Guidelines for Certification

Part 10 - Industry

Volume 2

GUIDELINES FOR OFFSHORE CONCRETE STRUCTURES

2020

Biro Klasifikasi Indonesia

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Foreword

This Guidelines provides principles, technical requirements for the design, construction and in service inspection of Offshore Concrete Structures. The general description about this guidelines in every section describe below:

Section 1 General

Section 2 Safety philosophy

Section 3 Design documentation

Section 4 Materials

Section 5 Loads and analyses requirements

Section 6 Detailed design of offshore concrete structures

Section 7 Construction

Section 8 In-service inspection, maintenance and conditional monitoring

Annex A Environmental loading

Annex B Structural analyses – model

Annex C Structural analyses

Annex D Use of alternative detailed design standard

Annex E Crack width calculation (informative)

Annex F Requirements to content in certificates for FRP bars

Annex G QA/QC system for manufacture of FRP bars

Annex H Requirements to content in certificate for structural grout

Annex I QA/QC system for manufacture of structural grout

Annex J Mock-up test requirements

Annex K Supplemental requirements for steel reinforcement specified for use with this guidelines

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Section 1 General

A. Introduction

1.1 This Guideline shall be used together with the general offshore design standards for steel structures Rules for Structures (Pt.5, Vol.II) or other equivalent standards recognized by BKI.

1.2 For design and construction of offshore concrete support structures for wind turbines, see Rules for Fixed Offshore Installation (Pt.5, Vol.VII) or other equivalent standards recognized by BKI.

1.3 For design and construction of LNG terminal structures and containment systems, see Guidelines for Floating Offshore Liquefied Gas Terminals (Pt.5, Vol.2).

B. Objective

The objectives of this Guideline are to:

- Provide a standard for the design, fabrication/construction, installation and in-service inspection of offshore concrete structures with an acceptable level of safety by defining minimum requirements for design, construction control and in-service inspection.
- Provide technical requirements for certification of cementitious structural grouts and FRP reinforcement.
- Serve as a contractual reference document between supplier and purchasers related to design, construction and in-service inspection of offshore concrete structures.
- Serve as a guideline for designer, supplier, purchasers and regulators.

C. Scope

1. The guideline comprises of eight (8) sections focusing on:

- safety philosophy
- design documentation
- materials
- loads and analysis requirements
- detailed design of offshore concrete structures
- construction
- in-service inspection,
- maintenance and condition monitoring.

2. In addition, several annexes give more detailed information. Informative annexes are non-mandatory.

- Annex A contains guidelines for evaluation of environmental loading.
- Annex B and Annex C contain guidelines for modelling and structural analysis.
- Annex D contains guidelines for the use of alternative design standards.
- Annex E contains guidelines for calculation of crack widths.
- Annex F specifies requirements for fibre reinforced polymer (FRP) bars subject to BKI certification service
- Annex G contains minimum requirements for the QA/QC system for manufacture of FRP bars.
- Annex H specifies requirements for cementitious grouts subject to BKI certification services.
- Annex I contains minimum requirements for the QA/QC system for manufacture of structural grout and fibre
- Annex J contains minimum requirements for mock-up testing for cementitious grouts subject to BKI certification services.
- Annex K contains minimum requirements for steel reinforcement specified for use with this guideline.

3. This Guideline specifies:

- Principles, technical requirements and guidelines for the design, fabrication/construction, installation and in-service inspection of offshore concrete structures.
- Minimum technical requirements for certification of cementitious structural grouts and FRP reinforcement.

4. This guideline covers fixed and floating structures where reinforced concrete, prestressed concrete and cementitious grout are used as structural materials.

5. In addition to the requirements provided in this guideline, it is the responsibility of the designer, owner and operator to comply with additional requirements that may be imposed by the flag state or any other jurisdictions in the intended area of deployment and operation.

D. Application

1. General

1.1 The Guidelines may be used in the design, fabrication/construction, installation and in-service inspection of the following types of support structures, which are referred in this guideline as offshore concrete structures:

- gravity based structures (GBS) for oil/gas production offshore
- GBS for oil/gas production with oil/gas storage facility
- floating concrete structures for production/storage of oil/gas. The structure may be of any type: floating
- structure, e.g. tension leg platform (TLP), column stabilized units
- barge units
- deep-water caisson type concrete foundation of bridges
- floating foundations for bridges, parking houses or storage buildings
- other types of offshore/nearshore concrete structures.

1.2 The development and design of new concepts for offshore concrete structures requires a systematic hazard identification process in order to mitigate the risk to an acceptable risk level. Hazard identification is therefore a central tool in this guideline.

E. References

1. General

In this guideline, when dated references of BKI guideline are presented, only the edition cited applies. For undated references, the latest edition of the referenced document (including amendments) applies.

2. Standards other than BKI guideline

2.1 In case of conflict between the requirements of BKI guideline and a reference document other than BKI guideline, the requirement of BKI guideline shall prevail.

2.2 The provision for using standards other than BKI guideline is that the same safety level as provided by this BKI guideline is obtained.

2.3 Where reference is made to standards other than BKI guideline, the valid revision shall be taken as the revision which is current at the date of issue of this guideline, unless otherwise noted.

3. References

3.1 The standards in Table 1.1 include provisions, which through reference in this text constitute provisions and acceptable methods for fulfilling the requirements of this guideline.

3.2 Other recognised standards may be applied provided it is documented that they meet or exceed the level of safety of this BKI guidelines, see Annex D.

Table 1.1 BKI References

Reference	Title
Part 5, Vol II	Rules for structures
Part 5, Vol VII	Rules for Fixed Offshore Installation
Part 5, Vol 2	Guidelines for Floating Offshore Liquefied Gas Terminal
Part 1, Vol. IX	Rules for Ships Carrying Liquefied gases in bulk
Part 1, Vol. V	Rules for Materials
Part 5, Vol. IX	Rules for single point mooring
Part 5, Vol. C	Guidance for buckling and ultimate strength
Part 5, Vol. B	Guidance for Fatigue assessment

Table 1.2 Other references

Reference	Title
ACI 440.1R-15	Guide for the Design and Construction of Structural Concrete Reinforced with Fibre Reinforced Polymer (FRP) Bars
ACI 440.3R-12	Guide Test Methods for Fibre-Reinforced Polymer (FRP) Composites for Reinforcing or Strengthening Concrete and Masonry Structures
ACI 440-4R–04	Prestressing Concrete Structures with FRP Tendons
ACI 440R-07	Report on fibre-reinforced polymer (FRP) reinforcement for concrete structures.
ASTM C114	Standard Test Method for Chemical Analysis of Hydraulic Cement
ASTM C150	Standard Specification for Portland Cement
ASTM C157	Standard Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete

Table 1.2 Other references *(Continued)*

Reference	Title
ASTM C187	Standard Test Method for Amount of Water Required for Normal Consistency of Hydraulic Cement Paste
ASTM C191	Standard Test method for Time of Setting of Hydraulic Cement by Vicat Needle
ASTM C204	Standard Test Method for Fineness of Hydraulic Cement by Air-Permeability Apparatus
ASTM C230	Standard Specification for Flow Table for Use in Tests of Hydraulic Cement
ASTM C348	Standard Test Method for Flexural Strength of Hydraulic Cement Mortars
ASTM C403	Standard Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance
ASTM C457	Standard Test Method for Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete
ASTM C469	Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression
ASTM C490	Standard Practice for Use of Apparatus for the Determination of Length Change of Hardened Cement Paste, Mortar, and Concrete
ASTM C496	Standard Test Method for Splitting Tensile strength of Cylindrical Concrete Specimens
ASTM C512	Standard Test Method for Creep of Concrete in Compression
ASTM C666	Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing
ASTM C940	Standard Test Method for Expansion and Bleeding of Freshly Mixed Grouts for Preplaced Aggregate Concrete in the Laboratory
ASTM C1437	Standard Test Method for Flow of Hydraulic Cement Mortar
ASTM C1581	Standard Test Method for Determining Age at Cracking and Induced Tensile Stress Characteristics of Mortar and Concrete under Restrained Shrinkage
ASTM C1698	Standard Test Method for Autogenous Strain of Cement Paste and Mortar
CSA S806-12	Design and construction of building structures with fibre-reinforced polymers
CSA A23.1-14	Concrete materials and method of concrete construction
CSA A23.2-14	Test methods and standard practices for concrete
EN 196-1	Methods of testing cement – Part 1: Determination of strength
EN 196-2	Methods of testing cement – Part 2: Chemical analysis of cement
EN 196-3	Methods of testing cement – Part 3: Determination of setting times and soundness
EN 196-6	Methods of testing cement – Part 6: Determination of fineness
EN 206	Concrete - Specification, performance, production and conformity
EN 445	Grout for prestressing tendons - Test methods
EN 447	Grout for prestressing tendons - Basic requirements
EN 1015-6	Methods of test for mortar for masonry - Part 6: Determination of bulk density of fresh mortar
EN 1015-7	Methods of test for mortar for masonry - Part 7: Determination of air content of fresh mortar
EN 12350-6	Testing fresh concrete - Part 6: Density
EN 12350-7	Testing fresh concrete - Part 7: Air content - pressure methods
EN 12350-8	Testing fresh concrete - Part 8: Self-compacting concrete - Slump flow test
EN 12390-1	Testing hardened concrete - Part 1: Shape, dimensions and other requirements for specimens and moulds
EN 12390-2	Testing hardened concrete - Part 2: Making and curing specimens for strength tests
EN 12390-3	Testing hardened concrete - Part 3: Compressive strength of test specimens
EN 12390-6	Testing hardened concrete - Part 6: Tensile splitting strength of test specimens
EN 12390-7	Testing hardened concrete – Part 7: Density of hardened concrete
EN 12504-1	Testing concrete in structures - Part 1: Cored specimens - Taking, examining and testing in compression
EN 13670	Execution of concrete structures
EN 13791	Assessment of in-situ compressive strength in structures and precast concrete components
ISO 1920-4	Testing of concrete - Part 4: Strength of hardened concrete
ISO 10406-1	Fibre-reinforced polymer (FRP) reinforcement of concrete – Test methods – Part 1 FRP bars and grids

Table 1.2 Other references *(Continued)*

Reference	Title
ISO 19900	Petroleum and natural gas industries – General requirements for offshore structures
ISO 19901-1	Petroleum and natural gas industries – Specific requirements for offshore structures – Part 1: Metocean design and operating considerations
ISO 19901-2	Petroleum and natural gas industries – Specific requirements for offshore structures – Part 2: Seismic design procedures and criteria
ISO 19901-4	Petroleum and natural gas industries – Specific requirements for offshore structures – Part 4: Geotechnical and foundation design considerations
ISO 19901-8	Petroleum and natural gas industries – Specific requirements for offshore structures – Part 8: Marine soil investigations
ISO 19903	Petroleum and natural gas industries – Fixed concrete offshore structures
MC2010	fib Model Code for Concrete Structures 2010
NORSOK	N-003 Actions and Actions Effects
NORSOK	N-004 Design of Steel Structures
SINTEF STF22 A98741	Eurocrete. Modifications to NS3473 when using fibre reinforced plastic (FRP) reinforcement

F. Definitions

1. Terms

Terms and definitions as shown in Table 1.3 are used in this guideline.

Table 1.3 Definitions of terms

Terms	Definitions
abnormal level earthquake (ALE)	intense earthquake of abnormal severity under the action of which the structure should not suffer complete loss of integrity
accidental limit states (ALS)	limit state related to the possibility of the structure to resist accidental loads and maintain integrity and performance of the structure due to local damage or flooding
accidental loads (A) aggregates	rare occurrences of abnormal environmental loads, fire, flooding, explosions, dropped objects, collisions, unintended pressure differences, thermal shock due to LNG spilling or overflow, etc. constituent material of concrete or grout added to increase volume, weight or durability of the material Aggregates are the main constituent, both with respect to volume and weight, in a structural concrete mix. They may generally be divided into two groups, these being: sand or fine aggregate (materials less than 5 mm) and coarse aggregate (materials larger than 5 mm).
air gap	free distance between the design wave and the underside of a topside structure supported on columns allowing the wave to pass under the topside structure
as-built documentation	documentation of the offshore structure as finally constructed Section 3, A.5 presents the list of documents that are part of the as-built documentation.
atmospheric zone	the external surfaces of the unit above the splash zone
cathodic protection	technique to prevent corrosion of a steel surface by making the surface to be the cathode of an electrochemical cell
cement	binder component in a structural concrete or grout mix
cement grout	general term referring to grout batched at the work site consisting of mainly cement and water May refer to neat cement grout or a cement and water mix with a limited dosage of admixtures added during batching.

Table 1.3 Definitions of terms *(Continued)*

Terms	Definitions
certification	third-party issue of a statement, based on a decision following review, that fulfilment of specified requirements has been demonstrated related to products, processes or systems Review shall in this context mean verification of the suitability, adequacy and effectiveness of selection and determination activities, and the results of these activities, with regard to fulfilment of specified requirements by an object of conformity assessment.(ISO 17000:2004).
certification service	the process of performing certification in accordance with a service specification and with a BKI certificate as deliverable.
characteristic load	reference value of a load to be used in the determination of load effects The characteristic load is normally based upon a defined fractile in the upper end of the distribution function for load.
characteristic material strength	nominal value of material strength to be used in the determination of the design resistance The characteristic material strength is normally based upon a 5% fractile in the lower end of the distribution function for material strength.
characteristic value	representative value associated with a prescribed probability of not being unfavourably exceeded during some reference period
classification	a service which comprises the development and maintenance of rules, and the verification of compliance with the rules throughout the Vessels' life. The extent of and methods for verifying compliance will be decided by the Society to establish reasonable assurance that the relevant rules are complied with.
coating	metallic, inorganic or organic material applied to steel surfaces for prevention of corrosion
concrete grade	parameter used to define the concrete strength
corrosion allowance	extra wall thickness added during design to compensate for any anticipated reduction in thickness during the operation
cryogenic temperature	being or related to very low temperature down to -200°C
deck mating	operations through which the deck floated on barges is mated with the concrete support structure
deformation loads (D)	loads effects on the structure caused by thermal effects, prestressing effects, creep/shrinkage effects, differential settlements/deformations, etc
design basis	document where owners' requirements in excess of this guideline should be given
design hazards	hazards likely to occur are identified as part of the risk assessment Design hazards are mitigated into the structural design of the structure.
design life	duration to which the parameters used in structural design are related
design temperature	lowest daily mean temperature in air for areas where the unit will be transported, installed and operated for the given period of operation Temperature experienced by the element due to local effects during its design life, may include influences from cargo temperature, sea temperature, operational requirements etc
design value	value used in the deterministic design procedure, i.e. characteristic value modified by the resistance factor or load factor
driving voltage	he difference between closed circuit anode potential and the protection potential
ductility	property of a steel or concrete member to sustain large deformations without failure
environmental loads (E)	loads from wind, wave, tide, current, snow, ice and earthquake
expected loads and response history	history for a specified time period, taking into account the number of load cycles, the resulting load levels and response for each cycle
expected value	most probable value of a load during a specified time period
extreme level earthquake (ELE)	earthquake with a severity which the structure should sustain without major damage When exposed to an ELE, a structure is supposed to retain its full capacity for all subsequent conditions.
fatigue	degradation of the material caused by cyclic loading
fatigue critical	structure with calculated fatigue life near the design fatigue life
fatigue limit states (FLS)	limit state related to the possibility of failure due to the effect of cyclic loading

Table 1.3 Definitions of terms *(Continued)*

Terms	Definitions
fibre mass fraction	ratio of fibre mass to total mass of FRP material within a reinforcement bar
fibre	short fibres made from steel or FRP used in structural concrete or grout
fluid	a liquid that in most cases considered will be seawater, water or oil A concrete structure might be exposed to the pressure and chemical properties of such fluids on the outer or inner face.
FRP material	fibre reinforced polymer (FRP) composite made from carbon, glass, aramid or basalt
fibre reinforced concrete	structural concrete mixed with short fibre material
fibre reinforced grout	grout mixed with short fibre material
fibre volume fraction	ratio of fibre volume to total volume of FRP material within a reinforcement bar
functional loads	permanent (G) and variable loads (Q), except environmental loads (E), to which the structure is exposed
grout	see cement grout, pre-blended grout, fibre reinforced grout and structural grout
hazards identification	List of critical situations that will have the potential to cause, or contribute substantially to a major accident if they happen to fail The list is based on consequence of failure only, not on likelihood of failure of the individual hazards.
headed reinforcement (T-heads)	headed reinforcement bars are ordinary reinforcement bars with circular, square or rectangular shaped steel plates attached at one or both ends, generally by means of friction welding
high strength concrete	concrete of grade in excess of C65
hindcasting	method using registered meteorological data to reproduce environmental parameters, which is mostly used for reproducing wave parameters
inspection	activities such as measuring, examination, testing, gauging one or more characteristics of an object or service and comparing the results with specified requirements to determine conformity
live loads of permanent character	live loads that the structure may be exposed to for its entire service life or a considerable part of it, e.g. weight of furniture, stored goods etc
live loads of variable character	live loads that the structure may be exposed to only for limited durations much less than the service life, such as e.g. weight of occupants and (not permanently stored) vehicles
light weight aggregate (LWA)	aggregates made from expanded clay, expanded shale, slate or sintered pulverized ash from coal-fired power plants, or from other materials with corresponding documented properties in accordance with the requirements of recognized standards e.g. ASTM, ACI, EN.
light weight aggregate concrete (LWAC)	concrete made with lightweight aggregates conforming to requirements contained in recognized standards, e.g. relevant ASTM, ACI or EN standard The provisions of this guideline are valid only for LWAC having a lower limit of oven-dry density of 1200 kg/m^3 and an upper limit of 2200 kg/m^3.
limit state	state beyond which the structure no longer satisfies the performance requirements. The following categories of limit states are of relevance for structures: ULS = ultimate limit states FLS = fatigue limit states ALS = accidental limit states SLS = serviceability limit states
limit state design	design of the offshore concrete structure in the limit states of ULS, SLS, FLS and ALS
load and resistance factor design (LRFD)	method for design where uncertainties in loads are represented with a load factor and uncertainties in resistance are represented with a material factor
load effect	effect of a single design load or combination of loads on the equipment or system, such as stress, strain, deformation, displacement, motion, etc.

Table 1.3 Definitions of terms *(Continued)*

Terms	Definitions
lowest daily mean temperature	lowest value on the annual mean daily average temperature curve for the area in question,. for temporary phases or restricted operations the lowest daily mean temperature may be defined for specific seasons Mean daily average temperature = the statistical mean average temperature for a specific calendar day. — Mean: statistical mean based on number of years of observations. — Average: average during one day and night.
lowest waterline	typical light ballast waterline for ships, transit waterline or inspection waterline for other type of units
mill certificate	document made by the manufacturer of cement which contains the results of all the required tests and which certifies that the tests have been carried out by the manufacturer on sample taken from the delivered cement itself
neat cement grout	grout made from a mixture of cement and water only
non-cementitious materials	materials such as epoxy and polyurethane which are specially made for use together with structural concrete to improve the concrete properties or to supplement, repair or replace the concrete.
non-destructive testing (NDT)	testing techniques used to evaluate the properties of materials, components or systems without causing damage such as rebound hammer, resistivity, radiographic, ultrasonic, impact eco for concrete testing and radiography, ultrasonic or magnetic powder methods for inspection of welds
normal strength concrete	concrete of grade C35 to C65
normal weight concrete	ordinary concrete with an oven-dry density of at least 2200 kg/m^3 and an upper limit of 2600 kg/m^3
offshore concrete structure	fixed and floating structures where reinforced concrete, prestressed concrete and cementitious grout are used as structural materials.
offshore standard	a BKI Rules, Guidelines, Guidances that contain technical requirements, principles and acceptance criteria related to certification and classification of offshore units
offshore installation	general term for mobile and fixed structures and facilities which are intended for exploration, drilling, production, processing or storage of hydrocarbons including installations intended for accommodation of personnel engaged in these activities The term covers subsea installations and pipelines but not traditional shuttle tankers, supply boats and other support vessels which are not directly engaged in the activities described above.
one-compartment damage stability	characteristic of a floating object which remains stable even if one of its compartments is flooded
operating conditions	conditions wherein a unit is on location for purposes of production, drilling or other similar operations, and combined environmental and operational loadings are within the appropriate design limits established for such operations (including normal, survival and accidental)
partial load factor	is part of the safety approach and varies in magnitude for the different load categories dependent on the individual uncertainties in the characteristic loads
permanent functional loads (G)	self-weight, ballast weight, weight of permanent installed parts of mechanical outfitting, external hydrostatic pressure, prestressing force, etc.
post-tensioned reinforcement	reinforcement (normally tendons, wires, strands or bars) placed inside ducts and tensioned after the concrete has hardened
potential	voltage between a submerged metal surface and a reference electrode
pre-blended grout	grout proportioned at a factory following strict QA/QC procedures and delivered to site for mixing with a predefined proportion of water May refer to pre-packed and silo stored/transported products.
prestressing systems	tendons (wires, strands, and bars), anchorage devices, couplers and ducts or sheaths are part of a prestressing system May refer to pre-tensioned or post-tensioned systems.

Table 1.3 Definitions of terms *(Continued)*

Terms	Definitions
pre-tensioned reinforcement	reinforcement (normally wires or strands) tensioned before concrete has been placed
product certificate	certificate to document conformity with the requirements of the applicable standard. It lists material properties documented through testing Test samples shall be taken from the delivered products themselves and testing, or a part there-of shall be performed in the presence of a third party or in accordance with special agreements.
product data sheet	sheet issued by the manufacturer with data about the product which may contain design data for the product and may be appended to product or type approval certificate
quality plan	plan implemented to ensure quality in the design, construction and in-service inspection/maintenance
reinforcement	constituents of structural concrete providing the tensile strength that will give the reinforced concrete its ductile characteristics, in this guideline, reinforcement is categorised as: —ordinary reinforcement —prestressing reinforcement —fibre reinforced polymer reinforcement (limited to carbon, glass, aramid and basalt) —special reinforcement.
robustness	a robust structure is a structure with low sensitivity to local changes in geometry and loads
redundancy	the ability of a component or system to maintain or restore its function when a failure of a member or connection has occurred, for instance by introducing alternative load paths or force redistribution
reference electrode	electrode with stable open-circuit potential used as reference for potential measurements
reliability	the ability of a component or a system to perform its required function without failure during a specified time interval
repair materials	materials used to structurally repair the offshore concrete structure
risk	qualitative or quantitative likelihood of an accidental or unplanned event occurring considered in conjunction with the potential consequences of such a failure In quantitative terms, risk is the quantified probability of a defined failure mode times its quantified consequence.
risk based inspection	decision making technique for inspection planning based on risk – comprising the probability of failure and consequence of failure
service temperature	reference temperature on various structural parts of the unit used as a criterion for the selection of steel grades or acceptable crack width, etc. in SLS
service life	expected lifetime, or the expected period of use in service of the facility or structure
serviceability limit states (SLS)	limit state corresponding to the criteria applicable to normal use or durability
sheaths	ducts for post-tensioning tendons, typically taken to be of semi rigid or rigid type, water tight and with adequate stiffness to prevent damages and deformations
short term tensile strength	the strength of a FRP bar characterized in a standard test in terms of the rupture strength due to tension that increases at a constant rate till rupture, typically over 1 – 5 minutes
slamming	impact load on a member from a rising water surface as a wave passes May also occur within tanks due to stored liquids.
sloshing	effects caused by the movement of liquid inside a container, which is typically also undergoing motion
S-N curve	is a plot of the magnitude of an alternating stress versus the number of cycles to failure for a given material
specified minimum yield strength (SMYS)	the minimum yield strength prescribed by the specification or standard under which the material is purchased

Table 1.3 Definitions of terms *(Continued)*

Terms	Definitions
specified value	minimum or maximum value during the period considered which may take into account operational requirements, limitations and measures taken such that the required safety level is obtained
splash zone	external surfaces of the unit that are periodically exposed to water, the determination of which includes evaluation of waves, tidal variations, settlements, subsidence and vertical motions
stability	ability of the floating structure to remain upright and floating when exposed to small changes in applied loads The ability of a structural member to carry small additional loads without buckling.
standards	technical requirements and acceptance criteria. In the context of this document, the term standard shall be understood to cover document types such as codes, guidelines and recommended practices in addition to bona fide standards.
structural concrete	cementitious composite material which is the main ingredient for construction of concrete structures
structural grout	a cementitious material which is part of the load carrying system of the structure with a characteristic compressive strength higher than 35 MPa containing cement, water and often additions, admixtures and appropriate fine aggregates Structural grout may be cement grout, pre-blended grout and fibre reinforced grout.
submerged zone	part of the unit which is below the splash zone, including buried parts
survival condition	condition during which a unit may be subjected to the most severe environmental loadings for which the unit is designed when operations such as drilling may have been discontinued due to the severity of the environmental loadings The unit may be either afloat or supported on the sea bed, as applicable.
target safety level	nominal acceptable probability of structural failure
temporary phase conditions	design conditions not covered by operating conditions, e.g. conditions during fabrication, mating and installation phases, transit and towing phases, accidental conditions
test report	document made by the manufacturer which contains the results of control tests on current production, carried out on products having the same method of manufacture as the consignment, but not necessarily from the delivered products themselves
tensile strength	for steel it is the minimum stress level where strain hardening is at maximum or at rupture For concrete it is the direct tensile strength
text	tow size in grams per km length of tow or fibre
time to rupture	time it takes from when a specified load is applied until this load causes rupture of the FRP bar, may refer to both fatigue and stress rupture normally, the time to rupture under a constant sustained load is measured
tow	untwisted bundle of fibres in the form they are delivered on bobbins by the fibre supplier (synonym: roving, untwisted yarn)
transit conditions	unit movements from one geographical location to another
type approval certificate (TAC)	BKI certificate documenting approval of conformity with specified requirements on the basis of a systematic examination of one or more specimens of a product representative for the production
ultimate limit states (ULS)	limit state corresponding to the maximum load carrying resistance
unit	general term for an offshore structure
utilization factor	fraction of anode material that may be utilised for design purposes
variable functional loads (Q)	weight and loads caused by the normal operation of the offshore structure which may vary in position, magnitude and direction during the operational period and includes; modules, gas weight, stored goods, pressure of stored components, pressures from stored LNG, temperature of LNG, loads occurring during installation, operational boat impacts, mooring loads etc.

Table 1.3 Definitions of terms *(Continued)*

Terms	Definitions
verification	confirmation, through the provision of objective evidence (analysis, observation, measurement, test, records or other evidence), that specified requirements have been fulfilled (ISO 9000:2015)
yarn	twisted bundle of fibres, twisted tow
works certificate	document signed by the manufacturer stating conformity with BKI rule requirements, that tests are carried on samples taken from the delivered product itself and that tests are witnessed and signed by a qualified department of the manufacturer

2. Abbreviations

Abbreviations as shown in Table 1.4 are used in this guideline.

Table 1.4 Abbreviations

Abbreviations	In full
A	Accidental loads
ACI	American Concrete Institute
AISC	American Institute of Steel Construction
ALE	abnormal level earthquake
ALS	Accidental limit states
API	American Petroleum Institute
ASR	Alkali silica reaction
ASTM	American Society for Testing and Materials
BS	British Standard (issued by British Standard Institute)
CoG	Centre of gravity
D	Deformation loads
DDF	Deep draught floaters
E	Environmental loads
ELE	extreme level earthquake
EN	European norm
ETM	Event tree method
ESD	Emergency shut down
FLS	Fatigue limit state
FM	Fracture mechanics
FMEA	Failure mode effect analysis
FRP	fibre reinforced polymer
FTM	Fault tree method
G	Permanent loads
HAT	Highest astronomical tide
HAZOP	Hazop and operability study
HISC	Hydrogen induced stress cracking
HPC	high performance concrete
HS	High strength
IGC	International gas carrier
IMO	International maritime organisation
ISO	International organisation of standardisation
LAT	Lowest astronomic tide
LNG	Liquified natural gas
LRFD	Load and resistance factor design
LWA	Light weight aggregate concrete
LWAC	lightweight aggregate concrete
MPI	Magnetic particle inspection
MSA	manufacturing survey arrangement
MSF	Module support frame

Table 1.4 Abbreviations (*Continued)*

Abbreviations	In full
MSL	Mean sea level
NACE	National Association of Corrosion Engineers
NDT	Non-destructive testing
NS	Norwegian standard
NW	Normal weight concrete
OPC	ordinary Portland cement
QRA	Quantitative risk analysis
RP	Recommended practice
SLS	Serviceability limit state
SMYS	specified minimum yield stress
TAC	type approval certificate
TTR	time to rupture
ULS	ultimate limit state
UR	utilization ratio
W/C	Water to cement ratio in a mix, may include pozzolanic or latent hydraulic additions

3. Symbols - Greek characters

3.1 Symbols, Greek characters, as shown in Table 1.5 are used in this guideline.

Table 1.5 Greek characters

α	angle between transverse shear reinforcement and the longitudinal axis also angle between the reinforcement and the contact surface, where only reinforcement with an angle between 90° and 45° (to the direction of the force) shall be taken into account.
α_c	factor applicable to E_{cn} and f_{cn} for offshore concrete structures Section 6, C.1.11
α_f	thermal expansion coefficient of FRP reinforcement
α_t	factor applicable to f_{tn} for offshore concrete structures. Section 6, C.1.11
β	opening angle of the bend Section 6, L.1.12
δ	deflection
Δ_σ	stress variation of the reinforcement (MPa) Section 6, M.2.2
ε	strain
ε_1	average principal tensile strain Section 6, H.1.7
ε_{cu}	max strain, NW concrete (2,5 m – 1,5) ε_{cn} Section 6,C.1.14
ε_{cm}	mean stress dependent tensile strain in the concrete at the same layer and over the same length as ε_{sm} Section 6, O.8.2
ε_{cs}	free shrinkage strain of the concrete (negative value) Section 6, O.8.2
ε_{s1}	tensile strain in reinforcement slightly sensitive to corrosion on the side with highest strain Section 6, O.3.7
ε_{s2}	tensile strain at the level of the reinforcement sensitive to corrosion Section 6, O.3.7
ε_{sm}	mean principal tensile strain in the reinforcement in the crack's influence length at the outer layer of the reinforcement Section 6, O.8.2
γ_c	material coefficient concrete
γ_f	partial load factor
γ_m	material factor (material coefficient)
γ_s	material factor for steel reinforcement

Table 1.5 Greek characters *(Continued)*

γ_F	material factor to account for statistical variation in the material strength, potential placement inaccuracy in the section due to the physical characteristics of the bars and the level of control implemented during manufacturing of FRP bars
γ_{FI}	material factor to be used for ULS check with load combination type I for FRP bars
γ_{FII}	material factor to be used for ULS check with load combination type II for FRP bars
γ_{FIII}	material factor to be used for ULS check with load combination type III for FRP bars
$\gamma_{F,ssa}$	material factor to be used for long term safe service life assessment for FRP bars
γ_{FA}	material factor to be used in accidental limit states for FRP bars
γ_{FE}	material factor applied to Young's modulus to account for long term creep of the FRP bars It is used to determine strains and deformations for ULS, SLS, FLS and ALS.
γ_{FS}	material factor to be used in serviceability limit states for FRP bars
ℓ	geometric slenderness ratio
ℓ_N	force dependent slenderness
θ	angle between the inclined concrete compression struts and the longitudinal axis in the truss model method
ϕ	diameter of the reinforcement bar
ϕ_e	equivalent diameter in term of reinforcement cross-section
μ	friction coefficient
ρ	coefficient of Findley's creep rate equation
ρ	density
ρ_F	density of FRP bars
ρ_f	fibre density
ρ_m	matrix density
ρ_x	reinforcement ratio in x – direction = $A_{sx}/(b \cdot d)$
ρ_y	reinforcement ratio in y – direction = $A_{sy}/(b \cdot d)$
η	limit for cumulative damage ratio
η_b	conversion factor for bends for the bend radiuses covered
$\eta_{f,TTR}$	conversion factor derived from the characteristic time to rupture curve for the load durations under consideration
η_T	conversion factor for tensile strength of FRP reinforcement from room temperature to specified service temperature
$\eta_{t_{emp}}$	temperature constant to allow for inaccuracies in maintaining and recording low temperatures during grout/ concrete testing as well as inaccuracies associated with temperature forecasting offshore Annex H
φ	creep coefficient
σ_F	stress in a FRP bar in response to specified loading (referred to nominal bar area)
σ_f	stress in the fibres in a FRP bar in response to specified loading (referred to net fibre area)
σ_c	concrete stress due to long-term loading
σ_d	design stress
σ_M	edge stress due to bending alone (tension positive) Section 6, O.8.1
σ_{max}	numerically largest compressive stress, calculated as the average value within each stress block
σ_{min}	numerically least compressive stress, calculated as the average value within each stress-block
σ_N	stress due to axial force (tension positive) Section 6,O.8.1

Table 1.5 Greek characters *(Continued)*

σ_P	steel stress due to prestressing
σ_{trough}	stress at the trough of the stress cycle (minimum stress)
σ_{peak}	peak stress of the stress cycle (maximum stress)
τ_{cd}	bond strength
$\tau_{b\max}$	maximum bond stress within fatigue stress block
$\tau_{b\min}$	minimum bond stress within fatigue stress block
v_f	volume fraction of fibre in FRP bar

4. Symbols - Latin characters

Symbols, Latin characters, as shown in Table 1.6 are used in this guideline.

Table 1.6 Latin characters

Symbol	Description
A	distance from the face of the support
A_1	loaded area
A_2	assumed distribution area
A_c	concrete area of a longitudinal section of the beam web
A_c	cross-sectional area of uncracked concrete
A_{cf}	effective cross section area of the flange, $h_f\ b_{eff}$
A_F	cross-sectional area of FRP reinforcement
A_f	Net fibre area in a FRP reinforcement bar
$A_{F,BAR}$	cross-sectional area of each FRP reinforcement bar
$A_{F,\min}$	minimum area of FRP reinforcement needed to prevent excessive cracking
$A_{F,tow}$	net fibre area of tow
$A_{F,V}$	amount of FRP shear reinforcement with spacing s [mm^2]
$A_{F,v\min}$	minimum amount of FRP shear reinforcement with spacing s [mm^2]
A_{Fs}	nominal FRP bar surface area
A_s	cross-sectional area of steel reinforcement or Reinforcement area that is sufficiently anchored on both sides of the joint and that is not utilized for other purposes
A_{st}	area of transverse reinforcement not utilized for other tensile forces and having spacing not greater than 12 times the diameter of the anchored reinforcement. If the reinforcement is partly utilized, the area shall be proportionally reduced
A_{sv}	amount of shear reinforcement
A_{sx}	amount of reinforcement in x-direction
A_{sy}	amount of reinforcement in y-direction
a_v	vertical acceleration
b_{eff}	part of the slab width which according to Section 6, A.4 is assumed as effective when resisting tensile forces
b_w	width of beam (web) [mm]
b_x	length of the side of the critical section Section 6, F.5.10

Table 1.6 Latin characters *(Continued)*

Symbol	Description
b_y	length of the side perpendicular to b_x
C	coefficient of characteristic safe service life formula for FRP bar specification
C	concrete grade (normal weight concrete)
C_1	factor on Wöhler curves concrete Section 6, M.2
C_1	minimum concrete cover, see Table 6.15
C_2	factor on Wöhler curves concrete section 6, M.2
C_2	actual nominal concrete cover
C_3	factor on Wöhler curve reinforcement Section 6, M.2
C_4	factor on Wöhler curve reinforcement Section 6, M.2
C_5	fatigue strength parameter Section 6,M.2
D	deformation load
D	distance from the centroid of the tensile reinforcement to outer edge of the compression zone
d_1	1000 mm
D_F	nominal diameter of FRP bar
D_k	diameter of the concrete core inside the centroid of the spiral reinforcement, A_{ss}
E	environmental load
e	eccentricity of loading
E_{cd}	design value of Young's Modulus of concrete used in the stress-strain curve
E_{cn}	normalized value of Young's Modulus of concrete used in the stress-strain curve
E_F	characteristic value of the Young's modulus of FRP reinforcement bar (referred to nominal bar area A_F)
E_{Fd}	design value of Young's Modulus of FRP bars
E_{sd}	design value of Young's Modulus of steel reinforcement
E_{sk}	characteristic value of Young's Modulus of steel reinforcement (200000 MPa)
f_{bc}	concrete related portion of the design bond strength in accordance with Section 6, K.1.16
f_{bd}	design bond strength, calculated in accordance with Section 6, K.1.16
f_{c2d}	truss analogy: design compressive strength Section 6, F.3.8 in the compression field General: reduced design compressive strength Section 6, G.1.7
f_{cck}	characteristic compressive cylinder strength of concrete or grout
f_{cck2}	94 MPa Section 4, C.3.7
f_{cckj}	characteristic strength of the drilled cores converted into cylinder strength for cylinders with height/diameter ratio 2:1
f_{cckt}	characteristic compressive cylinder strength at 28 days based on in-situ tests
F_{cd}	compressive capacity
f_{cd}	design compressive strength of concrete/grout
f_{ck}	characteristic concrete/grout cube strength
f_{cn}	normalized compressive strength of concrete/grout
F_d	design load

Table 1.6 Latin characters *(Continued)*

Symbol	Description
F_F	tensile force at rupture of FRP bar
f_F	characteristic short term tensile strength (force per area) of FRP bar
$f_{F,bend}$	characteristic tensile strength of bent portion of FRP bar
f_{Fb}	design strength of the bend portion of FRP bar
f_{Fd}	Design strength of FRP reinforcement
$f_{F,TTR(i)}$	characteristic tensile strength (force per area) in FRP bar until failure at considered load duration, i, derived from characteristic TTR curve. i is taken as I, II, III corresponding to load durations of 50 years, 1 year, and 1 week respectively
F_k	characteristic load
F_{rd}	reference strength for use in fatigue calculation, dependant on the type of failure in question Section 6, M.2
$F_{rd,fat}$	reference strength for use in fatigue calculation, dependant on the type of failure in question Section 6, M.2 including the material specific factor C_5
f_{sd}	design strength of steel reinforcement
f_{sk}	characteristic strength of steel reinforcement
f_{ssd}	design strength of the spiral reinforcement, A_{ss}
F_{SV}	additional tensile force in longitudinal reinforcement due to shear
f_{td}	design strength of concrete/grout in uniaxial tension
f_{tk}	characteristic uniaxial tensile strength of concrete/grout
f_{tk}	$f_{tk} + 0{,}5P_w$ for structures exposed to pressure from liquid or gas in the formulae for calculating the required amount of minimum reinforcement Section 6, Q.6.3
f_{tn}	normalized tensile strength of concrete/grout
F_{VN}	force corresponding to shear failure at cross wire welds within the development length
G	permanent load
g, g_o	acceleration due to gravity
H	cross-section height
H'	distance between the centroid of the reinforcement on the tensile" and compression side of the member
h_f	thickness of the flange (the slab)
l_c	moment of inertia of A_c
L	length of FRP bar
l_b'	development length for welded wire fabric
l_b	development length bond – bars or bundle of bars
l_{bp}	development length for the prestressing force
l_e	effective length, theoretical buckling length
L_i	distance between zero moment points
l_{sk}	influence length of the crack considering that some slippage in the bond between reinforcement and concrete may occur Section 6, C.8.2
M	$\varepsilon_{co}/\varepsilon_{cn}$
m	total moment in the section acting in combination with the shear force V_f

Table 1.6 Latin characters *(Continued)*

Symbol	Description
m_f	mass fraction of fibres (average from production records)
m_m	average mass fraction of matrix resin $\left(m_m = 1 - m_f\right)$
$\lvert M_{OA} \rvert$	numerical smallest member end moment calculated from 1. order theory at end A
$\lvert M_{OB} \rvert$	numerical largest member end moment calculated from 1. order theory at end B
m_{tex}	tow or fibre mass expressed in tex [g/km]
N	exponent of Findley's creep rate equation
N	design life of concrete subjected to cyclic stresses
n_f	$N_f / f_{cd} A_c$
N_f	design axial force (positive as tension)
n_i	number of cycles in stress-block i Section 6, M.1.8
N_i	number of cycles with constant amplitude which causes fatigue failure Section 6, M.1.8
N_x	axial force in x-direction
N_{xy}	shear force in the x-y plane
N_y	axial force in y-direction
P	load
P	pressure
P_d	design pressure
Q	variable functional load
R	radius
r_c	radius of curvature
R_d	design resistance
R_k	characteristic resistance
s	centre to centre distance between the spiral reinforcement, measured in the longitudinal direction of the column Section 6, D.1.6 or, spacing between shear reinforcement in longitudinal direction
s_1	spacing of the transverse reinforcement
S_c	area moment about the centroid axis of the cross-section for one part of the concrete section
S_d	design load effect
S_k	characteristic load effect
T	specified longitudinal tolerance for the position of the bar end
$t_{app,\max}$	maximum temperature of application, defined by the manufacturer, for a grout or fibre reinforced grout Shall be taken as +30°C in the absence of data from an elevated temperature test programme.
$t_{app,\min}$	minimum temperature of application, defined by the manufacturer, for a grout or fibre reinforced grout Shall be taken as +5°C in the absence of data from a low temperature test programme.
$t_{test,\max}$	temperature which the equipment, constituent materials and test and curing environments shall be maintained at during material testing of grout to be qualified for application at temperatures above 30°C

Table 1.6 Latin characters *(Continued)*

Symbol	Description
$t_{test,\min}$	temperature which the equipment, constituent materials and test and curing environments shall be maintained at during material testing of grout to be qualified for application at temperatures below +5°C
V_{ccd}	design shear capacity of a concrete cross-section (shear compression mode of failure)
V_{cd}	design shear capacity of a concrete cross-section (shear tension made of failure)
V_f	design shear force for the cross-section under consideration
$V_{\max}$	maximum shear force within fatigue stress block
$V_{\min}$	minimum shear force within fatigue stress block
V_{sd}	design shear capacity of transverse reinforcement (shear tension mode of failure)
W_c	section modulus of the concrete cross-section with respect to the extreme tension fibre or the fibre with least compression
w_k	nominal characteristic crack widths
z	0,9 d for sections with a compression zone
z_1	the greater of 0,7 d and I_c/S_c

5. Verbal forms

5.1 Verbal forms, as shown in Table 1.7 are used in this guideline.

Table 1.7 Definitions of verbal forms

Term	Definition
shall	verbal form used to indicate requirements strictly to be followed in order to conform to the document
should	verbal form used to indicate that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others, or that a certain course of action is preferred but not necessarily required
may	verbal form used to indicate a course of action permissible within the limits of the document

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