebnisse erforderlich ist.

Anmerkung 2 zum Begriff: In E.1.2 und E.1.3 wird die Benennung „Eignungsklasse“ benutzt. Die Benutzung der Benennung „Eignungsklassen“ erfolgt wie die Benutzung der Benennung „Anwendungsklassen“ zu dem Zweck, als Orientierungshilfe für die Auswahl der Arten der technischen Ausrüstung auf der Grundlage der für die Anwendung der Ergebnisse erforderlichen Genauigkeit zu dienen.

Anmerkung 3 zum Begriff: Die in diesem Teil von ISO 19901 benutzte Benennung „Anwendungsklasse“ ist synonym zu der in 3.4.1 von EN 1997-2:2007 benutzten Benennung „Güteklasse“, in EN 1997-2:2007 wird die Benennung „Anwendungsklasse“ nicht angewendet. Definition für „Güteklasse“ in diesem Teil von ISO 19901, siehe 3.22.

3.3

geophysikalische Vermessung des Bohrlochs

Messung physikalischer Eigenschaften eines Bohrlochs und/oder des umgebenden Bodens mit einer oder mehreren in das Bohrloch eingebrachten Messsonden

3.4

charakteristischer Wert

der einer Grundvariablen zugeordnete Wert in Verbindung mit einer vorgegebenen Wahrscheinlichkeit, dass er während einer bestimmten Bezugsdauer nicht durch ungünstige Werte überschritten wird

Anmerkung 1 zum Begriff: Ein charakteristischer Wert ist der wichtigste repräsentative Wert. In einigen Bemessungsfällen können einer Variablen zwei charakteristische Werte zugeordnet werden, ein oberer und ein unterer charakteristischer Wert.

3.5

Charakterisierung

Beschreibung, Bewertung und/oder Bestimmung der typischsten Merkmale einer Lokation auf der Grundlage aller Arten von Untersuchungen und anderer verfügbar Daten

3.6**Auftraggeber**

Partei oder Person, die für die Erkundung des Meeresbodens einschließlich der Erarbeitung der Vorhabensspezifikationen die Gesamtverantwortung trägt

3.7**Auftragnehmer**

Partei oder Person, die für einen festgelegten Umfang der in den Vorhabensspezifikationen beschriebenen Arbeiten die Verantwortung trägt

3.8**abgeleiteter Wert**

Wert für einen geotechnischen Parameter, der aus Prüfergebnissen durch theoretische Überlegungen, durch Korrelationen oder durch Wissen aus gesammelten Erfahrungen ermittelt wird

3.9**gestörte Probe**

Probe, deren Bodenstruktur, Wassergehalt und/oder Bestandteile bei Probenahme und Handhabung verändert wurden

3.10**dränierter Bedingungen**

Bedingungen, bei denen aufgebrauchte Spannungen und Spannungsänderungen vom Bodenskelett so aufgenommen werden, dass keine Veränderung des Porendrucks verursacht wird

3.11**Bohrspülung****Bohrflüssigkeit; Spülflüssigkeit**

Flüssigkeit, die zur Unterstützung des Bohrprozesses in ein im Rotary-Bohrverfahren erzeugtes Bohrloch gepumpt wird

Anmerkung 1 zum Begriff: Hardwarekomponenten, die beim Umgang mit Bohrflüssigkeiten angewendet werden, enthalten in ihrer Benennung meist das Wort „Spül[ung]“ (E: mud) (z. B. Spülungstank, Spülpumpe, Spülventil usw.). Gleiches gilt für Bohrparameter im Zusammenhang mit Bohrflüssigkeiten (Spülungsdruck, Spülungsumlauf usw.).

3.12**Geogefahr**

geologisches Phänomen, das eine Gefahr oder ein unkontrolliertes Risiko darstellt oder das Potenzial besitzt, sich so zu entwickeln, dass eine Situation entsteht, die zu einer Gefahr oder einem unkontrollierten Risiko führt

3.13**geophysikalische Untersuchung; geophysikalische Erkundung**

Untersuchung von Lokationen (Bohrstellen) auf dem Meeresboden/Meeresgrund mit Hilfe zerstörungsfreier Verfahren, die das Ausbringen geophysikalischer Geräte ins Meer erfordern

Siehe auch Bild 1 in der Einleitung.

3.14**Vermessung im Bohrloch**

Vermessung in einem Abschnitt des Bohrlochs oder des Bohrgestänges, die zwischen dem Messgerät und der Wand des Bohrlochs durchgeführt wird

Anmerkung 1 zum Begriff: Die Anzahl der Parameter, für die eine Messung unter diesen Umständen sinnvoll ist, ist begrenzt.

3.15**intakte Probe**

Probe, die mit dem Ziel gesammelt wurde, die in-situ vorhandenen Kennwerte der Probe beizubehalten

3.16**Erkundung von Lokationen (Bohrstellen) im Meer**

alle Arten von Untersuchungen an Offshore- oder Nearshore-Lokationen

Siehe auch Bild 1 in der Einleitung.

BEISPIEL Beispiele für die Erkundung von Lokationen im Meer: Meeresbodenuntersuchungen, geophysikalische Untersuchungen, Umgebungsuntersuchungen, Metocean-Untersuchungen (d. h. meteorologische Messungen im Ozean).

3.17**Untersuchung des Meeresbodens**

Art der Erkundung von Lokationen im Meer mit dem primären Ziel, zuverlässige und repräsentative Daten zur Charakterisierung der Bodenbedingungen am Meeresgrund für die Auslegung von Offshore-Plattformen und/oder für Bewertungen von Geogefahren zu ermitteln

Siehe auch Bild 1 in der Einleitung.

Anmerkung 1 zum Begriff: Der Umfang der Arbeiten und der Umfang der Untersuchungen des Meeresbodens ist spezifisch für jedes Projekt, umfasst aber im Allgemeinen einen oder mehrere der in Abschnitt 1 aufgeführten Punkte.

3.18**Messwert; gemessener Wert**

Wert, der bei einer Prüfung gemessen wird

3.19**Nennwert; nomineller Wert**

der einer Grundvariablen zugeordnete Wert, der auf einer nicht statistischen Basis, typischerweise aus der gewonnenen Erfahrung oder aus den physikalischen Bedingungen bestimmt wird

3.20**Bohrlochvermessung im offenen Bohrloch**

Vermessung in einem Abschnitt des Bohrlochs, z. B. ohne Futterrohr oder Bohrgestänge, so dass eine direkte Messung der Bodeneigenschaften außerhalb der Bohrlochwand möglich ist

3.21**Vorhabensspezifikation; Projektspezifikation**

Umfang der Arbeiten für Untersuchungen des Meeresbodens, mit denen ein Auftraggeber einen Auftragnehmer beauftragt hat

3.22**Güteklasse**

Klassifizierung der Qualität der Probe für den OCR (Überkonsolidationsgrad) von Böden mit geringem bis mittlerem Tonanteil, wobei die Probenqualität auf der bei Konsolidierungsversuchen im Laboratorium gemessenen Volumenänderung basiert

Anmerkung 1 zum Begriff: Exakte Definitionen der verschiedenen Güteklassen für Proben sind im Abschnitt 10.5, in Tabelle 6 angegeben.

Anmerkung 2 zum Begriff: Die in diesem Teil von ISO 19901 angegebene Definition für „Güteklasse“ unterscheidet sich von der in EN 1997-2:2007, 3.4.1 angegebenen Definition. Für die Benennung „Güteklasse“ in EN 1997-2:2007 wird im vorliegenden Teil von ISO 19901 die Benennung „Anwendungsklasse“ benutzt, siehe 3.2. In EN 1997-2:2007 wird die Benennung „Anwendungsklasse“ nicht benutzt.

3.23**Vorbohrloch; Rattenloch; Kellyloch**

die am Ende des Bohrlochs (über den letzten interessierenden Bereich hinaus) gebohrte zusätzliche Tiefe, die sicherstellt, dass eine vollständige Auswertung des interessierenden Bereichs durchführbar ist

Anmerkung 1 zum Begriff: Durch das Vorbohrloch können die am Vermessungsstrang weiter oben angebrachten Instrumente den tiefsten interessierenden Bereich erreichen und vermessen.

3.24**aufgearbeiteter Probekörper**

Labor-Probekörper, der durch Rekonstruktion einer Bodenprobe nach ihrer gründlichen Durchmischung hergestellt wird

Anmerkung 1 zum Begriff: Bei feinkörnigen Böden wird der Probekörper aus Schlamm (an oder über der Fließgrenze) hergestellt und dann konsolidiert. Bei grobkörnigen Böden wird der Probekörper trocken (getrocknet) oder im Wasser entweder geschüttet oder eingeregnet (Pluviationsverfahren) und danach verdichtet oder konsolidiert.

3.25**aufgearbeitete (durchwalkte) Probe
aufgearbeiteter (durchwalkter) Probekörper**

Probe, aus der ein Probekörper für den zu untersuchenden Boden mechanisch unter Beibehaltung des Wasseranteils vollständig aufgearbeitet wird

3.26**repräsentativer Wert**

Wert, der einer Grundvariablen für die Verifizierung eines Grenzzustands zugeordnet wird

Anmerkung 1 zum Begriff: Ein repräsentativer Wert kann ein charakteristischer Wert oder ein zugehöriger Wert sein. In einigen Bemessungsfällen können einer Variablen zwei repräsentative Werte zugeordnet werden, ein oberer und ein unterer repräsentativer Wert.

3.27**Probe**

Teil vom Boden oder Gestein, der mit Hilfe bestimmter Probenahmetechniken aus dem am Meeresgrund aufgenommenen Boden gewonnen wird

3.28**Meeresgrund**

Materialien unter dem Meeresboden

3.29**Meeresboden**

Grenzfläche zwischen Meer und Meeresgrund

3.30**Absacken**

dauerhafte Abwärtsbewegung einer Plattform aufgrund ihres eigenen Gewichts und aufgrund anderer Einwirkungen

Anmerkung 1 zum Begriff: Eine dauerhafte Aufwärtsbewegung wird als vertikale Verschiebung bezeichnet.

3.31**Lokation; Bohrstelle**

der festgelegte Untersuchungsbereich

3.32**(geotechnischer) Bodenparameter**

gemessener, abgeleiteter oder repräsentativer (geotechnischer) Bodenparameter

Anmerkung 1 zum Begriff: Die Benennung „geotechnisch“ beinhaltet sowohl Boden als auch Gestein.

3.33

Probekörper; Probemuster

Teil einer Probe, an dem eine Prüfung im Laboratorium durchgeführt wird

3.34

Indexversuch zur Bestimmung der Festigkeit

Prüfung, die einen Hinweis auf die Scherfestigkeit liefert

3.35

Schwellen; Quellen

Ausdehnung aufgrund einer Verringerung der wirksamen Spannung, die entweder auf der Verringerung der gesamten Spannung oder (im Allgemeinen) auf der Absorption von Wasser bei konstanter gesamter Spannung beruht

Anmerkung 1 zum Begriff: Das Schwellen schließt die Umkehr sowohl der Zusammendrückung als auch der Konsolidation ein.

Anmerkung 2 zum Begriff: Ein signifikantes Schwellen der Proben kann durch Entmischung von gelöstem Gas infolge einer Spannungsentlastung bei der Probenahme hervorgerufen werden.

3.36

Unsicherheit

Zuverlässigkeit der Messergebnisse infolge von Quellen für systematische und zufällige Fehler

3.37

ungestörte Probe

Probe, bei der keine nennenswerte Veränderung in den Bodeneigenschaften aufgetreten ist

3.38

undrained Bedingungen

Bedingungen, bei denen aufgebrachte Spannungen und Spannungsänderungen sowohl vom Bodenskelett als auch von der Porenflüssigkeit so aufgenommen werden, dass keine Volumenänderung hervorgerufen wird

3.39

Kohäsion des undrained Bodens

maximale Scherspannung beim Fließen des Werkstoffs oder bei einer festgelegten maximalen Dehnung unter undrained Bedingungen

Anmerkung 1 zum Begriff: Unter Fließen wird der Zustand eines Werkstoffs verstanden, bei dem eine merkliche bleibende Dehnung ohne oder bei einer nur geringen Zunahme der Spannung auftritt.

Anmerkung 2 zum Begriff: Eine Entfestigung ist ebenfalls zu beachten.

4 Symbole und Abkürzungen

4.1 Symbole

a Netto-Flächenverhältnis des Konuspenetrometers

c_v Konsolidierungsbeiwert

C_s Schwellbeiwert (für Konsolidierungsversuche)

h_{sf} Höhe des Bezugspunkts über dem Meeresboden

f_s	Reibung der Konushülse
$G_{\max}$	Anfangsschermodul (bei kleiner Dehnung)
I_L	Liquiditätszahl
I_P	Plastizitätszahl
i	Neigung
K_0	Erddruckbeiwert im Ruhezustand ($= \sigma'_{h0} / \sigma'_{v0}$)
m_v	Koeffizient der Volumenänderung
p_0'	wirksame Vertikalspannung in situ ($= \sigma'_{v0}$)
q_c	Spitzenwiderstand
q_t	Spitzenwiderstand, korrigiert um den Porenwasserdruck
s	Dicke der Flügelsonde
$s_u = c_u$	Kohäsion des undrnierten (ungestörten) Bodens
s_{uC}	statische Kohäsion des undrnierten Bodens beim triaxialen Druckversuch
s_{uD}	statische Kohäsion des undrnierten Bodens beim Einfachscherversuch (DSS)
s_{uE}	statische Kohäsion des undrnierten Bodens beim triaxialer Extensionsversuch
s_{ufv}	Scherfestigkeit aus dem Flügelscherversuch
$s_{ufv,rem}$	gestörte Scherfestigkeit aus dem Flügelscherversuch
$s_{ufv,res}$	Restscherfestigkeit aus dem Flügelscherversuch
S_t	Bodenempfindlichkeit
u_2	Porendruck
V_p	Kompressionswellengeschwindigkeit
V_s	Scherwellengeschwindigkeit
v_{vh}	Geschwindigkeit horizontaler (h), polarisierter Scherwellen mit vertikaler Ausbreitung (v)
ξ	Dämpfungsverhältnis des Werkstoffs
z	Nullwerte der In-situ-Sonde in der Höhe über dem Meeresboden für die Betriebsart Bohren
γ'	Einheitsgewicht des Bodens unter Wasser

γ_m	Werkstofffaktor
ν	Poissonsche Zahl
σ	Spannung
σ'_{v0}	wirksame Vertikalspannung in situ ($= p_0'$)
σ'_{h0}	wirksame Horizontalspannung in situ
ϕ'	wirksamer innerer Reibungswinkel

4.2 Einheiten

Die in den einzelnen Abschnitten angewendeten Einheiten können sich unter Berücksichtigung des früher üblichen Gebrauchs leicht unterscheiden. Beispielsweise sollte gegenwärtig die Querschnittsfläche eines CPT-Konus in Quadratmillimetern (mm²) und nicht, wie früher, in Quadratmetern (m²) angegeben werden. Die folgenden Einheiten müssen jedoch angewendet werden, wenn die Benutzung anderer, früher üblicher Einheiten nicht speziell zu begründen ist:

Kraft	kN
Moment	kNm
Dichte	kg/m ³
Einheitsgewicht	kN/m ³
Spannung, Druck, Festigkeit und Steifigkeit	kPa
Durchlässigkeitsbeiwert	m/s
Konsolidierungsbeiwert	m ² /s

4.3 Abkürzungen

BHA	Bestückung der Bohrlochsohle (en: bottom hole assembly)
CCV	konsolidiertes konstantes Volumen (en: consolidated constant volume)
CD	konsolidiert entwässert (en: consolidated drained)
CPT	Drucksondierung (en: cone penetration test)
CPTU	Drucksondierung mit Porenwasserdruckmessung (en: cone penetration test with pore-pressure measurement)
CRS	kontrollierte Dehngeschwindigkeit (en: controlled rate of strain)
CT	Computertomographie (en: computerized tomography)
CU	konsolidiert undrained (en: consolidated undrained)
DS	direkter Scherversuch (en: direct shear)

DGPS	differenzielles Geopositionssystem (en: differential global positioning system)
DSS	Einfachscher Versuch (en: direct simple shear)
ERP	Notmaßnahmen-Plan (en: emergency response plan)
FVT	Feld-Flügelscherversuch (en: field vane test)
GIS	geographisches Informationssystem (en: geographical information system)
GNSS	globales Satellitennavigationssystem (en: global navigation satellite system)
HAZID	Gefahrermittlung (en: hazard identification)
HAZOP	Gefahren- und Betriebsfähigkeit (en: hazard and operability)
HSE	Gesundheit, Sicherheit und Umwelt (en: health, safety and environment)
HVAC	Heizung, Lüftung und Klimatisierung (en: heating, ventilation and air conditioning)
IL	inkrementelle (schrittweise) Belastung (en: incremental loading)
LAT	niedrigste astronomische Tide (en: lowest astronomical tide)
LBL	lange Basislinie (en: long baseline)
MSL	mittlerer Meeresspiegel; Normalnull (en: mean sea level)
MSCL	multisensorische Kernaufzeichnung (en: multi-sensory core logging)
OCR	Überkonsolidationsgrad (en: over-consolidation ratio)
PEP	Projektentwicklungsplan (en: project execution plan)
PPE	Persönliche Schutzausrüstung (en: personal protective equipment)
QA	Qualitätssicherung (en: quality assurance)
QC	Qualitätskontrolle (en: quality control)
RFID	Identifizierung mit Hilfe elektromagnetischer Wellen (en: radio-frequency identification)
ROP	Bohrfortschritt (en: rate of penetration)
ROV	Fahrzeug mit Fernbedienung (en: remotely operated vehicle)
RS	Kreisringscherversuch (en: ring shear)
SCPT	seismische Drucksondierung (en: seismic CPT)
SH	Scherwellen (en: shear waves)
SHANSEP	Bestimmung des zeitlichen Verlaufs der Spannungen und normierter Bodenkenngrößen (en: stress history and normalized soil engineering parameters)
SIMOPS	gleichzeitig ablaufende Arbeitsgänge (en: simultaneous operations)

SOW	Arbeitsumfang (en: scope of work)
SRB	sulfatreduzierende Bakterien (en: sulphate-reducing bacteria)
SWL	sichere Arbeitslast (en: safe working load)
TC	triaxialer Druckversuch (en: triaxial compression)
TE	triaxialer Extensionsversuch (en: triaxial extension)
TOC	gesamter organischer (Kohlenstoff)anteil (en: total organic content)
UCT	Druckversuch mit unbehinderter Querdehnung (en: unconfined compression test)
USBL	Ultra Short Baseline (Unterwassernavigationssystem mit ultrakurzer Basislinie) (en: ultra-short baseline)
UU	unkonsolidiert, undränert (en: unconsolidated-undrained)
WGS	Geodätisches Weltsystem (en: World Geographic System)
VSP	vertikale seismische Profilierung (en: vertical seismic profiling)
YSR	Streckspannungsverhältnis (en: yield stress ratio)

Nationaler Anhang NB (informativ)

Literaturhinweise

DIN EN ISO 19901-4, *Erdöl- und Erdgasindustrie — Besondere Anforderungen an Offshore-Bauwerke — Teil 4: Geotechnische und Fundament-Auslegungsmerkmale*

DIN EN ISO 22476-1, *Geotechnische Erkundung und Untersuchung — Felduntersuchungen — Teil 1: Drucksondierungen mit elektrischen Messwertaufnehmern und Messeinrichtungen für den Porenwasserdruck*

March 2013

ICS 75.180.10

English Version

**Petroleum and natural gas industries - Specific requirements for
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(ISO/DIS 19901-8:2013)**

Industries du pétrole et du gaz naturel - Exigences
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Erdöl- und Erdgasindustrie - Spezielle Anforderungen für
Offshore-Anlagen - Teil 8: Meeresbodenuntersuchungen
(ISO/DIS 19901-8:2013)

This draft European Standard is submitted to CEN members for parallel enquiry. It has been drawn up by the Technical Committee CEN/TC 12.

If this draft becomes a European Standard, CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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Recipients of this draft are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

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Contents

	Page
Foreword	4
Introduction	5
1 Scope	7
2 Normative references	7
3 Terms and definitions	8
4 Symbols, units and abbreviated terms	12
4.1 Symbols	12
4.2 Units	13
4.3 Abbreviated terms	13
5 Objectives, planning and requirement	15
5.1 Objectives	15
5.2 Planning	15
5.3 Scope of work	18
5.4 Health, safety and environmental (HSE) requirements for marine operations	19
5.5 Other requirements	20
6 Deployment of investigation equipment	21
6.1 Deployment modes	21
6.2 Precision of vertical depth measurements	23
6.3 Positioning requirements	24
6.4 Interaction of investigation equipment with the seafloor	24
7 Drilling and logging	25
7.1 General	25
7.2 Project-specific drilling requirements	25
7.3 Drilling objectives and selection of drilling equipment and procedures	26
7.4 Drilling operations plan	26
7.5 Recording of drilling parameters	27
7.6 Borehole geophysical logging	27
8 <i>In situ</i> testing	27
8.1 General	27
8.2 General requirements for the documentation of <i>in situ</i> tests	28
8.3 Cone penetration test (CPT/CPTU)	28
8.4 Pore pressure dissipation test (PPDT)	33
8.5 Ball and T-bar penetration tests	34
8.6 Seismic cone penetration test (SCPT/SCPTU)	38
8.7 Field vane test	40
8.8 Other <i>in situ</i> tests	44
9 Sampling	45
9.1 General	45
9.2 Purpose of sampling	45
9.3 Sampling systems	46
9.4 Selection of sampling tools	46
9.5 Sample recovery considerations	48
9.6 Handling, transport and storage of samples	49
10 Laboratory testing	51
10.1 General	51
10.2 Presentation of laboratory test results	52
10.3 Instrumentation, calibration and data acquisition	53
10.4 Preparation of soil specimens for testing	53
10.5 Evaluation of intact sample quality	55
11 Reporting	56
11.1 Definition of reporting requirements	56
11.2 Presentation of field operations and measured and derived parameters	56
11.3 Data interpretation and evaluation of representative geotechnical parameters	57

Annex A (informative) Objectives, planning and requirements	59
A.1 Scope of work	59
A.2 Project execution plan and health, safety and environmental (HSE) requirements	61
A.3 Examples of unconventional soils	63
Annex B (informative) Deployment of investigation equipment	65
B.1 Deployment systems and precision of vertical depth measurements	65
B.2 Minimization of seafloor disturbance effects	70
B.3 Operations on steep seafloor gradients	71
Annex C (informative) Drilling and logging	73
C.1 Drilling methods	73
C.2 Selection of drilling equipment and procedures	74
C.3 Drilling operations plan	76
C.4 Shallow gas	77
C.5 Borehole geophysical logging	79
Annex D (informative) <i>In situ</i> testing	81
D.1 CPTU/CPT equipment and procedures	81
D.2 Documentation of reference readings for CPTU/CPTs	82
D.3 Seismic cone tests (SCPTU/SCPT)	86
D.4 Field vane tests (FVT)	86
D.5 Other <i>in situ</i> tests	86
Annex E (informative) Sampling	87
E.1 Selection of sampling tools	87
E.2 Sample handling and storage	94
Annex F (informative) Laboratory testing	97
F.1 General	97
F.2 Classification and index tests	97
F.3 One-dimensional consolidation	103
F.4 Consolidated triaxial tests	106
F.5 Direct shear tests	115
F.6 Resonant column test	123
F.7 Piezoceramic bender element tests	125
F.8 Thixotropy test	126
F.9 Permeability	127
F.10 Heat conductivity test	128
F.11 Other laboratory tests	128
F.12 Geological and geochemical tests	129
F.13 Rock testing	132
Annex G (informative) Reporting	133
G.1 General	133
G.2 Field operations and preliminary results	134
G.3 Measured and derived geotechnical parameters and final results	134
G.4 Data interpretation and evaluation of representative geotechnical parameters	135
Bibliography	138

Foreword

This document (prEN ISO 19901-8:2013) has been prepared by Technical Committee ISO/TC 67 “Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries” in collaboration with Technical Committee CEN/TC 12 “Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries” the secretariat of which is held by AFNOR.

This document is currently submitted to the parallel Enquiry.

Endorsement notice

The text of ISO/DIS 19901-8:2013 has been approved by CEN as prEN ISO 19901-8:2013 without any modification.

Introduction

The series of International Standards applicable to offshore structures, ISO 19900 to ISO 19906, constitutes a common basis covering those aspects that address design requirements and assessments of all offshore structures used by the petroleum and natural gas industries worldwide. Through their application, the intention is to achieve reliability levels appropriate for manned and unmanned offshore structures, whatever the nature or combination of the materials used.

It is important to recognize that structural integrity is a concept comprising models for describing actions, structural analyses, design rules, safety elements, workmanship, quality control procedures and national requirements, all of which are mutually dependent. The modification of one aspect of design in isolation can disturb the balance of reliability inherent in the overall concept of structural integrity. The implications involved in modifications, therefore, need to be considered in relation to the overall reliability of all offshore structural systems.

This part of ISO 19901 is applicable for marine soil investigation, which is only one of many possible marine site investigations as illustrated in Figure 1 below. The terminology used in Figure 1 and other important terminology are defined and given in Clause 3.

The extent of and what is to be included in a marine soil investigation, such as field programme, equipment to be used, laboratory testing programme, soil parameters to be established (measured, derived, representative) and reporting should be defined in project specifications based on important factors such as type of structures involved, type of soil conditions expected, regional or site-specific investigation, preliminary or final soil investigation.

The reporting can comprise anything from field data only to reporting of soil parameters. An example of reporting format is given in Annex G, Table G.1, but for each project the final reporting structure can be adjusted by deleting inapplicable sections, or by adding new sections.

This part of ISO 19901 gives requirements, recommendations and guidelines for the planning and execution of marine soil investigations and is applicable from the planning phase to reporting of representative soil parameters. It is important to use documented methods when soil parameters are established, and to refer to these methods in the report.

In situ and laboratory testing methods included in this part of ISO 19901 are selected based on their importance in marine soil investigation practice, availability in commercial geotechnical laboratories and the existence of an accepted testing procedure.

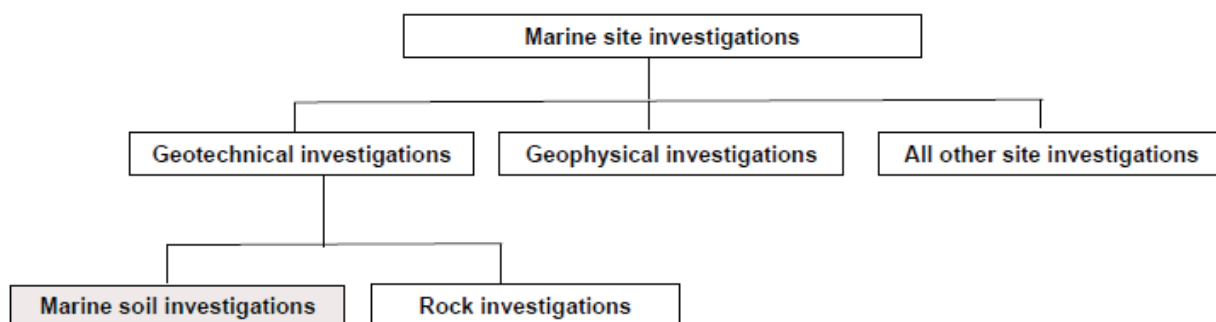


Figure 1 — Illustration showing marine soil investigations as one of many types of marine site investigations

Seabed characterization may require several types of site investigations, for example marine soil investigations and geophysical investigations including geological and geohazard evaluations. For each project the type of site investigations required have to be defined. Of importance for proper seabed

characterization is also the consideration of required investigation equipment, equipment deployment mode(s) and methods in order to acquire necessary soil data of adequate quality to target depth.

This part of ISO 19901 is applicable for marine soil investigations at any water depth and to any depth below seafloor which can be reached with the tools used.

Use of this part of ISO 19901 is based on the assumptions that:

- adequate communication takes place between geotechnical personnel involved in marine soil investigations and the personnel responsible for foundation design, construction and installation of the offshore structures;
- soil parameters are collected, recorded and interpreted by qualified personnel
- project specific scope of work for marine soil investigations is defined by one or more project specifications;

Seabed soils can vary widely, and experience gained at one location is not necessarily applicable at another. The scope of a soil investigation for one type of structure is not necessarily adequate for another. Extra caution is therefore necessary when dealing with unconventional soils or unconventional foundation concepts. Marine soil investigations include both offshore and nearshore soil investigations, which may provide very different challenges.

The detailed requirements for equipment and methods given in this part of ISO 19901 are only applicable if relevant for the scope of work defined in the project specifications.

This part of ISO 19901 is intended to provide flexibility in the choice of soil investigation techniques without hindering innovation.

The primary objectives of this part of ISO 19901 is to provide requirements and guidance for how the most important aspects of a marine soil investigation shall be performed to obtain reliable soil parameters based on documented methods.

In this part of ISO 19901, the following verbal forms are used:

- “Shall” and “shall not” are used to indicate requirements strictly to be followed in order to conform to the document and from which no deviation is permitted.
- “Should” and “should not” are used to indicate that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others, or that a certain course of action is preferred but not necessarily required, or that (in the negative form) a certain possibility or course of action is deprecated but not prohibited.
- “May” and “need not” are used to indicate a course of action permissible within the limits of the document.
- “Can” and “cannot” are used for statements of possibility and capability, whether material, physical or causal

This part of ISO 19901 includes informative annexes. Informative annexes give additional information intended to assist the understanding or use of the document. They shall not contain requirements, except that Informative annexes may contain optional requirements (for example a test method that is optional may contain requirements), but there is no need to comply with these requirements to claim compliance with this part of ISO 19901.

1 Scope

This part of ISO 19901 is intended for clients, soil investigation contractors, designers, installation contractors, geotechnical laboratories and public and regulatory authorities concerned with marine soil investigations for any type of offshore and nearshore structures, or geohazard assessment studies, for petroleum and natural gas industries.

This part of ISO 19901 provides requirements, recommendations and guidelines for marine soil investigations regarding:

- a) objectives, planning and execution of marine soil investigations;
- b) deployment of investigation equipment;
- c) drilling and logging;
- d) *in situ* testing;
- e) sampling;
- f) laboratory testing;
- g) reporting.

Rock materials are only covered by this part of ISO 19901 to the extent that ordinary marine soil investigation tools can be used, e.g. for chalk, calcareous soils, cemented soils or similar soft rock. Hard rock investigations are not covered by this part of ISO 19901; see also F.13.

Foundation design is not covered by this part of ISO 19901, but covered in ISO 19901-4 and in the respective design standards for the specific types of offshore structures as listed in the Foreword.

Planning, execution and interpretation of geophysical investigations are not covered by this part of ISO 19901. However, the results from geophysical investigations should, where appropriate, be used for planning, optimization and interpretation of marine soil investigations.

Regarding geohazard assessment studies this part of 19901 does not cover planning, scope and the assessment itself, only the marine soil investigations.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 19901-4, *Petroleum and natural gas industries — Specific requirements for offshore structures — Part 4: Geotechnical and foundation design considerations*

ISO 22476-1, 2012-05-31, *Geotechnical investigation and testing — Field testing — Part 1: Electrical cone and piezocone penetration tests*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1

accuracy

exactness of a measurement compared to the true value of the quantity being measured

3.2

application class

classification of equipment types which can achieve different accuracy

Note 1 to entry: Application classes have been developed to give guidance on selection of equipment types, and the selection should be based on required accuracy for use of the results.

Note 2 to entry: In E.1.2 and E.1.3, the terminology “suitability class” is used. However, the intention by giving “suitability classes” is the same as for “application classes”, which is to give guidance on selection of equipment types based on required accuracy for use of the results.

Note 3 to entry: The term “application class” in this part of ISO 19901 is called “quality class” in 3.4.1 of EN 1997-2:2007, and the term “application class” is not used. For the definition of “quality class” in this part of ISO 19901, see 3.22.

3.3

borehole geophysical logging

measurement of physical properties of a borehole and/or the surrounding soil, obtained by one or more logging probes deployed in the borehole

3.4

characteristic value

value assigned to a basic variable associated with a prescribed probability of not being violated by unfavourable values during some reference period

Note 1 to entry: The characteristic value is the main representative value. In some design situations a variable can have two characteristic values, an upper and a lower value.

3.5

characterization

description, evaluation and/or determination of the most typical characteristics based on all types of site investigations and other available data

3.6

client

party or person with overall responsibility for the marine soil investigation including preparation of project specifications

3.7

contractor

party or person responsible for an assigned scope of work described in project specifications

3.8

derived value

value of a geotechnical parameter obtained from test results by theory, correlation or empiricism

3.9

disturbed sample

sample whose soil structure, water content and/or constituents have been changed during sampling and handling

3.10

drained condition

condition whereby the applied stresses and stress changes are supported by the soil skeleton and do not cause a change in pore pressure

3.11

drilling mud

drilling fluid

fluid pumped down a rotary drilled borehole to facilitate the drilling process.

Note 1 to entry: The hardware associated with handling drilling fluids is commonly prefixed 'mud' (e.g. mud tank, mud pump, mud valve, etc.). Drilling parameters associated with drilling fluids are similarly prefixed (mud pressure, mud flow etc.).

3.12

geohazard

geological state which represents or has the potential to develop further into a situation leading to damage or uncontrolled risk

3.13

geophysical investigation

marine site investigation of seafloor or seabed by the use of non destructive methods requiring marine deployment of geophysical tools

See also Figure 1 in Introduction.

3.14

in-pipe logging

logging in a section of the borehole or drill pipe between the tool and the borehole wall

Note 1 to entry: The number of parameters that can be usefully measured in these circumstances is restricted.

3.15

intact sample

sample that was collected with intention to preserve its *in situ* characteristics

3.16

marine site investigations

any type of investigation at an offshore or nearshore site

See also Figure 1 in Introduction.

EXAMPLE Examples of marine site investigations: Marine soil investigation, geophysical investigation, environmental investigation, metocean investigation.

3.17

marine soil investigation

type of marine site investigation with primary objectives to obtain reliable and representative soil data for characterization of the seabed soil conditions for design of offshore structures and/or for geohazard evaluations

See Figure 1 in Introduction.

Note 1 to entry: The scope of work and extent of a marine soil investigation will vary from one project to another, but will usually include one or more of the items listed in Clause 1.

3.18

measured value

value that is measured in a test

3.19

nominal value

value assigned to a basic variable determined on a nonstatistical basis, typically from acquired experience or physical conditions

3.20

open-hole logging

logging in a section of the borehole without for example casing or drill pipe, allowing a direct measurement of the soil properties outside the borehole wall to be made

3.21

project specification

scope of work for marine soil investigations assigned by the client to a contractor

3.22

quality class

classification of sample quality for low to medium OCR clays, where the sample quality is based on measured volume change from laboratory consolidation tests

Note 1 to entry: Exact definitions of the various sample quality classes are given in 10.5, Table 6.

Note 2 to entry: The definition of “quality class” given in this part of ISO 19901 differs from the definition of “quality class” given in 3.4.1 of EN 1997-2:2007. What is called “quality class” in EN 1997-2:2007 is called “application class” in this part of ISO 19901, see 3.2. The term “application class” is not used in EN 1997-2:2007.

3.23

rat hole

additional depth drilled at the end of the borehole (beyond the last zone of interest) to ensure that the zone of interest can be fully evaluated

Note 1 to entry: The rat hole allows tools at the top of the logging string to reach and measure the deepest zone of interest.

3.24

reconstituted specimen

laboratory specimen prepared by reconstituting a thoroughly mixed soil sample

Note 1 to entry: For fine soils, the specimen is prepared as a slurry (at or above the liquid limit) and then consolidated. For coarse soils, it is either poured or pluviated in dry (dried) or wet conditions and compacted, or consolidated.

3.25

remoulded sample

remoulded specimen

sample of which the soil specimen is thoroughly reworked mechanically at constant water content

3.26

representative value

value assigned to a basic variable for verification of a limit state

Note 1 to entry: A representative value may be the characteristic value or an accompanying value. In some design situations a variable can have two representative values, an upper and a lower value.

3.27

sample

portion of soil or rock recovered from the seabed soil by sampling techniques

3.28

seabed

materials below the seafloor

3.29

seafloor

interface between the sea and the seabed

3.30

settlement

permanent downward movement of a structure as a result of its own weight and other actions

Note 1 to entry: Permanent upward movement is called vertical displacement

3.31

site

defined investigation area

3.32

soil [geotechnical] parameter

measured, derived or representative soil [geotechnical] parameter

Note 1 to entry: The term “geotechnical” includes both soil and rock.

3.33

specimen

part of a sample used for a laboratory test

3.34

strength index test

test that yields an indication of the shear strength

3.35

swelling

expansion due to reduction of effective stress, resulting from either reduction of total stress or absorption of (in general) water at constant total stress

Note 1 to entry: Swelling includes the reverse of both compression and consolidation.

Note 2 to entry: Exsolution of dissolved gas due to stress relief during sampling can cause significant swelling in samples.

3.36

uncertainty

reliability of the measurement results due to sources of systematic and random errors

3.37

undisturbed sample

sample in which no change of practical significance has occurred in the soil characteristics

3.38

undrained condition

condition whereby the applied stresses and stress changes are supported by both the soil skeleton and the pore fluid and do not cause a change in volume

3.39

undrained shear strength

maximum shear stress at yielding or at a specified maximum strain in an undrained condition

Note 1 to entry: Yielding is the condition of a material in which a large plastic strain occurs at little or no stress increase.

Note 2 to entry: Strain softening is also to be considered.

4 Symbols, units and abbreviated terms

4.1 Symbols

a	net area ratio of the cone penetrometer
c_v	coefficient of consolidation
C_s	swelling index (for consolidation tests)
h_{sf}	height of reference point above seafloor
f_s	cone sleeve friction
G_{max}	initial (small strain) shear modulus
I_L	liquidity index
I_P	plasticity index
i	inclination
K_o	coefficient of earth pressure at rest ($= \sigma'_{h0} / \sigma'_{v0}$)
m_v	coefficient of compressibility
p_0'	in situ vertical effective stress ($= \sigma'_{v0}$)
q_c	cone penetration resistance
q_t	cone penetration resistance corrected for pore water pressure effects
s	vane blade thickness
$s_u = c_u$	undrained (undisturbed) shear strength of soil
s_{uC}	static triaxial compression undrained shear strength
s_{uD}	static DSS undrained shear strength
s_{uE}	static triaxial extension undrained shear strength
s_{ufv}	shear strength by vane testing
$s_{ufv,rem}$	remoulded shear strength by vane testing
$s_{ufv,res}$	residual shear strength by vane testing
S_t	soil sensitivity
u_2	pore pressure
V_p	compression wave velocity

V_s	shear wave velocity
v_{vh}	vertically (v) propagated, horizontally (h) polarized shear wave velocity
ξ	material damping ratio
z	height above seafloor for drilling mode <i>in situ</i> probe zero reference readings
γ'	submerged unit weight of soil
γ'_m	material factor
ν	Poisson's ratio
σ	stress
σ'_{v0}	in situ vertical effective stress (= p'_0)
σ'_{h0}	in situ horizontal effective stress
ϕ'	effective angle of internal friction

4.2 Units

Units to be used may vary somewhat from one clause to another based on historical use. For example, a CPT cone cross-sectional area should be given in units of square millimetres (mm²) as used today, and not for example in square metres (m²). However, if there are no special historical reasons for deviating from the units listed below, then the units to be used are:

force	kN
moment	kNm
density	kg/m ³
unit weight	kN/m ³
stress, pressure, strength and stiffness	kPa
coefficient of permeability	m/s
coefficient of consolidation	m ² /s

4.3 Abbreviated terms

BHA	bottom hole assembly
CCV	consolidated constant volume
CD	consolidated drained
CPT	cone penetration test
CPTU	cone penetration test with pore-pressure measurement
CRS	controlled rate of strain
CT	computerized tomography

CU	consolidated undrained
DS	direct shear
DGPS	differential global positioning system
DSS	direct simple shear
ERP	emergency response plan
FVT	field vane test
GIS	geographical information system
GNSS	global navigation satellite system
HAZID	hazard identification
HAZOP	hazard and operability
HSE	health, safety and environment
HVAC	heating, ventilation and air conditioning
IL	incremental loading
LAT	lowest astronomical tide
LBL	long baseline
MSL	mean sea level
MSCL	multi-sensory core logging
OCR	over-consolidation ratio
PEP	project execution plan
PPE	personal protective equipment
QA	quality assurance
QC	quality control
RFID	radio-frequency identification
ROP	rate of penetration
ROV	remotely operated vehicle
RS	ring shear
SCPT	seismic CPT
SH	shear waves
SHANSEP	stress history and normalized soil engineering parameters
SIMOPS	simultaneous operations

SOW	scope of work
SRB	sulphate-reducing bacteria
SWL	safe working load
TC	triaxial compression
TE	triaxial extension
TOC	total organic content
UCT	unconfined compression test
USBL	ultra-short baseline
UU	unconsolidated-undrained
WGS	World Geographic System
VSP	vertical seismic profiling
YSR	yield stress ratio

5 Objectives, planning and requirements

5.1 Objectives

The objectives of marine site investigations are to make relevant and adequate soil data available at the various project phases. In particular, the acquired data is usually required to enable assessment of the site suitability with respect to the offshore structure and the level of acceptable risks for the foundation and integrity of that structure.

NOTE ISO 31000 provides guidance on risk management principles.

The general objectives of a marine soil investigation are to establish the characteristics and mechanical properties of the seabed soils by acquisition, evaluation and presentation of geotechnical information derived from methods relying on tools penetrating into the seabed. The requirements given in ISO 19901-4 for marine soil investigations shall apply. Specific objectives of a marine soil investigation may be given in project specifications.

5.2 Planning

Marine site investigations commonly consist of the following sequence of activities:

- desk study, including the evaluation of information available in the public domain, available geophysical data, and the results of any previous marine soil investigations in the area;
- shallow geophysical investigations;
- marine soil investigations, which may comprise one or more phases to suit the design phases;
- further integrated study combining the information gathered in the desk study, shallow geophysical investigation and marine soil investigation phases.

Shallow geophysical investigations typically comprise

- bathymetry and seafloor topography, using echo-sounding or swath bathymetry;
- seabed features and obstructions, using methods such as side-scan sonar imaging and magnetometry;

- seabed stratigraphy, using methods such as sub-bottom profiling, usually by means of high-resolution reflection seismic.

NOTE 1 Shallow geophysical investigations are not covered by this part of ISO 19901, but the use of the results is important for marine soil investigations.

NOTE 2 ISSMGE (2005) provides guidance on shallow geophysical investigations.

A “limited-scope” marine soil investigation is commonly performed in conjunction with shallow geophysical investigations for the purpose of preliminary ground-truthing of the sub-bottom profiling data. The results of a shallow geophysical investigation, alone or in addition to a desk study, are generally not sufficient for detailed design of an offshore structure.

A shallow geophysical investigation typically covers a large extent of seabed, enabling the identification of localized, non-characteristic seabed features such as:

- buried channel or ice gouge features;
- erosion features;
- slides or shallow mass transport deposits;
- gas, gas pockets or potential gas pockets;
- specific seafloor features (e.g. pockmarks, concretions, chemo-synthetic communities and seafloor expulsion features, drill cuttings mounds).

A marine soil investigation can include logging, *in situ* testing and sampling operations, with field and onshore laboratory testing performed on the recovered samples, evaluation of geotechnical data and results and reporting. Specific guidance is given on selection of appropriate equipment and procedures in subsequent clauses of this part of ISO 19901. The date by which appropriate geotechnical information is required determines when a marine soil investigation should be done. Having the marine soil investigation on the critical path can adversely impact subsequent activities, particularly in case of unexpected findings that require additional work.

Considerations for planning a marine soil investigation include project phases, requirements of the offshore structure and risk level.

NOTE Examples of project phases are site selection, conceptual design, preliminary design, detailed design, re-certification, decommissioning. Risk level is commonly expressed by probability of failure and consequences of failure. Design codes commonly rely on implicit or explicit risk levels.

Geotechnical design requirements for the offshore structure depend on several factors that can influence the planning of the scope and extent (spatial area and explored depth) of the marine soil investigation, in particular the following:

- design phase, ranging from concept selection to decommissioning;
- type of offshore structure and foundation solutions;
- type and dimensions of loadings;
- related design situations, such as bearing capacity, stability, settlements/displacements, soil-structure interaction, installation/removal aspects etc;
- criticality of design situations and the possible need for optimization of design and related geotechnical parameter values;
- methods to be adopted for solving/analysing the various design situations;

- geohazards.

Depth coverage may range from a few metres below seafloor for a seabed pipeline to generally 100 m below seafloor. Coverage to 200 m may apply for foundations of specific offshore structures and to possibly 400 m may be necessary for characterizing geohazards such as for example shallow water flow sands.

The following factors are typically considered for planning a marine soil investigation:

- the type of offshore structures to be designed and the way in which they will interact with the seabed;
- the needs for determination of the area geology and related geohazards;
- the results of desk studies, earlier geophysical and marine soil investigations;
- the prior knowledge of seabed conditions and local geological variability and geohazards including shallow gas;
- other considerations, such as local metocean conditions, existing facilities, unexpected unexploded ordnance, and the possibility of contaminated ground;
- interaction of investigation equipment with seafloor, see 6.4 for more details;
- regulatory requirements.

Investigation of contaminated ground can require special equipment and procedures.

The variability of the seabed and soil conditions at the site is important for the scope of marine soil investigation. Investigations are usually targeted at locations where variations in seabed and soil conditions are anticipated, if of significance to the development, as well as at locations more typical of the site.

The choice of vessel, equipment and procedures typically includes the following considerations:

- operational requirements, including:
 - project specific HSE (for example, risk of encountering shallow gas),
 - local metocean conditions,
 - equipment capability to reach target depth,
 - grouting or not of boreholes after they have been drilled as part of the marine soil investigations (for example, if the borehole is at the location of a structure it may be desirable to grout it up, whereas in areas with shallow gas it may be preferable to leave the borehole open).
- quality requirements including:
 - accuracy and resolution of control of depth below seafloor,
 - tolerance of actual locations relative to target locations,
 - sampling (for example, whether sharp edged thin wall piston sample tubes are desirable),
 - need for and testing activities suitable for the anticipated soil conditions (for example, full flow penetrometers versus CPTU),
 - logging,
 - water depth,

- seafloor slope or unevenness, in terms of deployment of equipment and effects on, for example, depth control.

The planning and the scope of work may be modified during the course of a marine soil investigation, upon review and evaluation of the results from the investigation as they become available.

5.3 Scope of work

5.3.1 Responsibility and development of scope of work

The scope of work and extent of a marine soil investigation shall be given in the project specifications, including any planning activities to be undertaken by the contractor.

The project specifications should consider the possibility of an activity that cannot be completed as intended and should consider an appropriate course of action.

NOTE A project may have more than one project specification.

Regarding marine operations, project specifications shall define responsibility for clarifying site clearance issues and any required mitigation measures. Site clearance issues typically include:

- navigation requirements such as minimum stand-off distance from existing facilities;
- water depth, seafloor slope and unevenness;
- risk of encountering shallow gas, unexploded ordnance and contaminated ground;
- site permits, including sample export.

Where the client holds relevant information, this shall be made available to the contractor.

The project specifications should state the objectives of the marine soil investigation.

The project specifications should, if relevant, include foundation details of the offshore structures and the selected design approaches.

Where relevant, the project specifications should refer to methods described in this part of ISO 19901. Any references to methods should be accompanied by method-specific information as applicable. If method-specific information is not contained in the project specification, then the contractor's practice shall apply. The project specifications may refer to or describe alternative methods not covered by this part of ISO 19901.

The project specifications shall, where applicable, include requirements for:

- determination of the extent of logging, sampling and testing, consisting of:
 - type, number, location and depth of in situ testing locations (see Clause 8),
 - type, number, distribution, location and depth of sampling locations (see Clause 9),
 - type and number of offshore and onshore laboratory tests (see Clause 10),
- choice of appropriate vessel, equipment and techniques (see Clauses 5 through 10);
- reporting including presentation of the results of the marine soil investigation and any associated data interpretation (see Clause 11).

5.3.2 Default and project specified application classes/methods

The following clauses of this part of ISO 19901 give requirements and information on items that should be specified, which include application classes that are considered to be appropriate in many cases. Application classes should be specified such that the objectives of the marine soil investigation can be met.

Default application classes and default methods that shall be used if otherwise not given in project specifications, are:

- depth accuracy; see 6.2.3; default is class Z5;
- *in situ* test accuracy for:
 - CPT/CPTU; see 8.3.3.1; default is class 3,
 - vane test; see 8.7.3; default is class 2.

When assessing the required accuracy, consideration should be given as to whether relative accuracy or absolute accuracy is required, and the level of variability of the quantity being specified. For example, when specifying depth accuracy, relative accuracy can be more important than absolute accuracy. Knowledge of the thickness of a soil unit can be required to be known to a greater degree of accuracy than its absolute depth. In addition, it should be considered that the depth and thickness of a soil unit can vary across a site and therefore determining its depth at a given location to a high degree of accuracy may not be necessary if the variability of depth between locations is substantially greater or unknown.

If any requirements are not specified in the project specifications, or not given as default values in this standard, then the contractor's usual practice shall apply.

5.4 Health, safety and environmental (HSE) requirements for marine operations

The marine soil investigation shall comply with governmental, local legislative authority and project HSE requirements. Marine operations should be conducted in accordance with a project HSE plan. The project HSE plan can be part of a project execution plan, see Annex A.

ISO 19901-6 should be considered for marine operations from a vessel used for marine soil investigations. The vessel shall have a Health, Safety and Environment Management System (HSEMS), and the HSEMS should comply with the requirements of the International Management Codes for Safe Operation of Ships (ISM code) and for Pollution Prevention (MARPOL code), and with the Safety of Life at Sea (SOLAS) code, or equivalent codes. The vessel should also comply with the International Ship and Port Facility Security (ISPS) code, where applicable.

The vessel should be crewed/staffed with a sufficient number of qualified, trained, and experienced personnel to perform required marine soil investigation operations, including the operation, maintenance and repair of critical equipment.

The safety and well-being of those involved in, and impacted by, the marine soil investigation shall be considered. All persons shall be familiar with safety procedures requisite for the safe completion of tasks in which they participate [Job Safety Analysis (JSA)] and general onboard safety. The operators of marine soil investigation equipment shall have proper training and experience in the use of the equipment. All persons shall be aware of proper reporting requirements for HSE incidents.

The investigation vessel shall have appropriate safety equipment to comply with SOLAS codes or equivalent codes, including adequate maritime lifesaving equipment, and personal protective equipment (e.g. hard hats, safety glasses, floatation work vests, safety lines) as required by individual JSAs and vessel HSEMS, and shall have onboard personnel familiar with and trained in its use.

Special care should be exercised for "specially-mobilized" vessels, as opposed to purpose-built vessels, for marine soil investigation, to ensure all temporarily-mobilized equipment is safely installed and operated, and that interfaces between permanent vessel crew, who may be unfamiliar with marine soil investigation operations, and temporary crew members (e.g. positioning crew, client representative(s) and any other specialist crew members) are properly managed.

Marine soil investigation equipment shall not be used before it is safely installed. Lifting equipment, such as cranes, booms, hoists, spreader bars, slings, etc., shall be suitable for the proposed use, checked/inspected/certified and appropriately tagged/marked. During the marine soil investigation, the vessel should be subject to ongoing safety monitoring.

When operations become unsafe for any reason, such as excessive vessel motion, work shall cease and equipment shall be secured.

Attention shall be paid to the impact of marine soil investigation equipment on HSE. Special substances such as drilling mud, laboratory chemicals and radioactive sources can require special care during handling and storage. The presence and special handling and storage requirements of any hazardous material on board the vessel should be documented in a project-specific safety plan.

A project specific HSE plan should consider the potential impact of in-water investigation equipment on the marine environment (e.g. loss of hydraulic fluid, acoustic noise, etc.).

5.5 Other requirements

5.5.1 Operational requirements

The environmental conditions at the planned fieldwork site, such as water depth, seafloor slope, wave and current conditions, the risk of shallow gas/hydrates and the proposed scope of the marine soil investigation, shall be considered when selecting vessels and investigation tools. Responsibility for undertaking this shall be defined in the project specifications. The primary concern when considering the size and class of a vessel is the safety of the operations and personnel during the work.

Lifting, handling and deployment facilities (A-frames, booms, davits, cables, cradles, drilling equipment, winches, etc.) for the required logging, sampling and *in situ* testing equipment, supplies and other equipment shall be safe and certified. The additional frictional and suction components imposed on a piece of investigation equipment (e.g. seafloor frame, corer, CPTU) shall be considered when determining the maximum anticipated load on a lifting element as these additional loads can be significant.

Equipment used during the marine soil investigation should have documentation consisting of operational and maintenance procedures. Where two or more pieces of equipment have a critical interface, those interfaces shall be evaluated to ensure proper operation.

Vessel positioning and equipment positioning requirements shall be defined in the project specifications. Further guidance is provided in 6.3.

5.5.2 Quality requirements

Experienced geotechnical practitioners shall be involved during the planning and preparation of the soil investigation scope and project specifications. The fieldwork shall be executed by suitably experienced personnel.

The client should have an appropriate project quality management system in place with quality control to be exercised consistently and competently in all phases of investigation and evaluation. The contractor should operate a documented quality management system based on the ISO 9000 series of International Standards.

A project quality plan should be incorporated as part of a project execution plan (PEP) for the marine soil investigation (see Annex A). This should detail the organizational responsibilities, activities, and an index of referenced and applicable procedures to complete the scope of the marine soil investigation.

Quality system audits against the quality management system should be performed. The client and contractor should address and resolve audit reports, recommendations and/or corrective actions within the responsibility of the client and contractor respectively.

5.5.3 Specific requirements for unconventional soils

The requirements and recommendations in this part of ISO 19901 have been developed primarily for use in conventional soils, i.e. siliceous sands and clays of terrigenous origins which have relatively well understood generic properties, and for which there are well established global marine soil investigation practices. When performing a marine soil investigation in frontier areas, or areas known or suspected to contain unconventional soils, this may require special handling or treatment for soils such as:

- more regional siliceous terrigenous soils (e.g. glacial tills, frozen soils etc);
- unusual terrigenous soils (e.g. volcanic ash, silts, glauconitic soils, micaceous soils etc);
- non-terrigenous soils (e.g. carbonate soils - see Note below, calcareous soils, siliceous oozes etc).

The equipment, methods and procedures may also need to be tailored to investigate characteristic properties that may pose particular difficulties for geohazard assessments and engineering. Examples of soils with specific generic properties that may need special attention are listed in Table A.3.

NOTE Carbonate deposits offer an example of how an investigation may need to be adapted to suit soil type: such soils can be variably cemented and range from lightly cemented with sometimes significant void spaces to extremely well cemented. This is particularly the case for sands and silts that contain more than 15 % to 20 % carbonate material. Therefore, in planning a marine soil investigation, it is important to incorporate sufficient flexibility in the scope of work to switch between soil sampling, rock coring, and *in situ* testing techniques as appropriate. In these soils, a carefully developed field and laboratory testing programme can be warranted. ISO 19901-4 includes guidance.

General guidance on types of unconventional soils and soils with generic properties that have potential difficulties associated with them is given in A.3.

6 Deployment of investigation equipment

6.1 Deployment modes

6.1.1 General

Marine soil investigation equipment can be deployed in a variety of ways. The elected deployment method can influence the quality and the depth to which data can be acquired. The end user of the geotechnical data should ensure that the selected equipment is capable of providing suitably accurate and sufficient geotechnical data for the intended purpose.

6.1.2 Non-drilling mode

Non-drilling mode encompasses the practice by which geotechnical testing or sampling tools are initiated at the seafloor and penetrated in a single stroke to refusal depth or to a predetermined depth. Tool penetrations generally vary from 0,5 m to greater than 25 m below seafloor, depending on the tool that is deployed and the geology that is encountered. Penetrations in excess of 40 m are possible using specialist equipment within very soft seabed.

A vast array of geotechnical testing and sampling equipment is deployed using this technique. The more sophisticated of these tools are landed on the seafloor prior to the commencement of the seabed penetration. The simplest of these tools are simply lowered until they encounter the seafloor, allowed to penetrate to refusal under their own weight, then extracted and recovered to the vessel deck.

The quality of data acquired varies with the level of sophistication of the tools. Sophisticated seafloor-founded, non-drilling mode rigs can acquire high quality samples or *in situ* data. At the other end of the spectrum, non-heave-compensated winch-controlled tools such as gravity corers, Kullenberg piston corers and vibro corers can have a limited capacity to acquire high quality samples.

A common limitation of non-drilling mode equipment relates to their inability to achieve a target penetration depth when a seabed layer is intercepted whose strength exceeds the penetration capabilities of the tool.

Notwithstanding the above, non-drilling mode tools are widely used for acquiring seabed geotechnical data in favourable geological conditions, due to their generally high level of availability, comparatively lower cost, and their capacity to be deployed from a wide range of vessels.

6.1.3 Drilling mode

6.1.3.1 General

In drilling mode, logging, sampling and *in situ* test tools are deployed into the seabed, initially commencing from the seafloor and thereafter from the bottom of a borehole that is progressed via rotary drilling.

Drilling mode operations can be undertaken either from the sea surface, (referred to as 'vessel drilling'), or alternatively using remotely controlled, seafloor-founded drill rigs (referred to as 'seafloor drilling').

Geotechnical tools are deployed to the bottom of the borehole using a variety of techniques, including wireline, free fall, or via advancement and recovery of the drill string itself. Once located at the bottom of the borehole, the geotechnical tool is penetrated via electrical, hydraulic or mechanical means until the maximum stroke length, the borehole target depth, or the mechanical capacity of the system is achieved.

At the completion of a testing or sampling interval, the tool is either recovered to the surface through the drill string (vessel drilling), or temporarily stored on the rig (seafloor drilling). The borehole is then progressed to the next testing or sampling depth.

Further guidance related to rotary drilling techniques is provided in Clause 7.

6.1.3.2 Vessel drilling

Vessel drilling operations are undertaken from either:

- a) a spudded, anchored or dynamically positioned floating vessel, such as a drill ship, semi-submersible vessel, barge or similar craft, or
- b) a stable platform, such as a jack-up or permanent seabed structure.

Vessel drilling systems are influenced by movements associated with surface environmental conditions. For many vessel drilling systems, the vertical stability of the drill string may be controlled or limited by means of:

- a seafloor-founded template with a 'hard tie system' heave compensator, ref. Zuidberg et al 1986, or
- a heave compensator on the drilling vessel in conjunction with soil resistance that prevents movement of the drill string.

Less sophisticated vessel drilling systems are uncompensated against vessel heave. Further discussion of the effects of vessel heave on drill string stability, and the precision of borehole depth measurements, is provided in B.1.

6.1.3.3 Seafloor drilling

Seafloor drilling systems are either landed on the seafloor and a catenary is formed with the control umbilical, or alternately a constant tension winch is used to isolate the rig from vessel movements. All operations are then undertaken via remote control.

The stability of seafloor drilling systems is largely dependent on the capabilities of the footings used to support the rig. Sophisticated footings systems may incorporate the capacity to self level the rig, and monitor the vertical height of the rig relative to the seafloor to enhance the precision of borehole depth measurements. Less sophisticated rigs may lack the capacity to land and stay reliably at the seafloor, leading to uncontrolled penetration on landing, an increased potential for tilting, and poor estimation of actual borehole depth.

The action of initially landing equipment on the seafloor can disturb the natural characteristics of the upper seabed. This issue is discussed further in B.2.

6.2 Precision of vertical depth measurements

6.2.1 General

The precision of vertical depth measurements is a critical component of a marine soil investigation. Precise measurement of vertical depth assists in ensuring, for example:

- that variations in seabed stratigraphy are accurately defined;
- that appropriate overburden and pore water pressure corrections are applied to *in situ* test data;
- that adjacent samples and *in situ* test data are able to be precisely correlated; and
- that appropriate confining stresses are specified during the course of subsequent laboratory test programmes.

6.2.2 Factors affecting the precision of vertical depth measurements

A data point can be defined as any discrete location within a borehole. The depth precision of a data point will vary depending on the mode of equipment deployment, the availability of measuring systems to estimate the location of the tool point relative to the seabed, and the type of tool deployed.

For example, the achievable depth accuracy when using a vessel-mounted drilling system can be dependent on the prevailing environmental conditions at the sea surface, the associated vessel motions, the water depth, the capability of a vessel's heave-compensation system, and whether the drill string can be stabilized at the seafloor during downhole data acquisition. In contrast, the depth accuracy achieved with a seafloor-founded system can be dependent on the capabilities of the monitoring system used to estimate the position and levelness of the rig relative to the seafloor, and the length of the drill string or push rods deployed downhole.

Data point depth accuracy can additionally vary as a result of the performance of a sampling tool. For example, the allocation of sample loss within a sampling run is often solely based on engineering judgement. This can introduce additional uncertainty as to the actual depth from which the sample originated.

Further discussion on the factors affecting the precision of vertical depth measurements is provided B.1.

6.2.3 Specification of depth accuracy classes

The project specifications should include the class of depth accuracy to be achieved in a marine soil investigation based on the intended use of the geotechnical data, with due consideration of the capabilities of the equipment under consideration. Different degrees of depth accuracy may be specified for *in situ* testing and sampling operations.

Documentation demonstrating the depth accuracy that can be achieved with proposed investigation equipment should be provided by the geotechnical contractor(s). For cases where depth accuracy is expected to vary with changes in water depth and/or borehole depth below seafloor, the variation in accuracy class should be estimated for each intended investigation area.

Depth accuracy classes are presented in Table 1. Information on the factors affecting depth accuracy for different equipment types, and key parameters for consideration in calculations, are included in Annex B.

Table 1 — Depth accuracy classes for data point measurements below seafloor

Depth accuracy class	Maximum data point depth uncertainty m
Z1	0,1
Z2	0,5
Z3	1,0
Z4	2,0
Z5	>2,0

A default value, Z5, shall apply for the case where depth accuracy is not given in project specifications.

6.3 Positioning requirements

The requirements regarding horizontal vessel and equipment positioning accuracy shall be given in the project specifications (as noted also in 5.5.1).

The accuracy to which boreholes and/or equipment are located on the seafloor is an important aspect of a geotechnical dataset to ensure that:

- current investigation locations are aligned with previous and future soil investigations, and the installation of facilities;
- known seafloor hazards, including installed facilities, natural seabed obstructions, excessive gradients, identified areas of shallow gas and other features are avoided with confidence.

The geodetic system, positioning datum and other corrections to be applied to the data set must be specified, and minimum acceptable calibration and integrity testing exercises are to be completed prior to the commencement of an investigation.

Specification of horizontal positioning tolerances may be influenced by:

- the type of facilities to be installed on the seafloor;
- the type, accuracy capabilities & levels of equipment redundancy of the positioning equipment;
- the proximity of existing facilities (including the estimated accuracy of their actual positions);
- the known seabed topography: water depth, seafloor slopes, natural features.

For further guidance on horizontal positioning requirements, reference is made to the IHO standards, and OGP-IMCA 2010.

6.4 Interaction of investigation equipment with the seafloor

Most sophisticated marine soil investigation equipment interacts with the upper seabed prior to commencement of data acquisition.

The action of landing equipment on the seafloor can disturb and apply elevated surcharge pressures to the upper seabed, which can be detrimental to data quality. The expected interaction of investigation equipment with the seafloor should be clarified prior to the commencement of a soil investigation.

Operation of investigation equipment on high seafloor gradients can be impeded. Detailed bathymetry information is normally required to confirm that the investigation equipment can be safely operated in such environments.

Further guidance related to disturbance of the seabed, and operation of equipment on steep seafloor gradients is provided in B.2.2 and B.3, respectively.

7 Drilling and logging

7.1 General

Drilling operations can be undertaken either from the sea surface ('vessel drilling') or alternatively using remotely controlled, seafloor-founded drill rigs ('seafloor drilling'). The various modes of equipment deployment are defined within Clause 6, which also describes the particular aspects that relate to rotary drilling and the subsequent logging of a borehole (if applicable).

In both drilling system deployment modes outlined above, a borehole is advanced by the combined action of a rotating cutting surface (the drill bit) on material at the bottom of the hole and the flow of drilling fluids that flushes drill cuttings in suspension from the bottom of the hole up the enclosing annulus between the drill pipe and borehole wall (or casing inner wall).

Some soil disturbance ahead of the drill bit is inevitable and can have a measurable effect on data quality. Excessive, or varying, weight on the drill bit will tend to increase soil disturbance as the bit impacts virgin material at the drill face. Excessive drilling fluid pressure can induce hydraulic fracture or erosion of virgin material. Excessive drilling-fluid flow can soften or erode virgin material. Soil disturbance can often be assessed by inspection of the results from the sampling and *in situ* testing. The depth of soil disturbance below the drill face, and the magnitude of its effect, tend to be greater for softer soils.

For marine drilling operations, the vertical stability of the drill string during borehole advancement is critical to the recovery of high quality geotechnical data. Fluctuations in applied bit weight, and associated displacements, during sampling and *in situ* testing operations can be very detrimental to data quality. Drill string stability is largely affected by the type of equipment used to deploy the drill string. Further information on this issue is provided in Clause 6.

The efficient delivery of the drilling operation can be fundamental to the overall success of the marine soil investigation. Clause 7 and Annex C describe the process for selection and adoption of the most appropriate drilling equipment and procedures for the work, based on project-specific requirements and drilling objectives.

7.2 Project-specific drilling requirements

The choice of drilling equipment suitable for a particular soil investigation is generally dictated by a number of key project-specific drilling requirements, which may consist of:

- expected soil conditions and possible drilling hazards, such as shallow gas, flowing sands, swelling clays, hydraulic fracture potential;
- required borehole depth and purpose of geotechnical borehole(s), i.e.
 - 1) borehole suitable for deployment of specific testing or sampling tools, and/or
 - 2) borehole to acquire drilling parameters (i.e. destructive drilling);
- site environment and seafloor characteristics, e.g. water depth, expected weather and sea conditions (current, tide, extremes of temperature), proximity of surface/submerged/seafloor/buried infrastructure, seafloor topography, natural seafloor features;
- allowable uncertainty in borehole depth measurements (see 6.2);
- HSE considerations, e.g. manned interventions on the drill floor, environmental discharge regulations for drill cuttings, etc.;

— logistical considerations, e.g. project schedule, availability of equipment.

7.3 Drilling objectives and selection of drilling equipment and procedures

Drilling objectives of the soil investigation are typically one or more of the following:

- To recover data of optimal quality, with minimal soil disturbance from drilling, where the soil investigation results will be used to determine geotechnical parameters for design purposes.
- To maximize the continuity of data recovered within a borehole (at the possible expense of reduced data quality), for example for geological investigations for which key horizons can be very thin and therefore require a data record as continuous as possible.
- To maximize the speed of drilling, at the expense of data quality and/or continuity, in the interests of providing as much spatial or depth coverage of a site as possible within a given time or budget constraint, for example for hard-layer detection, or pilot-hole drilling (for detection of shallow gas).
- To minimize the potential for a shallow gas incident. The rapid extraction of wireline tools from the seabed (swabbing effect) can induce a shallow gas 'kick'. It may also be necessary to perform a pilot-hole for the detection of shallow gas, thereby de-risking further drilling operations.

The drilling equipment and procedures shall be based on the identified drilling objectives, with due consideration of the range of expected soil conditions and drilling hazards that may be encountered. For rotary core drilling, the system and the associated sampling techniques may follow the requirements of ISO 22475-1 (mainly for onshore and nearshore soil investigations).

Further guidance on the selection of drilling equipment and procedures is given in Annex C.

7.4 Drilling operations plan

A separate drilling operations plan (see Annex C) or the project execution plan for the soil investigation (see Annex A) shall cover the proposed drilling operations and shall describe the predicted sequence of activities and contingencies, from initiation to completion of each geotechnical borehole, and include details of the required sampling/testing/logging programme.

The purpose of the drilling operations plan is twofold:

- a) during the pre-fieldwork phase, to provide assurance that:
 - all required information is in place,
 - the proposed solution is capable of meeting all of the project objectives,
 - due consideration has been paid to potential drilling hazards, and
 - contingency plans are in place in the event of foreseeable drilling-related problems;
- b) during the fieldwork phase, to control the execution of the drilling and borehole works.

The level of detail required depends on the complexity of the soil investigation, on the tools and techniques to be employed, and on whether any new or modified equipment or procedures are required.

Some areas where marine soil investigations are carried out pose a potential risk of encountering shallow gas, either natural or released from a nearby hydrocarbon extraction/ processing infrastructure. Where the potential for a gas release exists, a shallow gas plan shall be developed. Part of this plan may include the drilling of a separate pilot hole; prior to any geotechnical sampling or *in situ* testing.

Guidance for the content of the drilling operations plan and for the performance of shallow gas risk assessment is provided in Annex C.

7.5 Recording of drilling parameters

During the process of borehole drilling the system operational and performance parameters shall be recorded either manually (usually by the driller) or by use of an electronic automated logging system. When depth resolution of logged parameters better than about 1 m is required, use of an automated logging is the preferred method.

Depending on project-specific requirements and upon the logging method adopted (manual or electronic), recorded parameters may include:

- time (dd/mm/yyyy hh:mm:ss);
- penetration (m);
- rate of penetration (ROP) (m/min);
- drilling fluid pressure at the output of the pump (kPa);
- drilling fluid circulation rate (input) (l/min);
- drilling fluid recovery rate (l/min) (only for riser drilling with recirculation of drilling fluid);
- drill head rotational torque (Nm);
- drill head rotational speed (min^{-1});
- bit load (kN).

The accurate recording of drilling parameters can provide a valuable data set for use in interpolation/extrapolation of soil data and detection of layering. An example of such application for detection of hard layers in carbonate material is given in Becue *et al.* (1988).

7.6 Borehole geophysical logging

Depending upon project-specific requirements, geophysical wireline logging or logging while drilling may be employed. Typically, these methods provide enhanced geological and engineering detail over the logged borehole section.

A number of tools are available, some for in-pipe measurements and some for open-hole measurements (see Digby (2002) and ISO/TR 14685 for further information).

Refer to Annex C for further guidance.

8 *In situ* testing

8.1 General

Results of *in situ* tests depend on how the tools or probes are deployed into the seabed, and whether the soil is disturbed prior to probe insertion. As noted in Clause 6, tools can be deployed via two alternative methods:

- a) non-drilling mode, in which tool penetration is initiated at the seafloor and penetrated in a single stroke to refusal, or to a predetermined depth; or
- b) drilling mode, where the tool is lowered down a predrilled borehole, and *in situ* testing is initiated at the bottom of the borehole.

The specifications and requirements given in Clause 6 should be taken into account when planning and performing *in situ* tests. For tests undertaken in drilling mode, Clause 7 should also be consulted.

8.2 General requirements for the documentation of *in situ* tests

For each test, the following information shall (underlined) or may (not underlined) be recorded and reported:

- a) site geographical details, including:
 - geographical location,
 - facility name,
 - borehole or test title,
 - coordinates including site datum (e.g. WGS 84),
 - water depth (e.g. lowest astronomical tide; mean tide).
- b) equipment details (as applicable):
 - equipment name,
 - deployment mode,
 - borehole progression method (drilling or non-drilling);
- c) test details (as applicable):
 - test type,
 - test/stroke number,
 - current borehole depth,
 - tool type (geometry/capacity).

Reference should be made to any deviations from the requirements of this part of ISO 19901, where identified, including:

- testing procedures;
- tool wear or damage;
- corrections made for depth below seafloor;
- actual borehole positions versus original target positions.

8.3 Cone penetration test (CPT/CPTU)

8.3.1 General

This clause covers cone penetration tests performed with a friction cone (CPT) and with a piezocone (CPTU)

8.3.2 Equipment

The standard cone penetrometer is defined as having a nominal cross section, A_c , of 1 000 mm². The geometry of the standard cone penetrometer and allowable tolerances should be as given in 4.4 of ISO 22476-1:2012.

Cone penetrometers with a diameter between 25 mm ($A_c = 500$ mm²) and 50 mm ($A_c = 2\,000$ mm²) are permitted for special purposes, without the application of correction factors. The geometry and tolerances given for the nominal 1 000 mm² cone penetrometer should be linearly scaled in proportion to the diameter.

The friction sleeve shall be placed just above the cone. The dimensions and tolerances for the friction sleeve should be as given in 4.5 of ISO 22476-1:2012.

For measuring pore pressures, a filter location in the cylindrical part just above the conical part is recommended. Pore pressure measured at this location is denoted u_2 . Pore pressures may sometimes also be measured on the cone face (u_1) and/or just above the friction sleeve (u_3). Requirements for the location of the filter(s), dimensions and tolerances should be as given in 4.6.1 of ISO 22476-1:2012. The penetrometer tip and adjoining rod(s) should have the same diameter for at least 400 mm behind the tip for the 1 000 mm² cone penetrometer. For other size cones, this distance shall be scaled linearly in proportion to the diameter.

NOTE Changing rod diameter at a distance of less than 400 mm (for standard 1 000 mm² cone penetrometers) can influence the measured cone resistance.

8.3.3 Test procedures

8.3.3.1 Selection of equipment and procedures

For cone penetration tests, the use of application classes as defined below should be adopted. Equipment and procedures to be used should be selected according to the required application class given in Table 2. Application classes are defined as follows:

- a) **Application Class 1** is intended for very soft to soft soil deposits. Class 1 penetration tests are normally not achievable for mixed bedded soil profiles with weak to strong layers (although pre-drilling through these layers can overcome the problem). Tests can only be performed as CPTU.
- b) **Application Class 2** is intended for precise evaluation for mixed bedded soil profiles with weak to strong layers, in terms of profiling and material identification. Interpretation in terms of engineering properties is also possible, with restriction to indicative use for the soft or weak layers. The test type should be CPTU.
- c) **Application Class 3** is intended for evaluation of mixed bedded soil profiles with soft to stiff clays and loose to dense sands, in terms of profiling and material identification. Interpretation in terms of engineering properties is appropriate for very stiff to hard clay and for dense to very dense sand layers. For stiff clays or silts and loose sands, only an indicative qualitative interpretation can be undertaken using data acquired under this application class. The test type should be CPTU but in some cases CPT may be accepted.

NOTE Mixed bedded soil profiles refer to soil conditions containing typically dense and stiff to hard soils, but possibly also including soft or weak layers.

If all possible sources of errors are added, the minimum accuracy of the recorded measurements for each application class should be better than the largest of the values given in Table 2. The uncertainty analysis should include internal friction, errors in the data acquisition, eccentric loading, temperature effects (ambient and transient), pore pressure effects in gaps below and above the friction sleeve, and dimensional errors. The resolution of the measurements should be better than one-third of the required accuracy applicable to the application class given in Table 2.

With reference to Table 2, the following should be noted. Seafloor CPT systems generally provide thrust perpendicular to the seafloor, with no opportunity for correcting the pushing force to vertical. In drilling mode, verticality of the downhole CPTU/CPT system depends on verticality of the drill string. A vertical pushing force is normally assumed for the calculation of the penetration depth.

NOTE The difference between accuracy and uncertainty is described in Clause 3.

Table 2 — Accuracy of CPT/CPTU parameter values for application classes

Application Class	Test type ^a	Measured parameter	Allowable minimum accuracy ^a
1	CPTU	Cone resistance	35 kPa or 5 %
		Sleeve friction	5 kPa or 10 %
		Pore pressure	25 kPa or 5 %
2	CPT or CPTU	Cone resistance	100 kPa or 5 %
		Sleeve friction	15 kPa or 15 %
		Pore pressure ^b	50 kPa or 5 %
3	CPT or CPTU	Cone resistance	200 kPa or 5 %
		Sleeve friction	25 kPa or 15 %
		Pore pressure ^b	100 kPa or 5 %

^a The allowable minimum accuracy of the measured parameter is the larger value of the two quoted. The relative accuracy applies to the measured value and not the measuring range.

^b Pore pressure can only be measured if CPTU is used.

If the client does not specify a required application class, Application Class 3 will be the default.

The allowable minimum accuracies for cone resistance, sleeve friction and pore pressure shall apply relative to the seafloor.

The allowable minimum accuracy for penetration depth should be estimated in accordance with depth accuracy recommendations as provided in Clause 6.

8.3.3.2 Preparation for testing

The thrust machine should act on the push rods so that the axis of the penetration force is as close to vertical as possible. The axis of the penetrometer shall correspond to the loading axis at the start of the penetration.

It is permissible to use the same filter for several tests, but the pore pressure response should be closely monitored for each test and the filter replaced when an unsatisfactory response is observed.

8.3.3.3 Pushing of cone penetrometer

The nominal rate of penetration should be 20 ± 5 mm/s.

The length of each stroke should be as long as possible, with due consideration for the mechanical and strength limitations of the equipment. Continuous penetration is preferred. The data recording frequency shall be at least 1 Hz.

For downhole and shallow (< 5 m penetration) seafloor tests, inclination measurements are not required.

8.3.3.4 Dissipation tests

Guidance and recommendations related to the CPTU dissipation test are given in 8.4.

8.3.3.5 Test completion

The penetration of the cone penetrometer shall be terminated when

- the required depth below seafloor has been reached, or
- the agreed maximum thrust or maximum capacity of the measuring system has been reached, or
- the cone inclination approaches or is beyond the allowable limit.

For CPT/CPTUs in drilling mode, reaching maximum thrust capacity at one depth should not prevent subsequent strokes being performed. The fact that maximum thrust capacity is reached is also important information.

Potential damage to the equipment can also be a valid reason to prematurely terminate a test.

For quality control, zero-reference readings of cone resistance, sleeve friction and, if applicable, the pore pressure, shall be recorded before and after each test.

The zero reference for seafloor (with and without drilling) CPT/CPTUs shall be the seafloor. For downhole CPT/CPTU from a surface vessel, the zero reference shall be at deck level, and the reference readings at the bottom of the borehole shall also be recorded and compared to theoretically calculated values. Both non-drilling mode and drilling mode tests shall be reported for all measurements referenced to the seafloor.

NOTE 1 Results of CPTU/CPTs carried out in drilling mode prior to 2010 may show q_c , f_s and u corrected relative to the bottom of the borehole rather than the seafloor.

For seafloor-based drilling systems, reference readings can be made at the seafloor or a fixed distance above, with values corrected to the seafloor where appropriate; see Annex D for further guidance on this topic.

NOTE 2 The achievable penetration length or penetration depth depends on the soil conditions, the allowable penetration force, the allowable forces on the push rods and push rod connectors, the use of a friction reducer and/or push rod casing and the measuring range of the cone penetrometer.

8.3.3.6 Equipment checks and calibration

For each cone penetrometer, a calibration shall be made of the area ratios of the cone (a) and of the friction sleeve (b) in accordance with 7.2 of ISO 22476-1:2012. These values are unique to each cone penetrometer and should be documented in the field report, as they are very important for data reduction. The (a) and (b) calibrations should be checked at least once a year, and preferably at the beginning of each offshore campaign.

It is recommended to use more than one calibrated cone on each project, preferably two in the first deep borehole.

8.3.4 Presentation of test results and reporting

The reporting of results from CPT/CPTUs shall comply with 8.2. The net area ratio, a , of the cone penetrometer and the end areas of the friction sleeve shall also be given.

The following measured parameters shall be presented as functions of depth:

- cone resistance, q_c ;
- pore pressure, u_2 ;
- sleeve friction, f_s ;
- inclination, i .

NOTE 1 Inclination is defined as the angular deviation of the cone penetrometer from the vertical.

Derived parameters to be presented as functions of depth should include, but not necessarily be limited to:

c) corrected cone resistance, $q_t = q_c + (1 - a) u_2$

where

a is the net area ratio = A_n/A_p ;

A_p is the projected area of the penetrometer in a plane normal to the shaft;

A_n is the area of the load cell or shaft on which pore pressure can act.

NOTE 2 The measured sleeve friction is influenced by surrounding water pressure. Since it is not standard practice to measure the pore pressure u_3 above the friction sleeve, the uncorrected sleeve friction f_s is commonly used. A possible correction method for the friction sleeve (to get f_t) is given in Annex D.

d) friction ratio, $R_f = f_s/q_c$

e) pore pressure ratio, $B_q = (u_2 - u_o) / (q_t - \sigma_{vo})$

where

σ_{vo} is the estimated total vertical stress relative to seafloor;

u_o is the estimated or measured *in situ* equilibrium pore pressure relative to seafloor.

The basis for computation of the σ_{vo} and u_o profiles shall be given.

NOTE 3 Additional parameters that can be plotted include: $q_{net} = q_t - \sigma_{vo}$, $Q_t = q_{net}/\sigma_{vo}$ and $F_r = f_s/q_{net}$

In general, the test results shall be plotted with a depth scale of 1 scale unit = 1 m, but for shallower profiles, e.g. pipeline investigations, an enlarged scale can be used provided this is maintained across the acquired data set.

For the measured and derived CPTU parameters, the following scales are recommended for use where applicable:

- cone resistance q_c, q_t 1 scale unit = 2 MPa or 0,5 MPa;
- sleeve friction, f_s : 1 scale unit = 0,05 MPa;
- pore pressure, u : 1 scale unit = 0,2 MPa or 0,02 MPa;
- friction ratio, R_f : 1 scale unit = 2 %;
- pore pressure ratio, B_q : 1 scale unit = 0,5 units.

Different scales for cone resistance, sleeve friction and pore pressure can be used if the values in the profile fall outside a reasonable range.

NOTE 4 It can also be very beneficial to present two sets of plots in one profile. This is especially so if there are layers of dense sand and clay in the same profile. If the results in clay are to be used for interpretation in terms of soil parameters,

it is particularly important to use an enlarged scale in the presentation of test results. It is also important that consistent scale(s) are used in the investigation report.

The measured and derived CPTU data shall be reported in digital (i.e. numerical) form in addition to being presented in the field report.

It is recommended that reference readings are recorded and documented in accordance with the procedure outlined in Annex D.

8.4 Pore pressure dissipation test (PPDT)

8.4.1 General

This subclause covers pore pressure dissipation tests (PPDT) performed with a piezocone penetrometer.

The project specifications shall include:

- a) type of test according to Table 3;
- b) test depth;
- c) test duration in terms of termination criteria.

The accuracy of measurement is that for the corresponding application class of the piezocone penetration test (see 8.3), unless agreed otherwise.

NOTE 1 Increasing test duration can improve the accuracy of interpretation of test results, particularly for test types PPDT1 and PPDT2.

NOTE 2 Termination criteria can include: an agreed maximum test duration of for example 5 hours; a certain percentage of the dissipation of the pore pressure immediately before the penetration interruption, relative to the estimated in-situ equilibrium pore pressure; that the change in pore pressure over a given time interval is below a certain value, for example 3 kPa per 10 min. Termination criteria may also consider gas in the soil preventing reliable pore pressure measurement, soil heterogeneity or absence of significant penetration pore pressure for interpretation of the test results.

Table 3 —Test types

Test type	Description	Test duration
PPDT1	Pore pressure dissipation for estimation of <i>in situ</i> equilibrium pore pressure	Typically 90 % dissipation of the pore pressure immediately before the penetration interruption, relative to the estimated <i>in situ</i> equilibrium pore pressure
PPDT2	Pore pressure dissipation for estimation of coefficient of (radial) consolidation in fine grained, low permeability soil	Typically 50 % dissipation of the pore pressure immediately before the penetration interruption, relative to the estimated <i>in situ</i> equilibrium pore pressure
PPDT3	Pore pressure dissipation for qualitative indication of soil permeability	Typically <600 s
PPDT4	Pore pressure dissipation to distinguish between drained, undrained and partially drained soil behaviour during cone penetration	Typically <60 s

8.4.2 Equipment

Equipment for a pore pressure dissipation test should consist of a piezocone penetrometer and ancillary equipment in accordance with 8.3.

Other probe types may be acceptable, for example a piezoprobe or a ball penetrometer equipped with a pressure sensor.

8.4.3 Test procedure

The test procedure is as follows:

- a) interruption of the push-in penetration of the penetrometer at the required test depth for pore pressure dissipation;
- b) recording of pore pressure, cone resistance and sleeve friction versus time until the agreed termination criterion;
- c) resumption of penetration, if applicable.

Data recording should be at 1 Hz or higher during the initial 60 s, and may be halved every log (time) cycle thereafter.

NOTE Influence of the tidal variation should be considered, especially in shallow water.

8.4.4 Presentation of results

The following information shall be presented:

- results from the CPT/CPTU data acquisition according to 8.3, where applicable;
- test type according to Table 3;
- test depth for the filter position of the piezocone penetrometer;
- method of fixing the position of the piezocone penetrometer during the dissipation phase;
- pore pressure, u_2 , and cone resistance, q_c , versus time and log time, including the values of pore pressure (u_{2i}) and cone resistance (q_{ci}) immediately before the penetration interruption.

Normalized excess pore pressure, U , may additionally be presented versus time and log time, where $U = (u_2 - u_0)/(u_{2i} - u_0)$.

NOTE Guidance on interpretation of pore pressure dissipation test results is given by Lunne *et al.* (1997). See also Orange *et al.* (2005)

8.5 Ball and T-bar penetration tests

8.5.1 General

The ball and T-bar are particularly suitable for characterizing very soft to soft clays and clayey silts with an undrained shear strength < 50 kPa. There are many similarities between ball and T-bar penetrometers. In practice, the ball can be used in both non-drilling and drilling modes. The T-bar is best suited for non-drilling mode.

8.5.2 Equipment

8.5.2.1 Ball penetrometer

The ball, see example in Figure 2, is a steel sphere attached to a push rod, which is pushed into the soil using CPT/CPTU type deployment systems. The standard ball shall have a projected area of $2,500 \text{ mm}^2$ (corresponding to a diameter of 56,4 mm) to $10\,000 \text{ mm}^2$ (corresponding to a diameter of 113 mm). The diameter of the push rod shall be such that the minimum ratio of the projected area of the ball to the area of the push rod is 7:1, and with no increase in diameter of the connecting push rod for a distance of 10 times the diameter of the rod.

The ball should be manufactured to a surface roughness, R_a , of $0,4 \mu\text{m} \pm 0,25 \mu\text{m}$.

The load sensor for ball resistance shall be positioned within the ball or immediately above the ball. The load sensor shall be compensated for possible eccentricity of axial forces. The ball penetrometer shall be fitted with an inclination sensor; but this is not required where the target penetration is less than 5 m. The inclination sensor shall normally have a measuring range of at least $\pm 15^\circ$ relative to the vertical axis. Requirements for the thrust machine, the push rods and the measuring system for penetration are as given in 8.3.

8.5.2.2 T-bar penetrometer

The T-bar is a cylinder, or short bar, attached to a push rod, which is pushed into the soil in non-drilling mode using CPT/CPTU-type deployment systems, see Figure 2. The standard T-bar used in offshore practice has a nominal diameter of 40 mm and a length of 250 mm (projected area of 10 000 mm², see example in Figure 2), although smaller devices may be used. The T-bar should satisfy similar requirements as above for the ball, in terms of the 7:1 ratio of the projected area of the T-bar to the area of the connecting push rod and the minimum length of any push rod of reduced diameter. In addition, it should have a minimum length to diameter ratio of 5, and a diameter that is no smaller than the connecting push rod.

The T-bar should be manufactured to a surface roughness, R_a , of $0,4 \mu\text{m} \pm 0,25 \mu\text{m}$.

The ball and T-bar shown in Figure 2 are of a size suitable for mounting directly on standard CPT rods. The load cell(s) within the cone penetrometers may then be used to measure the soil resistance mobilized on the ball (T-bar) penetrometer.

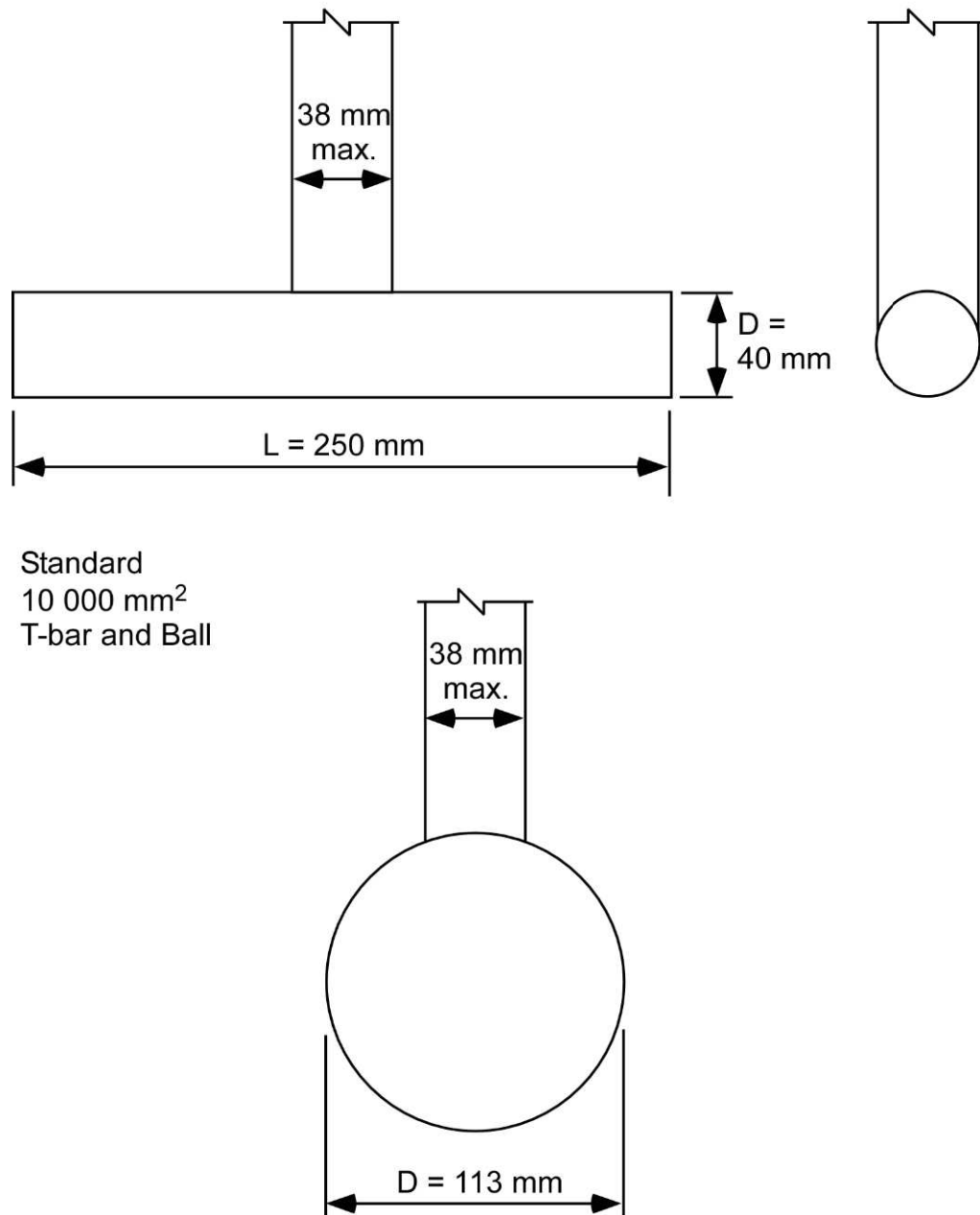


Figure 2 — Dimensions of 10 000 mm² ball and T-bar

8.5.3 Test procedures

8.5.3.1 General

The following procedures shall be followed:

- the ball (T-bar) resistance shall be measured during penetration;
- the rate of penetration shall be nominally (20 ± 5) mm/s;
- for tests with penetration deeper than 5 m, the inclination of the rod attached to the ball (T-bar) shall be measured;
- readings from all sensors shall be recorded at least once per second (i.e. for every 20 mm of penetration);