

Planning, Designing, and Constructing Fixed Offshore Platforms—Load and Resistance Factor Design

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Foreword

This document contains engineering design principles and good practices that have evolved during the development of offshore oil resources. Good practice is based on good engineering; therefore, this recommended practice consists essentially of good engineering recommendations. In no case is any specific recommendation included that could not be accomplished by presently available techniques and equipment. Consideration is given in all cases to the safety of personnel, compliance with existing regulations, and antipollution of water bodies.

Offshore technology continues to evolve. In those areas where the committee felt that adequate data were available, specific and detailed recommendations are given. In other areas, general statements are used to indicate that consideration should be given to those particular points. Designers are encouraged to utilize all research advances available to them. As offshore knowledge continues to grow, this document will be revised. It is hoped that the general statements contained herein will gradually be replaced by detailed recommendations.

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Attention Users of This Publication: This edition supersedes the 1st Edition dated July 1993, as well as Errata dated October 1993 and Supplement 1 dated February 1997. Portions of this publication have been changed from the previous edition. In some cases the changes are significant, while in other cases the changes reflect minor editorial adjustments in order to conform to current API styling. Because the document was significantly reformatted from the previous edition, no attempt was made to indicate the locations of changes with bar notations.

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Introduction

The API offshore structures standards constitute a common basis covering those aspects that address design requirements and assessments of all offshore structures used by the petroleum and natural gas industries worldwide. Through their application, the intention is to achieve reliability levels appropriate for manned and unmanned offshore structures, whatever the type of structure and the nature of the materials used.

It is important to recognize that structural integrity is an overall concept comprising models for describing loads/actions, structural analyses, 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. The implications involved in modifications, therefore, need to be considered in relation to the overall reliability of all offshore structural systems.

The offshore structures standards are intended to provide a wide latitude in the choice of structural configurations, materials, and techniques without hindering innovation. Sound engineering judgment is therefore necessary in the use of these standards.

Annex A provides background to and guidance on the—much but not all—use of this document and needs to be read in conjunction with the main body of this document. The section numbering in Annex A is the same as in the normative text to facilitate cross-referencing.

Materials, welding, and weld inspection requirements can be based either on a “material category” or on a “design class” approach, as discussed in Sections 19 and 20. If the material category approach is used, the corresponding provisions of Annexes C and D are normative; if the design class approach is used, the corresponding provisions of ISO 19902 are normative.

Annex E gives requirements on fabrication tolerances. To meet certain needs of industry for linking software to specific elements in this document, a special numbering system has been permitted for figures, tables, equations, and bibliographic references.

Planning, Designing, and Constructing Fixed Offshore Platforms—Load and Resistance Factor Design

1 Scope

This document specifies requirements and provides recommendations applicable to the following types of fixed steel offshore structures for the petroleum and natural gas industries:

- caissons, free-standing and braced;
- jackets;
- monotowers;
- towers.

In addition, it is applicable to compliant bottom founded structures, steel gravity structures, jack-ups, other bottom founded structures, and other structures related to offshore structures (such as underwater oil storage tanks, bridges, and connecting structures), to the extent to which its requirements are relevant.

This document contains requirements for planning and engineering of the following tasks:

- design, fabrication, transportation, and installation of new structures as well as their future removal;
- in-service inspection and integrity management of both new and existing structures;
- assessment of existing structures;
- evaluation of structures for reuse at different locations.

Requirements for topsides structures can be found in API 2TOP, for marine operations in API 2MOP, and for the site-specific assessment of jack-ups in ISO 19905-1. Additional requirements for the design of fixed steel offshore structures in arctic environments can be found in API 2N.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document applies (including any addenda/errata).

API Recommended Practice 2EQ, *Seismic Design Procedures and Criteria for Offshore Structures*

API Recommended Practice 2FB, *Recommended Practice for Design of Offshore Facilities Against Fire and Blast Loading*

API Recommended Practice 2GEO, *Geotechnical and Foundation Design Considerations*

API Recommended Practice 2GEO, *Geotechnical and Foundation Design Considerations*, First Edition

API Recommended Practice 2MET, *Derivation of Metocean Design and Operating Conditions*

API Recommended Practice 2MOP, *Marine Operations*

API Recommended Practice 2MOP, *Marine Operations*, First Edition

API Recommended Practice 2SIM, *Structural Integrity Management of Fixed Offshore Structures*

ISO 10414-1¹, *Petroleum and natural gas industries—Field testing of drilling fluids—Part 1: Water-based fluids*

ISO 12135, *Metallic materials—Unified method of test for the determination of quasistatic fracture toughness*

ISO 19900, *Petroleum and natural gas industries—General requirements for offshore structures*

3 Terms, Definitions, Symbols, and Abbreviated Terms

3.1 Terms and Definitions

For the purposes of this document, the terms and definitions given in API 2EQ, API 2GEO, API 2MET, API 2SIM, and ISO 19900 and the following apply.

3.1.1

abnormal value

Value of a parameter of abnormal severity used in accidental limit state checks in which a structure should not suffer complete loss of integrity.

NOTE 1 Abnormal design situations are used to provide robustness against events with a probability of exceedance of typically between 10^{-3} and 10^{-4} per annum by avoiding, for example, gross overloading.

NOTE 2 Abnormal values and events have probabilities of exceedance of the order of 10^{-3} to 10^{-4} per annum; in the limit state checks, some or all of the partial factors are set to 1.0.

3.1.2

accidental design situation

Design situation involving exceptional conditions of the structure or its exposure.

EXAMPLE Impact, fire, explosion, local failure, loss of intended differential pressure (e.g. buoyancy).

3.1.3

action

The word “action” is equivalent to the words “load/imposed displacement/accelerations” in various API documents used as references.

3.1.4

after damage design situation

Design situation for which the condition of the structure reflects damage due to an accidental design situation and for which the environmental conditions are specially defined.

3.1.5

analysis type

Method including governing equations for deriving load/action effects.

EXAMPLE Static analysis, transient dynamic analysis, nonlinear analysis.

¹ International Organization for Standardization, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, www.iso.org.

3.1.6**basic variable**

One of a specified set of variables representing physical quantities that characterize loads/actions, environmental influences, geometrical quantities, or material properties including soil properties.

3.1.7**boundary conditions**

Loads/actions and constraints on a [section of a] structural component [or a group of structural components] by other structural components or by the environment surrounding it.

NOTE Boundary conditions can be used to generate reaction forces at locations of restraint.

3.1.8**braced caisson**

Monotower where the lower part of the monocolumn is supported laterally by one or more inclined braces between the column and one or more foundation piles.

3.1.9**bucket foundation**

Foundation consisting of a cylindrical shell open on one end and installed by suction.

3.1.10**characteristic value**

Value assigned to a basic variable associated with a prescribed probability of not being violated by unfavorable values during some reference period.

NOTE 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.

3.1.11**compliant bottom founded structure**

Structure that is supported at its base by foundation piles or by another nonsuperficial foundation system and that is sufficiently flexible that applied lateral dynamic loads/actions are substantially balanced by inertial reactions.

NOTE Although this document is applicable to fixed steel offshore structures and is not intended to form a complete standard for compliant bottom founded structures, some of its requirements and guidance can be applied to compliant bottom founded structures; parts of its requirements can also apply to other bottom founded structures (e.g. some forms of minimal structure), as considered appropriate and as agreed upon by parties concerned on a case-by-case basis.

3.1.12**consequence category**

Classification system for identifying the environmental, economic, and indirect personnel safety consequences of failure of a platform.

NOTE See 6.4.3.

3.1.13**critical component**

Structural component, failure of which would cause significant strength loss to or failure of a significant part of or the whole structure.

3.1.14**deformation capacity**

Ability of a structure or structural component to deform without significant loss of resistance, e.g. ductility, or the extent to which it can do so.

3.1.15**design service life**

Assumed period for which a structure is to be used for its intended purpose with anticipated maintenance, but without substantial repair being necessary.

3.1.16**design value**

Value derived from the representative value for use in the design verification procedure.

3.1.17**dynamic amplification factor****DAF**

Ratio of a dynamic load/action effect to the corresponding static load/action effect.

NOTE An appropriately selected dynamic amplification factor can be applied to static loads/actions to simulate the effects of dynamic loads/actions.

3.1.18**explosion**

Rapid chemical reaction of gas or dust in air.

NOTE An explosion results in increased temperatures and pressure impulses; a gas explosion on an offshore platform is usually a deflagration in which flame speeds remain subsonic.

3.1.19**exposure level**

Classification system used to define the requirements for a structure based on consideration of life-safety and of environmental and economic consequences of failure.

3.1.20**extreme value**

Value of a parameter used in ultimate limit state checks, in which a structure's global behavior is intended to stay in the elastic range.

3.1.21**fit-for-service**

Meeting the intent of a standard although not meeting specific provisions of that standard in local areas, such that failure in these areas will not cause unacceptable risk to life-safety or the environment.

3.1.22**fixed structure**

Structure that is bottom founded and transfers all loads/actions on it to the sea floor.

3.1.23**free-standing caisson**

Monotower where the structure consists, over its full height, of a single vertical column that continues into the seabed as the foundation pile.

3.1.24**global analysis**

Determination of a consistent set of internal forces and moments, or stresses, in a structure that are in equilibrium with a defined set of loads/actions on the entire structure.

NOTE When a global analysis is of a transient situation (e.g. seismic), the inertial response is part of the equilibrium.

3.1.25**hazard**

Potential for human injury, damage to the environment, damage to property, or a combination of these.

NOTE Several of the usual hazards to a platform (e.g. extreme storms) are treated as design situations for a structure; in this document, hazards are errors and abnormal and accidental situations.

3.1.26**jacket**

Fixed structure with leg piles and axial force transfer from the structure and topsides into the piles at the top of the structure.

NOTE See 4.2.

3.1.27**jack-up**

Mobile offshore unit that can be relocated and is bottom founded in its operating mode.

NOTE See 4.4.

3.1.28**life-safety category**

Classification system for identifying the applicable level of life-safety for a platform.

NOTE See 6.4.2.

3.1.29**load arrangement**

Identification of the position, magnitude, and direction of a free load/action.

3.1.30**load case**

Compatible load arrangements, sets of deformations and imperfections considered simultaneously with permanent loads/actions and fixed variable loads/actions for a particular design or verification.

3.1.31**local analysis**

Determination of a consistent set of internal forces and moments, or stresses, in a cross-section of a structural component, or in a subset of structural components forming part of the structural system, that are in equilibrium with the boundary conditions.

3.1.32**maintenance**

Set of activities performed during the working life of the structure in order to enable it to fulfil the requirements for reliability.

NOTE Activities to restore the structure after an abnormal, accidental, or seismic event are outside the scope of maintenance.

3.1.33**monotower**

Fixed structure in which the whole structure, or at least the upper part of the structure, consists of a single vertical column (tubular or framed) that carries the topsides.

NOTE Where only the upper part of the structure is a single vertical column, the lower part of the structure consists of tubular members or frames that connect the vertical column to the foundation piles or to another nonsuperficial foundation system that supports the monotower at its base, such as bucket foundations.

3.1.34**nominal geometrical properties**

Properties of a structural component derived from its representative geometrical dimensions, remote from the location under consideration and with any corrosion allowance removed.

NOTE 1 The nominal cross-section of a member at a joint is the cross-section beyond any joint can or brace stub forming part of the joint.

NOTE 2 Nominal geometrical properties are used in a global analysis to calculate the global behavior of the structure.

NOTE 3 The nominal thickness of a component excludes any thickening of the component due to weldments.

3.1.35**nominal stress**

Stress calculated in a sectional area, including the stress-raising effects of the macro-geometrical shape of the component of which the section forms a part, but disregarding the local stress-raising effects from the section shape and any weldment or other fixing detail.

NOTE Overall elastic behavior is assumed when calculating nominal stresses.

3.1.36**nominal value**

Value assigned to a basic variable determined on a nonstatistical basis, typically from acquired experience or physical conditions.

3.1.37**owner**

Representative of the companies that own a development.

NOTE The owner will normally be the operator on behalf of co-licensees.

3.1.38**primary structure**

All main structural components that provide the structure's main strength and stiffness.

3.1.39**quasi-static analysis**

Static analysis of a structure subjected to loads/actions that vary slowly in relation to the structure's fundamental natural period such that the influence of structural accelerations can be either safely neglected or is approximated by using an equivalent quasi-static load/action.

3.1.40**redundancy**

Ability of a structure to find alternative load paths following failure of one or more noncritical components, thus limiting the consequences of such failures.

3.1.41**regulator**

Authority established by a national governmental administration to oversee the activities of the offshore oil and natural gas industries within its jurisdiction, with respect to the overall safety to life and protection of the environment.

NOTE 1 The term "regulator" can encompass more than one agency in any particular territorial waters.

NOTE 2 The regulator can appoint other agencies, such as marine classification societies, to act on its behalf, and in such cases, "regulator" as it is used in this document includes such agencies.

NOTE 3 In this document, the term "regulator" does not include any agency responsible for approvals to extract hydrocarbons, unless such agency also has responsibility for safety and environmental protection.

3.1.42**repair**

Activities performed to preserve or to restore the function of a structure that fall outside the definition of maintenance.

3.1.43**representative value**

Value assigned to a basic variable for verification of a limit state.

3.1.44**representative yield strength**

Stress at which a material exhibits a specified deviation from proportionality of stress and strain.

NOTE An offset of 0.2 % is used for many metals, including the steels covered by this document.

3.1.45**reserve strength ratio****RSR**

Measure of the capacity of a structural system to withstand overload.

NOTE For fixed steel offshore structures, the concept of a reserve strength ratio is usually applied to environmental loads/actions (see 7.10), but is not limited to these loads/actions.

3.1.46**risk-reducing measures**

Measures undertaken to reduce either the probability or the consequences of an accident, including the preparation of contingency plans.

3.1.47**robustness**

Ability of a structure to withstand events with a reasonable likelihood of occurring without being damaged to an extent disproportionate to the cause.

3.1.48**secondary structure**

Structural components that, when removed, do not significantly alter the overall strength and stiffness of the structure.

3.1.49**steel gravity structure**

Fixed structure that is held in place against environmental loads/actions solely by the weight of the structure and any contained ballast, together with foundation resistance resulting from its weight and lateral resistance from any skirts.

NOTE Although this document is not intended to form a complete standard for gravity structures, some of the requirements and guidance could be applied to gravity structures.

3.1.50**strength**

Mechanical property of a material indicating its ability to resist loads/actions, usually given in units of stress.

3.1.51**stress concentration factor****SCF**

Factor relating a nominal stress to the local stress at a detail.

NOTE Stress concentration factors are very important for and especially used in determining fatigue damage (see 16.10.2).

3.1.52**structural analysis**

Process or algorithm for determining load/action effects from a given set of loads/actions.

NOTE Structural analyses are performed at three levels (global analysis of an entire structure, local analysis of a structural component, local analysis of a section of a structural component) using different structural models.

3.1.53**structural component**

Physically distinguishable part of a structure.

NOTE The main structural components of a fixed steel structure are tubular members (see Section 13), tubular joints (see Section 14), mechanical connectors and clamps (see Section 15), foundation piles and bucket foundations (see Section 17).

3.1.54**structural system**

Load-bearing components of a structure and the way in which these components function together.

3.1.55**topsides**

Structures and equipment placed on a support structure (fixed or floating) to provide some or all of a platform's functions.

NOTE 1 For a ship-shaped floating support structure, neither the deck nor a superstructure integral with the hull is part of the topsides.

NOTE 2 For a jack-up, the hull is not part of the topsides.

NOTE 3 A separate fabricated deck or module support frame is part of the topsides.

3.1.56**tower**

Fixed structure that is supported by foundation arrangements at the base of the structure.

NOTE See 4.3.

3.1.57**utilization****member utilization****joint utilization**

Maximum value of the ratio of the generalized representation of the design stress (force) in a structural component to the generalized representation of the design resistance in stress (force) units of the component.

NOTE 1 The utilization is the maximum absolute value of the ratio for all conditions being considered.

NOTE 2 Only utilizations smaller than or equal to 1.0 satisfy the design criteria for a particular limit state.

NOTE 3 The design stress (force) is the stress (force) due to factored loads/actions: $F_d = F_r \gamma_f$; the design resistance is the representative resistance divided by the partial resistance factor: $R_d = R_r / \gamma_R$.

NOTE 4 For members and joints subjected to a single force, the utilization, U , is equal to: $F_d / R_d = F_r \gamma_f \gamma_R / R_r$.

NOTE 5 For members and joints subjected to combined forces, the internal stress (force) pattern and the design resistance combine into an interaction equation; if the interaction equation governing the design check is, or can be, reduced to an inequality of the form $I \leq 1.0$, then the utilization is equal to I .

3.2 Symbols

The following is a summary of the main symbols that are used throughout this document. Many other symbols are locally defined where they are used. Local use includes main symbols with one or more subscripts when a more specific use and associated definition of the symbol is intended.

A	accidental load/action
A	area
C	coefficient in general
C_d	hydrodynamic drag coefficient
C_m	hydrodynamic inertia coefficient
C_m	moment reduction factor
C_r	seismic reserve capacity factor
C_s	shape coefficient
C_s	slamming coefficient
c_u	undrained shear strength of the soil, in stress units
D	diameter of a circular cylindrical element
D	diameter of a tubular joint chord
D	Palmgren-Miner fatigue damage ratio
D	equivalent quasi-static load/action representing dynamic effects
D_r	relative density of sand
d	water depth
d	diameter of tubular joint brace
E	Young's modulus of elasticity, which may be taken as 205,000 MPa for structural steel, in lieu of more detailed information
E	quasi-static environmental load/action
E_e	extreme quasi-static environmental load/action due to wind, waves, and current
E_o	environmental load/action due to owner-defined operating wind, wave, and current parameters
F	load/action
F_d	design value of load/action

F_r	representative value of load/action
f	unit skin friction of a pile, in stress units
f	representative strength in general, in stress units
f_b	representative bending strength, in stress units
f_c	representative axial compressive strength, in stress units
f_{cu}	unconfined cube strength of grout
f_e	Euler buckling strength, in stress units
f_h	representative hoop buckling strength, in stress units
f_t	representative axial tensile strength, in stress units
f_v	representative shear strength, in stress units
f_y	representative yield strength, in stress units
G	permanent load/action
g	acceleration due to gravity
g	gap
H	height of an individual wave
H_s	significant wave height
I	moment of inertia
K	factor (locally defined with subscript for specific meaning)
K	effective length factor
K	dimensionless coefficient of lateral earth pressure
K	Keulegan-Carpenter number
k	factor (locally defined with subscript for specific meaning)
k	wave number
k_{DAF}	dynamic amplification factor
L	length
M	moment (bending or torsion) due to factored loads/actions

M_d	design value of joint bending moment strength, in moment units
M_{uj}	representative value of joint bending moment strength, in moment units
m	inverse slope of the S - N curve
m	mass
N	number of cycles to failure in fatigue of a specified constant amplitude stress range, S
n	number of occurrences of a specified stress range, S , during a specified time
P	percentage
P	member axial force due to factored loads/actions
P_d	design value of joint axial strength, in force units
P_{uj}	representative value of joint axial strength, in force units
P_f	probability of failure
$P-\Delta$	second-order bending effect due to axial compressive force, P , and lateral deflection, Δ
$P(x)$	cumulative probability of variable x
p	factored hydrostatic pressure
p_a	atmospheric pressure
p_0'	effective overburden stress of the soil
$p(x)$	probability density function of variable x
p - y	lateral soil resistance versus local pile displacement
Q	variable load/action
Q_d	design axial pile capacity
Q_f	representative value of the total shaft friction resistance of a pile, in force units
Q_f	chord force factor
Q_g	gap factor for a joint
Q_p	representative value of the end bearing capacity of a pile, in force units
Q_r	representative value of the axial pile capacity
Q_u	chord strength factor

$Q-z$	pile end bearing resistance versus pile tip displacement
Q_β	geometrical factor for a joint
q	unit end bearing of a pile, in stress units
R	radius of a circular cross-section
R_d	design value of a component resistance (from ISO 19900)
Re	Reynolds number
R_{RS}	reserve strength ratio (RSR)
r	radius of gyration
S	internal force (load/action effect)
S	constant amplitude stress range for fatigue assessments
Sr	Strouhal number
S_r	Stress range
T	quasi-static transient load/action
T	wall thickness of the chord member
T	period in general
T_{app}	apparent wave period
T_z	average zero-crossing wave period
t	time
t	wall thickness in general
t	wall thickness of the brace member
$t-z$	soil pile shear transfer versus local pile displacement
U	utilization
V	beam shear due to factored loads/actions
V	displaced volume
V	coefficient of variation
Z_e	elastic section modulus
Z_p	plastic section modulus
α	slope angle of a cone section

β	ratio of brace outside diameter to chord outside diameter
γ	ratio of chord outside radius to chord wall thickness
γ'	submerged unit weight of soil
γ_f	partial load/action factor of which the value reflects the uncertainty or randomness of the load/action
γ_R	partial resistance factor of which the value reflects the uncertainty or variability of the component resistance including those of material properties (from ISO 19900)
θ	angle in general
θ_m	mean wave direction
λ	wave length
λ	column slenderness parameter
ν	Poisson's ratio, which may be taken as 0.3 for structural steel, in lieu of more detailed information
ρ_a	mass density of air, which may be taken as 1.22 kg/m ³ , in lieu of more detailed information
ρ_s	mass density of steel, which may be taken as 7850 kg/m ³ for structural steel, in lieu of more detailed information
ρ_w	mass density of seawater, which may be taken as 1025 kg/m ³ , in lieu of more detailed information
σ	stress in general
τ	shear stress in general
τ	ratio of brace wall thickness to chord wall thickness
ν	kinematic viscosity of water
ϕ'	angle of internal friction in sand
Ω	ratio of frequency of excitation to natural frequency
ω	circular frequency
ω_e	frequency of excitation
ω_n	natural frequency in general
ω_1	first natural frequency
ξ	factor (locally defined with subscript for specific meaning)
ξ	fraction of critical damping
$\emptyset$	diameter

3.3 Abbreviated Terms

ALE	abnormal level earthquake
ALS	accidental limit states
ASD	allowable stress design
COV	coefficient of variation
CTOD	crack tip opening displacement
CVN	Charpy V-notch
DAF	dynamic amplification factor
DC	design class
ELE	extreme level earthquake
ERW	electric resistance welded
FEA	finite element analysis
FLS	fatigue limit states
GS	geometrical stress
GSR	geometrical stress range
HAT	highest astronomical tide
HAZ	heat affected zone
HISC	hydrogen-induced stress cracking
IC	impressed current
IPB	in-plane bending
JIP	joint industry project
LAST	lowest anticipated service temperature
LAT	lowest astronomical tide
LBZ	local brittle zone
MC	material category
MIC	microbiologically influenced corrosion
MPI	magnetic particle inspection
MPM	most probable maximum

NDT	nondestructive testing
OPB	out-of-plane bending
PLS	progressive collapse limit states
POD	probability of detection
PQR	procedure qualification record
PWHT	post-weld heat treatment
QA	quality assurance
QC	quality control
QMS	quality management system
Q&T	quenched and tempered
RAO	response amplitude operator
RMS	root-mean-square
RSR	reserve strength ratio
RT	radiographic testing
SAW	submerged arc welding
SCF	stress concentration factor
SDOF	single degree of freedom
SIM	structural integrity management (system)
SLS	serviceability limit states
SMYS	specified minimum yield strength
SRA	structural reliability analysis
SRC	seismic risk category
SRD	soil resistance to driving
SSSV	subsurface safety valve
TMCP	thermo-mechanically controlled process
ULS	ultimate limit states
UT	ultrasonic testing
VIV	vortex-induced vibration
WPS	welding procedure specification
WPQ	welding procedure qualification

4 Types of Fixed Steel Offshore Structure

4.1 General

A fixed steel offshore structure can take many forms, including the following:

- a) braced caisson (3.1.8);
- b) free-standing caisson (3.1.23);
- c) jacket (3.1.26, see 4.2);
- d) monotower (3.1.33);
- e) tower (3.1.56, see 4.3);
- f) steel gravity structure (3.1.49);
- g) jack-up (3.1.27, see 4.4).

This document specifies requirements for braced caissons, free-standing caissons, jackets, monotowers, and towers. Some of the requirements may also be used, as appropriate, for other forms of steel bottom founded offshore structures. The design of other forms of fixed steel bottom founded offshore structures shall achieve a level of reliability consistent with that intended by this document.

There have been historical differences in the usage and understanding of the terms “jacket” and “tower,” particularly between the United States and Europe. The difference in such understanding of the terms has no significant impact on the application of this document as long as the differences in structural behavior are considered in the analyses of the different structures.

There have been historical differences, which continue to exist, in the use and understanding of the term “caisson.” In the offshore oil and gas industry, this term, together with its variants “braced caisson” or “free-standing caisson” (see, respectively, 3.1.8 and 3.1.23), has traditionally been used to refer to a particular type of minimum fixed structure, where the main component is a relatively large diameter tubular member, with or without additional lateral support, intended to satisfy various functional requirements such as supporting one or more wells, or supporting small decks and associated facilities. Conversely, in the geotechnical arena the term “caisson” has traditionally been used to refer to “foundation caisson,” i.e. foundation component/system consisting of shorter and more rigid chamber of larger diameter or larger lateral dimensions than the caisson structures described above.

Section 17 covers the geotechnical design of long slender piles (i.e. satisfying the condition $L/D \geq 10$, where L is the length embedded in the soil, and D is the outside diameter) for fixed steel structures. The provisions of that section apply also to braced or free-standing caisson structures with $L/D \geq 10$. However, the content of Section 17 does not apply to the design of short and rigid, large diameter foundations with $L/D < 10$. Guidance on the geotechnical design of this type of foundations is within the scope of API 2GEO.

4.2 Jackets

Jackets and towers are superficially similar structures, the essential differences between them being the arrangement of the foundation piles and, associated with this, the location of axial force transfer from the structure and topsides into the piles. The location and method of transferring the axial forces result in significant differences in the behavior of jackets and towers.

A jacket is a welded tubular space frame with three or more vertical (or near vertical) tubular chords (the legs) and a bracing system between the legs. The jacket provides support for the foundation piles, conductors, risers, and other appurtenances.

A jacket foundation includes leg piles that are inserted through the legs and are connected to the legs either at the top, by welding or mechanical means, or along the length of the legs, by grouting. Additional piles, called “skirt piles,” can be inserted through and connected to sleeves at the base of the structure. Leg and skirt piles jointly anchor the structure and transfer both vertical and horizontal loads/actions to the seabed.

Where the foundation piles are connected to the legs only at the top of the jacket, the axial forces (including moments caused by shear forces) are transferred to the piles at the connection and the jacket “hangs” from the piles.

Where the foundation piles are connected to the legs by grouting along the full length of the leg, the jacket behavior is similar to that of a tower, with the legs and piles acting together as composite components.

4.3 Towers

A tower type structure is supported by foundation arrangements at the base of the structure.

The tower is again made of a welded tubular space frame with three or more vertical (or near vertical) tubular chords, called “legs,” with a bracing system between the legs. The tower provides support for the topsides, conductors, risers, and other appurtenances.

A tower foundation usually includes cluster piles that are inserted through and connected to sleeves around the (corner) legs at the base of the structure. Additional piles, called “skirt piles,” can be inserted through and connected to sleeves at the base and along the perimeter of the structure. As an alternative to piles, a tower can be supported by another nonsuperficial foundation system that supports it at its base, such as bucket foundations. Cluster and skirt piles, or another nonsuperficial foundation system, anchor the structure and transfer both vertical and horizontal loads/actions to the seabed.

The global behavior of a tower is that of a vertical cantilever, with all loads/actions being transferred to the foundation system at the base of the tower.

4.4 Jack-ups

A jack-up comprises a floating hull and one or more legs, which can move up and down relative to the hull. A jack-up reaches its operational mode by lowering the leg(s) to the sea floor and then raising the hull to the required elevation. The majority of jack-ups have three or more legs, each of which can be moved independently and which are supported on the sea floor by spudcans or mats.

The majority of jack-ups are built for short-term operations at different locations around the world. As metocean and foundation conditions vary between locations, such jack-ups are assessed for each particular location (see ISO 19905-1 [4]). A few jack-ups are purpose built for production operations at a single location, albeit that there can be an intent for eventual reuse at further locations.

Two options are available for a jack-up within the framework of the ISO 19900 series; these are as follows:

- a) design, assessment, and operation to the requirements of this document, and
- b) site-specific assessment to the requirements of ISO 19905-1 [4], in which case either the periodic inspection requirements of the IACS member or the alternative requirements for long-term deployment in ISO 19905-1 [4] shall be satisfied.

NOTE ISO 19905-1 [4] applies only to structures holding valid certification as self-elevating units from an IACS member, or equivalent.

Option a) above shall be used for a jack-up purpose built for production at a particular location and where option b) does not apply. Option b) should be used for a jack-up built to operate in a variety of locations. In other cases, when an existing jack-up is to be used for an extended period at a single location for production (rather than for exploration, appraisal, or other short-term application), the owners and regulators shall apply either the reuse requirements (see Section 23) of this document or the requirements of ISO 19905-1 [4].

When option a) is selected, some aspects of the requirements of this document do not apply, including the determination of environmental loads/actions and load/action effects due to dynamic response, structural behavior, and foundation behavior. The alternative procedures given in ISO 19905-1 [4] may be used in such cases; however, the procedures shall be modified as necessary to give an equivalent level of structural integrity to that intended by this document. The foundation strength, the foundation preload, overturning, leg chord strength, and the strength of the holding system shall be checked in accordance with the requirements of ISO 19905-1 [4].

A limitation on the use of this document for jack-ups is the strength and ductility of high-strength jack-up steels (with yield strengths of 700 N/mm² or more) for major structural components—as compared with yield strengths of less than 500 N/mm² for other conventional fixed steel offshore structures. The designer or assessor of such jack-up units shall take note of the limitations of this document for steels with yield strengths higher than 500 N/mm² and shall obtain sufficient data to justify the design for such cases.

5 Planning

5.1 General

Adequate planning should be completed before actual design is started in order to obtain a safe, workable, and economical offshore structure. The initial planning should include the determination of all limit states, design situations, and design criteria upon which the design of the structure is to be based, following the general requirements and conditions specified in ISO 19900.

5.2 Foundations and Active Geological Processes

The capacity and suitability of the foundations and the susceptibility to active geological processes shall be assessed in selecting the type of structure and the location. Requirements and guidance are given in Section 17 and in API 2GEO.

5.3 Design for Inspection and Maintenance

ISO 19900 notes that “Structural integrity, serviceability throughout the intended service life, and durability are not simply functions of the design calculations but are also dependent on the quality control exercised in construction, the supervision on site, and the manner in which the structure is used and maintained.” Therefore, during the planning stage, a philosophy for inspection and maintenance should be developed. The design of the structure as a whole, as well as the structural details, should be consistent with this philosophy. In preparing the philosophy, a realistic assessment should be made of the ability to actually achieve the intended quality of the results of inspection and maintenance efforts. This assessment should be taken into account when progressing the design and fine-tuning design situations and criteria. Relevant requirements related to inspection and maintenance requirements are given in API 2SIM.

5.4 Design Situations and Criteria

Design situations as used herein include all the service and operational requirements resulting from the intended use of the structure and the environmental conditions that can affect the design of the structure in accordance with ISO 19900. In the absence of site-specific information on the environmental conditions, API 2MET contains indicative values for the extreme conditions in certain areas. These values may be used for conceptual design

studies. The owner shall review the validity of these values and, if necessary, use site-specific data for the final design of a structure (see also 6.3.2 and 7.3). Criteria that are to be met by the design are directly related to the specific formulation of the design situations. Therefore, design situations and design criteria shall not be separated from one another. They are jointly specified in Sections 8 to 17.

5.5 Regulations

The requirements of national regulations and standards where a structure will be used can be different from those given in this document. It shall be ensured that the requirements of safety, reliability, and durability implicit in the requirements of this document are met. This applies to all phases of planning, design, fabrication, transportation, installation, service, and removal.

6 Overall Considerations

6.1 Service and Operational Considerations

6.1.1 General Considerations

The principal service and operational requirements to be considered to establish the design basis for fixed steel offshore structures are summarized in ISO 19900. Operational requirements include the following:

- service requirements, i.e. function of the platform;
- manning;
- conductors and risers;
- equipment and material layouts, including rig access to conductor slots;
- personnel and material transfer;
- motions and vibrations;
- any special requirements;
- location and orientation.

In addition, requirements for decommissioning and removal should be considered.

6.1.2 Water Depth

The water depth, surge height, and tide should be determined as accurately as possible, so that elevations can be established for boat landings, fenders, decks, and corrosion protection; see API 2MET for information on these parameters. The potential subsidence of the sea floor and settlement of the structure shall be evaluated when determining the design water depth.

6.1.3 Structural Configuration

6.1.3.1 General

Requirements for the structural configuration are given in ISO 19900; some further requirements are given in 6.1.3.2 and 6.1.3.3.

6.1.3.2 Deck Elevation

Large forces result when waves strike a platform's deck and equipment. To avoid this, the bottom of the lowest deck shall be located at an elevation that will clear the calculated crest of the design wave with adequate allowance for safety to allow the passage of wave crests of abnormal values (see A.6.1.3.2). For new platforms in the Gulf of Mexico, the elevation for the underside of the deck shall not be lower than the 1000-year return period maximum crest elevation provided in API 2MET or site-specific data developed in accordance with the requirements of API 2MET.

An air gap, the distance between the maximum crest elevation used for deck clearance and the bottom of steel on the lower deck, shall be provided for any known or predicted long-term seafloor subsidence, both regional and that due to hydrocarbon extraction. An additional air gap should be allowed to account for structures that experience significant structural rotation or "set down."

In general, no platform components, piping, or equipment should be located below the lower deck. However, when it is unavoidable to position such items as minor subcellars, sumps, drains, or production piping below bottom of steel on the lower deck, provisions should be made for the wave forces developed on these items. These wave forces may be calculated using the crest pressure of the design wave applied against the projected area. These forces may be considered on a "local" basis in the design of the item. These provisions do not apply to vertical members such as deck legs, conductors, risers, etc., which normally penetrate the air gap. The design process accounts for forces on those vertical members.

Whenever this requirement is not satisfied, the structure shall be designed to resist any wave and current loads/actions on the deck(s), including the loads/actions on facilities or equipment supported by the deck(s).

6.1.3.3 Equipment and Material Layouts

Layouts and centers of gravity associated with permanent and variable loads/actions, as defined in 9.2, are required in the development of the design. Heavy concentrated loads/actions on the structure should be located such that proper framing to support these loads/actions can be planned. When possible, consideration should be given to maintenance requirements and future operations.

If portable equipment or materials are to be placed on a lower deck, then adequately sized hatches shall be provided and conveniently located in the upper decks.

6.1.4 Access and Auxiliary Systems

The number and location of stairways and access boat landings on the structure should, as a minimum, be governed by safety considerations. Consideration should be given to providing access to the water level for sea escape and to facilitate self-rescue in man-overboard situations. Furthermore, operating requirements as well as installation, maintenance, and inspection requirements should be considered in determining the number and location of access platforms, walkways, and stairways.

6.2 Safety Considerations

6.2.1 General

The safety of life, environment, and property depends upon the ability of the structure to withstand the loads/actions for which it was designed and to survive the environmental conditions that can occur. Good practice dictates the use of certain structural additions, equipment, and operating procedures such that injuries to personnel and the risks of accidental events are minimized.

6.2.2 Accidental Events

Personnel safety and possible damage to or loss of the structure require that attention be given to accidental events as summarized in ISO 19900. With regard to methods of protecting against fires and explosions, the selection of the system depends upon the function of the platform. Procedures should conform to any applicable national or regional requirements and shall be in accordance with API 2FB. Additional guidance is given in API 2TOP.

6.3 Environmental Considerations

6.3.1 General

Information on the consideration of environmental conditions and their use is provided in ISO 19900. Further requirements and information are contained in API 2MET, as well as in this document that provides specific guidance for the US Gulf of Mexico area.

6.3.2 Selecting Design Metocean Parameters and Load/Action Factors

The reliability of a structure depends on the combination of design loads/actions and design resistances. The design loads/actions are the product of selected representative loads/actions and associated partial load/action factors. Representative environmental loads/actions are governed by the selection of appropriate metocean (meteorological and oceanographic) parameters for design. As a guide, the recurrence interval for metocean design parameters should be several times the design service life of the structure.

Unless noted otherwise, design in accordance with this document shall be based on extreme values with probabilities of exceedance of the order of 10^{-2} per annum, e.g. a return period of 100 years. Where the data are available and sufficient, the 100-year return period may apply to responses (load/action effects) of the structure instead of to metocean design parameters. Further requirements and guidance are provided in Section 9 and in API 2MET.

A robustness level analysis (see 10.5) is required for new platforms based on risk considering life-safety and consequence of failure, as noted in 6.4. Requirements depend on the exposure category (see Table 6.4-1) and platform configuration. Guidelines are also provided in Table 6.3-1 for selecting the abnormal/robustness level hydrodynamic force criteria (see 10.1.5) to be used in the required abnormal/robustness ultimate strength analysis. Information on ultimate strength analysis is provided in API 2SIM.

Table 6.3-1—Gulf of Mexico Design Criteria and Robustness Analysis

Exposure Category	Design Criteria	Robustness Level Ultimate Strength Analysis
L-1 ^a	Use the 100-year full population and associated conditions from API 2MET or site-specific data developed in accordance with the requirements of API 2MET	Use the 1000-year full population wave and associated conditions from API 2MET or site-specific data developed in accordance with the requirements of API 2MET
L-2	Use the 50-year full population and associated conditions from API 2MET or site-specific data developed in accordance with the requirements of API 2MET	Not required if L-2 exposure category platform has a robust configuration For nonrobust configurations, use the 500-year full population wave and associated conditions from API 2MET or site-specific data developed in accordance with the requirements of API 2MET
L-3	Use the 25-year full population and associated conditions from API 2MET or site-specific data developed in accordance with the requirements of API 2MET	Not required
^a Manned nonevacuated platforms are presently not applicable to the US Gulf of Mexico waters where platforms are normally evacuated ahead of hurricane events. The metocean design criteria in 6.3 have not been verified as adequate for manned nonevacuated in the US Gulf of Mexico. However, the winter storm, sudden hurricane, and earthquake criteria for the US Gulf of Mexico have been verified as adequate for the manned nonevacuated situation occurring during those events when platforms in the US Gulf of Mexico waters are not normally evacuated.		

An L-2 exposure category platform has a robust configuration if it has all of the following characteristics.

- a) The structure has four or more legs.
- b) The lower deck bottom of beam elevation is above the 1000-year return “max crest elevation” provided in API 2MET, or site-specific data are developed in accordance with the requirements of API 2MET.
- c) The piles are founded in competent soils that are not susceptible to mudslide or other type of seafloor instability.
- d) The nominal sections of any ungrouted legs have a maximum D/t ratio of 50 at the nominal sections between the joint cans. Alternately, piles are grouted to the jacket leg for the full length of the leg.
- e) The vertical framing transmitting shear forces between horizontal frames consists of X-braces, or single (leg-to-leg) diagonals, arranged such that shear between horizontal frames is carried by braces in both tension and compression. K-bracing cannot be used. See Figures 6.3-1 and 6.3-2.
- f) Horizontal members are provided between all adjacent legs at horizontal framing levels in vertical frames and these horizontal members have sufficient strength in compression to support the redistribution of loads/actions resulting from any buckling of adjacent diagonal braces. See Figure 6.3-2.
- g) The slenderness ratio $(K \cdot L/r)$ of primary diagonal bracing in vertical frames is limited to no more than 80 and $(F_y D)/(Et) \leq 0.069$.
- h) Joints for primary structural members are sized for either the tensile yield load or the compressive buckling load of the members framing into the joint, as appropriate for the ultimate behavior of the structure. This can be accomplished by increasing the 50 % minimum cord capacity requirement of 14.2.3 to 100 % for in-place design conditions.
- i) All pile-jacket shim connections are complete 360-degree welded connections with smooth curved crown shims designed to reduce stress concentrations that affect fatigue life and are designed to carry the ultimate capacity of the pile.

Any robustness level analysis shall follow the ultimate strength analysis procedures provided in API 2SIM.

Extreme metocean parameters for the Gulf of Mexico are provided in API 2MET. Specific annual conditions are also provided in API 2MET with information on how to combine different wave, wind, and currents.

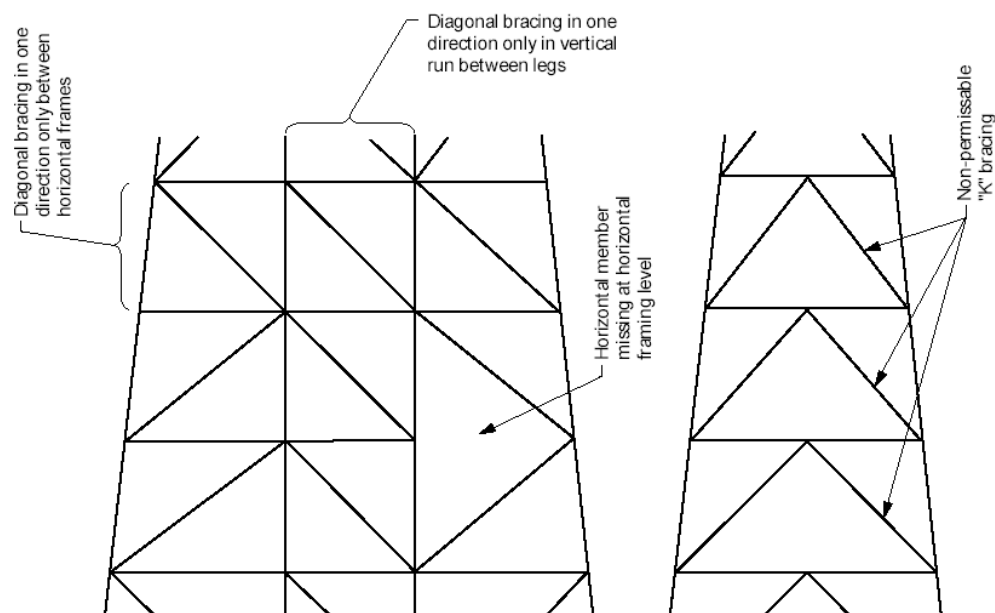


Figure 6.3-1—Vertical Framing Configurations Not Meeting Robustness Requirements

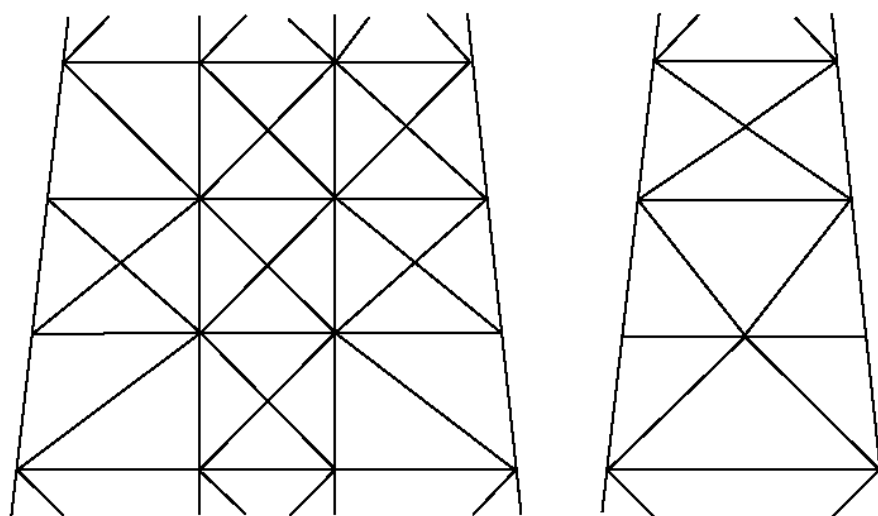


Figure 6.3-2—Vertical Framing Configurations Meeting Robustness Requirements

In addition to specifying extreme and abnormal metocean parameters, the owner shall specify the limiting environmental conditions for performing any particular operation inducing specific loads/actions, or for any particular situation of the platform.

6.4 Exposure Levels

6.4.1 General

Structures can be categorized by various levels of exposure to determine criteria that are appropriate for the intended service of the structure. This applies to the design of new structures and to the assessment of existing structures. The levels are determined by consideration of life-safety and of environmental and economic consequences.

The life-safety category addresses personnel on the platform and the likelihood of successful evacuation before a design environmental event occurs.

The consequence category considers the potential risk to life of personnel brought in to react to any incident, the potential risk of environmental damage, and the potential risk of economic losses.

6.4.2 Life-safety Categories

The category for life-safety should be selected from the following options with specific requirements.

a) S1—Manned Nonevacuated

The manned nonevacuated category refers to a platform that is continuously (or nearly continuously) occupied by persons accommodated and living thereon, and from which personnel evacuation prior to the design environmental event is either not intended or impractical.

A platform shall be categorized as S1 manned nonevacuated unless the particular requirements for S2 or S3 apply throughout the design service life of the platform.

b) S2—Manned Evacuated

The manned evacuated category refers to a platform that is normally manned except during a forecast design environmental event. For categorization purposes, a platform shall not be categorized as a manned evacuated platform unless:

- 1) reliable forecast of a design environmental event is technically and operationally feasible, and the weather between any such forecast and the occurrence of the design environmental event is not likely to inhibit an evacuation;
- 2) prior to a design environmental event, evacuation is planned;
- 3) sufficient time and resources exist to safely evacuate all personnel from the platform, and all other platforms are likely to require evacuation for the same storm.

c) S3—Unmanned

The unmanned category refers to a platform that is only manned for occasional inspection, maintenance, and modification visits. For categorization purposes, a platform shall not be categorized as unmanned unless:

- 1) visits to the platform are undertaken for specific planned inspection, maintenance, or modification operations on the platform itself;
- 2) visits are not expected to last more than 24 hr during seasons when severe weather can be expected to occur;
- 3) the evacuation criteria 1) to 3) for S2 manned evacuated platforms are also met.

A platform in this category may also be described as “not normally manned.”

It is recognized that life-safety category definitions include a degree of judgment. The owner of the structure shall determine the applicable category prior to the design of a new structure or the assessment of an existing structure and shall obtain the agreement of the regulator where applicable.

6.4.3 Consequence Categories

Factors that should be considered in determining the consequence category include:

- life-safety of personnel on or near to the platform brought in to react to any consequence of failure, but not personnel who are part of the normal complement of the platform;
- damage to the environment; and
- anticipated losses to the owner, to other installation owners, to industry, and/or to other third parties as well as to society in general.

The consequence category shall be selected from the following options with specific requirements.

a) C1—High Consequence Category

The high consequence category refers to platforms with high production rates or large processing capability and/or those platforms that have the potential for well flow of either oil or sour gas in the event of platform failure. In addition, it includes platforms where the shut-in of the oil or sour gas production is not planned, or not practical, prior to the occurrence of the design event (such as areas with high seismic activity). Platforms that support trunk oil transport lines and/or storage facilities for intermittent oil shipment are also considered to be in the high consequence category.

A platform shall be categorized as C1, high consequence, unless the particular requirements for C2 or C3 apply throughout the design service life of the platform.

b) C2—Medium Consequence Category

The medium consequence category refers to platforms where production can be shut-in during the design event. For categorization purposes, a platform shall not be categorized as medium consequence unless:

- 1) all wells that can flow on their own in the event of platform failure contain fully functional subsurface safety valves (SSSVs), manufactured and tested in accordance with applicable specifications;
- 2) oil storage is limited to process inventory and “surge” tanks for pipeline transfer;
- 3) pipelines are limited in their ability to release hydrocarbons, either by virtue of inventory and pressure regime, or by check valves or seabed safety valves.

c) C3—Low Consequence Category

The low consequence category refers to minimal platforms where production can be shut-in during the design event. These platforms may support production departing from the platform and low volume in-field pipelines. For categorization purposes, a platform shall not be categorized as low consequence unless:

- 1) all wells that can flow on their own in the event of platform failure contain fully functional SSSVs, manufactured and tested in accordance with applicable specifications;
- 2) oil storage is limited to process inventory;
- 3) pipelines are limited in their ability to release hydrocarbons, either by virtue of inventory and pressure regime, or by check valves or seabed safety valves.

It is recognized that consequence category definitions include a degree of judgment. The owner of the structure shall determine the applicable category prior to the design of a new structure or the assessment of an existing structure and shall obtain the agreement of the regulator where applicable.

6.4.4 Determination of Exposure Level

The three categories for both life-safety and consequence can, in principle, be combined into nine exposure levels. However, the level to be used for structure categorization is the more restrictive level for either life-safety or consequence.

This results in three exposure levels as illustrated in Table 6.4-1.

Table 6.4-1—Determination of Exposure Level

Life-safety Category	Consequence Category		
	C1 High Consequence	C2 Medium Consequence	C3 Low Consequence
S1 Manned nonevacuated	L-1	L-1	L-1
S2 Manned evacuated	L-1	L-2	L-2
S3 Unmanned	L-1	L-2	L-3

The exposure level applicable to a structure shall be determined by the owner prior to the design of a new structure or the assessment of an existing structure, and be agreed upon by the regulator where applicable.

Platform categorization may be revised over the design service life of the structure as a result of changes in factors affecting life-safety or consequence category.

6.5 Assessment of Existing Structures

Any assessment of existing structures to confirm that they comply with this document or are fit-for-service shall be performed in accordance with the assessment requirements of API 2SIM.

6.6 Structure Reuse

Structures may be removed and relocated for use at a new location. When this is considered, the structure should be assessed in accordance with the assessment requirements of Section 23, for the use (including exposure level) and conditions that are applicable at the new location. Any repairs or modifications that are necessary shall be in accordance with this document.

7 General Design Requirements

7.1 General

The general principles on which structural design requirements are based are documented in ISO 19900. ISO 19900 requires that structural design be performed with reference to a specified set of limit states. For each limit state, design situations shall be determined and an appropriate calculation model shall be established. ISO 19900 describes the following:

- the variables that occur in a calculation model, comprising geometrical parameters, loads/actions, and properties of materials and soils;
- the analyses to be performed;
- the design format using partial load/action and partial resistance factors.

This section outlines the overall requirements for the following:

- incorporating limit states (see 7.2);
- determining design situations (see 7.3);
- structural modeling and analysis (see 7.4);
- design of the structure (see 7.5 to 7.11).

These requirements are a minimum.

7.2 Incorporating Limit States

The limit state categories are as follows.

- a) Ultimate limit states (ULS): The design loads/actions to be used in the various ULS are specified in Sections 8, 9, and 11. The design resistances and the application of the ULS are specified in Sections 13, 14, 15, and 17.
- b) Serviceability limit states (SLS): The design shall comply with the serviceability requirements of caissons, conductors, risers, and topsides interfaces, as defined by the owner.

NOTE See also commentary in A.17.3.4 c) on estimating caisson or pile tilt for SLS checks.

- c) Fatigue limit states (FLS): The various FLS are addressed in Section 16, covering methods, loads/actions, and resistances. Additionally, FLS requirements for grouted connections, mechanical connections, and clamps are given in Section 15.
- d) Accidental limit states (ALS): ALS are addressed in Section 10, in respect of loads/actions and modifications to both partial load/action factors and partial resistance factors.

7.3 Determining Design Situations

Determination of situations for which structures are to be designed is the responsibility of the owner in accordance with the requirements of a regulator, where one exists. Aspects to be considered in determining design situations should include the following:

- a) service requirements for the intended function of the structure;
- b) expected service life for each function;
- c) method and duration of construction activities;
- d) expected method of removal of the structure and, where applicable, any intended relocation;
- e) hazards (accidental and abnormal events) to which the structure can be exposed during its service life;
- f) potential consequences of partial or complete structural failure;
- g) the nature and severity of environmental conditions (meteorological, oceanographic, and active geological processes) to be expected during its construction and service life.

Usually, three sets of environmental conditions should be considered: one associated with operating situations (normal conditions), one associated with extreme conditions, and one associated with abnormal conditions.

7.4 Structural Modeling and Analysis

Internal forces in components shall be determined by an analysis method that is suitable for statically indeterminate structures and that accounts for bending as well as for axial load/action effects. In general, a linear elastic model of the structure is sufficient; however, the nonlinear behavior of structure-foundation interaction shall be addressed. For piled foundations, the nonlinear behavior of the axial and lateral pile-soil support shall be explicitly modeled to ensure load-deflection compatibility between the structure and pile-soil system. For a pile analysis, the effects of geometrical and material nonlinearities shall also be assessed within the structure-pile-soil system. In no case shall additional or adjusted partial load/action factors be used as a substitute for a rational analysis to determine internal forces. Other aspects of structural modeling and analysis are discussed in Sections 8 to 17 and API 2SIM.

7.5 Design for Pre-service and Removal Situations

The structure should be designed to resist loads/actions occurring during fabrication, loadout, transportation, installation, and removal, as specified in Section 8. For structures that are intended to be relocated to new sites, loads/actions resulting from removal, on-loading, transportation, upgrading, and re-installation shall also be considered in the design, in addition to the above construction loads/actions.

Methods for fabrication, assembly, loadout, transportation, installation, and removal of the structure should be considered during design in order to identify potential difficulties and limitations for available equipment. Design situations for partially fabricated components of the structure and for the assembled structure as a whole should be established. Fabrication and assembly tolerances assumed in design should be compatible with those specified in the construction specifications and achievable during construction.

7.6 Design for the In-place Situation

The structure should be designed to resist permanent loads/actions, variable loads/actions, environmental loads/actions, repetitive loads/actions, and accidental loads/actions occurring during its service life, as well as rational combinations thereof, to obtain the most onerous conditions for all structural components. The representative values of these loads/actions are given in Sections 9 to 11. Clarification on the selection of representative values and return periods is provided in A.7.6.

7.7 Determination of Resistances

7.7.1 General

The resistances of components in a fixed steel offshore structure shall, wherever possible, be derived from the formulae given in Sections 13 to 15. These formulae provide representative resistances to which the partial resistance factors are applied.

Where the resistance of a component is not adequately described in Sections 13 to 15, the resistances shall be determined from a rational study of the behavior of the component. Both physical testing and computer simulation may be used to derive representative resistances, but in both cases the results shall be compared to any other available test data.

7.7.2 Physical Testing to Derive Resistances

Physical tests may be used to derive resistances for specific components. Care shall be taken to account for the differences between the test arrangements and the arrangement of the component within the structure. Guidance on these differences is given in A.7.7.2.

Comparisons shall be made with other available test data to give an indication of the variability of the component behavior.

7.7.3 Resistances Derived from Computer Simulations Validated by Physical Testing

Computer simulations can provide an indication of resistance and can be particularly valuable for investigating the effects of changes of various parameters. Computer simulations shall be validated against physical test data wherever possible. If test data are not available, the requirements of 7.7.5 apply.

7.7.4 Resistances Derived from Computer Simulations Validated Against Design Formulae

As an alternative to validation against physical test data, computer simulations may be validated against the formulae given in Sections 13 to 15. It should be noted that Sections 13 to 15 give representative resistances and therefore take account of structural behavior variability.

7.7.5 Resistances Derived from Unvalidated Computer Simulations

Unvalidated computer simulations may only be used when no physical test data or design formulae are available. The similarity of available data and the component being simulated is a matter of judgment, and the analyst shall take account of statistical variability of material and component behavior, and limitations and errors that can be introduced in computer simulations.

7.8 Strength and Stability Checks

7.8.1 Load/Action and Resistance Factors

A partial load/action factor shall be applied to each of the external loads/actions in the combinations given in Sections 8 to 11. The combination of factored representative loads/actions results in design values of internal forces. These internal forces are designated by the symbol S in Sections 8 to 11.

A partial resistance factor is applied to the strength of each member, joint, and foundation component to determine its design resistance.

7.8.2 Strength and Stability Equations

Each component shall be proportioned to resist the internal forces, S . The appropriate strength and stability equations are given in Sections 13, 14, 15, and 17. These equations comprise the following:

- the formulae for the representative strength of the component;
- the partial resistance factors;
- the internal force, S , from the design loads/actions specified in Sections 8 to 11.

7.8.3 Unfactored Loads/Actions

Where loads/actions are time-varying and nonsynchronous, the most onerous values of load/action effects cannot generally be determined by simply adding factored individual loads/actions. In some construction and installation situations, the load/action effects are best computed from unfactored loads/actions and by investigating the sensitivity of the load/action effects with realistic variations of the governing parameters. The design values of the internal forces, S , may then be obtained by factoring the load/action effects by the partial load/action factors given in Section 8.

7.9 Robustness

A structure shall incorporate robustness as noted in 6.3 and through assessment of the effects of all hazards and their probabilities of occurrence, to ensure that consequent damage is not disproportionate to the cause. Damage from an event with a reasonable likelihood of occurrence shall not lead to complete loss of integrity of the structure. In such cases, the structural integrity in the damaged state shall be sufficient to allow a process system close down and a safe evacuation (see Section 10).

Robustness is achieved by either of the following:

- a) designing the structure such that the failure of any single load-bearing component carrying its normal design loads/actions will not cause the collapse of the structure or any significant part thereof, or
- b) ensuring (by design or by protective measures) that no critical component exposed to hazard can be made ineffective, or
- c) a combination of a) and b), above.

7.10 Reserve Strength

7.10.1 New Structures

All new structures complying with this document are intended to have a similar margin of system reserve strength for the same exposure level (L-level). The system reserve strength gives the structure a margin to withstand load/action effects that exceed the design load/action effects and is evaluated as the reserve strength ratio (RSR), R_{RS} , expressed in Equation (7.10-1).

$$R_{RS} = F_{\text{collapse}}/F_{100} \quad (7.10-1)$$

where

F_{collapse} is the unfactored global environmental load/action that, when co-existing unfactored permanent and variable loads/actions are added, causes collapse of the structure;

F_{100} is the unfactored 100-year global environmental load/action calculated in accordance with Section 9.

This intent may be achieved in either of two ways, as described in 9.10. The partial load/action factors for environmental loads/actions shall be determined based on the guidelines given in Section 9.

When using this document for structures that provide less inherent system reserve strength (smaller RSR) for the environmental loads/actions than a typical space frame type structure, the partial load/action factor for environmental loads/actions shall be increased to yield the same RSR as for a typical space frame type structure.

7.10.2 Existing Structures

During its service life, the reserve strength of a structure can vary (increase or decrease) due to a variety of causes. API 2SIM provides requirements for the assessment of existing structures, including the use of system strength approaches.

7.11 Indirect Loads/Actions

Consideration should be given to internal forces and stresses induced by indirect loads/actions, including imposed or constrained deformations, temperature changes, relaxation, and prestressing.

7.12 Structural Reliability Analysis

A description of structural reliability analysis (SRA) can be found in A.7.12.

8 Loads/Actions for Pre-service Situations

8.1 General

Users of this document should be aware of API 2MOP. Where the provisions in API 2MOP overlap with this document, API 2MOP may be used in preference unless noted otherwise.

8.1.1 Coverage

This section presents requirements for pre-service situations. The requirements apply both to the structure and to any temporary components such as buoyancy aids, mooring supports, or sea-fastening attached to the structure for pre-service situations. The primary objective is to ensure that a structure begins its service life at an offshore location with its required strength and structural integrity intact. The section covers the following topics:

- a) the type of loads/actions to be included;
- b) procedures for determining representative values for the loads/actions;
- c) the partial load/action factors to be applied;
- d) methods for determining the internal forces due to the effect of factored loads/actions or combinations of factored loads/actions.

8.1.2 Situations

Pre-service design situations are transient in nature and include:

- a) fabrication (including assembly during fabrication);
- b) loadout (including float-out);
- c) transportation;
- d) installation (including launching and uprighting).

Further requirements concerning pre-service situations are given in Sections 19 to 22.

The requirements for b), c), and d) are primarily addressed in API 2MOP; however, some aspects are also addressed within this document.

Loads/actions on (parts of) the structure and internal forces in components of the structure should be calculated for each phase of pre-service in accordance with the principles given in 7.3 to 7.5.

Structural modeling and analysis requirements for the pre-service situations are given in 12.4.3, and operational requirements for loadout, transportation, and installation are given in Section 22.

8.2 General Requirements

8.2.1 Design Situations

Design situations during pre-service situations are generally governed by permanent and variable loads/actions. These loads/actions are predominantly static in nature, in particular due to weights of structural components, appurtenances, and equipment. When dynamic effects can be important, these should be considered. When appropriate, environmental and accidental loads/actions should also be given due attention, following the requirements of Sections 9 and 10.

8.2.2 Weight Control

The weight and center of gravity of each structure or part of a structure should be evaluated during design and during all pre-service situations. This applies in particular prior to any lifting being performed. Where applicable, allowances for weight variations based on weight reports, the status of design and/or fabrication, known outstanding items and/or operational modifications to the structures should be applied.

During pre-service situations the behavior of the structure and the magnitude and distribution of internal forces in the structure can be very sensitive to the position of the center of gravity. In such cases, due allowances shall be made for uncertainties and potential changes in the position of the center of gravity.

NOTE Guidance on weight control is given in ISO 19901-5 [5].

8.2.3 Dynamic Effects

If operations during pre-service situations involve significant motion of large masses, the dynamic loads/actions involved should be considered.

The load/action effects should be adjusted to arrive at adequate representative internal forces for the design of the components affected. These representative internal forces can be derived from an appropriate analysis to determine the static and dynamic effects due to both the external loads/actions and the motion, or they can be based on relevant previous experience.

For dynamic effects during lifting, see the requirements given in 8.3.2.

8.2.4 Internal Forces

8.2.4.1 Internal Forces due to Factored Loads/Actions

Each member, joint, and other relevant component shall be checked for strength using the internal force (load/action effect) (S) resulting from the design load/action (F_d).

The design load/action, F_d , is due to the following:

- factored permanent loads/actions (G);
- factored variable loads/actions (Q);
- factored quasi-static transient loads/actions (T).

Equation (8.2-1) defines F_d for situations not involving lift (additional factors are applied for lift conditions; see 8.3.6):

$$F_d = \gamma_{f,GT} G_T + \gamma_{f,QT} Q_T + \gamma_{f,T} T \quad (8.2-1)$$

where

G_T is the load/action imposed either by the weight of the structure in air during the transient situation being considered, including any permanent equipment or other objects and any piles or conductors installed on the structure;

Q_T is the load/action imposed by the weight of the temporary equipment or other objects, including any rigging installed or carried by the structure, during the transient situation being considered;

T represents the loads/actions from the transient situation being considered, including:

- 1) when appropriate, environmental loads/actions;
- 2) when appropriate, a suitable representation of dynamic effects (see A.8.1 and 8.2.4.2);
- 3) for lifting, the effects of fabrication tolerances and variances in sling length as detailed in 8.3.3 and for a multi-crane lift as detailed in 8.3.4;

$\gamma_{f,GT}$, $\gamma_{f,QT}$ and $\gamma_{f,T}$ are the partial load/action factors.

The three design situations in Table 8.2-1 shall all be assessed.

Table 8.2-1—Partial Load/Action Factors for Calculating Internal Forces

Situation	Partial Load/Action Factor		
	$\gamma_{f,GT}$	$\gamma_{f,QT}$	$\gamma_{f,T}$
1	1.3	1.3	1.0
2	1.1	1.1	1.35
3	0.9	0.9	1.35
NOTE 1 Situation 1 governs for components in which permanent and variable load/action effects are dominant.			
NOTE 2 Situation 2 governs for components in which transient load/action effects are dominant and in which the permanent and variable loads/actions increase the magnitudes of the internal forces.			
NOTE 3 Situation 3 governs for components in which transient load/action effects are dominant, but in which the permanent and variable loads/actions decrease the magnitudes of the internal forces.			

Additional requirements and factors for lifting situations are given in 8.3.

8.2.4.2 Internal Forces due to Unfactored Loads/Actions

In some situations, it is not possible or appropriate to apply load/action factors to each of the individual actions (see A.8.1 and 7.8.3). An example of such a situation is lifting in which substantial dynamic or nonlinear effects can occur. In such cases, each member, joint, and other relevant component shall be checked for strength using the internal force (load/action effect) (S) determined from the following equations:

$$F_{un} = G_T + Q_T + T$$

$$S = \gamma_{f,Sun} S_{un} \quad (8.2-2)$$

where

F_{un} is the total load/action due to the unfactored loads/actions G_T , Q_T , and T defined in 8.2.4.1;

S_{un} is the internal force resulting from F_{un} ;

$\gamma_{f,Sun}$ is the partial factor to be applied to S_{un} , usually 1.3.

Additional requirements and factors for lifting situations are given in 8.3.

If both this method and the one according to 8.2.4.1 can be applied, that giving the more onerous result shall be used.

8.3 Loads/Actions Associated with Lifting

8.3.1 General

Lifting imposes static and dynamic loads/actions on the structure during pre-service situations. The magnitude of these loads/actions shall be based on the weight of the (part of the) structure to be lifted and shall be determined considering static and dynamic equilibrium during the lift. The internal forces in the structure and in the lifting slings and rigging equipment (e.g. spreader bars) should be derived from a rational analysis of the lifting arrangement. General guidance on lifting is given in A.8.3.1.

Dynamic amplification (see 8.3.2), as well as the effects of fabrication and sling length tolerances (see 8.3.3), and weight and center of gravity location inaccuracies (see 8.2.2), should be included in such rational analysis.

Additional factors and considerations apply to members adjacent to lifting attachments (see 8.3.5), and to the lifting attachments themselves (see 8.3.6 and 8.3.7).

Alternative lift criteria can be appropriate, for example, when the characteristics of, and interactions between, the structure and crane are fully understood. Alternative criteria may be used, subject to demonstration of a margin of safety, consistent with the requirements of this document, and to the agreement of the owners of the structure, the contractors, and any appropriate regulator or warranty surveyor.

8.3.2 Dynamic Effects

Dynamic effects of onshore crane(s) taking up load(s)/action(s) and movements of either the crane or the lifted structure shall be accounted for by the use of a dynamic amplification factor (DAF), k_{DAF} , as specified in Table 8.3-1 (extracted from Table 15 in API 2MOP, First Edition). For offshore lifts, reference is made to 8.7.1.

Table 8.3-1—Dynamic Amplification Factor for a Single Onshore Crane

Mass of Lifted Object * tonnes	Gross Weight W kN	k_{DAF} in Air	
		Moving	Static
≤ 100	$W \leq 1000$	1.15	1.00
From 100 to 1000	$1000 < W \leq 10,000$	1.10	1.00
From 1000 to 2500	$10,000 < W \leq 25,000$	1.05	1.00
Greater than 2500	$25,000 < W$	1.05	1.00
* This column is included to facilitate comparison with weight reporting.			

NOTE The lifting DAFs are in accordance with certification society rules such as Lloyds ^[58] and are addressed in API 2MOP.

8.3.3 Effect of Tolerances

Both fabrication misalignments in the structure and sling length variability affect the distribution of forces in the lifting system. However, the effects of fabrication misalignments may be ignored provided they fall within the tolerances specified in Annex E (see 12.3.3.1); 12.3.3.1 also provides for modeling requirements in the cases where fabrication misalignments exceed those specified in Annex E.

When sling length variability does not exceed the greater of 0.25 % of the nominal sling length or 40 mm (sling length tolerance), the effect of sling length variability may be ignored in the analysis of statically determinate lifts, i.e. lifts involving three or fewer slings, although such analyses do not normally account for changes in, e.g. centers of gravity.

However, the effect of sling length variability shall be accounted for when executing statically indeterminate lifts. The requirements and partial load/action factors specified in 8.2.4, 8.3.1, and 8.3.2 apply to situations where the variability in sling length does not exceed the sling length tolerance. Sling forces or sling lengths shall be varied in a stiffness analysis of the structure and lifting system so as to determine the redistribution of forces in both slings and structural members. A.8.3.3 provides specific guidance on how this may be conducted. The resulting sling forces shall be increased by a factor of not less than 1.25 (1.15 for floating spreader beams) to determine the required safe working load of the sling in 8.3.8; the local effects on the structure shall be checked using the local factor given in 8.3.5.

Where sling length variability exceeds the sling length tolerance, the guidance provided in A.8.3.3 may be followed while the resulting sling forces shall be increased by a factor of not less than 1.40. A lower factor may be adopted if both sling stiffnesses and sling lengths have been measured and the analysis performed using these measured values: in no case shall a factor less than 1.25 be used.

8.3.4 Multi-crane Lift

For an onshore lift using multiple cranes, an additional rigging factor should be considered in lieu of assessment of the effects of differential soil settlement under the cranes. Unless special and reliable investigations are performed to substantiate lower values, a minimum value of such a rigging factor of $\gamma_{f,dl} = 1.10$ shall be applied. For single crane lifts, $\gamma_{f,dl} = 1.00$. (In API 2MOP, this factor is referred to as “dual lift rigging factor.”)

Where a multi-crane lift is used, the most onerous orientations of the structure shall be assessed and the design of lifting attachments shall allow for any necessary rotation of the lifting arrangements.

NOTE See API 2MOP.

8.3.5 Local Factor

Due to local inaccuracies that often occur in the analysis of internal force distributions around the lifting points, a further factor ($\gamma_{f,lf}$), for both statically determinate and statically indeterminate lifts, shall be applied to account for the importance of the structural components involved. This local factor includes the effects of tolerances (see 8.3.3) and shall be applied in addition to the DAF (k_{DAF}) in accordance with 8.3.2 and the rigging factor ($\gamma_{f,dl}$) in accordance with 8.3.4.

- For lifting attachments (padeyes, trunnions, padears), spreader beams, and internal members (including both end connections) framing into the joint where the lifting attachment is located and transmitting lift forces, the local factor $\gamma_{f,lf}$ shall be 1.15.
- For other structural members, $\gamma_{f,lf} = 1.00$.

8.3.6 Member and Joint Strengths

The DAF (k_{DAF}), the multi-crane lift factor ($\gamma_{f,dl}$), and the local factor ($\gamma_{f,lf}$) shall be applied to either the factored loads/actions to determine the design load/action (F_d) as in Equation (8.2-1), giving Equation (8.3-1), or to unfactored loads/actions to give the internal forces (S) as in Equation (8.2-2), giving Equation (8.3-2):

$$F_d = k_{DAF} \gamma_{f,dl} \gamma_{f,lf} (\gamma_{f,GT} G_T + \gamma_{f,QT} Q_T + \gamma_{f,T} T) \quad (8.3-1)$$

$$S = k_{DAF} \gamma_{f,dl} \gamma_{f,lf} \gamma_{f,Sun} S_{un} \quad (8.3-2)$$

where

$\gamma_{f,GT}$, G_T , $\gamma_{f,QT}$, Q_T , $\gamma_{f,T}$, T , $\gamma_{f,Sun}$, S_{un} are as defined in 8.2.4 and incorporate the effects of sling length variability as discussed in 8.3.3;

k_{DAF} is as specified in 8.3.2;

$\gamma_{f,dl}$ is as specified in 8.3.4;

$\gamma_{f,lf}$ is as specified in 8.3.5.

8.3.7 Lifting Attachments

Lifting attachments can be of various forms, including the following.

- Padeyes— where a shackle pin passes through a hole in a padeye plate attached to or built into the structure, the sling being connected to the shackle. The padeye plate is normally reinforced to increase strength and avoid undue slack between the shackle and the padeye, thereby reducing eccentricity between the padeye plate and the sling.
- Trunnions— where the sling, or an eye of a sling, passes round a short tubular that transfers the forces into the structure, and that allows rotation of the sling around the axis of the trunnion. Trunnions can be arranged to carry either end of a sling on either side of a central plate.
- Padears— which are similar to trunnions, but in which rotation of the sling is not intended.

Padeye plates should be oriented in such a direction that the possibility for out-of-plane loading of the padeye plate and shackle is minimized.

To account for any side loading on lifting attachments, lifting attachments and the connections to the supporting structural members shall be designed for a lateral force of 5 % of the sling force, in addition to the calculated horizontal and vertical components of the sling force (including DAF, rigging factor, local factor, and partial load/action factors) for the equilibrium lifting condition. This lateral force acts simultaneously with the static sling force and shall be applied perpendicular to the lifting attachment at the center of the pinhole or tubular. However, where sling is out-of-plane with the padeye, the static sling force shall be applied at the bow of the shackle. Where a spreader bar is directly connected to the padeyes, a lateral force of 8 % shall be used.

Where two slings are connected to one padeye, or where a sling is doubled over a trunnion, the padeye or trunnion should be designed for a 45:55 % split of the lift point force between the two slings.

NOTE See API 2MOP.

8.3.8 Slings, Shackles, and Fittings

The calculated sling force is the maximum force on each sling, as calculated in 8.3.1 to 8.3.4, by taking into account all loads/actions, the equilibrium position of the lift, any dynamic amplification, the effect of tolerances, and multi-crane lift considerations. For normal offshore conditions, slings should have a resistance factor of 4.0

applied to the manufacturer's rated minimum breaking strength or a resistance factor of 1.0 applied to the sling safe working load compared to the worst calculated sling force. The total resistance factor includes all necessary partial resistance factors. The total resistance factor should be increased when unusually severe conditions are anticipated. Conversely, the total resistance factor may be reduced to a minimum of 3.0 for carefully controlled conditions.

Where two slings are connected to one padeye, or where a sling is doubled over a trunnion, the slings should be assumed to carry the lift point force in a 45:55 % split of the lift point force between the two slings.

Shackles and fittings should be such that the manufacturer's rated working load is greater than or equal to the calculated sling force, provided the manufacturer's specifications include a minimum resistance factor of 3.0 on the minimum breaking strength.

NOTE See API 2MOP.

8.4 Loads/Actions Associated with Fabrication

In addition to the associated permanent and variable loads/actions, the effects of wind-induced vortex shedding vibrations on long slender members during fabrication should be considered.

8.5 Loads/Actions Associated with Loadout

8.5.1 Direct Lift

Loads/actions on a structure that is lifted onto the transportation barge shall be evaluated in accordance with 8.3. If the lifting arrangement is the same as that used to offload the structure from the transportation barge at sea, it will normally suffice to check the latter load case(s) only (see 8.7.1).

NOTE See API 2MOP.

8.5.2 Horizontal Movement onto Barge

Structures skidded onto transportation barges are subject to loads/actions resulting from horizontal and/or vertical movement of the barge due to tidal fluctuations, nearby marine traffic, environmental conditions, and/or changes in draught, as well as to loads/actions derived from the location, slope, and/or settlement of supports onshore and the flexibility of the barge, at all stages of the skidding operation.

The effect of loads/actions on the structure during loadout should be investigated, taking account of the tolerances on the levels of support on land and on the barge. The effect of pulling/pushing, friction forces, and twisting of the structure due to differential horizontal jacking or winching during loadout should be considered.

In cases of loadout with trailers, the effect of wind and hydraulic pressure variation plus the distributed loads/actions imposed by hydraulic trailers and the effect of dynamic loads/actions due to the braking of the trailers should be considered. This can require consideration of the methods of controlling the elevation and alignment of trailers. Effects of inertial loads during trailer movement shall be addressed for unusually tall and slender structures.

Because movement is normally slow, impact does not need to be considered.

NOTE See API 2MOP.

8.5.3 Self-floating Structures

Self-floating structures are generally not transported on a barge but are towed while floating to the offshore location.

Self-floating structures skidded directly into the water at the fabrication yard should be analyzed to determine the loads/actions on the structures as they move down the slipways and into the floating position. Consideration should be given to local environmental conditions and dynamically induced forces.

This subsection does not apply to self-floating structures built in a dry dock and floated by flooding the dock.

8.6 Loads/Actions Associated with Transportation

8.6.1 General

Loads/actions on a structure or structural part during transportation should be considered in the design of the structure, whether it is transported on barges or is self-floating. Such loads/actions result from the way in which the structure is supported, either by barge or by buoyancy, and from the response of the towing arrangement (structure, tug boats, tow lines, and, where applicable, barge and/or additional buoyancy) to environmental conditions encountered en route to the site.

8.6.2 Environmental Conditions

For the selection of environmental conditions to be used in determining the motions of the towing arrangement and the resulting loads/actions on the structure, the sea-fastenings, and the barge system, the following should be considered:

- a) previous experience along the tow route;
- b) exposure time and reliability of predicted weather windows;
- c) accessibility of safe havens;
- d) seasonal weather systems;
- e) appropriateness of the recurrence interval used in determining design wind, wave, and current conditions in relation to the characteristics of the tow.

8.6.3 Determination of Loads/Actions

The motions of the towing arrangement due to the environmental conditions determined from 8.6.2 should be analyzed using suitable methods. Relevant requirements and guidance are provided in API 2MOP. Sea states with peak periods corresponding to the natural periods of the loaded barge, as well as peak periods corresponding to wave lengths that are critical in relation to the dimensions of the barge, shall be assessed, as these can represent governing conditions. In combining responses, the analysis shall correctly account for relative phasing between motion components (heave, pitch, roll, etc.).

Head, beam, and quartering winds and seas should be considered to determine maximum responses due to the environmental loads/actions on the overall system. In cases of large barge-transported structures, the stiffnesses of both the structure and the barge shall be included in the structural analysis.

Loads/actions on the structure, sea-fastenings, and the barge system should be derived from appropriate combinations of permanent, environmental, and inertial loads/actions resulting from the state of motion, taking due account of the position, orientation, and possible differential deformations of parts of the overall system.

8.6.4 Other Considerations

Large structures overhanging the barge are usually subjected to partial submersion during tow. Submerged members should be investigated for loads/actions due to slamming and buoyancy. These loads/actions should be included in the local and, where relevant, overall design of the structure and the sea-fastenings. Large buoyant overhanging members can also affect motions, and this effect should also be considered. The effects of vortex-induced vibrations (VIVs) due to wind on long slender members also should be investigated.

The effects of repetitive loads/actions during tow can become significant to the fatigue life of certain members, joints, or other components, especially for long transoceanic tows. These effects should be investigated using methods and acceptance criteria agreed upon by the owner and the design or transportation contractor.