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BSI Group Headquarters

389 Chiswick High Road London W4 4AL

Tel: +44 (0)20 8996 9000

Fax: +44 (0)20 8996 7400

www.bsigroup.com

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Responsible Committee Secretary: Ms Asky Desta (BSI)

Direct tel: 0208 996 7171

E-mail: asky.desta@bsigroup.com

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Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

For national standards, comments will be reviewed by the relevant UK national committee and the resulting standards published as a British Standard.

UK Vote

Please indicate whether you consider the UK should submit a negative (with supporting technical reasons) or positive vote on this draft. Please indicate if you are aware of any reason why this draft standard should not be published as a British Standard.

Submission of Comments

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Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/ Figure/Table/Note	Type of comment	Comment (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	

English Version

Eurocode 1 - Actions on structures - Part 1-8: Actions from waves and currents on coastal structures

Eurocode 1 - Actions sur les structures - Partie 1-8 :
Actions des vagues et des courants sur les structures
côtières

Eurocode 1 - Einwirkungen auf Tragwerke - Teil 1-8:
Einwirkungen durch Wellen und Strömungen auf
Küstenbauwerke

This draft European Standard is submitted to CEN members for enquiry. It has been drawn up by the Technical Committee CEN/TC 250.

If this draft becomes a European Standard, CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

This draft European Standard was established by CEN in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

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Recipients of this draft are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

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COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

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European foreword

This document (prEN 1991-1-8:2024) has been prepared by Technical Committee CEN/TC 250 “Structural Eurocodes”, the secretariat of which is held by BSI.

CEN/TC 250 is responsible for all Structural Eurocodes and has been assigned responsibility for structural and geotechnical design matters by CEN.

This document is currently submitted to the CEN Enquiry.

The first generation of EN Eurocodes was published between 2002 and 2007. This document forms part of the second generation of the Eurocodes, which have been prepared under Mandate M/515 issued to CEN by the European Commission and the European Free Trade Association.

The Eurocodes have been drafted to be used in conjunction with relevant execution, material, product and test standards, and to identify requirements for execution, materials, products and testing that are relied upon by the Eurocodes.

The Eurocodes recognise the responsibility of each Member State and have safeguarded their right to determine values related to regulatory safety matters at national level through the use of National Annexes.

Introduction

0.1 Introduction to the Eurocodes

The structural Eurocodes comprise the following standards generally consisting of a number of parts:

- EN 1990, *Eurocode — Basis of structural and geotechnical design*
- EN 1991, *Eurocode 1 — Actions on structures*
- EN 1992, *Eurocode 2 — Design of concrete structures*
- EN 1993, *Eurocode 3 — Design of steel structures*
- EN 1994, *Eurocode 4 — Design of composite steel and concrete structures*
- EN 1995, *Eurocode 5 — Design of timber structures*
- EN 1996, *Eurocode 6 — Design of masonry structures*
- EN 1997, *Eurocode 7 — Geotechnical design*
- EN 1998, *Eurocode 8 — Design of structures for earthquake resistance*
- EN 1999, *Eurocode 9 — Design of aluminium structures*
- New Eurocodes under development, e.g. Eurocode for design of structural glass

The Eurocodes are intended for use by designers, clients, manufacturers, constructors, relevant authorities (in exercising their duties in accordance with national or international regulations), educators, software developers, and committees drafting standards for related product, testing and execution standards.

NOTE Some aspects of design are most appropriately specified by relevant authorities or, where not specified, can be agreed on a project-specific basis between relevant parties such as designers and clients. The Eurocodes identify such aspects making explicit reference to relevant authorities and relevant parties.

0.2 Introduction to EN 1991 (all parts)

EN 1991 specifies actions for the structural design of buildings, bridges and other civil engineering works, or parts thereof, including temporary structures, in conjunction with EN 1990 and the other Eurocodes.

EN 1991 does not cover the specific requirements of actions for seismic design. Provisions related to such requirements are given in EN 1998 (all parts), which complement and are consistent with EN 1991.

EN 1991 is also applicable to existing structures for their:

- structural assessment,
- strengthening or repair,
- change of use.

NOTE In these cases additional or amended provisions can be necessary.

EN 1991 is applicable for the design of structures where materials or actions outside the scope of the other Eurocodes are involved.

NOTE In this case additional or amended provisions can be necessary.

EN 1991 is subdivided in various parts:

- EN 1991-1-1, *Eurocode 1 — Actions on structures — Part 1-1: Specific weight of materials, self-weight of construction works and imposed loads for buildings*
- EN 1991-1-2, *Eurocode 1 — Actions on structures — Part 1-2: Actions on structures exposed to fire*
- EN 1991-1-3, *Eurocode 1 — Actions on structures — Part 1-3: Snow Loads*
- EN 1991-1-4, *Eurocode 1 — Actions on structures — Part 1-4: Wind Actions*
- EN 1991-1-5, *Eurocode 1 — Actions on structures — Part 1-5: Thermal Actions*
- EN 1991-1-6, *Eurocode 1 — Actions on structures — Part 1-6: Actions during execution*
- EN 1991-1-7, *Eurocode 1 — Actions on structures — Part 1-7: Accidental actions*
- EN 1991-1-8, *Eurocode 1 — Actions on structures — Part 1-8: Actions from waves and currents on coastal structures*
- EN 1991-1-9, *Eurocode 1 — Actions on structures — Part 1-9: Atmospheric icing*
- EN 1991-2, *Eurocode 1 — Actions on structures — Part 2: Traffic loads on bridges and other civil engineering works*
- EN 1991-3, *Eurocode 1 — Actions on structures — Part 3: Actions induced by cranes and machines*
- EN 1991-4, *Eurocode 1 — Actions on structures — Part 4: Silos and tanks*

0.3 Introduction to EN 1991-1-8

EN 1991-1-8 gives guidance for the determination of actions by waves and currents to be used for the design of structures in the coastal zone/area.

As wind is the governing physical parameter for wave generation on the sea surface and storm surge, i.e waves and design water levels are strongly correlated with wind, EN 1991-1-4 is particularly relevant in this respect.

0.4 Verbal forms used in the Eurocodes

The verb “shall” expresses a requirement strictly to be followed and from which no deviation is permitted in order to comply with the Eurocodes.

The verb “should” expresses a highly recommended choice or course of action. Subject to national regulation and/or any relevant contractual provisions, alternative approaches could be used/adopted where technically justified.

The verb “may” expresses a course of action permissible within the limits of the Eurocodes.

The verb “can” expresses possibility and capability; it is used for statements of fact and clarification of concepts.

0.5 National annex for EN 1991-1-8

National choice is allowed in this document where explicitly stated within notes. National choice includes the selection of values for Nationally Determined Parameters (NDPs).

The national standard implementing EN 1991-1-8 can have a National Annex containing all national choices to be used for the design of buildings and civil engineering works to be constructed in the relevant country.

When no national choice is given, the default choice given in this document is to be used.

When no national choice is made and no default is given in this document, the choice can be specified by a relevant authority or, where not specified, agreed for a specific project by appropriate parties.

National choice is allowed in EN 1991-1-8 through notes to the following clauses:

4.3.3(4)	4.7.1(2) – 4 choices	4.7.2(1)	4.7.2(2)
4.7.4(1)	4.7.4(2)	4.7.5(1)	4.7.5(2)
4.8(1)	4.8(2)	4.8(3)	4.9.2(1)
4.9.3(1)	4.9.4(4) – 2 choices	4.10(2)	5.2.1(11)
5.5.2(2)	6.1.3(1)	6.2(4)	6.3.1(8)
7.2.2(2) – 2 choices	7.2.3(1) – 2 choices	12.4.1.1(2)	

National choice is allowed in EN 1991-1-8 on the application of the following informative annexes:

Annex A	Annex B	Annex C	Annex D
Annex E	Annex F	Annex G	

The National Annex can contain, directly or by reference, non-contradictory complementary information for ease of implementation, provided it does not alter any provisions of the Eurocodes.

1 Scope

1.1 Scope of EN 1991-1-8

(1) EN 1991-1-8 gives principles and rules to determine the values of wave and current actions on structures and civil engineering works in the coastal zone, i.e. works connected or in close vicinity to the shore.

NOTE 1 As opposed to offshore conditions, waves or currents in the coastal zone are substantially affected by the presence of seabed or shore.

NOTE 2 In typical seabed morphology the affected area lies between the shoreline and the deep-water limit.

(2) EN 1991-1-8 describes the principles for defining the design sea conditions, including design water level variability for structures in the coastal area.

NOTE Wave and current conditions vary for different construction sites. It is very important to assess the wave and current conditions at a given site. Assessment procedures for these conditions and for their uncertainties are included in this document.

(3) In EN 1991-1-8 the following structure types are specifically addressed:

- cylindrical structures;
- suspended decks;
- sub sea pipelines;
- breakwaters:
 - mound breakwaters;
 - vertical face breakwaters;
 - composite breakwaters;
- coastal embankments:
 - revetments;
 - seawalls;
- permanently moored floating structures.

NOTE Additional guidance can be needed for:

- floating platforms in the coastal zone related to oil and gas production or processing;
- floating platforms in the coastal zone for renewable energy production.

(4) EN 1991-1-8 does not fully cover principles for determining actions from waves and currents on:

- port structures like piers, jetties, quay walls, marine terminals in sheltered marine areas;
- installations for mooring and berthing of ships.

(5) For hydraulic pressures on structural envelopes caused by quasi-static water levels, and for under pressures in the ground, see EN 1997 (all parts).

(6) EN 1991-1-8 does not cover:

- tsunamis;
- hydraulic consequences of an accidental breakdown of water actions from retaining structures;
- waves from passing ships;
- currents induced by jets or ship's propellers;
- coastal structures where flood risk and/or erosion or sediment management is the dominant function.

1.2 Assumptions

(1) The assumptions given in EN 1990 apply to this document.

(2) Qualification and experience related to this document refer also to the following fields:

- a) physical coastal environment including physics of waves and currents, statistical properties and propagation of such;
- b) marine hydrodynamics, wave and current disturbance by structures in general and wave and current actions on structures in the coastal zone including i) fixed structures, and ii) floating structures;
- c) advanced methods including probabilistic methodology and physical model testing.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE See the Bibliography for a list of other documents cited that are not normative references, including those referenced as recommendations (i.e. in 'should' clauses), permissions ('may' clauses), possibilities ('can' clauses), and in notes.

EN 1990:2023¹, *Eurocode — Basis of structural and geotechnical design*

¹ As impacted by EN 1990:2023/prA1:2024.

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 1990 and the following apply.

3.1.1 Terms relating to physical environment and environmental processes

3.1.1.1

shallow water

typically water depths less than one twentieth the wavelength

Note 1 to entry: Region of water in which waves propagate is often classified into three categories: deep water, intermediate depth, and shallow water. According to this classification, shallow water represents the zone of depth less than about one-twentieth of the wavelength.

Note 2 to entry: Intermediate (or transitional) water represents the zone of depth between about one-twentieth and one-half of the wavelength

3.1.1.2

deep water

water of such a depth that surface waves are little affected by bottom topography

Note 1 to entry: Intermediate (or transitional) water represents the zone of depth larger than about one-half the wavelength.

3.1.1.3

tide

astronomical tide

water movements that essentially are generated by the global response of oceans to celestial effects

Note 1 to entry: On the continental shelves and in coastal waters, particularly bays and estuaries, the effect is amplified by shallow water and coastal platforms.

3.1.1.4

storm surge

phenomenon of the rise of the sea surface above astronomical water level in the open coast, bays, and in estuaries due to the actions of wind stress and atmospheric pressure variations (static and dynamic)

3.1.1.5

foreshore

water zone of the shore between the mean low water mark (springs) and the mean high water level (springs)

Note 1 to entry: Definitions of foreshore can be different in some countries due to legislation or engineering practice.

3.1.1.6

surf zone

area between the outermost breaker and the limit of the wave run-up

3.1.1.7**wave climate**

usually statistical description of wave conditions at a particular location over months, seasons, or years

Note 1 to entry: The wave climate is often expressed by the statistics of wave height; mean zero crossing or spectral peak wave period; and wave direction.

3.1.1.8**wave breaking**

wave transformation process when the wave reaches a critical wave height, overturns on itself and breaks, dissipating energy

Note 1 to entry: Wave breaking can be due to water depth limitation or excess wind energy input.

3.1.1.9**wave set-up**

rise of water level inshore of depth-induced wave breaking associated with water transport by wave action

Note 1 to entry: Wave set-up can amount to more than 10 % of the offshore significant wave height.

3.1.1.10**gravity wave**

wave in a fluid or at the interface between two fluids for which the predominant restoring forces are gravity and buoyancy

EXAMPLE Wind-generated surface waves.

3.1.1.11**regular waves**

waves with a single frequency, amplitude and direction

Note 1 to entry: Often the definition of regular waves is expanded to include waves of constant shape during propagation with some of them containing more than one determined spectral components, while the said definition refers only to monochromatic (or linear) waves.

3.1.1.12**irregular waves**

waves with random wave periods (and in practice, also heights), which are typical for natural wind-induced waves

3.1.1.13**wind waves**

waves being generated by and/or developed by wind

3.1.1.14

swell

swell waves

wind-generated waves of long period that have propagated out of their generating area and are not affected by wind actions anymore

Note 1 to entry: Swell characteristically exhibits a more regular and longer period and has flatter crests than waves within their generating area.

Note 2 to entry: When categorizing wave types from a spectrum or from measurements, energy in the period range from 8 s to 25 s can typically be described as swell. Energy at periods longer than 25 s can be described as infragravity wave energy.

3.1.1.15

internal wave

gravity wave which propagates within a stratified fluid

3.1.1.16

reflected wave

wave that carries seaward a part of the incident energy when a wave impinges on a beach, seawall or other reflecting surface

3.1.1.17

refraction

process by which the direction of a wave front moving in non-deep water at an angle to the depth contours is changed so that the wave crests tend to become more aligned with those contours

Note 1 to entry: The part of a wave front in shallower water moves slower than its associated part in deeper water, so when the depth along a wave crest varies, the wave “bends”.

3.1.1.18

tidal currents

alternating or circulating currents associated with tidal variation

Note 1 to entry: Tides and tidal currents are generally strongly modified by the coastline.

3.1.1.19

density driven currents

currents induced by horizontal gradients of water density

Note 1 to entry: Such currents can be generated by changes in the salinity and/or temperature caused by the influx of fresh water from land run-off as through an estuary heat flux from coastal power stations, or other reasons.

3.1.1.20

wind driven current

currents induced by wind stress on the sea surface

Note 1 to entry: In coastal waters, wind driven currents are influenced by the bottom topography and the presence of coastline.

3.1.1.21**gust**

wind agitation caused by a steep rise and fall in wind speed lasting for less than one minute

Note 1 to entry: The wind speed of a gust can be averaged, for design purposes, over longer time periods.

3.1.1.22**wind set-up**

rise of water level at the downwind side of a bounded water body caused by wind stresses on the water surface

Note 1 to entry: In coastal waters wind set-up can be developed over the continental shelf for winds blowing against the coastline.

3.1.1.23**tsunami**

long gravity waves with period of several minutes to one hour and wavelength of some kilometres, generated by a sudden vertical movement of the sea floor associated to submarine earthquake, by a land slide or volcanic eruption, and other causes

Note 1 to entry: Tsunami wave heights at the coast can be up to a few tens of metres.

3.1.2 Terms relating to analysis of metocean parameters**3.1.2.1****annual maximum method**

method of estimating extreme wave heights or water levels, based on a sample of annual maximum wave heights or water levels

3.1.2.2**Peak-over-Threshold method****POT method**

method of estimating extreme parameter values applied to wave heights, based on a sample of peak values/heights of storm waves exceeding some threshold level

3.1.2.3**total sample method**

method of estimating wave heights exhibiting unconditional exceedance probabilities, by considering all wave heights measured at the site

3.1.2.4**extreme value**

random quantity that can be considered in a semi-probabilistic analysis by a representative value

Note 1 to entry: Extreme events are used in the verification of the non occurrence of limit states.

3.1.2.5

marginal return period of the value x of a random variable X

$T(x)$

inverse of the probability that the random variable X is larger than x , i.e. $T(x) = 1/\text{Prob}(X > x)$

Note 1 to entry: The unit of $T(x)$ is the average duration between two consecutive outcomes of X .

3.1.2.6

joint return period of the couple (x, y) of random variables (X, Y)

$T(x, y)$

inverse of the probability that the random variable X is larger than x and simultaneously that the random variable Y is larger than y , i.e. $T(x, y) = 1 / \text{Prob}(X > x \text{ and } Y > y)$

Note 1 to entry: The unit of $T(x, y)$ is the average duration between two consecutive and assumed to be simultaneous outcomes of X and Y .

3.1.2.7

n^{th} spectral moment

integral over frequency of the spectral density function multiplied by the n -th power of the frequency,

either expressed in Hertz (cycles per second) as $m_n(f) = \int_0^{\infty} f^n S(f) df$ or expressed in circular frequency

(radians/second) as $m_n(\omega) = \int_0^{\infty} \omega^n S(\omega) d\omega$

Note 1 to entry: As $\omega = 2\pi f$, the relationship between the two moment expressions is: $m_n(\omega) = (2\pi)^n m_n(f)$.

Note 2 to entry: The integration extends over the entire frequency range from zero to infinity. In practice the integration is often truncated at a frequency beyond which the contribution to the integral is negligible and/or the sensor no longer responds accurately. Care is needed when utilizing moments of order higher than 2, as for standard spectral models, the 4th moment will not converge; the value is in effect determined by the choice of truncation.

3.1.2.8

wave spectrum

function expressing the energy density distribution of the sea surface variance in the frequency domain and for all directions

Note 1 to entry: Usually, the term wave spectrum is used for the frequency-energy spectrum determined from linear Fourier transform.

Note 2 to entry: For the generation of representative sea states, the wave frequency spectrum (integrated over all directions) is often described by use of some parametric form such as the Pierson–Moskowitz or JONSWAP wave spectrum.

Note 3 to entry: The area under the wave spectrum is the zero-th spectral moment m_0 , which is a measure of the total energy in the sea state and can be used to calculate spectral wave height H_{m0} .

3.1.2.9**directional wave spectrum**

function expressing the energy density distribution of waves in the frequency and directional domains

Note 1 to entry: This function is often expressed as the product of frequency wave spectrum and the directional spreading function.

3.1.2.10**spectral peak period**

period at the maximum (peak) energy density in the spectrum

Note 1 to entry: In practice, in addition to the maximum peak there are often secondary peaks in a spectrum.

3.1.2.11**two-dimensional model****2D model**

mathematical or physical model in which the flow parameters vary in two spatial dimensions

3.1.2.12**three-dimensional model****3D model**

mathematical or physical model in which the flow parameters vary in three spatial dimensions

3.1.2.13**directional spreading function**

function expressing the relative distribution of wave energy in the directional domain

3.1.2.14**extreme waves**

waves in a storm event that can be considered in a semi-probabilistic analysis by representative values based on adequate statistical definitions

Note 1 to entry: In case of a storm event, short term statistics are used to express extreme waves in terms of the significant wave height or the maximum wave height or any other short term statistical parameter thereof, and the mean or significant wave period at the peak of storm event.

3.1.2.15**random waves**

superposition of a number of regular waves with different frequencies and amplitudes

Note 1 to entry : The term is often used to denote the laboratory simulations of irregular waves that occur in nature.

3.1.2.16**seiche**

standing oscillation of the water surface of an enclosed or semi-enclosed body of water at its natural period

3.1.2.17

level

elevation

vertical distance from a stated geodetic datum

3.1.3 Terms relating to statistical metocean parameters

3.1.3.1

metocean event

storm event defined by its sea state conditions

Note 1 to entry: A metocean event is usually expressed by short-term distributions of the parameters still water level, wave height, wave period and wave direction, while other metocean parameters can be also included at specific cases.

3.1.3.2

datum level

reference level for survey, design, construction and maintenance of coastal structures, often set at a chart datum or national geodetic datum

3.1.3.3

chart datum

locally assigned reference datum related to navigation charts

Note 1 to entry: Chart datum is usually an approximation to the level of the lowest astronomical tide.

3.1.3.4

international marine chart datum

chart datum set at the lowest astronomical tide level, as adopted by the International Hydrographic Organization (IHO)

3.1.3.5

lowest astronomical tide

LAT

tide at the lowest level that can be predicted to occur under average meteorological conditions and under any combination of astronomical conditions

Note 1 to entry: LAT is not reached every year and does not represent the lowest sea level which can be reached, because storm surges (negative) and tsunamis can cause considerably lower levels to occur.

Note 2 to entry: LAT level is approximately realized every 19 years.

3.1.3.6**highest astronomical tide****HAT**

tide at the highest level that can be predicted to occur under average meteorological conditions and under any combination of astronomical conditions

Note 1 to entry: HAT is not reached every year and does not represent the highest sea level that can be reached, because storm surges and tsunamis can cause considerably higher levels to occur.

Note 2 to entry: HAT level is approximately realized every 19 years.

3.1.3.7**still water level****undisturbed water level SWL**

theoretical water surface level that exists in the absence of wave action, but taking into account other effects as needed such as wind and atmospheric pressure influences

Note 1 to entry: Still water level is typically used for the calculation of wave kinematics for global actions and wave crest elevation for minimum deck elevations.

Note 2 to entry: Still water level is an abstract concept for engineering purposes calculated by adding the effects of tides, storm surge and allowances for future sea level change but normally excluding variations due to waves.

3.1.3.8**water depth**

vertical distance between the sea floor and still water level

Note 1 to entry: As there are several options for the still water level, there can be several water depth values. Generally, design water depth is determined to LAT or to mean sea level.

Note 2 to entry: The water depth used for calculating wave kinematics varies between the maximum water depth of the highest astronomical tide plus a positive storm surge, and the minimum water depth of the lowest astronomical tide less a negative storm surge, where applicable. The same maximum and minimum water depths are applicable to bottom-founded and floating structures, although water depth is usually a much less important parameter for floating structures. Water depth is, however, important for the design and analysis of the mooring system and risers for floating structures.

3.1.3.9**mean sea level****MSL**

long-term value of water surface level calculated from observations over a complete astronomical tidal cycle of 18,6 years

Note 1 to entry: The simplest way to calculate MSL is to take the arithmetic average of hourly (or three-hourly) observations, but more elaborate methods include the application of low-pass numerical filters to eliminate tides and surges before taking the average.

Note 2 to entry: The average of all high and low water levels called the mean tide level, is close to but not identical with mean sea level.

Note 3 to entry: Seasonal and inter-annual changes in mean sea level can be expected in some regions, and over many years the mean sea level can change.

3.1.3.10

mean water level

MWL

average elevation of the water surface over a given time period

Note 1 to entry: The mean water level is usually determined from hourly tidal level readings.

Note 2 to entry: The monthly mean water level can vary over seasons by a few tens of centimetres.

3.1.3.11

mean high water springs

MHWS

average level of high waters occurring at the time of spring tides measured over an astronomical tidal cycle

3.1.3.12

mean low water springs

MLWS

average level of low waters occurring at the time of spring tides, measured over an astronomical tidal cycle

3.1.3.13

extreme high water

highest sea level predicted at a location as a combination of astronomical tides, positive storm surges, seiches and river flow for an extreme event of a defined return period

3.1.3.14

extreme low water

lowest level that is predicted at a location as a combination of astronomical tides, negative storm surges, seiches and river flow for an extreme event of a defined return period

3.1.3.15

extreme water level

EWL

Statistically determined highest or lowest water level, by the combination of astronomical tide, storm surges, and climate change influence, referenced to a fixed datum

3.1.3.16

design water level

water level selected for design and analysis of coastal structures, in view of the acceptable level of risk of failure/damage due to an extreme event of a defined return period

Note 1 to entry: Generally, it is the water level that mostly affects the safety of the structures/facilities in question.

3.1.3.17**sea state**

condition of sea surface within a short time span, being expressed by still water level, wave heights, wave periods and wave directions

Note 1 to entry: The time span normally used is from 20 minutes up to a few hours.

Note 2 to entry: The length of time span is chosen as the result of compromise between the requirement of a short duration to guarantee that the sea state is constant during the recording time and that the duration is sufficiently long with necessary number of waves for reliable statistical estimates of characteristic wave heights and wave periods.

3.1.3.18**wave height**

vertical distance between a trough and the preceding (following) crest, as determined by zero-down (zero-up) crossing

3.1.3.19**wavelength**

horizontal distance between two successive zero-down or zero-up crossings in a wave record

3.1.3.20**wave number**

inverse of the wavelength times 2π

3.1.3.21**wave period**

time for two successive zero-down or zero-up crossings to pass a fixed point

3.1.3.22**wave phase velocity**

speed at which a wave propagates (sometimes referred to as wave celerity or velocity of wave propagation)

3.1.3.23**wave steepness**

ratio of wave height to wavelength, H/L

3.1.3.24**wave crest**

highest point of a wave profile

3.1.3.25**maximum wave height****highest wave height**

$H_{\max}$

height of the highest wave in a given wave record

3.1.3.26

***T*-year wave height**

extreme wave height of a sea state corresponding to the return period of T years

Note 1 to entry: In applications this height is usually the significant wave height or the maximum wave height.

3.1.3.27

significant wave height

H_s

$H_{1/3}$

mean wave height of the highest third of the waves of a given wave record determined from time-domain analysis, $H_s = H_{1/3}$

Note 1 to entry: Often the spectral wave height H_{m0} is used instead of H_s , determined from frequency-domain analysis of the wave record as function of the zero-th spectral moment m_0 of the Fourier spectrum. In deep water $H_{1/3}$ and H_{m0} are in general very close in value and are both considered good estimates of H_s , but in intermediate and shallow waters, $H_{1/3}$ and H_{m0} estimates may differ substantially.

3.1.3.28

significant wave height estimated from wave spectrum

H_{m0}

spectral wave height determined from the zero-th spectral moment of the Fourier spectrum of the wave record, $H_{m0} = 4\sqrt{m_0}$

3.1.3.29

representative wave height

wave parameters selected for design and analysis of coastal structures, chosen in view of the acceptable level of risk of failure/damage due to an extreme event of a defined return period

3.1.3.30

storm-representative wave

statistical outcome of short-term distribution of the wave heights in a sea state

EXAMPLE The significant wave height and the maximum wave height.

Note 1 to entry: The storm-representative wave represents an engineering abstraction, typically expressed in terms of a regular wave used for calculation of quasi-static wave actions on a structure.

3.1.3.31

reflection coefficient

ratio of the height of reflected wave to the height of incident wave

3.1.3.32

refraction coefficient

ratio of the height of waves having been affected by the refraction effect to their height in deep water, with the shoaling effect being eliminated

3.1.3.33**stability number**ratio $H_s/\Delta D_n$ **3.1.3.34****mean wave period** T_m

average period of all zero crossings of waves in a given record by application of a time-domain analysis

Note 1 to entry: Instead of T_m the spectral mean wave periods $T_{m-1,0}$ or $T_{m0,2}$ can be used. These frequency-domain parameters are obtained by the moments of the Fourier transform of the wave record.

3.1.3.35**peak period****peak wave period** T_p

wave period determined by the inverse of the frequency at which the wave energy spectrum reaches a maximum

3.1.3.36**significant wave period**

average period of the one-third highest waves of a given wave record in time-domain analysis

Note 1 to entry: Mean (from time-domain analysis) or peak wave (from frequency-domain analysis) periods (T_m and T_p) are more commonly used but a significant wave period, T_s , has often been used in prediction methods based on older North American approaches.

3.1.3.37**representative wave period**

wave period statistically determined by short term distribution

EXAMPLE The significant wave period or the maximum wave period in a sea state.

3.1.3.38**residual current**

part of the total current not belonging to the tidal stream, hence not constituted from harmonic tidal components

Note 1 to entry: Residual currents are caused by a variety of physical mechanisms and comprise a large range of natural frequencies and magnitudes in different parts of the world.

3.1.4 Terms relating to metocean effects in interaction with structures**3.1.4.1****air gap**

vertical distance measured from the still water level/top of the wave crest up to the bottom of the deck structure

3.1.4.2

wave overtopping

passing of water over the top of a structure as a result of wave run-up or surge action

3.1.4.3

diffraction

diffraction of waves in a process by which wave energy is transmitted laterally along wave crests

Note 1 to entry: This process results in bending of wave fronts and propagation of diffracted waves into sheltered areas, such as the breakwater shadow.

3.1.4.4

diffraction coefficient

ratio of the height of diffracted waves to the height of incident waves

3.1.4.5

reflection

process by which part of the wave energy is returned seaward when waves impinge on an obstacle

Note 1 to entry: Waves reflect from seawalls, breakwaters, but also from beaches and at locations with sharp depth changes.

3.1.4.6

run-up/run-down

process of waves running up and down a beach or a coastal structure, also their upper and lower levels reached relative to still water level

3.1.4.7

hydrodynamic loads

quantity representing the action from currents and waves on coastal structures

EXAMPLE Pressures, forces, moments, tensions flow velocities, wave overtopping discharges.

3.1.4.8

slamming actions

actions developed when a water surface and a structure suddenly collide

3.1.4.9

transmission

process of wave energy passing over and through a (low) crested structure and generating waves behind the structure

3.1.4.10

wave pressure

water pressure exerted on a structure induced by waves, excluding hydrostatic pressure

3.1.4.11

buoyancy

resultant of upward forces, exerted by the water on a submerged or floating body, equal to the weight of the water displaced by this body

3.1.4.12**uplift force**

upward water pressure in the pores of a material or the base of a structure due to waves, excluding buoyancy

3.1.4.13**drag coefficient**

C_D

coefficient used to determine the drag force induced by currents/waves

3.1.4.14**lift coefficient**

C_L

coefficient used to determine the lift force induced by currents/waves

3.1.4.15**inertia coefficient**

C_M

coefficient used to determine the inertia force induced by currents/waves

3.1.4.16**scour**

removal/erosion of underwater sand and stone material by shear forces associated with waves and currents, especially critical at the base or toe of a structure

3.1.4.17**hydrodynamic estimate approach**

HEA

methodology to assess metocean parameters that relates to the consequence class of the structure and the local hydrodynamic conditions

3.1.4.18**design approach**

DA

collective description of the design path, based on the HEA level and the structure design and response uncertainty, to verify whether a structure complies with reliability requirements

3.1.4.19**importance factor**

φ_I

multiplier of the characteristic and design marginal and joint return periods of metocean events allowing for the consequence class of the structure

3.1.4.20**dynamic amplification factor**

DAF

dimensionless number which multiplied by responses caused by static load accounts for dynamic loading

3.1.4.21

empirical (design formulae)

design formulae based on research using full scale and/or model tests

3.1.4.22

vortex induced vibration

VIV

vibration induced by vortices shed alternatively from either side of a cylinder in a current and/or waves

3.1.5 Terms relating to coastal structures

3.1.5.1

breakwater

structure protecting a shore area, harbour, anchorage, intake or outfall from waves and currents

3.1.5.2

armour layer

outer layer composed of armour units protecting breakwaters, embankments or other rubble mound structures against waves and currents

3.1.5.3

armour unit

relatively large quarry stone or concrete shaped unit selected to fit specified geometric dimensions, density and strength requirements

3.1.5.4

crown wall

concrete superstructure on a rubble mound breakwater

3.1.5.5

roundhead

circular-shaped head of a breakwater

Note 1 to entry: Often a roundhead is reinforced by heavier armour units and/or reduced slope than in the trunk.

3.1.5.6

toe

lowest part of a coastal structure, providing often support for slope protection and forming the transition to the seabed

3.1.5.7

trunk

longitudinal section of a breakwater or similar structure, excluding the roundhead(s)

3.1.5.8

embankment

collectively representation of revetments and seawalls

3.1.5.9**seawall**

protective structure against coastland erosion and wave overtopping, built along the shoreline with nearly vertical seaward face inducing wave reflection

3.1.5.10**revetment**

protective structure against coastland erosion and wave overtopping, built along the shoreline with sloping seaward face inducing wave breaking

3.1.5.11**floating structure**

permanently moored floating object

3.1.5.12**jetty pier**

deck structure supported by vertical or near-vertical piles projecting into the sea, frequently in a direction normal to the coastline

3.1.5.13**free span**

pipeline section not supported by the seabed

3.1.5.14**slender structures or members**

structural members that are geometrically slender. i.e. with small ratio of a characteristic cross sectional dimension to length

3.1.5.15**moorings**

system to hold a floating object in position by annulling excessive movements

3.1.5.16**anchors**

units placed on the seabed, such as ship anchors, piles driven into the seabed or concrete blocks, to which mooring lines are attached to restrain a floating object from excessive movements

3.1.5.17**berm**

horizontal step in the sloping profile of an embankment or breakwater

3.1.5.18**core**

inner portion of a breakwater, embankment and other rubble mound structure, often with small permeability

3.1.5.19

crest

highest point of a coastal structure

3.1.5.20

filter

intermediate layer, preventing fine materials of an underlayer from being washed through the voids of the upper layer

3.1.5.21

geotextile

synthetic fabric used as filter in earthworks

Note 1 to entry: Geotextiles can be woven or non-woven.

3.1.5.22

stone

quarried or artificially broken rock for use in construction, either as aggregate or cut into shaped blocks as dimension stone

3.1.5.23

riprap

usually, wide-graded quarry stone, bulk placed to prevent erosion

3.1.5.24

lee

shelter or sheltered side from wind or waves provided by neighbouring natural or artificial structures or installations

3.1.5.25

marine growth

additional layer on subsurface structures formed by marine plants, colonies of animals, etc.

3.1.5.26

permeability

capacity of bulk material in permitting movement of water through its pores

Note 1 to entry: Bulk materials can be sand, crushed rock and soft rock in situ.

3.1.5.27

pore pressure

interstitial pressure of water within a mass of soil or rock

3.1.5.28

scale or physical model

simulation of a structure and its (hydraulic) environment, usually in much smaller dimensions, to enable the study of the structure behaviour under specified conditions

Note 1 to entry: The model can be built with a fixed or a movable bed.

3.2 Symbols and abbreviations

3.2.1 Latin upper-case letters

A	Vibration amplitude
A_e	Eroded area around SWL
A_p	Projected surface area
B	Width [length]
$B(\gamma)$	Normalizing factor
BEM	Boundary element method
C	Celerity
C	Non-dimensional force coefficient
C_D	Drag coefficient
C'_D	Drag coefficient corresponding to maximum of fluctuating in-line forces (drag forces)
C'_{DS}	Drag coefficient corresponding to maximum of fluctuating in-line forces (drag forces) in steady flow
C_{DC}	Drag coefficient with respect to current
C_{DS}	Drag coefficient for steady flow
C_L	Lift coefficient
C'_L	Lift coefficient corresponding to maximum of transversal forces (lift forces)
C'_{LS}	Lift coefficient corresponding to maximum of transversal forces (lift forces) in steady flow
C_{LS}	Lift coefficient for steady flow
C_M	Inertia coefficient
C_a	Added mass coefficient
CFD	Computational fluid dynamics
D	Diameter or characteristic cross-sectional dimension
$D(\theta/f)$	Directional spreading function
D_{er}	Percentage of eroded volume
D_n	Nominal block diameter, $D_n=(M/\rho_{app})^{1/3}$
D_{n50}	Median nominal diameter of armour stones
D_0	Normalizing constant
DA	Design approach
DAF	Dynamic amplification factor
Ds-EM	Deep-sea extremes methods
F_c	Current drag force

F_D	Drag force [force]
F_G	Buoyancy reduced weight of caisson [force]
$F_h(t)$	Horizontal force time history
F_H	Horizontal wave force [force]
F_I	Inertia force [force]
F_s	Slamming force [force]
F_U	Wave induced uplift force [force]
$F_v(t)$	Vertical force time history
FTA	Full transfer approach
GBS	Ground based structure
H	Wave height
H_b	Breaking wave height
H_i	Height of incoming wave of normal incidence
$H_{\max}$	Maximum wave height
H_{m0}	Significant wave height extracted from the spectrum
H_n	Representative wave heights of wave group n
H_q	Storm-representative wave height corresponding to an annual exceedance probability of q
H_s	Significant wave height, $H_s = H_{1/3}$
$H_{s,toe}$	Significant wave height at structure toe
H_{s0}	Deep-water significant wave height
H_s^T	Significant wave height with return period T
$H_{1/3}$	Significant wave height based on time domain analysis
$H_{2\%}$	Wave height exceeded by 2 % of waves
HAT	Highest astronomical tide
HEA	Hydrodynamic estimate approach
JDs-EM	Joint deep-sea extremes methods
K_D	Stability coefficient in Hudson's formula
K_s	Stability parameter
KC	Keulegan-Carpenter number $= u_{\max} T / D$ ($= \pi H / D$; in deep water),
L	Length
L_r	Model scale
L_o	Wavelength in deep water

LAT	Lowest astronomical tide
M	Mass
Ma_z	Vertical added mass
Ma_x	Lateral added mass
MDs-EM	Marginal deep-sea extremes method
MHWS	Mean high water springs
MLWS	Mean low water springs
MSL	Mean sea level
N	Number of data points
N_d	Ratio of number of units moved out of place
N_f	Number of simulations to failure
N_{od}	Damage number expressed by the relative number of displaced units out of armour layer
P_f	Probability of failure
$P_{f,L}$	Failure probability level for L years service life
$P_{f,L,T}$	Failure probability level for L years service life and action return period T
R	Radius of a cylinder
Re	Reynolds number = $(u_{\max}D)/\vartheta$, where $u_{\max}$ is the maximum orthogonal local particle velocity
R_u	Maximum run-up or water-surface elevation measured vertically from the still-water level [length]
$R_{u,2\%}$	Run-up level achieved by only 2 % of the incoming waves at the toe of the structure
S_d	Damage parameter expressed by the non-dimensional eroded area
$S(f)$	Spectral density function
SDi	Severe displacement ultimate limit state
Sp	Directional spreading
St	Strouhal number
SWL	Still water level (no waves or wave effects)
T	Return period
T_{lf}	Design service life [years]
T_m	Mean wave period (time-domain)
$T_{m0,2}$	Spectral wave period estimated from the zero-th and second moments of wave spectrum (frequency-domain)
$T_{m-1,0}$	Spectral mean energy wave period, $T_{m-1,0} = m_{-1}/m_0$
T_p	Period corresponding to the peak of the wave spectrum (energy frequency spectrum)
T_s	Significant wave period

T_z	Zero crossing wave period
$T(x)$	Marginal return period of the value x of a random variable X
$T(x, y)$	Joint return period of the couple (x, y) of random variables (X, Y)
TLP	Tension leg platform
U	Current velocity
U_C	Mean current velocity
U_w	Wave particle velocity
U_0	Current velocity
V	Relative velocity of water surface to that of the surface of a member
V	Group waves celerity
V_r	Reduced velocity
VIV	Vortex induced vibrations
WL	Water level

3.2.2 Latin lower-case letters

a_x	Horizontal acceleration
a_0	Distance between highest water level and bottom of deck
c	Instantaneous wetted height
c_d	Apparent soil cohesion
c_u	Undrained shear strength of clay [force/length ²]
e	Relative surface roughness
f	Frequency
$f^{(1)}$	Linear force based on linear wave theory for a regular wave and complete reflection off a wall
$f^{(2)}$	Non-linear mean force
f_j	Natural frequency of vibration for the j -th mode of a structural member
f_p	Frequency at spectral peak
f_v	Vortex shedding frequency
$f_X(\bar{x})$	Joint probability function of multidimensional variable X taking value $\bar{x}$
g	Acceleration due to gravity
h	Water depth [length]
h_s	Water depth in front of a structure
h_S	Threshold level
k	Surface roughness height
k_{nl}	Non-linear wave number

l	Characteristic length of a structural member
m	Dependence parameter of the Gumbel-Hougaard copula
m_e	Effective virtual mass per unit length
m_n	n^{th} moment of wave spectrum $m_n = \int_0^{\infty} f^n S(f) df$
pdf	probability density function
q	Annual probability of exceedance
r	Dolos waist ratio [dimensionless]
s	Spreading parameter
$s_{\max}$	Peak spreading parameter
t	Thickness
u	Local water particle velocities normal to the member axis
$\dot{u}$	Local water particle accelerations normal to member axis
u^*	Friction velocity
$u_{\max}$	Maximum orthogonal local particle velocity
w	Vertical velocity underneath the deck
$\dot{x}(t)$	Velocity of member normal to its axis positive in the wave direction
$\ddot{x}(t)$	Acceleration of member normal to its axis positive in the wave direction
z	Vertical motion of a structure
z_s	Stretched vertical coordinate
z_0	Bed roughness length

3.2.3 Greek upper-case letters

Π_R	Ursell number
Δ_{mod}	Relative density in model
Δ_{pro}	Relative density in prototype
ΔSL	Sea level variation
Ψ	Wake amplification factor

3.2.4 Greek lower-case letters

α	Weibull distribution scale parameter
α	Coefficient
β	Reliability index
β	Current flow velocity ratio

β_s	Weibull distribution shape parameter
γ	Peak enhancement factor
γ_F	Partial factor for actions
γ_{Sd}	Partial factor associated with the uncertainty of the action and/or action effect model
δ	Generalized logarithmic decrement
δ_h	Hydrodynamic damping
δ_{soil}	Soil's damping or other damping
ζ_a	Amplitude of the wave
η	Wave surface elevation
η_b	Maximum elevation of the free surface
η_{max}	Maximum crest height
θ	Wave direction
θ_m	Mean wave direction
κ	van Karman's constant, $\kappa = 0,4$
λ	Wavelength
λ_c	Curling factor
λ_{nl}	Non-linear wavelength
μ	Mean value
ν	Kinematic viscosity
ν°	Angle of friction in granular material [degrees]
ρ_{app}	Applied mass density of block material
ρ_{arm}	Density of armour block
ρ_{mg}	Density of marine growth and biofouling
ρ_{mod}	Density of model
ρ_w	Apparent mass density of water
σ	Standard deviation
σ	Spectral width parameter
σ_η	Standard deviation of the surface elevation
σ_θ	Angular standard deviation
φ	Packing density coefficient
φ_I	Importance factor
ψ_0	Combination factor applied to a variable action to determine its combination value
ψ_1	Combination factor applied to a variable action to determine its frequent value

ψ_2 Combination factor applied to a variable action to determine its quasi-permanent value

4 Basis of wave and current action assessment

4.1 General

(1) Actions from waves and currents shall be represented by appropriate hydrodynamic loads.

4.2 Design approaches

4.2.1 General

(1) The design approach, which sets out the recommended requirements in terms of the assessment that should be applied to estimate the action or action effect arising from the marine environment, should be selected following the selection of the hydrodynamic estimate approach (HEA).

NOTE 1 For the hydrodynamic estimate approach, see 4.6(1) – 4.6(3).

NOTE 2 For the selection of design approach, see 4.6(4).

4.2.2 Semi-probabilistic design approach

(1) In the semi-probabilistic approach the representative values of hydrodynamic loads due to the actions from waves and currents shall be assessed following the indications given in this Clause 4.

NOTE 1 See EN 1990:2023, 1.1(4) and EN 1990:2023, C.3.1(3).

NOTE 2 In this document, the semi-probabilistic design approach is denoted DA1.

4.2.3 Reliability-based design approach

(1) The available metocean data and the available environmental sea conditions shall suit the probabilistic method used to implement the reliability-based design approach in accordance with EN 1990.

NOTE In this document, the reliability-based design approach is denoted DA2.

(2) Where a sufficient length of record of environmental sea conditions is available considering the design service life of the coastal structure and the target value for the reliability index β , one of the following probabilistic methods may be used:

- using a statistical summary or a sample of environmental deep-sea conditions, e.g. a scatter table or a matrix of schematized conditions (possibly above/over a specified threshold) yielding structure's responses from which the relevant probability of failure can be identified;
- using series of structural responses based on a representative sample of environmental sea conditions at the vicinity of the structure and to which it is exposed (possibly above/over a specified threshold), or on a full-time series, from which the relevant probability of failure can be identified.

(3) Where only a limited duration record of environmental sea conditions is available, extrapolation of data can provide values of the important parameters for lower chances of occurrence (longer return periods), through appropriate fitting of extreme value distributions and extrapolation to the required return period using a valid mathematical method, e.g. a Monte-Carlo simulation.

NOTE Extrapolated data are also called “synthetic data”.

(4) The validity of the extrapolation method shall be verified.

NOTE Further guidance and recommendations relating to application of reliability-based design approach can be found in Clause 13 and Annex H.

4.2.4 Risk-informed decision-making design approach

(1) The available metocean data of the required environmental sea conditions shall suit the probabilistic method used to implement the risk-informed decision-making design approach in accordance with EN 1990.

NOTE In this document, the risk informed decision-making design approach is denoted DA3.

(2) The same provisions related to the probabilistic methods specified in 4.2.3 for the assessment of wave and current actions shall apply.

NOTE The risk-informed decision-making design approach enables to determine the optimal probabilities of failure or the optimal safety indexes on a case-by-case basis.

4.2.5 Design assisted by physical testing

(1) Hydraulic physical model tests may be used to validate the assessment of the wave and current actions undertaken in accordance with a relevant design approach (DA1 to DA3), considering the design service life and the consequence class of the coastal structure.

NOTE 1 In this document, the design assisted by physical testing is denoted DA4.

NOTE 2 DA4 is not a separate design approach but an option to be considered alongside DA1 to DA3.

NOTE 3 Further guidance and recommendations concerning application of physical models to coastal structures is provided in Clause 12 and Annex G.

NOTE 4 Further guidance on design assisted by testing is given in EN 1990.

4.3 Action modelling

4.3.1 Classification of actions from waves and currents

(1) Actions from waves and currents shall be considered as variable free dynamic actions.

(2) Actions on structural parts induced by the global dynamic response of floating or fixed structures subjected to waves and currents, shall be considered as direct actions.

(3) Unless a dynamic analysis is carried out, actions from waves and currents on fixed coastal structures may be modelled by equivalent quasi-static actions, for the duration of the design metocean event.

NOTE 1 Dynamic analysis are often carried out in the design of floating structures and often include dynamic wind action analysis.

NOTE 2 Quasi-static water-levels and their variations with space and time (e.g. storm surges) play an important role in the action of waves and currents (they influence wave heights, wave periods, current velocities..., and the propagation of metocean events to the structure's site) and cause hydraulic pressures. They are not considered as a separate action.

4.3.2 Metocean parameters

(1) Metocean events shall be represented by a set of metocean parameters.

NOTE Metocean parameters are addressed in Clause 5.

4.3.3 General methods for the assessment of the hydrodynamic loads

(1) Hydrodynamic loads should comprise several of the following: wave or current-induced pressures and forces, forces/moments along structural parts of the structure, including foundations, tensions on mooring lines, including dynamic effects, wave conditions (height, period, direction) or flow velocities at the toe of a coastal structure or at other locations, mean wave overtopping discharges (acting as a functional requirements of coastal structures or as an indirect load of parts of coastal structures) see Clauses 6 to 11.

NOTE Non-dimensional stability numbers comprise action-related parameters and material (resistance)-related parameters: the wave stability number or Hudson number, the Isbash number (when considering the current velocity), the Shields parameter (when considering the shear stress caused by a moving fluid), etc. They appear in hydraulic limit state conditions.

(2) Hydrodynamic loads should be calculated either with the Deep-Sea Extremes Methods (Ds-EM), whose sub-divisions are the Marginal Deep-sea Extremes Method (MDs-EM) and the Joint Deep-Sea Extremes Method (JDs-EM), or with the Full transfer approach (FTA).

(3) For Deep-Sea Extremes Methods (Ds-EM) the following steps should be performed:

- selection of a small number of sets of offshore (deep-sea) metocean parameters according to the rules explained in 4.7 through statistical analysis using either marginal (Marginal Deep-sea Extremes Method – MDs-EM) or joint (Joint Deep-Sea Extremes Method – JDs-EM) probabilistic distributions of the metocean parameters when available;
- transfer of the selected sets to the site of the (coastal) structure;
- identification of the design values of the hydrodynamic loads as the most adverse responses of the structure coming out of the selected sets of metocean parameters.

(4) For the full transfer approach (FTA) the following steps should be performed:

- transfer of a sufficiently large set of the most extreme metocean events of the dataset to the site of the (coastal) structure;
- identification of the design values of the hydrodynamic loads based on the extreme value analysis of the distributions and/or frequency distributions of the responses of the structure.

NOTE The National Annex can select the method or provide guidance for the choice of a method.

4.4 Design situations

(1) Actions from waves and current shall comply with the physical environment entailed by the design situations for which the structure is verified.

NOTE Persistent design situations include not only the normal “everyday use” conditions but also the severe conditions experienced infrequently, as caught up by the return periods used for the assessment of the design values of the action.

(2) Persistent design situations should be defined to allow for the variations of still water level.

NOTE 1 It can be useful to define a set of design situations commanded by the water levels, each of those situations being relevant for a given part of the structure for example, the toe of a rubble mound breakwater may be designed under a low water level situation, the main armour blocks under a mean water level situation, the crest and the harbour-side slope under a high-water level situation.

NOTE 2 Water levels influence wave heights, wave periods, current’s velocities, etc., and the propagation of metocean events to the structure’s site.

(3) Specific persistent design situations should be defined to allow for changing climate and sea level conditions.

NOTE It may be useful to define persistent design situations under the climate and sea level conditions prevailing at the beginning and at the end of design service life of the structure.

(4) Specific metocean events, hence specific actions from waves and currents, shall be considered during temporary environmental influence, and during the execution and maintenance phases, making several transient design situations.

NOTE 1 The coastal environment can involve sub surface construction works and subsea construction works that influence construction procedures, structural design, material selection and size (dimensions, volume).

NOTE 2 Examples of transient design situations are the towing of a caisson from a dry dock to the structure's site, the account for intermediate breakwaters' heights during construction.

(5) A fatigue design situation may be defined to allow for the repetition of load cycles by waves and currents.

NOTE Several equivalent static hydrodynamic loads can be used for the verification of fatigue limit state.

(6) Tsunamis caused by earthquakes should be considered in the seismic design situation.

(7) Wave and current actions may be neglected in a design situation provided that a sufficient air gap or ground space is provided between sea water and structure.

(8) Extreme metocean events much more severe than the ones described for persistent and transient design situations should be considered in the accidental design situation.

4.5 Geometrical parameters

(1) Due care should be taken for possible effects of scouring, long term morphological developments, liquefaction, settlement and deformations of the structure, its protecting elements and its foundation both due to wave and current actions, and by other causes.

(2) Geometrical parameters intervening in the waves and currents action models shall take into account the design service life of the structure and the design situation to ensure that the structure provides the required level of performance over its entire service life.

NOTE 1 Geometrical parameters include structure-related parameters as well as near-structure topographic and bathymetric parameters (slope, seabed, etc.).

NOTE 2 Due to the interaction between environmental marine conditions and structure responses, the final geometrical properties of a structure and of the bathymetry may be the result of an iterative assessment process.

(3) The predictable time evolution of geometrical parameters shall be accounted for by considering their most adverse values likely to occur within the design situation, regarding the hydrodynamic loads and the limit states to be checked.

NOTE The most adverse values of the geometrical parameters correspond often to the end-of-service life conditions. However, this is not always true: for example, the steeper the slope of a berm breakwater, the higher the run-up.

(4) In particular, wave overtopping and resulting flooding should be analysed based on the end-of-service life conditions including allowance for settlement and climate change.

4.6 Hydrodynamic estimate approaches

(1) The consequence class of the structure and the hydrodynamic uncertainty on the site shall be considered when determining the minimum Hydrodynamic estimate approach (HEA) level from Table 4.1.

Table 4.1 — HEA level selection matrix

Consequence class	Hydrodynamic uncertainty		
	Low	Medium	High
CC1	HEA1	HEA1	HEA2
CC2	HEA1	HEA2	HEA3
CC3	HEA2	HEA3	HEA3

(2) Hydrodynamic uncertainty shall be assessed considering the environmental sea conditions at the site of interest, the quality of the metocean data and the complexity of the local physical processes (boundary condition generation and transformation to the site).

EXAMPLE 1 Examples of low hydrodynamic uncertainty can include tidal range < 1 m, surge < 0, 5m, fetch-limited seas (with fetch < 10 km), uniform currents with spring tide velocities < 1 m/s, regular bathymetry.

EXAMPLE 2 Examples of high hydrodynamic uncertainty can include tidal range > 5 m, surge > 2 m, ocean seas (swell and wind-waves), non-uniform currents (stratified) and/ or tide or surge current velocities > 3 m/s, irregular bathymetry (e.g. reefs or sub-sea canyons).

(3) The HEA levels are defined in Table 4.2 (NDP).

Table 4.2 (NDP) — Hydrodynamic Estimate Approach methodology guidance

HEA level	Boundary condition data	Pathway assessment	Other considerations
HEA1	Locally or nationally determined metocean parameters data, mainly from published sources, with limited probabilistic definition or limited reliability information attached.	Wind-wave ^a hindcast using empirical calculations taking into account fetch/ duration limitations. Extrapolation of sea-level or current values from published values for nearby sites.	Data unlikely to be calibrated or validated for developed statistical treatments. Expertise is required.
HEA2	Individual (marginal) long-term ^b time-series data (or statistical distributions/ summaries thereof) of metocean parameters. Measured data, or, if not available, calibrated and validated model data, e.g. regional or global hindcast models, or synthetic data.	Numerical wave transformation ^c model representing (with reasonable accuracy) all key physical processes expected. Adjustment of statistically estimated sea-level or current values to account for site-specific physical processes, either by empirical or numerical model.	Data likely to be used for the statistical assessment of the representative values of the actions from waves and currents (hydrodynamic loads), including the combination of metocean parameters, based on marginal statistics.
HEA3	Joint long-term ^b time-series data (or statistical distributions/ summaries thereof) of metocean parameters. Measured data, or, if not available, calibrated and validated model data, e.g. regional or global hindcast models, or synthetic data.	Calibrated numerical wave/ water level/ current transformation ^c model representing (with reasonable accuracy) all key physical processes expected.	Data likely to be used for the statistical assessment of the representative values of the actions from waves and currents (hydrodynamic loads), including the combination of metocean parameters, based on joint statistics.
^a When the predominant wave energy system only is analysed and can be expected to be wind-sea dominated. ^b «Long-term» is to be understood in relation to the design service life and to the return periods of the metocean events, also considering the quality of data available (filtering/ removal of erroneous records). ^c This is based on the typical situation where long-term boundary condition data is not available in close proximity to the structure's site and must be transformed from a remote location.			

(3) Following selection of the hydrodynamic estimate approach (HEA), the design approach may be selected from Table 4.3 which sets out the recommended requirements in terms of the assessment that should be applied to estimate the action or action effect arising from the marine environment.

Table 4.3 — Design approach selection matrix

HEA level	Low-to medium structure design/ response uncertainty ^a	High structure design/ response uncertainty ^a
HEA1	DA1	Not applicable
HEA2	DA1 or DA2 ^b	DA1 + DA4 or DA2 + DA4
HEA3	DA1 or DA2 or DA3 or any previous with DA4	DA1 ^c + DA4 or DA2 + DA4 or DA3 + DA4

^a Where the term «uncertainty» is defined in Note 3.

^b See Clause 13 and Annex H for DA2 methods.

^c More advanced design approaches than DA1 should be used at HEA3 level especially with highest structure design/response uncertainty.

NOTE 1 As explained in 4.2:

- DA1: Semi-probabilistic partial factors approach (loads and resistances) with appropriate sensitivity testing of key parameters based on the application of semi-empirical structure response formulae;
- DA2: Probabilistic (reliability based) approach with allowable probabilities of failure or β indexes;
- DA3: Risk-informed approach with a socio-economic optimisation to determine optimum probability of failure of the considered structure;
- DA4: Design assisted by testing approach, in combination with DA1, DA2 or DA3.

NOTE 2 Guidance and limitation of use of DA2 and DA3 are given in EN 1990:2023, C.3.1.

NOTE 3 The term «structure uncertainty» is associated mainly with the structure (and sub-element) type and excludes uncertainty pertaining to the hydrodynamic (sea) conditions at the structure's site. Low structure uncertainty can, for example, apply where the physical processes/ response mechanisms are relatively simple and/ or there is an established and validated structural analysis approach, whereas high structure uncertainty may apply where the physical processes/response mechanisms are complex and/ or there are several analytical methods available giving widely varying results and/or the conditions are significantly outside the application limits of an established structural analysis approach.

NOTE Whatever the design approach, physical tests and numerical models based on Computational Fluid Dynamics (CFD) or other fluid-structure simulation methods are widely used for assessing wave and current actions to coastal structure as well as the structure's response. Further guidance and recommendations concerning their application and calibration is provided in Clauses 6 to 11 and in Annexes D to F.

4.7 Representative values of hydrodynamic loads

4.7.1 General

(1) Representative values of hydrodynamic loads shall account for the uncertainty of the occurrence of and variability of metocean events.

NOTE 1 The distribution of individual wave heights and individual wave periods within metocean events (i.e. during storms) is sometimes directly accounted for in action models by calibration or through statistical and/or spectral descriptions. Wave heights mentioned in semi-empirical design formulae are therefore specified quantiles of the wave height short-term statistical distribution, according to the action model and to the type of structure. This is why the uncertainty associated with individual wave distributions (short term statistics) is not detailed in this subclause (see Clauses 5 to 11).

NOTE 2 The metocean events governing the design can depend on the limit state to be checked and on the part of the structure under consideration.

(2) Local or regional variations due to climate and sea level changes shall be taken into account when determining representative values of hydrodynamic loads.

NOTE 1 For the determination of representative hydrodynamic loads for a coastal structure a climate change scenario can be chosen that is based on recent IPCC (International Panel on Climate Change) projections, or local refinements thereof. From these climate scenarios a medium emission scenario, RCP4.5 (Representative Concentration Pathway with a possible range of radiative forcing values in the year 2100 of 4,5 W/m²), can be applied together with the most likely of all model outcomes, unless the National Annex describes another method.

NOTE 2 For non-adaptable and non-replaceable structures or parts thereof, the most adverse metocean parameters' random processes during the design service life of the structure are considered, according to the climate change scenario in Note 1, unless the National Annex describes another method.

NOTE 3 For adaptable or replaceable structures or parts thereof, provided a maintenance and monitoring plan is explicitly addressed, the most adverse climate and sea level until the first major planned maintenance, are considered according to the climate change scenario in Note 1, unless the National Annex describes another method.

NOTE 4 In case the maintenance schedule is not known, the climate change scenario in Note 1, and the marine conditions (waves, currents, winds, water levels, etc.) for 2/3 of the intended design service life of the structural parts are considered, unless the National Annex describes another method.

NOTE 5 Further considerations on climate change are given in Clause 5.

(3) When a statistical data analysis of the metocean events is performed, representative values of hydrodynamic loads should be assessed using return periods or time-exceedance frequencies of metocean parameters that are representative of metocean events (i.e. using long term statistics).

(4) Taking into account a shorter duration of transient design situations, shorter return periods than those suited for persistent design situations may be defined.

(5) In the Deep-sea Extremes Method, when there is clear evidence of a moderate or greater degree of correlation between primary variables of metocean parameters, a joint probability assessment of the metocean parameters should be performed as long as this is compatible with the available data. The characteristic value of the hydrodynamic load should be based on the characteristic joint return period introduced in 4.7.2(2) and on the combination marginal return period introduced in 4.9.3.

NOTE When there is a very strong correlation, a full correlation can be assumed and fitting a joint probability distribution is not necessary anymore.

(6) In the Deep-sea Extremes Method a marginal (individual) probability assessment of the metocean parameters may be performed when:

- there is a little degree of correlation between primary variables of metocean parameters; or
- the structure's response can be proved not to be sensitive to combined waves, currents and water levels; or
- the available data do not allow for a joint probability assessment.

(7) The characteristic value of the hydrodynamic load should be based on the characteristic marginal return period introduced in 4.7.2(1) and on the combination marginal return period introduced in 4.9.2.

(8) The representative value of a favourable/stabilizing action shall be the minimum value likely to occur in the design situation under consideration.

NOTE The minimum value is often equal to zero.

(9) In the Full Transfer Approach, representative values of the hydrodynamic loads on structural elements (i.e. the characteristic value, the frequent value, the quasi-permanent value) should be assessed with identical marginal return periods of the loads' own distributions as those given in 4.7.2, 4.7.4 and 4.7.5.

4.7.2 Characteristic value

(1) The value of the characteristic marginal return period shall be assessed.

NOTE The characteristic value is assessed as the 100-year marginal return period (the "characteristic marginal return period") unless the National Annex gives a different value.

(2) When a two-variables joint statistical analysis of the metocean parameters is performed, the value of the characteristic joint return period shall be assessed.

NOTE 1 The characteristic value is assessed as the 350-year joint return period (the "characteristic joint return period") unless the National Annex gives a different value.

NOTE 2 The value of the characteristic joint return period for use in a three- or more variables statistical analysis is not covered in this document.

(3) When the physical processes are relatively simple/benign so that statistical analyses might not be needed (HEA1), the characteristic value may be the best estimate of the extreme value with the return period mentioned in (1) and (2).

4.7.3 Combination value

(1) The combination value of the hydrodynamic loads with non-metocean actions shall be found by multiplying the characteristic or the design value by the ψ_0 factors defined in EN 1990.

4.7.4 Frequent value

(1) The frequent value shall be assessed:

- as a 0,02 % frequency of time exceedance; or
- as a 5-year marginal return period (the "frequent marginal return period"); or
- when a two-variables joint statistical analysis of the metocean parameters is performed, as a 15-year joint return period (the "frequent joint return period").

NOTE 1 The National Annex can select the method or provide guidance for the choice of a method for the assessment of the frequent value.

NOTE 2 The value of the frequent joint return period for use in a three- or more variables statistical analysis is not covered in this document.

(2) When the physical processes are relatively simple/benign so that statistical analyses might not be needed (HEA1), the frequent value may be:

- the best estimate of the value with the return period or the frequency of time exceedance that are mentioned in (1); or
- calculated by multiplying the characteristic value by the ψ_1 factor defined in EN 1990.

NOTE The National Annex can select a method or provide guidance for the choice of a method.

4.7.5 Quasi-permanent value

(1) The quasi-permanent value shall be assessed:

- as a 0,1 % frequency of time exceedance; or
- as a 1-year marginal return period (the “quasi-permanent marginal return period”); or
- when a two-variables joint statistical analysis of the metocean parameters is performed, as a 3-year joint return period (the “quasi-permanent joint return period”).

NOTE 1 The National Annex can select one method or provide guidance for the choice of a method for the assessment of the quasi-permanent value.

NOTE 2 The value of the quasi-permanent joint return period for use in a three- or more variables statistical analysis is not covered in this document.

(2) When the physical processes are relatively simple/benign so that statistical analyses might not be needed (HEA1), the quasi-permanent value may be:

- the best estimate of the value with the return period or the frequency of time exceedance that are mentioned in (1); or
- calculated by multiplying the characteristic value by the ψ_2 factor defined in EN 1990.

NOTE The National Annex can select one method or provide guidance for the choice of a method.

(3) The quasi-permanent value of the still water level shall be the mean sea level and take into account the sea level rises due to climate change.

4.8 Design value and importance factor

(1) The design value used in the verification of serviceability and ultimate limit states shall be assessed by multiplying the importance factor φ_I with the characteristic marginal return period defined in 4.7.2(1) and the characteristic joint return period defined in 4.7.2(2).

NOTE The values of the importance factor φ_I are given in Table 4.4 (NDP) unless the National Annex gives a different value.

(2) The design value used in the verification of the ultimate limit states shall be calculated with partial factors on action γ_F as defined in EN 1990:2023, Table A.6.8 (NDP) or assessed directly (i.e. without partial factors).

NOTE 1 Water levels are never factored. Hydrostatic pressures can be factored, see Clauses 6 to 11.

NOTE 2 Time independent uncertainties due to hydrodynamic load action models are covered by means of partial factors given in EN 1990:2023, Table A.6.8 (NDP), design formulae, especially those based on model tests, and the limit state's allowable design criteria.

NOTE 3 The National Annex can provide guidance on how to assess directly the design value of the action from currents and waves for use in the verification of ultimate limit states, using specific design marginal and joint return periods.