

# Design and Construction of Foundation for Offshore Structures

## Procedure

This Standard replaces and cancels its previous revision.

The CONTEC - Authoring Subcommittee provides guidance on the interpretation of this Standard when questions arise regarding its contents. The Department of PETROBRAS that uses this Standard is responsible for adopting and applying the sections, subsections and enumerates thereof.

**Technical Requirement:** A provision established as the most adequate and which shall be used strictly in accordance with this Standard. If a decision is taken not to follow the requirement ("non-conformity" to this Standard) it shall be based on well-founded economic and management reasons, and be approved and registered by the Department of PETROBRAS that uses this Standard. It is characterized by imperative nature.

**Recommended Practice:** A provision that may be adopted under the conditions of this Standard, but which admits (and draws attention to) the possibility of there being a more adequate alternative (not written in this Standard) to the particular application. The alternative adopted shall be approved and registered by the Department of PETROBRAS that uses this Standard. It is characterized by verbs of a nonmandatory nature. It is indicated by the expression: **[Recommended Practice]**.

Copies of the registered "non-conformities" to this Standard that may contribute to the improvement thereof shall be submitted to the CONTEC - Authoring Subcommittee.

Proposed revisions to this Standard shall be submitted to the CONTEC - Authoring Subcommittee, indicating the alphanumeric identification and revision of the Standard, the section, subsection and enumerate to be revised, the proposed text, and technical/economic justification for revision. The proposals are evaluated during the work for alteration of this Standard.

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## CONTEC

Comissão de Normalização  
Técnica

## SC - 04

Civil Construction

## Introduction

*PETROBRAS Technical Standards are prepared by Working Groups - WG (consisting specialized of Technical Collaborators from Company and its Subsidiaries), are commented by Company Units and its Subsidiaries, are approved by the Authoring Subcommittees - SCs (consisting of technicians from the same specialty, representing the various Company Units and its Subsidiaries), and ratified by the Executive Nucleus (consisting of representatives of the Company Units and its Subsidiaries). A PETROBRAS Technical Standard is subject to revision at any time by its Authoring Subcommittee and shall be reviewed every 5 years to be revalidated, revised or cancelled. PETROBRAS Technical Standards are prepared in accordance with PETROBRAS Technical Standard N-1. For complete information about PETROBRAS Technical Standards see PETROBRAS Technical Standards Catalog.*

## Prefacio

Esta Norma es la versión en Español (aprobada en 08/2014) de la PETROBRAS N-2001 REV. E 11/2013, incluyendo su enmienda de 08/2014. En caso de duda, debe ser usada la versión en portugués, que es la válida para todos los efectos.

## 1 Alcance

1.1 Esta Norma fija las condiciones exigibles para la presentación de proyecto, y para proyecto y ejecución de cimentaciones para estructuras marítimas fijas.

1.2 Esta Norma se aplica a proyectos iniciados a partir de la fecha de su edición.

1.3 Esta Norma contiene Requisitos Técnicos y Prácticas Recomendadas.

## 2 Referencias Normativas

Los documentos relacionados a continuación son indispensables a la aplicación de este documento. Para referencias datadas, se aplican solamente las ediciones citadas. Para referencias no datadas, se aplican las ediciones más recientes de los referidos documentos.

PETROBRAS [N-381](#) - Execução de Desenhos e Outros Documentos Técnicos em Geral;

PETROBRAS [N-1710](#) - Codificação de Documentos Técnicos de Engenharia;

PETROBRAS [N-1852](#) - Estruturas Oceânicas - Fabricação e Montagem de Unidades Fixas;

PETROBRAS [N-2000](#) - Investigações Geofísicas e Geotécnicas no Mar;

ABNT [NBR 5629](#) - Execução de Tirantes Ancorados no Terreno;

ABNT [NBR 6118](#) - Projeto e Execução de Obras de Concreto Armado;

ABNT [NBR 7480](#) - Aço Destinado a Armaduras para Estruturas de Concreto Armado – Especificação;

ABNT [NBR 8800](#) - Projeto de Estruturas de Aço e de Estruturas Mistas de Aço e Concreto de Edifícios;

ABNT [NBR 9782](#) - Ações em Estruturas Portuárias, Marítimas ou Fluviais;

ABNT [NBR 12131](#) - Estacas - Prova de Carga Estática - Método de Ensaio;

ABNT [NBR 13208](#) - Estacas - Ensaio de Carregamento Dinâmico;

ISO [10426-1:2009](#) (Identical) - Petroleum and Natural Gas Industries - Cements and Materials for Well Cementing - Part 1: Specification;

AISC 325 - Manual of Steel Construction;

API [RP 2A-WSD](#) - Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms - Working Stress Design;

DNV [OS C101](#) - Design of Offshore Steel Structures General (Lfrd Method);

DNV [CN 30.4](#) - Foundations.

**NOTE** For documents referred in this Standard and for which only the Portuguese version is available, the PETROBRAS department that uses this Standard should be consulted for any information required for the specific application.

### **3 Terms and Definitions**

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

## **4 Design**

### **4.1 Coding of Documents**

Technical documents shall be coded according to PETROBRAS-1710.

### **4.2 Presentation of Documents**

The design to be presented shall be comprised of the following documents:

- a) design assumptions;
- b) calculation sheets;
- c) drawings;
- d) recommendations for execution and control;
- e) contingency plan.

#### **4.2.1 Design Assumptions**

The following design assumptions shall be considered:

- a) basic design data;
- b) feasibility and resources;
- c) material specifications;
- d) design execution methodology.

##### **4.2.1.1 Basic Design Data**

Basic design data shall consist of documented information on the following subjects:

- a) geophysical and geotechnical investigations (see PETROBRAS N-2000);
- b) loading conditions;
- c) installation methodology;
- d) equipment for installation;
- e) verification of the structural elements of foundation during the stages of handling and driving system.

##### **4.2.1.2 Material Specifications**

Specifications shall be presented for:

- a) foundation materials;
- b) foundation-to-structure connection materials.

##### **4.2.1.3 Design Execution Methodology**

The design execution methodology shall be determined beforehand and the design description shall include:

- a) list of analyses;
- b) brief description of computer programs adopted in the analyses.

#### **4.2.2 Calculation Sheets**

4.2.2.1 The documents referring to calculation sheets shall be presented in accordance with PETROBRAS [N-381](#) and contain at least the following elements:

- a) loading assumptions and determination of critical loading conditions;
- b) evaluation of geotechnical design parameters;
- c) analysis of ultimate axial load capacity (compression and tension, separately and in groups);
- d) studies of behavior of foundation subjected to lateral loading;
- e) soil-to-structure interaction analysis;
- f) pile drivability studies and/or studies related to the construction of foundations;
- g) structural and geometric sizing of foundations;
- h) determination of foundation-to-structure connection elements;
- i) analysis of temporary instability during installation;
- j) standards and bibliographies adopted;
- k) symbols.

4.2.2.2 The figures, tables, abacuses and calculation methods used shall be furnished as an integral part of the documents comprising the calculation sheets.

#### **4.2.3 Drawings**

Documents shall be presented and drawn up in compliance with the provisions in PETROBRAS [N-381](#) and contain at least the following elements and information:

- a) key plan;
- b) location and positioning of elements of the foundation;
- c) geometry of foundation elements;
- d) details of weld and finishing, bevels, claws, thickness variations, holes;
- e) details of specific equipment for foundation construction, e.g. hammer, connections, valves, diaphragmes etc.;
- f) detailed execution sequence for installation;
- g) details of operational steps for construction of foundations;
- h) referenced procedures for testing accessories and group of accessories after assembling (when required);
- i) criteria for inspection of welded joints;
- j) list and specification of materials;
- k) limit values of quality control parameters in foundation construction or foundation-to-structure connection in line with the criteria recommended in 4.3.6.

4.2.3.1 The key plan shall contain the following information:

- a) geometric arrangement of foundation elements in relation to the bottom elevation of the structure;
- b) nomenclature adopted for piles.

4.2.3.2 The key plan shall be an integral part of all drawings relating to foundations.

4.2.3.3 Each drawing shall contain a table giving the specifications, quantities, dimensions, unit weights and totals weights for each type of material.

#### **4.2.4 Recommendations for Execution and Control**

Recommendations shall be presented in the design for:

- a) selection of equipment used for installation;
- b) installation procedures;
- c) quality control of parts comprising the foundation;
- d) foundation instrumentation and/or load testing.

#### **4.2.5 Contingency Plan**

The contingency plans shall be submitted for all phases of the installation.

### **4.3 Design Criteria**

#### **4.3.1 General**

4.3.1.1 The conception and development of the foundation design shall be integrated and compatible with the design of the structure.

4.3.1.2 The International System of Units (S.I.) shall be used in the design and the designer may simultaneously use another system of units in parentheses after the S.I. unit.

4.3.1.3 Among the conceptual safety conditions adopted, the ones recommended in API [RP2A -WSD](#), or the Rules for Design issued by DNV [OS C101](#) , shall be included as a minimum.

#### **4.3.2 Basic Data**

4.3.2.1 The basic parameters for soil and geotechnical design profile to be used shall be derived from the Geophysical and Geotechnical Investigation Reports of the installation site and from possible logs of other structures already installed in the region or in areas having a similar geotechnical profile.

4.3.2.2 The types of investigations and geotechnical testing laboratory shall be specified.

4.3.2.3 The loading assumptions shall consider the critical combinations for foundations of loadings from the superstructure under extreme design (storm), operation and installation conditions.

4.3.2.4 Concerning the foundation design for port structures, the minimum loading recommended in ABNT [NBR 9782](#) shall be adopted.

4.3.2.5 The foundation design shall consider the types of installation equipment to be used and their availability.

#### **4.3.3 Material Specifications**

4.3.3.1 The specifications of steels for metallic pile foundations and the specifications of the constituent steels of the accessories for installation of metallic piles shall comply with the minimum classification and selection requirements set forth in API [RP 2A-WSD](#).

4.3.3.2 The specifications of filler materials (slurry, mortar or concrete) of drilled and grouted or driven and injected piles and of the pile/sleeve annulus shall comply with the minimum workability characteristics, mechanical resistance, contraction and resistance to attack by chemical agents found in seawater, particularly sulfates, according to the standards referenced in Section 2.

4.3.3.3 In the case of drilled and grouted piles using an reinforcement, the specifications of the reinforcement shall conform to ABNT [NBR 6118](#) and [NBR 7480](#).

4.3.3.4 In the case of foundations with tie-rod type piles, the specifications of the materials comprising the tie-rod type system shall conform to ABNT [NBR 6118](#) and [NBR 8800](#).

#### **4.3.4 Design Execution Methodology**

4.3.4.1 The calculation methods used in the various design analyses shall comply with the provisions recommended in API [RP 2A-WSD](#), DNV [CN 30.4](#), DNV [OS C101](#) e AISC [325](#) and be compatible with the execution processes used for the installation.

4.3.4.2 In analyses of designs in which calculation methods are not recommended in the standards referred to in 4.3.4.1, other methods shall be used provided they have been proven in similar cases or through reliable tests.

4.3.4.3 The computer programs used shall be identified through a description of their methodology, limitations, input and output data and shall be proven by "verification and validation" tests or similar applications.

#### **4.3.5 Calculation Sheets**

4.3.5.1 Among the loading assumptions analyzed in the design of the structure, those representing critical conditions for the installation phase and the service life of foundations shall be selected and described in detail.

4.3.5.2 For application of the methods referred to in 4.3.4, the soil parameters obtained from the geophysical and geotechnical investigation described in 4.3.2.1 shall be evaluated.

4.3.5.3 The effects of the maximum seabed erosion during the service life of the structure shall be considered in the design, with due regard for the characteristics of the surface soil, foundation and sea currents.

4.3.5.4 The axial load capacity of a pile foundation shall be analyzed according to a method or combination of calculation methods, such as those based on load testing through static or dynamic formulas or semi-empirical methods based on "in situ" tests. These methods shall comply with the provisions in item 4.3.4.1. The group effect based on the number of piles, the spacing between them, the soil characteristics and the installation method shall be considered in the analysis.

4.3.5.5 In the soil-to-structure interaction analysis, both for the axial capacity and the lateral behavior of piles, the soil rigidity and the transfer of loads to the soil shall be considered. The group effect shall also be taken into account.

4.3.5.6 In the case of a foundation consisting of driven piles, the drivability analysis shall be conducted through the wave equation methodology according to the equipment foreseen and available for installation.

4.3.5.7 The structural sizing of a pile foundation, that is, the determination of the length and cross-sectional area of the various sections comprising it, shall be determined by the analyses considered in 4.3.5.4, 4.3.5.5 and 4.3.5.6 above.

4.3.5.8 The temporary stability of a structure shall be analyzed considering the period of recurrence of environmental loads corresponding to the installation phase of the structure. In the case of a pile foundation this analysis shall size the temporary spud cans and the partial construction of piles, if necessary.

4.3.5.9 The foundation-to-structure connection for transfer of loads to the foundation shall be made through mechanical forming, cementing of the annulus, and/or welded devices, that is, securing wedges, crowns or another process previously tested and of proven efficiency.

4.3.5.10 All standards and bibliographical references shall be indicated in each calculation phase.

4.3.5.11 Technical symbols shall be previously identified and listed in the calculation sheets.

#### **4.3.6 Recommendations for Execution and Control**

4.3.6.1 The minimum criteria for quality control of welds for joining structural steel segments of the foundation shall be recommended by the design.

4.3.6.2 The design shall indicate, for quality control of the cement slurry mixture, acceptable limit parameters relating to:

- a) density;
- b) resistance in the axial compression test for test specimens aged as follows:
  - 24 hours;
  - 48 hours;
  - 28 days;
- c) specific parameters, such as:
  - volumetric retraction;
  - time for beginning and end of setting.

4.3.6.3 If instrumentation or foundation load testing proves to be necessary for foundation construction, the design shall specify the respective procedures.

## **5 Execution**

### **5.1 Presentation of Documents for Execution**

The installation procedure for the construction phase of foundations shall contain information and documents relating to:

- a) objective;
- b) reference standards;
- c) definitions;

- d) equipment;
- e) details of piling operations;
- f) details of foundation-to-structure connection operations;
- g) verification of load capacity;
- h) methodology for recording results;
- i) acceptance/rejection criteria;
- j) general recommendations.

#### **5.1.1 Equipment**

The documentation shall cover the specification of the following types of equipment:

- a) naval means;
- b) driving and/or concreting;
- c) for cementing and/or concreting;
- d) accessories;
- e) for execution of quality control of materials and services.

##### **5.1.1.1 Naval Means**

The following information shall be provided regarding the installation vessel:

- a) crane;
  - nominal hoisting capacity;
  - swing radius;
  - maximum hoisting height;
- b) space available for work and storage on deck (layout of equipment distribution on deck);
- c) auxiliary equipment.

##### **5.1.1.2 Pile Driving Equipment**

The following information shall be provided:

- a) hammers:
  - type of operation;
  - geometry and weight;
  - nominal driving energy;
  - range of use and limitations (minimum pressure needed for feeding the driving fluid, limit of blows for each pad replacement);
  - accessories;
- b) percussion tools:
  - geometry;
  - maximum height of drop;
  - range of use and limitations of equipment.

##### **5.1.1.3 Drilling Equipment**

The following information shall be provided:

- a) characteristics of the drilling machine;
- b) string composition (geometry and weight);
- c) range of use and limitations (torque, maximum rotation under working conditions, maximum pull-up and push-down forces);
- d) types of bits available;
- e) characteristics of air lift system (number of stages, maximum working pressure);
- f) accessories.