



Exploration & Production

GENERAL SPECIFICATION

SURVEYS

GS GEO 701

**Geotechnical data and foundation design
considerations for subsea production systems
and pipelines**

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1. Scope

The purpose of this General Specification is to describe the requirements for:

- Acquisition and interpretation of specific site and soil data
- Geotechnical and foundation design considerations, applicable to both subsea production systems and pipelines.

This specification covers the following development structures:

- Subsea Production Systems (SPS), including both (a) individual well concept connected to a subsea manifold centre, or (b) multi-wells concept with production manifold
- Subsea water or gas injection structures
- Pre-drilling templates
- Pipelines and flow-lines, either rigid or flexible
- Associated foundation and support structures, e.g. spool pieces and mid-water arch anchor structures, etc.

This specification covers both permanently installed systems, as well as temporary equipment or structures possibly required for offshore site installation works.

The document is valid for all phases of an offshore field development, including site and soil investigation, design studies, construction, field installation and operation.

Deviations from any of the requirements defined herein shall be treated as non-conformances in accordance with COMPANY procedures.

2. Reference documents

The reference documents listed below form an integral part of this General Specification. Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published at the EFFECTIVE DATE of the CONTRACT.

2.1 General

This specification is complementary to the following documents:

- **GS SPS 001** and **GS SPS 002** for subsea production systems
- **GS PLR 101** and **GS PLR 102** for pipelines
- **GS GEO 101** and **GS GEO 201** for site investigation equipment and procedures.

Therefore, this specification shall be read in conjunction with said documents and the other COMPANY specifications and standards identified herein.

The reference lists given in sections 2.2 and 2.3 only include general standards and professional documents where specific references have been made in this document. Unless otherwise stated in COMPANY Project requirements, the latest revision shall apply for all documents.

Standards

Reference	Title
ISO/DIS 13623	Petroleum and Natural Gas Industries – Pipeline Transportation Systems
ISO/DIS 13628	Petroleum and Natural Gas Industries – Design and Operation of Subsea Production Systems – Part 1: General Requirements and Recommendations – Part 2: Flexible Pipe Systems for Subsea and Marine Applications
ISO/DIS 19900-1	Petroleum and Natural Gas Industries – Offshore Structures – Part 1: General Requirements for Fixed Steel Structures
ISO/DIS 19901-4	Petroleum and Natural Gas Industries – Offshore Structures – Part 4: Geotechnical and Foundation Design Considerations

Professional Documents

Reference	Title
API RP 2A	Recommended Practice for Planning, Designing, and Constructing Fixed Structures
API RP 2N	Recommended Practice for Planning, Designing, and Constructing Pipelines in Arctic Conditions
API RP 17A	Recommended Practice for Design and Operation of Subsea Production Systems
BS 8010	Pipelines Subsea - Part 3: Design, Construction and Installation
DNV	Rules for Submarine Pipeline Systems (1981, 1996)

Regulations

Reference	Title
Not applicable	

Codes

Reference	Title
Not applicable	

Other documents

Reference	Title
Not applicable	

Total General Specifications

Reference	Title
GS GEO 101	Offshore Geotechnical Soil Survey
GS GEO 201	Offshore Geophysical Survey
GS GEO 202	Geophysical Survey for Offshore Pipeline Installation
GS GEO 301	Offshore Surface Positioning Works
GS GEO 302	Subsea Positioning Works
GS GEO 702	Requirements for design and installation of skirted foundations and suction anchors
GS PLR 101	Design of Submarine Pipelines as per DNV 1981
GS PLR 102	Design of Submarine Pipelines as per API RP 1111 and ANSI B 31.4/31.8
GS STR 100	Fixed Offshore Steel Platforms – General
GS STR 101	Design of Offshore Jacket and Subsea Structures
GS STR 431	Installation of Piles for Offshore Steel Structures – Driven piles
GS SPS 001	Design Philosophy and Requirements for subsea stationsSystems
GS SPS 002	Design of subsea structures

3. Introduction

3.1 Abbreviations

The following abbreviations are used:

- API American Petroleum Institute
- ASTM American Society for Testing and Materials
- BS British Standard
- CPTU Cone Penetration Test with pore pressure measurement
- DNV Det Norske Veritas
- ISO/DIS International Standard Organisation / Draft International Standard
- ROV Remotely Operated Vehicle
- SPS Subsea Production System

4. Site investigation requirements

4.1 General requirements

The general site investigation equipment and procedures shall be in agreement with the COMPANY specifications:

- **GS GEO 201** for geophysical site survey
- **GS GEO 101** for soil sampling and laboratory testing, in-situ testing, as well as data interpretation and foundation design.

The following site specific data shall be determined:

- Seabed features and seabed topography
- Type of sea bottom and subsurface soils
- Thickness and geotechnical properties of sea bottom and subsurface layers.

The data acquisition methods shall focus on the determination of the nature and characteristics of the sea bottom soil and first 5 to 20 metres of sediments, depending on the type of foundation considered.

The scope of work and extent of soil investigation shall depend on the soil type and strength, as well as on the type of foundation and support structure considered. As a guideline, the following basic soil parameters shall be determined as a minimum:

- In clayey type of soils: grain size, Atterberg plastic/liquid limits, in-situ water content, total unit weight, intact and remoulded undrained shear strength
- In sandy type of soils: grain size, min/max density, in-situ total unit weight and relative density, friction angle.

Depending on the Project requirements, additional geotechnical parameters may be required, e.g. permeability, sensitivity and strain rate effects, influence of cyclic loading, consolidation characteristics, etc.

Specific equipment and procedures may be required for:

- Uneven sea bottom topography with outcrops and depressions
- High slope gradients with potential slope instability
- Very soft sediments generally encountered in swamp areas or deep water sites
- Specific areas, such as carbonate soils with highly variable cementation degree, seismically active areas, or arctic conditions with possible iceberg scars and boulders.

Integration of the geophysical survey and geotechnical soil investigation results shall be performed by suitably qualified personnel, with the objective to obtain the full-value of these two components and to avoid misleading interpolation between individual sample and/or in-situ test locations.

Specific site investigation techniques and procedures may apply in environmentally sensitive areas, in particular for the shore approach and landfall areas for pipelines.

4.2 Geophysical survey

A geophysical survey shall be performed at the site to collect information on:

- Seabed topography, by echo-sounding or swath bathymetry
- Sea bottom features and obstructions, by methods such as side scan sonar
- Sub-bottom profiling of uppermost 10-50m, or so, of seabed, usually by means of reflection seismics.

Detailed requirements for data acquisition and processing are given in COMPANY document **GS GEO 201**.

Precise positioning of towed equipment is required because of the need to accurately map conditions across the relatively small footprint area of most subsea structures. Detailed requirements for positioning equipment and procedures are given in COMPANY documents **GS GEO 301** and **GS GEO 302**.

With the objective to focus on shallow strata definition, complementary data should be considered, including:

- Towed resistivity and refraction seismic methods
- Re-processing of digital seismic data to enhance resolution
- Use of high resolution 3D seismic data, in particular for deep water sites.

Unless site geotechnical data is already available, the performance of a geophysical survey alone, or in addition to a desk study, is not sufficient for detailed engineering purposes. Even if a geotechnical investigation is to be performed as a separate exercise, some soil samples shall be collected as part of the geophysical survey in order to aid the immediate interpretation of seabed and sub-bottom profiling data.

4.3 Soil sampling and laboratory testing

Detailed requirements for equipment and procedures for soil sampling and laboratory testing are given in COMPANY document **GS GEO 101**.

The type of soil sampler or corer, shall be adapted to the soil characteristics and strength, as well as to the maximum depth of investigation required.

- Seabed sampling equipment:
 - Grab sampler and box corer, for taking seabed soil samples
 - Vibro-corer
 - Gravity sampler, with or without internal liner and stationary piston
 - Rotary rock corer.
- Borehole sampling equipment, operated through the drill-string of a dedicated vessel:
 - Hydraulic Push sampler
 - Hammer sampler
 - Rotary rock corer.
- Laboratory soil testing:

The laboratory testing equipment and procedures shall be in agreement with recognised international standards (e.g. ISO, ASTM, BSI, or equivalent). If no standard exist, a detailed procedure shall be submitted to COMPANY for approval.

Offshore and onshore laboratory testing shall be supervised by experienced geotechnical engineers. Onshore laboratory soil testing shall not start before the testing programme has been formally approved by COMPANY.

4.4 In-situ testing

Detailed requirements for in-situ testing equipment and procedures are given in COMPANY document **GS GEO 101**.

The type of in-situ testing equipment shall be adapted to the soil characteristics and strength, as well as to the type of structure and foundation considered. Use of correlations to determine soil characteristics and strength from in-situ testing results shall be based on site specific data.

The in-situ testing equipment and procedures shall be in agreement with recognised international standards (e.g. ISO, ASTM, BSI, or equivalent). If no standard exist, a detailed procedure shall be submitted to COMPANY for approval.

- Seabed in-situ testing equipment:
 - Field vane test
 - CPTU cone penetration test
 - Plate load test
 - Specialist in-situ probes, including temperature/thermal conductivity, electrical conductivity, seismic cone, nuclear density cone, etc.
- Borehole in-situ testing equipment:

Apart from the plate load test, all in-situ testing equipment can also be applied through the drill-string of a dedicated geotechnical drilling vessel.

The in-situ testing programme shall be carried-out in conjunction with knowledge of the engineering objectives of the soil investigation and shall be supervised by experienced geotechnical engineers.

5. Foundation design requirements for subsea production systems

5.1 General requirements

Different types of foundation and support structures are covered by this specification, including:

- Small un-piled structure, supported by mudmats
- Large un-piled structure, supported by mudmats equipped with skirts, or not
- Piled structures, using driven or vibro-driven piles
- Subsea structures supported by caisson foundations installed by submerged weight only, or by suction under-pressure.

The selection of the type of foundation and support structure shall be recommended by CONTRACTOR and approved by COMPANY, on the basis of an evaluation of the site specific geotechnical conditions and Project requirements, including loads and installation means. The design of the foundation structure shall be done according to **GS SPS 001** and **GS SPS 002**.

The following requirements apply for all types of foundation and support structures:

- The foundation design parameters shall be given in a site specific report, including a summary of the results of the soil investigation.
- The foundation structure design shall allow for possible natural variability in the soil characteristics and for possible uncertainty on the seabed slope.

- The foundation structure shall be designed in order to reduce the consequences of possible scouring (if any).
- For each type of subsea system considered, the foundation structure shall be compatible with installation, drilling, ROV intervention, and retrieval operations (if required).

5.2 Specific foundation design requirements

Depending on the type of foundation and support structure, specific foundation design requirements apply, in particular:

- Gravity-based structures supported by mudmats, with or without skirts:
 - The seabed shall support the structure without incurring excessive immediate deformations or long term settlement.
 - Skirt penetration shall be feasible by submerged weight only.
 - Uplift and sliding resistance shall be sufficient to overcome vertical and horizontal loading from externally-applied forces, such as trawl board impact and snagging, in accordance with the Project requirements.
 - Sea bottom movements, due to earthquakes and/or slope instability, shall not cause loss of foundation support with soil liquefaction or excessive displacements.
- Pre-drilling templates:
 - Drilling wash-out shall not undermine the structure, and possible additional loads from drill cuttings shall be taken into account for the design of the foundation structure.
 - In the event of docking a jacket structure, the induced lateral loading shall be taken into account, in agreement with the Project requirements.
- Caisson foundations installed by suction under-pressure:
 - Feasibility of skirt penetration by suction under-pressure shall be addressed in detail, in particular in relatively hard soil conditions, including very dense sands, hard clays with gravel/cobbles or boulders.
- Piled structures:
 - Specific problems related to carbonate soils, such as possible hard cap-rock, cemented layers, and low bearing capacity of piles driven in calcareous sands, shall be addressed in detail.

5.3 Installation requirements

The possible types of installation means covered by this specification include:

- Crane barge, with large lifting capacity
- Relatively small support vessel, with limited lifting capacity from an A-frame and winch
- Drilling rig (i.e. jack-up, semi-submersible, or vessel type), with lifting capacity under the derrick and through a moon-pool.

Depending on the type of foundation and support structure, specific installation requirements shall be addressed, in particular:

- Gravity-based structures supported by mudmats, with or without skirts:
 - Bearing capacity failure due to lack of touch-down control, in particular at deep water sites with soft soils.
 - Differential settlements shall not prevent correct flow-line alignment and connection by ROV. In agreement with the Project requirements, verticality and orientation tolerances of the subsea system shall be addressed, and the need for including a levelling system in the foundation structure shall be considered accordingly.
- Caisson foundations installed by suction under-pressure:
 - Sufficient openings or roof hatches shall be available to avoid uplift during lifting through the splash zone and lowering through the water.
 - The structure landing speed shall be adapted to the openings and/or roof hatches dimensions for avoiding the water cushion effect at time of touch-down on the seabed. Depending on the structure dimensions and wave conditions, a heave compensating system shall be included in the handling/lifting system in order to limit vertical heaving of the caisson at time of touch-down.
 - The steel (or concrete) caisson structure shall be designed to withstand the required installation under-pressure and retrieval over-pressure (if needed).
- Piled structures:
 - Drivability of piles shall be in accordance with COMPANY document **GS STR 431**.

6. Geotechnical design requirements for soil-pipeline interaction

6.1 General requirements

This specification covers the following types of pipelines and flow-lines:

- Rigid pipelines, laid on the seabed or trenched
- Flexible pipelines
- Risers, in particular at their touch-down and connection point with the flow-lines.

The design of the pipelines shall be done according to **GS PLR 101** and **GS PLR 102**.

The following geotechnical design requirements shall apply for all soil-pipeline interaction concerns:

- The soil types and geotechnical design parameters along the intended pipeline route shall be given in a site specific report, including a summary of the results of the soil investigation.
- Possible variation and uncertainties in the soil characteristics along the pipeline route shall be clearly identified on alignment sheets, and duly taken into account.
- The type of sea bottom soils, and the seabed contour lines and slope gradient shall be addressed, in particular for reducing the number and consequences of possible free-spanning, and with respect to pipeline trenching feasibility (if required).

6.2 Specific design requirements

Depending on the type of soils and concerns along the pipeline route, specific foundation design requirements shall apply, in particular:

- Pipelines laid on seabed or trenched:
 - For pipelines laying on the seabed, longitudinal and lateral soil-pipeline friction coefficients shall be determined.
 - The influence of the seabed soil type and fines content on the choice and performance of the trenching equipment shall be taken into account.
 - Protection against thermal expansion and upheaval buckling shall be based on the characteristics and strength of the remoulded soil used for back-filling (if any).
 - Uplift and sliding resistance shall be sufficient to overcome vertical and horizontal loading from externally-applied forces, such as trawl board impact and snagging. In accordance with the Project requirements, stability of the pipeline can be enhanced by such means as rock dumping, protective structures, or anchoring.
 - Sea bottom movements, due to earthquakes and/or slope instability, shall not cause loss of support with soil liquefaction or excessive displacements.
 - In very soft soils, pipeline settlement shall be addressed, so that connection to the spool pieces and/or well jumpers is feasible in accordance with the Project requirements.
- Riser touch-down point:
 - In soft clayey soils, as well as in sandy soils likely to be influenced by cyclic loading, settlements shall be addressed, so that connection of the riser to the flow-line is feasible in accordance with the Project requirements.
- Shore approach and landfall:
 - Coastal erosion and beach movements shall not undermine the pipeline stability.
 - In areas with carbonate soils, specific problems related to the possible presence of hard cap-rock and cemented layers shall be addressed.
 - In environmentally sensitive areas, an assessment of the pipeline impact shall be performed in agreement with the Project requirements.

6.3 Installation requirements

The survey performed during pipeline installation shall be done according to **GS GEO 202**.

Depending on the type of installation means and equipment, specific requirements shall be addressed, in particular:

- Pipeline initiation:
 - Anchoring reaction for pipeline initiation can be provided from several anchor types, e.g. dead-weight anchor, conventional embedment anchor, driven pile, etc. The type of pipeline initiation anchor shall be adapted to the soil characteristics and in agreement with the Project requirements.
 - Drivability of piles shall be in accordance with COMPANY document **GS STR 431** "Installation of piles for offshore steel structures - Driving".



- Vibro-driven piles may also be proposed by CONTRACTOR, subject to approval from COMPANY. In such case, a specific method for vibro-drivability prediction shall be provided, supported by previous experience in similar type of soils.
- Pipeline free-spanning:
 - Spans in pipelines shall be controlled, in particular at sites with uneven site topography, outcrops and depressions (such as iceberg scars/plough marks).
 - In accordance with the Project requirements, means for reducing free-spans in pipelines shall be considered, such as sand-bagging, high pressure jetting, or other. The efficiency of such free-spanning reduction shall be evaluated with due consideration to the in-situ soil characteristics.