



GUIDE FOR BUILDING AND CLASSING

BOTTOM-FOUNDED OFFSHORE WIND TURBINE INSTALLATIONS

OCTOBER 2015

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the State of New York 1862**

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Foreword

This Guide provides criteria for the design, construction, installation and survey of Bottom-Founded Offshore Wind Turbine Installations, which comprise permanently sited support structures and foundations of offshore wind turbines attached on and supported by the sea floor.

The criteria applicable to floating offshore wind turbine installations are provided in the *ABS Guide for Building and Classing Floating Offshore Wind Turbine Installations (FOWTI Guide)*.

Requirements for ancillary offshore wind farm installations such as meteorological measuring towers, accommodation units, and transformer platforms are not addressed in this Guide. For the requirements for such bottom-founded installations, refer to the *ABS Rules for Building and Classing Offshore Installations*.

This revision incorporates the following changes:

- 1-1/3 – A new optional class notion for the Rotor-Nacelle Assembly (RNA) is offered.
- 1-2/9 – More specific requirements were added regarding the number of turbines subject to commissioning surveys as well as the scope of commissioning survey. These requirements are adapted from the current *FOWTI Guide* and are in line with IEC 61400-3.
- 3-6/15 – Guidance is provided on how the site assessment should be done with regard to electric network conditions.
- 4-2/3 – Further clarification for the return period of the design storms in tropical cyclone prone areas is added.
- 4-2/Table 1 – Additional requirements are provided for considering the directionality of wind and wave that may cause misaligned wave and wind conditions. A new design load case (new DLC 8.2) is added to account for possible fatigue damage during the temporary phase.
- Appendix 2 – A new Appendix is added detailing the tropical cyclone wind model developed based on the measurements of tropical cyclone wind in the past 20 years.
- Appendix 3 – A new Appendix is added that provides guidance on fatigue analysis of support structures.

This Guide becomes effective on the first day of the month of publication.

Users are advised to check periodically on the ABS website www.eagle.org to verify that this version of this Guide is the most current.

We welcome your feedback. Comments or suggestions can be sent electronically by email to rsd@eagle.org.

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CHAPTER 1 Classification and Surveys

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CHAPTER 1 Classification and Surveys

SECTION 1 Scope and Conditions of Classification

1 Classification

The general requirements for conditions of classification are contained in the *ABS Rules for Conditions of Classification – Offshore Units and Structures (Part 1)*.

Additional requirements specific to Bottom-founded Offshore Wind Turbine Installations are provided in the following Subsections.

3 Classification Symbols and Notations (15 January 2013)

(1 October 2015) The following class notations are designated for the Bottom-founded Offshore Wind Turbine Installation as defined in 1-4/3.3. Additionally, at the request of the Owner, the Rotor-Nacelle Assembly (RNA) may be included in the classification subject to the ABS Type Approval requirements of the *ABS Rules for Conditions of Classification – Offshore Units and Structures (Part 1)*.

When the RNA is not included in the classification, the RNA installed on the ABS classed Bottom-founded Offshore Wind Turbine Installation is required to have a type certificate in accordance with IEC 61400-22 or other recognized standards. The RNA type certificate will be reviewed by ABS solely to verify that the information of the installed RNA is consistent with the design information, criteria and limitations considered in the classification of the Bottom-founded Offshore Wind Turbine Installation. ABS will not review or be responsible for the accuracy of the RNA type certificate. Use of the RNA which does not have an appropriate type certification or the wind turbine having a non-horizontal-axis configuration will be subject to special consideration by ABS.

3.1 Installations Built under ABS Survey

Installations built and constructed to the satisfaction of the ABS Surveyors and to the requirements of this Guide or to their equivalent, where approved by ABS, may be classed and distinguished in the *ABS Record* by the following symbol:

✠ A1 Offshore Wind Turbine Installation (Bottom-Founded)

The mark ✠ (Maltese cross) signifies that the installation was built, installed and commissioned to the satisfaction of the ABS Surveyors.

3.3 Installations Not Built under ABS Survey

Installations not built under ABS survey but submitted for classification, are subject to special classification survey. Where found satisfactory and thereafter approved by ABS, such installations may be classed with the symbol:

A1 Offshore Wind Turbine Installation (Bottom-Founded)

3.5 Additional Class Notation (1 October 2015)

The RNA, as defined in 1-1/3.43, may be considered for the classification at the Owner's request. Where the RNA are in full compliance with the requirements of the ABS Type Approval requirements of the *ABS Rules for Conditions of Classification – Offshore Units and Structures (Part 1)*, the installation may be classed and distinguished in the *Record* by the optional class notation **RNA**.

5 Rules for Classification (15 January 2013)

5.1 Application

The requirements in this Guide are applicable to the Bottom-founded Offshore Wind Turbine Installation, as defined in 1-4/3.3. The design criteria specified in this Guide are intended for the Bottom-founded Offshore Wind Turbine Installation to achieve the normal safety class as defined in IEC 61400-3 (2009).

This Guide is applicable to those features that are permanent in nature and can be verified by plan review, calculation, physical survey or other appropriate means. Any statement in this document regarding other features is to be considered as guidance to the designer, Fabricator, Owner, et al.

5.3 References

Reference is made in this Guide to ABS Rules and other criteria issued by ABS and other organizations. Appendix 4 contains a list of such references. Unless otherwise noted, the applicable edition of a reference is the one officially issued and available on the date the Agreement for Classification is accepted by ABS. Where a particular edition or date associated with a reference is given, it means that particular edition is relevant to the topic being presented in this Guide. ABS may consider at its discretion, upon the request of the Owner, the application of other appropriate alternative methods and recognized codes of practice.

5.5 Alternatives (1 October 2015)

Any departure from the requirements of this Guide may be considered by ABS on the basis of **suitable engineering analyses or risk assessments**. In the case of such departures, classification is subject to ABS's approval upon a demonstration of acceptable levels of safety in line with the principles of this Guide and recognized and generally accepted current offshore wind industry practice. Risk acceptance criteria are subject to ABS's approval. The *ABS Guidance Notes on Risk Assessment Application for the Marine and Offshore Oil and Gas Industries* contains an overview of risk assessment techniques and additional information.

Using a risk assessment approach to justify alternatives may be applicable either to the Bottom-founded Offshore Wind Turbine Installation as a whole or to individual systems, subsystems or components. As appropriate, account must be given to remote hazards outside of the bounds of the system under consideration. Such account must include incidents relating to remote hazards directly affecting or being influenced by the system under consideration. ABS will consider the application of risk-based techniques in the design of the Bottom-founded Offshore Wind Turbine Installation as well as surveys during construction and surveys for maintenance of class.

Portions of the Bottom-founded Offshore Wind Turbine Installation not included in the risk assessment are to comply with the applicable parts of the ABS Rules.

The following are the responsibility of the Owner:

- i) Risk acceptance criteria
- ii) Hazard identification
- iii) Risk assessment
- iv) Risk management
- v) Compliance with the applicable requirements of the coastal State or other governmental authorities

7 Design Documentation to be Submitted

(15 January 2013) The design documentation to be submitted is to describe the data, tools, procedures and methodologies of design and analysis which are employed to establish the design of the Bottom-founded Offshore Wind Turbine Installation. The intended design life is also to be stated.

Where model testing is used as a basis for a design, the applicability of the test results depends on the demonstration of the adequacy of the methods employed, including enumeration of possible sources of error, limits of applicability, and methods of extrapolation to full scale. Preferably, procedures are to be reviewed and agreed upon before model testing is done.

As required in the subsequent Paragraphs, calculations are to be submitted to demonstrate the sufficiency of the proposed design. Such calculations are to be presented in a logical and well-referenced fashion employing a consistent system of units. Where the calculations are in the form of computer analysis, the submittal is to provide input and output data with computer generated plots for the structural model. A program description (not code listings), user manuals, and the results of program verification sample problems may be required to be submitted.

The design documentation to be submitted is to include the reports, calculations, plans, specifications and other documentation where applicable. The extensiveness of the submitted documentation is to reflect:

- i) The uniqueness of a specific design of the Bottom-founded Offshore Wind Turbine Installation within an offshore wind farm, and
- ii) The level of experience with conditions in an area where the Bottom-founded Offshore Wind Turbine Installation is to be located.

Design documentation should generally be submitted electronically to ABS. However, hard copies will also be accepted.

7.1 Reports

Reports by consultants and other specialists used as a basis for design are to be submitted for review. The contents of reports on offshore wind farm conditions, environmental considerations, foundation data, and materials are, in general, to comply with the recommended list of items given below.

7.1.1 Offshore Wind Farm Conditions (15 January 2013)

A report on offshore wind farm conditions is to present the configuration of an offshore wind farm and exact locations of all individual offshore wind turbines, transformer platform, service and accommodation units and any other supporting structures and facilities in the offshore wind farm where applicable.

The report is also to contain the information of wind turbine RNAs, particularly those properties that are used as the input or as the basis of the input for the load calculation and structural assessment for the Support Structure.

7.1.2 Environmental Considerations (15 January 2013)

Reports on environmental considerations, as described in Chapter 3, Section 1, are to describe all environmental phenomena appropriate to the areas of construction, transportation, installation, maintenance, and repair. The types of environmental phenomena to be accounted for, as appropriate to the type and location of the Bottom-founded Offshore Wind Turbine Installation, include wind, waves, current, temperature, tide, marine growth, chemical components and density of air and water, snow and ice, earthquake, and other pertinent phenomena.

The establishment of environmental conditions is to be based on appropriate original data or, when permitted, data from analogous areas. Demonstrably valid statistical models are to be employed to perform the extrapolation to long-term values. Calculations required to establish the pertinent design environmental parameters are to be submitted for review.

The report on environmental considerations is also to contain the calculations which quantify the effects or loadings on the Bottom-founded Offshore Wind Turbine Installation if they are not provided in other documentation.

7.1.3 Foundation Data

Reports on foundation data are to present the results of investigations or, when applicable, data from analogous areas on geophysical, geological and geotechnical considerations existing at and near the installation site of an offshore wind turbine. The manner in which such data is established and the specific items to be assessed are to comply with 5-4/1 and 5-4/5. The report is to contain a listing of references to cover the investigation, sampling, testing, and interpretive techniques employed during and after the site investigation.

The report is to include a listing of the predicted soil-structure interaction, such as p - y data, to be used in the design. As appropriate to the planned structure, the items which may be covered in the reports are: axial and lateral pile capacities and response characteristics, the effects of cyclic loading on soil strength, scour, settlements and lateral displacements, dynamic interaction between soil and structure, the capacity of pile groups, slope stability, bearing and lateral stability, soil reactions on the structure, and penetration resistance.

Recommendations relative to any special anticipated problem regarding installation are to be included in the report. Items such as the following are to be included, as appropriate: hammer sizes, soil erosion during installation, bottom preparation, and procedures to be followed in the case that pile installation procedures significantly deviate from those anticipated.

The documentation for the foundation design is to be submitted in accordance with Chapter 5, Section 4.

7.1.4 Materials and Welding

Reports on structural materials and welding may be required for metallic structures, concrete structures or welding procedures where materials or procedures do not conform to those provided in Chapter 2 of this Guide.

For metallic structures, when it is intended to employ new alloys not defined by a recognized specification, reports are to be submitted indicating the adequacy of the material's metallurgical properties, fracture toughness, yield and tensile strengths, and corrosion resistance, with respect to their intended application and service temperatures.

For concrete gravity foundation structures, when it is not intended to test or define material properties in accordance with applicable standards of the American Society for Testing and Materials (ASTM) as listed in Chapter 2, Section 1 of this Guide, a report is to be provided indicating the standards actually to be employed and their relative adequacy with respect to the corresponding ASTM standards.

7.3 Design Data and Calculations

Design and analysis calculations are to be submitted for items relating to loadings and structural responses for in-place and marine operations, structural dynamic properties, and foundation designs. Calculations are in general to include the items listed below.

Calculations which may be required in association with environmental considerations and foundation data are described in 1-1/7.1.

7.3.1 Loadings

Calculations for loadings are to be submitted in accordance with Chapter 4.

7.3.2 Structural Dynamic Properties (15 January 2013)

Calculations of natural periods of the Support Structure are to be submitted for review. A resonance diagram (Campbell diagram) depicting the relationship between the rotor speeds and the natural periods of turbine components and the Support Structure is to be submitted.

As applicable, the calculation of vibration amplitudes, velocities, and accelerations of the Support Structure may also be required.

7.3.3 Structural Responses

The stress and deflection calculations to be submitted are to include nominal element or member stresses and deflections. Calculations are also required for stresses in localized areas and structural joints, dynamic responses of the structure, and fatigue life of critical members and joints.

For a pile-supported structure, calculations for stresses in each pile and the load capacity of the connection between the structure and the pile are to be submitted. For a gravity structure, calculations are to be submitted for the effects of soil's reaction on the foundation structure.

For a Self-Elevating Unit to be used as the Support Structure of an offshore wind turbine, the applicable calculations required in 3-1/3 of the *ABS Guide for Building and Classing Mobile Offshore Units* are to be submitted.

7.3.4 Marine Operations (15 January 2013)

Calculations are to be submitted in compliance with Chapter 6. For structural responses resulting from the marine operations described in Chapter 6, calculations are to demonstrate the adequacy of structural elements, members, or local structure, as deemed necessary. In addition, the calculations are to demonstrate, as applicable, that deflections resulting from applied loadings and overall structural displacement and settlement do not impair the structural performance of the Support Structure.

7.3.5 Other Calculations

As required, additional calculations which demonstrate the adequacy of an overall design are to be submitted. Such calculations are to include those performed in the design of corrosion protection system.

7.5 Plans and Specifications (15 January 2013)

Plans or specifications depicting or describing arrangements and details of major items of the Bottom-founded Offshore Wind Turbine Installation are to be submitted for review or approval in a timely manner.

Where deemed appropriate, and when requested by the Owner, a schedule for information submittal and plan approval can be jointly established by the Owner and ABS. This schedule, which affects the time required for review of submitted data and ABS will adhere to as far as reasonably possible, is to reflect the construction schedule and the complexity of the Bottom-founded Offshore Wind Turbine Installation.

These plans are to include the following, where applicable.

- i) Arrangement plans, elevations, and plan views clearly showing in sufficient detail the overall configuration, dimensions and layout of the rotor, nacelle, tower, substructure, foundation, etc.
- ii) Layout plans indicating the locations, dimension and weights of main turbine components (e.g., blade, hub, shaft, nacelle, etc.) and the components (e.g., electrical, mechanical and control systems, etc.) in nacelle housing.
- iii) Layout of secondary structures, fenders, ladders, access platform, boat landing, J-tube, etc.
- iv) Structural plans indicating the complete structural arrangement, dimensions, member sizes, plating and framing, material properties, and details of connections and attachments
- v) Pile plans indicating arrangements, nominal sizes, thicknesses and penetration
- vi) Welding details and procedures, and schedule of nondestructive testing
- vii) Corrosion control systems
- viii) Various information in support of novel features utilized in the design where applicable

For a Self-Elevating Unit to be used as the Support Structure of an offshore wind turbine, the additional plans and design data required in 3-1/1 of the *ABS Guide for Building and Classing Mobile Offshore Units* are to be submitted.

7.7 Information Memorandum (15 January 2013)

An information memorandum is to be prepared and submitted to ABS. ABS will review the contents of the memorandum to establish consistency with other data submitted for the purpose of obtaining classification. ABS will not review the contents of the memorandum for their accuracy or the features described in the memorandum for their adequacy.

An information memorandum is to contain, as appropriate to the installation, the following:

- i) Specifications of the RNA to be installed.
- ii) Site plan indicating general features at the installation site and the layout of the offshore wind farm
- iii) Environmental design criteria, including the recurrence interval used to assess environmental phenomena
- iv) Plans showing the general arrangement of the Support Structure and its connection to the RNA
- v) Description of the safety and protective systems provided

- vi) Description of modes of operation
- vii) Listing of governmental authorities having cognizance over the offshore wind farm
- viii) Listing of any novel features
- ix) Brief description of any monitoring proposed and security systems installed on the Support Structure
- x) Description of transportation, installation and maintenance procedures

9 Operating Manual (*15 January 2013*)

The Operating Manual of the Bottom-founded Offshore Wind Turbine Installation is to be submitted for review by ABS solely to verify the operational procedures and conditions are consistent with the design information, criteria and limitations considered in the classification. ABS is not responsible for the operation of offshore wind turbines.

A copy of the Operating Manual is preferably to be stored onboard of the Bottom-founded Offshore Wind Turbine Installation. Alternatively, the Operating Manual may be retained by the Owner and made readily available to the ABS Surveyor and to service personnel prior to conducting any maintenance or inspection.

The Operating Manual required by this Subsection does not need to be in addition to that required by the coastal State or other governmental authorities.

CHAPTER 1 Classification and Surveys

SECTION 2 Surveys During Construction, Installation, and Commissioning

1 Overview

1.1 Scope

This Section pertains to surveys during the construction and installation of the Bottom-founded Offshore Wind Turbine Installation. The requirements of 1-2/1 are to apply to all Bottom-founded Offshore Wind Turbine Installations covered by this Guide regardless of type. Additional specific requirements are contained in 1-2/3 for steel Support Structures and in 1-2/5 for concrete Support Structures.

The phases of construction covered by this Section include material manufacture, fabrication, installation and final field erection of the foundation, substructure, tower, and RNA.

1.3 Quality Control Program

A quality control program compatible with the type and size of the planned Bottom-founded Offshore Wind Turbine Installation is to be developed and submitted to ABS for review. ABS will review, approve and, as necessary, request modification of this program. The Fabricator is to work with the attending Surveyor to establish the required hold points on the quality control program to form the basis for all future surveys at the fabrication yard. As a minimum, the items enumerated in the various applicable Subsections below are to be covered by the quality control program. Surveyors will be assigned to monitor the fabrication of items within the scope of classification, and to verify that competent personnel are carrying out all tests and inspections specified in the quality control program. It is to be noted that the monitoring provided by ABS is a supplement to and not a replacement for inspections to be carried out by the Fabricator or Owner.

1.5 Access and Notification

During construction, the Surveyor is to have access to structures at all reasonable times. The attending Surveyor is to be notified as to when and where parts of the structure may be examined. If, at any visit, the Surveyor finds occasion to recommend repairs or further inspection, notice is to be made to the Fabricator or his representatives.

1.7 Identification of Materials

The Fabricator is to maintain a system of material traceability to the satisfaction of the attending Surveyor, for all Special and Primary Application Structures. Data as to place of origin and results of relevant material tests for structural materials are to be retained and made readily available during all stages of construction (see 1-2/3.25 and 1-2/5.17). Such data are to be available to the Surveyor upon request.

3 Steel Structures

3.1 Quality Control Program

The quality control program (see 1-2/1.3) for the construction of the steel Support Structure is to include the following items, as appropriate.

- i) Material quality and traceability
- ii) Steel forming
- iii) Welder qualification and records
- iv) Welding procedure specifications and qualifications
- v) Weld inspection
- vi) Tolerances alignments and compartment testing
- vii) Corrosion control systems
- viii) Tightness and hydrostatic testing procedures
- ix) Nondestructive testing
- x) Installation of the Support Structure

The items which are to be considered for each of the topics mentioned above are indicated in 1-2/3.3 through 1-2/3.23.

3.3 Material Quality and Traceability

The properties of the material are to be in accordance with Chapter 2, Section 1 of this Guide. Manufacturer's certificates are to be supplied with the material. Verification of the material's quality is to be done by the Surveyor at the plant of manufacture, in accordance with Section 2-1-1 of the *ABS Rules for Materials and Welding (Part 2)*. Alternatively, material manufactured to recognized standards may be accepted in lieu of the above steel requirements provided the substitution of such materials is approved by ABS. Materials used are to be in accordance with those specified in the approved design. All materials required for classification purposes are to be tested in the presence of the ABS Surveyor. The Fabricator is to maintain a material traceability system for all the Primary and Special Application Structures.

3.5 Steel Forming

When forming changes base plate properties beyond acceptable limits, appropriate heat treatments are to be carried out to re-establish required properties. Unless approved otherwise, the acceptable limits of the re-established properties are to meet the minimums specified for the original material before forming. As required, ABS will survey formed members for their compliance with the forming dimensional tolerances required by the design.

3.7 Welder Qualification and Records

Welders who will work on the Bottom-founded Offshore Wind Turbine Installation are to be qualified in accordance with the welder qualification tests specified in a recognized code or, as applicable, the *ABS Rules for Materials and Welding (Part 2)* to the satisfaction of the attending Surveyor. Certificates of qualification are to be prepared to record evidence of the qualification of each welder qualified by an approved standard/code, and such certificates are to be made available to the Surveyor. In the event that welders have been previously tested in accordance with the requirements of a recognized code and provided that the period of effectiveness of the previous testing has not lapsed, these welder qualification tests may be accepted.

3.9 Welding Procedure Specifications and Qualifications

Welding procedures are to be approved in accordance with the *ABS Rules for Materials and Welding (Part 2)*. Welding procedures conforming to the provisions of a recognized code may, at the Surveyor's discretion, be accepted. A written description of all procedures previously qualified may be employed in the structure's construction provided it is included in the quality control program and made available to the Surveyor. When it is necessary to qualify a welding procedure, this is to be accomplished by employing the methods specified in the recognized code, and in the presence of the Surveyor.

3.11 Weld Inspection

As part of the overall quality control program, a detailed plan for the inspection and testing of welds is to be prepared. This plan is to include the applicable provisions of this Section.

3.13 Tolerances and Alignments

The overall structural tolerances, forming tolerances, and local alignment tolerances are to be commensurate with those considered in developing the structural design. Inspections are to be carried out to verify that the dimensional tolerance criteria are satisfied. Particular attention is to be paid to the out-of-roundness of members for which buckling is an anticipated mode of failure. Structural alignment and fit-up prior to welding are to be monitored to verify consistent production of quality welds.

3.15 Corrosion Control Systems

The details of any corrosion control systems employed for the structure are to be submitted for review. Installation and testing of the corrosion control systems are to be carried out to the satisfaction of the attending Surveyor in accordance with the approved plans.

3.17 Tightness and Hydrostatic Testing Procedures

Compartments, which are designed to be permanently watertight or to be maintained watertight during installation, are to be tested by a procedure approved by the attending Surveyor. The testing is also to be witnessed by the attending Surveyor.

3.19 Nondestructive Testing

A system of nondestructive testing is to be included in the fabrication specification of the structures. The minimum extent of nondestructive testing is to be in accordance with this Guide or recognized design Code. All nondestructive testing records are to be reviewed and approved by the attending Surveyor. Additional nondestructive testing may be requested by the attending Surveyor if the quality of fabrication is not in accordance with industry standards.

3.21 Installation of the Support Structure (Foundation, Substructure, and Tower)

Installation procedures are to be submitted to ABS for review and approval as described in Chapter 6. The Surveyor is to witness the following activities, as applicable to the planned structure, to ascertain whether they have been accomplished in a manner conforming to the approved procedures.

- i) Installation of the Support Structure
- ii) Piling and grouting
- iii) Welding and nondestructive testing
- iv) Final field erection and leveling
- v) Pre-tensioning

Significant deviations from approved plans and procedures or any incidents such as excessive tilting of the foundation or abnormal vibrations during pile driving may require re-submittal of supporting documentation to provide an assessment of the significance of deviation and any necessary remedial actions to be taken.

To verify that overstressing of the structure during transportation has not occurred, ABS is to have access to towing records to ascertain if conditions during the towing operations exceeded those employed in the design. Results are to be submitted to demonstrate compliance with the reviewed design analysis.

3.23 Testing and Trials of a Self-Elevating Unit to be Used as the Support Structure

A Self-Elevating Mobile Offshore Unit intended to be converted to the site-dependent Support Structure of an offshore wind turbine is to be subject to the applicable surveys during construction and installation specified in this Guide in addition to the testing and trials required by Chapter 6, Section 1 of the *ABS Guide for Building and Classing Mobile Offshore Units*.

3.25 Records

A data book of the records of construction activities is to be developed and maintained so as to compile a record as complete as practicable. The pertinent records are to be adequately prepared and indexed to assure their usefulness, and they are to be stored so that they may be easily recovered.

For a steel structure, the construction record is to include, as applicable, the following:

- i) Material traceability records including mill certificates
- ii) Welding procedure specification and qualification records
- iii) Shop welding practices
- iv) Welding inspection records
- v) Construction specifications
- vi) Structural dimension check records
- vii) Nondestructive testing records
- viii) Records of completion of items identified in the quality control program
- ix) Towing and pile driving records
- x) Position and orientation records
- xi) Leveling and elevation records, etc.

The compilation of these records is a condition of classification

After fabrication and installation, these records are to be retained by the Owner or Fabricator for future references. The minimum time for record retention is not to be less than the greatest of the following: the warranty period, the time specified in construction agreements, or the time required by statute or governmental regulations.

5 Concrete Structures

5.1 Quality Control Program

The quality control program (see 1-2/1.3) for a concrete structure is to cover the following items, as appropriate.

- i) Inspections prior to concreting
- ii) Inspection of batching, mixing and placing concrete
- iii) Inspections of form removal and concrete curing
- iv) Inspection of prestressing and grouting
- v) Inspection of joints
- vi) Inspection of finished concrete
- vii) Installation of the Support Structure
- viii) Tightness and hydrostatic testing as applicable (see 1-2/3.17)

The items which are to be considered for each of the topics mentioned above, except for *viii*), are indicated in 1-2/5.3 through 1-2/5.15.

5.3 Inspections Prior to Concreting

Prior to their use in construction, the manufacturers of cement, reinforcing rods, prestressing tendons and appliances are to provide documentation of the pertinent physical properties. These data are to be made available to the attending Surveyor for verification of conformity with the properties specified in the approved design.

As applicable, at the construction site, the Surveyor is to be satisfied that proper consideration is being given to the support of the structure during construction, the storage of cement and prestressing tendons in weathertight areas, the storage of admixtures and epoxies to manufacturer's specifications, and the storage of aggregates to limit segregation, contamination by deleterious substances and moisture variations within the stock pile.

Forms and shores supporting the forms are to be inspected to verify that they are adequate in number and type, and that they are located in accordance with the approved plans. The dimensions and alignment of the forms are to be verified by the attending Surveyor. The measurements are to be within the allowable finished dimensional tolerances specified in the approved design.

Reinforcing steel, prestressing tendons, post-tensioning ducts, anchorages and any included steel are to be checked, as appropriate to the planned structure, for size, bending, spacing, location, firmness of installation, surface condition, vent locations, proper duct coupling, and duct capping.

5.5 Inspection of Batching, Mixing, and Placing Concrete

The production and placing of the concrete are to employ procedures which will provide a well-mixed and well-compacted concrete. Such procedures are also to limit segregation, loss of material, contamination, and premature initial set during all operations.

Mix components of each batch of concrete are to be measured by a method specified in the quality control program. The designer is to specify the allowable variation of mix component proportions, and the Fabricator is to record the actual proportions of each batch.

Testing during the production of concrete is to be carried out following the procedures specified in the quality control program. As a minimum, the following concrete qualities are to be measured by the Fabricator.

- i) Consistency
- ii) Air content
- iii) Density or Specific Gravity
- iv) Strength

Field testing of aggregate gradation, cleanliness, moisture content, and unit weight is to be performed by the Fabricator following standards and schedules specified in the quality control program. The frequency of testing is to be determined with consideration of the uniformity of the supply source, volume of concreting, and variations of atmospheric conditions. Mix water is to be tested for purity following the methods and schedules specified in the quality control program.

5.7 Inspections of Form Removal and Concrete Curing

The structure is to have sufficient strength to bear its own weight, construction loads and the anticipated environmental loads without undue deformations before forms and form supports are removed. The schedule of form removal is to be specified in the quality control program, giving due account to the loads and the anticipated strength.

Curing procedures for use on the structure are to be specified in the quality control program. When conditions at the construction site cause a deviation from these procedures, justification for these deviations is to be fully documented and included in the construction records.

Where the construction procedures require the submergence of recently placed concrete, special methods for protecting the concrete from the effects of salt water are to be specified in the quality control program. Generally, concrete is not to be submerged until 28 days after placing (see also 5-3/11.3.5).

5.9 Inspection of Prestressing and Grouting

A schedule indicating the sequence and anticipated elongation and stress accompanying the tensioning of tendons is to be prepared. Any failures to achieve proper tensioning are to be immediately reported to the designer to obtain guidance on needed remedial actions.

Pre- or post-tensioning loads are to be determined by measuring both tendon elongation and tendon stress. These measurements are to be compared. In the case that the variation of measurements exceed the specified amount, the cause of the variation is to be determined and any necessary corrective actions are to be accomplished.

The grout mix is to conform to that specified in the design. The Fabricator is to keep records of the mix proportions and ambient conditions during grout mixing. Tests for grout viscosity, expansion and bleeding, compressive strength, and setting time are to be made by the Fabricator using methods and schedules specified in the quality control program. Employed procedures are to verify that ducts are completely filled.

Anchorage are to be inspected to verify that they are located and sized as specified in the design. Anchorages are also to be inspected to verify that they will be provided with adequate cover to mitigate the effects of corrosion.

5.11 Inspection of Joints

Where required, leak testing of construction joints is to be carried out using procedures specified in the quality control program. When deciding which joints are to be inspected, consideration is to be given to the hydrostatic head on the subject joint during normal operation, the consequence of a leak at the subject joint, and the ease of repair once the Bottom-founded Offshore Wind Turbine Installation is in service.

5.13 Inspection of Finished Concrete

The surface of the hardened concrete is to be comprehensively inspected for cracks, honeycombing, pop-outs, spalling and other surface imperfections. When such defects are found, their extent is to be reported to the Surveyor and to the designer for guidance on any necessary repairs.

The structure is to be examined using a calibrated rebound hammer or a similar nondestructive testing device. Where the results of surface inspection, cylinder strength tests or nondestructive testing do not meet the design criteria, the designer is to be consulted regarding remedial actions to be taken.

The completed sections of the structure are to be checked for compliance to specified design tolerances for thickness, alignment, etc., and to the extent practicable, the location of reinforcing and prestressing steel and post-tensioning ducts. Variations from the tolerance limits are to be reported to the designer for evaluation and guidance on any necessary remedial actions.

5.15 Installation of the Support Structure (Foundation, Substructure and Tower)

Installation procedures are to be submitted to ABS for review and approval as described in Chapter 6. The Surveyor is to witness the following operations, as applicable to the planned structure, to verify that they have been accomplished in a manner conforming to plans or drawings covering these operations.

- i) Installation
- ii) Final field erection and leveling
- iii) Pre-tensioning

Significant deviations from approved plans and procedures may require re-submittal of supporting documentation to provide an assessment of the significance of the deviation and the remedial actions to be taken.

To verify that overstressing of the structure during transportation has not occurred, ABS is to have access to towing records to ascertain if conditions during the towing operations exceeded those employed in the design. Results are to be submitted to demonstrate compliance with the reviewed design analysis.

5.17 Records

Reference is made to 1-2/3.25 regarding the need to compile construction records. For the concrete Support Structure of an offshore wind turbine, the construction records are to include, as applicable, the following:

- i) All material certificates and test reports
- ii) Tensioning and grouting records
- iii) Concrete records including weight
- iv) Moisture content and mix proportions
- v) A list of test methods and results
- vi) Ambient conditions during the pours
- vii) Calibration data for test equipment
- viii) Towing records
- ix) Data on initial structural settlements
- x) Inspector's logs

These records are to be retained by the Owner.

7 Rotor-Nacelle Assemblies (RNAs) (15 January 2013)

The Surveyor is to witness the installation of at least one RNA per each type and the hook-up of the associated export electrical cable. Where there are more than fifty (50) RNAs of the same type, at least one RNA installation per every fifty (50) turbines of the same type and the hook-up of the associated export electrical cable are to be witnessed by the Surveyor. The selection of RNA installations to be witnessed is to reflect having Surveys at the start and end of RNA installation periods and the rate of RNA installation within an installation period.

The attending Surveyor is to verify that the RNAs to be installed are in compliance with the relevant design documents for the Bottom-founded Offshore Wind Turbine Installation. Deviations from approved design documents and plans or any incidents such as damage or overstress to the Bottom-founded Offshore Wind Turbine Installation during the installation of RNAs may require re-submittal of supporting documentation to provide an assessment of the significance of deviation and any necessary remedial actions to be taken.

9 Commissioning Surveys (1 October 2015)

The Surveyor is to observe the Bottom-Founded Offshore Wind Turbine Installation operating under various capacities and conditions. The Surveyor is to witness the commissioning of at least one (1) RNA per each type. Where there are more than fifty (50) RNAs of the same type, the commissioning of at least one RNA per every fifty (50) turbines of the same type is to be witnessed by the Surveyor. The selection of RNA commissioning to be witnessed is to reflect having Surveys at the start and end of RNA commissioning periods. Approved turbine RNA operations including emergency procedures are to be verified to the extent deemed necessary by the attending Surveyor. The overall performance of the turbine RNA is to be verified for compliance with the design parameters used in the design of the Bottom-Founded Offshore Wind Turbine Installation. Records of all these performance are to be maintained and made available to ABS.



CHAPTER 1 Classification and Surveys

SECTION 3 Surveys After Construction

1 Condition for Surveys after Construction

1.1 Damage, Failure, and Repair

1.1.1 Examination and Repair

Damage, failure, deterioration or repair to a classed Bottom-founded Offshore Wind Turbine Installation, which affects or may affect classification, is to be submitted by the Owner or their representatives for examination by the Surveyor at the first opportunity. All repairs found necessary by the Surveyor are to be carried out to the Surveyor's satisfaction.

1.1.2 Repairs on Site

Where repairs to the structure, which affect or may affect classification, are intended to be carried out at site, complete repair procedure including the extent of proposed repair and the need for Surveyor's attendance on site is to be submitted to and agreed upon by the Surveyor reasonably in advance. The above is not intended for routine maintenance.

1.1.3 Representation

Nothing contained in this Section or in a regulation of any government or other administration, or the issuance of any report or certificate pursuant to this Section or such a rule or regulation, is to be deemed to enlarge upon the representations expressed in 1-1-1/1 through 1-1-1/7 of the ABS *Rules for Conditions of Classification – Offshore Units and Structures (Part 1)*.

1.3 Notification and Availability for Survey

The Surveyor is to have access to a classed Bottom-founded Offshore Wind Turbine Installation at all reasonable times. The Owners or their representatives are to notify the Surveyor on all occasions when the Bottom-founded Offshore Wind Turbine Installation can be examined on site.

The Surveyor is to undertake all surveys on the classed Bottom-founded Offshore Wind Turbine Installation upon request, with adequate notification, from the Owners or their representatives and is to report thereon to ABS. Should the Surveyor find occasion during any survey to recommend repairs or further examination, notification is to be given immediately to the Owners or their representatives in order that appropriate actions may be taken. The Surveyor is to avail himself of every convenient opportunity for performing periodical surveys in conjunction with surveys of damages and repairs in order to avoid duplication of work. Also see 1-1-8/3 of the ABS *Rules for Conditions of Classification – Offshore Units and Structures (Part 1)*.

1.5 Annual Surveys

Annual Surveys of the Bottom-founded Offshore Wind Turbine Installation are to be made within three months either way of each annual anniversary date of crediting of the previous Special Periodical Survey or original construction date. Where the Surveyor is engaged in the survey of a grouping of structures of similar design and location, and where requested by the Owner, special consideration will be given to the timing of Annual Surveys and Special Periodical Surveys such that all periodical survey due dates can be harmonized.

1.7 Special Periodical Surveys

Special Periodical Surveys of the Bottom-founded Offshore Wind Turbine Installation are to be carried out at least once every five years. If a Special Periodical Survey is not completed at one time, it will be credited as of the completion date of the survey provided the due date of the Special Periodical Survey is not overdue by more than six months. Where the Surveyor is engaged in the survey of a grouping of structures of similar design and location, and where requested by the Owner, special consideration will be given to the timing of Special Periodical Surveys so that the due dates for all periodical surveys can be harmonized.

1.9 Continuous Surveys

At the request of the Owner, and upon approval of the proposed arrangement, a system of Continuous Surveys may be undertaken whereby all the Special Periodical Survey requirements are carried out in regular rotation and completed within the normal Special Periodical Survey interval.

For Continuous Surveys, a suitable notation will be entered in the *ABS Record* and the date of completion of the cycle published. If any defects are found during these surveys, they are to be examined and dealt with to the satisfaction of the Surveyor.

1.11 Reactivation Surveys

When the Bottom-founded Offshore Wind Turbine Installation has been out of service for an extended period, the requirements for surveys on reactivation are to be specially considered in each case. Due regard is to be given to the status of surveys at the time of the commencement of the deactivation period, the length of the period, and conditions under which the Bottom-founded Offshore Wind Turbine Installation had been maintained during that period.

1.13 Incomplete Surveys

When a survey is not completed, the Surveyor is to report immediately upon the work done in order that the Owner and ABS may be advised of the remaining parts to be surveyed.

1.15 Alterations

No major alterations, which affect classification of the installation, are to be made to a classed Bottom-founded Offshore Wind Turbine Installation unless plans of the proposed alterations are submitted and approved by ABS before the alterations are undertaken. Such alterations are to be carried out to the satisfaction of the Surveyor. Nothing contained in this Section or in a rule or regulation of any government or other administration, or the issuance of any report or certificate pursuant to this Section or such a rule or regulation, is to be deemed to enlarge upon the representations expressed in 1-1-1/1 through 1-1-1/7 of the *ABS Rules for Conditions of Classification – Offshore Units and Structures (Part 1)* and the issuance and use of any such reports or certificates are to be, in all respects, governed by 1-1-1/1 through 1-1-1/7 of the above Part 1.

1.17 Survey of a Self-Elevating Unit to be Used as the Support Structure (15 January 2013)

A Self-Elevating Mobile Offshore Unit that has been converted to the site-dependent Support Structure of an offshore wind turbine is to be subject to the surveys after construction required in this Guide in addition to the applicable surveys of structures required by Chapter 6, Section 2 of the *ABS Guide for Building and Classing Mobile Offshore Units*.

1.19 Survey for Extension of Use

Existing installations to be used at the same location for an extended period of time beyond their original design life are subject to additional surveys, as deemed necessary, to determine the actual condition of the Bottom-founded Offshore Wind Turbine Installation. The extent of the survey will depend on the completeness of the existing survey documents. ABS will review and verify maintenance manual, logs and records. Any alterations, repairs or installation of equipment since installation are to be included in the records.

Those survey requirements in 1-3/1.7 for the Special Periodical Survey have to be included in the survey for extension of use. The surveys generally cover examination of splash zone, inspection of above water and underwater structural members and welds for damages and deteriorations, examination and measurements of corrosion protection systems and marine growth, sea floor condition survey, examination of secondary structural attachments such as J-Tube, service decks, etc. Special attention is to be given to the following critical areas.

- i) Areas of high stress
- ii) Areas of low fatigue life
- iii) Damage incurred during installation or while in service
- iv) Repairs or modifications made while in service
- v) Abnormalities found during previous surveys

An inspection report of the findings is to be submitted to ABS for review and evaluation of the condition of the Bottom-founded Offshore Wind Turbine Installation.

The need for more frequent future periodical surveys is to be determined based on the calculated remaining fatigue life described in Part 4, Section 1 of the *ABS Rules for Building and Classing Offshore Installations*, with the exception that the load, strength and fatigue calculations are to follow Chapters 4 and 5 of this Guide as well as past inspection results.

1.21 Relocation of Existing Installations

Existing installations that are classed at a specified location require special consideration when relocation to a new site is proposed. The Owner is to advise ABS of the proposal to change locations addressing removal, transportation and re-installation aspects of the change. The survey requirements described in Chapter 1, Section 2 and 1-3/1.19, wherever applicable, are to be complied with in addition to engineering analyses required to justify the integrity of the installation for the design life at the new location.

3 Annual Surveys

Each Annual Survey is to include a thorough visual examination of above water structure. Special attention will be given to the splash zone for possible damage or deterioration from corrosion. Additionally, where it appears that significant deterioration or damage has occurred to an installation since the last survey, a general examination, by diver, underwater camera, submersible, or other suitable means, of the underwater structure, the scour protection, the sea floor, and the corrosion control system is to be carried out. Underwater examinations are to be contracted by the Owner and monitored by the Surveyor.

Any novel features incorporated in the design are to be given special attention according to procedures agreed to during review of the design.

Particular attention is to be given to significant modifications or repairs made as a result of findings at the previous survey.

The Annual Survey is also to include verification that the approved design life has not been exceeded. The Surveyor is to confirm the design life limits. The ABS technical office is to be consulted for verification. If the end of the design life has been reached, the provisions of Part 4, Section 1 of the *ABS Rules for Building and Classing Offshore Installations*, with the exception that the load, strength and fatigue calculations are to follow Chapters 4 and 5 of this Guide, are to be applied and specific requirements for maintaining the class of the Bottom-founded Offshore Wind Turbine Installation are to be obtained from ABS.

5 Special Periodical Surveys

The requirements of the Annual Survey are to be met during the Special Periodical Survey. Additionally, underwater inspection of selected areas is to be carried out. In addition, nondestructive testing is to be carried out on representative joints of the structures and if found necessary, structural supports of J-Tubes. The extent and methods to be employed in such testing, cleaning, and inspection of the structure are to be in accordance with an approved inspection plan. The inspection plan, which is to be submitted for approval, is to cover all Special Periodical Surveys for the design life of the Bottom-founded Offshore Wind Turbine Installation. It is to enumerate in detail the items to be surveyed, the testing and inspection procedures to be employed, and where necessary, cleaning and nondestructive testing procedures. The plan is to include sufficiently detailed drawings which can be used by the Surveyor to reference and locate the items to be surveyed. The testing, cleaning, and inspection services are to be provided by the Owner and monitored by the Surveyor. Divers carrying out structural inspections and nondestructive testing on the structures are to be suitably qualified.

In addition, the Special Periodical Survey is to include monitoring of the effectiveness of the corrosion protection system. The effectiveness of the corrosion protection system is to be monitored by taking measurements of the potential voltages generated by such systems. Scour in way of foundation legs and tilt of the Bottom-founded Offshore Wind Turbine Installation are also to be checked and witnessed by the attending Surveyor.

The Special Periodical Survey is also to include verification that the approved design life has not been exceeded. The Surveyor is to confirm the design life limits and the ABS technical office is to be consulted for verification. If the end of the design life has been reached, the provisions of Part 4, Section 1 of the *ABS Rules for Building and Classing Offshore Installations*, with the exception that the load, strength and fatigue calculations are to follow Chapters 4 and 5 of this Guide, are to be applied and specific requirements for maintaining the class of the Bottom-founded Offshore Wind Turbine Installation are to be obtained from ABS.

7 Continuous Surveys

As an alternative arrangement for the Special Periodical Surveys, the Continuous Surveys are to be applied annually to a minimum of 20% of the Bottom-founded Offshore Wind Turbine Installations selected from the offshore wind farm. All the Special Periodical Survey requirements as specified in 1-3/5 are to be fulfilled during the Continuous Surveys. Each Bottom-founded Offshore Wind Turbine Installation in the offshore wind farm is to be subject to at least once Special Periodical Survey within any five consecutive years. Where significant deterioration or damage has occurred to the installations or specific problems are identified as an indication of a serial defect, the Continuous Surveys are to be carried out to the satisfaction of the Surveyor for an increased number of the Bottom-founded Offshore Wind Turbine Installations.

9 Gauging

Thickness gauging is required to be taken at each Special Periodical Survey. Suspect areas including structures in way of the splash zone are to be tested for thickness and results submitted to the attending Surveyor for review.

11 Structural Deterioration

Where thickness measurement and visual examination show evidence of significant structural deterioration, the structural integrity of the structure for continuous use is to be justified by engineering analyses. Deteriorated structural members are to be modeled such that they will add hydrodynamic or wind loads to the Bottom-founded Offshore Wind Turbine Installation, but will not contribute to the strength of the Bottom-founded Offshore Wind Turbine Installation. Results of these analyses are to be submitted to ABS for review and approval. If the results show that structural integrity is inadequate, the deteriorated structural components are to be suitably reinforced or replaced with new materials having required dimensions and properties in accordance with approved procedure.

13 Marine Growth

During any Annual or Special Periodical Survey, assessment of the degree of marine growth is to be carried out. Marine growth is to be removed where it is found to be thicker than the original approved design. If the Owner decides to leave the marine growth greater than what is allowed in the approved design, the Owner is to justify that the higher hydrodynamic loading due to the additional marine growth will not affect the structural integrity of the structure. The Owner is to at least submit an in-place analysis to justify that the installation is capable of withstanding environmental wave loads resulting from the maximum marine growth that the Owner is prepared to maintain.

15 Maintenance of Rotor-Nacelle Assembly (15 January 2013)

The Owner is to submit an annual report for review by the attending ABS Surveyor attesting to the following:

- i) Maintenance has been carried out by authorized and qualified personnel in accordance with the maintenance manual.
- ii) The control settings have been checked with regard to conformance with the limiting values specified in design documentation of the classed Bottom-founded Offshore Wind Turbine Installation.
- iii) All repair, modification and replacement have been carried out in accordance with the manufacturers' recommendations and have not altered values of RNA parameters specified in design documentation of the classed Bottom-founded Offshore Wind Turbine Installation.

17 Statutory Certification (15 January 2013)

When ABS is authorized to perform surveys on behalf of a coastal State or a governmental authority, and when requested by the Owner, items as specified by the coastal State, the governmental authority or Owner will be surveyed. Reports indicating the results of such surveys will be issued accordingly. Where the periodicity and types of surveys on behalf of a coastal State or a governmental authority differ from those required by the applicable portions of this Section, coastal State or governmental authority's requirements take precedence.

19 Risk-based Surveys for Maintenance of Class (15 January 2013)

A properly developed risk-based inspection plan or reliability centered maintenance plan may be credited as satisfying requirements of surveys for maintenance of Class for the Bottom-founded Offshore Wind Turbine Installation. The plan is to be developed in accordance with the *ABS Guide for Surveys Using Risk-Based Inspection for the Offshore Industry* or the *ABS Guide for Surveys Using Reliability-Centered Maintenance*.

The application of the Guides referenced above in this Subsection does not cover any statutory survey requirements that may apply to the Bottom-founded Offshore Wind Turbine Installation being considered. Only when the governmental authorities accept and authorize ABS for certification based on risk-based inspection techniques, ABS will carry out such surveys, as authorized. The Owner is to ensure that in developing the inspection plan, due consideration is given to applicable requirements external to ABS. If the governmental authorities do not accept a risk-based approach, surveys will be carried out in a conventional, prescriptive manner in compliance with 1-3/1 through 1-3/17.

CHAPTER 1 Classification and Surveys

SECTION 4 Definitions

1 Types of Support Structures

1.1 Pile-Supported Structure

A structure supported by foundation elements or suction type piles driven into the sea floor

1.3 Gravity Structure

A structure supported by the foundation structure resting directly on the sea floor

The geometry and weight of foundation structure are selected to mobilize available cohesive and frictional strength components of the sea floor soil to resist loadings.

1.5 Self-Elevating Unit to be Used as the Support Structure

A unit with movable legs capable of raising its hull above the surface of the sea and intended to be used as the site-dependent Support Structure of an offshore wind turbine

The hull of a self-elevating unit has sufficient buoyancy to transport the unit to a desired location. Once on location, the hull is raised to a predetermined elevation above the sea surface on its legs, which are supported by the sea floor. The legs of such unit may be designed to penetrate the seabed, may be fitted with enlarged sections or footings, or may be attached to a bottom mat.

1.7 Compliant Tower

A structure that consists of a slender tower supported at the sea floor by an installed foundation or by a large spudcan

A compliant tower may also be partially supported by buoyancy aids. Guy lines may be used for lateral restraints.

3 Terminology

3.1 Material Application Categories

The material application of structural members in the Bottom-founded Offshore Wind Turbine Installation is to be in accordance with the categories listed in this paragraph.

3.1.1 Special Application Structure

Special application structure refers to highly stressed members, located at intersections of main structural elements and other areas of high stress concentration where the occurrence of a fracture could induce a major structural failure.

3.1.2 Primary Application Structure

Primary application structure refers to primary load carrying members of a structure where the occurrence of a fracture could induce a major structural failure.

3.1.3 Secondary Application Structure

Secondary application structure refers to less critical members due to a combination of lower stress and favorable geometry or where an incidence of fracture is not likely to induce a major structural failure.

3.3 Bottom-founded Offshore Wind Turbine Installation (15 January 2013)

A Bottom-founded Offshore Wind Turbine Installation is a site-dependent Support Structure of an Offshore Wind Turbine attached on and supported by the sea floor. The Support Structure, which is defined in 1-4/3.51, encompasses the Tower, Substructure, and Foundation.

The design of the Bottom-founded Offshore Wind Turbine Installation is based on environmental and foundation conditions at a particular offshore site where it is intended to be installed. The sea floor attachment of the Support Structure may be obtained by pilings, direct bearing, or other types of foundation.

In this Guide, the Bottom-founded Offshore Wind Turbine Installation does not include wind turbine components such as nacelle, rotor, generators, and gear box.

3.5 Consultant

A consultant is any person who, through education and experience, has established credentials of professionalism and knowledge in the stated field.

3.7 Cut-In Wind Speed (V_{in})

The lowest 10-minute mean wind speed at Hub Height at which the wind turbine starts to produce power in the case of steady wind without turbulence

3.9 Cut-Out Wind Speed (V_{out}) (15 January 2013)

The highest 10-minute mean wind speed at Hub Height at which the wind turbine is designed or chosen to produce power in the case of steady wind without turbulence

3.11 Emergency Shutdown

Rapid shutdown of the wind turbine triggered by a protection function or by manual intervention

3.13 Fabricator (15 January 2013)

A Fabricator is any person or organization having the responsibility to perform any or all of the following: fabrication, assembly, erection, inspection, testing, load-out, transportation, and installation.

3.15 Gust

Brief rise and fall in wind speed lasting less than 1 minute

3.17 Hub Height (15 January 2013)

Height of the center of the swept area of the wind turbine rotor above the Still Water Level

3.19 Idling

Condition of a wind turbine that is rotating slowly and not producing power

3.21 Mean Sea Level or Mean Still Water Level (MSL)

Average level of the sea over a period long enough to remove variations due to waves, tides and storm surges

3.23 Mean Wind Speed

Statistical mean value of the instantaneous wind speed over a specified time interval

3.25 Normal Shutdown

Wind turbine shutdown operation in which all stages are under the control of the control system

3.27 Offshore Wind Farm

A group of Offshore Wind Turbines installed at an offshore site

3.29 Offshore Wind Turbine

An Offshore Wind Turbine consists of a Rotor-Nacelle Assembly and its Support Structure, as defined in 1-4/3.43 and 1-4/3.51, respectively.

3.31 Omni-directional (Wind, Waves or Currents)

Acting in all directions

3.33 Owner

An owner is any person or organization who owns Offshore Wind Turbines.

3.35 Parked

Condition of a wind turbine that is either in a Standstill or an Idling condition, depending on the design of the wind turbine

3.37 Rated Power

Quantity of power assigned, generally by a manufacturer, for a specified operating condition of a component, device, or equipment. For wind turbines, it is the maximum continuous electrical power output which a wind turbine is designed to achieve under normal operating and external conditions.

3.39 Rated Wind Speed (V_r)

Minimum 10-minute mean wind speed at Hub Height at which a wind turbine's Rated Power is achieved in the case of steady wind without turbulence

3.41 Return Period (Recurrence Period)

A return period is an average time duration between occurrences of an event or of a particular value being exceeded. A return period in years is equal to the reciprocal of the annual probability of exceedance of an event or of a particular value of a random parameter such as wind speed, wave height or sea elevation.

3.43 Rotor-Nacelle Assembly (RNA)

A Rotor-Nacelle Assembly of a horizontal axis wind turbine, carried by the Support Structure, consists of:

- i) The Rotor components, including blades, hub, shaft, and spinner.
- ii) The Nacelle, a housing which contains the mainframe, generator frame, drive train components, electrical generator components, wind turbine control and protection components and other elements on top of the Tower.

3.45 Splash Zone (15 January 2013)

Part of the Support Structure containing the areas above and below the Mean Sea Level and regularly subjected to wetting due to wave and tide action

3.47 Standstill

Condition of a wind turbine that is not rotating

3.49 Still Water Level (SWL) (15 January 2013)

Abstract water level used for the calculation of wave kinematics and wave crest elevation. Still Water Level, which can be either above or below the Mean Sea Level, is calculated by adding the effect of tide and surge to the Mean Sea Level.

3.51 Support Structure (15 January 2013)

A Support Structure consists of the Tower, Substructure, and Foundation, which are defined as follows:

3.51.1 Tower

Structure component which extends upward from somewhere above the Still Water Level and connects the Substructure to the Rotor-Nacelle Assembly (RNA)

3.51.2 Substructure

Structure component which extends upward from the sea floor and connects the Foundation to the Tower

3.51.3 Foundation

Structural and/or geotechnical component which is located on and beneath the sea floor and transfers the loads acting on the structure into the sea floor

3.53 Surveyor

A Surveyor is a person employed by ABS whose principal functions are the surveillance during construction and the survey of marine structures and their components for compliance with the ABS Rules or other standards deemed suitable by ABS.

3.55 Turbulence Intensity

Ratio of the wind speed standard deviation to the mean wind speed, determined from the same set of measured data samples of wind speed, and taken over a specified period of time

3.57 Uni-directional (Wind, Waves or Currents)

Acting in a single directions

3.59 Water Depth

Vertical distance between the sea floor and the Still Water Level

3.61 Wind Profile (Wind Shear Law)

Mathematical expression for assumed wind speed variation with height above the Still Water Level

3.63 Yawing

Rotation of the rotor axis about a vertical axis for horizontal axis wind turbines

3.65 Yaw Misalignment

Horizontal deviation of the wind turbine rotor axis from the wind direction

CHAPTER 2 Materials and Welding

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CHAPTER 2 Materials and Welding

SECTION 1 Materials

1 Structural Steels

1.1 General

1.1.1 Scope

This Subsection covers specifications for materials used for the construction of offshore steel structures. When material other than steel is used as a structural material, documentation is to indicate the mechanical properties, toughness, fatigue, and corrosion characteristics of the proposed material. Where such materials are used in combination with steel, galvanic effects are to be taken into account, as applicable.

This Subsection is not intended for metals used in reinforced or prestressed concrete, which is addressed in 2-1/3. All materials are to be suitable for intended service conditions; they are to be of good quality, defined by a recognized specification and free of injurious imperfections.

1.1.2 Material Selection

Materials used are required to exhibit satisfactory formability and weldability characteristics. As required, documentation is to be submitted to substantiate the applicability of proposed steel. Reference can be made to 2-1/Table 2 and 2-1/Table 3 of this Guide for ASTM and API steel grades and to Appendix A of the *ABS Rules for Building and Classing Offshore Installations* for guidance on selection of ABS grades of steel.

1.1.3 Corrosion Control

Details of corrosion control systems (such as coatings, sacrificial anodes or impressed current systems) are to be submitted with adequate supporting data to show their suitability. Such information is to indicate the extent to which the possible existence of stress corrosion, corrosion fatigue, and galvanic corrosion due to dissimilar metals are to be considered. Where the intended sea environment contains unusual contaminants, any special corrosive effects of such contaminants are also to be considered. Appropriate coatings may be used to achieve satisfactory corrosion protection for miscellaneous parts such as bolts and nuts.

1.1.4 Toughness

Materials are to exhibit fracture toughness which is satisfactory for the intended application as supported by previous satisfactory service experience or appropriate toughness tests. Where the presence of ice is judged as a significant environmental factor, material selection may require special consideration.

1.1.5 Through Thickness Stress

In cases where principal loads, from either service or weld residual stresses, are imposed perpendicular to the surface of a structural member, the use of steel with improved through thickness (Z-direction) properties may be required.

1.3 Steel Properties

1.3.1 General

Material specifications are to be submitted for review or approval. Due regard is to be given to established practices in the country in which material is produced and the purpose for which the material is intended.

1.3.2 Tensile Properties

In 2-1/Table 1, the designation Group I, II or III is used to categorize tensile properties.

1.3.3 Toughness

Appropriate supporting information or test data are to indicate that the toughness of the steels will be adequate for their intended application and minimum service temperature. Criteria indicative of adequate toughness are contained in 2-1/1.5.

1.3.4 Bolts and Nuts

Bolts and nuts are to have mechanical and corrosion characteristics comparable to the structural elements being joined and are to be manufactured and tested in accordance with recognized material standards.

1.5 Toughness Criteria for Steel Selection

1.5.1 General

When members are subjected to significant tensile stress, fracture toughness is to be considered in the selection of materials.

1.5.2 Steel Classification

Steels are to be classified as Groups I, II or III according to their tensile properties as listed in 2-1/Table 1. It should be noted that the yield strengths given in 2-1/Table 1 are provided only as a means of categorizing steels.

TABLE 1
Steel Tensile Properties

Group	Yield Strength f_y	
	ksi	MPa
II	$f_y < 40$	$f_y < 275$
II	$40 \leq f_y \leq 60$	$275 \leq f_y \leq 415$
III	$60 \leq f_y \leq 100$	$415 \leq f_y \leq 690$

Some of the typical ASTM and API steels belonging to the groups of 2-1/Table 1 are shown in 2-1/Table 2 and 2-1/Table 3. Steels other than those mentioned therein may be used, provided that their chemical composition, mechanical properties and weldability are similar to those listed.

TABLE 2
Structural Steel Plates and Shapes

Group	Specification & Grade	Yield Strength		Tensile Strength	
		ksi	MPa	ksi	MPa
I	ASTM A36	36	250	58-80	400-550
	ASTM A131 Grade A (ABS Grade A)	34	235	58-75	400-515
	ASTM A285 Grade C	30	205	55-75	380-515
	ASTM A131 Grades B, D (ABS Grades B, D)	34	235	58-75	400-515
	ASTM A516 Grade 65	35	240	65-85	450-585
	ASTM A573 Grade 65	35	240	65-77	450-530
	ASTM A709 Grade 36T2	36	250	58-80	400-550
	ASTM A131 Grade E (ABS Grade E) (ABS Grade E)	34	235	58-75	400-515
II	ASTM A572 Grade 42	42	290	60 min.	415 min.
	ASTM A572 Grade 50	50	345	65 min.	450 min.
	ASTM A588 (to 2 in. thick)	50	345	70 min.	485 min.
	ASTM A709 Grades 50T2, 50T3	50	345	65 min.	450 min.
	ASTM A131 Grade AH32 (ABS Grade AH32)	46	315	68-85	470-585
	ASTM A131 Grade AH36 (ABS Grade AH36)	51	350	71-90	490-620
	API Spec 2H-Grade 42	42	290	62-80	425-550
	API Spec 2H-Grade 50 (to 2½ in. thick)	50	345	70-90	485-620
	(over 2½ in. thick)	47	325	70-90	485-620
	API Spec 2W-Grade 42 (to 1 in. thick)	42-67	290-460	62 min.	425 min.
	(over 1 in. thick)	42-62	290-430	62 min.	425 min.
	Grade 50 (to 1 in. thick)	50-75	345-515	65 min.	450 min.
	(over 1 in. thick)	50-70	345-485	65 min.	450 min.
	Grade 50T (to 1 in. thick)	50-80	345-550	70 min.	485 min.
	(over 1 in. thick)	50-75	345-515	70 min.	485 min.
	API Spec 2Y-Grade 42 (to 1 in. thick)	42-67	290-460	62 min.	425 min.
	(over 1 in. thick)	42-62	290-430	62 min.	425 min.
	Grade 50 (to 1 in. thick)	50-75	345-515	65 min.	450 min.
	(over 1 in. thick)	50-70	345-485	65 min.	450 min.
	Grade 50T (to 1 in. thick)	50-80	345-550	70 min.	485 min.
	(over 1 in. thick)	50-75	345-515	70 min.	485 min.
	ASTM A131 Grades DH32, EH32 (ABS Grades DH32, EH32)	46	315	68-85	470-585
	Grades DH36, EH36 (ABS Grades DH36, EH36)	51	350	71-90	490-620
	ASTM A537 Class 1 (to 2½ in. thick)	50	345	70-90	485-620
	ASTM A633 Grade A	42	290	63-83	435-570
	Grades C, D	50	345	70-90	480-620
	ASTM A678 (80) Grade A	50	345	70-90	485-620
	ASTM A992	50-65	345-450	65 min.	450 min.
III	ASTM A537 Class 2	60	415	80-100	550-690
	ASTM A633 Grade E	60	415	80-100	550-690
	ASTM A678 (80) Grade B	60	415	80-100	550-690
	API Spec 2W-Grade 60 (to 1 in. thick)	60-90	415-620	75 min.	515 min.
	(over 1 in. thick)	60-85	415-585	75 min.	515 min.
	API Spec 2Y-Grade 60 (to 1 in. thick)	60-90	415-620	75 min.	515 min.
	(over 1 in. thick)	60-85	415-585	75 min.	515 min.
	ASTM A710-Grade A Class 3 (to 2 in. thick)	75	515	85 min.	585 min.
	(2 in. to 4 in. thick)	65	450	75 min.	515 min.
	(over 4 in. thick)	60	415	70 min.	485 min.

TABLE 3
Structural Steel Pipes

Group	Specification & Grade	Yield Strength		Tensile Strength	
		ksi	MPa	ksi	MPa
I	API 5L-Grade B	35	240	60 min.	415 min.
	ASTM A53 Grade B	35	240	60 min.	415 min.
	ASTM A135 Grade B	35	240	60 min.	415 min.
	ASTM A139 Grade B	35	240	60 min.	415 min.
	ASTM A381 Grade Y35	35	240	60 min.	415 min.
	ASTM A500 Grade A	33-39	230-270	45 min.	310 min.
	ASTM A501	36	250	58 min.	400 min.
	ASTM A106 Grade B	35	240	60 min.	415 min.
	ASTM A524 (strength varies with thickness)	30-35	205-240	55-85	380-585
II	API 5L95 Grade X42 (2% max. cold expansion)	42	290	60 min.	415 min.
	API 5L95 Grade X52 (2% max. cold expansion)	52	360	66 min.	455 min.
	ASTM A500 Grade B	42-46	290-320	58 min.	400 min.
	ASTM A618 Grade Ia, Ib & II (to 3/4 in. thick)	50	345	70 min.	485 min.
	API 5L95 Grade X52 (with SR5, SR6, or SR8)	52	360	66 min.	455 min.

1.5.3 Toughness Characteristics

Satisfactory toughness characteristics can be demonstrated by any one of the following.

- Demonstration of past successful application, under comparable conditions, of a steel produced to a recognized standard (such as those of the ASTM, API or other recognized standard).
- Demonstration that the steel manufactured by a particular producer using a specific manufacturing process has minimum toughness levels representative of those listed herein.
- Charpy impact testing in accordance with 2-1/Table 4.

1.7 Minimum Service Temperature

Minimum service temperature refers to the temperature of the material and is generally to be established in accordance with 2-1/1.7.1 to 2-1/1.7.3 below. This temperature is to be based on meteorological data taken over a period of not less than 10 years for the lowest average daily temperature.

1.7.1 Material below the Splash Zone

For material below the splash zone (see 5-1/5.11), the service temperature is defined as 0°C (32°F). A higher service temperature may be used if adequate supporting data can be presented relative to the lowest average daily water temperature applicable to the depths involved.

1.7.2 Material within or above the Splash Zone

For material within or above the splash zone, the service temperature is the same as the lowest average daily atmospheric temperature. A higher service temperature may be used if the material above the waterline is warmed by adjacent sea water temperature or by auxiliary heating.

1.7.3 Special Conditions

In all cases where material temperature is reduced by localized cryogenic storage or other cooling conditions, such factors are to be taken into account in establishing minimum service temperature.

TABLE 4
Charpy Toughness Specification for Steels

Group	Section Size	Energy Absorption (Longitudinal)	
		ft-lb	Joules
I	6 mm < t < 19 mm (0.25 in. < t < 0.75 in.)	15	20
	t > 19 mm (0.75 in.)	20	27
II, III	t > 6 mm (0.25 in.)	25	34

Notes

- 1 Test Temperatures – The following applies for service temperatures down to –30°C (–22°F). For lower service temperatures, test requirements are to be specially considered.

- a For structural members and joints whose performance is vital to the overall integrity of the structure and which experience an unusually severe combination of stress concentration, rapid loading, cold working, and restraint, the impact test guidelines of 2-1/Table 4 are to be met at test temperatures as given below.

Group	Test Temperature	Minimum Service Temperature (As determined by 2-1/1.7)
I, II	30°C (54°F) below Minimum Service Temperature	
III	–40°C (–40°F)	–10°C (32°F)
	–50°C (–58°F)	–10°C (14°F)
	–50°C (–58°F)	–20°C (–4°F)
	–60°C (–76°F)	–30°C (–22°F)

- b For structural members and joints which sustain significant tensile stress and whose fracture may pose a threat to the survival of the structure, the impact test guidelines of 2-1/Table 4 are to be met at test temperatures as given below.

Group	Test Temperature	Minimum Service Temperature (As determined by 2-1/1.7)
I, II	10°C (18°F) below Minimum Service Temperature	
III	–40°C (–40°F)	–10°C (32°F)
	–40°C (–40°F)	–10°C (14°F)
	–40°C (–40°F)	–20°C (–4°F)
	–50°C (–58°F)	–30°C (–22°F)

- c For primary structural members subject to significant tensile stresses and whose usage warrants impact toughness testing, the impact test guidelines of 2-1/Table 4 are to be met at the following test temperatures.

Group	Test Temperature	Minimum Service Temperature (As determined by 2-1/1.7)
I, II	At Minimum Service Temperature	
III	Same as Note 1b	

- d For structural members which have sufficient structural redundancy so that their fracture would not pose a threat to the survivability of the structure, the toughness criteria specified for c above may be relaxed provided the materials used in such cases are appropriate for the loading conditions, loading rates, and temperatures encountered in service.

- 2 Impact tests are not necessary for section sizes below 6 mm (0.25 in.) in thickness.

TABLE 4 (continued)
Charpy Toughness Specification for Steels

- 3 Energy values in 2-1/Table 4 are minimum average values for full-size longitudinal specimens. Alternative toughness criteria which may be applied are:
 - i) Under-sized longitudinal specimens: proportional reduction in 2-1/Table 4 energy values in accordance with ASTM A20 or equivalent.
 - ii) Transverse specimens: $\frac{2}{3}$ of the energy values shown in 2-1/Table 4 but in no case less than 20 Joules (15 ft-lb).
 - iii) Longitudinal or transverse specimens: lateral expansion is not to be less than 0.5 mm (0.02 in.), or 0.38 mm (0.015 in.), respectively.
 - iv) Nil-ductility temperature (NDT) as determined by drop weight tests is to be 5°C (10°F) below the test temperature indicated in note 1 above.
 - v) Other fracture toughness tests as appropriate.
- 4 The minimum number of specimens to be tested per heat is to be three; however, this number is to be increased in accordance with usage of the material (see ASTM A673 or equivalent).

3 Materials for Concrete Construction

3.1 General

3.1.1 Scope

This Subsection covers specifications for materials for concrete used in the construction of the Support Structure of an offshore wind turbine. It includes the metals used in reinforced or prestressed concrete. All materials are to be suitable for intended service conditions and are to be of good quality, defined by recognized specifications and free of injurious defects. Materials used in the construction of concrete structures are to be selected with due attention given to their strength and durability in the marine environment. Materials which do not conform to the requirements of this Subsection may be considered for approval upon presentation of sufficient evidence of satisfactory performance.

3.1.2 Zones

Particular attention is to be given in each of the following zones (see 5-1/5.11):

- i) *Submerged zone*: chemical deterioration of the concrete, corrosion of the reinforcement and hardware, and abrasion of the concrete.
- ii) *Splash zone*: freeze-thaw durability, corrosion of the reinforcement and hardware, chemical deterioration of the concrete, and fire hazards.
- iii) *Ice zone*: freeze-thaw durability, corrosion of the reinforcement and hardware, chemical deterioration of the concrete, fire hazards, and abrasion of the concrete.
- iv) *Atmospheric zone*: freeze-thaw durability, corrosion of reinforcement and hardware, and fire hazards.

3.3 Cement

3.3.1 Type

Cement is to be equivalent to Types I or II Portland cement as specified by ASTM C150 or Portland-pozzolan cement as specified by ASTM C595. ASTM C150 Type III Portland cement may be specially approved for particular applications.

3.3.2 Tricalcium Aluminate

The tricalcium aluminate content of the cement is generally to be in the 5% to 10% range.

3.3.3 Oil Storage

For environments which contain detrimental sulfur bearing materials (such as where oil storage is planned and the oil is expected to contain sulfur compounds which are detrimental to concrete durability), the maximum content of tricalcium aluminate is to be at the lower end of the 5% to 10% range. Alternatively, pozzolans, or pozzolans and fly ash, may be added or a suitable coating employed to protect the concrete.

3.5 Water

3.5.1 Cleanliness

Water used in mixing concrete is to be clean and free from injurious amounts of oils, acids, alkalis, salts, organic materials or other substances that may be deleterious to concrete or steel.

3.5.2 Non-potable Water

If non-potable water is proposed for use, the selection of proportions of materials in the concrete is to be based on test concrete mixes using water from the same source. The strength of mortar test cylinders made with non-potable water is not to be less than 90% of the strength of similar cylinders made with potable water. Strength test comparisons are to include 7-day and 28-day strength data on mortars prepared and tested in accordance with recognized standards such as ASTM C109.

3.7 Chloride or Sulfide Content

Water for structural concrete or grout is not to contain more than 0.07% chlorides as Cl by weight of cement or more than 0.09% sulfates as SO_4 when tested by ASTM D512. Chlorides in mix water for prestressed concrete or grout are to be limited to 0.04% by weight of cement.

Total chloride content, as Cl, of the concrete prior to exposure is not to exceed 0.10% by weight of the cement for normal reinforced concrete and 0.06% by weight of cement for prestressed concrete.

3.9 Aggregates

3.9.1 General

Aggregates are to conform to the requirements of ASTM C33 or equivalent. Other aggregates may be used if there is supporting evidence that they produce concrete of satisfactory quality. When specially approved, lightweight aggregates similar to those specified in ASTM C330 may be used for conditions that do not pose durability problems.

3.9.2 Washing

Marine aggregates are to be washed with fresh water before use to remove chlorides and sulfates so that the total chloride and sulfate content of the concrete mix does not exceed the limits defined in 2-1/3.7.

3.9.3 Size

The maximum size of the aggregate is to be such that the concrete can be placed without voids. It is recommended that the maximum size of the aggregate is not to be larger than the smallest of the following: one-fifth of the narrowest dimension between sides of forms; one-third of the depth of slabs; three-fourths of the minimum clear spacing between individual reinforcing bars, bundles of bars, prestressing tendons or post-tensioning ducts.

3.11 Admixtures

3.11.1 General

The admixture is to be shown capable of maintaining essentially the same composition and performance throughout the work as the product used in establishing concrete proportions. Admixtures containing chloride ions are not to be used if their use will produce a deleterious concentration of chloride ions in the mixing water.

3.11.2 Recognized Standards

Admixtures are to be in accordance with applicable recognized standards such as ASTM C260, ASTM C494, ASTM C618 or equivalents.

3.11.3 Pozzolan Content

Pozzolan or pozzolan and fly ash content is not to exceed 15% by weight of cement unless specially approved.

3.13 Steel Reinforcement

Steel reinforcement used in offshore concrete structures is to be suitable for its intended service and in accordance with recognized standards.

3.13.1 Reinforcement for Non-Prestressed Concrete

Non-prestressed reinforcement is to be in accordance with one of the following specifications or its equivalents.

- i) Deformed reinforcing bars and plain bars: ASTM A615
- ii) Bar and rod mats: ASTM A184
- iii) Plain wire for spiral reinforcement: ASTM A82, ASTM A704
- iv) Welded plain wire fabric: ASTM A185
- v) Deformed wire: ASTM A496
- vi) Welded deformed wire fabric: ASTM A497

3.13.2 Welded Reinforcement

Reinforcement which is to be welded is to have the properties needed to produce satisfactory welded connections. Welding is to be in accordance with recognized specifications such as AWS D1.1, or is to be proven to produce connections of satisfactory quality.

3.13.3 Steel Reinforcement for Prestressed Concrete

Steel reinforcement for prestressed concrete is to be in accordance with one of the following specifications or equivalent.

- i) Seven-wire strand: ASTM A416
- ii) Wire: ASTM A421

3.13.4 Other Materials

Other prestressing tendons may be approved upon presentation of evidence of satisfactory properties.

3.15 Concrete

The concrete is to be designed to assure sufficient strength and durability. A satisfactory method for quality control of concrete is to be used which is equivalent to ACI 318. Mixing, placing and curing of concrete are to conform to recognized standards.

3.17 Water-Cement Ratios

Unless otherwise approved, water-cement ratios and 28-day compressive strengths of concrete for the three exposure zones are to be in accordance with 2-1/Table 5.

TABLE 5
Water-Cement Ratios and Compressive Strengths

<i>Zone</i>	<i>Maximum w/c Ratio</i>	<i>Minimum 28-day Cylinder Compressive Strength</i>
Submerged	0.45	35 MPa (5000 psi)
Splash and Atmospheric	0.40 to 0.45*	35 MPa (5000 psi)

* Depending upon severity of exposure

3.19 Other Durability Requirements

3.19.1 Cement Content

Minimum cement content is to have an adequate amount of paste for reinforcement protection and is generally not less than 355 kg/m³ (600 lb/yd³).

3.19.2 Freeze-Thaw Durability

When freeze-thaw durability is required, the concrete is to contain entrained air in accordance with a recognized standard such as ACI 211.1. Attention is to be paid to the appropriate pore distribution of the entrained air and the spacing between pores in the hardened concrete. The calculated spacing factors are not to exceed 0.25 mm (0.01 in.).

3.19.3 Scouring

When severe scouring action is expected, the coarse aggregate is to be as hard as the material causing the abrasion, the sand content of the concrete mix is to be kept as low as possible, and air entrainment is to be limited to the minimum appropriate to the application.

3.21 Grout for Bonded Tendons

3.21.1 General

Grout for bonded tendons is to conform to ACI 318 or equivalent.

3.21.2 Chlorides and Sulfates

Grout is not to contain chlorides or sulfates in amounts which are detrimental to the structure. Limitations are included in 2-1/3.7.

3.21.3 Contents

Grout is to consist of Portland cement and potable water, or Portland cement, sand, and potable water. Admixtures may be used only after sufficient testing to indicate that their use is beneficial and that they are free of harmful quantities of chlorides, nitrates, sulfides, sulfates or any other material which has been shown to be detrimental to the steel or grout.

3.21.4 Sand

Sand, if used, is to conform to ASTM C144 or equivalent, except that gradation may be modified as necessary to obtain increased workability.

3.21.5 Preparation

Proportions of grouting materials are to be based on results of tests on fresh and hardened grout prior to beginning work. The water content is to be the minimum necessary for proper placement but in no case more than 50% of the content of cement by weight. Grout is to be properly mixed and screened.

3.21.6 Temperature

Temperature of members at the time of grouting is to be above 10°C (50°F) and is to be maintained at this temperature for at least 48 hours.

CHAPTER 2 Materials

SECTION 2 Welding and Fabrication

1 Introduction

Welding for steel structures is to comply with the pertinent requirements of a recognized code, such as the AWS D1.1 *Structural Welding Code – Steel*, or Chapter 4 of the *ABS Rules for Materials and Welding (Part 2)*. While the requirements of this Section are to be addressed using a recognized reference code, the reference code may not provide coverage of all necessary items. Therefore, this Section provides additional requirements which, as the need arises, extend the scope of the code to make it suitable for classification purposes. Also, because of the possible wide variation of requirements which may exist among selected welding codes, 2-2/9 through 2-2/13 give some specific requirements which are intended to verify a basic degree of uniformity in the welding performed for structures classed with ABS.

3 Overview

3.1 Plans and Specifications

Submitted plans or specifications are to be in accordance with 1-1/7 and they are to indicate clearly the extent of welding for the main parts of the structure. The plans or specifications are to indicate the extent of nondestructive inspection of the weld. The welding process, filler metal and joint design are to be indicated on plans or in separate specifications submitted for approval, which are to distinguish between manual and automatic welding. The Surveyor is to be informed of the planned sequences and procedures to be followed in the erection and welding of the main structural members. In all instances, welding procedures and filler metals are to be applied which will produce sound welds that have strength and toughness comparable to that of the base material.

3.3 Workmanship and Supervision

It is to be demonstrated that all welders and welding operators to be employed in the construction of structures to be classed are properly qualified and are experienced in the type of work proposed and in the proper use of the welding processes and procedures to be followed. A sufficient number of skilled supervisors is to be employed to verify thorough supervision and control of all welding operations. Inspection of welds employing methods outlined in 2-2/7.17 is to be carried out to the satisfaction of the Surveyor.

3.5 Welding Procedures

Procedures for the welding of all joints, including types of electrodes, edge preparations, welding techniques and proposed positions, are to be established before construction begins. Details of proposed welding procedures and sequences may be required to be submitted for review, depending on the intended application.

Special precautions, with regard to joint preparation, preheat, welding sequence, heat input and interpass temperature, are to be taken for welding thick sections. Ultrasonic inspection to verify the absence of injurious laminations may be required for material used where through thickness (Z-direction) properties are important.

5 Preparation for Welding

5.1 Edge Preparation and Fitting

Edge preparations are to be accurate and uniform and the parts to be welded are to be fitted in accordance with the approved joint detail. All means adopted for correcting improper fitting are to be to the satisfaction of the Surveyor. Where excessive root openings are encountered for butt weld connections, weld buildup of the edges may be approved by the Surveyor, depending upon the location of the joint and the welding procedures employed. Unless specially approved, such buildup of each edge, where permitted, is not to exceed $t/2$ or 12.5 mm ($1/2$ in.), whichever is less, where t is the thickness of the thinner member being welded. Where sections to be butt welded differ in thickness and have an offset on any side of more than 3 mm ($1/8$ in.), a suitable transition taper is to be provided. In general, the transition taper length is to be not less than three times the offset. The transition may be formed by tapering the thicker member or by specifying a weld joint design which will provide the required transition.

5.3 Alignment

Means are to be provided for maintaining the members to be welded in correct position and alignment during the welding operation. In general, strongbacks or other appliances used for this purpose are to be so arranged as to allow for expansion and contraction during production welding. The removal of such items is to be carried out to the satisfaction of the Surveyor.

5.5 Cleanliness

All surfaces to be welded are to be free from moisture, grease, loose mill scale, excessive rust and paint. Primer coatings of ordinary thicknesses, thin coatings of linseed oil or equivalent coatings may be used, provided it is demonstrated that their use has no adverse effect on the production of satisfactory welds. Slag and scale are to be removed not only from the edges to be welded but also from each pass or layer before the deposition of subsequent passes or layers. Weld joints prepared by arc-air gouging may require additional preparation by grinding or chipping and wire brushing prior to welding, to minimize the possibility of excessive carbon on the surfaces. Compliance with these cleanliness requirements is of prime importance in the welding of higher-strength steels (see 2-1/1.5, especially those which are quenched and tempered.

5.7 Tack Welds

Tack welds of consistent good quality, made with the same grade of filler metal as intended for production welding and deposited in such a manner as not to interfere with the completion of the final weld, need not be removed, provided they are found upon examination to be thoroughly clean and free from cracks or other defects. Preheat may be necessary prior to tack welding when the materials to be joined are highly restrained. Special consideration is to be given to using the same preheat as specified in the welding procedure when tack welding higher-strength steels, particularly those materials which are quenched and tempered. These same precautions are to be followed when making any permanent welded markings.

5.9 Run-on and Run-off Tabs

When used, run-on and run-off tabs are to be designed to minimize the possibility of high stress concentrations and base-metal and weld-metal cracking.

7 Production Welding

7.1 Environment

Proper precautions are to be taken to verify that all welding is done under conditions where the welding site is protected against the deleterious effects of moisture, wind, and severe cold.

7.3 Sequence

Welding is to be planned to progress symmetrically so that shrinkage on both sides of the structure will be equalized. The ends of frames and stiffeners are to be left unattached to the plating at the subassembly stage until connecting welds are made in the intersecting systems of plating, framing and stiffeners at the erection stage. Welds are not to be carried across an unwelded joint or beyond an unwelded joint which terminates at the joint being welded, unless specially approved.

7.5 Preheat and Postweld Heat Treatment

The use of preheat is to be considered when welding higher-strength steels, materials of thick cross section, materials subjected to high restraint, and when welding is performed under high humidity conditions or when the temperature of the steel is below 0°C (32°F). The control of interpass temperature is to be specially considered when welding quenched and tempered higher-strength steels. When preheat is used, the temperature is to be in accordance with the accepted welding procedure. Postweld heat treatment, when specified, is to be carried out using an approved method.

7.7 Low-hydrogen Electrodes or Welding Processes

Unless otherwise approved, the use of low-hydrogen electrodes or welding processes is required for welding all higher-strength steels, and may also be considered for ordinary-strength steel weldments subjected to high restraint. When using low-hydrogen electrodes or processes, proper precautions are to be taken to verify that the electrodes, fluxes and gases used for welding are clean and dry.

7.9 Back Gouging

Chipping, grinding, arc-air gouging or other suitable methods are to be employed at the root or underside of the weld to obtain sound metal before applying subsequent beads for all full-penetration welds. When arc-air gouging is employed, the selected technique is to minimize carbon buildup and burning of the weld or base metal. Quenched and tempered steels are not to be flame gouged using oxy-fuel gas.

7.11 Peening

The use of peening is not recommended for single-pass welds and the root or cover passes on multipass welds. Peening, when used to correct distortion or to reduce residual stresses, is to be effected immediately after depositing and cleaning each weld pass.

7.13 Fairing and Flame Shrinking

Fairing by heating or flame shrinking, and other methods of correcting distortion or defective workmanship in fabrication of main strength members and other members which may be subjected to high stresses, are to be carried out only with the expressed approval of the Surveyor. These corrective measures are to be kept to an absolute minimum when higher-strength quenched and tempered steels are involved, due to high local stresses and the possible degradation of the mechanical properties of the base material.

7.15 Weld Soundness and Surface Appearance

Production welds are to be sound, crack-free and reasonably free from lack of fusion or penetration, slag inclusions and porosity. The surfaces of welds are to be visually inspected and are to be regular and uniform with a minimum amount of reinforcement and reasonably free from undercut and overlap and free from injurious arc strikes. Contour grinding when required by an approved plan or specification or where deemed necessary by the Surveyor is to be carried out to the satisfaction of the Surveyor.

7.17 Inspection of Welds

Inspection of welded joints in important locations is to be carried out preferably by established nondestructive test methods such as radiographic, ultrasonic, magnetic-particle or dye-penetrant inspection. Approved acceptance criteria, or the *ABS Guide for Nondestructive Inspection of Hull Welds*, are to be used in evaluating radiographs and ultrasonic indications (see also 2-2/7.21). Radiographic or ultrasonic inspection, or both, is to be used when the overall soundness of the weld cross section is to be evaluated. Magnetic-particle or dye-penetrant inspection may be used when investigating the outer surface of welds, as a check of intermediate weld passes such as root passes, and to check back chipped, ground or gouged joints prior to depositing subsequent passes. Surface inspection of important tee or corner joints in critical locations, using an approved magnetic-particle or dye-penetrant method, is to be conducted to the satisfaction of the Surveyor. Some steels, especially higher-strength steels, may be susceptible to delayed cracking. When welding these materials, the final nondestructive testing is to be delayed for a suitable period to permit detection of such defects. Weld run-on or run-off tabs may be used where practicable and these may be sectioned for examination. The practice of taking weld plugs or samples by machining or cutting from the welded structure is not recommended and is to be used only in the absence of other suitable inspection methods. When such weld plugs or samples are removed from the welded structure, the holes or cavities thus formed are to be properly prepared and welded, using a suitable welding procedure as established for the original joint.