



Exploration & Production

GENERAL SPECIFICATION

STRUCTURAL

GS STR 431

Installation of piles for offshore steel structures Driven piles

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1. Scope

The document defines the minimum requirements to the studies and works associated with installation of piles and conductor pipes.

The document also defines references for obtaining satisfactory and consistent quality in the reports to be provided by the CONTRACTOR in charge of pile or conductor pipe driving works.

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.

Recognition of reference documents

Only the main reference documents are mentioned. The CONTRACTOR shall be responsible for complying with all secondary reference documents dealing with the subject of this document.

Unless otherwise indicated in the detailed contractual conditions, all the reference documents to be used as well as their supplements, shall be the latest editions.

Standards

Reference	Title
ISO	INTERNATIONAL STANDARD ORGANISATION
ISO 1000	Specification for SI Units and Recommendations for the Use of their Multiples and of Certain other Units
ISO 9001:2000	Quality Management Systems : Requirements
ISO/DIS 19900	International Standard for Offshore Structures – Part 1: General Requirements
DNV	DET NORSKE VERITAS
	Rules for Planning and Execution of Marine Operations
API	AMERICAN PETROLEUM INSTITUTE
API RP 2A - WSD	Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms. Working Stress Design
API RP 2T	Recommended Practice for Planning, Designing and Constructing Tension Leg Platforms

Professional Documents

Reference	Title
Not applicable	



Regulations

Reference	Title
Not applicable	

Codes

Reference	Title
Not applicable	

Other documents

Reference	Title
Not applicable	

Total General Specifications

Reference	Title
GS STR 301	Fabrication of offshore steel structures
GS STR 432	Installation of piles for offshore steel structures. Drilled and grouted piles

3. General

Proper installation of piling, including conductor piles, is vital to the life and permanence of the platform and requires each pile to be driven or drilled and grouted to the design target penetration, without damage, and for all field-made structural connections to be compatible with the design requirements.

Unless otherwise indicated, piles shall be placed as stipulated by [API RP 2A - WSD](#).

No piles shall be stabbed until COMPANY has reviewed and approved the location and level of the jacket on the seabed.

The CONTRACTOR shall take all measures necessary to avoid dropping any equipment into the sea.

The CONTRACTOR shall make good any faults occurring on the piles during installation (driving, skimming, etc.).

4. Pile preparation

Pile sections shall be identified with the chronological driving sequence.

The CONTRACTOR shall mark the piles every 0.25 m to allow the hold length to be read during pile driving (zero reference level: Pile tip at seabed).

The CONTRACTOR shall ensure that the piles pass freely through the legs. Jacket member closures shall be either removed or destroyed as the pile passes.

If piles are locally reinforced, the CONTRACTOR shall attach particular importance to the depth tolerances detailed on drawings.

The closure device on the lower end of the jacket legs and pile sleeves, when required, shall be designed to avoid interference with the installation of the piles.

5. Alignment and handling

Refer to the stipulations of paragraphs 12.5.2 to 12.5.4 of [API RP 2A - WSD](#).

The CONTRACTOR shall be responsible for supplying and using lifting lugs, stabbing guides and any other accessories required. Hydraulic gripper/lifting tools shall be of good condition and tested at 125 % of their nominal capacity.

When the lifting lugs or stabbing guides are removed, the CONTRACTOR shall grind flush the outer surface of the piles and shall perform 100 % MPI and 100 % U.T inspection according to Total General Specification [GS STR 301](#).

6. Add-on pile sections

- a) Add-on pile sections shall be provided with guides to facilitate stabbing and alignment.
- b) The guides shall be capable of safely supporting the full weight of the add-on pile section prior to welding.
- c) Add-on pile section shall be welded to the main pile sections already installed. Mechanical connectors may be used, subject to COMPANY approval.
- d) Welding shall be performed as stipulated in § 8.1.
- e) Add-on pile sections shall be designed (length and wall thickness) according to the installation procedure: driving, drilling, etc.
- f) The maximum stick-up length shall be defined with $K = 2.1$ and with respect to the highest horizontal guide level and not the top of the jacket leg or sleeve.

7. Obtaining required pile penetration

7.1 General

The adequacy of the platform foundation depends upon each pile being installed to or near its design penetration.

To reach the design pile penetration the following techniques can be used:

- Driving
- Drilling
- Drilling to assist driving
- Drilling for drilled and grouted insert piles.

For drilled and grouted piles, reference shall be made to the Total General Specification [GS STR 432](#).

7.2 Driven piles

7.2.1 Driveability analysis

CONTRACTOR shall perform a driveability study in order to assess the driveability of the piles with the proposed hammers, with due consideration to stress levels induced in the piles and set-up effects.

The driveability analysis shall include the following:

- The characteristics of the piles and hammers to be used
- The review of the soil conditions encountered
- The calculation of the soil resistance to driving (SRD) for each type of pile, with the method used and the references
- The results of the driveability analyses, including:
 - Driving simulation curves (blowcount versus SRD for each hammer, hammer global efficiency, pile and soil conditions)
 - The corresponding predicted blowcount curves versus penetration
 - The maximum stick-up length including the cut-off length.

CONTRACTOR shall provide the procedure used to calculate the hammer driving simulation curves. These curves have to be determined for each selected hammer for two different global efficiencies:

- Diesel hammer: 25 to 35 %
- Steam hammer: 50 to 65 %
- Hydraulic hammer: 75 to 90 %

The global efficiency is defined as the ratio of the net energy delivered to the pile (entru energy) to the maximum rated energy of the hammer (given by MANUFACTURER).

CONTRACTOR shall submit to COMPANY the driveability study for approval.

7.2.2 Driven pile refusal criteria

The fact that a pile has met refusal does not assure that it is capable of supporting the design load. Final blow count can not be considered as assurance of the adequacy of piling.

The pile driving refusal criteria is contingent upon the hammer being operated at the pressure and rate recommended by the MANUFACTURER.

7.2.2.1 Definitions

7.2.2.1.1 Layers of sands and clays

Absolute pile driving refusal: the blow count from which the pile is considered to be stopped.

The absolute pile driving refusal, with a properly operating hammer, is defined as the point where pile resistance under continuous driving conditions exceeds:

- 250 blows per 0.25 m or 70 blows per 50 mm
- or 125 blows for 0.25 m counted over six consecutive 250 mm intervals.

If pile driving operations are interrupted for one hour or more, the criteria specified above shall only be considered as applicable, when the pile has been driven at least 30 cm after recommencing driving operations.

The number of blows indicated above can be decreased or increased depending on the results of the driving simulation and the stresses induced into the pile steel by the hammer.

7.2.2.1.2 Cemented-Rock layers

The criteria for interrupting driving shall be based on the level of dynamic stresses at the base of the pile. The following criteria shall be considered:

- Without pile instrumentation during driving: driving blow count rate greater than 150 blows per 0.25 m counted over two consecutive 250 mm intervals
- With pile instrumentation during driving: ratio of reflected stress to incident stress greater than 60 % during 25 consecutive hammer blows.

7.2.3 Hammers

7.2.3.1 Nominal energy of the hammers

The CONTRACTOR shall take all measures necessary to operate the hammer at the nominal energy as defined by MANUFACTURER. When the maximum driving energy of the hammer is necessary to reach the target penetration, the following is requested:

- Diesel and steam hammers: the ram drop height shall never be less than the nominal drop height, less 100 mm.
- Hydraulic hammers: the kinetic energy of the ram before impact shall never be less than 95 % of the nominal kinetic energy.

Hammers shall be kept in good condition: they shall be regularly controlled and lubricated. Steam feed pipes or hydraulic pipes and their accessories shall be inspected before the hammer is installed. Any defective lengths or seals shall be replaced.

Driving cushions (Diesel or steam hammer) shall be kept in good condition and shall be replaced following a schedule which allows a complete driving sequence to be carried out without interruption for cushion replacement.

Prior to start the driving of the last add-on pile section, the cushion shall be replaced.

The driving of each pile shall be carried out to completion with as little interruption as possible to minimize the possible increased driving resistance due to "set-up" effect.

Workable back-up hammers with leads and major items shall always be available.

7.2.4 Piles and add-on sections

A driving cap shall be used between the pile head and the hammer ram. An extension of at least 1.5 times the pile diameter shall be provided on the head of each add-on, except in case of pile driving monitoring (§ 7.2.6). This extension shall be carefully cut-off after driving.

All driving surfaces shall be cut off square before beginning welding.

Maximum stick-up heights shall be determined by the CONTRACTOR for his proposed hammers and one to be set so that the utilisation factor for any item is no greater than 1.0 according to the AISC code (latest edition) with $K = 2.1$ (see § 6.f) for basic allowable stresses and material properties given in relevant specifications.

7.2.5 Dynamic stress level considerations

The maximum dynamic stress induced by the hammer impact into the pile steel shall not exceed at the top of pile:

- 67 % of the steel yield stress for driving with Diesel or steam hammers,
- 80 % of the steel yield stress for driving with hydraulic hammers.

The assessment of the maximum stress induced by the hammer impact into the pile steel at the top of pile shall be performed prior the installation and using driving simulation programmes based either on the wave equation theory or on the characteristics methods.

The following global efficiency, defined as the ratio of the net impact energy delivered to the pile (enthru energy) to the nominal rated energy of the hammer (given by the MANUFACTURER), shall be considered for the driving simulations:

- Diesel hammers: Glob. Eff. = 25 and 35 %
- Steam hammers: Glob. Eff. = 50 and 65 %
- Hydraulic hammers: Glob. Eff. = 75 and 90 %

In case of driving in hard soil layers, the stress amplification at the bottom part of the pile shall be assessed using the driving simulation programmes.

The maximum compressive stress into the pile steel at the bottom of pile shall not exceed:

- 67 % of the steel yield stress for driving with the risk to encounter cemented-rock layers,
- 80 % of the steel yield stress for driving in soils without hard layers.

7.2.6 Pile driving monitoring

Unless otherwise indicated in the Particular Specification, pile driving monitoring shall be performed at least for the two first piles or groups of piles and the two first conductor pipes.

The pile driving monitoring system shall be able to provide for each hammer blow:

- Hammer global efficiency
- Impact driving energy in the pile (enthru energy)
- Driving stresses, including impact stress at pile top and reflected stress at bottom of pile
- Estimated soil resistance to driving.

The CONTRACTOR shall provide an extension of each add-on permitting the monitoring of the totality of the length of the pile to be driven into the soil.

- Typical example results of monitored driving blows shall be stored on a digital medium for later detailed analysis. Drilling

The installation procedures of the piles shall take into account a possible re-driving test for all instrumented piles or conductor pipes.

The re-driving test shall be performed as follows:

- Interruption of the last add-on pile section driving at a level of 1 meter above the final penetration
- Re-driving of the pile to the final penetration after a delay of 24 hours, or as stipulated in the Particular Technical Specification.

For the re-driving test, the pile shall be marked every 0.10 meter over the last meter to be driven and the number of blows shall be counted and recorded each 10 cm.

7.2.7 Pile penetration

The CONTRACTOR shall take all measures necessary to drive the piles down to the design penetration.

A penetration of less than the design penetration may be acceptable depending on the type of soil encountered, hammer global efficiency and evolution of the soil resistance to driving. The COMPANY's representative in liaison with the geotechnical specialist only shall be mandated to modify the design parameters in this way.

However, under no circumstances the design penetration shall be modified if the hammer global efficiency is less than:

- 30% for Diesel hammers
- 60% for steam hammers
- 90% for hydraulic hammers.

If the required penetration cannot be obtained by driving only, drilling shall be used to assist penetration. For drilling operations, reference shall be made to the Total General Specification **GS STR 432**.

CONTRACTOR shall provide to COMPANY representative for approval the revised procedures and revised design pile penetration.

7.2.8 Recording of observations

The following information shall be recorded for each pile installed:

- a) The pile number, leg reference and date.
- b) The self penetration under the weight of pile and pile plus hammer.
- c) The serial number and type of hammer used to install the pile.
 - For hydraulic hammers:
 - Stroke of the ram
 - Oil pressure
 - Ram velocity at impact
 - Calculated impact driving energy
 - For Diesel and steam hammers:
 - Short fall of the ram during driving.
- d) The agreed reference level used to determine the pile penetration and blow count.
- e) The depth of penetration of the pile.
- f) The cumulated number of blows applied to the pile by each hammer.
- g) The number of blows for each 250 mm of pile penetration.
- h) The number of blows per minute during driving measured at intervals no greater than 10 minutes.

- i) The cushion condition before and after driving and any obvious changes during driving.
- j) The level of the upper part of the plug inside the pile.
- k) The beginning and end time of driving each pile section. This shall include an indication of the time spent on welding operations.
- l) The as-built drawing of the pile, with the positions of the welded joints, the penetration and cut lengths, identification of pile sections used, soil plug and water levels.
- m) The verticality of the jacket prior to the commencement and after the completion of driving of all of the piles.
- n) The time lost due to bad weather or equipment failures, including the pile position at the time.

7.2.9 Driving using followers

The CONTRACTOR shall install the temporary pile guide in appropriate position prior to stabbing any followers.

No follower shall be stabbed if prevailing positions are such that damage to the pile or follower or permanent jacket structure is likely to arise from this operation.

Followers shall be visually inspected by the CONTRACTOR for damage and conformity to the design length immediately prior to lifting off supply barge and stabbing. Any damage or discrepancy found shall be immediately reported to the COMPANY Representative.

The top and bottom of the followers, in particular the driving surfaces, shall be periodically inspected between or during pile driving operations and those showing signs of wear shall be discarded or repaired to the satisfaction of the COMPANY Representative.

The maximum allowable hammer blows for each follower for a given hammer size shall be determined by CONTRACTOR using driving simulation programmes and submitted to COMPANY for approval.

In no case shall this number of blows exceed 10,000.

When the total cumulated number of hammer blows on a follower has reached the maximum allowable (10,000), the follower shall be wire brushed and tested by magnetic particle inspection and ultrasonic means to determine whether any fault has developed in and adjacent to the driving surfaces. Tests shall be repeated at each recurrence of 10,000 blows. If a follower is shown to have a fault the follower shall be discarded or repaired to the satisfaction of the COMPANY Representative.

8. Welding

The CONTRACTOR shall take the following precautions for all welds to be made (between pile sections and between piles and the jacket):

- Scaffolding shall be installed and sufficiently spacious work platforms provided to allow the welders and inspectors to work under the best conditions, to be approved by COMPANY Representative
- Screens or shelters shall be installed to protect the welding zone from wind, fog or rain.



8.1 Welds between pile sections

The procedures, guiding systems and temporary connections between pile sections shall be submitted for COMPANY's approval.

After carefully aligning the pile section on the pile which has already been placed, the CONTRACTOR shall make the weld, in line which the procedure previously approved by the COMPANY (see § 6.f). The longitudinal seam welds of the upper and lower pile sections shall be at 180° at each pile splice. At top of the upper pile section, the pile longitudinal seam welds shall be at least at 90° of the deck leg longitudinal seam weld. The upper pile girth weld shall be at least at 1.2 metre away from the pile to deck leg (or transition pile) splice.

Preheating parameters (duration and equipment) shall be strictly respected.

The welds shall be 100 % inspected, either ultrasonically or by X-Ray after welding as stipulated in the specification **GS STR 301** § 9.2.

The CONTRACTOR shall supply the manpower and equipment required to carry out these inspections to the COMPANY's satisfaction.

8.2 Weld between piles and the jacket

After setting the jacket to within its final tolerances and installing shims or crown piece the CONTRACTOR shall make the weld as stipulated by the procedure.

The COMPANY's representative shall have the right to require a non-destructive inspection as stipulated in § 9.2 of the specification **GS STR 301**.