
**Actions from waves and currents on
coastal structures**

Effets des vagues et des courants sur les structures côtières

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ISO 21650:2007

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Published in Switzerland

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Foreword

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

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 21650 was prepared by Technical Committee ISO/TC 98, *Bases for design of structures*, Subcommittee SC 3, *Loads, forces and other actions*.

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Introduction

This International Standard, which deals with the actions from waves and currents on structures in the coastal zone and in estuaries, is the first of its kind. Waves and currents and actions from waves and currents on structures in deeper water, especially structures for the petroleum industry, are dealt with in ISO 19901-1 and ISO 19902, ISO 19903 and ISO 19904-1. Some of the structural elements for deeper water structures and coastal structures are the same, especially elements with cylindrical shapes. There will thus be, to some extent, an overlap between this International Standard and other ISO standards on the wave and current actions on cylindrical structural elements. There is though, a difference in wave conditions and wave kinematics between coastal waves and deeper water waves.

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Actions from waves and currents on coastal structures

1 Scope

This International Standard describes the principles of determining the wave and current actions on structures of the following types in the coastal zone and estuaries:

- breakwaters:
 - rubble mound breakwaters;
 - vertical and composite breakwaters;
 - wave screens;
 - floating breakwaters;
- coastal dykes;
- seawalls;
- cylindrical structures (jetties, dolphins, lighthouses, pipelines etc.).

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For the rubble mound structures it is not possible to determine the forces on and the stability of each individual armour unit because of the complex flow around and between each armour unit. But there are formulae and principles to estimate the necessary armour unit mass given the design wave conditions. Coefficients in these formulae are based on hydraulic model tests. Since the rubble mound structures are heavily used, they are included in this International Standard, although they may not be treated exactly in accordance with ISO 2394.

This International Standard does not include breakwater layout for harbours, layout of structures to manage sediment transport, scour and beach stability or the response of flexible dynamic structures, except vortex induced vibrations.

Design will be performed at different levels of detail:

- concepts;
- feasibility;
- detailed design.

This International Standard is aimed at serving the detailed design.

It is pointed out that the annexes are only informative and are not guidelines/manuals. The annexes have no regulatory power.

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.

2 Terms and definitions

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

- 2.1 actions**
force (load) applied to the structure by waves and/or currents
- 2.2 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
- 2.3 annual maximum method**
method of estimating extreme wave heights based on a sample of annual maximum wave heights
- 2.4 armour layer**
protective layer on a breakwater, seawall or other rubble mound structures composed of armour units
- 2.5 armour unit**
relatively large quarry stone or concrete shaped unit that is selected to fit specified geometric characteristics and density
- 2.6 astronomical tide**
phenomenon of the alternate rising and falling of sea surface solely governed by the astronomical conditions of the sun and the moon, which is predicted with the tidal constituents determined from harmonic analysis of tide level readings over a long period
- 2.7 breakwater**
structure protecting a shore area, harbour, anchorage and/or basin from waves
- 2.8 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
- 2.9 chart datum**
CD
reference level for soundings in navigation charts
- 2.10 core**
inner portion of a breakwater, dyke and rubble mound structures, often with low permeability
- 2.11 crest**
1. highest point of a coastal structure
2. highest point of a wave profile
- 2.12 crown wall**
concrete superstructure on a rubble mound

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2.13**datum level**

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

2.14**deep water**

water of such a depth that surface waves are little affected by bottom topography, being larger than about one-half the wavelength

2.15**design water level****DWL**

water level selected for functional design, structural design and stability analysis of marine structures

NOTE Generally it is the water level that mostly affects the safety of the structures/facilities in question. DWL is chosen in view of the acceptable level of risk of failure/damage.

2.16**density driven currents**

currents induced by horizontal gradients of water density generated by changes in the salinity and/or temperature, which are caused by the influx of fresh water from run-off from land through an estuary, heat flux from coastal power stations, or other reasons

2.17**diffractions coefficient**

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

2.18**directional spreading function**

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

2.19**directional wave spectrum**

function expressing the energy density distribution of waves in the frequency and directional domains, being expressed as the product of frequency wave spectrum and the directional spreading function

2.20**drag coefficient**

coefficient used in the Morison equation to determine the drag force

2.21**dyke berms**

nearly horizontal area in the seaward and landward dyke slope which are primarily built to provide access for maintenance and amenity and which reduce wave run-up and overtopping

2.22**dyke toe**

part of a dyke that terminates the base of the dyke on its seaward face

NOTE Various toe constructions are used to prevent undermining of the dyke.

2.23**extreme sea state****extreme waves**

state of waves occurring a few dozen times a year to once in many years, expressed with the significant wave height and the mean or significant wave period at the peak of storm event

2.24

filter

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

2.25

floating breakwater

moored floating object to reduce wave heights in the area behind the floating breakwater

2.26

foreshore

shallow water zone near the shore on which coastal dykes, seawalls and other structures are built

NOTE In beach morphology the term foreshore is used to denote the part of the shore lying between the crest of the seaward berm and the ordinary low water mark.

2.27

frequency wave spectrum

function expressing the energy density distribution of waves in the frequency domain

2.28

geotextile

synthetic fabric which may be woven or non-woven used as a filter

2.29

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

2.30

highest wave height

height of the highest wave of a given wave record or that in a wave train under a given sea state

2.31

impulsive wave pressure

water pressure of high peak intensity with a very short duration induced by the collision of the front surface of a breaking wave with a structure or the collision of a rising wave surface with a horizontal or slightly inclined deck of a pier

2.32

inertia coefficient

coefficient used in the Morison equation to determine the inertia force

2.33

international marine chart datum

IMCD

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

2.34

jetty GB

pier US

deck structure supported by vertical and possibly inclined piles extending into the sea, frequently in a direction normal to the coastline

2.35**lift coefficient**

coefficient used to determine the lift force

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

2.37**mean high water springs****MHWS**

average height of high waters, occurring at the time of spring tides

2.38**mean low water springs****MLWS**

average height of low waters occurring at the time of the spring tides

2.39**mean sea level****MSL**

average height of the sea level for all stages of the tide over a 19-year period, generally determined from hourly height readings

2.40**mean water level****MWL**

average elevation of the water surface over a given time period, usually determined from hourly tidal level readings

NOTE The monthly mean water level varies around seasons by a few tens of centimetres.

2.41**mean wave period**

average period of all waves among a given wave record

NOTE The mean wave period is often estimated from the spectral information obtained from a wave record. See 5.2.1.

2.42**moorings**

ropes, wires or chains to hold a floating object in position

2.43**overtopping**

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

NOTE This definition could serve as a general definition and should not be given individually for each structure.

2.44**parapet**

low wall built along the crest of a seawall

2.45

peaks-over-threshold method

POT method

method of estimating extreme wave heights based on a sample of peak heights of storm waves exceeding some threshold level

2.46

peak wave period

period corresponding to the peak of frequency wave spectrum

2.47

permeability

capacity of bulk material (sand, crushed rock, soft rock *in situ*) in permitting movement of water through its pores

2.48

pipeline

structure for carrying water, oil, gas, sewage, etc.

2.49

pipng

erosion of closed flow channels caused by water flowing through soil usually underneath the dyke body

NOTE Soil particles are carried about by seepage flow, thus endangering the stability of the dyke.

2.50

pore pressure

interstitial pressure of water within a mass of soil or rock

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2.51

porosity

percentage of the total volume of a soil and/or granular material occupied by air/gas and water

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2.52

pulsating wave pressure

wave pressure with a period comparable with the wave period

2.53

refraction coefficient

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

2.54

reflection coefficient

ratio of the height of reflected waves to the height of incident waves

2.55

revetment

cladding of concrete slabs, asphalt, clay, grass and other materials to protect the surface of a sea dyke against erosion

2.56

rip-rap

usually, well-graded quarry stone, randomly placed as an armour layer to prevent erosion

2.57

rock

aggregate of one or more minerals

2.58**run-up/run-down**

phenomenon of waves running up and down the seaward slope of a sloping structure, their height being measured as the vertical distance from the still water level

2.59***R*-year wave height**

extreme wave height corresponding to the return period of *R* years

NOTE When used, the specific value of *R* is indicated such as 100-year wave height.

2.60**scour**

removal of underwater sand and stone material by waves and currents, especially at the base or toe of a structure

2.61**sea state**

condition of sea surface within a short time span, being expressed with characteristic wave heights, periods and directions

2.62**seaward dyke slope**

slope of the dyke on the seaward side that is generally flatter than 1:4 to reduce wave run-up, protected by a revetment made of clay and grass, concrete slabs, asphalt, or stones to prevent erosion

2.63**shallow water**

water of such a depth that surface waves are noticeably affected by bottom topography, being less than about one-half the wavelength

NOTE Region of water in which waves propagate is sometimes classified into three categories of 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.

2.64**shoaling coefficient**

ratio of the height of waves affected by the depth change in shallow water to their height in deep water with the refraction effect eliminated

2.65**shoreward dyke slope**

slope of dyke on the landward side, generally no steeper than 1:3 to prevent erosion by wave overtopping

NOTE It is generally protected by a revetment made of clay/grass.

2.66**significant wave height**

average height of the one-third highest waves of a given wave record

NOTE The significant wave height is often estimated from the spectral information obtained from a wave record. See 5.2.1.

2.67**significant wave period**

average period of the one-third highest waves of a given wave record

2.68**slamming actions**

actions when a water surface and a structure suddenly collide

2.69
still water level
SWL

level of water surface in the absence of any wave and wind actions, is also called the undisturbed water level

2.70
stone

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

2.71
storm surge

phenomenon of the rise of the sea surface above astronomical water level on the open coast, bays and on estuaries due to the action of wind stresses on the water surface, the atmospheric pressure reduction, storm-induced seiches, wave set-up and others

2.72
swell

wind-generated waves that have advanced out of the wave generating area and are no longer affected by winds

2.73
tidal currents

alternative or circulating currents associated with tidal variation

NOTE Tides and tidal currents are generally strongly modified by the coastline.

2.74
toe

lowest part of sea- and port-side breakwater slope, generally forming the transition to the seabed

2.75
total sample method

method of estimating extreme wave heights by extrapolating a distribution of all the wave heights measured at a site of interest

2.76
tsunami

long waves with the period of several minutes to one hour and the height up to a few tens of meters, which are generated by the vertical movement of sea floor associated with a submarine earthquake, by plunging of large mass of earth into water by land slide or volcanic eruption, and other causes

2.77
uplift

upward water pressure exerted up the base of a structure or pavement due to waves, excluding buoyancy

2.78
vortex induced vibration
VIV

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

2.79
wave climate

description of wave conditions at a particular location over months, seasons or years, usually expressed by the statistics of significant wave height, mean or significant wave period, and wave direction

2.80
wave induced currents

currents in the nearshore zone, which are induced by the horizontal gradient of wave energy flux being attenuated by wave breaking

2.81**wave pressure**

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

2.82**wave set-up**

rise of water level near the shoreline associated with wave decay by breaking

NOTE Wave set-up may amount to more than 10 % of the offshore significant wave height.

2.83**wave transmission coefficient**

ratio of the height of waves transmitted behind a structure to the height of incident waves

2.84**wind waves**

waves generated by and/or developed by wind

2.85**wind driven current**

currents induced by the wind stress on the sea surface

NOTE In coastal waters, wind driven currents are influenced by the bottom topography and the presence of the coastline.

2.86**wind set-up**

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

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3 Symbols

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$H_{1/3}$	significant wave height or the average height of highest one-third waves
H_{\max}	highest wave height
H_{m0}	significant wave height estimated from wave spectrum
m_n	n -th moment of wave spectrum such as m_0 and m_2
$T_{1/3}$	significant wave period
T_m	mean wave period
$T_{m0,2}$	mean wave period estimated from the zero-th and second moments of wave spectrum
T_p	period corresponding to the peak of frequency wave spectrum

4 Basic variables for actions from waves and currents**4.1 Water levels****4.1.1 Tides**

The astronomical tide levels at a design site shall be calculated with the tidal constituents obtained through the harmonic analysis of a long-term tide record at the site or those estimated from a nearby tide station.

The highest and lowest water levels that have occurred at or near the site should be taken into account in the evaluation of the actions from waves and currents.