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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 8, *Ships and marine technology.*

Introduction

The series of International Standards applicable to the offshore wind industry, ISO 29400 to ISO 29406[1)], constitutes a comprehensive and common basis covering port and marine operations of all offshore structures installed and maintained by the offshore wind industries worldwide. Through their application, the intention is to achieve reliability levels appropriate for offshore wind farm components, whatever the type of structure and the nature or combination of materials used.

This International Standard presumes compliance with international (e.g. IMO), national and local rules and regulations. This International Standard does not replace the applicable rules and regulations. Adherence to this International Standard will not necessarily ensure compliance with all applicable rules and regulations.

It is important to recognize that during port and marine operations the structural integrity of the component is an overall concept comprising models for describing actions, structural analysis, design rules, safety elements, workmanship, quality control procedures and national requirements, all of which are mutually dependent. The modification of one aspect of design in isolation can disturb the balance of reliability inherent in the overall concept or structural system. It is necessary, therefore, to consider the implications involved in modifications in relation to the overall reliability of structures in offshore wind farms.

The series of International Standards applicable to offshore wind farms is intended to provide a wide latitude in the choice of structural configuration, material and techniques without hindering innovation. Sound engineering judgment is, therefore, necessary in the use of these International Standards.

ISO 29400 was developed to provide comprehensive requirements and guidance for the planning, engineering and safe execution of port and marine operations for all types of components of offshore wind farms including cable-laying and -burial barges and diving support vessels but excluding floating structures.

Port operations for installation of components of offshore wind farms cover all component transport to the ports, whether by land or via inland waterways, any intermediate storage as well as preassembly activities at the ports until placing the components close to any quayside for subsequent marine operations to start.

Marine operations for offshore wind farm structures cover loadout from the quayside, offshore transportation and installation phases when the structure is at risk from the marine environment up to and including any marine logistics during offshore commissioning works. Marine operations can extend to decommissioning, redeployment, removal, etc.

ISO 29400 describes the principles of and provides requirements and guidance for port and marine operations associated with WTG, cables and topsides installed in offshore wind farms, from the point of view of planning, engineering, implementation and documentation. Alternative requirements, methods and provisions can fulfil the intention of ISO 29400 and may be applied, provided it can be demonstrated that they achieve at least the same level of assurance and reliability. The overall objective of ISO 29400 is to ensure that port and marine operations are conducted within defined and recognized safety and reliability levels, wherever they are performed. Additional standards, codes and guidelines should also be taken into account, where applicable. Special attention should be paid to national regulations governing the area in which the port and marine operations are performed.

It is not the intent of ISO 29400 to govern the design of structures, systems and components used in port and marine operations, beyond the principles given. Recognized codes and standards are normally accepted as the basis for the detailed design and the fabrication requirements of such components.

Annex A provides some background and some additional information to the main body of the document and it is intended that it be read in conjunction with the main body of the document.

This International Standard is based on ISO 19901-6 while adapting it extensively to the specific requirements of the offshore wind industry.

1) Planned International Standards.

Ships and marine technology — Offshore wind energy — Port and marine operations

1 Scope

This International Standard provides comprehensive requirements and guidance for the planning and engineering of port and marine operations, encompassing all documents and works related to such port and marine operations, e.g. the design and analysis of the components, systems, equipment and procedures required to perform port and marine operations, as well as the methods or procedures developed to carry them out safely.

This International Standard is intended to be comprehensive, covering all relevant information related to port and marine operations necessary for the installation and maintenance of offshore wind farms. It is not applicable to the case of floating turbines moored to the seabed.

This International Standard is applicable to port and marine operations for offshore structures including:

— foundations made from steel and concrete gravity base structures (GBS);

— piled steel foundation structures;

— subsea templates and similar structures applied for pre-piling of foundations;

— steel towers, nacelles and blades forming part of the wind turbine generators (WTG);

— mobile offshore units (MOU): jackup vessel/self-elevating offshore unit topsides and components of any of the above for offshore substations or offshore accommodations platforms;

— array cables within the wind farms as well as export cables connecting the wind farm to the grid.

This International Standard is also applicable to modifications of existing structures, e.g. installation of additional modules or exchange of components.

This International Standard is not applicable to the following operations:

— construction activities, e.g. in a fabrication yard onshore, where there is no exposure to the marine environment;

— operational and routine activities during the service life of the windfarm related to the technical maintenance works regularly required for the components;

— diving;

— marine operations related to the operational and routine activities during the service life of the windfarm.

This International Standard presumes compliance with international, national and local rules and regulations. This International Standard does not replace the applicable rules and regulations.

2 Normative references

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

ISO 15544, *Petroleum and natural gas industries — Offshore production installations — Requirements and guidelines for emergency response*

ISO 17776, *Petroleum and natural gas industries — Offshore production installations — Guidelines on tools and techniques for hazard identification and risk assessment*

ISO 19901-1, *Petroleum and natural gas industries — Specific requirements for offshore structures — Part 1: Metocean design and operating considerations*[2)]

IMCA M 179, *Guidance on the Use of Cable Laid Slings and Grommets*

3 Terms and definitions

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

NOTE Other terms and definitions relevant for the use of this International Standard are also found in [10], [11] and [12].

3.1
action
external load applied to the structure (direct action) or an imposed deformation or acceleration (indirect action)

Note 1 to entry: An imposed deformation can be caused by fabrication tolerances, settlement, temperature change or moisture variation.

Note 2 to entry: An earthquake typically generates imposed accelerations.

[SOURCE: ISO 19900:2013, 3.3]

3.2
action effect
effect of actions on structural components

EXAMPLE Internal forces, moments, stresses, strains, rigid body motions or elastic deformations.

[SOURCE: ISO 19904-1:2006, 3.5]

3.3
adverse weather
meteorological and oceanographic conditions which may affect people, equipment or facilities, to such an extent that precautionary measures must be taken to safeguard the facility to maintain a safe system of work

Note 1 to entry: Adverse weather includes, snow, ice, hail, lightning, heavy rain, high wind, low cloud base, poor visibility, severe sea states and strong currents. Weather conditions can change quickly and the effects of short-term variations such as wind gusts must be considered

3.4
air cushion
air pumped into underbase compartments of the structure

Note 1 to entry: An air cushion is normally applied in order to reduce the draught and increase the freeboard and/or to alter the structural loading.

Note 2 to entry: Adapted from ISO 19903:2006, 3.10]

3.5
array cables
all cables between WTGs and between a wind turbine generator (WTG) and the offshore substation (3.100) connecting the WTGs with the offshore substation

2) To be published.

3.6
assembly
designed and fabricated group of bulk and equipment items that form one unit

[SOURCE: ISO 19901-5:2003, 3.1.1]

3.7
ballast
variable solid or fluid content in order to change the draught, stability, trim and/or heel of a structure afloat

Note 1 to entry: Adapted from ISO 19901-5:2003, 3.1.2.

3.8
ballast system
system used to change the draught, stability, trim and/or heel of a structure afloat

3.9
barge
simple floating vessel, normally non-propelled, on which material components of an offshore wind farm, material, people and equipment are transported

3.10
basic variable
one of a specified set of variables representing physical quantities that characterize actions, environmental influences, geometrical quantities or material properties, including soil properties

[SOURCE: ISO 19900:2013, 3.7]

3.11
bending efficiency factor
factor by which the calculated breaking strength of a rope is reduced to take account of the reduction in strength caused by bending around a shackle, trunnion, padear or crane hook

[SOURCE: ISO 19901-6:2009, 3.9]

3.12
blade
one of a number of structural members with aerodynamic lift surfaces assembled around the hub of a wind turbine

3.13
boat landing
part of the foundation appurtenance to be designed and used for accessing the foundation by means of a sea going vessel

3.14
bollard pull
towing or manoeuvring action that can be generated by a tug for an indefinite period of time with its propulsion system running at operational, as opposed to maximum revolutions per minute

Note 1 to entry: Bollard pull is expressed in kilonewtons.

[SOURCE: ISO 19901-6:2009, 3.10]

3.15
bolting
work to be carried out to join two components of the wind turbine generator (WTG) or between foundation and tower by means of a bolted connection

3.16
bridging document
document that aligns and co-ordinates the requirements and responses of various parties in relation to a specific aspect of a project

Note 1 to entry: A bridging document is commonly used to align and coordinate the emergency response procedures for owner and contractors.

[SOURCE: ISO 19901-6:2009, 3.11]

3.17
bumper
temporary structure designed to protect structures or modules during the initial fitting stage of an installation operation

[SOURCE: ISO 19901-6:2009, 3.12]

3.18
cable burial
process to bury a cable into the seabed up to a defined burial depth which was either previously laid on the seabed or which is directly buried during installation by using specific equipment

3.19
cable laying
all operations related to paying out an array cable (3.5) or an export cable (3.47) from a cable lay vessel onto the seabed

Note 1 to entry: For array cables the operations between the 1st-end (3.21) and 2nd-end pull-in (3.22) if array cables are not immediately buried.

3.20
cable pull-in
all activities and equipment to be carried out and used to safely pull array cables (3.5) or export cables (3.23) through the J-tubes and/or monopiles

3.21
1st end pull-in
pulling the first end of a section of an array cable (3.5) or export cable (3.23) into the foundation of a wind turbine generator (WTG) or an offshore substation

3.22
2nd end pull-in
pulling the second end of an array cable (3.5) or export cable (3.23) into the foundation of a wind turbine generator (WTG) or an offshore substation

3.23
cable string
several sections of array cables connected in a row and feeding into the offshore substation

3.24
cable testing
tests conducted with either array cables (3.5) or export cables (3.47) and, where relevant, also the fibre optics cables in order to verify the functionality of the cables, e.g. after loadout, after cable laying and/or after cable burial and electrical connection

3.25
characteristic value
value assigned to a basic variable associated with a prescribed probability of not being violated by unfavourable values during some reference period

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

[SOURCE: ISO 19900:2013, 3.10]

3.26
CoG envelope
defined constraint volume within which the centre of gravity (CoG) of an assembly or a module shall remain

Note 1 to entry: Adapted from ISO 19901-5:2003, 3.1.8.

[SOURCE: ISO 19901-6:2009, 3.14]

3.27
commissioning
activities after mechanical completion including electrical testing and start-up of wind turbine generators (WTGs), offshore substations, foundations and array and export cables

3.28
consequence factor
factor applied to critical structural components in the design of lifting operations to ensure that these components have an increased factor of safety in relation to the consequence of their failure

Note 1 to entry: Consequence factors are additional safety factors, applied to critical structural components of the lifted object over and above the normal safety factors used in a working stress design (WSD) analysis of the lifted object. They are, accordingly, applied to lift points, their attachments to the object and components in the object supporting lift points. They are not intended for application to slings, grommets and shackles.

[SOURCE: ISO 19901-6:2009, 3.15]

3.29
construction afloat
addition of material or outfitting to the structure while afloat

Note 1 to entry: Adapted from ISO 19903:2006, 3.17.

[SOURCE: ISO 19901-6:2009, 3.16]

3.30
crane vessel
vessel, ship or barge on which lifting equipment is mounted

Note 1 to entry: For the purposes of this International Standard, this term includes jack-up vessels, crane barges, crane ships, derrick barges, shear-leg barges and semi-submersible crane vessels.

[SOURCE: ISO 19901-6:2009, 3.17]

3.31
cribbing
arrangement of timber baulks, secured to the deck of the barge or vessel, designed to support the cargo

Note 1 to entry: Cribbing is generally arranged at strong points of the deck and/or cargo.

[SOURCE: ISO 19901-6:2009, 3.18]

3.32
currents
flow of water past a fixed location usually described in terms of a current speed and direction

[SOURCE: IEC 61400–3: 2009, 3.2]

3.33
deadweight
total carrying capacity of a floating structure

Note 1 to entry: This includes cargo weight, deck cargo, snow and ice, marine growth, ballast water, consumables and crew onboard a floating unit.

Note 2 to entry: Adapted from ISO 19901-5:2003, 3.1.11.

[SOURCE: ISO 19901-6:2009, 3.19]

3.34
deck mating
marine operation in which the platform topsides is floated into position and connected to the support structure

Note 1 to entry: This operation is normally conducted by ballasting and deballasting of the support structure.

Note 2 to entry: Adapted from: ISO 19903:2006, 3.18.

[SOURCE: ISO 19901-6:2009, 3.20]

3.35
decommissioning
process of shutting down a structure in an offshore wind farm and removing hazardous materials at the end of its production life

Note 1 to entry: Adapted from ISO 19900:2013, 3.14.

3.36
design criterion
quantitative formulation that describes the conditions that shall be fulfilled for each limit state

Note 1 to entry: Adapted from ISO 19900:2013, 3.15.

[SOURCE: ISO 19901-6:2009, 3.22]

3.37
design situation
set of physical conditions representing potential conditions during a certain time interval for which the design is expected to demonstrate that relevant limit states are not exceeded

Note 1 to entry: Adapted from ISO 19900:2013, 3.17.

[SOURCE: ISO 19901-6:2009, 3.23]

3.38
design value
value derived from the representative value for use in the design verification procedure

[SOURCE: ISO 19900:2013, 3.18]

3.39
determinate lift
lift where the slinging arrangement is such that the sling forces are statically determinate and not significantly affected by minor differences in sling length or elasticity

[SOURCE: ISO 19901-6:2009, 3.25]

3.40
displacement
weight of the volume of water displaced by a floating structure

Note 1 to entry: The weight of the water displaced is the sum of the lightship weight, deadweight and anchoring system load including vertical component of the mooring pre-tension.

Note 2 to entry: Adapted from ISO 19901-5:2003, 3.1.12.

3.41
dunnage
arrangement of timber on deck of a barge or vessel laid out to support the cargo

[SOURCE: ISO 19901-6:2009, 3.27]

3.42
dynamic action
action that induces acceleration of a structure or a structural component of a magnitude sufficient to require specific consideration

[SOURCE: ISO 19901-7:2013, 3.8]

3.43
dynamic amplification factor
DAF
ratio of a dynamic action effect to the corresponding static action effect provided as a factor to account for the dynamic effects on a crane while lifting an object — where applicable

Note 1 to entry: An appropriately selected DAF can be applied to static actions to simulate the effects of dynamic actions.

[SOURCE: ISO 19902:2007, 3.16]

3.44
electrical completion
all electrical works inside a wind turbine generator (WTG) conducted after finalization of mechanical completion (3.89) in order to allow for energization of the WTG

3.45
emergency preparedness bridging document
EPBD
document bridging emergency response plans of various parties working at an offshore installation site in order to achieve a mutually aligned procedure in case of emergency

3.46
exclusive cable zones
areas within the offshore installation site designated exclusively for the array cables of the wind farm and for the offshore installation works of the cable supplier

3.47
export cable
cables connecting an offshore wind farm with the shore via a cable connection between an offshore substation (3.100) and an onshore substation

3.48
failure mode and effect analysis
FMEA
analysis of possible failures of any component of the safety device and determination of their consequences for the overall safety function; allowing the classification of any failure as safe, dangerous, detected or undetected with respect to the safety function

3.49
fibre rope
rope made of various yarns and various types of construction

EXAMPLE A fibre rope can be a stranded rope consisting of three to eight strands, a parallel strand rope, a single or double-braided rope, etc.

Note 1 to entry: Each combination of yarn and type of construction normally results in different properties and characteristics.

[SOURCE: ISO 19901-6:2009, 3.30]

3.50
fibre rope grommet
FRG
endless loop-shaped sling made up from a single length of fibre rope

Note 1 to entry: A fibre rope grommet is of similar construction to a steel wire rope grommet (3.145).

[SOURCE: ISO 19901-6:2009, 3.31]

3.51
fibre rope sling
FRS
sling made from a single fibre rope, usually with spliced eye end terminations

[SOURCE: ISO 19901-6:2009, 3.32]

3.52
float-off
offloading an object from a submersible transport vessel or barge by means of submerging the vessel or barge deck to a depth that is sufficient to allow the object to float and be removed from the vessel/barge

[SOURCE: ISO 19901-6:2009, 3.34]

3.53
float-on
loading an object onto a submersible transport vessel or barge by means of submerging the vessel or barge deck to a depth that is sufficient to allow the floating object to be manoeuvred into position over the vessel/barge

Note 1 to entry: The object is then lifted from the water and onto the vessel/barge deck by deballasting the vessel/barge to its seagoing condition.

[SOURCE: ISO 19901-6:2009, 3.35]

3.54
float-out
transfer of a floating structure out of a flooded dry dock

[SOURCE: ISO 19901-6:2009, 3.36]

3.55
float-over
transfer of a major assembly supported on barge(s) onto its temporary or permanent structure by means of manoeuvring the major assembly over the structure and setting it down by means of ballasting the barge(s) supporting the assembly, deballasting the structure or lowering the supports of this assembly or combination thereof

[SOURCE: ISO 19901-6:2009, 3.37]

3.56
foundation
<offshore wind energy> part of an offshore wind turbine support structure which transfers the loads acting on the structure into the seabed

[SOURCE: IEC 61400-3: 2010; 3.11]

EXAMPLE Monopile, jacket structures or gravity based structures.

Note 1 to entry: Different foundation concepts are shown in Figure 1 together with other parts of an offshore wind turbine.

Note 2 to entry: While Figure 1 defines the foundation as the part below the substructure which is in the seabed, the term foundation as used in the offshore wind industry usually refers to the substructure and the foundation (terms as used in Figure 1). Thus a foundation as usually referred to in the offshore wind industry would be e.g. a monopile or a piled jacket structure. Therefore, when talking about a lift or an installation of e.g. a monopile, this ISO uses the term "foundation" instead of talking about "foundation and substructure" to be lifted.

3.57
good wind industry practice
(in connection with the operation as relevant), design and construction of the works, those practices, methods, acts, techniques and standards which are prudent and in accordance with applicable and generally accepted good practice for the works and in particular for carrying out works of a similar size and complexity as that of the works or operation of offshore wind farms of the similar size and type

3.58
grillage
steel structure, secured to the deck of a barge or vessel, designed to support the cargo and distribute the loads between the cargo and the barge or vessel

[SOURCE: ISO 19901-6:2009, 3.38]

3.59
grommet
endless loop-shaped sling made up from a single length of (fibre or steel wire) rope

Note 1 to entry: See also fibre rope grommet (3.50) and steel wire rope grommet (3.145).

[SOURCE: ISO 19901-6:2009, 3.39]

3.60
gross weight
calculated or weighed weight of the structure being lifted, including a weight contingency factor

Note 1 to entry: Sometimes the gross weight is referred to as a not-to-exceed (NTE) weight.

[SOURCE: ISO 19901-6:2009, 3.40]

3.61
grouting
offshore construction process used to connect steel sections of the foundations, e.g. monopile and transitions piece or jacket and piles by using a special concrete type of mixture which is being pumped into the void between the steel structures

3.62
guard vessel
special ship attending the offshore installation site required to maintain a higher degree of readiness in order to enforce the safety zone around an offshore construction site for non-construction vessels

3.63
gust wind speed
maximum value of the wind speed of a gust averaged over a short (3 s to 60 s) specified duration within a longer (1 min to 1 h) specified duration

Note 1 to entry: For design purposes, the specified duration depends on the dimensions and natural period of the (part of the) structure being designed such that the structure is designed for the most onerous conditions; thus, a small part of a structure is designed for a shorter gust wind speed duration (and hence a higher gust wind speed) than a larger (part of a) structure.

Note 2 to entry: In practice, for design purposes, the gust wind speeds for the different durations (e.g. 3 s, 5 s, 15 s, 60 s) are derived from the wind spectrum.

[SOURCE: ISO 19901-1:2005, 3.8]

3.64
Health, Safety, Security and Environment plan
HSSE plan
plan that includes activities on health, safety, security and environment during planning, design and execution of operations

3.65
heave compensation
system fitted to hoisting/lowering machinery on offshore construction vessels to enable the object being hoisted or lowered to maintain a constant vertical position when the vessel is oscillating in a vertical direction

[SOURCE: ISO 19901-6:2009, 3.41]

3.66
hook load
sum of the rigging weight, including the dynamic amplification factor (DAF), and the nominal lift weight

Note 1 to entry: static hook load is the hook load is the gross weight or NTE weight plus the rigging weight; dynamic hook load is the static hook load times DAF; nominal hook load is maximum allowed weight (including rigging) as per crane chart.

[SOURCE: ISO 19901-6:2009, 3.42]

3.67
hub
part mounted to the nacelle of a wind turbine in order to connect the blades forming the rotor assembly

3.68
indeterminate lift
any lift where the sling forces are not statically determinate

[SOURCE: ISO 19901-6:2009, 3.43]

3.69
intermediate storage
area in the staging port where the components for an offshore wind farm are temporarily stored before pre-assembly (3.112) and/or loadout onto transport vessels

3.70
jacket
foundation type of an offshore wind farm made of tubular steel members which are usually piled into the seabed

3.71
J-tube
tube being part of the foundation appurtenance designed and to be used for support and protection of the array cables (3.5) or export cable (3.47) from the seabed up to the top of the transition piece or a topside

3.72
launching
offloading an object into the water from a barge or other floating unit by means of sliding the object longitudinally, or less commonly, sideways along the floating unit

[SOURCE: ISO 19901-6:2009, 3.44]

3.73
lift point
connection between the rigging and the structure being lifted

Note 1 to entry: Lift points include padears, padeyes and trunnions.

[SOURCE: ISO 19901-6:2009, 3.45]

3.74
lift weight
gross weight times the dynamic amplification factor (DAF)

[SOURCE: ISO 19901-6:2009, 3.46]

3.75
lightship weight
dry and invariable weight of a floating unit

[SOURCE: ISO 19901-6:2009, 3.47]

3.76
limit state
state beyond which the structure no longer fulfils the relevant design criteria

[SOURCE: ISO 19900:2013, 3.28]

3.77
link beam
connecting beam between the quay and the barge

Note 1 to entry: The link beam can provide a structural connection, or can solely provide a smooth path for skidding or trailers.

[SOURCE: ISO 19901-6:2009, 3.49]

3.78
load case
compatible load arrangements, sets of deformations and imperfections considered simultaneously with permanent actions and fixed variable actions for a particular design or verification

[SOURCE: ISO 19902:2007, 3.29]

3.79
loadout
transfer of a foundation or, a wind turbine component, cables, a topside module of an offshore substation or any other equipment or components from land onto a barge or vessel by horizontal movement or by lifting

Note 1 to entry: The following types of loadout operation can be distinguished:

—floating: loadout from the quay onto a floating barge;

—grounded: loadout from the quay onto a grounded barge;

—lifted: loadout performed by crane;

—skidded: loadout where the structure is skidded, using a combination of skidways, skidshoes or runners, propelled by towing engines, jacks or winches;

—trailer: loadout where the structure is wheeled onto the barge using trailers or self-propelled modular transporters (SPMT).

Note 2 to entry: Adapted from ISO 19901-5:2003, 3.1.30.

3.80
location
one of many areas of an offshore construction site where a foundation with a wind turbine, an offshore substation or offshore accommodation platform will be or is located

3.81
marine operation
planned and controlled vertical or horizontal movement of a structure or component thereof over, in or on water

[SOURCE: ISO 19903:2006, 3.36]

3.82
marine spread
fleet of vessels assembled to perform a marine operation

[SOURCE: ISO 19901-6:2009, 3.53]

3.83
Marine Warranty Surveyor
MWS
independent expert appointed by the owner on behalf of a construction-all-risk (CAR) insurance company for third party review and approval of the planning, design and execution of the loadout, offshore transport and installation

3.84
marshalling port
harbour chosen to perform loadout and start the offshore transport

3.85
mating
transfer of a major assembly supported on barge(s) or vessel(s) to a temporary or permanent support structure

Note 1 to entry: The following types of mating operation can be distinguished:

—afloat: transfer of the barge supported major assembly to a floating structure by means of submerging the structure sufficiently to allow the assembly to be manoeuvred over it, then lifting the assembly off the barges by deballasting the structure;

—onto structure foundation: transfer of the barge supported major assembly to a foundation by means of manoeuvring it over the foundation, then ballasting the barge supporting the assembly or lowering the supports of this assembly in order to transfer the weight of the assembly onto the structure.

Note 2 to entry: Adapted from ISO 19901-5:2003, 3.1.31.

[SOURCE: ISO 19901-6:2009, 3.54]

3.86
maximum wave height
H_{max}
largest of all wave crests to adjacent trough values related to a certain time and area

3.87
mean wave period
T_{z}
zero-crossing period of a wave

3.88
mean wind speed
average velocity of wind commonly measured by anemometer at a defined height and averaged over a certain time frame

3.89
mechanical completion
stage of the process when the WTG is firmly bolted to the foundation, before in-situ commissioning and prior to commencing power generation

EXAMPLE Connection of ladders, WTG internal cabling, software installation required.

3.90
minimum breaking strength
MBS
certified strength of a chain, wire rope, fibre rope or accessories

[SOURCE: ISO 19901-6:2009, 3.55]

3.91
monopile
single pile to be driven into the seabed at foundation whereupon a transition piece is to be installed

3.92
mooring component
general class of component used in the mooring of floating structures

EXAMPLE Chain, steel wire rope, synthetic fibre rope, clump weight, buoy, winch/windlass or anchor.

[SOURCE: ISO 19901-6:2009, 3.56]

3.93
nacelle
housing which contains the drive-train and other elements an top of a horizontal axis wind turbine tower

[SOURCE: IEC 61400-3:2010, 3.34]

3.94
nominal value
value assigned to a basic variable determined on a non-statistical basis, typically from acquired experience or physical conditions

[SOURCE: ISO 19900:2013, 3.29]

3.95
not-to-exceed weight
NTE weight
maximum acceptable weight of the structure, with an associated limiting centre of gravity (CoG) envelope

Note 1 to entry: Adapted from ISO 19901-5:2003, 3.1.34.

[SOURCE: ISO 19901-6:2009, 3.58]

3.96
offload
transfer of a major assembly or a module from a barge or transport vessel to land by horizontal movement or by lifting

[SOURCE: ISO 19901-6:2009, 3.59]

3.97
offshore accommodation platform
fixed platform located inside an offshore wind farm used for accommodation of personnel during operational phase from which personnel embarks via helicopter, crew transfer vessel or other vessels to the wind turbine generator (WTG) for conducting service and maintenance

3.98
offshore installation site
area where the locations (3.80) of the foundations for the wind turbine generators (WTGs) and the offshore substation will be installed offshore

3.99
offshore installation vessel
vessel(s) installing the components of an offshore wind farm

EXAMPLE Foundations, transition pieces, towers, nacelles, blades, topsides.

3.100
offshore substation
structure in an offshore wind farm which connects the array cables (3.5) and the export cable (3.47) and transforms the voltage level between both

3.101
offshore wind farm
offshore site generating electricity from wind energy with the components such as foundations, transition pieces, piles, towers, nacelles, hub, blades, array cables (3.5) as well as export cable (3.47) and offshore substation (3.100) and/or offshore accommodation platform where required

3.102
Offshore Transmission Owner
OFTO
entity which takes responsibility of the assets which usually link offshore generation to the onshore network based on a long-term licence

Note 1 to entry: In terms of physical assets an OFTO will normally have the ownership of (i) offshore electricity transmission infrastructure such as offshore substations, the export cable as well as the onshore cabling, (ii) any onshore substations, and (iii) the electrical equipment relating to the operation thereof.

Note 2 to entry: OFTO differs from owner (3.106).

3.103
offshore transport
offshore transportation of the components of an offshore wind farm from designated marshalling port or another fabrication yard to the offshore installation site

3.104
offshore type certificate
type certificate for rotor and nacelle assembly in accordance with WT-01 & 61400-1 ed.3 or any other offshore-specific type certificate for other components of an offshore wind farm, such as cranes

3.105
operational duration
planned duration of a port and marine operation, excluding a contingency period

Note 1 to entry: See also weather window (3.168).

[SOURCE: [57]]

3.106
owner
representative of the company or companies which own an offshore wind farm project

EXAMPLE An owner can be wind farm lease and permit holder, developer, employer of contractors which manufacture and install the components of an offshore wind farm and potential operator of the offshore wind farm.

Note 1 to entry: “Owner” differs from “OFTO” (3.102).

3.107
padear
lift point consisting of a central member of tubular or flat plate form with horizontal trunnion, or consisting of a solid casting, around which a sling or grommet can be passed

[SOURCE: ISO 19901-6:2009, 3.62]

3.108
padeye
lift point consisting essentially of a plate, reinforced by cheek plates if necessary, with a hole through which a shackle can be connected

[SOURCE: ISO 19901-6:2009, 3.63]

3.109
permit to access
permit issued by the construction management of an offshore wind farm during construction on a daily basis to an offshore installation vessel (3.99) to allow entry into the safety zone of an offshore installation site in order to conduct its designated works agreed by the construction management

3.110
platform
complete assembly including structure, topsides and, where applicable, foundations

[SOURCE: ISO 19901-6:2009, 3.64]

3.111
point of no return
PNR
point during an operation that represents the final opportunity to reverse, delay or abandon the operation

[SOURCE: ISO 19901-6:2009, 3.65]

3.112
pre-assembly
all stages of the process for the assembly of the wind turbine generator (WTG) components at the staging port including works and parts of the WTG or other required components in order to commence loadout of pre-assembled WTG component

3.113
pre-piling
all activities in relation to installing piles in the seabed where upon a jacket or a similar deep foundation is going to be installed

3.114
recognized organisation
RO
organisation that has been assessed by a flag State, and found to comply with Part 2 of the Code for Recognized Organizations (RO Code) MSC.349(92) and MEPC.237(65)

Note 1 to entry: Adapted from MSC.349(92).

3.115
remote-operated vehicle
ROV
underwater vehicle operated remotely from a surface vessel or installation

[SOURCE: ISO 14723:2009, 4.32]

3.116
representative value
value assigned to a basic variable for verification of a limit state

[SOURCE: ISO 19900:2013, 3.38]

3.117
reserve buoyancy
contingency buoyancy expressed in percentage of the nominal total intact buoyancy of barges or vessels

[SOURCE: ISO 19901-6:2009, 3.68]

3.118
resistance
capacity of a structure, component or a cross-section of a component to withstand action effects without exceeding a limit state

[SOURCE: ISO 19904-1:2006, 3.32]

3.119
return period
average period between occurrences of an event or of a particular value being exceeded

Note 1 to entry: The offshore industry commonly uses a return period measured in years for environmental events. The return period in years is equal to the reciprocal of the annual probability of exceedance of the event.

[SOURCE: ISO 19901-1:2005, 3.23]

3.120
rigging
slings, shackles and other devices including spreader bars/frames used to connect the structure being lifted to the crane

[SOURCE: ISO 19901-6:2009, 3.71]

3.121
rigging weight
total weight of rigging, including contingency

[SOURCE: ISO 19901-6:2009, 3.72]

3.122
rotor-nacelle assembly
part of an offshore wind turbine carried by the support structure

Note 1 to entry: See Figure 1 for information.

[SOURCE: IEC 61400-3:2010; 3.35]

3.123
safe haven
sheltered location at which a tow or transport can seek refuge from inclement weather

[SOURCE: ISO 19901-6:2009, 3.73]

3.124
scour protection
materials to place on the seabed to prevent scour from developing around the foundation where the foundation penetrates into the seabed

3.125
seabed
materials below the sea in which the structure is founded, whether of soils such as sand, silt or clay, cemented material or of rock

Note 1 to entry: The seabed can be considered as the half-space below the sea floor.

Note 2 to entry: Adapted from ISO 19901-4:2003, 3.6.

[SOURCE: ISO 19901-6:2009, 3.74]

3.126
sea fastening
temporary fastening items which keep movable items in position during transportation at sea

Note 1 to entry: Adapted from ISO 19901-5:2003, 3.1.38.

[SOURCE: ISO 19901-6:2009, 3.75]

3.127
sea floor
interface between the sea and the seabed

[SOURCE: ISO 19901-4:2003, 3.5]

3.128
Search And Rescue
SAR
operation to retrieve persons in distress, provide for their initial medical or other needs and deliver them to a place of safety

3.129
section of array cable
length of array cable (3.5) of a specific cable type between two foundations or a foundation and an offshore substation or between a foundation and an onshore substation

3.130
semi-submersible
floating structure normally consisting of a deck structure with a number of widely spaced, large cross-section, supporting columns connected to submerged pontoons

[SOURCE: ISO 19904-1:2006, 3.36]

3.131
significant wave height
H_S
mean wave height (crest to trough) of the one-third highest waves

3.132
site chart
updated map of the offshore installation site showing important information of e.g. all planned locations (3.80), allowable jack-up positions, jack-up footprints, as as-built/as-laid information, safety zone, positions of all other equipment temporarily anchored in the offshore installation site such as measurement equipment, cardinal buoys, to allow the bridges of all offshore installation vessels and other offshore spreads working in the offshore installation site to have the same information

3.133
skew load factor
SKL
factor by which the load on any lift point, or pair of lift points, is multiplied to account for sling length mismatch in a statically indeterminate lift

[SOURCE: ISO 19901-6:2009, 3.78]

3.134
skidshoe
bearing pad attached to the structure that engages in the skidway and carries a share of the vertical load

[SOURCE: ISO 19901-6:2009, 3.79]

3.135
skidway
system of structural beams (concrete or steel) or rails, on the quay and on the barge, on which the structure is loaded out via the skidshoes

[SOURCE: ISO 19901-6:2009, 3.80]

3.136
skirt
structure constructed at or below the base of a structure that extends downwards from the bottom of the foundation plate, penetrating into the seabed

Note 1 to entry: Skirts are used to increase the capacity of the foundation to resist vertical and horizontal loads and improve erosion resistance.

[SOURCE: ISO 19901-6:2009, 3.81]

3.137
sling eye
loop at each end of a sling, either formed by a splice or by a mechanical termination

[SOURCE: ISO 19901-6:2009, 3.82]

3.138
special purpose vessel
mechanically self-propelled vessel which by reason of its function might carry more than 12 special personnel

Note 1 to entry: A special purpose vessel fulfils various roles on offshore wind farms include rock dumping vessel, fall pipe vessel, Unexploded Ordnance (UXO) survey, explosive ordnance disposal, and deployment and operation of bubble curtains for noise mitigation measures.

[SOURCE: See [37] in Bibliography]

3.139
splash zone
area of a structure that is frequently wetted due to waves and tidal variations or during lift operations

Note 1 to entry: Refers to the wave-affected zone of the water column surrounding a structure.

[SOURCE: ISO 19901-6:2009, 3.83]

3.140
splice
that length of sling where the rope is connected back into itself by tucking the tails of the unit ropes back through the main body of the rope(s), after forming the sling eye

[SOURCE: ISO 19901-6:2009, 3.84]

3.141
spreader bar
spreader frame
structure designed to resist the bending and compression forces induced by angled slings by altering the line of action of the force on a lift point into a vertical plane

Note 1 to entry: The usual purpose of a spreader bar or frame is to avoid a clash between the rigging and the structure, which would result if the rigging were connected directly from the lift point to the hook.

[SOURCE: ISO 19901-6:2009, 3.85]

3.142
squat effect
tendency of floating objects or vessels to undergo an increase in draught when underway

[SOURCE: ISO 19901-6:2009, 3.86]

3.143
Steel Cable-Laid Sling
SCLS
assembly of several (usually six) round stranded steel wire ropes (referred to as unit ropes), laid helically around a core (usually a seventh rope)

Note 1 to entry: The definition strictly applies to the type of steel wire rope construction. Cable-laid slings have hand-spliced eye end terminations by splicing the rope back on itself to form an eye termination.

Note 2 to entry: See IMCA M 179 for construction and use of cable-laid slings.

[SOURCE: ISO 19901-6:2009, 3.87]

3.144
steel wire rope
rope made of various types of steel wire construction

EXAMPLE A steel wire rope can be a stranded rope consisting of six or eight strands laid helically around a core (steel core, fibre core, IWRC), a spiral rope, etc.

Note 1 to entry: Each combination of material and type of construction normally results in different properties and characteristics.

[SOURCE: ISO 19901-6:2009, 3.88]

3.145
Steel Wire Rope Grommet
SWRG
endless loop-shaped sling made up from a single length of round stranded steel wire rope

Note 1 to entry: As for cable-laid slings, the steel wire rope used in a grommet is also referred to as a unit rope.

Note 2 to entry: A SWRG is constructed from one continuous length of stranded wire rope and consists of a body composed of six strands around a strand core. The rope is spirally wound around the core rope in six loops. During the production of grommets a temporary rigid core is used, which is replaced by the first half loop and the last half loop of the stranded wire rope. At the start of looping, the core rope changes into an outer rope, and at the end the sixth outer rope changes back into the core rope. When removing the temporary rigid core, the ends of the stranded wire are tucked into the body core, with the tuck position diametrically opposite to the core butt position.

Note 3 to entry: See IMCA M 179 for construction and use of SWRG.

[SOURCE: ISO 19901-6:2009, 3.89]

3.146
Steel Wire Rope Sling
SWRS
sling made from a single steel wire rope with various possible end terminations

Note 1 to entry: Terminations include spliced eyes, Flemish eye with swaged steel sleeve (also known as super loop), spelter sockets, resin sockets, etc.

[SOURCE: ISO 19901-6:2009, 3.90]

3.147
strength
mechanical property of a material indicating its ability to resist actions, usually given in units of stress

[SOURCE: ISO 19902:2007, 3.49]

3.148
structure
organized combination of connected parts designed to withstand actions and provide adequate rigidity

[SOURCE: ISO 19900:2013, 3.49]

3.149
sub-structure
part of an offshore wind turbine support structure which extends upwards from the seabed and connects the foundation to the tower

Note 1 to entry: See Figure 1.

[SOURCE: IEC 61400-3: 2010; 3.46]

3.150
support structure
part of an offshore wind turbine consisting of the tower, sub-structure and foundation

Note 1 to entry: See Figure 1.

[SOURCE: IEC 61400-3:2010; 3.47]

3.151
termination efficiency factor
factor by which the calculated breaking strength of a rope is reduced to take account of the reduction in strength caused by a splice or other end termination

[SOURCE: ISO 19901-6:2009, 3.93]

3.152
third party
person or body that is recognized as being independent of the parties involved, as concerns the issue in question

3.153
topsides
structures and equipment placed on a supporting foundation such as a tower including nacelle, hub and blades as well as topside for offshore substations or offshore accommodation platforms

Note 1 to entry: For a jack-up, the hull is not part of the topsides.

Note 2 to entry: A separate fabricated deck or module support frame is part of the topsides.

Note 3 to entry: Adapted from ISO 19900:2013, 3.52.

3.154
tow
marine transportation of an object or its supporting barge by being pulled or pushed by tow vessel(s)

Note 1 to entry: A tow can be defined into the following types:

—dry: marine transportation of an object with the object located clear of the water aboard a barge or other unit;

—wet: marine transportation of an object with the object floating directly in the water.

[SOURCE: ISO 19901-6:2009, 3.95]

3.155
tower
tower constituting the part of a support structure for the wind turbine generator (WTG) between the top flange of the foundation and the bottom flange of the nacelle connecting the sub-structure to the rotor-nacelle assembly

Note 1 to entry: See Figure 1.

[SOURCE: IEC 61400-3]

3.156
trailer
system of steerable wheels, connected to a central spine beam by hydraulic suspension that can be raised or lowered

[SOURCE: ISO 19901-6:2009, 3.96]

3.157
transport frames
steel structure to support, if required, the onshore transport of the wind turbine generator (WTG) components which will be joined onto the corresponding steel structure at the vessel (i.e. bolting frames or twistlocks) for sea-fastening

3.158
transition piece
part of the foundation connecting the foundation support structure to the wind turbine generator (WTG) tower

3.159
tripod
three-legged offshore foundation, normally fixed by piles to the seabed

3.160
trunnion
lift point on a structure consisting of a tubular member or cast cantilever with a stopping plate at the end, around which a sling or grommet can be passed

Note 1 to entry: An upending trunnion is used to rotate a structure from horizontal to vertical, or vice versa, and the trunnion forms a bearing point around which the sling, grommet or another structure rotates.

[SOURCE: ISO 19901-6:2009, 3.97]

3.161
tugger line
line between a winch and an object to control the orientation and position to prevent or reduce the motion, or to position a lifted object during an installation operation

[SOURCE: ISO 19901-6:2009, 3.98]

3.162
upending
process of changing the orientation of an object in the water from the horizontal to the vertical by means of ballasting, flooding, by crane assistance or a combination of these techniques, or in air only by means of crane assistance

EXAMPLE Upending in air only by means of crane assistance, e.g. of a flare.

[SOURCE: ISO 19901-6:2009, 3.99]

3.163
verification
examination made to confirm that an activity, product, or service is in accordance with specified requirements

[SOURCE: ISO 19901-6:2009, 3.100]

3.164
watertight
capability of preventing the penetration of water into or through the structure with a water pressure head corresponding to that for which the surrounding structure is designed

[SOURCE: ISO 19901-6:2009, 3.101]

3.165
weather-restricted operation
marine operation that can take place safely within the limits of a favourable weather forecast

Note 1 to entry: It is not necessary that the design weather criteria reflect the statistical extremes for the area and season. A suitable factor should be applied between design weather criteria and operational weather limiting criteria.

[SOURCE: ISO 19901-6:2009, 3.102]

3.166
weathertight
capability of preventing the penetration of water into the structure during temporary exposure to water

Note 1 to entry: A watertight closing appliance is also considered weathertight.

[SOURCE: ISO 19901-6:2009, 3.103]

3.167
weather-unrestricted operation
marine operation that can take place safely in any weather condition that can be encountered during a season

Note 1 to entry: The statistical extremes for the area and seasons are considered in the design weather criteria.

[SOURCE: ISO 19901-6:2009, 3.104]

3.168
weather window
operational duration [3.105] including a contingency period determined with due allowance for the nature and criticality of the individual operations (safe to safe) and for which forecast environmental conditions remain below prescribed operational limits

3.169
50/50 weight estimate
value representing the median value in the probability distribution of weight estimates

Note 1 to entry: The actual weight is equally likely to be smaller or larger than the 50/50 weight estimate.

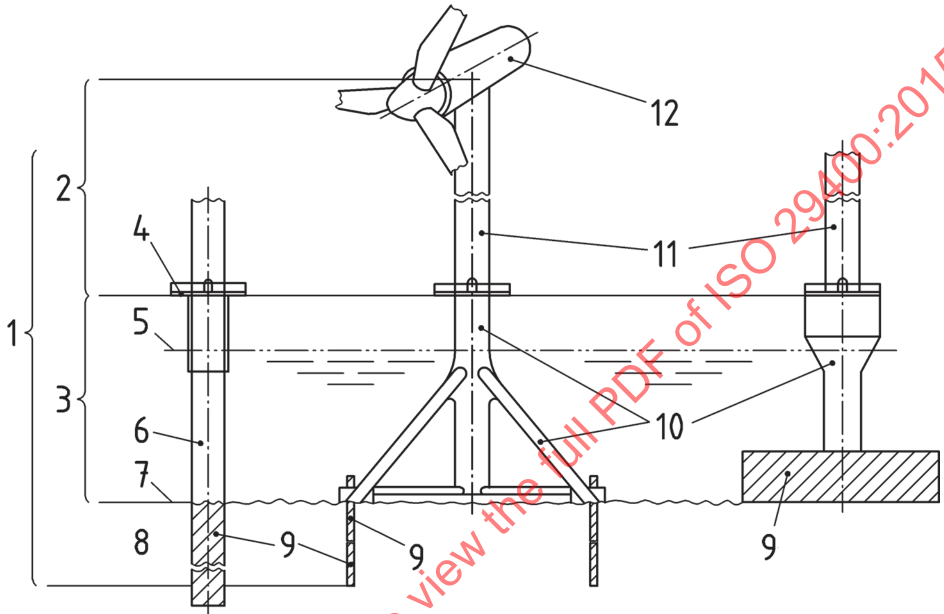
Note 2 to entry: The 50/50 weight estimate is used as the basis for weight budgeting.

[SOURCE: ISO 19901-5:2003, 3.1.54]

3.170
wind turbine generator — offshore wind turbine generator
WTG
wind turbine generator forming part of the permanent works, including the tower, local turbine control and monitoring system and electrical system down to and including the switchgear at the base of the wind turbine tower onto which the high voltage sea cable is to be connected

Note 1 to entry: To avoid misinterpretation, the high voltage sea cable is not part of the WTG.

Note 2 to entry: See Figure 1 depicting all parts of an offshore wind turbine.



Key

1 support structure
2 tower
3 sub-structure
4 platform
5 water level
6 pile
7 sea floor
8 seabed
9 foundation
10 sub-structure
11 tower
12 rotor-nacelle assembly

Figure 1 — Parts of an offshore wind turbine

[SOURCE: IEC 61400-3:2009, Figure 1]

3.171
working load limit
WLL
maximum load that can safely be applied to a rope, sling, grommet, shackle or lift point

[SOURCE: ISO 19901-6:2009, 3.106]

4 Symbols and abbreviated terms

4.1 Symbols

$A_1, A_2, A_3,$ areas under or between the wind heeling moment curve and the hydrostatic righting moment curve (see Figures 4 and 5)

b breadth, expressed in metres

B_0	total available buoyancy of the structure
B_r	reserve buoyancy, expressed in percent of B_0
d	nominal diameter of a rope, sling or leg of a grommet, expressed in millimetres
d_h	diameter of shackle pinhole, expressed in millimetres
d_p	diameter of shackle pin, expressed in millimetres
D	minimum diameter over which a sling or grommet is bent, expressed in millimetres
f_{fr}	calculated percentage friction force
f_{SF}	safety factor (in WSD method)
$f_{SF, sh}$	safety factor for a shackle (in WSD method)
$f_{SF, Y}$	safety factor for component Y (in WSD method)
	Y = SWRS; SCLS; FRS; SWRG or FRG
F_{dgf}	design grommet force (for a complete grommet)
$F_{dgf, 1}$	design force for one leg of a grommet
F_{dhl}	design hook load for a one-crane lift
$F_{dhl, i}$	design hook load on hook i for a two-hook lift
F_{dsf}	design sling force for a one-part sling
$F_{dsf, 2 parts}$	design sling force for each part of a two-part sling
F_{min}	minimum value of the breaking strength of a steel wire rope, expressed in kilonewtons
F_{hl}	nominal hook load, expressed in kilonewtons
F_{rgf}	representative grommet force (for a complete grommet)
$F_{rgf, 1}$	representative force for one leg of a grommet
F_{rhl}	representative hook load for a one-hook lift by a single crane
$F_{rhl,i}$	representative hook load on hook i for a two-hook lift (i = 1, 2)
F_{rsf}	representative sling force for a one-part sling
$F_{rsf, 2 parts}$	representative sling force for each part of a two-part sling
$F_{srhl, i}$	nominal hook load, F_{hl}, statically resolved between hooks (i = 1, 2)
F_{BP}	continuous static bollard pull of each tug, expressed in kilonewtons
$F_{CS,X}$	calculated strength (CRBL) of the body of component X in force terms, where X is a sling or one leg of a grommet (see 19.6.2)
	X = SWRS; SCLS; FRS; SWRG, 1 or FRG, 1
$F_{CS,X}$	calculated strength (CGBL) of a complete grommet of type X in force terms (see 19.6.2)
	X = SWRG, 2 or FRG, 2
$F_{DS,sh}$	design strength of a shackle in force terms

$F_{DS,Y}$ design strength of component Y in force terms, where Y is a sling or a grommet (in PFD method, see 19.6.6)

Y = SWRS; SCLS; FRS; SWRG or FRG

F_{min} minimum value of the breaking strength of a steel wire rope, expressed in kilonewtons

F_{PR} minimum towline pull required, expressed in kilonewtons

$F_{RS, sh}$ representative strength of a shackle in force terms

$F_{RS,Y}$ representative strength of component Y in force terms, where Y is a sling or a grommet (see 19.6.5)

Y = SWRS; SCLS; FRS; SWRG or FRG

$F_{WLL, sh}$ working load limit (WLL) of a shackle in force terms

$F_{WLL, Y}$ working load limit (WLL) of component Y in force terms, where Y is a sling or a grommet (in WSD method, see 19.6.6)

Y = SWRS; SCLS; FRS; SWRG or FRG

g acceleration of gravity, equal to 9,81 m/s^2

H_c height of cribbing above deck, expressed in millimetres

H_{max} maximum anticipated wave height at the site during loadout, expressed in metres

H_s significant wave height, expressed in metres

k_{be} bending efficiency factor

k_{CoG} CoG factor, the value of which reflects the uncertainty in the position of the CoG when statically distributing the lift weight between the lift points

k_{DAF} dynamic amplification factor

k_{lf} lateral force factor

k_{sf} CoG shift factor, the value of which reflects the uncertainty in the position of the CoG when statically distributing the total hook load between the two hooks

k_{skl} skew load factor, the value of which reflects unequal load sharing in an indeterminate lift between slings that differ in length as a result of manufacturing tolerances

k_{te} termination efficiency factor

k_{tf} tilt factor, the value of which reflects the effect of uneven heights of the crane hooks and/or uneven hoisting speeds when statically distributing the total hook load between the two hooks

k_{wcf} weight contingency factor

k_{yaw} yaw factor, the value of which reflects the effect of yawing during lifting with two cranes when statically distributing the lift weight between the lift points

K empirical factor for the minimum breaking strength for a given rope class and core type

l_{freebd} effective freeboard, expressed in metres

L_{OA} length over all, expressed in metres

$\max(a_{i,j})$ largest value of a for all i and all j

$\min(a, b)$ lower value of a and b

P_{clf} calculated lateral force on a lift point due to known misalignment between the orientation of the lift point and the sling direction (where applicable)

P_{dlf} design lateral force on a lift point

P_{ddf} design force on a lift point in line with the sling direction

P_{dvf} design vertical force on a lift point

P_{rlf} representative lateral force on a lift point

P_{rdf} representative force on a lift point in line with the sling direction

P_{rvf} representative vertical force on a lift point

R_t rope grade (tensile strength grade of the wires in the rope), expressed in newtons per square millimetre

T_{eff} tug efficiency in the considered sea conditions, expressed in percent

W gross weight

W_c cargo weight, expressed in kilonewtons

W_{cw} calculated weight

W_{lw} nominal lift weight

$(W_{rlw})_{one\ crane}$ representative lift weight on a lift point for one-hook lifts by one crane

$(W_{rlw})_{two\ cranes}$ representative lift weight on a lift point for lifts by two cranes

W_{rw} rigging weight

$W_{rw,i}$ rigging weight associated with crane hook i (i = 1, 2)

W_s weight of the sling

$W_{srlw,i}$ statically resolved lift weight for crane hook i (i = 1, 2)

$W_{srlw,j}$ statically resolved lift weight acting on lift point j

$W_{srlw,i,j}$ statically resolved lift weight for crane hook i acting on lift point j

W_{ww} weighed weight

W_0 weight of the structure in air

α heeling angle where the maximum hydrostatic righting moment occurs, expressed in degrees

β sum of the static wind heeling angle and the maximum roll angle, expressed in degrees

γ_f partial action factor (in PFD method)

$\gamma_{f,hl}$ partial action factor for hook load (in PFD method)

$\gamma_{f,lp}$ partial action factor for forces on a lift point when designing lift points and their attachment to the structure (in PFD method)

$\gamma_{f,mf}$ partial action factor for forces on a lift point when designing structural members directly supporting or framing into the lift points (in PFD method)

$\gamma_{f,m}$ partial action factor for forces on a lift point when designing other structural members (in PFD method)

$\gamma_{f,s}$	partial action factor for forces in slings, grommets and shackles (in PFD method)
γ_R	partial resistance factor (in PFD method)
$\gamma_{R,sh}$	partial resistance factor for a shackle (in PFD method)
$\gamma_{R,Y}$	partial resistance factor for component Y (in PFD method)
	Y = SWRS; SCLS; FRS; SWRG or FRG
ϕ_{max}	maximum dynamic heeling angle due to wind and waves, expressed in degrees
θ	angle between the sling and the horizontal plane, expressed in degrees

4.2 Abbreviated terms

ASD/WSD	Allowable Stress Design/Working Stress Design
CMS	Condition Monitoring System
CPT	Cone Penetration Test
EPBD	Emergency preparedness bridging document
EPIRB	Emergency Position Indicating Radio Beacon
GBS	Gravity Base Structure
HAZID	HAZard IDentification study
LRFD	Load and Resistance Factor Design
MOU	Mobile Offshore Unit
NDT	Non-Destructive Test
OWF	Offshore Wind Farm
PMS	Positioning Monitoring System
SCADA	Supervisory Control And Data Acquisition system for the WTGs
SPMT	Self Propelled Modular Transporters
QRA	Quantified Risk Analysis

5 General considerations

5.1 Introduction

5.1.1 General

There are two categories of "port facility" when installing offshore wind farms:

— almost all WTG components, foundations, topsides and cabling are manufactured in facilities adjacent to a loadout quay, and this constitutes the "manufacturer's port";

— most often the components are transported to a "marshalling port", from where they are loaded out onto the installation vessel and taken to the offshore wind farm, but sometimes they are transferred directly from the manufactures to the OWF on board the installation vessel.

In terms of activities at ports there are also two distinct types:

— between the former two types of facility there are vessel operations associated with "transportation" which can be characterized as "Project Cargo Logistics";

— operations when components leave the marshalling port are associated with "installation" which is a "construction" activity.

Port operations include activities at the staging port in order to prepare the components for loadout as well as any preparations of the port areas for the construction. Such operations can include:

— pre-assembly of components;

— temporary storage;

— positioning components at the quayside for loadout;

— set-up of offices for construction;

— implementation of port security measures;

— offload of components from barge or vessel to shore;

— soil preparation and levelling at the quayside (where required).

Marine operations for offshore installation include transient marine movements and other activities where the structure or the operation is at risk from the marine environment. Such operations can include:

— loadout from shore to barge or vessel;

— launching from shore to water;

— float-out from dry docks;

— wet or dry towage and other marine transportations;

— temporary anchoring and station keeping during construction;

— installation by means of launching or float-off, upending, lowering by ballasting, float-over or lifting;

— cable installation;

— unexploded ordnance survey;

— refuelling offshore substations and temporary generators used on WTG before full energization (if required);

— provisioning of vessels and structures in the offshore wind farm;

— paint repair works;

— scour protection;

— decommissioning and total or partial removal of the structure.

ISO 29400 gives requirements and guidance on the planning and execution of port and marine operations during the temporary phases of port operations, loadout, construction, transportation and installation of the various structures and their components.

General requirements and guidance on safety and emergency issues, and reference to applicable legislation are contained in 5.1.2 to 5.10. Effective management of these issues requires full knowledge of applicable regulatory requirements.

General disclaimer to technical requirements on stability, crane and towline stated in these rules: If special purpose vessels are used, they shall follow IMO rules in respect to these requirements. It should also be noted that marine operations in coastal waters can involve more than one nation's area of jurisdiction and that, for barges and ships, while the flag state jurisdiction is primary, additional requirements may be imposed by the coastal or port state.

5.1.2 Safety requirements

The overall objective of the safety of marine operations is to perform all operational activities at minimum risk of accidents or incidents to personnel, environment and property. This can be met if:

- the operation is designed taking into account the statistical weather extremes for the area and season;
- the operational weather conditions, chosen at values not exceeding the specified operational limits, are forecasted for a sufficiently long period to enable completion of the operation;
- the required equipment, vessels and other means are designed and checked for adequate performance with respect to their intended use;
- there is redundancy in the equipment provided to cover possible breakdown situations;
- the operations are planned, in nature and duration, such that accidental situations, breakdowns or delays have a very low probability of occurrence and are covered by detailed contingency plans;
- adequate documentation has been prepared for a safe, step-by-step execution of the operation, with clear indications of the organization and chain of command;
- the operations are conducted by competent personnel;
- safe systems of work are devised in light of a systematic risk assessment.

Special precautions must be adhered to during any jacking operations. Location specific assessment and procedures must be provided by each of the respective offshore installation vessels for each jacking location in a vessel approach plan and reviewed by the marine warranty surveyor before any jacking operations take place. Marine coordination of the owner will issue a site chart to be used by all offshore installation vessels in planning their vessel movements. The approval of the vessel approach plan by the marine warranty surveyor (MWS) is a precondition for obtaining permit to access the location in question.

Each of the respective offshore installation vessels must take full account of the exact locations where vessels have previously jacked and the positions of proposed and/or installed subsea cables.

In case of anchoring, the respective offshore installation vessel must provide detailed anchor plans taking full account of project plan, sub-sea cables etc. for approval by the MWS and the marine coordination of the owner. Actual anchor positions shall be documented by the offshore installation vessel when deployed and again when recovered. Each of the respective offshore installation vessel safety zones must take into account anchor positions.

5.2 Jurisdiction

5.2.1 Introduction

Installation of offshore wind farms and related port and marine operations are subject to approval by appropriate parties in due time before actual activities commence. Thus, national and international regulations and guidelines on personnel safety and protection of the environment are the governing requirements. It should also be noted that marine operations can involve more than one nation's area of jurisdiction and that, for barges and vessels, while the flag state jurisdiction is primary, additional requirements may be imposed by the coastal or port state.

5.2.2 Life at sea

In order to respect life at sea, information with respect to conventions, codes and guidelines is required. The information is subdivided into separate provisions with respect to vessels on international voyages and vessels on domestic voyages, and is further subdivided to separately address mandatory instruments (i.e. conventions) and recommended instruments (i.e. codes and recommendations).

For vessels on international voyages, the vessel's flag state generally requires the vessel's compliance with the international conventions and mandatory codes identified in References [20] to [26],[35] and [40]. Such compliance is generally demonstrated by the issuance of the relevant certificate mandated by the convention.

Before selection of any vessel where the vessel's flag state is not party to the most recent protocols or amendments to the instruments referenced above, careful consideration should be exercised.

The international conventions identified in References [20] to [26] do not apply to domestic voyages. In such cases, national standards offering equivalent levels of safety should be applied.

References [31] ,[34], [36] to [38], and [41] to [44] provide recommendations that the flag state can adopt and apply as mandatory requirements, as applicable, to vessels under their jurisdiction. Where these are not adopted and applied by the flag state, national standards offering equivalent levels of safety should be applied.

5.2.3 Environment

The legislation for the protection of the environment is evolutionary and covers various purposes. It is embodied in a number of instruments of broad scope, from the law of the sea and general practices covering natural resources exploitation, protection of marine environment, pollution and dumping of waste, through to international conventions, regional conventions and national rules.

Applicable international conventions can be found in References [32] to [36].

5.3 HSSE plan

A Health, Safety, Security and Environment (HSSE) plan shall be established. The objectives of the plan shall be:

— to document the HSSE standards, processes and procedures that apply to the work;

— to identify, assess and manage hazards and risks arising from the work, reducing them to as low as reasonably practicable;

— to ensure that safety is inherent in planning and design of the work;

— to ensure minimal impact on the environment;

— to protect the health of the workforce;

— to ensure the security of the work site, particularly the port facilities including components and access procedures.

The plan shall include HSSE activities during all phases of the work, from planning and design through to execution of the operation.

Selected issues to be taken up in the HSSE plan are described in 5.4 to 5.10.

The use of alcohol, drugs or narcotics by personnel involved in marine operations is not permitted.

5.4 Risk management

5.4.1 Introduction

For risk management, ISO 17776 and the provisions of 5.4 and 5.5 apply.

It is good industry practice that no major activity is carried out on a site without an approved method statement. The risk assessment process shall be part of that approval procedure. The risk assessment itself shall be part of any method statement. A mandatory interface shall be defined to ensure that there is extensive and adequate communications with all parties involved including the party responsible for the engineering and design related to installation issues as well as the party responsible for the method statements. As a consequence all design phase documents related to the installation shall be cross referenced in the method statements.

The overall responsibility for risk management shall be clearly defined when planning marine operations.

Risk management shall be applied to the project to reduce the effects of hazards and to limit the overall risk. This objective can be achieved by addressing the following functions in turn:

— identification of potential hazards;

— assessment of risk potential;

— prevention to avoid hazards wherever possible;

— control to reduce the potential consequences of unavoidable hazards;

— measures to mitigate the consequences of an incident, should one occur.

Each port and marine operation, including each major system that is essential to the performance and safety of port and marine operations, e.g. lifting procedures, power generation and supply systems, ballast and compressed air systems, shall be subjected to a rigorous hazard study.

Personnel and organisations involved in port and marine operations, as well as those involved in the design and operation of the systems, shall take part in the hazard studies.

It is recommended that consequence assessment be used to rank the probabilities and consequences of various events, to form a basis for further investigation if necessary.

5.4.2 Techniques to evaluate risks

Appropriate techniques to evaluate risks include, but are not limited to:

— design and execution: HAZID and scenario based risk assessments;

— execution implementation: job safety analyses, safety campaigns and drills, hazard hunts and tool box talks, which can be applied at field supervision level.

QRA techniques can be used:

— to compare levels of risk between alternative proposals or between known and novel methods; and

— to enable rational choices to be made between alternatives.

5.5 Job safety analysis

Job safety analysis should be performed to detail the:

— sequence of the operation;

— equipment to be used at each stage;

— hazards to be controlled;

— precautions to take and the responsibilities of persons involved.

The analysis should be performed and documented by the port contractor as well as the marine contractor for their respective field of work as a basis for the method statement for the operation. When completed, the results of the job safety analysis should be communicated to personnel involved in the various operation activities through kick-off meetings and tool-box talks resulting in officially issued permit-to-work documents.

5.6 Environmental impact study

An environmental impact study should be carried out, where appropriate, to identify and deal with generally recognized risks to the environment (e.g. waste management, disposal at sea, hazardous materials transports) or to personnel, and to population and wildlife (e.g. toxicity, explosives, noise, vibrations and other disturbances).

5.7 Manning, qualifications, job and safety training

Personnel shall be appropriately qualified, trained and assessed for the work they are expected to undertake so as to ensure that they can undertake that work competently. Communication should be agreed to be conducted in a language commonly shared by all key personnel. Supervisors shall possess a thorough knowledge of the entire operation under their control and have prior experience with similar operations. Other key personnel shall have knowledge and experience within their area of responsibility.

Qualification requirements for job categories critical to safe operations shall be specified. Special care and training shall be given to all repetitive offshore operations such as installation of foundations, cable laying and burial, WTG-tower installation as well as nacelle and blade installation. See Reference [46] for regulations on safe manning. Before commencement of an operation, personnel involved shall be briefed by the supervisors regarding responsibilities, communication, work procedures and safety, as well as given a step-by-step run-through of the operation in form of tool-box talks.

Job-specific training shall be carried out and should cover the following topics:

— general and specific site regulations;

— legal obligations;

— instructions regarding the operation in question and any associated activities;

— instructions regarding the use of the components of the offshore wind farm and equipment used for marine operations.

Computer simulations, model tests and simulator training of the operation can give valuable information for the personnel carrying out the operation.

Personnel should receive safety training in accordance with the requirements of applicable national and international conventions, codes and guidelines. The training should include general safety requirements, emergency training and drills as appropriate to the job requirements and locations in which work is to be performed.

Fire and evacuation alarms should be periodically tested, and drills should be carried out periodically, or as required by safety legislation. Where more than one manned platform or vessel is affected by the construction activities, consideration should be given to joint emergency drills.

An up-to-date list with information of next of kin should be maintained.

5.8 Incident reporting

During port and marine operations, incident reporting depends on the contract requirements and governmental regulations and is preferable provided with daily progress reports. It can include:

— periodic reports;

— incident, accident and near-miss accident reports;

— pollution or substantial threat of pollution reports.

Specific requirements on incident reporting, investigation and loss adjusting could apply in case of incidents related to the construction-all-risk insurance (where in place).

5.9 Personnel tracking

A suitable security and tracking system corresponding to the requirements as stated in the HSSE plan where allowed by government regulations/legislation should be in use to:

— record the presence of personnel on the port premises and the installation and supporting vessels;

— track their whereabouts;

— restrict access to certain areas to authorized personnel only, if required.

Recording for each individual shall include information such as name, address, telephone number, NOK information, date and expiry of training and health certificates, records of site inductions etc. including facilities to register PPE with inspection intervals;

Each person shall receive his/her personal identification (ID) card which shall always be carried when on the site. Whenever a person is scheduled to go offshore, the database will be checked by construction management to investigate if all training, inductions etc. are in place for the person and fits the task to be performed; The ID card may be used for electronic tracking of personnel movement by presenting the card to a terminal on the vessels when a vessel or installation is boarded or left. In this case the ID and location is automatically recorded in the people tracking system. If the electronic system is not used the system will be kept up to date semi manually by the owner's construction management based on e-mail and voice communication.

Special attention shall be given to the fact that during offshore installation of offshore wind farm multiple installation and commissioning works are likely to take place at various locations simultaneously, e.g. commissioning of foundations, array cables, and mechanical and electrical completion of WTG as well as contractual taking-over between owner's contractors and owners. Due to these works, high traffic via crew transfer vessels, accommodation vessels or helicopters is likely to take place during the construction phase requiring an effective personnel tracking system.

5.10 Approval by national authorities

National authorities can decide to survey and approve the operations, or parts thereof.

6 Organization, documentation and planning

6.1 Introduction

The organization, documentation and planning that shall be set up for the performance of port and marine operations are outlined in 6.2 to 6.7. The degree of documentation shall suit the complexity and risks involved in the operation.

6.2 Organization and communication

6.2.1 Project organization

An appropriate organization shall be set up to govern how the port and marine operations integrate with the rest of the project. Key responsibilities shall be clearly defined. The responsibilities and reporting lines shown on the organization chart shall include:

— owner's organization and project management for the project;

— contractor's project management for the project;

— engineering design;

— procurement;

— manufacturing;

— port operations;

— marine operations;

— HSSE management;

— project controls;

— quality management;

— interface management;

— document management.

6.2.2 Operational organization

Separate organization charts shall be drawn up for each port and marine operation, showing the reporting line into the project organization. The details of the organization charts and their overall setup should be consistent with the size or complexity of the project and should be limited to the parties actually involved. Each operational organization chart should indicate, as appropriate, the functional links among the following entities:

— owner's representative;

— overall project management;

— operational management;

— port management;

— towing vessels;

— mooring and anchoring systems;

— marine spread;

— ballast system operation;

— weather forecasting;

— support services;

— marine warranty services;

— certification services;

— advisory panel providing expertise as required;

— HSSE management;

— statutory, regulatory and approving bodies.

In each case, the responsibilities and duties of each function should be clearly defined and published to minimize uncertainties and overlapping responsibilities.

Where transfer of responsibility is involved, the hand-over point from one organization to another (e.g. fabrication to marine operations, or onshore to offshore) should be identified.

During on-going marine operations, the selection of site team members shall be limited to those persons with defined roles during the operation. Any organisational changes that are part of an emergency response should be clearly identified. Back-up services, including emergency services, contingency assistance and technical advisory services, shall be identified and appropriately located.

Communication systems, including radio channels, telephone, telefax, internet, e-mail and out-of-hours numbers, shall be identified.

Personnel changes that occur during the course of an operation as a result of shift changes should be identified. Every effort should be made to avoid changes of personnel during critical stages of the operation.

Key personnel participating in port or marine operations shall communicate in one language.

NOTE For preparation of appropriate operational manuals information on operational organization should also be included, see 6.5.2 to 6.5.6.

6.3 Quality assurance and administrative procedures

An acceptable quality management system shall be in place and all activities shall be managed through it. A system such as the ISO 9000- series [16], or any other equally acceptable system, may be used.

Operators of vessels shall have a management system in compliance with the ISM Code [35], verified by valid ISM certificates; see 6.6.2.

6.4 Technical procedures

Technical procedures shall be set up to control the design and engineering related to port and marine activities.

These procedures shall define the use of applicable technical standards and ensure agreement and uniformity on matters such as:

— the use of international and national standards;

— the use of certifying authority/regulatory body standards;

— project information and conditions;

— design briefs and design basis;

— metocean criteria;

— calculation procedures.

Design briefs are defined as the fundamental principles and philosophy upon which the design basis and detailed design of port and marine operations are based; design briefs include, among others, design criteria, methods of analysis and a description of software used.

Port and marine operations involving complex procedures that are not proven by past experience shall require analysis and/or the performance of simulations and/or model tests in order to demonstrate the adequacy of the planned procedures. Such analyses, simulations or model tests shall be used primarily to investigate the anticipated motions and the stability of the structure during any critical phases of port and marine operations.

Mandatory interfaces shall be defined to ensure that there is extensive and adequate communications with all parties involved including the party responsible for the engineering and design related to installation issues as well as the party responsible for the method statements. As a consequence all design phase documents related to the installation shall be cross referenced in the method statements.

6.5 Technical documentation

6.5.1 Document numbering system

The document numbering system used for marine operations should normally follow and comply with the overall numbering system already in place for the project. As an alternative, a specific document numbering system and document register may be used.

Port and marine operations documents shall be clearly identified by number, revision and date, type of document, discipline involved and review status.

6.5.2 Port and marine operations documents

6.5.2.1 Documents relating to port and marine operations should be grouped into levels according to their status, for example:

- design basis and criteria documents;
- structural weight control reports including weighing procedures if applicable and weighing reports;
- port operations procedure documents (pre-assembly, intermediate storage, transport of components to the quayside, loadout including mooring arrangements or jacking-procedures);
- marine operations procedures documents (transit including towing where applicable and offshore installations of all components of the offshore wind farm);
- supporting documents, including definitions of actions, structural and naval architectural calculations, systems operational manuals, equipment specifications and decommissioning reports.

Procedural documents that are intended for use as an active tool during port and marine operations should include a section that clearly shows their reference to higher and lower level documents and should list interrelated documents.

Documents listed in port or marine operations procedures documents should be available and accessible on board or on-site close to the operation for reference by anyone that is involved.

All technical drawings should be provided in draughting form with ISO 128-1 as a preferable reference standard, but equivalent standards should also be regarded as acceptable.

6.5.2.2 Elements that are considered essential and that should be included in, or referred to by, port and marine operations documents are the following:

- project system management:
  - project organization, responsibilities and lines of command;
  - job descriptions for key personnel;
  - organisational chart;
  - offshore installation site and marking;

  - contractual approvals and hand-over;
- appendices listing more detailed information, such as drawings, calculations, equipment specifications, site information, dimensional control, operational monitoring and control systems, logging of operational control parameters, communication systems, ROV procedures, check lists;
- operational schedule (programme) as bar chart, showing the anticipated operational duration of each activity split into single steps plus defined contingency durations thus summarizing the weather windows required for each activity and indicating interrelated activities;
- preparations, surveys and outline check lists;
- specific step-by-step instructions for each phase of the operation, including sequence, timing, resources, key decision points and hold points;
- principle for transport and transfer of personnel:
  - access for personnel to the offshore site;
  - personnel database;
  - procedures for offshore transfer of personnel;
  - night transfers, transfers in reduced visibility and bad weather.
- principle for project related vessel traffic and access to the site:
  - vessel requirements weekly traffic information;
  - guard vessel;
  - principle for accessing the site;
  - restricted areas and exclusion zones;
  - trespassing traffic;
  - results of related calculations, e.g. environmental actions, moorings, ballast, stability, bollard pull;
- HSSE plan: safety plan, including a description of safety equipment, the location and signalization of safety routes, and requirements for personnel training, contingency plans;
- emergency preparedness bridging document (EPBD);
- information on authorities and permits, including notification requirements;
- environmental criteria, including design and operational limits.

6.5.3 Operational schedule/programme

A detailed activity schedule should be established showing how the port and marine operations are planned. The schedule should be presented as an operational bar chart, showing the duration of each repetitive and non-repetitive activity, interrelated activities, key decision points and hold points.

For weather-restricted activities, the operational schedule/programme shall be set equal to the following items:

- operational duration for a specific operation plus a certain time contingency determined with due allowance for the nature and criticality of the individual operations (safe to safe). The operational duration plus the time contingency result in the required weather window for the operation;
- estimated weather downtime related contingency covering the time for waiting on weather usually based on site specific long-term weather statistics;

— estimated technical downtime related contingency covering the time for e.g. technical breakdowns and maintenance;

— time for learning curves at the start of all repetitive processes.

Due to the interdependence of installation processes during installation of all components of an offshore wind farm, reasonable buffer time between each sequence should be included in the operational schedule. Site specific conditions as well as seasonal influences should be driving factors for establishing sufficient buffer time.

Risk analysis should be used as an assisting tool to establish realistic contingency times.

6.5.4 Contingency philosophy

Port and marine operations shall include contingency and back-up plans.

These contingency and backup plans shall be included within the method statement for the operation to which they relate. Risk assessments shall be a natural part of the approval process for the method statement.

Where there are limits on an operation, the operation shall either be completed within the limits or aborted. In the latter case, the vessel(s) should be able to return to a safe condition or safe haven within the available time, even if a breakdown occurs to any system or equipment.

To be able to meet such requirements, essential systems, parts of systems or equipment should have redundancy systems, back-up systems or back-up system alternatives.

Back-up systems may be an integrated part of the primary system when feasible.

For systems consisting of several units or requiring repetitive processes, back-up or redundancy may be provided by having a sufficient number of spare units available on-site. The time required for the transfer of operations to back-up or redundancy systems shall be assessed.

Spare parts and key service personnel should be available on-site or on stand-by. If key parts and service personnel are on stand-by, then the time taken to mobilize them to the site should be assessed in order to check the effectiveness of the contingency arrangements.

6.5.5 Contingency planning and emergency procedures

For emergency procedures and response, ISO 15544, and the provisions of 6.5.5 and 6.5.6 should be followed.

Contingency and emergency planning shall form part of the general operational procedures. Plans for responding to foreseeable emergencies that can be identified by a risk assessment shall be held. These may include, but not limited to:

— occurrence of severe weather or sea states in excess of allowable metocean criteria;

— planned precautionary action in the event of forecast severe weather;

— structural or stability parameters approaching pre-set limits;

— failure of ballast or compressed air system;

— failure of equipment, such as lift or hammer system;

— failure of grouting system (if applicable);

— loss of communication;

— loss of vessel or barge control;

— loss of electrical power;

— fire;

- collision;
- pollution;
- leakage;
- structural failure;
- anchor line failure;
- man overboard;
- personnel accidents or medical emergencies;
- medical evacuation from remote locations;
- grounding;
- unexpected water depth limitations or sea floor hazards;
- piracy, mutiny, terrorism, or other unauthorized intervention.

Emergency procedures for all phases of port and marine operations shall be prepared to cover foreseeable hazards, including those due to adverse weather conditions, human errors, technical failures and associated changes on the configuration of the operations underway.

The procedures should include details on alarm signals, reporting, communication, organization and required equipment, for instance personnel rescue means and fire-fighting equipment.

The project operational organization shall be prepared to manage, as contingency measures, any changes to an agreed procedure arising from an emergency situation not previously identified in hazard studies. The management of such an unforeseen situation shall support any decision made by means of adequate risk and safety assessment tools as described in 5.4 and 5.5.

6.5.6 Emergency preparedness bridging document

Procedures issued by parties involved in a marine operation should be compatible with each other, and gathered in an emergency preparedness bridging document (EPBD).

In the event of an emergency situation, the EPBD should define who is the on-scene commander and their role, and the interfaces between the various parties involved.

The EPBD should also include a flow chart outlining the responsibility for notifying a maritime rescue co-ordination centre and, if necessary, onshore base organisations, the owner and public relations.

The extent of any onshore support required depends on the nature and scale of the emergency situation. Should onshore support be required, the EPBD should define which emergency response organization among the involved parties takes primacy in the organization of the onshore support.

6.5.7 As-built documentation

As-built-data can consist of foundation locations and array cable and export cable route position lists, etc.

The as-built/as-laid-data following the construction/lay down of either foundations, export and array cables or other offshore structures shall be delivered to the construction management of the owner as soon as possible as some of this data has to be made available to subsequent installation operators. All as-built-data should be inserted into the site chart which should regularly be provided to all operators active in the construction works.

In case of simultaneous operations at one location or in the vicinity of one location, the construction management shall ensure that any as-built-data are verbally communicated and exclusion zones are clearly defined in order to avoid any incidents.

6.5.7.1 Position data of foundation and other offshore structures

Recommended delivery time of as-built-data shall be:

— unapproved position data: within 24 h after the operation;

— final approved data: as soon as possible, latest one week after the actual operation.

As-built-data shall consist of:

— foundations/offshore structure: installation date;

— water depth relevant to chart datum;

— coordinates of position of foundation/offshore structure;

— coordinates of footprints of jack-up vessels in the vicinity of the foundations.

6.5.7.2 As-laid-data of cable

Recommended delivery time of as-built-data of foundation/offshore structures shall be:

— unapproved position data: within 24 h after the operation;

— final approved data: as soon as possible, latest one week after the actual operation.

As-built-data of foundation/offshore structures shall consist of:

— export and array cable: connection between WTG locations, between WTG location and offshore substation, between offshore substation and other connecting substations, between offshore substation and onshore connection point;

— export and array cable: installation date;

— export and array cable: water depth relevant to chart datum;

— export and array cable: burial depth from seabed and burial depth from chart datum at each coordinate;

— export and array cable: if applicable, protection thickness/burial depth, from chart datum at each coordinate;

— coordinates of position of cable turning points;

— coordinates and type of cable protection system, if applicable.

6.5.8 Standards for data transfer to CAD systems

6.5.8.1 Introduction

During the design, manufacturing and construction phase of a wind farm certain CAD and GIS files are transferred between contractors and owner, which will be essential information for all parties.

Particularly during the construction phase, the site chart shall be set up and continuously updated by the construction management.

Requirements regarding geographical data that is exchanged between contractors and the owner are specified in 6.5.8.2 to align the coordination systems used by all parties during the operations.

6.5.8.2 Geographical data

This clause summarizes the key geographical data requirements. If these requirements cannot be met for any reason then an alternative approach shall be proposed to the owner for approval.

— horizontal datum: The preferred geodetic datum for use offshore is World Geodetic System 1984 (WGS84);

— spheroid: WGS1984;

— geodetic reference system, onshore: The preferred geodetic reference system for use on European land is ETRS89;

— horizontal projection: Universal Transversal Mercator Zone 32 North, Central Meridian 9° East (UTM32N);

— vertical datum, offshore: The preferred vertical datum for use offshore is Lowest Astronomical Tide (LAT);

— all soundings shall be reduced to LAT using the relevant tidal information from relevant national publications;

— vertical datum, onshore: The preferred vertical datum for use onshore is to be determined according to national standards;

— geoid: The reduction of the ellipsoid heights measured on the WGS84-ellipsoid requires an undulation (separation of the geoid), which are available as geoid models. The relevant ellipsoid of reference has to be determined according to national specifics;

— where appropriate such as near shore land/sea interfaces both vertical datums should be referenced;

— all constituent data that has been used to compile the submitted data shall be stored in its original format and made available at the request of the owner;

— raw data, e.g. from side-scan-sonar and similar data, shall be passed to the owner.

6.5.8.3 Presentation of coordinates

6.5.8.3.1 Geodetic coordinates

Coordinates shall be expressed as degrees and decimal minutes. The position of coordinates relative to the prime meridian shall be expressed using compass directions (i.e. coordinates west of the prime meridian shall be quoted by W and coordinates east of the prime meridian shall be quoted by E). The position of latitude coordinates relative to the equator shall also be expressed using compass directions (i.e. coordinates north of the equator are quoted by N).

An example of compliant coordinates is provided in Table 1.

Table 1 — Format of geodetic coordinates (example)

Latitude	Longitude
N 55°02,123’	E 007°52,123’

6.5.8.3.2 Projected coordinates

Where appropriate projected coordinates referenced to a projected coordinate reference system may be used:

— the preferred system for use offshore is the Universal Transverse Mercator (UTM);

— the preferred geodetic reference system for use on European land is ETRS89.

The position of coordinates relative to the prime meridian shall be expressed using compass directions (i.e. coordinates west of the prime meridian shall be quoted by W and coordinates east of the prime meridian shall be quoted by E). The position of latitude coordinates relative to the equator shall also be expressed using compass directions (i.e. coordinates north of the equator are quoted by N).

In both cases coordinates shall be presented in numeric eastings and northings as shown in the example in Table 2.

Table 2 — Format of project coordinates (example)

Easting	Northing
E 387365.00	N 6109930.00

6.5.8.4 Map requirements

All maps provided as part of any deliverable (e.g. within reports etc.) shall include the following:

— coordinate reference system definition by ETRS89 code or a minimum set of defining parameters. Reference is made to [69];

— chart datum;

— scale bar;

— scale ratio stating the paper size at which the ratio is valid;

— north arrow;

— appropriate grid or graticule;

— drawing units shall be metric;

— a title appropriate for the contents of the map;

— a unique figure number which to be referred to in any written report;

— a drawing number which corresponds to a source map document such that the data used in the map can later be identified if required;

— drawing version number or revision identifier (i.e. rev A or rev 2);

— appropriate copyright notices/information;

— contact details (an address as a minimum);

— in the case of multiple maps being produced, for consistency each map should be produced to the same style;

— chart revision date.

6.5.8.5 Meta data

All data shall be accompanied by metadata conforming to, as a minimum [9], and the INSPIRE profile of [9] and ISO 19119. The ISO 19139 XML encoding standard shall be used to encode metadata (these standards are options in the ArcCatalog Metadata editor).

6.5.8.6 Geospatial images

All photographs should be supplied in JPEG format.

Side-scan-sonar and similar data shall be provided as tiled GeoTIFF files or as ECW compressed wavelet images.

Where colours are used to represent discrete values or ranges of values and it is applicable for these images to be tiled, then a consistent stretch shall be applied across all tiles/images such that the data appears as a single coherent data set when displayed.

6.5.8.7 Vectordata

Final deliverables that include electronic mapping shall be provided as an ESRI shape file.

6.6 Certification and documentation

6.6.1 General

Statutory obligations for documentation and certification requirements for any particular structure, vessel or operation shall be determined in advance. For each document required, the issuing authority and the applicable rules shall be identified.

A project assurance plan should be established, defining the minimum requirements for vessel certification and for the reports from inspection and maintenance condition surveys.

A complete and updated list of certificates and documents that is required to carry on board ships is given in Reference [47]. A review of the required and recommended documents is given in 6.6.2 and in A.2.

The certification, documentation and all correspondence should be in English. Where the original certification, documentation or correspondence is not in English, a reliable translation into English or another agreed working language should be provided.

6.6.2 Required or recommended documentation

Table 3 lists the documentation that is either required or recommended for transportation using various types of vessels.

For marine operations in general, at least some, if not all, of the documentation listed in Table 3 is mandatory for compliance with international legislation. Specialist advice should be obtained regarding required documentation.

Vessels involved in the performance of marine operations should be in possession of a certificate of compliance with the ISM Code[35], demonstrating that the company owning the vessel(s) has developed and put into effect a vessel safety management system in line therewith.

In addition, vessels carrying crew and passengers should carry an international ship security certificate indicating that they comply with the requirements of the ISPS Code.

6.7 Marine warranty survey

This clause only applies to those marine operations for offshore wind farms which have decided to sign a construction-all-risk (CAR) insurance. In case a CAR insurance is in place, the insurers usually will request that documentation for the marine operations related to the components is reviewed by a MWS. Furthermore the MWS will have to conduct vessel and equipment suitability surveys before start of marine operations and will attend a reasonable number of marine operations to ensure compliance with planned procedures while issuing the certificate of approval.

This clause does not apply to those offshore wind farms for which no CAR insurance was decided to be issued. This clause provides information for the planning of offshore wind farms in respect to CAR insurance and employment of MWS. It does not intend to state that a CAR insurance or the employment of a MWS is mandatory.

6.7.1 Role of the marine warranty surveyor

An insurance warranty is a clause in the insurance policy for a particular marine project, requiring the approval of one or more marine operations by marine warranty surveyors from a specified independent survey house. In most cases the ensured employs the survey house though occasionally an insurance broker or underwriter may do so.

The warranty clause can include coverage from as early as the factory gate. This involves inshore temporary stages as well as offshore marine operations. Normally the insurer or insuring consortium prepares a list of trusted MWSs. The ensured then chooses from tendering offers.

The requirement is normally satisfied by the issue of one or more certificates of approval. Responsibility for interpreting the terms of the warranty so that an appropriate scope of work can be defined rests with the ensured who may be the operator, owner or his contractor.

The MWS service besides certificates for marine activities, delivers reports for surveyed equipment, project based acceptance of tools and technical expertise in developing manuals and procedures. The scope of work is based on a marine warranty clause in the insurance policy.

The surveyor may also decide during an operation to monitor the operations and agree any changes in procedures. In this case he has no executive authority on the project but when necessary he shall submit recommendations to the ensured's representative in order to ensure that the project is run in a safe and proper manner.

6.7.2 Certificate of approval

A certificate of approval is the formal document issued by the warranty surveyor when, in their judgement and opinion, all reasonable checks, preparations and precautions have been taken to keep risks within acceptable limits, and an operation may proceed. It is the main deliverable of the approval process.

The certificate of approval for a marine operation such as load out, towage or installation will normally be issued when:

— all preparations including engineering reviews, acceptance of procedures/manuals, sea-fastening and ballasting are complete;

— marine equipment such as tugs, jack-ups, vessels or barges and towing connections have been inspected and accepted;

— a readiness meeting has been held; and

— the actual and forecast weather are suitable for the operation to begin.

Agreement is required on the end-point of each certificate of approval.

In extreme cases a warranty surveyor may be unable to issue a certificate of approval due to inadequate procedures or equipment for the likely conditions. Similarly failure to follow the procedures and conditions in the certificate of approval could lead to its being withdrawn. In the event of a loss, the lack of a valid certificate of approval could invalidate the insurance warranty and prevent or reduce payment by underwriters for any loss.

Failure to issue a certificate of approval, or its withdrawal after issue is a very rare and serious issue within the MWS scope and makes all the risks rest with the ensured.

A statement of acceptability may be issued when the client requires documentary proof that MWS has completed the necessary reviews of procedures and supporting calculations and that subject to any stated limitations on the statement the procedures are considered acceptable. No surveys or site checks are usually required for a statement.

6.7.3 MWS scope of work

Details of scopes of work, including surveys, reviews and calculations required, are specific to the warranted operation and usually part of the overall design package.

Early involvement of the MWS in agreeing criteria at an early or planning design stage is recommended as it will often save time and expense in changing designs shortly before or after construction has started. Similarly alternative criteria may be agreed during the project to give a better or similar level of risk.

Project specific release notes may be required for some projects. Third party certification has normally three components:

— design approval (finalized with statement of acceptability);

— inspection during construction (inspection reports); and

— final release (release note issued only after design was approved, tool was constructed and tested).

6.7.4 Certificate of approval

A certificate of approval is issued for a particular towage, voyage or operation only or a set of repetitive operations.

A certificate of approval is issued based on external conditions observed by the attending surveyor of the jacket, hull(s), machinery and equipment, without removal, exposure or testing of parts.

Any alterations in the surveyed items or agreed procedures after issue of the certificate of approval may render the certificate void unless approved by the MWS.

No responsibility is accepted by the MWS for the way in which transportation is conducted after departure.

Fatigue damage is excluded from a transportation certificate unless specific instructions are received from the client to include it in the scope of work.

A certificate of approval for transportation does not cover any moorings prior to the start of transportation, or at any intermediate shelter port or arrival port, unless specifically approved by the MWS.

A certificate of approval for installation applies to the safety of the structure and associated equipment during the defined installation period. It does not imply that the completed jacket, platform or other installation will be fit for purpose. The safety of personnel will not be specifically addressed by the MWS. Detailed requirements are included in the scope of work of the MWS.

6.8 Systems and equipment

6.8.1 General

Operational systems and equipment should be tested and commissioned prior to the operation.

Vessels, systems and equipment required for installation operations shall be in good condition with appropriate certification (see also Table 3), and fit for the purpose for which they are intended. They should have the capability and capacity to operate effectively under the environment and actions for which the operation is designed. They should be used in accordance with manufacturer's instructions and procedures. Where possible, they should be designed to be fail-safe and should possess an adequate level of reliability and redundancy.

6.8.2 Marine vessels

Marine vessels and their equipment should be inspected prior to the operation to confirm their suitability and validity of certification, as applicable for the type of vessel and voyage planned; see 5.6.

Vessel stability should be in accordance with Clause 12 throughout all stages of the operation, unless it can be shown that reduced stability requirements can be accepted. For example, during phases of deck mating, taking account of the reduced environmental conditions and the partial restraints of the structure to the vessel, reduced stability criteria may be considered.

Table 3 — Required or recommended documentation for the transportation of various types of vessels and floating structures [47] [60]

	Document	Cargo vessel	Offshore construction vessel/supply/tug	All towage (manned)	Barge towage (unmanned)	Other towage (unmanned)
Required documents						
1	Certificate of registry	✓	✓	✓	–	–
2	Certificate of class (hull)	✓	✓	✓	✓	–
3	Certificate of class (machinery)	✓	✓	✓	✓	–
4	International tonnage certificate	✓	✓	✓	✓	–
5	Cargo ship safety construction certificate	✓	✓	✓	–	–
6	Cargo ship safety equipment certificate	✓	✓	✓	–	–
7	Certificates for navigation lights and shapes	–	–	–	✓	✓
8	Load line certificate	✓	✓	✓	✓	–
9	Load line exemption	–	–	–	✓	✓
10	MARPOL and IOPP certificate	✓	✓	✓	–	–
11	Safety management certificate (SMC)	✓	✓	✓	–	–
12	Customs clearance	✓	✓	✓	✓	✓
13	Ship sanitation control certificate (or exemption)	✓	✓	✓	–	–
14	Safety radio certificate	✓	✓	✓	–	–
15	Stability booklet	✓	✓	✓	✓	✓
16	ISPS certificate	✓	✓	✓	✓	✓
17	Certificates for bridle, tow wires, pennants, stretchers and shackles	–	✓	✓	✓	✓
18	Suez or Panama Canal documentation (if relevant)	✓	✓	✓	✓	✓
19	Certificates for life saving appliances	✓	✓	✓	–	–
20	Minimum safe manning document	✓	✓	✓	–	–
21	Muster list	✓	✓	✓	–	–

NOTE 1 Smaller vessels (cargo vessels and offshore construction vessels, including supply vessels and tugs) can be exempt from some certification requirements.

NOTE 2 Some documents are not required for inland voyages or inland towages.

NOTE 3 Table 3 should be considered for the assessment of vessels which will be used for marine operations. The vessel's capabilities should be confirmed by the listed certificates.

Table 3 *(continued)*

	Document	Cargo vessel	Offshore construction vessel/supply/tug	All towage (manned)	Barge towage (unmanned)	Other towage (unmanned)
22	Damage control plans and booklets	✓	✓	✓	✓	✓
Recommended documents, where applicable						
23	Medicine certificate	✓	✓	✓	–	–
24	POB list	✓	✓	✓	–	–
25	Bollard pull certificate	–	✓	–	–	–
26	Lift certificate	✓	✓	✓	✓	✓
27	Certificate of class (DP systems if applicable)	–	✓	–	–	–
28	Certificate of class (propulsion systems)	–	✓	–	–	–
29	Certificate of class (safety construction)	–	✓	–	–	–
30	Certificate of class (safety equipment)	–	✓	–	–	–

NOTE 1 Smaller vessels (cargo vessels and offshore construction vessels, including supply vessels and tugs) can be exempt from some certification requirements.

NOTE 2 Some documents are not required for inland voyages or inland towages.

NOTE 3 Table 3 should be considered for the assessment of vessels which will be used for marine operations. The vessel's capabilities should be confirmed by the listed certificates.

6.8.3 Major equipment

Repetitive marine operations during installation of offshore wind farms apply various types of major equipment, such as e.g. cranes, hammers for piling, spreader bars as well as specific custom-made lifting equipment for blades, transitions pieces and piles or equipment used for cable installation.

In principle all such major equipment shall be certified by an IACS member organization or a recognized organization (3.114).

Other major equipment like slings, grommets and shackles used during lifting shall have standard certificates.

7 Metocean and earthquake requirements

7.1 Introduction

It can be impractical and/or uneconomical to design marine operations for performance in extreme environmental conditions. Consequently, marine operations are generally weather-sensitive, requiring specification of weather windows of minimum duration and operational limits related to metocean parameters during which the marine operations can be performed. Setting the operational limits too high can lead to unacceptable risk, whereas setting the limits too low can lead to excessive wait on weather or weather downtimes.

With regards to marine operations, reference shall be made specifically to ISO 19901-1:2005, 5.9, which deals with metocean parameters for short-term activities.

Operational limits for marine operations shall provide a realistic evaluation of the sensitivity of a marine operation to meteorological and oceanographic conditions. These limits are a major step to ensuring the safe execution of a marine operation. The operational limits shall be obtained by establishing limiting criteria for the metocean parameters by which the meteorological and oceanographic conditions are characterized. The response characteristics of particular installation vessels to specific aspects of the metocean environment shall be considered when establishing these operational limits.

A set of operational limits that is dependent on the type and duration of the operation shall be established and documented in the relevant method statement. Such criteria shall include, but not be limited to:

— wind magnitude and direction;

— wave height and period;

— current magnitude and direction;

— swell magnitude and direction.

Operations can be defined as weather-restricted or weather-unrestricted; see 7.2.

The risk of subjecting a marine operation to an extreme event exceeding the defined operational limits varies with location, and regard should be paid to local codes of practice. The meteorological conditions that are specific to particular geographical areas (such as arctic, temperate, tropical and equatorial areas) should be considered. Oceanographic conditions that are swell-dominated or swell-protected and have significant currents due to tide, ocean circulation and local rivers should also be considered.

With increasing development in areas experiencing typhoons and tsunamis, it would be of value to also check the official risk levels of typhoon and tsunamis events, as well as seismic, and “metocean” events and to seek out the relevant local codes of practice for all relevant extreme weather and seismic hazards identified, where the probability of occurrence and the severity of such an event is assessed as a risk requiring some level of mitigation.

Appropriate weather policies shall be established and documented to secure a good prospect of personnel survival in the event of evacuation, escape and rescue.

Some consideration to earthquakes is given in 7.10.

7.2 Weather-restricted/weather-unrestricted operations

7.2.1 Weather-restricted operations

A weather-restricted operation is a marine operation that can be completed according to the favourable weather forecast within the weather window and operational limits required for the operation. The reliability of weather forecasts is such that weather-restricted operations should generally be completed within 72 h.

7.2.2 Weather-unrestricted operations

Weather-unrestricted operations can safely take place in any weather condition that can be encountered during a season. The weather condition(s) shall reflect the statistical extremes for the area and season concerned.

7.3 Metocean conditions

7.3.1 Wind

Wind conditions shall be considered in the planning and engineering of marine operations. For the description of the wind parameters, reference is made to ISO 19901-1.

7.3.2 Wave, wave period and swell conditions

Wave conditions as well as any wave periods limiting the operations, e.g. during jacking-operations shall be considered in the planning and engineering of marine operations. For the description of the wave, wave period and swell parameters, reference is made to ISO 19901-1.

If swell has a noticeable effect on the operation, the response of the vessel to combined wind-driven seas and swell should be evaluated. In shallow water, lateral surge motions due to shoaling swell and second order wave drift actions should be considered.

For operations involving phases that are sensitive to large or extreme wave heights, such as temporary on-bottom stability, the maximum wave height and associated period should be used.

For precise operations that are sensitive to small fluctuations of the sea level, even under calm sea state conditions, the occurrence of long period, small amplitude swell on the site should be checked.

Attention should also be paid to particular site conditions that are prone to current acting against the waves, which can amplify wave steepness.

7.3.3 Current

Current conditions shall be considered in the planning and engineering of marine operations including any operations involving divers. For the description of the current parameters, reference is made to ISO 19901-1.

For marine operations, data and forecasts should be provided for current speed and direction including, as appropriate, current profiles from the surface to the sea floor.

Possible rates of scour around spud cans induced by high currents should be anticipated. Additional scour protection should therefore be prescribed in conditions where excessive scour may endanger leg fixity and jack-up vessel stability.

Current can be divided into six different components:

— wind-generated current, which is typically a surface current in the direction of the wind;

— ocean currents (for example the Gulf Stream), which can have homogenous flow down to several hundred metres;

— tidal current, which can also be felt down to a considerable depth below the surface although the velocities normally decrease with depth;

— freshwater outflow (river generated), which is typically a surface current;

— local current phenomena, such as loop (inertial), soliton (internal) and topographical currents;

— bottom currents.

To be able to forecast current with the required reliability, the following is normally necessary:

— for sites where tidal current dominates: measurement during at least one complete lunar cycle during the same season of the year as the actual planned operation;

— for sites where the complexity of the bathymetry (topographical current) can generate unstable flow: real-time current measurements with devices that record the current velocity and direction, with readouts at various depths; an example is the shedding of current stream around land obstacles that can introduce macro vortices in the main current flow.

7.3.4 Tidal factors

Any relevant tidal factors shall be considered in the planning and engineering of marine operations such as limits to site access for certain vessels and their operations.

7.3.5 Other metocean factors

Other factors and combinations of factors that can be critical and shall be considered include:

— combinations of wind, wave and current;

— water level, including tide and surge;

— restricted visibility;

— sea ice, icebergs, snow and ice accretion on topsides and structure, exceptionally low temperatures;

— tropical cyclones, dust storms and wind squalls;

— water density and salinity;

— precipitation;

— air temperature;

— water temperature.

Additional guidance and recommendations for operations in ice-affected waters for certain geographic areas can be found in[51].

7.3.6 Temperature

The occurrence of extreme high and low environmental temperatures shall be considered for their effect on equipment, operations and personnel, particularly regarding grouting operations (where applicable). Very low or high temperature can adversely affect hydraulic, pneumatic, ballasting, mechanical and safety systems. Changes in operational fluids can be required and auxiliary heating or cooling systems can be necessary. Personnel activities can be affected by temperature.

Ice-build up can also affect the ability of certain safety equipment to function during extreme winter conditions. All lifeboat davits, inflatable life-raft quick-release mechanisms, hinges and locks of life-jacket storage lockers on decks, lift-ring and EPIRB beacon mountings etc. must be deemed suitable for deployment in the extreme conditions prevalent in the area of operation, and be in full compliance with all SOLAS requirements.

7.3.7 Marine growth

The effect of marine growth on corrosion, weight, effective diameter and surface roughness shall be considered.

7.4 Metocean criteria

7.4.1 Design criteria and operational limits

For each specific phase of a marine operation, the design criteria and operational limits shall be defined as follows:

— the design criteria are that set of values of metocean parameters (wind, wave, current, water level, visibility, water density, water salinity, water temperature, marine growth and icing), for which design calculations are carried out, and against which the structure and/or operation is checked;

— for the design metocean parameters, the directionality of waves, wind and current shall be considered;

— for weather-unrestricted operations, the operational limits are the same as the design criteria, although lower values can be set for practical reasons;

— for weather-restricted operations, the operational limits are that set of values of metocean parameters (wind, wave, current, water level, visibility, water density, water salinity, water temperature, marine growth and icing), which are not exceeded at the start of the operation and which are forecasted not to be exceeded for the required weather window, e.g. the operational duration plus a contingency (see 6.5.3).

7.4.1.1 Design wave method

The design wave method takes into account the wave climate, in the sense that a design wave is determined for the voyage. It can be the extreme value for the worst area, or the extreme value for a complete route by combining scatter diagrams, and has a return period of one or more (10) trips or years. It is recommended to define more than one design wave to ensure that the largest critical response is covered.

7.4.1.2 Design spectra

See[52]/Sec. Three – C800 and ISO 19901-1. The design spectra method is based on the calculation of motion and load responses in sea states characterized by a specific wave spectrum.

7.4.1.3 Short crested sea

See[52]/Sec. Three – C900 and ISO 19901-1. A directional short crested wave spectrum may be applied based on non- directional spectra.

7.4.1.4 Swell

See[52]/Sec. Three – C1000 and ISO 19901-1. Swell type waves shall be considered for operations sensitive to long periods of motion or loads. They may be assumed regular in period and height, and may normally also be assumed independent of wind generated waves. Critical swell periods should be identified and considered in the design verification.

7.4.2 Return periods

Metocean parameters used as design criteria for marine operations depend on the planned duration of the operation including contingency. Generally, operations with a planned duration of up to three days may be considered as weather-restricted operations for which a specific weather window may be defined, while operations with a planned duration of more than three days should be considered as weather-unrestricted operations. Return periods of the metocean parameters for weather-unrestricted operations may be estimated as a multiple of the operational duration/weather window; a minimum 10 times the duration of the operation may be used.

In areas with consistent weather patterns, the duration of a weather-restricted operation may be extended beyond three days, if such an extension can be justified by appropriate documentation.

The choice of return periods should be based on the consequence of failure of the operation. The regional hazard curve of the sea state should also be considered. As general guidance, the return periods in Table 4, which are based on North Sea weather conditions, may be applied. Unless otherwise specified, return periods can depend on location and notwithstanding Table 4, should be determined in each sea area.

It is noted for clarification that the reference to the return periods is a means of quantifying risk and relate to the consequential damage to the structure in case of marine operations such as, e.g. installations or transit (voyage). There is no relation to the design life time of the structure itself.

Table 4 — General guidance for return periods of metocean parameters for weather-unrestricted operations (based on North Sea conditions), partly from[56]

Duration of the marine operation	Return periods of metocean parameters
Up to 3 days	Specific weather window to be defined. The metocean reduction factors in Table 19 shall be considered when selecting the design criteria.
3 days to 1 week	1 year return independent extrems, seasonal
1 week to 1 month	10 year return independent extrems, seasonal
1 month to 1 year	10 year return independent extrems, seasonal
More than 1 year	50 year return independent extrems, all year

Above values have been considered for operations in non-benign areas (e.g. North Sea, Irish Sea). As very general information for worldwide identification of non-benign areas, Table 5 could be referred to showing benign areas, thus indirectly indicating non-benign areas. In order to finally define location-specific situations, investigations should be made at each sea area as stated above. Those areas have the following characteristics and span as per below table:

Table 5 — Northern and Southern boundaries of benign weather areas by month [56]

Basin	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
North Atlantic	20° N				15° N		10° N	9° N			13° N	15° N
Red Sea	23° N			coast							23° N	
Arabian Gulf	coast											
Arabian Sea[a]	coast			8° N		4° N				7° N	5° N	4° N
Bay of Bengal	coast			7° N		4° N				7° N	5° N	4° N
Northwest Pacific to 160° W	4° N	Hong Kong — Manila or 10° N		5° N	4° N		5° N	6° N	5° N	4° N		
Northeast Pacific[b]	23° N				8° N	9° N			11° N	9° N		23° N
South Atlantic	23° S											
South Indian	7° S	9° S	8° S	6° S		15° S					5° S	7° S
Southwest Pacific from 125° E to 130° W	8° S	10° S		8° S	7° S	23° S					8° S	
Southeast Pacific to 130° W	23° S											

NOTE

— Light grey highlighted cells: Maximum area boundary

— Dark grey highlighted cells: All year boundary

— Not highlighted cells: Intermediate boundary

a The boundary between the Arabian Sea and Bay of Bengal is assumed to be 75° E.

b The Northeast Pacific is from 160° W to the American coast but 88° W for May to November inclusive.

7.4.3 Response-based analysis

For critical, long-duration marine activities, or operations in complex offshore environments where wind, sea, swell and currents are all significant, an analysis of the vessel responses should be conducted. Through numerical simulations, statistical estimates of the vessel or component behaviour can be directly characterized. This technique is especially important when more than a single directional parameter can dictate the response and, therefore, the sensitivity of the operation.

7.4.4 Probability distributions of sea state parameters

In order to understand the relationship of sea state parameters, such as the significant wave height and peak period, the uni- and bi-variable distributions should be examined. This includes the joint frequency distributions of significant wave height and period, and wind speed, wave height and current speed versus direction. For those parameters that dictate operability, weather windows should be computed.

7.5 Weather windows

7.5.1 Weather-restricted operations

Weather-restricted operations shall be planned using reliable time history data provided with weather forecasts that indicate not only the probability of not exceeding the limiting criteria but also the persistence of such conditions for the season and the weather windows considered for the particular operations.

In mature areas like the North Sea, this information is normally available, but in other areas it does not always exist or can be difficult to obtain. In some cases, limitations in the availability of data can be compensated for, achieving the same level of confidence, by applying statistical extrapolation methods. The quality of data available can influence the assessment of overall risk.

Weather restricted operations are characterized by:

— an operational limit specific for the operation based on design criteria (see 7.4.1);

— a required weather window specific for the operation and including a time contingency (see 6.5.3).

Due to the fact, that a weather forecast will show varying uncertainties for different weather windows, a metocean reduction factor shall be applied to the operational limits only. Thus for marine operations with a weather window of less than 72 h, the maximum forecast operational limit for each phase of the operation shall not exceed the design criteria for that phase multiplied by the applicable metocean reduction factor from Table 19. The metocean reduction factor should be determined as a function of the duration of the operation (weather window), the number of data sources and the quality of the available data.

The following simplified example clarifies the principle to be applied:

— operation: offshore transport of foundations;

— weather window: 22 h (including contingency);

— design criteria: H_s = 3,5 m;

— weather forecast provisions: two independent, project-specific weather forecasts plus infield wind and wave monitoring plus availability of offshore meteorologist;

— applicable metocean reduction factor based on weather window < 24 h: 0,77;

— resulting operational limit for planned operation: H_s = 3,5 m × 0,77 = 2,7 m.

Weather windows should be developed based on thresholds of the key sensitive parameters of the operation. For example, based on known limiting thresholds for wind and wave, the duration statistics for favourable conditions should be computed.

The conduct of weather-restricted operations requires that a procedure document shall be in place containing details of the proposed work schedule with particular reference to the anticipated duration of each operation, and the time needed to suspend operations and to reach the nearest safe haven, or to reach a safe elevated location and complete positioning, jacking, preloading and elevation to the minimum safe air gap (where applicable) at that location. A contingency for delay caused by leg extraction problems (if jack-ups are used), waiting for slack water, breakdown and other delays shall be allowed. It is recommended that the total time estimated for suspension of operations, removal, transit and installation in a safe location (including the time for jacking, preloading and elevation to the minimum safe air gap (if required) should not exceed 48 h including contingency for delay[66].

7.5.2 Impact on design

During the design stage of the marine operation, the following shall be considered:

— measures to make the operation more efficient and provide more margin on the weather window;

— redesign of the operation to tolerate higher metocean parameters (higher waves, current and wind conditions);

— possible contingency situations, and back-up and stand-by measures;

— possible delays to previous activities, which can push the operation into an unfavourable season.

7.6 Operational duration and weather window

7.6.1 Time schedule

7.6.1.1 For defining the weather window required for a time-critical port or marine operation, the scheduled plan of the operational duration shall be as realistic as possible.

The weather window shall include the necessary contingencies for:

— inaccuracy in operational duration;

— technical or operational delays;

— uncertainty in the environmental statistics.

7.6.1.2 The forecast window duration shall be in excess of the total critical operational schedule. This should be evaluated against a background of the planned operation and the consequences of exceedance. As a guideline, the following points should be considered:

— extra allowance for operations with vulnerable or critical equipment;

— reduced allowance for operations with a time schedule based on previous similar operations;

— extra allowance for operations in geographical areas and/or seasons where conditions are difficult to predict.

7.6.2 Point of no return

Weather-restricted operations shall be divided into a series of phases where the operation can be aborted and brought to a safe condition within the remainder of the existing weather window. The weather window in which conditions remain below operational limits shall be of sufficient duration to reach a safe condition before proceeding beyond the point of no return (PNR).

The reliability of the weather window is crucial for the critical period during an operation between any PNR and the structure reaching a safe situation.

The planned duration of a weather-restricted operation should not normally exceed 72 h; however, the duration may be indefinitely extended in prolonged periods of benign weather, provided that the limits for the restricted mode are never exceeded, and provided also that a future weather window suitable for moving e.g. a jack-up to the safe location is clearly and consistently identified by the duty forecaster with a high level of confidence on each weather forecast[66].

If a future weather window for safe removal of e.g. a jack-up cannot be identified with a high level of confidence within the next 72 h and risk of continued severe weather to follow is deemed to exist such that the limits for the restricted mode could be exceeded, then the jack-up should be moved to shelter immediately before the limits for jacking down, moving off location, transit, jacking up and preloading at the safe location are approached or exceeded[66].

7.7 Operational limits

For weather-restricted operations, the maximum forecast operational limit should be lower than the design criteria multiplied by a margin depending on the area and season, the delicacy of the operation, and the typical reliability of the forecast. The factor is dependent on the weather window and the design criteria determined. For project specific weather forecasts and weather windows typical for repetitive operations during construction of offshore wind farms, specific metocean reduction factors are provided in Table 19.

The maximum operational limit stated to be expected in the weather forecast should not exceed the design criteria for that operation multiplied by the applicable metocean reduction factor from Table 19. Subject to MWS approval it is allowed to deviate from the metocean reduction factors in Table 19. It is required that the MWS is accredited and has a relevant track record in marine operations for offshore wind. In order to apply the most favourable metocean reduction factor for the operation, suitable weather forecasts, meteorologist support and measurement of metocean parameters are recommended.

7.8 Forecasted and monitored operational limits

Project specific forecasts shall be obtained before and during all marine operations. The forecast shall be issued at suitable regular intervals dependent on the operation, not exceeding 12 h. Wherever possible a second forecast should be obtained from an independent source before critical operations.

For complex and/or longer weather restricted operations, the forecaster(s) should preferably be present at site or are available 24/7 via phone to check the local situation and provide regular weather briefings. Reference may be made to[65].

Considering short operational windows used in construction of offshore windfarms design limits should be derived considering desired operational limits multiplied with factors in Table 19.

An example for the application of the metocean reduction factor is provided in 7.5.1.

7.9 Metocean forecast

7.9.1 General

Forecasts shall be obtained before and during marine operations. The forecast shall be issued at suitable regular intervals dependent on the operation, with the intervals not exceeding 12 h.

For complex and/or long weather-restricted operations, forecaster(s) with local experience shall preferably be present on-site to check the local situation and provide regular weather briefing based on forecasts from two independent sources. This applies to major marine operations such as:

— float-over topsides;

— float-out;

— GBS tow out;

— offshore installation and lifting;

— sensitive barge towing;

— pile driving;

— piling;

— drilling.

7.9.2 Forecast parameters

The forecast should cover short- and medium-term and outlook periods, and should include:

- synopsis, barometric pressure, temperature;
- wind direction and speed, where the speed should be given for 10 m and 50 m and hub heights above sea level; the wind speed should indicate 10 min and 1 h means and also indicate wind gusts at predefined intervals;
- waves and swell, including significant and maximum height, direction and period;
- loop currents and wind squalls;
- visibility, rain, snow, sleet, icing and sea ice;
- confidence level of the forecast.

7.9.3 On-site monitoring

Where operations are sensitive to local (near-site or on-site) environmental conditions or to changes in these, real-time measurement, as well as regular forecast, both prior to start and during operations, shall be considered.

7.10 Earthquake

Possible effects of earthquakes (not metocean effects as tsunamis) on structures during marine operations, machinery and equipment if applicable, should be taken into account.

7.11 Soil

Reference is made to 11.7, 15.2.2; and 18.9 in respect of soil investigation and punch-through analysis.

8 Onshore transport and nearshore transport

8.1 Introduction

Transports of components to a base port are often organized as an onshore or a nearshore transport. Onshore and nearshore transports include:

- land-based transports:
  - transports via roads;
  - transport via railways;
- water-based transports:
  - inland water transport via inland waterways;
  - nearshore transport via vessels or barges.

Depending on the transport mode different recommendations occur. These requirements are explained in the following clauses.

8.2 Structural integrity calculations

Components have to be proven to withstand dynamic forces to be expected during inshore transport. These forces include but are not limited to wind forces and barge motions.

In the case that a seafastening of components is required, load case calculations for structure, seafastening and barge need to be performed for the respective component and/or group of components.

8.3 Personnel qualifications

All engineering personnel have to meet professional standards and hold the certificates required for their specific tasks by national standards and regulations.

8.4 Loading, unloading and lifting

The requirement of method statements for the loading, unloading and lifting processes depends on national regulations, the transport medium used and specific contract appointments between owner and transport service provider. If a certified method statement for the loadout and lifting process is required, this statement has to address the specific component type, the transport medium and related processes. Annexes A.3 to A.6 of this International Standard and[60] provide an example for a method statement template which can be used as a guidance.

All components must be equipped with clearly marked and certified lifting points.

The lifting gear must be suitable and certified by authorities in charge.

8.5 Transport via roads

Transports via roads of components and sub-assemblies can be performed by different vehicles. These transport vehicles include, but are not limited to transports via:

— trucks;

— SPMTs;

— low-loader trailer.

For all transport vehicles certified lashing points have to be used for lashing the load. The lashing has to meet national regulation and safety standards. Lashing points of the components must be clearly marked and certified.

The requirement of a transport permit must be checked before starting the transport. If a transport permit is required, the transport operations must adhere closely to the particular transport permit provided by responsible authorities.

8.6 Transport via inshore waterways

Transport via inshore waterways refers to transports of components with inland vessels or barges on inland waterway (e.g. rivers). Seafastening requirements shall be adapted to the sheltered character of inland waterway. As stated in 8.2 it has to be proven that components and vessels withstand dynamic forces to be expected during inshore transport. All operations and process steps during the transport have to meet national regulations.

8.7 Transport via nearshore waterways

The transport via nearshore waterways addresses transports with ships or barges in coastal areas. In particular nearshore transports are defined as transports in an area of about 5 km away from the coastline for a short distance or, if for a longer distance, with sufficient shelter ports in close vicinity.

For nearshore transport a specific seafastening of components is required. The requirements for the seafastening depend on the particular nearshore area. Factors which influence the dimensioning of the seafastening are the expected:

— significant wave heights;

— wind speed.

Restrictions for the seafastening may differ in dependence of the nearshore route. Usually the requirements of the seafastening for nearshore transports are less restrictive than the seafastening for offshore transports.

8.8 Transport via railways

All transports via railways have to meet the requirements of the railway operator. Specific requirements of the relevant railway systems have to be fulfilled. In particular the components have to meet the requirements of the minimum clearance outline, structure gauge and the kinematic gauge. The minimum clearance outline profile may vary depending on the particular railway system used. Accordingly, if multiple railway systems should be used for the transport of components (e.g. across country borders), the requirements of the minimum clearance outline have to be checked for each railway system used for the transport.

8.9 Transport frames and equipment

Equipment and transport frames which are solely used for inshore transport have to be suitable for the respective tasks. They have to meet national regulations. All transport frames and equipment, which will be used inshore and offshore, must be built and certified for offshore use.

Transport frames should normally be certified by a competent body as suitable for multi-trip usage and consider fatigue cases. Before storing components, the transport frame shall be inspected visually and inspection records should be kept for later checking. If the inspection reveals any areas of concern or there are areas that could be subject to laminar tearing then special NDT inspection shall be carried out considering them as second-hand equipment. In addition, all areas should be subject to suitable NDT every 3 to 5 uses (depending on fatigue and/or likely maximum stress levels). Normally the transport frames will also be used as lifting frames so the lifting points should also be thoroughly inspected. Design of these frames should also have compatible lifting points

Before storing components, the equipment and storage frames have to be inspected visually. Damaged storage frames or frames with plastic deformations must not be used for storing or transporting components.

The design of transport frames should aim at a multiple use in different transport steps of the supply chain. This helps to avoid additional handling steps for the change of transport frames. Ideally, transport frames and transport units have compatible lashing points and a compatible system for the seafastening. This topic should be subjected during the contracting phase of an installation project.

9 Intermediate storage areas

9.1 Introduction

Intermediate storage is done between different transportation operations. It includes storage processes at the component manufacturers and their suppliers as well as the storage of components in marshalling ports. Components have to be stored at defined storage areas with suitable equipment (e.g. storage frames), which allow a secure storage for minimum six months. This leads to different requirements for:

— general infrastructure (e.g. accessibility of components, security measures);

— surface configuration and the floor load-bearing capacity;

— equipment for storage and the protection of components during the storage phase.

In this context the provision of components for next transportation operations (e.g. provision at quayside for installation vessels) is defined as an intermediate storage process.

9.2 Infrastructure requirements

The design of storage areas must provide sufficient manoeuvring areas. Accordingly, additional areas have to be included in the planned storage areas. The storage area should have at least a size of a minimum 1,4 times the square meters — as a rule of thumb — required for the simultaneous storage of the before scheduled components. If specified storage concepts are applied, these additional manoeuvring areas can be reduced. These concepts have to prove that the layout of storage areas meet minimal turning curves of used transport vehicles (e.g. SPMTs) and lifting equipment (e.g. stacker and mobile crane). Furthermore the underlying accessibility concept of components can reduce the requirement of additional manoeuvring areas. Storing components with a FIFO (first-in-first-out) or a LIFO (last-in-first-out) concept allows concentrating more components on a smaller area. However, these storage concepts ignore that components are in single access. Accordingly, changes in the provision order are not possible. The storage concept should be subjected during the contracting phase. The underlying storage concept has to prove that the concentration of components does not violate load bearing restrictions.

9.2.1 Load bearing

For storage areas which will be used for the storage of WTG components or other major parts such as foundations, a load bearing certificate must be provided and the maximum load bearing capacity on the storage yard must be clearly stated. At the major parts of the storage yard such as transport routes, quay side and storage access the maximum load bearing capacity must be at least the highest load bearing capacity required by the components which will be stored on the storage area. If not all parts of the storage area have the same load bearing capacity then it must be clearly marked in the statement and it is also advisable to mark it directly on the storage yard which parts have a lower load bearing capacity. These areas must be allocated to components where the load bearing capacity of the storage yard will not be lower than the required load bearing capacity by the components.

9.2.2 Surface

The surface of the storage area must be plane and no obstacles should hinder the transport and storage of the components. A statement must be provided showing the surface inclination, the connection points for water and electricity including the voltage and ampere at connection point, the position of light mast and the distribution of luminous intensity in LUX. The intensity of the illumination should meet the requirements mentioned in CIE S 015/E:2005 for the application in ports. The intensity of the illumination must meet national safety regulations.

9.3 Personnel qualifications

Required personnel qualifications are the same as in 8.3.

9.4 Loadout, unloading and lifting

For requirements see 8.4.

9.5 Storage frames and equipment

Storage frames and other storage related equipment have to be suitable for storing components for a period of at least six months. They have to meet national regulations. It should be certified that used storage frames are able to bear the load of the respective components. They have to transmit the load correctly to the surface and the ground. Before storing components on specified storage frames the equipment and storage frames have to be inspected visually. Damaged storage frames or frames with plastic deformations must not be used for storing components.

The design of storage frames should aim at a multiple use in the supply chain. Ideally, storage frames can also be used for transport activities. This topic should be specifically addressed during the contracting phase of an installation project.

9.6 Requirements of components for storage

Components have to provide clearly marked attachment points for storage and transport frames or other storage equipment. Manufacturers have to provide statements comprising requirements for the storage of their components. This statement should include any other requirements. These requirements may include, but are not limited to:

— provision of electrical current during the storage phase;

— specific environmental conditions during storage (e.g. humidity, temperature, etc.);

— maintenance routines during storage;

— additional protection measures against environmental conditions.

All measures provided in this statement should allow a secure storage phase of at least six months.

9.7 Protection of components against environmental conditions

The outside structure of the main components is constructed to be exposed to natural influences. Due to this reason only the connection points have to be protected against wind, water etc.

The connection points of the main components should be covered either with tarpaulin, a wooden cover or equivalent covers and be designed according to the different connection points. The chosen cover must guarantee that the connection points are totally covered and secured for the whole supply chain process. Also the connection of lifting pads/devices must be possible without the removing of the covers. The manufacturer of the component has to state requirements for the protection of the components.

Ideally, the protection measures can be used during the entire supply chain. Covering lifting points or connecting points to storage and transport frames should be avoided.

9.8 Structural integrity calculations

All major components must have a statement where it is clearly shown that the components can be stored over a longer period of at least six months. Further the statement must include the storing position e.g. towers upright or horizontal. The statement must include the general description of the component, the storing position, the stack ability and the required securing measures.

9.9 Safety and security

For the safety and security of the operations, the ISPS code, legal harbour, national and/or international regulations must be respected where applicable.

10 Pre-assembly

10.1 Introduction

Pre-assembly of components refers to assembly-processes which are not part of the manufacturing process of the components at the site of the manufacturer. Pre-assembly processes may occur for example in ports, e.g. WTG towers, blades mounted to hubs, or transition pieces as part of the foundations. Before and during the pre-assembly of components different requirements concerning the working area, lifting activities, operational conditions and the used equipment arise. For pre-assembly activities, the operator of the assembly area may differ from the operator of the assembly activities (e.g. pre-assembly of foundations by the manufacturer in the port area). Accordingly, different responsibilities of the involved parties have to be taken into account.

10.2 Pre-assembly area requirements

The general requirements of intermediate storage of components apply (see 9.2). Surfaces and the load bearing capacity have to be sufficient for the components that should be assembled. As appropriate, additional areas have to be planned for cranes and other equipment for the assembly. Further requirements for the assembly (e.g. access to electric current, water or compressed air) have to be stated by the operator of the assembly activities.

10.3 Personnel qualifications

Required personnel qualifications are the same as in 8.3

10.4 Loadout, lifting and internal transport

The measures/detailed procedures for loadout, lifting and internal transport must be stated in the manual of the component manufacturer.

See 8.4 (this clause expands upon that one).

10.5 Pre-assembly activities

A proven concept for pre-assembly activities/quality assurance must be provided. This concept has to cover all assembly activities. Furthermore, the concept has to provide protection measures for other goods which are stored near the assembly area (e.g. protection against contamination with flush rust induced by the assembly activities). A suitable countermeasure in this context may be housing of the working area with tarpaulin.

Health and security aspects must be included. The assembly operator has to define which dangerous substances are used and indicate quantities of these substances. The operator of the assembly activities is responsible for the safe storage of these substances. National regulations have to be met concerning the handling of hazardous substances. The operator of the assembly activities is also responsible for the correct disposal of these substances.

10.6 Operational limits/weather conditions

Operational limits must be stated for each area and equipment type. The required weather conditions should be specified for any part, equipment or area that can only be used in particular weather conditions.

10.7 Pre-assembly equipment

All equipment and machinery used during pre-assembly must be certified according to the local or national regulations. Only parts in the operational limits of the machinery and equipment can make use of such equipment.

10.8 Structural integrity calculations

For requirements see 8.2.

10.9 Safety and security

The safety and security requirement of 9.9 apply. In the case that the working operator and the operator of the working area differ, the working area operator has to provide access to the working operator.

11 Harbour activities

11.1 Introduction

Harbour activities address the requirement for the exchange of WTG components, foundations or other units of an offshore wind farm between different transport units and the port. Activities performed within the port, e.g. intermediate storage, pre-assembly, provision of components, are addressed by Clauses 9, 10 and 11. Specific requirements concerning the quayside, the access to harbour areas, soil requirements in the harbour and the vessel management are addressed in this clause.

11.2 Personnel qualifications

Required personnel qualifications are the same as in 8.3.

11.3 Accessibility of harbour areas

11.3.1 Water access

Vessels operating at offshore harbours usually require an always afloat, always accessible (AAAA) status, which means that vessels must not have ground contact during their laytime. Any exceptions regarding particularly loadout operations from jack-up vessels requiring semi-jacked positioning have to be agreed with the port agencies.

Furthermore, the harbour infrastructure has to be suitable for basic manoeuvres (e.g. turning manoeuvres) of the vessel. Factors which mainly determine this status are:

— tidal restrictions;

— draught of the vessel;

— loaded draught of the vessel;

— length of the quayside;

— general geometry of the harbour basin;

— width and length of locks;

— air draught in locks and under bridges;

— overhead power lines;

— other harbour traffic.

11.3.2 Inland access

For the inland transport of components all recommendations of Clause 8 apply. The surface and the load-bearing capacity have to be sufficient for the respective components.

11.4 Storage areas of quayside

The party responsible for the area must provide detailed descriptions of the operational limits of the quayside, as well as information on availability of electricity, freshwater, as well as any other appropriate requested information.

See also 11.6 and 11.7.

11.5 Safety and security measures

For the safety and security of the operations, all parties mentioned in this International Standard (see 9.9) must respect ISPS code, legal harbour, national and/or international regulations.

11.6 Quayside requirements

The party responsible for the harbour area must provide detailed information about tide and current conditions as well as quayside structure analysis, including maximum pressure loads close to the quay, safety distance between the quay wall and cranes/components, quay bollard and fender capacity. This information has to be considered during the planning of handling operations.

11.7 Harbour subsea soil requirements for jacking activities

As a pre-requisite of jacking activities the seabed must be analysed with regard to load bearing by the jack-up legs.

If the load bearing abilities are not sufficient, the sea bed must be strengthened up to desired load bearing abilities.

The load bearing quality of the sea bed must be documented and provided and analysed for specific jack-up vessels and loading situations.

The jack-up procedure has to be described and all relevant information (specifications of the jack-up vessel, type and dimensions of jack-up-legs, weights and forces during loading/unloading) has to be provided by the operator of the jack-up vessel.

Most common risks should have sufficient mitigation measures to allow comfortable margins in terms of soil capacity and prevention of uncontrolled movement of jacket legs. The risks with highest consequences considered in common practice are the following:

- punch-through;
- bearing failure and settlement;
- sliding failure;
- footprints;
- rack phase difference (RPD);
- scour;
- layered soils;
- foundation fixity;
- jack-up spudcan and jacket leg interaction;
- cyclic loading;
- debris;
- shallow gas;
- seafloor instability;
- soil liquefaction.

See also 18.1.3 (harbours) and 18.9 (jack-up soil assessment) in respect to punch-through during loadout and during offshore installation operations.

12 Weight control

12.1 Introduction

Weight control shall be performed by means of a well-defined procedural system, such as that described in[10].

Weight control procedures shall be in operation throughout construction and outfitting when afloat. In the weight control documentation, SI units should be used.

12.2 Weight control classes

In relation to weight control classes[10] as well as[56] states that:

— "Class A weight control shall apply if the project is weight or CoG sensitive for lifting and marine operations or during marine operations (with the addition of temporaries), or has many contractors with which to interface. Projects can also require this high definition if risk gives cause for concern."

— "Class B weight control shall apply to projects where the focus on weight and CoG is less critical for lifting and marine operations than for projects where Class A is applicable."

— "Class C weight control shall apply to projects where the requirements for weight and CoG data are not critical."

Unless it can be shown that a particular structure and specific lift operation are not weight or CoG sensitive, class A weight control shall apply using the following weight contingencies:

— Calculated weights: If the 50/50 weight estimate as defined in[10] is derived, an appropriate weight contingency factor no less than 1,05 shall be applied. The extreme of the CoG envelope (if applicable) shall be used[56].

— Weighed weights: A weight contingency factor of no less than 1,03 shall be applied to the final weighed weight. This may be reduced if it can be demonstrated, for the specific case in question, that the overall accuracy of the weighing method and equipment is better than 3 %[56].

The application of weight contingency factors for lift purposes is given in 19.4.

12.3 Weight and CoG constraints

For the purpose of planning marine operations, the 50/50 weight estimate method is not always used. Instead, not-to-exceed (NTE) weights with associated CoG envelopes are developed. In cases where minimum values of weight and CoG govern, these minimum values (not-to-go-under values) should be used.

Upon receipt of the as-built weight and CoG, normally obtained by direct measurement, the as-built results are compared against the values used in the analyses. If needed, the analysis is re-run using the as-built values with the selected weight contingency.

12.4 Weight control audits

When afloat, periodic draught measurements, weight control audits (of the construction and installation status, temporary item status and of the completeness of the weight reporting system) and appropriate inclining tests shall be carried out. Inclining tests shall only be carried out if subsequent operations require an accurate position of the CoG and if it is practical to do so.

For a description of the execution of an inclining test, see 13.12.

Alternatively a deadweight survey and displacement test may be carried out to determine the weight and the horizontal position of the CoG. If the indicated weight and/or CoG does not fall within some pre-agreed accuracy of the projected values (normally 1 %), a conservative penalty shall be applied for CoG determination by calculations. For more information, see 13.12.

12.5 Dimensional control

Where the balance between weight and buoyancy is critical to the draught, stability or floating behaviour, the dimensional control and monitoring shall be maintained to an appropriate level of accuracy.

12.6 Serial items

When a large number of virtually identical items are built with quality control and management system according to[17], weighing of each item may not be required. A reduced weight contingency factor may be agreed based on the standard deviation from weighing, of initial items with random subsequent weighing used to confirm consistency of manufacture. The manufacturer shall also supply a weight statement with tolerance and CoG envelope for all weight-sensitive items. Weighing of each item may not be required if the quality control and predictions of final weights in initial weighings are shown to be good enough and a reduced requirement for weighing may then be agreed.

12.7 Offshore wind farm components

Apart from[55], section 2.3.7, Table 2-3, the following weight contingencies may be accepted, unless proven otherwise:

— monopile lift weight and CoG contingencies: 3 %;

— transition piece weight and CoG contingencies: 5 % weighed and 10 % unweighed;

— WTG components (tower, nacelle, blades): 3 % weighed and 10 % unweighed unless can be proven that more precise weight can be achieved.

Weight and CoG evaluation for combination of components (nacelle and hub, hub and blades, etc.) should be documented into an explanatory report.

12.8 Weight determinations

The below information is meant to offer guidance in preparing weight determinations related to OWF components by physical weighing.

For weight determination, the following items should be engineered:

— weight control report containing components and contingency (for rough reference regarding expected weight);

— weighing procedure/method statement;

— structural integrity assessment for weighing loadcase;

— weighing results report.

13 Stability

13.1 Introduction

This clause does not cover the case of floating turbines moored to the seabed. Stability in this clause is referring (i) to vessels and barges, whether self-propelled or towed or (ii) to self-floating structures such as e.g. topsides of offshore substations or offshore accommodation platforms which are floated to the offshore location for installation by jacking up or any structures towed during transit for further installation at the offshore location.

In addition to the above current requirements, the stability and global strength of all vessels should also satisfy either; for vessels subject to IMO rules and regulations, the IMO criteria in order to remain in compliance with registration authorities' requirements or, for vessels that are subject to local requirements established by competent authorities, criteria set out by such authorities.

The general stability requirements for floating objects (e.g. wind turbine foundations, MOU substation topsides), with comments on the stability criteria for particular types of structure where they differ from the general requirements, are set out in 13.2 to 13.12.

Special consideration is given for structures designed for one time voyage from construction site to installation site (floating topsides, floating foundations, etc.) which in addition to below specified criteria may also need to follow operational specific requirements.

Reference is made to the IMO rules for special purpose vessels and work vessels operation in the offshore wind farms and other structures.

13.2 General requirements

Intact stability and damage stability in accordance with the criteria established for the project shall be documented.

The general requirements for intact and damage stability given in 13.4 and 13.5 shall be applied to vessels and floating structures. Exceptions and alternatives are dealt with separately.

Vessels and barges used in marine operations shall meet the stability requirements dictated by the flag state of the vessel.

13.3 Stability calculations

The purpose of carrying out stability calculations it is to verify, that the vessel/floating structure fulfils the requirements set out in the applicable rules and regulations. Thus for all floating structures and vessels to which current standard applies, stability calculations shall be carried out.

The results of the weight determinations (see Clause 12) shall be taken into account in these stability calculations.

If motion responses in various floating stages (such as construction afloat, towage and installation), that relate to the marine operations can cause loss of stability or can become critical for other considerations, dynamic analyses should be used to verify adequate reserves in stability for safe marine operation.

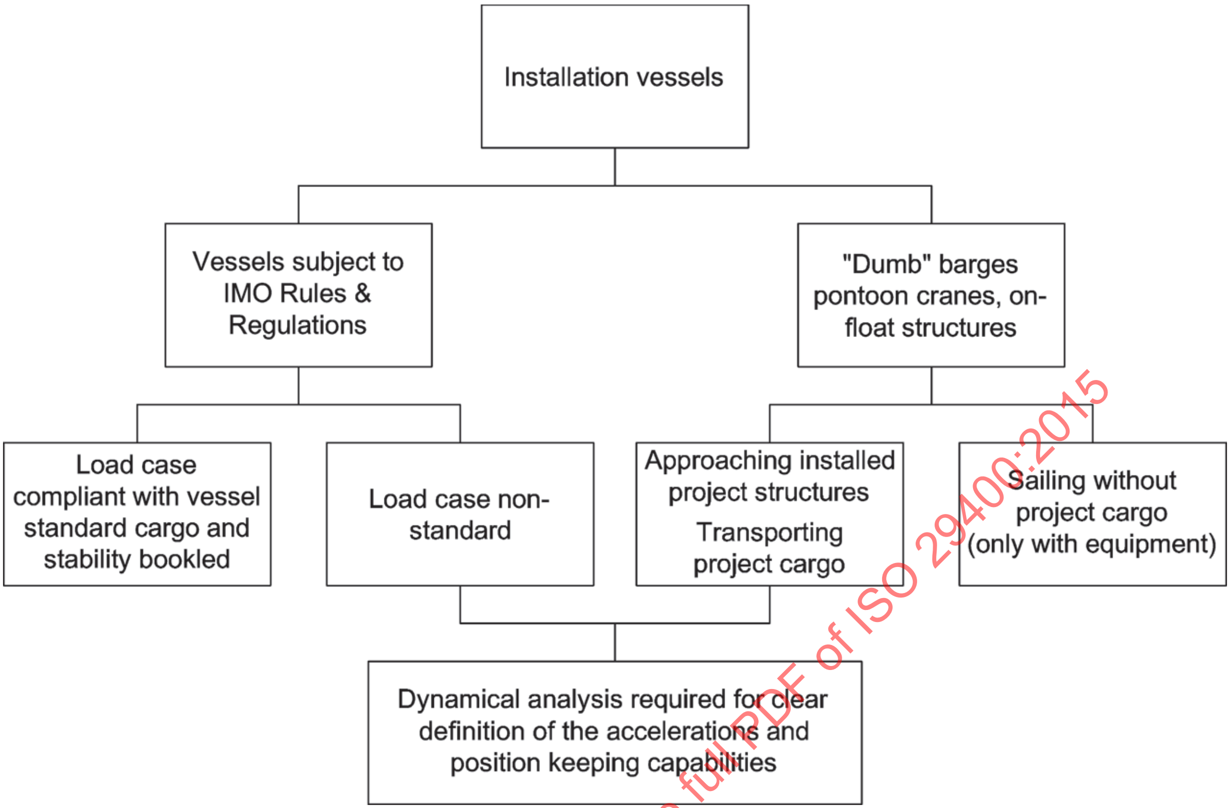


Figure 2 — Chart for dynamic analysis

The effective metacentric height (GM) together with the displacement and added mass and the moment of inertia determine the natural roll period. By employing the effect of free surface in cargo and ballast tanks, the natural periods can be shifted out of the region of spectral peak periods. This can avoid dynamic amplification. However, free surface effects at larger roll angles are limited by the tank shape and filling grades. The reduction in initial GM due to free surface shall be supported by adequate theoretical or experimental justification.

If the object considered is not essentially symmetrical about both a longitudinal and a transverse plane, then free-trimming calculations should be carried out.

NOTE For some self-floating structures, longitudinal stability can be more critical than transverse stability.

The cargo (such as overhanging legs of structures and hulls of transformer platforms) can contribute to the intact stability (see 13.4) and thus shall be included in the calculations.

Allowance for ice accumulation on exposed structures should be taken into account as well.

13.4 Intact stability

13.4.1 Introduction

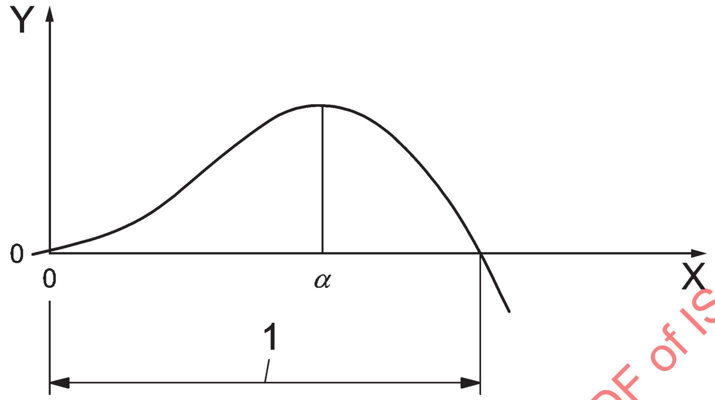
The intact stability range is the range between 0° heel or trim and the heeling angle at which the righting arm (GZ) becomes negative, as indicated in Figure 3.].

NOTE External actions other than wind heeling, such as current actions, mooring and towing line tensions, actions from propulsion units, either main or azimuthing, can also have impact on stability.

Figure 3 shows both the initial linear and the subsequent nonlinear relationship between the heeling angle and the righting arm. The heeling angle, α, indicates the angle where the maximum hydrostatic righting moment occurs.

The maximum amplitudes of motion and associated stability criteria for a specific towage or voyage can be derived from motion response calculations or model tests. In addition, a further limiting heeling angle shall be determined to account for structural design limitations of, for instance, the topsides modules and their attachments to the hull at both the fit-out and welded out stages. In other words, if the integrity of equipment foundations or topsides-to-hull attachments are compromised at 10°, it is irrelevant if the hull can heel to 15°.

In general, the stability criteria of the applicable flag state shall be satisfied, unless satisfying other safe stability criteria can be demonstrated and proven as equal.



Key

X heeling angle, expressed in degrees

Y righting arm, expressed in metres

1 intact stability range

Figure 3 — Illustration of stability terms

13.4.2 Intact stability criteria

The areas under the righting moment curve and the wind heeling moment (or wind moment) curve (see Figure 4) shall be calculated up to a heeling angle which is the smallest of:

— the angle corresponding to the second intercept of the two curves;

— the angle at which the progressive flooding occurs;

— the angle at which overloading of a structural member occurs, including grillage and sea fastening components.

Guidance on how to derive the wind heeling moment curve is given in[40].

The area under the righting moment curve shall not be less than 1,3 times the area under the wind heeling moment curve for column-stabilized floating structures (wet tow of semi-submersibles and TLPs) and shall not be less than 1,4 times the area under the wind heeling moment curve for other types of floating structures (including dry tow of semi-submersibles and TLPs) as given in the relationships in Formula (1) for column-stabilized structures and Formula (2) for other structures:

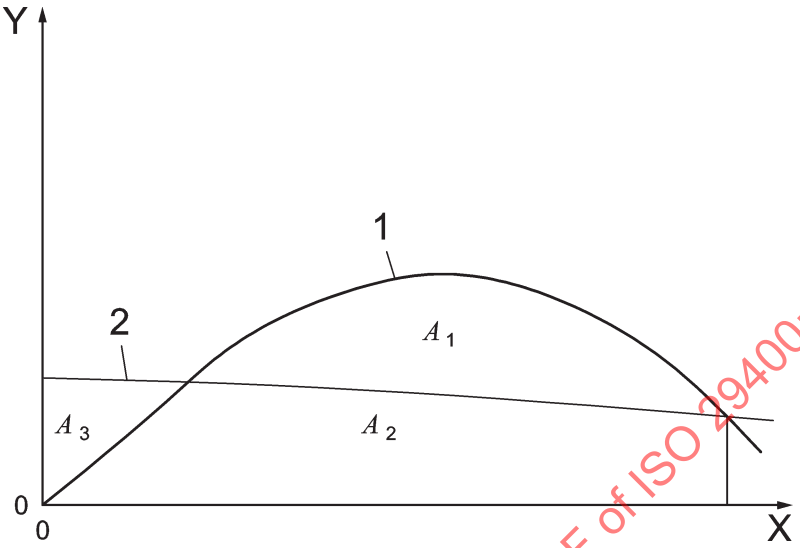
$$(A_1+A_2) \geq 1,3\ (A_2+A_3) \qquad (1)$$

$$(A_1+A_2) \geq 1,4\ (A_2+A_3) \qquad (2)$$

where A_1, A_2 and A_3 are the areas defined as indicated in Figure 4.

The wind speed used to compute the wind heeling moment curve shall be the 1 min sustained wind at an elevation of 10 m above sea level during the operation with return periods as defined in 7.4.2.

NOTE A 36 m/s wind speed is typically checked for normal operational conditions.



Key

X heeling angle, expressed in degrees

Y moment, expressed in kilonewton-metres

1 righting moment

2 wind overturning moment

Figure 4 — Intact stability requirement

The stability range should not be less than 20 + 0,8 β, where β is the sum of the static wind heeling angle and the maximum roll angle in degrees.

Where cargo overhangs are immersed as a result of heeling due to a 15 m/s beam wind in still water conditions, it shall be demonstrated that vessel controllability is not seriously impaired, and that no structural damage to the cargo can occur; see also sea fastening requirements as given in 16.17.5.

For marine operations of very short duration in sheltered waters (for instance harbour moves and out-of-dock operations) that are covered by a reliable weather forecast, an exemption from the intact stability requirements may be considered. However, the range of positive stability shall never be less than 15°.

13.5 Damage stability

13.5.1 Introduction

Damage stability shall be evaluated by considering the operational procedures and duration, environmental actions and responses, and the consequences of possible damage. Reference is made to[60].

Evaluation of damage stability shall be based on damage scenarios according to previously identified contingency situations. Collision, leakage and operational failure situations shall be evaluated. Damage cases shall include flooding of any one compartment located below the maximum subdivision waterline that is either adjacent to the sea or capable of being flooded by ballast water, sea water service or bilge piping passing through the compartment.

As a minimum, the floating object shall have sufficient stability and reserve buoyancy to remain floating at a waterline below any opening where progressive flooding can occur with any one compartment undergoing flooding.

Attention shall be paid to ingress of water caused by, for example:

— impacts from vessels, dropped objects, etc.;

— mechanical system failure;

— operational errors;

— vessel dynamics and variations of wave height in defined sea states;

— downflooding points.

In the case of collision, the following parameters shall be considered:

— compartments separated by a watertight deck within $^{+5}_{-3}$ m of the maximum subdivision waterline shall be considered as one compartment;

— transverse penetration of not less than 1,5 m, unless it can be demonstrated that such penetration is unlikely to occur;

— longitudinal damage of 3 m of horizontal extent, or one eighth of column perimeter of exposed areas in the worst region;

— piping ventilation systems, trunks, etc. within the extent of damage shall be assumed to be damaged.

Damage to compartments above the maximum subdivision waterline, including, for instance, caissons or cargo compartments, the buoyancy of which is required to meet the intact stability requirements of 13.4, should be taken into account in damage case definition.

The emptying of a full compartment to the waterline in damaged condition shall be considered if it gives a more severe result than the flooding of an empty compartment. The loss of air from any air cushion compartment shall also be considered.

13.5.2 Damage stability criteria

The areas under the righting moment curve and the wind heeling moment (or wind moment) curve (see Figure 5) shall be calculated from the equilibrium heeling angle up to a heel angle, which is the smallest of

— the angle corresponding to the second intercept of the two curves;

— the angle at which progressive flooding occurs;

— the angle at which overloading of a structural member occurs, including grillage and sea fastening elements.

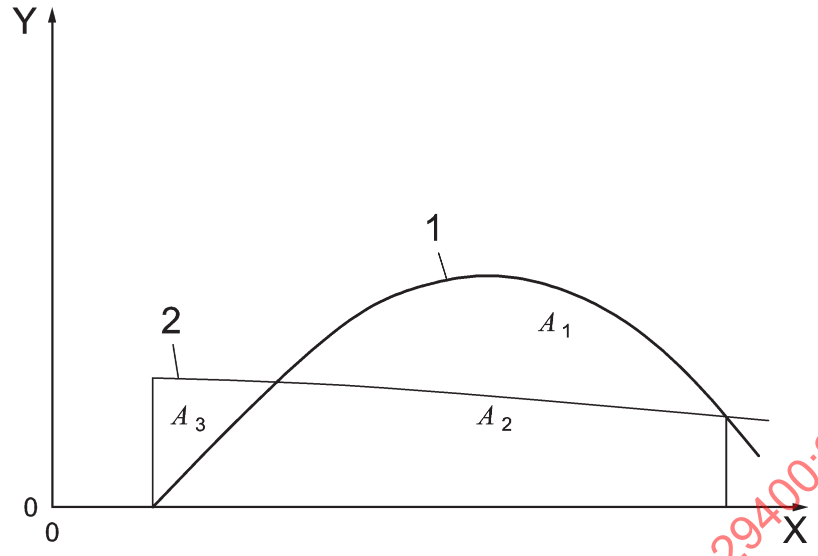
Guidance on how to derive the wind heeling moment curve is given in Reference[40].

The area under the righting moment curve shall not be less than 1,4 times the area under the wind heeling moment curve as given by Formula (3):

$$(A_1 + A_2) \geq 1{,}4\,(A_2 + A_3) \qquad (3)$$

where A_1, A_2 and A_3 are the areas defined as indicated in Figure 5.

NOTE This criterion has been found inadequate for jack-ups, and is likely to be inadequate also for barges with limited freeboard carrying cargoes[67].



Key

X heeling angle, expressed in degrees

Y moment, expressed in kilonewton-metres

1 righting moment

2 wind overturning moment

Figure 5 — Damage stability requirements

Where it is impractical to comply with damage stability requirements, a risk assessment shall be carried out, and the following precautions for the prevention of damage/collision impact shall be taken:

— reinforce or fender vulnerable areas to withstand collision from the largest towing or attending vessel, at a speed of typically 2 m/s;

— protect projecting hatches, pipework and valves against collision or damage from towing and handling lines;

— provide emergency towlines with trailing pick-up lines to minimize the need for vessels to approach the structure closely during the tow;

— provide emergency pumping equipment;

— minimize the potential for leaks via ballast or other systems;

— protect ballast intakes, discharges and any other penetrations through the skin of the vessel or object by means of a double barrier system or blanking off;

— conspicuously mark vulnerable areas and make masters of all towing or attending vessels aware of these;

— provide a guard vessel to warn off other approaching vessels.

13.6 Single-barge transports

Single-barge transports should conform to the requirements set out in 13.4 and 13.5.

13.7 Multi-barge transports

Multi-barge transports are transports where the cargo is supported by more than one barge, or by one or more barges supported in turn by additional barge(s).

Multi-barge transports shall conform to the requirements of 13.4 and 13.5, with the following additional recommendations:

— barges that are totally immersed in the intact condition should be classed as submersible barges;

— it should be demonstrated that the flooding of any one compartment of any barge cannot cause the damaged barge to change its heeling or trim angle relative to the overall heeling or trim of the combined barge assembly. The damaged barge should not pivot around any of the reaction points between it and the cargo or between it and another barge, thus losing contact at any other reaction point.

13.8 Classed vessels

The requirements of 13.4 also apply to classed vessels.

NOTE 1 For vessels that carry offshore or similar cargoes, reference is made to the IMO instruments in References[40] and[25].

The damage stability requirements in Clause 13 do not apply to the transport of cargoes on registered and classed trading vessels sailing at the assigned "B" freeboard or greater.

NOTE 2 The "B" freeboard is the minimum freeboard assigned to a type B vessel, which is generally defined as any vessel that is not carrying a bulk liquid cargo. Reduced freeboards can be assigned to a type B vessel that is over 100 m in length, depending on the arrangements for protection of crew, freeing arrangements, strength, sealing and security of hatch covers, and damage stability characteristics, see IMO instrument[48] for further details.

13.9 Self-floating structures

13.9.1 General

Self-floating structures are objects that are supported by their own buoyancy during construction afloat, towage and installation (such as GBSs with or without topsides, self-floating steel structures including floating monopiles, topside structures for offshore substations).

Because of the diversity of self-floating structures, where compliance with the general requirements and guidance in Clause 13 is not applicable or practical, a risk assessment shall be carried out (see 13.5.2).

13.9.2 Intact and damage stability

13.9.2.1 Unless existing IMO regulations are applicable, the requirements of 13.4 and 13.5 shall apply with the additional criteria specified in this subclause.

The initial intact GM, after correction for free surface and air cushion effects, shall not be less than 1 m.

Where the intact stability range required by 13.4 cannot be achieved, it shall be demonstrated that

— ϕ_{max}, the value of the maximum dynamic heeling angle due to wind and waves, expressed in degrees, is at most half that of the heeling angle, α, expressed in degrees, where the maximum hydrostatic righting moment occurs; see Figure 3;

— the area ratio required in 13.4.2 can be achieved.

During construction afloat, particular attention shall be paid to any internal or external openings to sea that can vary as construction proceeds. After damage, when subjected to the design wind and wave for the operation, an adequate freeboard shall remain.

A risk assessment shall be carried out for operations where, at any stage, stability and/or reserve buoyancy is critical. The duration of the critical condition shall be minimized. Requirements for back-up systems and their availability shall be assessed.

13.9.2.2 For some floating structures, applying damage stability requirements is impractical at some stages of construction or towage. In such cases alternative measures shall be considered, which can include the following:

— providing local structural reinforcements or fenders within the area bounded by two horizontal planes positioned 5 m above and 3 m below the maximum subdivision waterline, in order to minimize effects of a collision from the largest towing or attending vessel;

— developing rigorous procedures to ensure that flooding does not occur; this includes consideration of collision, leakage through the ballast or other systems, reliability and redundancy in pumping arrangements and redundancy of power supplies;

— carrying out a risk assessment for flooding.

13.9.3 Upending and installation of self-floating and launched steel structures

The following apply for the upending and installation of self-floating and launched steel structures:

— intact and damage conditions shall take into account the most severe combination of tolerances on structure weight, CoG, buoyancy, centre of buoyancy and water density;

— a FMEA or similar study should be carried out on the ballast and buoyancy systems to ensure that no single failure of a component or system can lead to an unsafe condition either during or after marine operations;

— reserve buoyancy (the remaining buoyancy that can be mobilized before flooding can occur) should not be less than that shown in Table 6;

— the minimum GM after launch and during upending should not be less than that shown in Table 7.

Reserve buoyancy, B_r, as a percentage of the total available buoyancy, is calculated using Formula (4):

$$B_r = 100\,(B_0 - W_0)/B_0 \tag{4}$$

where

B_0 is the total available buoyancy of the structure;

W_0 is the weight of the structure in air.

Table 6 — Recommended reserve buoyancy based on nominal total intact buoyancy

Case	Intact %	Damage %
Structure after launch	10	5
During upending by ballasting, without crane assistance	Sufficient to maintain required bottom clearance	

EXAMPLE Among other things, damage can be due to the unintended flooding of compartments during upending caused by tearing/breakage of rubber diaphragms on skirt pile sleeves.

Table 7 — Recommended minimum GM after launch and during upending

Case	Intact m	Damage m
After launch, transverse and longitudinal	1,0	0,2
During upending, transverse	1,0	0,2
During upending, longitudinal[a]	> 0	> 0
After upending, before final positioning, both directions	1,0	0,2

[a] A limited period during upending, when the steel structure is metastable or unstable longitudinally, can be acceptable, provided the behaviour has been investigated and all interested parties are aware of it. Practical problems that can be encountered with attending vessels, or rigging and handling lines, should be resolved.

Documents should be prepared to show the calculations of the minimum GM after launch and during upending with the top of steel structures immersed, if applicable.

As it is not practical to provide either damage stability or reinforcement against collision over the full range of waterlines, planning and risk assessment as mentioned in 13.9.2 should also include:

— a clear statement of the draughts, times, durations and operational sequences when damage stability is not available, or the reinforcement cannot be carried out;

— a procedure to return to a waterline that is reinforced against collision should the installation operation be aborted.

13.10 Loadout operations

The stability requirements for loadouts of objects onto barges or vessels (see Clause 15) can also be applied to a float-on to or a float-off of a buoyant cargo from a submersible barge or vessel.

Loadout operations from the quay onto a floating barge or vessel shall be performed with a GM adequate for the operation and shall take into account the CoG changes as the cargo crosses the quay edge. Normally, GM should be greater than 1 m, unless a smaller value can be justified.

The free surface effects of slack tanks or ballast tanks on GM during the loadout operation should be considered.

The area ratio requirements of 13.4.2 shall apply.

Except for a float-on onto a submersible barge or vessel, the effective freeboard, l_{freebd}, (the minimum vertical distance from the water surface to any opening, e.g. an open manhole) should satisfy Formula (5):

$$l_{freebd} \geq 0{,}5 \text{ m} + H_{max}/2 \quad (5)$$

where H_{max} is the maximum anticipated wave height at the site during the loadout, expressed in metres.

The maximum possible tide level and any possible heel or trim should be taken into account. Coamings can be installed at openings to increase the effective freeboard.

During float-on operations, when loading a buoyant cargo onto a submersible barge or vessel, the stability of the combined vessel and cargo can at times be minimal. The slope of the righting arm versus the heeling angle curve can be very sensitive to a small change in ballast condition. Care should be taken to ensure that a small change in ballast does not cause an unforeseen change in trim or heel (in floating condition). A sensitivity check should be undertaken, taking into account tolerances in cargo weight and CoG, and ballast quantity and position.

For additional information on the stability requirements during float-on onto submersible barges and vessels, see 15.12.

13.11 Watertight integrity and temporary closures

The number of openings in watertight bulkheads and decks shall be kept to a minimum.

Temporary closing devices, such as hatches, blind flanges and access openings shall be weathertight. Weathertight closing devices, which can be submerged or exposed to slamming or sloshing, should be designed for such actions and suitably verified as fit for purpose. These temporary closing devices should be marked “CLOSED AT SEA”. Type and securing of seals and gaskets should be carefully considered.

Openings between buoyant compartments that can contribute to progressive flooding should be closed during operations. If the above closings are temporary, they should be marked “CLOSED AT SEA”.

Where practical, regular inspections or gauging of water level, draught, heel, trim and air pressure should be carried out during operations.

13.12 Inclining tests

The provisions for the execution and analysis of the measurements of inclining tests given below shall be followed. Additional information on inclining tests can be found in Reference[40].

Inclining tests shall be carried out on structures where knowledge of the precise position of the vertical CoG is critical to the safety or feasibility of subsequent operations, such as installation of topsides. The necessity for such tests should be determined by the sensitivity of the planned operation, the accuracy of the calculated GM and weight control, and on whether previous tests have been performed.

A detailed procedure for the test shall be prepared.

The effects of external actions due to wind, waves, moorings, anchors, tugs and cranes should be considered and monitored.

Before the test, a sensitivity analysis of the parameters affecting the test results should be performed.

NOTE Such parameters include draught, heel angle, sea water density, inclining weights and distance moved, wind actions, dimensional control of the structure and accuracy of the measuring equipment.

The floating structure or vessel should be completed as much as possible to ensure accuracy of the results of the structure or vessel in operation. For floating objects with a large GM, an inclining test does not always give sufficiently accurate results. In this case, the stability calculations shall be based on the calculated weight and CoG, derived from the weight control and dimensional control systems.

For adding major components to a floating structure that cannot be inclined, weight and horizontal CoG confirmation may be obtained by direct measurement (i.e. displacement test or dry weighing).

Where the indicated weight and/or CoG is not within a prescribed accuracy of the projected weight (normally 1 %), a penalty shall be applied to the vertical position of the CoG. This penalty shall take the form of the full difference between the measured and projected weight applied at a conservative location so as to force the vertical position of the CoG upwards.

14 Ballasting operations

14.1 Introduction

In this clause the ballasting operations of offshore structures are considered, including steel structures, GBSs, compliant towers, barges, and, in particular, temporary or one-off ballasting requirements for transient marine operations rather than routine service life operations.

Attention should be paid to regulations or requirements relating to the transfer and/or treatment of ballast water locally and at destination.

Ballasting operations typically control the following:

— the draught, heel and trim of floating structures;

— the stability of floating structures;

— the deflection of, and/or the load distribution in, floating structures;

— the rate of immersion of floating structures;

— the ground reaction and distribution of reactions on seabed supported structures.

Ballasting is usually effected using sea water and distributed by pumping, gravity, air pressure or differential hydrostatic pressure through a system of pipes and valves into either open tanks or closed tanks that are vented.

Ballast systems using liquids can sometimes incorporate air cushions, typically to effect a decrease in draught. Air cushions can also be used to control the quantity of floodwater entering a compartment.

Less commonly, solid ballast can be used, typically in the form of heavy granular material, concrete or steel in the case of permanent ballast.

Ballast systems are typically used during transient phases in the following marine operations:

— lift-off or float-out from construction docks;

— immersion, trim and stability control during construction while afloat;

— load transfers from shore to barges (float-out operations);

— mating operations;

— launching operations;

— upending operations;

— steel structure setting operations;

— gravity structure installation operations;

— subsea immersion operations;

— float-on and float-off operations;

— decommissioning.

14.2 Ballast calculations for different stages

Ballast calculations have the purpose to fulfil the requirements set out in the applicable rules and regulations. Thus for all floating structures and vessels to which current standard applies, ballasting calculations shall be carried out. In case an automatic ballasting systems exists, potential loadcases shall be analysed using the ballasting/load-computer. In case potentially unsafe transient conditions cannot be ruled out, detailed calculations and a procedure to return to safe ballast condition shall be established in accordance with an FMEA of the ballast system.

14.3 In ballast system

14.3.1 Operational aspects

During planning of marine operations, aspects for consideration relative to the operation of the ballast system shall be documented, as a minimum, with

— arrangement drawings;

— line diagram(s) for the ballast piping or distribution system, identifying the system components, including its control mechanisms and power sources;

— line diagram(s) for the venting system, identifying the system components, including its control mechanisms and power sources;

— line diagram(s) for the compressed air system, identifying the system components, including its control mechanisms, safety devices and power sources;

— line diagram(s) for the hydraulic system, identifying the system components, including its control mechanisms, safety devices and power sources;

— system and equipment specifications to facilitate the measurement/monitoring of installed ballast;

— specification of system commissioning requirements and testing and trial parameters;

— ballast calculations for the planned operations;

— ballast calculations for contingency situations, including recovery from accidental flooding situations;

— drawings showing potential vulnerability of pipework passing through machinery spaces;

— certificates showing that checks have been completed on low-pressure pipework to ensure it does not become a downflooding conduit in a foreseeable event;

— drawings showing the location of a second station from which valves can be controlled in any foreseeable accidental event;

— associated stability, strength and deflection calculations for load cases, as appropriate;

— FMEA.

The ballast system should operate according to fail-safe principles so that the structure remains in a stable and controlled condition in the event of the failure of any single component. The definition of component should cover, at the very least, active components.

The ballast system shall have the capability to bring the structure back to a safe condition or interrupt the operations in the case of a possible failure.

Safe conditions for operations after passing a PNR should be defined.

Ballast and deballast systems should have sufficient capacity to complete the operation or to achieve a safe condition within the time limitations determined by weather forecasting periods, tidal cycles and any other constraints, with adequate contingency.

The ballast system should operate safely at feasible draughts and floating attitudes of the structure, including recovery from damaged conditions.

The ballast system should operate with adequate allowance for possible variations in the weight and in the position of the CoG of the structure; see Clause 12.

A FMEA study should be implemented to demonstrate that control of operations is not compromised by the failure of any single component, particularly where the component plays an important role in the performance of any stage of the operation.

14.3.2 Other operational considerations

Where the functions of the ballast system include compensation for weight transfer when affected by the tide, then wherever possible, certain tanks should be solely dedicated to the tidal compensation measures and other separate tanks should be solely dedicated to the weight transfer compensation measures.

A risk analysis should be carried out to verify the ability of the ballast system to function in accordance with the design parameters.

NOTE The risk analysis typically takes the form of a FMEA.

Back-up facilities should be arranged for ballasting or deballasting of each independent compartment.

Where relevant, the strength, function and workmanship of the components of the ballast system should satisfy the requirements of the RO rules.

The transfer of sea water between any tank and the sea should be through two independently controlled valves to provide double barriers against water ingress.

Consideration should be given to internal pressurizing with air and remote monitoring of air pressure in nominally dry compartments for the purpose of detecting damage or leakage, for example on launched steel structures.

Compartments that are vulnerable to flooding from either penetration damage or from internal leakages should be fitted with a pumped bilge drainage system. Where appropriate, the bilge system should comply with RCS rules.

The design life of the system components should be considered for future decommissioning and removal requirements.

14.4 Protection against damage and deterioration

14.4.1 General

Internal and external sea water inlets, vent piping and valves shall be protected against blockage or malfunction by the ingress of debris.

Control and indicating piping and cabling systems shall be protected against damage, for example from impacts during launch. Where appropriate, such systems should be routed to avoid areas that are vulnerable to penetration damage to the hull.

Sea water ballast systems shall consider the addition of a corrosion inhibitor and biocide if the ballast is either permanent or is to remain in the system for a prolonged period of time.

Regulatory authorities should be consulted regarding products that are accepted for discharge in areas under their jurisdiction.

Loose solid ballast, where submerged, should be protected against dispersal by wave or current action.

14.4.2 Freezing

When low temperatures are expected, measures shall be taken to prevent or minimize the effect of the freezing of ballast water contained in exposed compartments, and exposed tank vents should be checked and cleared of ice accumulation prior to ballasting operations.

14.5 Prevention of progressive flooding in damage condition

Ballast piping and vent lines shall be routed to avoid areas that are vulnerable to penetration damage to the hull. Where this arrangement is not practical, piping systems should be provided with shut-off valves that are located in the compartment containing the open end of the pipe or in a suitable position such that the compartment can be isolated in the event of damage to the piping system.

Piping systems and valves should be designed to prevent accidental cross-flooding and uncontrolled ingress of water in likely operational conditions and in the designed damage cases.

14.6 Control and indicating systems

Where appropriate, a central ballast control station shall be provided. It shall be located above the worst damaged waterline, adequately protected from weather and accessible in any conceivable floating condition. It should be provided with the following control and indicating systems where applicable:

— ballast pump control system;

— ballast pump status-indicating system;

— air compressor control system;

— air compressor status-indicating system;

— ballast valve control system;

— ballast valve status-indicating system;

— vent valve control system;

— vent valve status-indicating system;

— tank level indicating system;

— draught indicating system;

— heel and trim indicating system;

— power availability indicating system;

— ballast system hydraulic/pneumatic pressure-indicating system;

— air cushion pressures;

— air cushion water seal levels;

— air leakage rates.

Both the ballast control system and the ballast indicating system should be provided with uninterruptible power supplies.

Valves and operational controls should be clearly marked to identify the function they serve.

Means to indicate whether a valve is open or closed should be provided at each location from which the valve is controlled. The indication should rely on movement of the valve spindle. Remotely operated valves should have some local or other secondary means of determining its open or closed status.

The ballast control system and the ballast indicating system should function independently of each other so that a failure in any one system does not jeopardize the operation of the other systems.

The accuracy of electronic tank level soundings should be periodically verified against manual soundings to ensure accuracy.

Wherever practical, ballast tanks should be provided with a direct means to indicate their individual filling levels. Where tanks that are used for ballast have no means of indication, they should be designed to resist the loading from filling the compartment 100 % plus the greater of 66 % of its vent line height or the maximum pressure head that the tank can be subjected to by any pump used to fill it.

Ballasting operations shall be documented in an appropriate manner.

14.7 Pumps

Ballast pumps should be self-priming unless it can be demonstrated that this is unnecessary for the intended application in the intact and damaged (inclined) condition.

14.7.1 Specification and layout

Specification and layout of the ballasting system shall be done in accordance with applicable rules and regulations.

Schematics and details of manifolds and valves shall be done in accordance with applicable rules and regulations.

14.7.2 Pump performance curves and functional limitations

Pump performance curves shall be documented and fed into the ballasting system as appropriate so that the operator can judge the performance and limit of the system. If necessary the operations shall be laid down in a suitable operations manual.

14.8 Valve arrangements

Where valves are arranged with remote control and are power operated, a secondary means of operating the valves, which can be manual control, should be provided. Any automatic or radio-controlled system should be provided with a manual override system.

The valve system should be arranged to prevent the inadvertent transfer of ballast from one compartment to another in the event of failure of any single valve.

Valves that fail set (open) should be provided with an independent secondary means of closure. Sea inlet and submerged ballast discharge valves should automatically fail to the closed position upon loss of control or activating power, unless overriding considerations require a valve to fail set.

Consideration should be given to the requirement for non-return valves where there is a danger of unwanted siphoning between compartments, or between compartments and the sea.

The closing speed of power-operated valves should be limited where necessary to prevent excessive pressure surges. The actuators of control valves and the valves themselves should be designed to operate against the highest flow velocities operationally possible.

Valves that can permit ingress of sea water, but also the transfer of sea water between tanks in case of loss of power or control, shall be of the “fail closed” type.

14.9 Vent systems

Ballast tanks should be provided with air vents. The size of the vent pipes should be sufficient to prevent excess overpressure of the tanks from rapid filling.

Vent openings that can become intermittently immersed in a damaged condition should be self-closing in the event of immersion, or the vent system should be designed to withstand flooding of the vented compartments concerned.

Closing appliances that are fitted to ballast tank air vent pipes should be of an automatic opening type that allows the free passage of air or liquid to prevent the tank from being subjected to a pressure or vacuum greater than that for which it is designed.

14.10 Air cushion system capacity

Air cushion systems should be designed for:

— redundancy in compression;

— active control and top-up;

— loss of any cushion section, which should be manageable.

14.11 System testing

Where possible, the commissioning of pumps and/or compressor systems should include both functionality and capacity trials. Capacity trials should simulate realistic values of suction head, delivery head and backpressure as appropriate.

Where systems have no redundancy, the commissioning and testing prior to operation shall be sufficient to prove reliability for in-service conditions.

The operability risks associated with the flushing and cleaning of hydraulic and pneumatic control systems should be evaluated before a decision is made as to whether such systems should be flushed and cleaned as part of the testing process or after testing has been carried out.

15 Loadout

15.1 Introduction

This clause applies to the loadout of various types of structure, including, but not limited to, steel and concrete structures, jacket foundations, transformer substations, innovative WTG foundations, modules, components onto floating or grounded barges and ships. Loadout (float-on) of floating cargoes onto submersible barges and ships is covered in 15.12.

Due to the wide range of structures, loadout methods and transport vessels, this clause cannot cover all aspects of every loadout scheme. Alternative proposals and methods should be considered on their own merits in order to show that the operations are performed within defined and recognized safety/confidence levels.

This clause applies particularly to skidded and trailer-transported floating loadouts in tidal waters. Recommendations for grounded loadouts or loadouts accomplished by lifting (see also Clause 19) are also included.

Loadouts involve the use of an assemblage of commercially manufactured equipment and sometimes a fabricator's own purpose-built devices and specially fabricated components that are designed for a range of operational conditions. It is important to document these operational parameters and ensure that the planned loadout procedures stay within these. Analytical and operational checks should be made to ensure the integrity of the system.

Some of the more common checks are described in the remainder of this clause.

The following practices should be considered:

— use of contractors familiar with specialized equipment;

— performance of simulated tests prior to actual loadout, where practical, such as:

  — for skidded loadouts: perform a pre-skid (of a few metres only) to break friction and test equipment;

  — for trailered loadouts: perform a pre-lift and similar short movement.

The principles outlined in this clause also apply to the offloading of structures from a barge to shore. Barge-to-barge transfers should be considered on a case-by-case basis.

NOTE Reference to a “barge” includes a “ship” or “vessel” or vice versa, as applicable.

15.2 Categories of loadout

The loadout operation can be categorized according to tidal conditions as indicated in Table 8. The category does not reflect local weather conditions, which are accounted for elsewhere. Recommendations for design, reserves, and redundancy of mechanical systems can vary according to the category of loadout.

Table 8 — Categories of loadout operation according to tidal conditions [58]

Category	Tidal limitations
1	The tidal range is such that, regardless of the pumping capacity provided, it is not possible to maintain the barge level with the quay throughout the full tidal cycle, and the loadout should be completed within a defined tidal window, generally on a rising tide.
2	The tidal range is such that, provided sufficient pumping capacity is available, it is possible to maintain the barge level with the quay during the full tidal cycle, and for at least 24 h thereafter.
3	The tidal range is negligible or zero, and there are no tidal constraints. Pumping should be employed only to compensate for weight changes as the loadout operation proceeds.
4	Grounded loadout employing sufficient pumping to compensate for tidal range to maintain ground reaction and/or actions on the barge within acceptable limits.
5	Grounded loadout where no pumping is necessary to maintain ground reaction and/or actions on the barge within acceptable limits.

15.2.1 Design: structural analysis during all loadout phases

The item to be loaded, hereafter called the ‘structure’, shall be designed taking into account static and dynamic loads, support conditions, SPMT (loadout trailer) loads, environmental loads and loads due to misalignment of the barge and shore skidways or uneven ballasting.

For skidded loadouts, analyses which account for the structure and skidway should be presented which consider the elasticity, alignment and as-built dimensions of the shore and barge skidways for each stage of loadout. In the absence of detailed information, a 75/25 percent distribution of load across either diagonal may be considered as appropriate.

The structure and supports shall be demonstrated as being capable of withstanding the subsidence of any single support with respect to the others by at least 25 mm.

Consideration shall also be given to lifting off construction supports or onto seafastening supports where these operations form an integral part of the loadout operation

The primary structure shall be of high quality structural steelwork with full material certification and NDT inspection certificates showing appropriate levels of inspection. It shall be assessed using the methodology of a recognized and applicable offshore code including the associated load and resistance factors for LRFD codes or safety factors for ASD/working stress design (WSD) codes

15.2.2 Loadout planning

Normally, the owner of the structure will have the overall responsibility for planning and execution of the construction and marine operations, and hence also the safety of personnel, facilities and environment. The owner may delegate the execution and follow-up of these issues to the contractor.

Technical procedures shall be in place to control engineering related to the marine activities.

The objective of these procedures is to define applicable technical standards, to ensure agreement and uniformity, with bridging documents where necessary, on matters such as:

— international and national standards and legislation;

— certifying authority/regulatory body standards;

— marine warranty surveyor guidelines;

— project criteria;

— design basis;

— metocean criteria;

— calculation procedures;

— change management.

— document verification (essential as a quality assurance element in marine operations). The purpose of such verification is to avoid design or planning errors that may lead to unsuccessful marine operations;

— in case loadout is conducted from a jack-up vessel being jacked up during loadout, reference is made to 11.7 stating risks aligned with uncontrolled movement of jack-up legs and punch-through. Thorough investigation of the location for jacking during loadout is required.

15.2.3 Cargo weight details and COG information

Generally weight investigation and control measures, as well as CoG position accuracy requirements, must comply with the provisions expressed in Clause 12.

For calculation purposes conservative values of weight and CoG should be used. It should be noted that some calculation results, e.g. transportation motions, may be more critical with a lower value of weight and lower CoG.

Where an operation is likely to be CoG sensitive, the extremes of the CoG envelope shall be considered in calculations.

15.2.4 Deck loading plan

The deck strength must be determined adequate, including stiffener, frame and bulkhead spacing and capacity, for loadout and transportation loads

"Footprint" pressure on the quayside, linkbeam and barge deck shall be shown to be within the allowable values.

Linkspan bridge capacity shall be demonstrated by calculation and these calculations shall form part of the loadout procedure.

The reactions onto the barge and the quay from the link span bridge should also be checked as this can impart highly concentrated loads into the barge and quay.

15.3 Structure being loaded

The structure being loaded shall be designed taking into account static and dynamic actions, support conditions, environmental actions, actions due to misalignment of the barge or vessel and shore skidways, or uneven ballasting.

For skidded loadouts, results of analysis that consider the elasticity, alignment and as-built dimensions of the shore and barge skidways for each stage of loadout shall be presented.

For arrangements of trailers or SPMT loadouts, the reactions imposed by the trailer configuration should be considered.

For lifted loadouts, the structure, including the lift points, should be analysed for the support conditions proposed during the lift; see Clause 19.

Consideration should also be given to lifting off construction supports, or lifting onto sea fastening supports, where these operations form an integral part of the loadout operation.

Weight control shall conform to the requirements of Clause 12. For class A loadouts, pre-loadout weighing should be considered, in particular for more complex systems such as topsides, in lieu of depending on calculated predictions.

When the support geometry is sensitive to a shift of CoG, a stability sensitivity study evaluating an envelope of possible CoG shifts should be performed.

If weighing takes place shortly before loadout, the effect on the loadout procedures of any weight changes should be assessed in order to determine if planned weight contingencies are exceeded.

15.4 Site and quay

The quay, quay approaches, wall and foundations shall be adequate for the loadout and documented accordingly.

The capacity of mooring bollards, winches and other attachments shall be adequate for the loadout and documented accordingly.

Compatibility between quay strength and elasticity, and the support conditions used for analysis of the structure, should be demonstrated, where appropriate.

Bathymetric and height clearance information for the area covered or crossed by the barge during loadout operations, post-loadout operations and sail-away should be supplied.

Under-keel clearance should not be less than 1,0 m during the period during which the barge is in position for loadout. This may be reduced to 0,5 m, provided a recent check of the loadout area has been made by bar sweep or divers' inspection, and subject to confidence in the lowest predicted tide and surge water levels.

For tidal loadouts, an easily readable tide gauge should be provided adjacent to the loadout quay. The water line level should be monitored prior to, during and after loadout.

The approval of port and coastal state authorities should be obtained, as necessary, for the operation and for the institution of any necessary controls on marine traffic.

15.5 Barge

The barge shall be classed by an RO. All certificates shall be made available for checking.

A check shall be made that the actions induced during loadout, including longitudinal bending moments, loads on internal structure and local loads, are within the approved design strengths.

Some loadout operations can temporarily invalidate the class or load line certificate, and it is necessary for these to be reinstated after loadout. This can apply if, for instance, structural changes have been made, including holes cut in the deck for ballasting, if towing or mooring connections or vent pipes have been removed, or, in some instances, after grounding on a pad.

The adequacy of the barge stability should be shown at all stages of loadout, as recommended in 13.10.

Suitable survey should be performed prior to loadout to check the integrity of the barge with respect to ballast system, navigation aids, condition of shells, towing gear, etc.

15.6 Link beams, skidways and skidshoes

The strength of the link beams, skidways and skidshoes shall be adequate and documented accordingly.

Link beams shall be checked for actions induced by barge moorings, barge movements and pull-on/pull-back actions.

Tolerances on link beam movement shall be suitable for anticipated movements of the barge during the operation.

Suitable lateral guides shall be provided along the full length of skidways.

Sufficient articulation of skidshoes shall be provided to compensate for level and slope changes when crossing from shore to barge.

15.7 Moorings

15.7.1 Weather-restricted operation

A loadout should be considered a weather-restricted operation as defined in 7.2.1. Design and operational weather conditions for the loadout operation shall be defined, taking into account

— the forecast reliability for the area;

— the duration of the operation after the PNR, including a suitable contingency period;

— the exposure of the site;

— the time necessary for any operations before or after the loadout operation, including barge movements and moorings, ballasting, system testing, final positioning and initial sea fastening;

— currents during and following the operation.

For weather-restricted operations, the maximum forecast operational limits shall be lower than the design criteria; see 7.4 and 7.7.

15.7.2 Temporary mooring system

— The design of the loadout mooring system shall be consistent with the requirements and recommendations in Clause 13, with the following additional considerations. Moorings for the loadout operation should be designed for the weather conditions defined in accordance with 15.7 and Clause 7. The design should also take into account potential loading from unplanned events such as; SPMT breaking, contact forces from floating cranes, skidding forces etc.

— In cases where existing yard loadout mooring equipment is used, the wires and winches provided by the yard can sometimes have a breaking strength greater than the barge equipment to which they are connected. In such situations, great care should be exercised, and the forces should be controlled and monitored.

— In cases where the propulsion system (see 15.11) induces a reaction between the barge and the quay, the possible effects of this reaction shall be considered, including “hang-up” and sudden release.

— The consequences of mooring line failure should be evaluated and suitable measures taken to mitigate any risk (e.g. during skidding, a mooring line failure can result in high movement of the barge).

— Mooring prior to and after loadout should be considered a weather-unrestricted operation and should be designed for return periods in accordance with 7.4.2.

— Consideration should be given to adjustable moorings depending on the loadout method adopted and site condition (e.g. adjusting the tension in the mooring lines immediately before, during and after the loadout operation).

15.8 Grounded loadouts

A survey of ground levels over the area covered by the bottom of the barge shall be carried out, showing suitable support conditions for the barge.

A survey shall be made shortly before the barge is positioned to ensure that no debris is located where it can damage the bottom plating of the barge.

The plan area of the grounding pad with respect to the barge keel should be of sufficient extent to ensure the edges of the grounding pad will contain the 'footprint' of the barge keel. If evenly distributed support over the bottom plating of the barge cannot be achieved, either geotechnical site investigation data shall be submitted, together with calculations demonstrating the capacity of the grounding pad and showing that no overstress can occur, or the sea floor shall be levelled.

Sufficient ballast capacity shall be available to provide ground reaction to withstand the loadings from the return periods as defined in 7.4.2, Table 4, both prior to and after loadout, coincident with mean high water on spring tides (MHWS) plus storm surge, and the corresponding mean low water on spring tides (MLWS) and negative surge, without lift-off, sliding or overstress. It is recommended that a 10 year return period be used[58].

Care should be taken when ballasting before grounded loadouts, or for floating loadouts with small under keel clearances, to prevent seabed soil blocking the pumps or pipework. The highest possible water intakes should be used, and other precautions should be taken if there is significant suspended matter in the water.

If soils are soft and consolidation or settlement is expected to be significant, this shall be considered during the loadout. Where environmental conditions allow this, the barge can be placed on location in advance and preloaded with ballast in an attempt to induce the settlement prior to loadout. The designer is cautioned that consolidation of marine clays can take a long time. In any event, grounding on soft clay should be viewed with caution, considering the implications of adhesion and suction during removal of the barge.

Final skidway levels shall be compatible with the requirements of 15.3.

The ballast shall be adjusted during loadout, where necessary, to avoid barge settlement or overstress.

The plan for refloating of the barge shall be updated and, if necessary, revised in line with any changes in barge orientation not fully anticipated before the loadout. The plan for refloating the barge should include consideration of the moorings that are required, verification that the barge is undamaged and inspections or actions necessary to ensure that the barge remains in class following the grounding.

15.9 Pumping and ballasting

15.9.1 Pump capacity

Available pump capacity shall be based on the published pump performance curves, or verified by trial, taking account of the maximum head for the operational and pipeline losses.

15.9.2 Recommended pump capacity

Pump capacity shall be provided as given in Table 9, depending on the category of loadout as defined in Table 10 and to satisfy each case as defined below:

— case a: the nominal maximum pump capacity computed for the loadout as planned, to compensate for tidal changes and weight transfer, with no contingencies;

— case b: the computed pump capacity required, as a contingency, to hold the barge level with the quay, at the maximum rate of a rising or falling tide, assuming horizontal movement of the structure is halted;

— case c: the computed pump capacity required, as a contingency, to provide the requirements of either case a or case b, whichever is the greater, in the event of the failure of any one pump, component or pumping system; where two or more pumps are supplied from a common power source, this shall count as a single system.

Primary ballasting is generally performed using external ballast pumps. For loadout on cargo barges, the barge's internal ballast system can be used as a back-up system. If the barge pumping system is used as part of the main or back-up pump system, a barge engineer familiar with the system shall be in attendance throughout the operation and the loadout communication system should include the pump room.

Pumps and systems should be tested and shown to be operational within 24 h of the start of the loadout operation. A verification of pump capacity can be required.

Pumps that are necessary to reverse in order to function as part of the back-up capacity shall be capable of such reversal within 10 min, and adequate resources shall be available to perform this operation.

When barge internal pumps plan to be used as primary ballasting system a full pump test should be carried out, checking the pump functions and pump capacity. In case one pump fails, the other pump shall be able to provide ballasting for the all requested ballast tanks to maintain barge in even keel condition.

Responsiveness test described above could also be undertaken into a FEMA analysis.

Table 9 — Recommended pump capacity for each case and category [58]

Category[a]		Case	Pump capacity recommended, as a percentage of capacity calculated for each requirement %
1	Tidal window	a	150 %
		b	150 %
		c	120 %
2	Constant deck level > 24 h	a	150 %
		b	120 %
		c	100 %
3	Little tide	a	100 %
		b	No requirements
		c	75 %
4	Grounded and pumping	a	120 %
		b	120 %
		c	100 %
5	Grounded	All	No requirements

[a] See Table 8.

Pumps that are necessary to move around the barge in order to function as part of the back-up capacity shall be easily transportable, and may be considered only if free access is provided at all stages of loadout between the stations at which they can be required. Adequate resources shall be available to perform the operation.

Ballast and barge levels shall be monitored during loadout, and shown to be within the limits of movements of any link beams and the structural limitations of the barge and structure.

Where a compressed air system is used, the time lag required to pressurize or depressurize a tank should be taken into account, as should any limitations of the barge and structure.

Where a safe loadout plan is demonstrated, with reserve pumping capacity provided in accordance with Table 9, the reserve capacity may be used to enable the loadout to proceed faster, provided it can also be demonstrated that this is safe.

Table 10 gives an example for a category 2 loadout that assumes that the worst single system failure reduces the pumping capacity, expressed in any unit, to 80 % of the full capacity.

Table 10 — Example of required capacity calculation for a category 2 loadout [58]

Case	Nominal capacity m^3/h	Factor %	Recommended capacity m^3/h
a	1 000	150	1 500
b	1 100	120	1 320
c	1 100/0,8 = 1 375	100	1 375
Required	–	–	1 500 (case a)

Pump capacity shall be provided as given in Table 9, depending on the category of loadout as defined in Table 10 and to satisfy each case as defined below. The requirement for contingency pump capacity may be relaxed for weather and tidal unrestricted operations.

15.10 Loadouts by trailers, SPMTs or hydraulic skidshoes

15.10.1 Introduction

Where trailers or SPMTs are used to move the structure, the provisions of this subclause apply. When appropriate, the recommendations for trailers and SPMTs also apply to hydraulically operated skidshoes.

Maximum axle loading shall be shown to be within the trailer manufacturer's allowable values.

Footprint pressures on the quayside, link beam and barge deck shall be shown to be within the allowable values.

Shear force and bending moment curves should be prepared for the trailer spine structure, and maximum values shall be shown to be within the manufacturer's allowable figures.

Due to the nature of the behaviour of SPMTs, the SPMT reactions will impart loads onto the structure that do not reflect the behaviour an analysis suggests as the analysis method assumes simple vertical supports at the SPMT locations. Consequently, for long structures, the SPMT loads may cause excessive deflection in the structure. This effect will need to be considered and accounted for; e.g. by "locking off" axles so they are not active during the loadout, adjusting the position of the SPMTs, etc. Additionally, any limitations on the deflection allowable should be determined and, when the structure is raised, the deflections checked to confirm that they are acceptable.

In general, hydraulic systems should be linked or balanced to minimize torsion on the structure. In any event, the arrangement shall be compatible with the support assumptions considered for structural analysis. A contingency plan should be presented to cover hydraulic leakage or power-pack failure.

Vertical alignment of the barge, link beam and quay, including the effects of any change of slope and any movement of the barge due to wave action, should be within approximately one third of the maximum travel of the axles relative to the trailer spine.

15.10.2 Structural capacity

Documentation including a statement showing the strength of the skidways, link beams and skid shoes shall demonstrate compatibility with the statements made and assumptions used for the structural analysis

The line and level of the skidways and skidshoes shall be documented by dimensional control surveys and reports. The line and level shall be within the tolerances defined for the loadout operation and skidway/skidshoe design.

For floating loadouts care shall be taken to ensure that minimum friction exists between the barge and quay face. Where the quay has a rendered face, steel plates shall be installed in way of the barge fendering system.

15.10.3 Load equalization and stability

Hydraulic systems should be linked or balanced as a three point hydraulically linked system to provide a statically determinate support system thus minimising torsion on the structure. In any event the arrangement shall be compatible with the support assumptions considered for structural analysis of the structure being loaded out.

Stability of the hydraulic system to resist overturning shall be shown to be adequate, particularly when a 3-point hydraulic linkage system is proposed. The centre of action of the structure CoG shall remain within the middle quarter of the trailer support base, taking into account any uncertainty in:

— the horizontal and vertical centre of gravity (CoG);

— the design wind;

— any inclination of the structure/trailer assembly on shore;

— the predicted inclination of the barge under the design wind;

— possible change of heel or trim due to release of hang-up between the barge and the quay; and

— any free surface liquids within the structure.

15.10.4 Vertical alignment

Vertical alignment of barge, linkbeam and quay, including the effects of any change of slope and any movement of the barge due to wave or swell action, should generally be within approximately one third of the maximum travel of the axles relative to the trailer spine.

Due to the particularities of those loadouts vertical movement of the barge due to environmental condition should be limited as much as possible.

15.10.5 Skidshoes

Loadout operations involving skidding of cargo on the transportation vessel/barge must take into account the following aspects.

A statement showing the strength of the skidways, link beams and skid shoes shall be developed, demonstrating compatibility with the statements made and assumptions used for the structural analysis.

Link beams shall be checked for loads induced by barge moorings, barge movements and pull on/pull back forces

Suitable lateral guides shall be provided along the full length of skidways.

For floating loadouts care shall be taken to ensure that minimum friction exists between the barge and quay face.

The interface between the barge and barge fendering shall be liberally lubricated with a grease or other substitute which complies with local environmental rules

15.11 Propulsion system design, redundancy and back-up

15.11.1 Propulsion system

The propulsion system, including back-up and contingency systems, shall be designed according to the category of loadout as defined in 15.2, and as shown in Table 8. Recommendations for skidded loadouts include propulsion by wire and winch, hydraulic jacks or strand jacks. Recommendations for non-propelled trailer loadouts include propulsion by wire and winch or tractors.

If tractors provide motive power or if the trailers are self-propelled, the reversibility of motion should be demonstrated.

15.11.2 Redundancy ad recommendations

For system redundancy, adequate back-up systems shall be provided so that the loadout can still proceed in the event of failure of any one mechanical component, hydraulic system, control system, prime mover or power source.

Where a system requirement is built-in, it shall be demonstrated that it is operational.

Where Table 11 states that system redundancy is "recommended", this shall be taken to read "required" if a conceivable failure can extend the operation outside the planned weather window. If it is not planned to provide this requirement, a risk assessment should be carried out.

Care should be taken to ensure that non-propelled trailers have a braking system as this is not always built-in.

The recommendation for a braking system may be relaxed provided it can be demonstrated that excessive inclination and runaway of the structure cannot occur; for example, if a retrieval winch is employed as part of the contingencies and this winch is paid out as the structure is loaded out, the winch can be employed as a hold-back system.

The coefficients of friction used for design and sizing of the propulsion system shall not be less than the maximum values shown in Table 12, unless justification for a lower value can be provided. The typical values shown are for information only and should be justified if used.

Table 11 — Propulsion system design [58]

Category[a]	System requirement	Skidded loadouts	Trailer loadouts	
			Non-propelled	SPMT
1	Slope capacity	Actual slope 3 %	Actual slope 3 %	Actual slope 3 %
	System redundancy	Required	Required	Required
	Braking system	Required	Built-in	Built-in
	Pull-back system	Required	Required	Built-in
2	Slope capacity	Actual slope 2 %	Actual slope 2 %	Actual slope 2 %
	System redundancy	Recommended	Recommended	Recommended
	Braking system	Required	Built-in	Built-in
	Pull-back system	Recommended	Built-in	Built-in
3	Slope capacity	Actual slope 1 %	Actual slope 1 %	Actual slope 1 %
	System redundancy	Not required	Not required	Not required
	Braking system	Required	Built-in	Built-in
	Pull-back system	Not required	Not required	Built-in
4	Slope capacity	Actual slope	Actual slope	Actual slope
	System redundancy	Not required	Not required	Not required
	Braking system	Not required	Built-in	Built-in
	Pull-back system	Not required	Not required	Built-in

[a] See Table 8.

Table 11 *(continued)*

Category[a]	System requirement	Skidded loadouts	Trailer loadouts	
			Non-propelled	SPMT
5	Slope capacity	Actual slope	Actual slope	Actual slope
	System redundancy	Not required	Not required	Not required
	Braking system	Not required	Built-in	Built-in
	Pull-back system	Not required	Not required	Built-in

[a] See Table 8.

Table 12 — Coefficients of friction for the design and sizing of the propulsion system [58]

Level surfaces	Static		Moving	
	Typ.	Max.	Typ.	Max.
Sliding				
Steel on steel	0,15	0,30	0,12	0,20
Steel on Polytetrafluoroethylene (PTFE)	0,12	0,25	0,05	0,10
Stainless steel on Polytetrafluoroethylene (PTFE)	0,10	0,20	0,05	0,07
Polytetrafluoroethylene (PTFE) on wood	0,14	0,25	0,06	0,08
Steel on waxed wood	0,10	0,20	0,06	0,12
Rolling				
Steel wheels on steel	0,01	0,02	0,01	0,02
Rubber tyres on steel	–	0,02	–	0,02
Rubber tyres on asphalt	–	0,03	–	0,03
Rubber tyres on gravel	0,03	0,04	0,03	0,04

The design action on winching systems shall not exceed the certified safe working load (SWL), after allowance for splices, bending and sheave losses. If no certified SWL is available, the design action shall not exceed one-third of the breaking strength of any part of the system.

The winching system should be capable of moving the structure from fully on the shore to fully on the barge without rerigging. If rerigging cannot be avoided, this should be included in the operational procedures; adequate resources should be made available and the structure secured in a safe condition during rerigging.

For skidded loadouts, the structure may be moved closer to the quay edge prior to the commencement of the loadout. Breakout friction is generally higher than the values given in Table 12.

15.12 Float-on onto submersible barges or vessels

Floating transfers onto submerged barges or vessels should be accomplished by one of two methods.

— Stability is maintained by submerging the stern to the sea floor, while the bow or forecastle remains above the waterline. The water depth range during the operation should be limited to that which can be tolerated by the constraints of the operation. There should be a sufficient depth of water at the forward end of the cargo to clear the main deck and cribbing, and the angle of trim should not be excessive.

— The vessel is fitted with caissons at both ends or with forecastle forward and caissons aft, such that it can submerge its main deck sufficiently deep for the cargo to float over it, normally at a small or zero trim. No contact with the sea floor should occur, unless there is a contingency plan to contact the sea floor in the event of stability problems.

With either method, once the cargo has been floated over the vessel, the vessel is deballasted to induce sufficient reaction to ensure no further movement of the cargo and then further deballasted to the voyage waterline.

In either method, minimal stability phases can be encountered during ballasting and deballasting. Sometimes submergence of the unloaded vessel, when no cargo water plane area is present, causes a phase of minimal stability. During deballasting, a phase often occurs when the buoyancy and the water plane area of the cargo are lost, while the hull still does not provide a sufficient water plane area. Frequently this phase is achieved with a pre-determined trim or heel, calculated to maximize the contribution of the cargo to the overall stability.

Such float-ons are weather-restricted operations and should be planned either in sheltered water or in weather conditions such that relative motions, particularly vertical motions, of the vessel and cargo are minimal, and that wind and current action on the cargo during positioning are within the capacity of the handling and guidance systems.

The stability caution in 13.10 should be observed. A sufficient number of ballast stages should be calculated in advance, along with the corresponding stability condition. For the reasons outlined in 13.10, during critical stages the righting arm should be calculated in both directions to demonstrate that no instability can occur. Suitable tolerances on varying parameters should be considered.

Where sea floor contact is planned, or available as a contingency, or where under-keel clearance is small at any stage, adequate sea floor surveys should be carried out and requirements for sea floor preparation should be considered.

Where restraint of the cargo during float-on is temporarily reliant on friction, predictions for the maximum inclinations should be calculated, taking into account 13.10, to demonstrate that any sliding of the cargo cannot occur. It is recommended that 50 % of the minimum values shown in Table 12 be used for this value, based on observed operations; see also both 15.15 and 16.17 on sea fastening.

The cribbing or dunnage should be accurately positioned and surveyed prior to submergence of the vessel, and adequately secured against float-off.

Guideposts or another adequate positioning system should be provided to align the cargo. Allowance should be made for differential trim or heel between cargo and vessel at first contact with the guideposts. The contact points between guideposts and cargo should be clearly marked. Additional optical or other means of checking the cargo position should be available, and the position should be verified before starting the deballasting operation, and during the operation, until the cargo is firmly seated on the cribbing.

Adequate positioning lines and winches should be provided to manoeuvre the cargo over the cribbing and against the guideposts, and to maintain position until the cargo is firmly seated on the cribbing. Generally, the breaking strength of positioning lines and attachments should not be less than three times the maximum anticipated load. The position of the attachment points should be such that the lines are working at suitable angles at all stages of the positioning process.

Where there is a differential trim or heel between cargo and vessel at first contact, it should be demonstrated that the contact loads and pressures are within acceptable limits.

Positioning the cargo over the cribbing should be done with minimal tidal flow. However, this can be the time at which the current reverses and it is necessary, then, to reconcile these conflicting recommendations. It should be noted that at some locations, slack water does not necessarily coincide with high or low tide. Adequate tidal height and flow surveys should be carried out to establish the behaviour at the location at the same stage of the tidal cycle.

If any sea fastening elements are pre-installed or pre-positioned, it should be confirmed that they cannot damage either the cargo or the vessel during float-over, even in the event that the initial position is incorrect. In cases where this is impractical due to, for example, the number of anodes, appropriate clearances shall be selected.

Draught marks should be painted on the cargo at a point where they can easily be seen.

15.13 Lifted loadouts

If due to relative reduced weight of OWF components and due to other factors, lifting it chosen as the most suitable loadout method, the following aspects must be checked before the lift:

— Loads imposed by shore-based mobile cranes on the quay shall be shown to be within allowable values, either by calculation or historical data.

— Floating cranes shall be moored as required by marine practice, place and type of lifting. Thruster assistance may be used if available to augment the mooring arrangement following successful DP tests carried out immediately prior to loadout.

— Guideposts or another adequate positioning system should be provided to align the cargo. Allowance should be made for differential trim or heel between cargo and vessel at first contact with the guideposts. The contact points between guideposts and cargo should be clearly marked. Additional optical or other means of checking the cargo position should be available, and the position should be verified before starting the deballasting operation, and during the operation, until the cargo is firmly seated on the cribbing. The use of DP systems in combination with fixed mooring shall be carefully considered and DP system setup shall incorporate relevant features in order to enable this functionality.

— Where the offshore lifting padeyes are used for loadout, then a programme for inspection of the lift points after loadout shall be presented. As a minimum, inspection of the padeyes and their connection into the structure shall be carried out by a qualified NDT inspector in accordance with the original fabrication drawings. Access for this (including the possible de-rigging of the lift point) shall be provided as required. At the discretion of the attending surveyor, additional NDT inspections may be required.

— Where the loadout is carried out by lifting, the offshore installation rigging may be used. This rigging will have been designed to suit the offshore crane hook and the hook used for the loadout, may not be suitable (smaller bend radius causing damage to sling, etc.). If the offshore rigging is used, then it should be demonstrated that the onshore crane for the loadout does not damage the slings or cause tilts greater than allowed.

15.14 Transverse loadouts

Transverse loadout could be encountered as a method mainly for heavy items as topsides for transformer platforms, heavy nacelles or innovative foundations.

Loadouts where the structure is moved transversely onto the barge require special consideration and care, not limited to the following reasons:

— In nearly all cases the ballast plan must take account of additional parameters. Structure weight transfer, transverse heel, longitudinal trim and tidal level must all be considered.

— Friction between the side of the barge and the quay may be more critical than for an end-on loadout, as there may be a smaller righting moment available in heel than in trim to overcome this force. Snagging or hang-up can lead to the ballast operator getting out of synchronisation with the structure travel. Release of the snagging load has led to instability and failures.

— Stability may be more critical than for an end-on loadout and changes of heel may be significant. The moment to change the barge heel one degree should be computed and understood for all stages of loadout.

15.15 Barge reinstatement and sea fastenings

Sea fastening work shall be started as soon as possible after positioning the structure on the barge. Sea fastening shall be designed to minimize offshore cutting, to provide restraint after cutting and to allow lift-off without fouling. Relevant cargo positioning tolerances should be included in the structural design and capacity calculations.

No movement of the barge shall take place until sufficient sea fastening is completed to withstand the greater of the following:

— an inclination of 5°;

— an inclination caused by damage to any one compartment of the barge.

The seafastening should also be able to resist direct wind loading and any horizontal load on the barge from inclination of the barge due to the wind.

In circumstances where very limited barge movements are required, e.g. turning from end-on to alongside the quay, before it is practical to install sea fastenings fully in accordance with the provisions of this subclause, then friction may be taken into account to contribute to the sea fastenings. It is recommended that the coefficient of friction be 50 % of the minimum listed in Table 12 if friction is considered as a restraint to movement. Design and condition of the actual supporting structure and potential sliding surfaces at the time of movement should be taken into account. This subclause can also apply to loadout (float-on) onto submersible barges or vessels where loadout occurs away from the dock in deep water.

Final sea fastening connections shall be made in the barge ballasted condition as close as practical to the transport condition.

Manhole covers shall be reinstalled as soon as practical after loadout.

Holes cut for ballasting purposes should be closed as soon as practical and the barge certification reinstated before sail-away.

15.16 Tugs

Suitable and class-approved tug(s) shall be available or in attendance, as necessary, for:

— barge movements;

— removal of the barge from the loadout berth in the event of deteriorating weather;

— as back-up to the moorings.

15.17 Management and organization

Sufficient management and resources should be provided to carry out the operation efficiently and safely; see Clauses 5 and 6.

The management structure, including reporting and communication systems and links to safety and emergency services, shall be demonstrated.

Shift changes at critical stages of loadout should be avoided. If such a shift change cannot be avoided, the key supervisory and operational personnel shall have sufficient overlap in shifts to ensure a smooth handover.

A readiness meeting, attended by all parties involved, should be held shortly before the start of loadout.

A weather forecast predicting conditions that are within the prescribed limits should be received prior to the start of the operation, and at intervals of not more than 12 h thereafter until the barge is moored and the sea fastening is completed.

Fit-for-purpose safety procedures shall be in effect.

15.18 Loadout manual

A loadout manual and supporting document should be prepared for the operation and issued for information and approval, as appropriate. The items, in addition to those found in 6.5.2, that it is necessary to include in the loadout manual and supporting documents are listed in A.3.

15.19 Operating manual

Operating manual and documentation for loadout should contain the following statements and assessments.

- Structure to be loaded must be assessed from structural point of view using loadcases including derivation of weights and contingencies. Results to be presented with justification for high stressed members and suggestions for structural modification in case of overstressed members.
- Weighing report for structure, including results of weighing operation, load cell calibration certificates and tolerance.
- Site plan, showing loadout quay, position of structure, route to quay edge if applicable, position of all mooring bollards and winches and any reinforced areas with allowable bearing capacities.
- Drawing showing heights above datum of quay approaches, structure support points, barge, link beams, pad (if applicable) and water levels. The differential between civil and bathymetric datums shall be clearly shown.
- Statement of maximum allowable loadings on quay, quay approaches, wall, grounding pads and foundations.
- Method of fendering between barge and quay, showing any sliding or rolling surfaces and their lubrication.
- Barge or vessel general arrangement and compartmentation drawings, hydrostatic tables, ballast system description, tank tables, class, deck bearing capacity and bollards SWL.
- Stability and strength of barge/vessel for all stages of loadout including all temporary weights on board (pumps, jacking system, winches, skids, link beams, etc.).
- In case of loadout with SPMT's, trailer specification and configuration (mechanical and hydraulic connection), allowable load on axel, allowable spine bending moments and share force, stability of SPMT system.
- If ballasting is required with portable pumps, details regarding specification and layout of pumps, pipes and hoses scheme, performance curves and maximum head should be available in manual.

Lifted loadouts have specific items that must be present:

- crane specification, including load-radius curve;
- copy of crane certification;
- slinging arrangement;
- copy of certificates of slings, shackles and other equipment;
- for mobile cranes, position of crane at pick-up and set-down, travel route if applicable, actual and allowable ground bearing pressures at all locations;
- non-destructive testing report of lifting attachments and connection into structure;
- mooring arrangements and thruster specification for floating cranes;
- if the lift points and offshore lift rigging will be re-used offshore, proposals for inspection after loadout;
- rigging calculations;
- mooring design calculations showing environmental loads, line tensions and attachment point loads for limiting weather condition for loadout, and for post-loadout moorings if applicable. Calculation should contain limiting design and operational weather conditions for loadout.

Management of the operation should be detailed into the procedure/manual at least with the following information:

— organigram showing management structure and responsibilities.
— location of key personnel;
— details of manning levels, showing adequate coverage for all operations and emergency procedures;
— times of shift changes, if applicable;
— weather forecast arrangements;
— communications;
— adequate lighting for all critical areas;
— operation bar-chart showing time and duration of all critical activities;
— methods of monitoring barge level and trim, and ballast quantities, including consideration of hang-up between barge and quay;
— safety procedures, HAZOPs, HAZIDs and risk assessments;
— systems and equipment operating instructions;
— recording and reporting routines;
— checklists for the preparation and performance of the operations;
— readings from suitably calibrated measuring devices before and during the operations of e.g. environmental parameters (wind, wave, others).

Contingency plans shall be presented for all eventualities, including as appropriate:

— pump failure;
— mains power supply failure;
— jack-winch failure;
— trailer/skidshoe power pack failure;
— trailer/skidshoe hydraulics failure;
— trailer tyre failure;
— tractor failure;
— failure of any computerised control or monitoring system;
— mooring system failure;
— structural failure;
— deteriorating weather.

16 Transportation

16.1 Introduction

This clause applies to offshore transportation, inshore transportation and transportation in sheltered areas, using either wet tow or dry tow including also towage of floating monopiles with adequate plugs and cable hole covers applied as well as buoyancy where required. Additional information can be found in[11], Clauses 8 and 22, and in[12], Clause 11 as well as in [60].

16.2 General considerations

16.2.1 Manned tows

For information on manned tows, see Reference[44].

16.2.2 Unmanned tows

For unmanned tows, access to the towed object shall be provided for routine inspection and access or escape in case of emergency. Life-saving equipment, communication equipment, plans and instructions shall be provided for persons who can be temporarily on board the towed object. Consideration should be given to the nature and duration of their work on board of the towed object and to the ease of access between the towed object and supporting vessels.

16.2.3 Navigation lights, signals and day shapes

For information on navigation lights and day shapes, reference is made to COLREGS regulations [23]. Navigation lights shall have their own power supply and an emergency power supply. In order to prevent accidents in areas specifically prone to fog, equipment such as foghorn or sirens should be used to allow for adequate warning signals being sent.

16.2.4 Contingency

Contingency plans shall conform to 6.5. In case of aquaculture farms being close to transit routes of vessels conducting marine operations in the offshore wind farms, local rules, charts, and safety zones around these aquaculture farms shall be considered.

16.2.5 Motion responses

The evaluation of the motion of the structure during transportation shall be based on environmental criteria in accordance with Clause 7, and determined through analysis using well validated industrial software and/or model testing, assuming representative combinations of metocean parameters. For detailed information on the analysis methods, see 14.3.1.

The evaluation shall be carried out for a range of headings and speeds. The maximum responses shall be based on a 3 h exposure period; where avoidance of extreme actions depends on maintaining a certain heading, consideration shall be given to maximum responses based on longer exposure period.

If linear motion response analysis predicts extreme roll or pitch amplitudes that can exceed the heeling angle at which the maximum value of the righting moment occurs, the dynamic behaviour should be verified by model testing or nonlinear analysis.

If neither a motion study nor a model test programme is performed for standard configurations and subject to satisfactory marine procedures, the motion criteria given in Table 13 may be used as guidance. The default values given in Table 13 are from Reference[60]. Alternative default motion criteria, as set out, for example, in References[53] or [49], may also be used as guidance.

Table 13 — Default values of motion response for standard transportation analysis [60]

Type of vessel	Vessel dimensions L_{OA} and b[a] m	Roll amplitude degrees	Pitch amplitude degrees	Heave acceleration m/s²
Large vessels	$L_{OA} \geq 140$ and $b \geq 30$	20	10	0,2 g
Medium vessels	$L_{OA} \geq 76$ and $b \geq 23$	20	12,5	0,2 g
Small vessels	$L_{OA} < 76$ or $b < 23$	30	15	0,2 g
Large cargo barges	$L_{OA} \geq 76$ and $b \geq 23$	20	12,5	0,2 g
Small cargo barges	$L_{OA} < 76$ or $b < 23$	25	15	0,2 g

[a] L_{OA} indicates the length overall; b indicates the breadth, both expressed in metres.

The motion default values presented in Table 13 should be used in conjunction with the following provisions:

— the roll and pitch values relate to a 10 s full cycle period of motion for vessels and barges with $b \geq 23$ m. For vessels and barges with $b < 23$ m, the roll period can be shorter;

— the roll and pitch axes pass through the centre of floatation;

— the phasing considered combines, as separate load cases, the most severe combinations of:

  — roll and heave;

  — pitch and heave;

— for inland and sheltered water transportation, the greatest effect of the following cases is taken into account:

  — the static loads caused by an acceleration of 0,1 g applied parallel to the deck in both directions;

  — the static inclination caused by the design wind;

  — the most severe inclination in the one compartment damage condition;

— the additional heel or trim caused by the design wind is taken into account. For most transports, it is permissible to omit the effects of direct wind load when computing the forces on the cargo. If the total effect of the wind on the cargo due to direct loading and wind heel are more than 10 % of the loads from the default motion criteria, then they shall be added [60].

For many instances of transportation, however, the effects of direct wind action when calculating the actions on the cargo may be neglected.

A further limiting heeling angle shall be determined to account for structural design limitations of, for instance, the topsides modules and the structural design constraints associated with the sea fastening. In other words, if the integrity of the sea fastening is compromised at 10°, it is irrelevant that the hull can heel 15°.

16.2.6 Structural verification of the transported object

Actions and action effects that result from wind, wind heel, wave action, accelerations and towline pull shall be considered in the design. The applicable environmental conditions should be based on the planned duration of the tow, as defined in Clause 7.

Equipment, modules, etc. including temporary equipment, should be adequately sea fastened as described in 15.15.

Any allowable list angle or motion criteria of WTG component, particularly in the nacelle, shall be specified during the design. This may e.g. include limitations due to structural integrity or due to oil tank inclination angle or tolerances for switch-gear transport induced accelerations whether the switch-gear is placed in a sub-structure, e.g. transition piece, in the nacelle, in the tower or in a topside of the offshore substation.

16.2.7 Bunker ports

The distance between bunker ports shall be considered when deciding on the composition of the tow fleet. If tugs are released to go into port to refuel, the remaining tow vessels should be capable of holding tow.

16.2.8 Weather forecast

The transportation shall not start unless the forecast is for stable weather, predicting favourable environmental conditions for a period equal with the period of the tow or at least of 48 h as recommended in Clause 7 whichever is less. The forecast should be made by a competent forecaster who has the necessary data at his disposal to make a highly specific recommendation for the particular tow.

The forecast should show the operational weather conditions, taking into account the contingency defined in 6.5.3. If the transportation is a weather-unrestricted operation, departure should still take place on a favourable forecast in order to allow time to obtain adequate sea room.

16.2.9 Design: Structural analysis during all transport phases

The loads acting on grillages, cribbing, dunnage, seafastening and components of the cargo shall be derived from the loads acting on the cargo, according to previous sections, as applicable.

The loads shall include components due to the distribution of mass and rotational inertia of the cargo. This is of particular importance in the calculation of shear forces and bending moments in the legs of jack-up units and similar tall structures.

If the computed loads are less than the “Minimum allowable seafastening force” (friction in sea fastening design) shown in Table 16, then the values in the table shall apply.

Care should be taken in cases where the cargo may be designed for service loads in the floating condition, but is being dry-transported. Its CoG may be higher above the roll centre in the dry-transportation condition than in any of its floating service conditions. Even though the transportation motions may appear to be less than the service motions, the loads on cargo components and ship-loose items may be greater.

16.2.10 Transport planning

Planning of the voyage or towage shall be carried out in accordance with the requirements of the IMO International Safety Management Code.

Routeing procedures shall be agreed with the master prior to commencement of the voyage, taking into account the transport vessel or tug’s capacity and fuel consumption, the weather and current conditions and normal good navigation and seamanship.

Piracy is prevalent in many areas which will vary with time though Southeast Asia, the Indian Ocean and West Africa are hotspots. Recent incidents involve vessels and crew being hijacked and then held to ransom.

Maintaining sufficient distance from land throughout the voyage may help to reduce this risk and also ensures there is sufficient sea room in case of emergency. However, given that attacks now regularly occur many miles from the coastline (up to 1 500 nautical miles), it is essential vessels considering transiting these areas prepare well in advance for the possibility of an attack.

16.2.11 Operational limits

To undertake any operation, the “operation limits” shall be less than the “design criteria”. The margin is a matter of judgement, dependent on factors specific to each case.

During design the following should be considered:

— measures to speed up the operation and provide more margin on the weather window;

— re-design of the operation limitations to sustain higher metocean conditions;

— contingency situations, and back-up and stand-by measures;

— whether delays to previous activities could push the operation into an unfavourable season;

— marine operations with operational reference periods of less than 72 h the maximum forecast wave height shall not exceed the design wave height multiplied by the applicable factor from Table 19. The forecast wind and current shall be similarly considered when their effects on the operation or structure are significant;

— sheltered towage circumstances are to be taken into account.

16.3 Weather routeing and forecasting

Weather forecasts for the departure area should be commenced at least 48 h before the anticipated departure date. Whenever possible a second weather forecast should be obtained from a different independent source prior to departure.

For any towage, the weather conditions for departure from the departure port or any intermediate port or shelter area shall take into account the capabilities of the towing vessel, the marine characteristics of the tow, the forecast wind direction, any hazards close to the departure port or shelter area and the distance to the next port or shelter area. A suitable weather forecast may be one that predicts the weather window required for the operation with operational limits w applicable to the travelling distance as well as the chosen seafastening and grillage design including a favourable outlook for a further 24 h for a tow.

If appropriate, a weather routeing service, provided by a reputable company, should be arranged prior to the start of the towage or voyage. The utilization of a weather routeing service may be a requirement of the approval. In any event, every effort shall be made by the master to obtain regular and suitable weather forecasts from a reputable source during the towage.

Weather routing procedure showing criteria of assessment for alternative routes and method of route change must be in place whenever a weather routed transport is performed.

16.4 Ports of shelter, shelter areas, holding areas

Ports of shelter, or shelter areas on or adjacent to the route, with available safe berths, mooring or holding areas, shall be agreed before departure and all necessary permissions obtained.

Where such shelter points are required as part of a weather-restricted operation, as described in 7.3, they shall be capable of entry in worsening weather.

Assisting tugs shall be engaged at commencement of the towage, at any intermediate bunkering port and at the arrival destination, as appropriate.

The master shall engage local pilotage assistance during the towage or voyage, as appropriate.

A detailed log of events shall be maintained during the towage or voyage.

16.5 Inspections during the towage or voyage

Unless the tow is manned, it should be boarded on a regular basis by the crew of the tug, particularly after a period of bad weather, in order to verify that all the towing arrangements, condition of the cargo, sea fastenings and watertight integrity of the tow are satisfactory. Suitable access shall be provided (see 13.11).

For manned tows, and self-propelled vessels, the above inspections should be carried out on a daily basis as relevant.

Any adjustable sea fastenings or lashings should be re-tensioned as necessary.

16.6 Responsibility

The towmaster is responsible for the overall conduct of a tow, and towing arrangements during the towage.

If any special situations arise during the towage or voyage and it is not possible to comply with any specific recommendations, agreed procedures or international regulations, then such measures as appropriate for the safety of life and property shall be taken. Nothing in this International Standard shall set aside or limit the authority of the master who remains solely responsible for his vessel during the voyage in accordance with maritime laws.

16.7 Hazardous materials

Hazardous substances may be considered as materials which, when released in sufficient quantities or improperly handled, have the potential to cause damage to the asset, personnel or the environment through chemical means or combustion. Unless it is necessary the carriage of such materials should be avoided, unless it can be shown that the substances are effectively controlled. Stowage of such materials should take into account that the transportation may be unmanned and therefore remedial action in the case of inadvertent release will be limited.

The properties of such material should be contained in the COSHH (Control of Substances Hazardous to Health) data sheets and the recommended method of stowage and handling is found in the IMDG (International Maritime Dangerous Goods) Code.

Where identifiable hazardous material is found on board prior to a tow/transportation taking place, it should be controlled either through isolation or removal ashore.

16.8 Ballast water

In addition to the International convention for the control and management of ships' ballast water and sediments, 2004 (not being in force yet), a number of coastal states have applied domestic regulations controlling the discharge of ballast water and sediments in their waters.

Vessels may need to change ballast water before or at their arrival port for operational reasons (loading/discharging). There may be local laws that will have an impact on these activities. Compliance with these local laws should be part of the voyage planning process. The ballast water management plan and records should be available for any attending surveyor or inspector.

Reference [45] requires the monitoring and recording of ballasting and de-ballasting operations. Vessels flagged in signatory states are required to have on board and to implement a ballast water management plan. This plan is specific to each vessel and the record of ballast operations may be examined by the port state authorities.

Vessels may need to change ballast water before or at their arrival port for operational reasons (loading/discharging). There may be local laws that will have an impact on these activities. Compliance with these rules may need to become part of the voyage planning.

The necessary ballast plan and records should be available for any attending surveyor.

16.9 Restricted depths, heights and manoeuvrability

The following recommended clearances are general, and each towage should be assessed on its own, taking into account the following:

— environmental conditions;

— length of areas of restricted manoeuvrability;

— any course changes within the areas of restricted manoeuvrability;

- cross section of areas of restricted manoeuvrability in relation to underwater area/shape of the base structure; and
- capability of the tugs.

The recommended values give guidance. If it can be proved that smaller values give the same or even better level of confidence these values should be taken. For areas where the under-keel or side clearance is critical, a survey report that is not older than three months shall be available. If not, the tow route should be surveyed with a width of five times the beam, with a minimum of 500 m. Side-scan sonar and bathymetric data should be provided. The equipment used should be of a recognized industry standard. The spacing between depth contour lines should be appropriate for the purpose. Current surveys should be made in restricted parts of the tow route.

The survey requirements can be relaxed if it can be shown that the on-board bathymetry measurement systems and position management systems have sufficiently high precision.

Ideally passages through areas of restricted manoeuvrability and passing under bridges and power cables should not take place in the dark.

16.10 Under-keel clearances

The under-keel clearance allowing for protrusions below the hull shall account for the effects of:

- roll, pitch and initial heel and trim;
- heave;
- tow-line pull;
- inclination due to wind;
- tolerance on bathymetry;
- changes in draught of the transport or towed object;
- differences in water density;
- low water tidal height variations;
- squat effects:
- deflections of the structure;
- errors in measurement; and
- negative surge.

Furthermore, under-keel clearance shall include a margin of not less than the greater of 1 m or 10 % of the maximum draught. The 10 % may be reduced in very benign conditions.

Under-keel clearances for departure from dry-docks or building basins are covered in [56].

If sections of the passage are tidally dependent, safe holding areas should be identified in the vicinity with adequate sea room and water depth to keep the structure afloat at low tide, while maintaining the minimum under-keel clearance. Any delay time waiting for the tide must be included in the overall planning.

Immediately before critical sections of the passage the tidal level shall be confirmed by measurement.

Use of an air cushion to reduce draft to assist in crossing localized areas of restricted water depth may be considered subject to:

- any conceivable loss of air not increasing the draft by more than the reserve on underkeel clearance; and

— the recommendations contained in References[56] and[59], on air cushions.

16.11 Air draught

When passing under bridges and power cables, the overhead clearance shall be calculated allowing a margin of not less than 1 m plus dimensional tolerances on the items listed in 16.14 and 16.16. excluding squat. Where clearance is limited then a dimensional survey of the barge/vessel and structure shall take place just prior to sailaway in order to ensure that the required clearance exists.

Power cables need a "spark gap", as well as a physical clearance; the transmission company will have their own criteria on the minimum allowable clearance. It should be noted that the catenary of the power cable will change depending on the load being carried in the cable; the lowest position should be used.

The actual clearance shall be confirmed with all appropriate authorities including those responsible for the obstruction.

Immediately before the passage the tidal level shall be confirmed by measurement.

16.12 Channel width and restricted manoeuvrability

The minimum channel width along any inshore legs of the tow route with the underkeel clearance and air draught required in 16.10 and 16.11 should be three times the maximum width of the towed object after allowances for yaw.

16.13 Towline pull required, fleet composition and towing arrangement

16.13.1 Towline pull required

The tow shall be provided with tugs of sufficient power and arranged in such a manner as to give adequate speed, control and holding power. The towing resistance of the towed object should be determined by means of calculation, model tests (or by reference to previous model tests) or full-scale measurements.

Except as allowed or otherwise recommended below, the minimum towline pull required, F_{PR}, shall be calculated for zero forward speed against a 20,0 m/s wind, 5,0 m significant wave height sea state and 0,5 m/s current, acting simultaneously and collinearly. Allowance should be made for yaw of the towed objects.

For benign weather areas, lesser criteria for calculation of F_{PR} may be considered. Generally, these should not be reduced below 15,0 m/s wind, 2,0 m significant wave height sea state and 0,5 m/s current, acting simultaneously and collinearly.

For towages partly sheltered from wave action, but exposed to strong winds, alternative criteria may be considered.

If the tow route passes through an area of restricted navigation, of continuous adverse current or weather, or if a particular towing speed is required in moderate weather, a greater F_{PR} can be required. For weather-unrestricted operations in areas with limited sea room, the F_{PR} should be computed based on the design criteria defined by Clause 8.

For the tow of a large structure out of dock, including, as appropriate, the tow to the inshore construction site or holding area, the F_{PR} should be based on the operational metocean criteria given in Clause 8 and should utilize a minimum of 0,25 m/s forward speed.

The relationship between F_{PR}, the minimum towline pull required, expressed in kilonewtons, and the continuous static bollard pull, F_{BP}, of the tug(s) is given by Formula (6):

$$F_{PR} = \sum \left[F_{BP} \times \frac{T_{eff}}{100} \right] \tag{6}$$

where

T_{eff} is the tug efficiency in the sea conditions, expressed in percent;

F_{BP} is the continuous static bollard pull of each tug, expressed in kilonewtons;

$F_{BP} \times \frac{T_{eff}}{100}$ is the contribution to the F_{PR} of each tug, expressed in kilonewtons.

The tug efficiency, T_{eff}, depends on the size and configuration of the tug, the sea state considered and the towing speed achieved. In the absence of alternative information, T_{eff} may be estimated according to Table 14.

Table 14 — Estimation of the tug efficiency (based on experience from the North Sea environment)

Continuous static bollard pull F_{BP} kN	**Tug efficiency for various sea conditions** T_{eff} %		
	Calm	H_s = 2,0 m[a]	H_s = 5,0 m[a]
$F_{BP} \leq 300$	80	50+F_{BP}/10	F_{BP}/10
$300 < F_{BP} < 900$	80	80	30 + 0,75 [(F_{BP}/10) − 30]
$F_{BP} \geq 900$	80	80	75
[a] H_s indicates the significant wave height.			

16.13.2 Towing fleet

The effectiveness of the towing fleet in achieving speed and control of orientation depends on the configuration in which the tugs are arranged, as well as the number of tugs and the power of each tug. In particular, the effective bollard pull is substantially less than the sum of the bollard pulls of the tugs, particularly when working on short towlines or with tugs in close proximity to one another.

Any tug considered for the towing operation should be fully certified for the area of operation and should have certificates for towlines, pennants, stretchers, shackles and marine fittings as well as the certificates listed in Table 3. The bollard pull certificate should not be older than five years or, in the case of critical tows, not older than three months. Critical tows shall be identified on a project-by-project basis through utilization of a formal risk assessment.

For certain towing operations, for example for tows involving several tugs or for single tug towages where the towed object is sensitive to wind actions or is difficult to manoeuvre, an escort tug should be provided for critical phases of the operation. The escort tug should be of sufficient bollard pull and should be available for immediate use in case any of the towing tugs requires assistance.

Stern tugs should not be considered when calculating the total effective bollard pull.

16.13.3 Towing arrangement

The MBS of the towline shall be related to the continuous static bollard pull, F_{BP}, of the tug given in Table 15.

Table 15 — MBS of the towline [60]

Bollard pull F_{BP} kN	Benign areas kN	Other areas kN
$F_{BP} \leq 400$	2,0 F_{BP}	3,0 F_{BP}
$400 < F_{BP} \leq 900$	2,0 F_{BP}	$(3{,}8 - F_{BP}/500)\ F_{BP}$
$F_{BP} > 900$	2,0 F_{BP}	2,0 F_{BP}

The design strength of the towline connections to the tow, including bridle legs, chain pennants and fairleads, where fitted, shall not be less than 1,3 times the MBS of the towline. The design strengths of shackles or other mooring components can be applied for towing.

A retrieval system should be available to retrieve the part of the towing arrangement directly connected to the towed structure, in case any other part of the tow arrangement fails.

Transport vessels or cargo barges shall be equipped with a suitable emergency towline in good condition with an MBS of not less than the values given in Table 15. The emergency towline shall be fitted with a pick-up line.

16.13.4 Towline length

The towline shall, at all times, be sufficient to keep the peak loads within the SWL of the towline. For critical tows, an analysis of the towline dynamics is recommended.

A table that shows the catenary depth for various combinations of towline tension and length shall be displayed on the bridge to facilitate a good balance between sufficient towline length and required clearance from the sea floor.

16.14 Tow out from dry dock

16.14.1 General

Guidelines are given in 16.14.2 to 16.14.7 for the marine operations concerning the float-out of a structure from the dry dock, the tow out until clear of the dock sill and the preparation for onward towage.

16.14.2 Under-keel clearance

The under-keel clearance in the dry dock shall at no time be less than 0,5 m after corrections for the effect of possible deflections of base structure, towline pull, wind heeling, squat effects and variations in sea water density. It is recommended that during the initial design phase, an under-keel clearance of 1 m is used.

In areas outside the dock, the under-keel clearance shall, at no time, be less than 1 m, or 10 % of the maximum draught, whichever is the greater. Minimum water levels and the effect of possible deflections of the base structure, towline pull, wind heeling, squat effects and variations in sea water density should be taken into account.

The minimum under-keel clearance for float-out should be maintained for the duration of an adequate period for float-out, including contingencies.

16.14.3 Side clearances

Side clearances for exit from a dry dock are dependent on the design of the structure, the shape of the dock walls and gates, the method used to control the position during float-out and the environment.

If the structure is winched out along fenders on one side of the dock, there should be adequate clearance on the opposite side in order to allow the operation to proceed safely, accounting for possible corrective action in case of emergency.

When tugs are used to control the position during float-out, additional clearance can be required to give the tugs enough sea room to operate.

16.14.4 Air cushion/air pressure

The following apply when an air skirt compartment is used to temporarily reduce the draught of the structure:

— A water seal with a minimum height of 0,25 m should be maintained inside the skirt compartment during the float-out operation until the structure has arrived at the holding area outside the dock.

— The air skirt compartments should be sized to withstand safely an internal air pressure equivalent to 130 % of the water head between the bottom tip of the skirt and the still water level.

— The skirt compartments should be tested for airtightness prior to float-out. The compressor capacity installed on board should be adequate to cope with any foreseeable leakage after breakdown of any one compressor or system.

— Piping should be secure, protected and of adequate capacity and strength. Supply lines should have non-return valves. A venting system should be provided to guarantee that air is removed after use to ensure that no residual free surface remains.

— A reliable method of measuring the water seal should be provided.

— The air cushion should be isolated in separate compartments, so that failure of any part of the system does not cause a loss of buoyancy that is outside acceptable criteria for stability, draught or freeboard.

— The stability calculations should take into account the compressibility of the air as well as the free surface effects.

16.14.5 Capacity of winching and towing arrangements

Winches, winch wire ropes and control lines should have sufficient capacity to hold or manoeuvre the structure in the design environmental conditions.

The breaking strength of any wire rope used to hold or manoeuvre the structure should comply with 19.6.2.

16.14.6 Navigation systems

Two independent positioning systems should be provided. The position should be continuously updated with an interval of not more than 5 s. The required accuracy of the system should be determined through risk assessment, taking into account the minimum clearance between the structure and the dock. The recommended accuracy should be the smaller of half the minimum clearance or 2 m.

16.14.7 Survey requirements

For the tow out operation from the dock sill to the holding area for hand-over for inshore tow, an adequate area should be surveyed, taking into account the size and yaw of the structure and the required area of manoeuvrability of the tugs.

16.15 Inshore tow

16.15.1 Tow route and towing clearances

The minimum under-keel clearance for inshore tow should not be less than 2 m or 10 % of the maximum draught, whichever is greater, after deduction of effects due to roll and pitch, heave, towline pull, wind heeling, tolerance on bathymetry, differences in water density, squat effects and deflections of the structure.

The minimum channel width along the inshore leg of the tow route should be three times the maximum width of the towed object, allowing for yaw, local currents, wind and tidal effects, and including contingencies. The minimum channel width should also take into account the tug configuration.

If passages through narrows are tide-dependent, the tow route selection should allow for holding areas in the vicinity with adequate sea room and water depth to keep the structure afloat at low tide on standby, while maintaining the minimum under-keel clearance.

When passing under bridges and power cables, the overhead clearance should be adequate and should consider tidal variations and changes in draught of the towed object. Where clearance is limited, a dimensional survey of the barge/vessel and structure shall take place just prior to sailaway in order to ensure that the required clearance exists.

Passages through narrows and passing under bridges and power cables should not take place in darkness.

The recommended clearances are given as guidance, and each tow should be assessed on a case-by-case basis, taking into account environmental conditions, length of narrows, any course changes within the narrows, cross-section of narrows relative to underwater area and underwater shape of the base structure and capability of the tugs. If it can be proven that smaller values of clearances give the same level of confidence, these values may be used.

16.15.2 Survey requirements

For areas where the under-keel or side clearance can be critical, a recent survey report (not older than three months) should be obtained. Alternatively, the inshore tow route should be surveyed with a width of five times the beam of the object, with a minimum of 500 m. Sidescan sonar and bathymetric data should be obtained. The sidescan equipment used should be of recognized industry standard.

The spacing between depth contour lines should be appropriate for the purpose. Current surveys should be made in restricted parts of the tow route.

The survey requirements may be relaxed if it can be shown that the on-board bathymetry measurement systems and PMS systems are of sufficiently high precision.

16.15.3 Navigation systems

Guidelines for navigation systems are given in 16.14.6.

16.16 Offshore tow

16.16.1 Holding areas and contingency plans for routing

Suitable holding areas or safe havens shall be identified along the tow route to hold the transport when waiting on weather or tide. An offshore holding area near the installation site should also be identified. All necessary permits and agreements shall be arranged in advance.

Where holding areas are impractical, e.g. cross-ocean transits, weather forecasting capabilities to identify storms that exceed operational limits and contingency plans for routing around such storms shall be in place.

16.16.2 Under-keel clearance

The minimum under-keel clearance during an offshore tow should allow for 5 m above astronomical tide LAT level, after deductions for the effects of roll and pitch, heave, towline pull, wind heeling, tolerance on bathymetry, differences in water density, squat effects and deflections of the structure.

16.16.3 Special considerations

Special considerations should be given to transits in limited areas with small under-keel clearances subject to weather-restricted conditions, tidal windows and accuracy of the survey data.

16.16.4 Navigation systems

Navigation data shall be provided by two independent on-board systems and suit the navigational constraints of the tow route.

16.16.5 Survey requirements

In areas where the water depth is less than the structure draught plus 10 m, the offshore tow route should be surveyed over a width of 1 000 m. The tow route survey should provide sidescan sonar and bathymetric data.

16.17 Transport onboard a vessel

16.17.1 Vessel selection

The transport vessel should be selected based on its capacity to suit operations of the transport, including loadout and offload, and to demonstrate that the vessel meets deadweight, deck space, strength and stability requirements for the marine operation. Vessels conducting transport can be e.g. heavy lift vessels, barges or self-propelled jack-up vessels.

16.17.2 Stability

For stability requirements, see Clause 13.

16.17.3 Under-keel clearance

The minimum under-keel clearance for offshore transportation should be 5 m after considering the effects of roll and pitch, heave, towline pull, wind heeling, tolerance on bathymetry, differences in water density, squat effects and deflections of the vessel.

16.17.4 Special considerations

Special considerations should be given to transit in limited areas with smaller under-keel clearances subject to weather-restricted conditions, tidal windows and accuracy of the survey data.

16.17.5 Sea fastening

For sea fastening of objects for dry tow on a barge or aboard a heavy transport vessel, the following considerations apply.

- The provisions of 15.15 apply to the design of the sea fastening.
- Sea fastening should be designed with details that are robust with regard to fatigue; for critical transports, a fatigue assessment should be made and the calculated fatigue lives of the sea fastening and their connections shall be at least five times the anticipated transit time.
- For possible slam loads and their effects on overhanging parts of the cargo, such as capped pile sleeves, appropriate slam calculations should be prepared and documented.
- If the cargo becomes submerged when the vessel heels or rolls, the weight of the cargo is reduced by an amount equal to the buoyancy of the submerged cargo. This reduces the friction forces between the object and the vessel and the sea fastenings should be designed to account for this loss of resistance.
- A detailed analysis of heavy transport vessel or barge and its cargo, taking into account the cargo overhang, arrangement of cribbing and sea fastening, should be performed to enable appropriate local and global strength checking.
- For cargos supported on the deck by cribbing or dunnage, and in the absence of more detailed analysis, the coefficients of friction in Table 16 may be used for the combination of cargo weights,

cargo overhangs and arrangements of cribbing and sea fastenings listed therein. The computed frictional force on the cribbing can be deducted from the computed loading when determining the forces to be carried by the cribbing and sea fastenings. The sea fastening design strength shall be greater than the minimum force derived from the data in Table 16, which presents the maximum coefficients of friction and the minimum force, expressed as a percentage of cargo weight.

When using the information in Table 16, the following apply.

— Friction forces shall be computed using the reaction normal to the deck between the vessel and the cargo.

— The cargo should be supported by wood dunnage or cribbing; friction is not allowed for steel-to-steel interfaces.

— The overhang is the distance from the side of the vessel to the extreme outer edge of the cargo.

— For wood cribbing less than 600 mm high and with a width no less than 300 mm, the full friction force may be assumed to act in any direction relative to the cribbing.

— For cribbing heights between 600 mm and 900 mm high and with a width no less than 300 mm, the calculated percentage friction force assumed to act in a direction at right angles to the line of the cribbing should not exceed the calculated factor, f_{fr}, expressed as a percentage, as given by Formula (7):

$$f_{fr} = \frac{900 - H_c}{3} \tag{7}$$

where H_c is the height of the cribbing above deck, expressed in millimetres.

— For wood cribbing over 900 mm high, or with a width less than 300 mm, no friction force shall be assumed to act in a direction at right angles to the line of the cribbing.

— For cribbing with a height greater than its width, movement in the direction orthogonal to the length of the cribbing shall be prevented by steelwork designed to carry the full friction force in that direction.

— When the cribbing arrangement is predominantly in a single direction, the calculated friction force orthogonal to the predominant cribbing direction should be reduced accordingly unless the sea fastenings acting in the orthogonal direction are fitted with an interface that is compliant with the cargo and allows the development of the cribbing friction as the actions on the sea fastenings develop. Such interfaces can be comprised of an elastomeric bearing pad.

— The value of the minimum sea fastening force listed in Table 16 is the minimum value, expressed as a percentage of cargo weight, for which the sea fastening should be designed in the event that the computed sea fastening force is less than this value.

— For very short duration moves in sheltered water, such as turning a barge back alongside the quay after a loadout, friction forces may be considered. It should be demonstrated that all parts of the load path, including the potential sliding surfaces, are capable of withstanding these forces.

Table 16 — Allowance of friction in sea fastening design [60]

Overhang m	Maximum coefficient of friction Cargo weight W_c kN						
	< 1 000	1 000 to < 10 000	10 000 to < 50 000	50 000 to < 100 000	100 000 to < 200 000	200 000 to < 400 000	≥ 400 000
None	0	0,10	0,20	0,20	0,20	0,20	0,20
< 15	0	0	0,10	0,20	0,20	0,20	0,20
15 to < 25	0	0	0	0,10	0,20	0,20	0,20
25 to < 35	0	0	0	0	0,10	0,20	0,20
35 to < 45	0	0	0	0	0	0,10	0,10
≥ 45	0	0	0	0	0	0	0
Direction	**Minimum sea fastening force** % W_c						
Transverse	–	10	10	10	10	a	5
Longitudinal	–	5	5	5	b	c	1,5

a ≥ 15 – W_c/40 000.

b ≥ 7,5 – W_c/40 000.

c ≥ 3,5 – W_c/200 000.

NOTE Above friction coefficients are to be accounted when seafastening philosophy is made using friction only. Otherwise the beneficial effect of friction is normally neglected, resulting conservative results.

16.17.6 Navigation systems

Requirements for navigation systems are given in 16.14.6.

16.18 Transport manual

A transport manual and supporting document should be prepared for the operation and issued for information and approval, as appropriate. The items, in addition to those found in 6.5.2, that are necessary to include in the transport manual and supporting documents are given in A.4.

16.18.1 Voyage planning

A transportation or towing manual is required for all transportations or towages for the following reasons:

— It shall provide the master with the key information that he needs, including the cargo and route.

— It shall describe the structural and any other limitations of the cargo.

— It shall summarize contingency plans in the event of an emergency including contact details.

— It shall give approving bodies the key information that they require for approval.

— It shall define the responsibilities of different parties if parts of the transport/tow and installation are performed by different contractors. The scope split between the contractors shall be clearly defined, to ensure that all parties are aware of their responsibilities, handover points and reporting lines.

The purpose of the transportation or towing manual described in A.4 is to give to:

— the vessel or tug master; and

— Persons In Charge (PIC), or responsible persons ashore for emergency response planning in the event of an incident or accident.

It must contain information about:

— the cargo;

— routeing, including possible deviations to shelter points if required;

— what to do in an emergency;

— contact details (client, owner, local authorities, MWS etc.);

— organigram showing the scope split between different contractors (if applicable). These must be clearly defined, to ensure that all parties are aware of their responsibilities, handover points and reporting lines.

Where a manual has been produced to satisfy local authority requirements then this should take precedence, providing it satisfies the main requirements detailed below.

Detailed calculations and other documents may be in separate manuals referenced in the transportation or towage manual covering the following items:

— introduction. What is the cargo, where is it being transported or towed, who for and why;

— description of the vessel and cargo;

— proposed route (with plot or chart) including waypoints and any refuelling arrangements, anticipated departure date and speed;

— metocean conditions for the route for anticipated departure date;

— any limiting criteria and motions (roll, pitch and period etc.) for the transport or tow, weather forecasting arrangements and weather routeing details if applicable;

— contact details and responsibilities;

— reporting details. Who to, how often and content;

— summary of ballast conditions and stability (usually including anticipated departure and arrival loading conditions) with corresponding stability calculations and GZ curves. Calculations should also be provided for any ballasting required for loading or discharging where applicable;

— motions and strength. Detailed supporting calculations for the motions and accelerations, longitudinal strength and strength of the seafastening and cribbing/grillage;

— arrival details, contacts, field plan etc.;

— contingency arrangements;

— drawings to include, where applicable, cargo, GA and other key drawings of vessel and cargo, stowage plan, towing arrangement, cribbing/grillage arrangement, loadout/discharge plan, seafastening arrangement, guidepost details etc.;

— reference documents;

— tug bollard pull calculation (if applicable);

— tug or transport vessel specification.

17 Temporary mooring and stationkeeping for marine operations

17.1 Introduction

The design of temporary moorings and stationkeeping systems (including DP) for marine operations shall be in accordance with ISO 19901-7, as applicable, and with the provisions presented in 7.4.2 (return periods), 15.6 (loadout) and Clause 18 (Installation).

The temporary mooring systems include components, from the anchor points at the sea floor or the quayside to the mooring brackets or winches on the unit, that are required to hold the structure in a safe and stable position inshore and offshore, during construction and assembly afloat of offshore structures.

Temporary mooring systems are generally required during the construction phases of offshore structures for inshore or offshore applications and for various durations. The most frequently used types of moorings are listed as follows.

— Inshore construction moorings: These moorings are used to hold a structure during its construction and outfitting afloat, are generally suitable for long periods of operations in sheltered waters and are generally catenary moorings.

— Moorings alongside quays: These moorings are used to hold a low draught or slender structure during its inshore construction and outfitting, are most commonly used for ship-shaped structures and are generally treated as conventional berthings with a combination of spring and breast lines.

— Standby moorings: These moorings are used to hold the main structure or one of its components (e.g. topsides on a barge prior to float-over) in a safe position during standby before or after the performance of given operations. These standby moorings are of the catenary type or consist of a berthing alongside a quay or another floating unit.

— Position keeping moorings: These moorings are used as a positioning aid during precise operations, such as inshore loadout, inshore deck mating or offshore installation. Jack-up Legs/Spudpoles: These systems are used to provide temporary stationkeeping or holding forces to perform offshore operations such as cable laying, beach pull or diving support.

— Offshore mooring used for propulsion: These moorings are used for exact positioning within a certain limited range or e.g. for moving along a cable route.

17.2 Environmental criteria

The environmental conditions for consideration for the design of temporary mooring systems depend on the intended length of deployment during the construction phase afloat (see Clause 7, where the design criteria versus duration of operation are defined).

Extreme environmental conditions that can exist locally, such as hurricanes or typhoons, shall be accounted for when designing stationkeeping systems for inshore construction or offshore installation.

The environmental conditions shall be applied with due regard to local circumstances specific to the mooring location and its surroundings, in order to account for any directional effect or instability that can be generated by the landscape contour and/or the sea floor bathymetry.

In particular, when the temporary construction mooring is set up close to the shore, special consideration shall be paid to:

— change of wave direction when rounding the shore contour;

— instability of the tidal current in speed and direction due to the bathymetry close to headlands;

— increase in wind speed and change of direction when close to landscape highs.

Offshore installation mooring systems, deployed to provide a precise positioning aid during a temporary stage of offshore installation, should be designed based upon specific metocean criteria and shall meet stringent operability criteria in terms of mooring response and manoeuvrability.

Alternatively specific operational limits shall be defined to be able to evade the extreme conditions and move the vessel or structure to a sheltered area through the duration of the extreme condition.

17.3 Determination of mooring response

17.3.1 Analysis methods

For a determination of the mooring response and the design of the temporary mooring systems, analyses are normally carried out. The three methods generally used to compute the floating structure response and the associated forces in the mooring lines are:

— the frequency domain approach;

— the time domain approach;

— the combined time and frequency domain approach.

These methods involve different degrees of approximation and different limitations and, therefore, do not necessarily yield consistent results. If verification of the approach selected for the mooring design is required, model test data or an alternative approach should be used.

For detailed information on the analysis methods, see ISO 19901-7.

The analysis shall take into account environmental actions, including shallow water wave effects, if applicable. Guidance on calculations of actions induced by the environment can be found in ISO 19901-7.

17.3.2 General considerations on the mooring design

The calculation of the wind, wave and current actions shall be based upon recognized methods and account for any directional effect. The design of the temporary mooring system shall be checked for the various possible draughts and outfitting configurations of the structure, in order to document which construction phases can govern the sizing of the mooring components. Transient conditions are to be considered, however limited reduction of stability can be accepted, if an action plan for the execution of return to define safe position exists.

Wind actions should account for the variation of wind speed against height. Shielding effects and solidification effects should be included where appropriate. For large deck structures attracting high wind actions, the wind coefficients should preferably be validated by wind tunnel tests.

Wave drift actions should be investigated for the range of sea states that are likely to occur at the mooring site. In the absence of more precise site data, the wave data for sheltered locations can be established by accounting for the fetch from various sectors. Finite water depth should be accounted for, if applicable.

The calculation of current actions should preferably be based on detailed site data. In the absence of such data, a conservative value for the current speed should be established, based on the combination of tidal current, wind-generated current and currents generated by other causes, such as storm surges.

Where current actions are significant compared to the overall environmental actions, current actions should be calculated based on recognized methods or model tests.

Calculated wind, wave and current actions should include the contributions of barges and construction equipment likely to be moored temporarily alongside the structure that rely on the holding capacity of the temporary mooring system.

For inshore or offshore temporary moorings used as stationkeeping aids without stringent positioning requirements, a quasi-static mooring analysis can be adequate, provided that the influence of low frequency motions on the mooring response is included.

For temporary offshore moorings with strict positioning requirements, or if critical clearances between structures and vessels exist, model tests should be carried out if motion analyses are not expected to be sufficiently accurate.

For tall structures anchored to mooring systems in areas that are subjected to large current variations, whether or not of tidal nature, a check should be made that the mooring response is safe with respect to potential in-line and transverse vortex shedding that can generate vortex induced motions.

17.4 Sizing of mooring lines

17.4.1 General considerations

The design forces of individual lines should be based on the maximum actions and motions obtained from the analyses performed.

The calculations should account for the change of geometry of the mooring pattern after excursions due to relevant excitations.

The mooring system should be checked for suitability in intact conditions, for redundancy and for transient conditions, if relevant.

The intact condition is the condition in which all mooring lines are intact and all thrusters, if any, are working.

The redundancy check is the condition in which the structure has a new mean position after a single line breakage or a failure of one or more thrusters, as appropriately assessed by the FMEA and for DP capable vessels in accordance with the DP analysis.

The transient condition is the condition in which the structure undergoes transient motions between the intact and redundancy check conditions, including the possibility of overshoot, as a result of a single mooring line breakage or a failure of one or more thrusters, as appropriately assessed by the FMEA.

17.4.2 Line tension limits and design safety factors

The line tension limits applied in the quasi-static or dynamic mooring analyses shall comply with the requirements set forth in Table 17. The corresponding design safety factors are also listed.

Table 17 — ULS line tension limits and design safety factors[a]

Analysis condition	Analysis method[a]	Line tension limit % of MBS	Design safety factor
Intact	Quasi-static	50	2,00
	Dynamic	60	1,67
Redundancy check	Quasi-static	70	1,43
	Dynamic	80	1,25
Transient[b]	Quasi-static or dynamic	95	1,05

a From ISO 19901-7, Table 5 and [62], Table 10.1.

b Applies also for operational or temporary mooring (one line broken).

17.4.3 Particular mooring conditions

In the case where mooring pontoons are used along with one or several mooring lines, it should be demonstrated that they have sufficient strength, stability and reserve buoyancy when subjected to the maximum horizontal and vertical actions generated by the mooring in the intact and redundancy check conditions, for construction stages and draughts of the structure.

In the case where local current conditions and moored structure geometry can cause vortex shedding excitation of the moored structure, calculations of the mooring line strength should also account for the effect of the in-line and transverse vortex induced motions. These effects should be evaluated based on recognized methods.

For temporary moorings intended for long duration or where a chain is being re-used, consideration should be made for fatigue, taking into account the chain history.

For moorings alongside quays, consideration should be given to ensuring a correct balance of the line tensions.

17.5 Sizing of anchors

Temporary mooring systems normally include drag anchors, the holding capacity of which depends upon their correct embedment into the soil.

Sizing according to equipment number shall be considered for vessels or structures to which the specific rules apply.

When drag anchors are used, they should be sized to have a UHC greater than:

— 1,5 times the maximum force calculated in the line at the anchor point, in the intact condition;

— 1,0 times the maximum force calculated in the line at the anchor point, in the redundancy check condition.

In case alternative anchoring systems are used, applicability of ISO 19901-7 and [62] shall be checked.

Calculations of anchor UHC should take account of any uncertainties in the soil characteristics.

Other design safety factors on the anchor UHC can apply in particular cases, based on specific anchor types and soil conditions, and if approved by a recognized organization (3.114).

Where drag anchors are used, the mooring lines should generally be designed to avoid uplift at the anchor for extreme forces calculated in the redundancy check. If extreme forces induce uplift at the anchoring point, reduction of the holding capacity should be considered for conventional drag anchors. However, special types of drag anchors that can accept a limited uplift under extreme conditions can be used, provided that they have been tested and proven under similar conditions.

17.6 Sizing of attachments

Connections, such as mooring brackets on the structure or fixed points on the shore, should be sized for a design strength not less than 1,3 times the required breaking strength of the weakest component of the mooring line.

The design strength of such connections should reflect:

— variations of the angle of the line in the horizontal plane, accounting for possible deformations of the mooring pattern under extreme excursions and yaw motions of the structure or platform, in the intact and/or redundancy check conditions;

— variations of the angle of the line in the vertical plane, accounting for possible draught configurations of the structure or platform when connected to the temporary mooring system.

17.7 Sizing of mooring line components

Mooring line components should be sized following the principles listed in 17.4, 17.5 and 17.6.

Shackles and any component located along the mooring line should have a design strength equal to or larger than the design breaking strength (WLL) of the mooring line itself; see also 17.6.

Other components used to connect or lead the mooring line, e.g. fairleaders, winches, stoppers, etc., should have a design strength in accordance with 17.6.

Due consideration for wear, shock loads and chafing should be made in the design and specification of the mooring line components. It also should be checked that the mooring components are well matched to each other, so as to maintain the expected level of safety of the mooring system.

17.8 Clearances under extreme conditions

Adequate under-keel and side clearances with the seabed and with any other obstructions shall be maintained when the structure reaches the maximum excursions and rotations on its mooring, under extreme environmental conditions coming from any direction, in both the intact and redundancy check conditions.

The evaluation of minimum under-keel and side clearances should be made at the lowest and outermost part of the structure, after allowance for possible reduction effects, such as structure heel and pitch and low water density.

A detailed bathymetry of the site resulting from a recent underwater survey should be available when assessing minimum clearances with the seabed contour, and survey inaccuracies should be accounted for.

When a large object is moored at its deepest construction draught on a catenary inshore construction mooring, the clearances with the seabed at the maximum excursion should be in excess of 5 m vertically and 25 m horizontally in the intact and redundancy check conditions, including transient stages. Compatibility with respective tidal regimes shall be considered.

In the case of an inshore construction barge moored independently in the vicinity of the structure, smaller values of clearance between each unit or its appurtenances should be acceptable based on mooring analyses that account for dynamic motions in the design of the two mooring systems.

Clearance between any mooring line and any structure including other mooring lines, but other than assets of the offshore wind farm, e.g. cables, foundations, jack-up zones, should not be less than 10 m, unless appropriate risk assessments are performed to demonstrate that a smaller value can be used.

In the case of objects moored alongside a quay or alongside other objects, smaller side clearances may be considered as long as the motion responses of the object under the design environmental conditions have been taken into account, and the object has been equipped with appropriate fenders.

Likewise, the under-keel clearance for objects that are moored alongside a quay or alongside other objects, in completely sheltered areas only, may be reduced to a minimum of 0,5 m, once possible clearance reduction effects, such as tide, environmental actions acting on the object, trim and heel, and wind heeling effects, have been taken into account and provided a recent underwater survey has been performed.

Regarding horizontal clearance from cables and cable route corridors, see Clause 20.

For clearances for crane vessels, their associated mooring system and lifted objects, see 19.9.

17.9 Tensioning of moorings

After laying, drag anchors should be tested to the calculated maximum force generated in the line under the design environmental conditions, in the intact mooring system as predicted by the chosen design methodology. The test load should be applied gradually in the line and then maintained for a duration of at least 15 min; see also ISO 19901-7.

17.10 Other stationkeeping means

17.10.1 General

Vessels involved in specific installation operations (e.g. transport vessels, installation vessels and the structure being installed) sometimes need to be controlled by a stationkeeping system other than a mooring.

The stationkeeping system can consist of:

- a DP system;
- purpose-built mooring arrangements;
- tugs, moored and used as winch stations.

17.10.2 DP systems

DP systems should be designed, equipped and operated in accordance with References[50] and[32].

17.10.3 Purpose-built mooring arrangements

Where the stationkeeping system is not an integral part of the vessel's equipment, but it is purpose-built for the installation operation (winches, jacks, fenders, etc.), it should be sized to hold station when subjected to the design metocean criteria for the operation.

17.10.4 Use of tugs

In certain circumstances, a tug can be used to assist in a temporary mooring system. It is, then, normally connected at its bow to a pre-laid mooring, its towing winch being used to tension up the towline connected to the structure. With this arrangement, the tug effectively becomes a winch barge.

In such a case, some special considerations apply to the pre-laid mooring and the design of the tug. In particular, it should be demonstrated that the moored tug is able to function in sea conditions coming from any direction.

The connection to the pre-laid line at the bow of the tug should be checked to be suitable for the design conditions of the mooring system.

17.11 System for common reference stations

Due to multiple installation locations at an offshore installation site it is crucial that all vessels conducting installation works use a common reference station for component and vessel positioning as well as as-built-data. A system shall be used that allows for this requirement to send out correction data over e.g. radio modem. The principle of such a system is based on the comparison of a known position of a GNSS (Global Navigation Satellite System) reference station with the computed positions from the actual measurements.

During the construction phase, a fully workable GNSS-RTK reference station should be positioned at the offshore installation site including but not limited to:

- GNSS receiver;
- radio with omnidirectional antenna;
- power backup;
- interface capability with standard vessel GPS system;
- verification that the broadcasted correction signals from the system can be received across the entire offshore installation site.

The owner's construction management should provide all sufficient information and procedures on how to use the reference station as such including but not limited to all specification for technical equipment needed on vessel side.

An appropriate location at the offshore installation site shall be determined where the system including potential back-up units can be installed.

Companies conducting the installation should use the RTK reference station for positioning of components and vessels during installation and when determining the site specific coordinates of the installed components or ensure common reference station by other means.

18 Offshore installation operations

18.1 Introduction

18.1.1 General

The requirements, guidance and recommendations for marine operations involved in the offshore installation of structures, topsides, subsea templates and similar objects are provided in 18.1.2 to 18.24. Additional information can be found in [56] and [63].

18.1.2 Design: Structural analysis during all installation phases

Structural calculations, based on the load factors discussed above, shall include adequate loadcases to justify the structure. For example, for an indeterminate, 4-point lift the following loadcases should normally be considered:

— base case, using gross or NTE weight, resolved to the lift points, but with no skew load factor (SKL);

— gross or NTE weight, with SKL applied to one diagonal;

— gross or NTE weight, with SKL applied to the other diagonal.

In all cases the correct or minimum sling angle and point of action, and any offset or torsional loading imposed by the slings shall be considered.

The overall structure shall be analysed for the loadcases above, including loadings shown in Clause 22.

The primary supporting members shall be analysed using the most severe loading resulting from Clause 22, with a consequence factor applied (see below).

The following consequence factors shall be further applied to the structure including lift points and the lateral load effects on lift points, and their attachments into the structure.

Table 18 — Consequence factors [59]

Structural item	Consequence factor
Lift points including spreader bars and frames	1,30
Attachments of lift points to structure	1,30
Members directly supporting or framing into the lift points	1,15
Other structural members	1,00

The primary structure shall be of high quality structural steelwork with full material certification and NDT inspection certificates showing appropriate levels of inspection. It shall be assessed using the methodology of a recognized and applicable offshore code including the associated load and resistance factors for LRFD codes or safety factors for ASD/WSD codes.

18.1.3 Installation planning

The installation plan is part of the project execution plan and consists of a conceptual and a detailed part. It should be prepared before the start of the installation and should be issued for information and approval, as appropriate. Items included in the installation planning documentation, in addition to those in 6.5.2, are listed in A.5.

18.1.3.1 Conceptional installation planning

The conceptual part shall provide basic information about the following subjects:

- vessel description:
  - class and flag;
  - dimensions;
  - air draught;
  - GA-drawings;
  - cargo capacity;
  - accommodation;
  - autonomy;
- operability values (transit, operation, survival);
- transit speed;
- jacking system description and capability, if applicable;
- seakeeping capability (DP, anchoring);
- outfitting particulars:
  - main and auxiliary cranes;
  - access systems;
  - winch system;
  - helideck;
  - ballasting system;
  - cooling system;
  - power supply;
  - illumination arrangement;
  - monitoring and information system (LAN, TV);
  - preinstalled seafastening system (twist locks);
  - ROV systems;
- sensor and communication systems (positioning reference systems, DGPS, radar, satellite, laser surveying, taut wire, hydro-acoustic);
- offshore location:
- water depth;
- soil condition;
- restrictions;
- risks;
- harbours:

— location;

— tide size;

— sheltered areas/not sheltered (swell, waves, current);

— docking capacity (bollards, quay length and height);

— quay capacity (dimensions, bearing capacity);

— quay restrictions (e.g. minimum distance of jacking legs);

— heavy load logistic infrastructure (crane capacity, RoRo, skids, preassembly foundations);

— sea bottom profile (jacking location, on bottom obstruction, bearing capacity);

— inshore and sea access (inland waterways, roads, air draft);

— resources (fuelling, water and power supply, repair facilities, man power);

  — see also 18.9 for further details on risk assessment for punch-through risk and risk of uncontrolled movement of jacket legs;

— basic method statement:

  — basic sequence and schedule of operations;

  — installation tolerances;

  — operation restrictions;

  — interface descriptions;

  — components and modularity (COG, weight, attachment points, tugline connection points);

  — basic GA-drawings of components, lifting gear and lifting operations;

  — resources (equipment, tools, lifting devices, qualified man power);

— basic risk assessment;

— statistical and historical data about environmental conditions:

— average weather and seastate prognosis:

  — wind (main direction, mean wind, gusts);

  — waves (main direction, significant wave height, swell, wave scatter diagram);

— current;

— tidal excursion.

18.1.3.2 Detailed installation planning

The detailed installation planning starts after the following boundary conditions have been defined:

— baseport;

— installation units (jack up vessel or barge, cable layer);

— transportation units (feeder vessels, work boats);

— installation method;

— installation milestones (start, operational period);

— basic impact of environmental conditions.

The detailed installation planning includes the following elements:

— method statements for operations with the installation unit:

  — deck layout of installation unit;

  — lifting plan for offshore installation;

  — lifting plan for loadout at baseport.

Risk assessments, HAZOP/HAZID studies to be completed at an early stage so that the findings can be incorporated into the operational procedures;

The arrangements for control, manoeuvring and mooring of barges and/or other craft alongside the installation vessel

A weather forecast from an approved source, predicting that conditions will be within the prescribed limits, shall be received prior to the start of the operation, and at 12 hourly intervals thereafter, until the operation is deemed complete.

18.1.4 Cargo weight details and COG information

Weight and CoG position assessment will be according with Clause 12.

Dynamical effect will be correlated with the type of installation vessel (jack-up, semi-jack-up, DP) and duration to complete the installation (including contingency)

18.1.5 Operational limits

To undertake any operation, the "operation limits" shall be less than the "design criteria". The margin is a matter of judgement, dependent on factors specific to each case. Guidance can be found at [52],[54],[56] and[63].

During design the following should be considered:

— measures to speed up the operation and provide more margin on the weather window;

— re-design of the operation limitations to sustain higher metocean conditions;

— contingency situations, and back-up and stand-by measures;

— whether delays to previous activities could push the operation into an unfavourable season;

— marine operations with weather windows of less than 72 h the maximum forecast wave height shall not exceed the design wave height multiplied by the metocean reduction factor from Table 19 below. The forecast wind and current shall be similarly considered when their effects on the operation or structure are significant.

Table 19 — Metocean reduction factor [56]

Case	Weather forecast provision	Metocean reduction factor					
	Weather window (hours)	≤ 3	≤ 6	≤ 12	≤ 24	≤ 48	≤ 72
1	No project-specific forecast (i.e. public domain forecast only)	0,61	0,56	0,53	0,50	0,45	0,42
2	One project-specific forecast source	0,76	0,71	0,69	0,65	0,59	0,54

Table 19 *(continued)*

Case	Weather forecast provision	Metocean reduction factor					
	Weather window (hours)	≤ 3	≤ 6	≤ 12	≤ 24	≤ 48	≤ 72
3	Two project-specific forecast sources	0,78	0,72	0,71	0,67	0,60	0,55
4	One project-specific forecast source plus in-field wind and wave monitoring (e.g. wave rider buoy) without regular feedback to forecast source	0,78	0,73				
5	Two project-specific forecast sources plus in-field wind and wave monitoring (e.g. wave rider buoy) without regular feedback to forecast source	0,81	0,75	0,73	0,68	0,62	0,56
6	as case 4 but with regular feedback to forecast sources	0,82	0,76	0,75	0,70	0,63	0,58
7	as case 5 but with regular feedback to forecast sources	0,84	0,78	0,76	0,72	0,65	0,59
8	One project-specific forecast source plus in-field wind and wave monitoring and offshore meteorologist	0,88	0,83	0,80	0,75	0,68	0,62
9	Two project-specific forecast sources plus in-field wind and wave monitoring and offshore meteorologist	0,95	0,87	0,82	0,77	0,70	0,64

NOTE 1 Reference [56] only states metocean reduction factors between 12° – 72 h; values between 3 – < 12 h are specifically used in the offshore wind industry for repetitive operations with short weather windows.

NOTE 2 The location chosen for a wave rider buoy within the site should be representative for the conditions encountered at the specific locations of the foundations.

Weather window (operational reference period) shall include a contingency duration determined with due allowance for the nature and criticality of the individual operations in the operational reference period (safe to safe).

The duration of marine operations should be determined by definition of operation reference period.

$$T_R = T_{POP} + T_C$$

where

T_R is weather window (operation reference period);

T_{POP} is planned operation duration;

T_C is estimated maximum contingency period.

18.1.6 Design

Operations shall be designed in accordance with the contents of Clause 18. Results from analyses, tests and any other required design activities shall be documented. Minimum requirements on tolerances of installation shall be defined.

18.2 Installation site

18.2.1 Sea floor survey

A bathymetric survey of the site sea floor area shall be carried out to determine bottom topography, confirm cleanliness of the site including Unexploded Ordnance (UXO) survey where recommendable due to site-specific conditions and provide up-to-date and accurate information for the installation design.

Measurements locating pre-existing structures shall be performed.

18.2.2 Soil survey

Site-specific geophysical and geotechnical data shall be made available to design and plan the installation operations.

18.2.3 Soil preparation

Based on the results of the site-specific sea floor survey and the requirements specific for the installation of the foundation structure, soil preparations could be recommended. This could comprise levelling measures of the seabed or placing any scour protection layers where advisable.

Where suitable, instead of levelling the seabed, the foundation, particularly jacket structures, could be directly equipped with temporary support material e.g. underneath mud mats which would compensate for slight deviations in sea floor level during installation. After final fixation of the jacket, this material would remain at its place but would not be structurally relevant.

18.2.4 Site-specific site plan

Site-specific charts shall be made available to all parties working in the offshore wind farm during installation operations. The site plan shall provide detailed coordination information on e.g.:

— all existing structures;

— locations of components which were already installed during the campaign;

— planned locations of components;

— exclusion zones for e.g. jacking and anchoring;

— cable corridors;

— locations of any buoys, like e.g. cardinal buoys or wave measurement devices;

— locations of wrecks or other suspected objects including UXO.

The site plan shall be updated on a regular level and provided to all parties working during the installation operations.

18.2.5 Unexploded Ordnance (UXO) Survey

If relevant, unexploded ordnance survey may be carried out to confirm the clearing of the site.

18.3 Site actions on and motions of floating units

The following aspects shall be considered, as appropriate:

— environmental actions and induced motions of floating units;

— actions resulting from external or internal hydrostatic pressures;

— actions imposed from translation and rotation of the object;

— actions resulting from earth pressure;

— actions from lifting operations;

— actions imposed during set-down;

— actions imposed when passing through the splash zone.

Model tests can be considered as part of the design to substantiate analytical results to alert the designer to unanticipated responses and to indicate the levels of design margins for the findings of computer modelling assessment.

18.4 Systems and equipment

18.4.1 General

Guidelines for the selection of operational systems and equipment in general are given in Clauses 5 and 6. Considerations regarding specific items of systems and equipment are given in 18.4.2 to 18.4.6.

18.4.2 Vessels

The installation operation can be a direct continuation of the offshore transportation, using the transportation fleet as the core of the installation fleet.

18.4.2.1 Self-elevating vessels

Jack-ups are not designed, constructed or intended for unlimited service at sea. Each stage of the proposed operations must be considered separately because different limiting environmental criteria will apply to each sequential jack-up operating mode.

Jack-up operations can typically be divided into the following stages:

— mobilization;

— loadout;

— transit (including jacking down and re-floating);

— positioning (including jacking up and preloading);

— elevated operations (including lifting and load transfer operations).

Generic procedures for re-floating, towing or self-propulsion, dynamic positioning, jacking, preloading, and elevated operations as applicable to the routine operation of the jack-up are usually included in the vessel's operating manual.

18.4.2.2 Dynamic positioned vessels

A vessel with a minimum DP Class 2 will generally be preferable. For application of vessels with DP Class 1 or lower a detailed safety analysis (FMEA) for the planned operation is recommended.

DP operating and positioning procedures (as applicable) should be documented and include station keeping analyses/rosettes, vessel DP system FMEA and annual trials reports for crane vessels.

Any seagoing crane ship operating in an area for which it is classed should be able to survive in bad weather unless it is carrying vulnerable cargo.

Any lifting and mooring operation needs to be done in good weather and these design and operating criteria need to take into account metocean reduction factors as mentioned in previous clauses.

18.4.3 Equipment (e.g. hammer, upending tools, grout spread, ROV, special lifting tools)

All equipment used for installation such as hammer, upending systems, grippers, lift frames, should be certified for offshore use by a recognized organization (3.114).

Only trained personnel can manipulate, maintain or repair the tools.

18.4.4 Position monitoring system

Normally, two independent on-board positioning monitoring systems (PMSs) shall be utilized for operational monitoring and control purposes. Both systems shall be in operation at any time, each serving as the back-up for the other. Each should be fed by an independent power source.

Where underwater accuracy is important, at least one PMS shall be an underwater, hydro-acoustic reference system.

18.4.5 Ballast systems

Ballast systems shall be considered as the prime operational systems on floating units for installation purposes, where draught, trim, heel and stability are vital for a successful operation; see Clause 14 for further guidelines.

18.4.6 Transport vessel interface with marine equipment

If the transport vessel is a launch barge, cargo barge or motor vessel, consideration shall be given to handling and positioning during the installation activity.

18.4.7 Floating structure interface with marine equipment

The floating structure can be levelled, inclined with respect to its final attitude, and consideration shall be given to the methods for handling the marine equipment.

18.5 Launching

18.5.1 General

Launching can be performed by means of either longitudinal or, less commonly, sideways sliding of the structure from a barge or other floating unit.

18.5.2 Operational aspects

Aspects for consideration during planning and design shall include, as appropriate:

— stability, strength and hydrodynamic characteristics of the launch barge or unit and the launched object;

— ranges of both weight and CoG position;

— water depth at the launch site;

— sea floor clearance;

— launch barge stern submergence and tilt beam reactions;

— skidway friction, at rest and moving;

— anti-self-launch plates;

— minimization of sea fastening to simplify launch procedures;

— method of initiating launch;

— contingencies for failure modes;

— weather restrictions;

— boarding of launch barge during operation.

18.5.3 Preparations at fabrication yard

Activities for consideration at the fabrication yard shall be:

— installation of pre-installed handling and positioning lines;

— pre-installation of installation aids;

— fastening of pre-installed rigging, handling and positioning lines etc. so that it can withstand transportation and launch actions;

— commissioning of operational systems and equipment;

— checking of launch barge systems;

— provision of temporary access for installation activities;

— verification that operational systems and closures are in the proper condition/orientation;

— leak testing of all intact compartments and closure devices;

— provision of positive pressure in all intact compartments.

18.5.4 Operational control parameters

The following parameters shall be considered, monitored and controlled during operations:

— position of barge and tugs in attendance;

— launch direction relative to the wind and current directions;

— environmental conditions;

— draught, heel, trim and stability of the launched object.

Prior to initiation of the jacking operations that lead to free sliding of the object being launched, draught, trim, ballast and stability of the launch barge are adjusted and set.

18.6 Float-off

18.6.1 General

For the float-off of an object from a transport barge or vessel, the transport barge or vessel shall be ballasted so that the object can be floated off. The transport barge or vessel can be level or inclined in this operation, the latter tending towards a launch, but controlled to avoid dynamic effects.

18.6.2 Operational aspects

Aspects for consideration during planning and design shall include, as appropriate:

— stability, strength and hydrodynamic characteristics of the float-off barge or vessel and the object being floated off;

— ranges of both weight and CoG position;

— water depth at offload site;

— barge draught and submergence required for float-off;

— object/barge or object/vessel interaction during float-off, including friction forces;

— structure floating stability, including damage cases;

— release and recovery of sea fastening;

— position control of object and barge or vessel throughout;

— contingencies for failure modes.

18.6.3 Preparations at the fabrication yard

Activities for consideration at the fabrication yard shall include, as appropriate:

— installation and checking of rigging;

— installation of pre-installed handling and positioning lines;

— fastening of pre-installed rigging, handling and positioning lines, etc., so that they can withstand transportation and launch actions;

— commissioning of float-off systems and equipment;

— checking of float-off barge systems.

18.6.4 Operational control parameters

The following parameters shall be considered, monitored and controlled during operations:

— barge trim and draught;

— barge ballast and stability parameters;

— all intact compartments, for example by means of air pressure;

— position of barge and tugs in attendance;

— orientation in relation to wind and current directions;

— environmental conditions;

— draught, heel, trim and stability of the offloaded object.

18.7 Positioning of vessels

Vessels with DP capabilities are mostly used in offshore construction of windfarms. The notations assigned to units with dynamic positioning systems should be provided by classification societies.

The dynamic positioning system includes requirements for the following subsystems, control panels and back-up systems which are necessary to dynamically position the unit:

— power system;

— fire separation;

— controller;

— measuring system;

— thruster system;

— remote thrust control;

— control panels.

Those systems are periodically checked and tuned during DP-trials. Before any position keeping operation using DP, the system must be checked in open waters and the calibration of all systems confirmed.

18.8 Site reference system

Refer to 18.11.

18.9 Geotechnical site specific assessment

Geotechnical site specific assessment shall be performed in accordance with[13] and [68].

18.9.1 Required soil investigations

Site-specific geotechnical information is required. The type and amount of data required will depend upon the particular circumstances such as the type of jack-up, soil conditions and previous experience of the site, or nearby sites, for which the assessment is being performed.

For sites where previous preloading and elevated operations have been performed by jack-ups, it may be sufficient to identify the location of existing jack-up footprints. In this case the details of the previous jack-up footing design and the preload applied should be available and it should be verified that the foundation bearing pressure applied previously was in excess of the pressure to be applied by the jack-up under consideration. In the absence of such verification, soil investigation involving boreholes or CPT is required.

The location and number of boreholes or CPT’s required should account for lateral variability of the soil conditions, regional experience and the geophysical investigation. A borehole may not be required if there is sufficient relevant historical data and/or geophysical tie lines to boreholes in close proximity to the proposed jack-up location.

The geotechnical investigation should comprise a minimum of one borehole to a depth equal to 30 m or the anticipated penetration plus 1,5 to 2,0 times the footing diameter, whichever is greater. Investigation to lesser depths may be accepted in cases where only small penetrations are anticipated in hard soils; however, in such cases the advance approval of an geotechnical engineer with appropriate experience with jack-up foundation assessments is recommended and the reduced depth of investigation shall be justified in the foundation assessment. Estimations due to boreholes at positions in the vicinity of the jack-up zone in combination with CPTs and geophysical data are also possible if the soil properties allow for such estimates.

All layers shall be adequately investigated, including any transition zones between strata, such that the geotechnical properties of all layers are known with confidence and that there are no significant gaps in the site investigation record. Laboratory testing of soil samples may be required.

The nature of the seabed surface soil, together with the water depth and the current and wave regimes shall be assessed to determine whether potential for scour may exist. The assessment should consider whether scour has occurred around existing fixed or temporary structures such as foundations in the vicinity (if any) and records of previous scour that may have affected earlier jackup installations. In the event that the assessment indicates that the integrity of the jack up foundation could be adversely affected then seabed soil samples may be required and a scour analysis should be performed.

The soil investigation must produce sufficient reliable data on which to base a competent analysis that will provide a recommended soil strength design profile giving lower and upper bound strength estimates. This will be carried forward into the jack-up site-specific assessment.

18.9.2 Penetration analysis, punch-through and horizontal-vertical-interaction

The jack-up foundation assessment is required in all cases where the jack-up is to be preloaded and elevated above the sea surface to a working air gap or to the minimum safe survival air gap on location. The scope of the assessment and the amount of data required will depend upon the particular circumstances such as the type of jack-up, the soil conditions and variations in the soil across the site, and upon previous experience of the site, or nearby sites, for which the assessment is being performed.

The combinations of vertical and horizontal load shall be checked against a foundation bearing capacity envelope. The resistance factor may be taken as 1,0 when the load-penetration curve indicates significant additional capacity for acceptable levels of additional settlement. Minor settlement not exceeding the limits contained in the operating manual may be acceptable provided that:

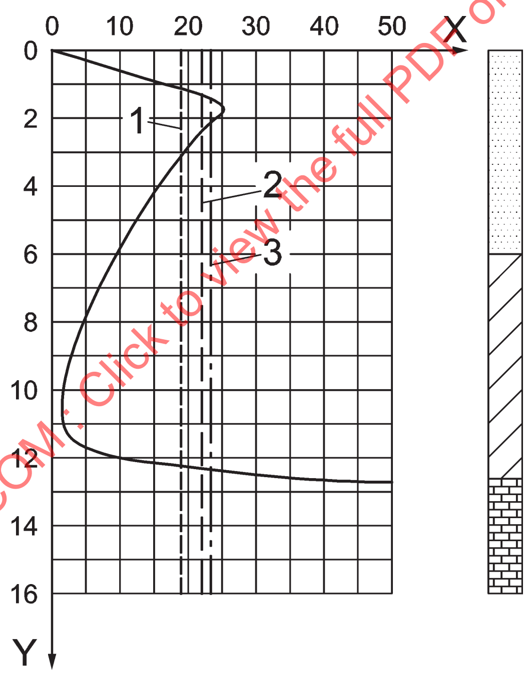
— the jack-up can withstand the storm loading plus the effects of the inclination;

— the lateral deflections will not result in contact with adjacent structures;

— the jacking system will remain fully operational at the angle of inclination considered.

Consideration shall be given to the operating limits of the jacking system. The capacity of any jacking system to elevate or lower the hull may be significantly reduced or eliminated by leg guide friction (binding) caused by small angles of inclination. Additionally, some hydraulic recycling jacking systems cannot usually be jacked at angles of inclination greater than 1,0 degree because even this small angle can result in inability to extract or engage the fixed and working pins (or catcher beams).

Extreme caution should be exercised if the soil profile reveals a risk of punch-through when it should be demonstrated that there is an adequate safety factor to ensure against punch-through occurring in both extreme (abnormal) storm events and operating conditions. Particular attention must be paid to the appropriate safety factor in cases where the jack-up's maximum preload capacity does not produce significantly greater foundation bearing pressure than that to be applied in the operating or survival modes (see Figure 6).



Key

X soil resistance in Nm

Y depth below mudline in m

1 leg penetration curve: operating

2 leg penetration curve: 50 year storm

3 leg penetration curve: maximum preload

Figure 6 — Predicted leg penetration curve [66]

Calculation of the safety factor against punch-through should normally be in accordance with the recommended practice; however, alternative methods that may provide an equivalent or greater level of safety exist and therefore consideration should be given as to which method is appropriate in the circumstances. See also[57]. Ultimately, the assessment of punch-through risk requires a high level of expertise and the exercise of sound judgment based on experience.

Consideration should be given to the limits of maximum and minimum penetration as determined by the jack-up design or operating manual. In cases where the limits stated in the manual are related simply to a sample elevated condition and the leg length installed, it can be ignored provided the leg length is sufficient to meet the survival air gap defined in [66], [57]. An analysis should be carried out for any case where the maximum or minimum penetration limit stated in the manual is related to leg or spudcan structural strength or to the jack-up's capacity for leg extraction.

Particular consideration shall be given to the requirement for extracting the leg footings and the probable effectiveness of the leg jetting system (if fitted). Temporary inability to extract the legs from the soil may involve serious risk if the unit cannot be quickly removed to shelter and/or cannot achieve the elevated survival mode and remain on location.

For jack-ups fitted with hydraulic recycling jacking systems there is the additional risk that the jacking system may become temporarily immobilised through inability to extract fixed or working pins during the leg extraction operation. If this occurs during a rising tidal cycle then damage or flooding may result.

The potential for seabed scour shall be considered and the potential impact this may have on the integrity of the jack-up foundation over time. At locations where risk of scour is deemed to exist, the foundation assessment shall include an assessment of the potential depth and rate of soil removal and that may affect foundation stability. The assessment shall include a caution to the effect that special jacking procedures may be required to mitigate the risk of foundation instability and should also recommend scour protection measures where appropriate.

18.10 Site specific installation plan

Any operational document involving a jack-up unit should contain as minimum all information relevant to the safety of the unit, personnel and major items of equipment on board the unit, including but not limited to:

— general specification, setting out limitations on operating water depths and corresponding environmental conditions;

— general arrangement plans and elevations;

— compartmentation and piping systems;

— weights and CoG of hull and equipment, skid unit, legs and spudcans;

— loading instructions, giving limitations on weight and CoG, with worked examples of loading calculations for elevated and afloat conditions;

— details of jacking system, stating maximum elevating, lowering and holding loads and all necessary checks before jacking operations, including where applicable the required torque and brake clearance for each motor;

— variable load capacities;

— tank calibration tables;

— details of propulsion units (if any);

— details of critical downflooding openings, means of closure, and instructions for ensuring closed under tow;

— limitations for going on and off location;

— critical motion curves for towage for relevant leg lengths and positions;

— preloading instructions;

— maximum and minimum permitted penetration, and reasons for any restrictions;

— instructions for filling and emptying spudcans;

— jetting system layout and operation;

— maintenance schedules for machinery and systems. inspection schedules for structure;

— reference to more detailed manuals for machinery and systems;

— allowable loadings and positions of cantilever and substructure for operating and survival conditions;

— calculations on allowable loadings during survival condition of jack-up vessel specifying the number of components allowed to be stored on deck during these conditions also taking into account the specific season in which the installation will be conducted and the probability of survival mode conditions being reached during this season;

— emergency procedures in case of punch through, for self-elevating units.

18.11 Jack-up preloading procedure

At locations where there is a risk of leg runs, rapid penetration or punch-through a cautious approach should be taken during the rig installation. The initial preload should be leg-by-leg with the hull in the water (in some circumstances a minimal air gap may be acceptable). It is recommended that, if the unit is to be placed near to a foundation, the leg furthest from the structure be preloaded first so that any unexpected spudcan penetrations result in hull movements away from the structure. At open locations the leg preloaded first should be the leg (for a three-leg unit) or one of the legs (for a four-leg unit) with the greatest distance to the axis through the centres of the other two legs.

Once full load has been achieved, the preload should be held for a sufficient time period specified by a geotechnical engineer based on the actual site-specific soil conditions. At the end of this time period, the load decrease should be negligible. Under some circumstances, geotechnical advice can be that longer hold times are required (perhaps 3 h or 6 h). Such longer hold times are typically required at locations where there is a high risk of punch through and in very soft formations when leg penetrations are in slow increments.

18.12 Upending of foundation structure

18.12.1 General

Upending of a horizontally placed or horizontally floating foundation structure to the vertical can be carried out in a number of ways, such as:

— no intervention during upending, in a self-upend, after initiation of gravity flooding;

— with intervention during upending, by controlled gravity flooding, or by pumped flooding, or a combination of both;

— with intervention during upending, by crane assisted control alone or in combination with controlled gravity flooding.

18.12.2 Operational aspects

Aspects for consideration during planning and design shall include, as appropriate:

— stability, strength and hydrodynamic characteristics of the upended object throughout the operation;

— water depth at upending location;

— bottom clearance during the upending;

— clearance from underwater objects and mooring lines of other vessels;

— provision of accessible control systems for flooding;

— system operation during all stages of upending;

— safe access to work locations;

— provision of accessible fill lines for external ballasting system;

— failure modes and effect analysis (damaged tank scenarios);

— compartmentation and contingencies.

18.12.3 Preparations at the fabrication yard/offload location

Preparations should be considered at the fabrication yard and offload location for the commissioning and checking of operational systems and equipment.

18.12.4 Operational control parameters

The following parameters shall be considered, monitored and controlled during operations:

— draught, heel, trim and stability of the upended object;

— sea floor clearance;

— mooring system;

— ballasting rate;

— ballasted weight;

— mode of operational valves;

— crane hook load;

— environmental conditions;

— position of the upended object, tugs and command vessel in attendance;

— provision of a tug control line or lines to mitigate lack of stability, if appropriate.

18.13 Ballasting

Ballasting or deballasting of a barge or vessel is part of a marine operation and, as such, detailed procedures should be established and implemented.

Operation of ballast systems should be considered during HAZID or similar sessions; see 5.4.2.

Ballast operators, in addition to operational managers and personnel vital to the performance of the operation, should participate in such sessions.

The design issues for ballasting, deballasting and addition of heavy ballast are dealt with in Clause 14.

18.14 Lifted installations

18.14.1 General

This section is to be considered a generic description of installation operation when the structures are lifted by means of floating, jack-up or fixed cranes (ex. cranes of offshore substations).

Lifting and lowering operations are generally carried out by floating cranes or vessel cranes, but can also be achieved by numerous types of equipment using specially rigged rotary, traction and linear winch systems, etc. The lifting systems should conform comply with one international recognized standard and be fitted for purpose.to accepted classification standards.

For detailed information on lifting operations, see Clause 19.

18.14.2 Installation of liftable jackets

Main aspects involved in installation of lattice structures or jackets are the following:

— rigging;

— lifting points;

— crane operations;

— weather conditions;

— content of method statement;

— barge — jack-up platform;

— jackup leg positions (if the case).

18.14.3 Installation of templates for piles

In order to increase productivity, efficiency and utilize wisely operational windows a method of pre-piling through a template followed by a jacket or tripod type foundation installation over pre-piled arrangement has become a favoured installation method used on wind farm jacket foundations.

Templates are mainly installation aids of type pin/bucket which are lowered on seabed to ensure verticality of the piles during the initial stages of hammering.

Template installation will influence the position of the piles and further position of foundations for WTGs.

Survey equipment should be certified and tested before every installation.

As templates are lowered and furthermore lifted through splash zone an operation specific study may be performed to achieve a more realistic loadcase as compared with results using Clause 19 recommended method.

Lifting of the template should account among other for friction of template with installed piles and influence of skewed lift over the strength of template/piles.

18.14.4 Installation of piles

Installation of piles is mainly influenced by soil type, on-bottom stability (see also 7.3.2 and 18.6.2), recurrent weather and type of installation vessel.

18.14.5 Installation of transition pieces

Installation of transition pieces is mainly influences by significant wave height and swell effects. Provision of appropriate guides/guide fingers is recommended. Where grouting is required as a sequential operation, suitable weather window selection shall reflect the operational limits of the stand-alone situation of an ungrouted transition piece. See also 18.18 and 18.19.

18.14.6 Installation of GBS

Installation of gravity based structures should involve suitable marine spread with good manoeuvrability and sufficient contingency on bollard pull.

18.14.7 Installation of topsides

Topside installation should be regarded as heavy lift and comply with requirements for those type of lifts.

18.14.8 Transfer of items from a barge to the deck of a crane vessel/jack-up vessel

Lifting items from a floating structure should account in rigging and lift points design for dynamical loads from motion response of floating vessel.

Lifting speed should be coordinated with floating vessel motion, existence of motion compensation (on vessel or crane) and crane capabilities.

Mooring arrangements shall be conducted according to Clause 17.

Ballasting procedures shall be conducted according to Clause 14.

18.14.9 Installation of towers

Lifting tools or aids (pad eyes, hook-up lugs, etc.) should be certified by a recognized organization (RO) (3.114). Their structure should be designed for maximum loads during transport and installation.

18.14.10 Installation of WTG including nacelle, hub and blades

All special items (nacelles, blades, hubs) should be designed and certified for transport and installation at their desired location. All lift points should include consequence factors not less than 30 % as per Clause 19 resulting in a factor 1:3 when applied to the design loads.

Due to relative high sensitivity to clash loads deck layout shall provide for sufficient clearances between the lifted objects and the structures on board the transport and installation vessels.

18.14.11 Operational aspects

Aspects for consideration during planning and design shall include, as appropriate:

— interaction between the lift vessel, crane(s), lift rigging, structure being lifted and transport barge or vessel during the lift, until the structure being lifted is free of the barge or vessel;

— structure weight and CoG and sensitivity to variations in these parameters;

— dynamic actions if the structure passes through the wave zone;

— added mass effects and dynamics of the lowering system, in the case of lowering an item to the sea floor;

— hook load and lowering system capacity;

— lift rigging specification, testing and design; see Clause 19;

— positioning;

— provision of anti-twist systems or suitable arrangements to overcome problems due to the natural rotation induced by the lay of wire ropes.

Twisting of hoist wire depends on:

— geometry of reeving (spacing between individual falls);

— construction of wire rope;

— length of wire rope;

— length of suspended reeving.

18.14.12 Fabrication yard

Rigging and equipment for lifting shall be prefitted. Equipment shall be protected against damage from the slings when tightening the system for lifting. The slings should be protected against sharp edges and corners that can cause damage to the slings.

18.14.13 Operational control parameters

The following parameters shall be considered, monitored and controlled during lifting and lowering:

— hook load;

— hook lowering speed;

— environmental conditions;

— position of the lifted object, crane and transportation barge or vessel, as appropriate;

— barge or vessel and structure clearances;

— access for connecting rigging to hook, and egress;

— procedure for removal of rigging from structure lift points, above water and under water

— tugger wires/tag lines;

— outreach;

— hook height.

18.15 Lowering by ballasting

18.15.1 General

Floating objects that are lowered in a controlled way by ballasting should project through the water plane; their stability shall be positive throughout.

For objects that are fully submerged during installation, special lowering and control procedures shall be developed.

18.15.2 Operational aspects

Aspects to be considered during planning and design shall include, as appropriate:

— provision of a gravity and/or pumped ballast system that allows the operation to be completed within the specified weather window;

— performance of failure modes and effects analysis;

— monitoring of stability throughout lowering, including an assessment of whether inclining the structure to maintain positive stability is necessary;

— provision of contingency deballasting methods if required;

— determination of heavy ballast requirements for stability of the floating structure and provision of an additional ballast system, if required;

— consideration of the change in water density with depth;

— consideration of compression of structure and resulting decrease of volume with depth.

18.15.3 Operational control parameters

The following parameters shall be considered, monitored and controlled during the operation:

— position and orientation;

— wind and current directions;

— stability;

— ballasting rate;

— ballast weight;

— mode and status of operational valves;

— layout of tugger lines and winches where these are required to bring the object into position;

— sand excavation if necessary;

— cleaning of steel surfaces from marine growth.

18.16 Precise positioning on the sea floor by active and passive means

18.16.1 General

For precise positioning of objects on the sea floor (close to existing structures), active positioning means, such as winches or tugs used as winch stations, can be used in combination with passive positioning means, such as docking piles and bumpers.

18.16.2 Operational aspects

Aspects for consideration during planning and design shall include, as appropriate:

— water depth;

— means of positioning and control to maintain the object within the required vertical boundaries;

— limiting environmental conditions for lowering, positioning and setting down of the object;

— achievable lowering rate of the object;

— dynamic behaviour of the object during lowering, positioning and setting down;

— structural and geotechnical design of docking pile(s) and bumpers, where appropriate;

— operational and accidental actions on docking pile(s) and bumper(s), where appropriate;

— applicable procedure for touchdown, e.g. using a small inclination to aid precise positioning of the object;

— on-bottom stability of the object at set-down and prior to fixing it in place, e.g. using a large inclination at the initiation of set-down to maintain stability of the object during the final lowering period.

18.16.3 Operational control parameters

The following parameters shall be considered, monitored and controlled during precise positioning and setting down:

— environmental conditions, during the operation and as forecast;

— position and orientation of the lowered object and the existing structure, including their relative position;

— wind and current directions;

— forces in lines;

— dynamic behaviour of the lowered object.

18.17 Skirt penetration

18.17.1 General

For general information and design issues of skirts, see ISO 19901-4 and [12].

18.17.2 Gravity penetration

Gravity penetration is achieved by adding weight to the structure by ballasting, while simultaneously allowing water from skirt compartments to discharge into the sea.

18.17.3 Suction penetration

Suction penetration is achieved by creating an underpressure in the skirt compartments to generate a downward action.

18.17.4 Operational aspects

Aspects for consideration during planning and design shall include, as appropriate:

— limiting environmental conditions;

— soil conditions;

— skirt configuration;

— skirt water evacuation system;

— predicted skirt penetration resistance;

— water ballast system;

— limitations to differential water pressure between skirt compartments and ambient sea;

— limitations to differential water pressure between ballast compartments and ambient sea;

— limitations to environmental conditions during the operation;

— tolerances on structure verticality and skirt penetration depth for the as-installed structure.

18.17.5 Operational control parameters

The following parameters shall be considered, monitored and controlled during skirt penetration:

— environmental conditions, during the operation and as forecast;

— skirt penetration depth, by paint marks or similar;

— inclination of the structure;

— sealing of the skirt compartments during initial weight penetration before creating the underpressure, if applicable;

— differential water pressure between skirt compartments and ambient sea;

— differential water pressure between ballast compartments and ambient sea.

18.18 Piles installation

18.18.1 General

Steel structures are generally secured to the seabed by open-ended tubular steel piles that are welded, grouted or bolted to the structure. The design of piles, including their connections to the structure, the required pile penetrations and the method of installing piles to their design penetrations, are strongly affected by soil conditions, by environmental conditions and by available equipment.

Piles are normally lowered from above the water to the sea floor by stabbing them through a leg, or by guiding them through an arrangement of pile guides to control their position and orientation (either vertical or inclined). Thereafter, their design penetrations are achieved by driving, vibrating, drilling or combinations thereof.

18.18.2 Operational aspects

Aspects for consideration during planning and design shall include, as appropriate:

— soil conditions;

— limiting environmental conditions for each pile installation stage in view of the foundation capacity of the structure;

— metocean criteria and limitations;

— configuration, dimensions and weights of piles;

— sequence of pile stabbing, sequence of pile installation to penetration and associated time scales;

— lifting equipment for piles;

— free head for handling of piles and piling equipment;

— guiding system for the lowering of the piles;

— pile sway due to waves and current;

— welding equipment requirements for welding pile sections together and for securing piles to the structure, if applicable;

— interactions of equipment used for piling with the pile and the soil;

— equipment specifications for driving or vibrating piles for penetration, for drilling oversize holes in the seabed in which piles are lowered, or for drilling or jetting out soil plugs from within the piles, as applicable;

— contingency measures in the event of inadequate or excessive penetration rates;

— penetrations due to self-weight of the pile without and with the pile driving hammer stabbed on top of the pile;

— stresses during driving, including *P*-delta effects, if applicable;

— design penetration, allowable excess or shortage of design penetration, and refusal criteria;

— resistance to sliding or overturning of the structure in unpiled condition;

— method of securing piles to the structure (welding, swaging or grouting);

— specification for grout material;

— equipment specification for grouting piles *in situ* and/or to the structure;

- sequence of grouting;
- equipment specification for bolting piles to the structure, if applicable;
- pile stability.

18.18.3 Operational control parameters

The following parameters shall be considered, monitored and controlled during piling:

- environmental conditions, during the operation and as forecast;
- pile position and verticality, if required;
- pile sway;
- pile penetration versus blow counts;
- performance of pile equipment;
- pile installation sequence and modifications thereof to suit actual and forecast environmental conditions;
- required time to reach a secure position versus available weather window;
- final heading, position and verticality of the structure, and pile penetrations achieved.

18.19 Grouting

18.19.1 General

The voids between the:

- skirt compartments of the base of a gravity structure and the sea floor;
- transition pieces and monopile foundations;
- pre-piles or post-piled piles of jacket foundations;
- connections between topside and jacket of offshore substations

are commonly filled with grout to improve the structure's foundation capacity or allow for a connection between topside and jacket of offshore substations. The grouted connection of e.g. a monopile and transitionpiece can be supported by using shear-keys structurally integrated e.g. in the overlap area between both components. In addition, the overlap area can be of a conical shape.

18.19.2 Grouting of pile — Transition-piece structure

Location of grouting equipment either on board the installation vessel or on a separate grout vessel as well as length of grout hoses with corresponding grout pumps should be determined during planning.

Any temperature restrictions, whether air or water, shall be included in the planning of the duration of the operations including pre-heating and insulation requirements.

The following operational aspects should be followed:

- normal grouting procedure including contingency procedure shall be determined;
- sea fastening of grout spread;
- power and water supply, sediment containers;
- monitoring plan of grout quality with defined acceptance criteria;

— monitor grout filling during operation;

— grout hose arrangement connection to grout annuli;

— stopping procedure;

— quality control, test and post grouting inspections;

— temperature log.

18.19.3 Underbase grouting of pile — Jacket structures

See 18.18.2 for general information. Specific operational aspects should be followed:

— plan for optimal positioning of grout annuli and grout lines;

— establish primary and secondary grout line for each jacket leg;

— clean annuli of any soil;

— observe grout overflow at top of each pile sleeve; (note: national legislations may provide stronger requirements);

— pre-define minimum overage (e.g. 10 %) of grout material excess of the theoretical annulus volume to be pumped to the annulus after good quality grout reached (note that national legislations may provide stronger requirements);

— ROV deployment for monitoring grouting progress.

18.19.4 Operational aspects

Aspects for consideration during planning and design shall include, as appropriate;

— limiting environmental conditions;

— grout property specifications: fluidity and flow, hardening, strength, durability, density of mix;

— skirt compartment configuration and theoretical volumes;

— operational schedule;

— compartment grouting sequence for optimal improvement of the structure's foundation capacity;

— supply logistics of grout material;

— capacity of grout mixing plant and grout distribution system;

— potential of undesired grout dilution in skirt compartments;

— acceptance criteria for grouting operations;

— structural and geotechnical grout pressure limitations.

18.19.5 Preparations

Activities carried out prior to the start of operations include:

— commissioning and calibration of the grout mixing plant;

— testing of the pumpability of the grout mix;

— checking of grout distribution lines;

— sand excavation (if necessary);

— cleaning of steel surfaces from marine growth.

18.19.6 Operational control parameters

The following parameters shall be considered, monitored and controlled during underbase grouting operations:

— environmental conditions, during the operation and as forecast;

— grouting sequence versus actual and forecast environmental conditions;

— quality of grout mix;

— grout injection rate and accumulated volume in each skirt compartment;

— blockage of grouting lines;

— grout returns at skirt compartment outlets;

— hydraulic pressures in skirt compartments;

— hydraulic piping in soil around skirts;

— acceptance criteria for grouting operations;

— final heading, position and verticality of the structure and penetration depth of skirts.

18.20 Bolted connections of foundation

As alternative to a grouted connection of a pile-shaped foundation, the foundation components (monopile and transitions piece) can be bolted during installation.

Installation procedures shall reflect the specific requirements for efficient bolting.

18.21 Welding of piles/foundation to topsides

Offshore welding procedures specifications should be aligned to the national requirements of permitting authorities. Corresponding NDT procedures shall be in place. The waiting time between end of welding operations and the NDT tests shall be aligned to the installation operations and the national requirements.

Required welding procedure qualifications records of the work force shall be in place.

18.22 Noise mitigation measures

Hydrosound emissions during piling of Foundation structures can negatively influence marine mammals. Depending on the national regulations, noise mitigation measures have to be applied during piling to minimize hydrosound emissions. Various noise mitigation techniques can be applied. The efficiency of the chosen method usually has to be documented by defined measurements.

Prior to piling, deterrent measures should be undertaken to prevent injury of marine organisms. Deterrent effects shall achieve the directed relocation of animals (here marine mammals) away from the construction site. For this, acoustic devices, i.e. pinger and seal scarer should be used to scare animals away from the construction site.

The coordination between installation/piling operations and any chosen noise mitigation measures have to be included in the engineering and planning of the marine operations.

18.23 Crew transfer from installation units

Guidance regarding crew transfer is stated in [33].

The method for personnel transfer shall be available, appropriately risk assessed and required training, competences as well as required equipment specified and certified where necessary. Personnel being transferred should be briefed prior to the transfer and should be familiar with the transfer and the equipment being used. The personnel should be physically able to conduct the transfer, should understand the intended activity and should have agreed to the transfer proposed. Adequate personal protective equipment (PPE) should be worn. The duties of personnel supervising or otherwise involved in supporting personnel transfer should be clearly defined.

Gangways are the primary means by which personnel transfer between a vessel (installation unit) and a foundation, particularly monopiles is conducted. Gangways should be constructed of appropriate material, be of appropriate length and width, fitted with non-slip walkways and handrails with sufficient lighting and should be placed with safe angles of inclination. Appropriate maintenance is required and landing points at foundations shall be designed for the loads related to positioning the gangways.

Personnel transfer can also be conducted using crew transfer vessels (CTV) or similar allowing transfer to and from the CTV via a boatlanding at the foundation. Seaworthiness of the CTV should be considered when choosing the right CTV appropriate for the conditions in the area of operation. During stepping over between CTV and boatlanding, experienced assistance shall be available on the CTV for the personnel conducting the transfer. The likelihood of water surging up between the CTV and the boatlanding once in close proximity should be risk assessed.

Other means of personnel transfer should be handled with similar care and diligence.

18.24 Offshore completion

18.24.1 General

Completion of the installation of Foundations can require the application of anti-scour measures around the base.

When the installation of the support structure has been finalized, topsides can be installed.

18.24.2 ROV inspection

After completion of the installation, an ROV survey shall be carried out according to an agreed plan to check for possible damage and debris. To facilitate the survey, the structures are generally suitably marked for reference purposes prior to the installation.

The following items, wherever applicable, shall be inspected and checked for damage:

— paint coatings;

— anodes;

— scouring of the top soil layers.

18.24.3 Removal of temporary equipment

Temporary equipment shall be removed in accordance with plans agreed to as part of the operational planning and design phase.

18.24.4 Scour protection

Depending on the geometry of the base and local current conditions, the foundations can require the application of anti-scour measures, such as graded rock, gravel and/or mattresses.

18.25 Operating manual

The operating manual shall include as a minimum details about the following:

- specifications of:
  - vessels;
  - lifting equipment;
  - tools;
  - machines;
  - access systems;
  - accessories;
- organization;
- communication routines and systems;
- general arrangement;
- operational procedure/(detailed) task plan(s);
- operation schedule;
- contingency planning and emergency procedures;
- permissible load conditions;
- environmental operation criteria;
- monitoring during the operation;
- tolerances;
- permissible draughts, trim, and heel and corresponding ballasting plan;
- systems and equipment including layout;
- systems and equipment operational instructions;
- vessels involved;
- tow routes and ports of refuge;
- navigation;
- weather (forecast) and current/wave reporting;
- safety equipment;
- recording and reporting routines;
- sample forms;
- check lists for preparation and performance of the operation;
- test and commissioning plans;
- contingency plans for high occurrence — high consequences risks;
- key personnel and responsibilities;

— clear step-by-step containing handover and hold points;

— management of change procedure;

— approach and positioning procedures;

— transit procedures (night/day);

— jacking procedures;

— operating limits;

— emergency procedures in case of punch through, for self-elevating units.

The operating manual should state reporting and recording in a timely manner (daily, hourly) to the responsible parties (owner, certification, MWS, etc.)

19 Design of lifting equipment

19.1 Introduction

This clause gives requirements and guidance for the design and execution of lifting operations (onshore, inshore and offshore). It covers lifting operations by floating crane vessels, including crane barges, crane ships and semi-submersible crane vessels. Onshore lifts by land-based cranes are also included when they form part of a marine operation such as a loadout.

Additional information on lifting operations can be found in [61].

Lift points on the object being lifted and lifting equipment (rigging) between the lift point(s) and the crane hook(s) are critically important components in all lifting operations.

Lift points can be of various types, including the following:

— padeyes (3.108), where a shackle pin passes through a hole in a padeye plate attached to or built into the structure, while the sling is connected to the shackle; the padeye plate is normally reinforced by cheek plates to increase its strength and provided with non-load bearing spacer plates to avoid undue slack between the shackle and the padeye, thereby reducing eccentricity between the padeye plate and the sling;

— trunnions (3.160), where a sling, or an eye of a sling, or a grommet passes around a short tubular, which transfers the forces into the structure and which allows rotation of the sling around the axis of the trunnion;

— padears (3.107), which are similar to trunnions, but in which rotation of the sling is not intended.

Lifting equipment (rigging) between the lift point(s) and the crane hook(s) includes slings, which can be divided into:

1) steel slings, which are either:

— steel wire rope slings (SWRS) (3.146) of single wire rope construction, or

— steel cable-laid slings (SCLS) (3.143) of cable-laid construction;

2) fibre rope slings (FRS) (3.51) of various types of construction;

grommets, which can be divided into:

1) steel wire rope grommets (SWRG) (3.145), which are always of cable-laid construction;

2) fibre rope grommets (FRG) (3.50), the construction of which can vary;

— shackles;

— spreader bars and spreader frames (3.141);

— lifting tools.

Where appropriate, the particular type of sling or grommet is indicated by the abbreviated designation shown above.

Where lifting tools are used as part of a lifting arrangement, the maximum loads imposed on such tools shall not exceed the stated certified WLL for the tool. The hydraulic system (if used) should be of a fail-safe nature, such that in the event of loss of hydraulic power, the tool will remain in fail-safe mode. Test certificates shall be issued or endorsed by a body approved for the certification of this type of equipment[56].

External and internal hydraulic lifting tools shall always have [56]:

— remote monitoring system close to the crane driver's cab;

— a pressure gauge (or indicator) in the system showing when the tool is closed or open;

— a duplicate pressure gauge (or indicator), as close as safely possible to the tool to avoid influences in pressure reading;

— a method to release the tool in the event of hydraulic system failure.

Automatic lifting tools shall have systems in place to control the stress in the lifted item in order to prevent excessive local stress for sensitive items. Redundant mechanical systems must be in place in case of power loss[61].

Consideration should be given to colour code the rigging, i.e. one colour per rigging set to each lift/upend point. This is good practice to avoid mix up, especially when the slings and connectors are pre-checked "loosely" on the ground or deck before attaching to the lift points [61].

To ensure the safety of lifting operations, it is necessary that the actions and resistances be determined and compared by a structured and coherent procedure. Two methods can be used for design verification: a partial factor design (PFD) method and a WSD method. The basic principle in both methods is the same and simple: the action effects resulting from the applied actions shall be smaller, by an adequate margin, than the resistances (strengths) of lift points and lifting equipment. However, the two methods differ in details and in terminology used.

Both methods are allowed. The PFD method is the method underlying this International Standard is also the preferred method for lifting operations. However, for lifting operations, the WSD method is the one most commonly applied in practice.

Actions and action effects are discussed in 19.3; resistances (strengths) are discussed in 19.6. Design checks according to the PFD and WSD methods are specified in 19.7.

In addition to the design checks for strength, recommendations and guidance on certain design aspects and operational considerations for lifting operations are given in 19.8 to 19.14.

In a PFD method, the PFD design actions and action effects shall not exceed the corresponding PFD design strengths. In a WSD method, the WSD design actions and action effects shall not exceed the WSD design strengths (in WSD methods, also referred to as allowable values or as working load limits (WLLs) divided by specific safety factors.

19.2 Rigging geometry

In general, the rigging geometry shall be configured such that the maximum tilt of the lifted structure does not exceed 2°. The tangent of the tilt angle is equal to the ratio of the horizontal distance between the hook and the CoG of the lifted structure in plan and the vertical distance between the hook and the CoG of the lifted structure.

In special circumstances, e.g. for lifted flare booms, flare towers and cantilevered modules, the angle of tilt may exceed 2° to permit the effective use of installation aids. Such lifted structures shall be reviewed as special cases.

19.3 Actions and action effects

In accordance with common terminology in the field of reliability of structures that is used in this International Standard, basic variables (3.10) are assigned nominal (3.94), representative (3.116) and design values (3.38).

The representative actions (loads) on the crane hook, and the representative action effects (forces) in the slings and on the lift points are determined in accordance with 19.4 to 19.5.6. Design values of actions and action effects are given in 19.5.6.5.

The forces on a lift point are governed by the lift weight, W_{lw}, while the forces in slings and the load on the crane are governed by the hook load, F_{hl}; the difference between these two being the weight of the rigging, W_{rw}, between lift point(s) and crane hook. Both lift weight and hook load are subject to dynamic amplification resulting from movements of the lifted object and/or the crane. Therefore, a distinction should be made between “static” and “dynamic” lift weights, and between “static” and “dynamic” hook loads. The lift weight, W_{lw}, in this International Standard is the “dynamic” lift weight in accordance with 3.74. Further, in accordance with common terminology in this International Standard, W_{lw} is, henceforth, referred to as the nominal lift weight. Analogously, in accordance with 3.66, the hook load, F_{hl}, in this International Standard is the “dynamic” hook load, and F_{hl} is, henceforth, referred to as the nominal hook load. The reference point to derive the nominal lift weight for the permissible hook load should be established, in some cases this is at the hook and in others at the boom head pulleys.

The representative values of actions and action effects are derived from the statically distributed nominal actions or action effects, multiplied by a variety of factors that account for uncertainties in geometry, uncertainties in the position of the CoG, contingencies and other circumstances. These factors are identically applied in PFD and WSD methods. Consequence factors (3.28) are an exception to this rule. They are part of the WSD method and are used on the resistance (strength) side of design checks for the lifted object to selectively enhance the safety margin for critical structural components; they are not applied to slings, grommets and shackles. In the PFD method, the resistance (strength) side of design checks is not altered and the consequence factors are, instead, applied as partial action factors; see also the discussion on WLL in 19.6.1 and on structural analysis by the WSD method in 19.7.3.3.

In a PFD method, the representative values of actions are multiplied by partial action factors in order to obtain design values of actions and action effects. In a WSD method, the representative actions serve directly as design actions without factoring them. Design values of actions and action effects for both methods are given in 19.7.3.3.

The various factors and their application are illustrated in Figure 7. This flowchart is for guidance only, and is not intended to cover every case. In case of any conflict between the flowchart and the text, the text shall govern.

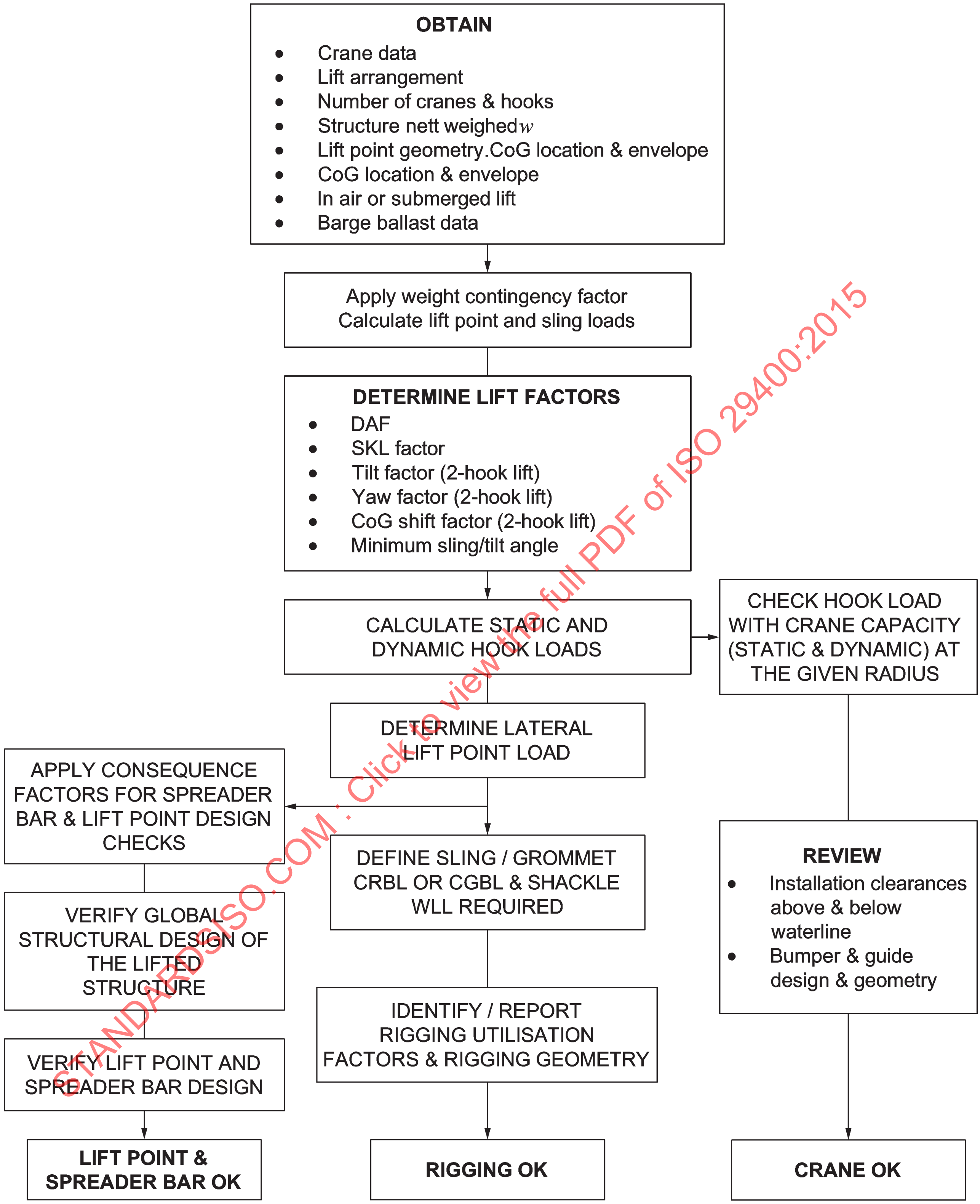


Figure 7 — Lift calculation flowchart [61]

19.4 Weight contingency factors

For the weight contingency factors, reference is made to Clause 12 and to [10].

For class A weight control (see 12.2), weight contingency factors shall be applied to the following weights:

— calculated weight: For a 50/50 weight estimate (3.169) derived in accordance with [10], a weight contingency factor, k_{wcf}, of not less than 1,05 shall be applied. The extreme CoG envelope (where applicable) shall be used.

— weighed weight: A weight contingency factor, k_{wcf}, of not less than 1,03 shall be applied to the final weighed weight. This value may be reduced if a certificate is produced from a competent body (RO) stating, for the specific case in question, that the weighing accuracy is better than 3 %.

For Class B and C structure lifts (as defined by[10]), the minimum weight contingency factor shall be 1.10 applied to the net weight for rigging and lift point design. The gross weight (3.60) is the calculated or weighed weight including the weight contingency factors given in a) or b) above. The gross weight, W, is determined from Formula (8) using the calculated weight and $k_{wcf} \geq 1{,}05$, or from Formula (9) using the weighed weight and, generally, $k_{wcf} \geq 1{,}03$:

$$W = k_{wcf} \times W_{cw} \tag{8}$$

$$W = k_{wcf} \times W_{ww} \tag{9}$$

where

k_{wcf} is the weight contingency factor;

W_{cw} is the calculated weight;

W_{ww} is the weighed weight.

19.5 Dynamic amplification factors (DAFs)

19.5.1 General

The gross weight from Formula (8) or Formula (9) is the static weight at rest of the object being lifted. However, the lift weight (3.74) experienced by the crane during lifting is larger as a result of dynamic effects caused by movements of the lifted object and/or the crane; this is accounted for by multiplying the gross weight by a dynamic amplification factor (DAF) (3.43), denoted by k_{DAF}.

DAF values differ with circumstances and apply to lifts made in air. DAF values for lifts made by a single crane on a vessel are given in 19.5.2. For lifts made simultaneously by two cranes on the same vessel the values given in 19.5.2 may be used as a guide, but they should be increased by an operation-specific factor, if appropriate. DAF values for lifts made by more than one crane, with each crane on a separate vessel, are discussed in 19.5.3.

If any part of the lifting operation includes lifting or lowering through water, including passing through the splash zone, analyses shall be submitted according to one of two methods, which either:

— show how the total in-water lifting actions are derived, taking into account weight, buoyancy, entrained mass, boom-tip velocities and accelerations, hydrodynamic inertia and drag actions; or

— calculate the dynamic sling forces and hook loads to document that slack slings do not occur in sea states that do not exceed sea state limitations for the offshore operation to be performed.

19.5.2 For lifts by a single crane on a vessel

For offshore lifts with one crane, a DAF shall be applied to account for the dynamic effects of the crane taking up the weight, and for movements of the crane or the lifted object during lifting. Unless operation-specific calculations show otherwise, the nominal lift weight, W_{lw}, (3.74) shall be derived using Formula (10) with a dynamic amplification factor, k_{DAF}, from Table 20:

$$W_{lw} = k_{DAF} \times W \tag{10}$$

Where W is the gross weight.

Table 20 — DAF for a single crane on a vessel [59]

Mass of lifted object[a] Tonnes	Gross weight, W kN	k_{DAF} in air			
		offshore	inshore	onshore[b]	
				moving	static
≤ 100	$W \leq 1\,000$	1,30	1,15	1,15	1,00
from 100 to 1 000	$1\,000 < W \leq 10\,000$	1,20	1,10	1,10	1,00
from 1 000 to 2 500	$10\,000 < W \leq 25\,000$	1,15	1,05	1,05	1,00
from 2 500	$25\,000 < W$	1,10	1,05	1,05	1,00

[a] This column is included to facilitate the comparison with weight reporting.

[b] Lifts by land-based cranes involved with marine operations such as loadouts.

For onshore lifts, where the crane can move horizontally, the “moving” column in Table 20 shall apply. The “static” column shall apply only if there is no crane movement other than luffing and slewing. The definitions of the movement of a crane with a suspended load are as follows:

— “moving” is horizontal translation of the whole crane, by crawling or other means, without luffing and slewing;

— “luffing” is raising the crane boom up and down, without moving and slewing;

— “slewing” is rotating the crane on the turntable, without moving and luffing.

19.5.3 For lifts by cranes on two or more vessels

Unless operation-specific calculations show otherwise, for offshore lifts by cranes on two or more similar vessels, the k_{DAF} in Table 20 shall be multiplied by a further factor of 1,1 as a minimum. If the crane vessels are not similar and have different natural periods, operation-specific calculations should be carried out.

For inshore lifts by cranes on two or more vessels in totally sheltered waters, the factors in Table 20 shall apply with no further multiplier for the multiple vessel condition.

For onshore lifts by two or more cranes, the k_{DAF} factors in Table 20 shall apply with no further factor for the multiple crane conditions.

For lifts by cranes on jacked-up crane vessels:

— onto or from floating vessels: use the “Offshore” or “Floating Inshore” column of Table 20, as appropriate;

— onto foundations from its own deck: use the “Floating Inshore” column of Table 20. If the crane is not moving horizontally on tracks or wheels, and horizontal motions of the load can be minimized by suitable located crane tuggers then the “Static” column may be used; see [61].

19.5.4 Representative hook load

19.5.4.1 For one-hook lifts by a single crane

The forces on a lift point of the lifted object are governed by the lift weight, W_{lw}, given by Formula (10) with the dynamic amplification factor, k_{DAF}, given in 19.5. However, forces in slings and the total load on the crane are governed by the nominal hook load, F_{hl}, (3.66) given by Formula (11):

$$F_{hl} = W_{lw} + k_{DAF} \times W_{rw} \quad (11)$$

where

W_{lw} is the nominal lift weight;

W_{rw} is the rigging weight (see 3.121).

The rigging weight, W_{rw}, includes all items between the lift points and the crane hook, including slings, grommets, shackles and spreaders, as well as a contingency as appropriate.

For one-hook lifts by a single crane, the representative hook load, F_{rhl}, is equal to the above nominal hook load as given in Formula (11):

$$F_{rhl} = F_{hl} \quad (12)$$

19.5.4.2 For two-hook lifts by two cranes

For a two-hook lift, the nominal hook load, F_{hl}, from Formula (11) represents the total hook load on the two cranes together. The nominal load on each crane hook is found by distributing the total F_{hl} statically between the two hooks, based on the location of the CoG of the lifted object with associated rigging between the hooks. The statically resolved nominal hook load on each hook is denoted by $F_{srhl,i}$, with i equal to 1 or 2, indicating the number of the crane hook.

Lifts by two hooks can be performed with two cranes on the same vessel and with two cranes on two vessels (one crane per vessel), in offshore, inshore and onshore conditions. The hooks can be from either revolving or from sheer-leg cranes. In all these situations, a CoG shift factor, k_{sf}, and a tilt factor, k_{tf}, shall be applied to the resolved hook loads $F_{srhl,i}$.

The two-hook lift factors k_{sf} and k_{tf} account for uncertainty in the position of the CoG of the lifted object, for possible uneven heights of the crane hooks and/or for uneven hoisting speeds.

The representative hook load on crane hook i for a two-hook lift, $F_{rhl,i}$, for i equal to 1 or 2, is given by Formula (13):

$$F_{rhl,i} = k_{sf} \times k_{tf} \times F_{srhl,i} \quad (13)$$

where

$F_{srhl,i}$ is the nominal hook load, F_{hl}, from Formula (11), statically resolved between crane hooks 1 and 2;

k_{sf} is the CoG shift factor, the value of which reflects the uncertainty in the position of the CoG when statically distributing the total hook load between the two hooks, and should be set equal to 1,03;

k_{tf} is the tilt factor, the value of which reflects the effect of uneven heights of the crane hooks and/or uneven hoisting speeds when statically distributing the total hook load between the two hooks, and should be set equal to 1,03.

19.5.5 Representative lift weight per lift point

19.5.5.1 One-hook lifts

For a one-hook lift, the nominal lift weight, W_{lw}, is given by Formula (10). The distribution between the lift points is obtained by statically distributing W_{lw} between the lift points to which the hook is connected. The result is denoted by $W_{srlw,j}$, where j = 1, 2, ..., indicates the number of the lift point. The largest statically resolved lift weight per lift point is max($W_{srlw,j}$).

The static distribution of the lift weight takes into account only the geometry of the lifting arrangement and the position of the CoG of the lifted object. To account for uncertainty in the position of the CoG, a CoG factor, k_{CoG}, shall be applied. Where the allowable CoG position is specified as a cruciform, or another geometric shape, the most conservative CoG position within the allowable area shall be taken and k_{CoG} = 1,0. If no CoG envelope is used a factor of k_{CoG} = 1,02 shall be applied.

For one-hook lifts made by a single crane, the representative lift weight on all lift points for one-hook lifts by one crane, $(W_{rlw})_{one\ crane}$, shall be taken in accordance with Formula (14):

$$(W_{rlw})_{one\ crane} = k_{CoG} \times \max(W_{srlw,j}) \quad (14)$$

where

k_{CoG} is the CoG factor, the value of which reflects the uncertainty in the position of the CoG when statically distributing the lift weight between the lift points;

max ($W_{srlw,j}$) is the largest value for all j of the statically resolved lift weight, $W_{srlw,j}$, acting on lift point j.

19.5.5.2 Two-hook lifts

For a two-hook lift by two cranes, the statically resolved lift weight on crane hook i, $W_{srlw,i}$, for i equal to 1 or 2, can be derived from the equivalent of Formula (11), applied in reverse to the hook load and rigging weight on crane hook i, as given in Formula (15):

$$W_{srlw,i} = F_{rhl,i} - k_{DAF} \times W_{rw,i} \quad (15)$$

where

$F_{rhl,i}$ is the representative hook load on hook i from Formula (13);

$W_{rw,i}$ is the rigging weight associated with crane hook i;

k_{DAF} is the dynamic amplification factor from 19.5.2, including the multiplier from 19.5.3 where applicable.

$W_{srlw,i}$ is next distributed between the lift points, j, to which crane hook i is connected. The largest statically resolved lift weight for crane hook i and lift point j is max($W_{srlw,i,j}$).

In addition to the uncertainties described in 19.5.5.1, for a two-hook lift, yawing of the lifted object can also occur, causing an increase in individual lift point actions. To account for this effect, the statically resolved lift weight per lift point shall further be multiplied by a yaw factor, k_{yaw}.

For a two-hook lift by two cranes, with two slings to each hook, the representative lift weight for all lift points, $(W_{rlw})_{two\ cranes}$, shall, therefore, be taken in accordance with Formula (16):

$$(W_{rlw})_{two\ cranes} = k_{CoG} \times k_{yaw} \times \max(W_{srlw,i,j}) \quad (16)$$

where

k_{yaw} is the yaw factor, the value of which reflects the effect of yawing during lifting with two cranes when statically distributing the lift weight between the lift points, and should be set equal to 1,05 for all lifts;

$\max(W_{srlw,i,j})$ is the largest value, for all i and all j, of the statically resolved lift weight, $W_{srlw,i,j}$, for crane hook i acting on lift point j.

The value of the yaw factor, k_{yaw}, may be reduced if other values can be shown to provide similar levels of safety.

Yaw factors for two-hook lifts with a rigging arrangement other than two slings to each hook require special consideration.

19.5.6 Representative forces on a lift point

19.5.6.1 Representative vertical force

The lift weight per lift point is a vertical force acting on the lift point. The representative value of the vertical force on a lift point is equal to the representative lift weight per lift point, W_{rlw}, from Formula (14) or Formula (16), as applicable, multiplied by a SKL, k_{skl}. The SKL (3.133) reflects the unequal load sharing in an indeterminate lift between slings that differ in length as a result of manufacturing tolerances.

The representative vertical force on a lift point, P_{rvf}, is accordingly given by Formula (17) for one-hook lifts by one crane or by Formula (18) for two-hook lifts by two cranes:

$$P_{rvf} = k_{skl} \times (W_{rlw})_{one\ crane} \quad (17)$$

$$P_{rvf} = k_{skl} \times (W_{rlw})_{two\ cranes} \quad (18)$$

The difference in length for a matched pair of slings shall not exceed 0,5d, where d is the diameter of the sling; see IMCA M 179. The value of k_{skl} also depends on whether or not a rigging arrangement contains elements capable of redistributing unequal sling forces due to sling length deviations, e.g. floating spreader bars.

For statically indeterminate 4-sling lifts using two matched pairs of slings to minimize tilt of the lifted object, a factor of k_{skl} = 1,25 shall be applied to each diagonally opposite pair of lift points in turn, see Reference[61].

For statically determinate lifts, k_{skl} = 1,05 may be used, provided it can be demonstrated that the sling length deviations do not significantly affect the force distribution in the lift system.

For a lift system incorporating one or more floating spreader bars that act as a sling force equalizing system, k_{skl} = 1,1 is applicable.

When combining new and re-used slings in one arrangement, a significantly higher value of k_{skl} can be applicable to account for differences in elasticity.

19.5.6.2 Representative force in line with the sling direction

The representative force on a lift point in line with the sling direction, P_{rdf}, is given by Formula (19):

$$P_{rdf} = \frac{P_{rvf}}{\sin\theta} \qquad (19)$$

where

P_{rvf} is the representative vertical force on a lift point from Formula (17) or Formula (18);

θ is the angle between the sling and the horizontal plane; normally the sling angle is restricted to (a minimum of) 60°.

19.5.6.3 Representative lateral force

Wherever possible, the orientation of the lift point should be aligned with the direction of the sling attached to the lift point. However, due to tolerances some unintentional and unknown misalignment between the orientation of the lift point and the direction of the sling can exist, which shall be accounted for by applying a lateral force factor, k_{lf}.

In some cases, it is not possible to align the orientation of the lift point by design with the direction of the sling. In such cases, there is an intentional and known misalignment between the orientation of the lift point and the direction of the sling. The calculated lateral force, P_{clf}, resulting from a known misalignment shall be calculated and applied to the lift point.

In order to account for both unknown and known misalignment, where present, between the orientation of the lift point and the actual direction of the sling, the representative lateral force, P_{rlf}, given by Formula (20) shall be applied perpendicular to the lift point:

$$P_{rlf}=k_{lf}\times P_{rdf}+P_{clf} \qquad (20)$$

where

k_{lf} is the lateral force factor and should be set equal to 0,05;

P_{rdf} is the representative force on a lift point in line with the sling direction given by Formula (19);

P_{clf} is the calculated lateral force on a lift point due to known misalignment between the orientation of the lift point and the sling direction, where applicable.

The representative lateral force shall be assumed to act through the centreline and along the axis of the pinhole in the padeye, or at the trunnion/padear geometric centre; see Reference[61].

In lift systems with one or more floating spreader bars or frames, k_{lf} shall be increased from 0,05 to 0,08 to account for increased horizontal dynamics. However, in lift systems where the spreader bar is connected directly to the lift points, k_{lf} = 0,05 may be used.

The lateral force factor may be reduced if a lower value can be shown to provide similar levels of safety.

19.5.6.4 Representative force for slings and grommets

The representative sling force, F_{rsf}, for a one-part sling and the representative force for a grommet, F_{rgf}, (the two legs together) are given by Formula (21):

$$F_{rsf} = F_{rgf} = P_{rdf} + \frac{k_{DAF} \times W_s}{\sin \theta} \quad (21)$$

where

- F_{rgf} is the representative grommet force (for a complete grommet);
- P_{rdf} is the representative force on a lift point in line with the sling direction given by Formula (19);
- k_{DAF} is the DAF in accordance with 19.5.2, including the multiplier from 19.5.3 where applicable;
- W_s is the weight of the sling or grommet;
- θ is the angle between the sling or grommet and the horizontal plane.

Where a two-part sling (a sling consisting of two parallel legs) or a grommet passes over, round or through a shackle, trunnion, padear or crane hook, the representative sling force and the representative grommet force, both from Formula (21), shall be distributed between each part of the sling or grommet in the ratio 45:55 to account for frictional losses over the bending point. The representative sling force for each part of the two-part sling, $F_{rsf,2\ parts}$, and the representative force for one leg of the grommet, $F_{rgf,1}$, shall, hence, be taken in accordance with Formula (22):

$$F_{rsf,2\ parts} = F_{rgf,1} = 0,55 F_{rsf} \quad (22)$$

where F_{rsf} is the representative sling force from Formula (21).

The 45/55 split on sling legs is a practical factor to be applied. However, where the sling is required to slide over the bearing surface (e.g. during a jacket upending), this can increase to approximately 67.5/32.5.

Where any wire rope sling or grommet is bent round a shackle, trunnion, padear or crane hook, the breaking load shall be assumed to be the calculated breaking load multiplied by a bending efficiency factor in accordance with 19.6.4.

19.5.6.5 Design values of actions and action effects

If the PFD method is used, design values of the actions and action effects are obtained by multiplying the representative values specified in 19.5.4 to 19.5.6 and 19.5.6.4 by partial action factors as given in Formulae (23) to (31):

$$(F_{dhl})_{PFD} = \gamma_{f,hl} \times F_{rhl} \quad (23)$$

$$(F_{dhl,i})_{PFD} = \gamma_{f,hl} \times F_{rhl,i} \quad (24)$$

$$(F_{dsf})_{PFD} = \gamma_{f,s} \times F_{rsf} \quad (25)$$

$$(F_{dsf,2\ parts})_{PFD} = \gamma_{f,s} \times F_{rsf,2\ parts} \quad (26)$$

$$(F_{dgf,1})_{PFD} = \gamma_{f,s} \times F_{rgf,1} \quad (27)$$

$$(F_{dgf})_{PFD} = \gamma_{f,s} \times F_{rgf} \quad (28)$$

$$(P_{\text{dvf}})_{\text{PFD}} = \gamma_{\text{f},P} \times P_{\text{rvf}} \quad (29)$$

$$(P_{\text{ddf}})_{\text{PFD}} = \gamma_{\text{f},P} \times P_{\text{rdf}} \quad (30)$$

$$(P_{\text{dlf}})_{\text{PFD}} = \gamma_{\text{f},P} \times P_{\text{rlf}} \quad (31)$$

where the subscript P represents one of three different subscripts depending on the element to which the action or action effect is applied.

— P represents “lp” when applied to lift points and attachment of lift points to the structure;

— P represents “mf” when applied to members directly supporting or framing into the lift points;

— P represents “m” when applied to other structural members.

If the WSD method is used, the design values are equal to the unfactored representative values, as given in Formulae (32) to (40):

$$(F_{\text{dhl}})_{\text{WSD}} = F_{\text{rhl}} \quad (32)$$

$$(F_{\text{dhl},i})_{\text{WSD}} = F_{\text{rhl},i} \quad (33)$$

$$(F_{\text{dsf}})_{\text{WSD}} = F_{\text{rsf}} \quad (34)$$

$$(F_{\text{dsf,2 parts}})_{\text{WSD}} = F_{\text{rsf,2 parts}} \quad (35)$$

$$(F_{\text{dgf,1}})_{\text{WSD}} = F_{\text{rgf,1}} \quad (36)$$

$$(F_{\text{dgf}})_{\text{WSD}} = F_{\text{rgf}} \quad (37)$$

$$(P_{\text{dvf}})_{\text{WSD}} = P_{\text{rvf}} \quad (38)$$

$$(P_{\text{ddf}})_{\text{WSD}} = P_{\text{rdf}} \quad (39)$$

$$(P_{dlf})_{WSD} = P_{rlf} \quad (40)$$

where

F_{dhl}	is the design hook load for a one-crane lift;
$F_{dhl,i}$	is the design hook load on hook *i* for a two-hook lift;
$\gamma_{f,hl}$	is the partial action factor for hook load;
F_{dsf}	is the design sling force for a one-part sling;
$F_{dsf,2\ parts}$	is the design sling force for each part of a two-part sling;
$F_{dgf,1}$	is the design force for one leg of a grommet;
F_{dgf}	is the design grommet force (for a complete grommet);
$\gamma_{f,s}$	is the partial action factor for forces in slings, grommets and shackles;
P_{dvf}	is the design vertical force on a lift point;
P_{ddf}	is the design force on a lift point in line with the sling direction;
P_{dlf}	is the design lateral force on a lift point;
$\gamma_{f,lp}$	is the partial action factor for the forces on a lift point when designing the lift points themselves and their attachment to the structure;
$\gamma_{f,mf}$	is the partial action factor for the forces on a lift point when designing the structural members directly supporting or framing into the lift points;
$\gamma_{f,m}$	is the partial action factor for the forces on a lift point when designing other structural members.

Unless operation-specific calculations show otherwise, the partial factors given in Table 21 shall be applied.

Table 21 — Partial action factors, γ_f

Design value/Load case	Partial factor
For hook load	$\gamma_{f,hl}$ = 1,0
For design of slings, grommets and shackles	$\gamma_{f,s}$ = 1,30
For design of lift points	$\gamma_{f,lp}$ = 1,30
For design of attachments of lift points to the structure	$\gamma_{f,lp}$ = 1,30
For design of members directly supporting or framing into the lift points	$\gamma_{f,mf}$ = 1,15
For design of other structural members	$\gamma_{f,m}$ = 1,00

19.6 Strengths of slings, grommets and shackles

19.6.1 General

For design verification, strengths (resistances) are assigned a representative value (3.116). If available data allow the determination of a characteristic value (3.25) for strength, this is the preferred representative value; otherwise, a nominal value (3.94) for strength serves as the representative value. In design verification by the PFD method, design values (3.38) for strength (resistance) are derived from the corresponding representative value by dividing the latter by a partial resistance factor. In design verification by the WSD method, design values for strength are referred to as working load limits (see following); they are derived from the corresponding representative strength value by dividing this by a safety factor.

As noted in 19.1, the WSD method is the method normally used for design verification of lifting operations. For consistency with existing practice, a number of terms that are in common use in practical applications are defined as follows and hereafter maintained in the discussion:

— F_{min}: The value F_{min} is a specified value, expressed in kilonewtons, below which the measured breaking strength of a rope, F_m, is not allowed to fall in a prescribed breaking strength test; see[2]. F_{min} is normally calculated in the manner described in [14], [2] and [18].

A calculated value is defined in [2] as a value obtained by calculation, based on given or measured values and on conventional factors.

— Calculated rope breaking load: The calculated rope breaking load, CRBL, is the calculated strength in force terms of a plain, straight rope after production, including the reduction in strength due to spinning losses during the manufacturing process. When applied to a manufactured sling, CRBL refers to the calculated strength of the body of the sling excluding end terminations and losses associated with application of the sling. The calculated strength of a plain straight rope and of the body of a sling are their respective representative strengths.

— Calculated grommet breaking load: A grommet is an endless sling with two legs. The calculated strength of each leg is given by the calculated rope breaking load, CRBL, so that the calculated strength of the complete grommet, CGBL, is two times the CRBL of a grommet's leg. The CGBL, the calculated strength of a complete grommet in force terms, is the representative strength of the body of a grommet, excluding losses associated with application of the grommet. The calculated grommet and sling breaking loads are also affected by bending losses.

— Calculated sling breaking load: The calculated sling breaking load, CSBL, is the representative strength of a manufactured sling in force terms, including the reduction in strength due to end terminations (expressed by the termination efficiency factor). CSBL is often recorded on a sling certificate with its identification ferrule for a straight sling. The calculated grommet and sling breaking loads are also affected by bending losses.

— Working load limit: The working load limit, WLL, (3.171) is the maximum load for which a sling, grommet, shackle or lift point is designed in accordance with the WSD method. The WLL is the design strength (also referred to generally as the allowable value) for use in design verification by the WSD method. It is obtained by dividing the representative strength by a safety factor, f_{SF}. The allowable strength value for structural components in the lifted object can be further reduced by the application of a consequence factor (3.28).

The design strength in design verification by the PFD method is obtained analogously by dividing the representative strength by a partial resistance factor, γ_R. Numerical values of the safety factor in WSD and the partial resistance factor in PFD are related by the relationship $f_{SF} = \gamma_f \times \gamma_R$.

For slings and grommets, calculated strengths are given in 19.6.2, representative strengths in 19.6.5 and design strengths in 19.6.6. The strength of shackles is presented in 19.6.7.

NOTE An object being lifted can be specified by its weight, in force units (kilonewtons), or by its mass, in mass units (metric tonnes); these differ by a factor of the acceleration of gravity, g: mass equals weight divided by g. Mass units (metric tonnes) are often used in lifting operations. WLLs and design strengths in force units (kilonewtons) are converted into masses by dividing by g.

19.6.2 Calculated strengths of the bodies of slings and grommets

19.6.2.1 Steel wire rope slings

Steel wire rope slings (SWRS) are made from a single steel wire rope with various end terminations (3.146). The minimum breaking strength, F_{min}, of a steel wire rope is the value specified by the manufacturer for the particular type of rope, or the value obtained by calculation (see 19.6.1). For steel wire rope with a diameter $d \leq 60$ mm, the minimum breaking strength, F_{min}, expressed in kilonewtons, is calculated from Formula (41) that is given in [14], [2] and [18]:

$$F_{min} = \frac{d^2 \times R_t \times K}{1000} \quad (41)$$

where

d is the nominal diameter of the rope, expressed in millimetres;

R_t is the rope grade (tensile strength grade of the wires), expressed in newtons per square millimetre[18]; specifies that, for diameters up to 60 mm, the rope grade shall be 1 770 N/mm², 1 960 N/mm² or 2 160 N/mm², or an intermediate grade specified by the manufacturer, but not exceeding 2 160 N/mm²;

K = 0,346 differs from[10] where, for these rope classes, a value of 0,356 is given.

For diameters from 60 mm to 264 mm[18], states that the identification of a rope grade is no longer applicable, but that the tensile strength grades of the wires shall be 1 770 N/mm², 1 960 N/mm² or 2 160 N/mm², or a combination thereof. For steel wire rope with $d > 60$ mm, the minimum breaking strength, F_{min}, expressed in kilonewtons, is calculated as given by Formula (42):

$$F_{min} = 8{,}55\, d + 0{,}592\, d^2 - 0{,}000\,615\, d^3 \quad (42)$$

The value of F_{min} that is specified by the manufacturer can be higher than that calculated from Formula (41) or Formula (42). In such cases, the higher value provided by the manufacturer may be used, as long as it can be properly documented.

The calculated strength, CRBL, of the body of a SWRS, $F_{CS,\,SWRS}$, in force terms is equal to F_{min}, as given by Formula (43):

$$F_{CS,\,SWRS} = F_{min} \quad (43)$$

19.6.2.2 Steel cable-laid slings

Steel cable-laid slings (SCLS) (3.143) are normally constructed from six stranded steel wire ropes, helically wound around one straight core steel wire rope, and are provided with spliced eye end terminations.

Cable-laid slings shall be constructed and used in accordance with IMCA M 179. The nominal diameter of the core rope should be at least 12 % but not more than 25 % larger than the nominal diameter of the outer ropes.

The CRBL of the body of a SCLS, in force terms, $F_{CS,\,SCLS}$, is given by Formula (44):

$$F_{CS,\,SCLS} = 0{,}85 \times \sum F_{min} \quad (44)$$

where

$\sum F_{min}$ is the sum of the minimum breaking strengths of the outer ropes and the core rope; see 19.6.2.1;

0,85 is an empirical factor accounting for the additional spinning losses in manufacturing a cable-laid sling from the separate wire ropes.

The value of $F_{CS,SCLS}$ (CRBL) is normally directly taken from the manufacturer's specification.

19.6.2.3 Steel wire rope grommets

Grommets are always of cable-laid construction. Steel wire rope grommets (SWRG) (3.145) shall be constructed and used in accordance with IMCA M 179. The locations of the butt and the tuck positions shall be marked by red paint.

The core rope of a SWRG is discontinuous at the butt and tuck positions and, for that reason, the core rope shall be excluded in calculating the grommet's calculated strength. The CRBL of one leg of a steel wire rope grommet, $F_{CS,SWRG,1}$, in force terms, is given by Formula (45):

$$F_{CS,SWRG,1} = 0{,}85 \times 6 \times F_{min} \tag{45}$$

where

$6 \times F_{min}$ is the accumulated minimum breaking strength of the six outer ropes of one leg of the grommet (see 19.6.2.1), excluding the core rope;

0,85 is an empirical factor accounting for the additional spinning losses in manufacturing the cable-laid grommet from the separate wire ropes.

The calculated strength (CGBL) of the complete SWRG, $F_{CS,SWRG,2}$, in force terms, is given by Formula (46):

$$F_{CS,SWRG,2} = 2 \times F_{CS,SWRG,1} \tag{46}$$

The value of $F_{CS,SWRG,2}$ is normally directly taken from the manufacturer's specification.

19.6.2.4 Fibre rope slings and fibre rope grommets

The CRBL of fibre rope slings (FRS) (3.51) with various types of construction and the CGBL of fibre rope grommets (FRG) (3.50) shall be taken as the breaking strength given on the certificate based on rope tensile destruction tests.

Analogous to 19.6.2.1 to 19.6.2.3, the CRBL of a fibre rope sling is denoted by $F_{CS,FRS}$. The CRBL of one leg of a fibre rope grommet is similarly denoted by $F_{CS,FRG,1}$, while the CGBL of the complete fibre rope grommet is denoted by $F_{CS,FRG,2}$, the value of which is twice $F_{CS,FRG,1}$. All values are in force terms.

19.6.3 Termination efficiency factor

19.6.3.1 Steel wire rope slings and steel cable-laid slings

The end termination is invariably the weakest point of steel wire rope slings (SWRS) and steel cable-laid slings (SCLS). The reduction in strength of the sling as a whole compared to the body of the sling is accounted for by applying a termination efficiency factor, k_{te}, to the calculated strength (CRBL) from 19.6.2.1 and 19.6.2.2.

The termination efficiency factor, k_{te}, shall be applied as given in the specifications provided by the manufacturer. For certain end terminations of SWRSs and of SCLSs, the following maximum values may be used as guidance:

— k_{te} = 1,00 for resin sockets;

— k_{te} = 0,90 for swage fittings on Flemish eyes;

— k_{te} = 0,75 for steel ferrules (mechanical termination);

— k_{te} = 0,75 for hand splices.

Other methods of termination require special consideration.

19.6.3.2 Fibre rope slings

For fibre rope slings (FRS), the termination efficiency factor shall normally be the value specified by the manufacturer.

19.6.3.3 Steel wire rope grommets and fibre rope grommets

As grommets are endless, loop-shaped slings without end termination, a termination efficiency factor is not applicable.

19.6.4 Bending efficiency factor

19.6.4.1 Steel wire rope slings and steel cable-laid slings

Where a wire rope sling is bent around a shackle, trunnion, padear or crane hook, the strength of the sling is locally reduced by bending. The reduction in strength of the sling is accounted for by applying a bending efficiency factor, k_{be}, to the calculated strength (CRBL) from 19.6.2.1 and 19.6.2.2.

The bending efficiency factor, k_{be}, for SWRS and SCLS can be calculated by Formula (47):

$$k_{be} = 1{,}0 - 0{,}5 / \sqrt{(D/d)} \tag{47}$$

where

- d is the nominal diameter of the wire rope sling or the cable-laid sling;
- D is the minimum diameter over which the sling is bent.

Values calculated using Formula (47) are summarized in Table 22.

Table 22 — Bending efficiency factors, k_{be}, for SWRS and SCLS [61]

D/d	< 1,0[a]	1,0	1,5	2,0	3,0	4,0	5,0	6,0	7,0
k_{be}	< 0,50	0,50	0,59	0,65	0,71	0,75	0,78	0,80	0,81

[a] Not permitted.

In order to avoid even limited permanent deformation of a sling, a D/d ratio of at least 4,0 should be used. The body of a sling shall not be bent around a diameter less than 2,5 d. D/d ratios smaller than 2,5 are applicable only to sling eyes. However, a sling eye shall not be bent around a diameter less than the diameter of the sling to avoid excessive permanent deformation of the eye.

Bending in the way of splices shall be avoided.

19.6.4.2 Steel wire rope grommets

Grommets are endless, loop-shaped slings that are used with one end connected to a lift point (typically a trunnion or padear) and one end laid over the crane hook. The bending efficiency factor for a steel wire rope grommet (SWRG) may be calculated from Formula (47) or determined from Table 22 for the lesser D/d ratio, taking d as the nominal diameter of one leg of the grommet and D as the smaller of the diameters over which the sling is bent at the lift point or the crane hook.

For a standard ratio of D/d = 4,0, a bending efficiency factor k_{be} = 0,75 may be used (see 19.6.4.1). It should be noted that the bending efficiency factors at the lift point and at the crane hook usually differ as a result of different values of D. If one or both of the bending efficiency factors is/are smaller than 0,75, the smaller value reflecting the more severe reduction in strength shall be used at both ends.

Bending in the way of grommet butt or tuck positions shall be avoided.