Ports and Harbours Bureau, Ministry of Land, Infrastructure, Transport and Tourism (MLIT)
National Institute for Land and Infrastructure Management, MLIT
Port and Airport Research Institute

TECHNICAL STANDARDS AND COMMENTARIES FOR PORT AND HARBOUR FACILITIES IN JAPAN

THE OVERSEAS COASTAL AREA DEVELOPMENT INSTITUTE OF JAPAN

2020

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Foreword

This book is an English version of *"the Technical Standards and Commentaries for Port and Harbour Facilities in Japan"* (hereinafter called "the Technical Standards"), which summarizes the ministerial ordinance and public notice articles as well as the related commentaries and technical notes in connection with the "Technical Standards for Port and Harbour Facilities" established by Japan's Ministry of Land, Infrastructure, Transport and Tourism (MLIT) based on the provisions of the Port and Harbour Law. This version has been made with the approval of the authors including the Ports and Harbours Bureau of MLIT, National Institute for Land and Infrastructure Management (NILIM; also a part of MLIT), and the Port and Airport Research Institute (PARI; a National Research and Development Agency). While whole Japanese version is not completely translated yet, the Table of Contents of both versions are the same. The remaining parts will be translated to insert in the current version not far future. Accordingly, it is suggested to visit OCDI's website (http://ocdi.or.jp) for updates.

Japan is an island nation with few underground resources. The country comprises approximately 6,800 islands, and has an area of 380,000 square kilometers and a total coastline of 34,000 km. For this reason, industry, which supports the nation's economy, has been located in coastal areas with ports and harbors for convenience in importing raw materials and exporting products. Given these conditions, Japan has constructed, improved and modernized approximately 1,100 ports and harbors as well as approximately 3,000 fishing ports during the past one and a half centuries. Because 99% of trade volume now depends on ports and harbors, they play a particularly important role in Japan.

The first Japanese manual on port and harbor technology was published in 1943 and was subsequently revised several times. Under the 1974 revision of the Ports and Harbours Law, "the Technical Standards for Port and Harbour Facilities" are provided in the form of ministerial ordinances. The first edition of the present "Technical Standards" was published by the Japan Port and Harbour Association in 1979 and it has been revised four times as of this writing. The English version of the "Technical Standards" was first published in 1980, and was revised and reissued in 1991, 2002 and 2009 corresponding to the revisions of the Japanese "Technical Standards."

Because many ports and harbors in Japan face the open sea, a considerable number of ports are exposed to severe wave condition with heights exceeding 10m. Furthermore, many Japanese ports and harbors have been constructed on soft and thick strata of cohesive soil deposited. Because Japan is located on one of the world's most vigorous earthquake active areas, the facilities of ports and harbors are potentially exposed to severe natural disasters of earthquakes and tsunamis. Many efforts for technical development have been undertaken to enable construction of port and harbor facilities that are both safe and economical under these severe natural conditions. As a result of these efforts, it is fair to say that Japanese standard has the world's most advanced level of technology for wave-resistant design, earthquake-resistant design and for countermeasures to cope with soft ground at port and harbor areas.

The 2018 edition of "the Technical Standards," in addition to incorporating the most advanced technology, is based on "performance-based design" in response to worldwide demands that the national standards should be based on "performance criteria," as advocated in the TBT Agreement (Agreement on Technical Barriers to Trade). "The Technical Standards" are consistent with the following international standards, and represent a compilation of Japan's world-class knowledge in connection with technology for ports and harbors:

ISO2394 General principles on reliability for structures,

ISO23469 Bases for design of structures – Seismic actions for designing geotechnical works,

ISO21650 Actions from waves and currents on coastal structures.

The system of technical standards in Japan is structured with "ministerial ordinances" and "public notices" which specify concrete methods in connection with "the Technical Standards" that port and harbor facilities must satisfy based on the Ports and Harbours Law. They are supplemented with the "interpretations" on those ordinances and public notices. Basically, this structure is followed in the English edition.

Because technology in respective countries has been developed to conform to the conditions in individual country, there may be aspects of the content of “the Technical Standards” which are difficult for engineers from foreign countries to understand. For parts which foreign engineers cannot be clearly understood and want to obtain more information, we recommend to refer to the reference literature. Engineers with a serious problem in the subject may also inquire of the relevant offices of the above-mentioned Ports and Harbours Bureau (MLIT), NILIM, and PARI.

It is our sincere hope that “the Technical Standards” will contribute to develop ports and harbors construction and to progress in port and harbor technology.

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Dr. KIYOMIYA Osamu
Chairman, Editing Committee

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Abbreviations

Abbreviation	Long form
AASHTO	American association of state highway and transportation officials
ADCP	Acoustic doppler current profiler
AE	Air-entrained
AGV	Automated guided vehicle
AIS	Automatic identification system
AMeDAS	Automated meteorological data acquisition system
AP	Standard height for construction in Arakawa River Area
ASCE	American society of civil engineers
AUV	Autonomous underwater vehicle
BDM	Bayesian method
B.M.	Bench mark
CADMAS-SURF	Super roller flume for computer aided design of maritime structure
CBR	California Bearing Ratio
CCA	Copper chromated arsenate
CDIT	Coastal Development Institute of Technology
C.D.L.	Chart datum level
CDM	Cement deep mixing method
CERC	US army coastal engineering research center
CFD	Computational fluid dynamics
CFS	Container freight station
CH	Coupled hybrid
CLT	Cross laminated timber
CN	Carbon normalized
COD	Chemical oxygen demand
CORS	Continuously operating reference station
CPT	Cone penetration test
CTD	Conductivity temperature depth
CU	Consolidated and undrained
CWD	Ultrasonic velocimeter-type wave gauge
DEM	Discrete element method
D.L.	Design level
DO	Dissolved oxygen
DOL	Deviation of outlier
DS	Double sounding survey
DSM	Digital surface models
DT	Displacement tonnage
DWT	Deadweight tonnage
DYNEQ	A computer program for DYNamic response analysis of level ground by EQuivalent linear method
ECDIS	Electronic Chart Display and Information System
EMEP	Extended maximum entropy principle
EPS	Expanded Polystyrene
FCI	Functional capacity index
FCL	Full container load
FDEL	Frequency-dependent equivalent linearized technique
FDM	Finite difference method
FEM	Finite Element Method
FGC	Fly-Ash Gypsum Cement
FFT	Fast fourier transfort
FLAC	Fast Lagrangian Analysis of Contina

Abbreviation	Long form
FLIP	Finite Element Analysis Program for Liquefaction Process
FOAM	Field operation and manipulation
FRP	Fiber Reinforced Plastic
FWD	Falling weight deflectometer
GL	ground level
GNSS	Global navigation satellite system
GNSS/IMU	Global navigation satellite system/ Internal measurement unit
GPS	Global positioning system
GPV	Grid point value
G.S.B.M	Geographical survey institute bench mark
GT	Gross tonnage
HGM	Hydrogeomorphic approach
HORF	Hazaki oceanographical research facility
HRDB	Hokkaido regional development bureau
H.W.L.	Highest water level
H.W.O.S.T.	High water of ordinary spring tide
ICP	Interactive closest point
ICT	Information and communication technology
IPCC	Intergovernmental panel on climate change
ISO	International Organization for Standardization
JEAAS	the Japan Emulsified Asphalt Association Standard
JGD	Japanese geodetic datum
JGS	Japanese Geotechnical Society
JH	Japan Highway Public Corp
JIS	the Japan Industrial Standards
JMA	Japan management association
JMAAS	Japan Modified Asphalt Association
JSCE	Japan Society of Civil Engineers
JSMST	Japan society for marine survey and technology
K_0CUC	K_0 Consolidated-undrained triaxial compression
K_0CUE	K_0 Consolidated-undrained triaxial extension
LCL	Less than container load
LNG	Liquefied Natural Gas
LO/LO	Lift-on/Lift-off
LPG	Liquefied Petroleum Gas
LRFD	Load and resistance factor design
L.W.L.	lowest water level
L.W.O.S.T.	Low water of ordinary spring tides
MAFCO	Maritime facility of cylindrical construction
MARS	Multi-interface advection and reconstruction solver
MASCON	Mass-consistent
MCS	Monte carlo simulation
MEM	Maximum entropy method
MIR	Minimum ratio of residual correlation coefficient
MKS	Meter, kilogram, and second
M.L.W.L.	Mean low water level
MPS	Moving particle semi-implicit
MRI	Meteorological research institute
M.S.L.	Mean sea level
M.W.L.	Mean water level
NC	Normally consolidated
NEXCO	Nippon Expressway Company Limited
NGO	Non-governmental organization

Abbreviation	Long form
N.H.H.W.L.	Nearly highest high H.W.L.
OC	Over consolidated
OCDI	Overseas Coastal Area Development Institute of Japan
OCR	Over consolidation ratio
O.D.L.	Observation datum level
OHBC	Overhead bridge crane
PARI	the Port and Airport Research Institute
PC	Prestressed concrete
PCB	Polychlorinated biphenyl
PCC	Pure Car Carriers
PDC	Piezo drive cone
PGA	Peak ground acceleration
PHC	Prestressed high strength concrete
PHRI	the Port and Harbour Research Institute
POS	Point of sale
PPP-AR	Precise point positioning with ambiguity resolution
PRC	Prestressed reinforced concrete
PS	P and S waves
PSInSAR	Permanent scatterers in synthetic aperture radar
PSU	Pennsylvania state university
PVC	Polyvinyl chloride
REC	Rejection of the candidate
RI-CPT	Radio-isotope cone penetration test
RMG	Rail mounted gantry crane
RO/RO	Roll-on/Roll-off
ROV	Remotely operated vehicle
RTG	Rubber tired gantry crane
RTK	Real time kinematic
RTK-GNSS	Real time kinematic- Global navigation satellite system
R.W.L.	Residual water level
SALM	Single anchor leg mooring
SAR	Synthetic aperture radar
SAR-X	X-band synthetic aperture radar
SBHS	Steels for Bridge High Performance Structure
SBPR	Steel bars for prestressed concrete
SC	Cast Steel
S.C.E.	Saturated calomel electrode
SCP	Sand compaction pile
SD	Standard deviations
SD	Deformed Steel bars
SDR	Rerolled deformed steel bars
SF	Forged steel
SGM	Super geo-material
SHK	H-shaped Steel Kui (H-shaped steel pile)
SKK	Steel kokan Kui (Steel pipe pile)
SKY	Steel Kokan Yaita (Steel pipe type sheet pile)
SMA	Steel Marine Atmospheric
SMAC	Seismic monitoring advisory committee
SMB	Sverdrup- munk-bretschneider
SPGA	Strong-motion pulse generation area
SPH	Smoothed particle hydrodynamics
SPT-*N* Value	N value of Standard Penetration Test
SR	Round steel bars
SRC	Steel-reinforced concrete

Abbreviation	Long form
SRI	Selective reduced integration
SRR	Rerolled round steel bars
SS	Structural steel
STD	Salinity temperature depth
STK	Steel Tube Kozo (structure)
SWAN	Simulating waves nearshore
SWM	Mild steel wire
SWRH	Steel wire rod hard
SWRS	Steel wire rod spring
SWPD	Prestressed deformed steel wire
SWPR	Prestressed round steel wire
SWOP	Stereo wave observation project
SY	Steel Yaita (sheet pile)
SYW	Steel Yaita (sheet pile) wide type
TEU	Twenty-foot equivalent units
TIN	Triangulated irregular network
TLP	Tension leg platform
T.P.	Tokyo Peil
TVG	Time varied gain
UAV	Unmanned aerial vehicle
UNEP	United nations environment programme
USW	Ultrasonic-type wave gauge
UU	Unconsolidated and undrained
VLCC	Very large crude carrier
VOF	Volume of fluid method
VRS-	Virtual reference station
WAM	WAve prediction Model
W/C	Water-cement ratio
WG	Working group
WGS	World geodetic system
WFI	Welded fabric intend
WFP	Welded fabric plain
WFR	Welded fabric rib
W.L.	Water level
WRF	Weather research and forecasting

Symbols

Symbols	Definitions
A	cross-sectional area (cm^2) or (m^2)
A_C	projected area of the submerged part of the floating body
A_p	cross-sectional area at the pile bottom (m^2)
A_s	amount of horizontal reinforcing bars in shear plane (mm^2)
A_s	cross-sectional area of the reinforcing bars (mm^2)
A_T	above-water bow projected area of the ship (m^2)
B_C	width of breakwater body (m)
B_f	width of a footing (m)
C	center of buoyancy
C	wave celerity (m/s)
c	cohesion (kN/m^2)
c'	undrained shear strength for cohesive soil ground or apparent adhesion under a drained condition for sandy soil ground (kN/m^2)
$\overline{c_a}$	mean adhesion of pile and the ground (kN/m^2)
$C.D.L.$	Datum level for port administration (L.W.L.)
C_0	chloride ion concentration at the surface of the concrete (kg/m^3)
c_0	undrained shear strength of the original ground (kN/m^2)
c_{0k}	characteristic value of undrained shear strength of clayey soil at the foundation bottom (kN/m^2)
C_b	block coefficient
C_D	drag coefficient
C_d	design value of chloride ion concentration at the position of the reinforcing bars (kg/m^3)
C_e	eccentricity factor
C_F	frictional resistance coefficient
$\overline{CG}$	distance between center of gravity and center of buoyancy (m)
C_M	inertia coefficient
C_m	virtual mass factor
c_v	coefficient of consolidation (cm^2/day) or (m^2/s)
C_y	coefficient for lateral wind pressure resistance
C_α	secondary compression index (also called coefficient of secondary consolidation)
D	embedment depth of foundation (m)
D	depth of the navigation channel (m)
D	diameter (mm)
D	draft (m)
d_{10}	grain diameter corresponding to 10% by mass passing (mm)
d_{50}	median grain size of sand (mm)
D_a	allowable deformation (cm)
D_e	equivalent diameter of a drain (cm)
D_F	embedded length of a sheet pile wall (m)
D_m	orbital diameter of a water particle (m)
D_{max}	maximum deformation (cm)
D_r	reference deformation
D_r	relative density
DT	full-load displacement tonnage of the ship (ton)
D_t	average storage days in the yard (day)
D_w	diameter of a drain (cm)
DWT	deadweight tonnage of the ship (ton)
E	modulus of elasticity (kN/m^2
E	wave energy (N/day)
e	avoid ratio
e	eccentricity (m)

Symbols	Definitions
e_0	initial void ratio
E_1	encounter probability
E_{50}	elastic modulus (kN/m^2)
E_A	active earth pressure (kN/m)
E_f	berthing energy of the ship (kJ)
e_f	hammer efficiency
EI	flexural rigidity of the pile (kNm^2)
e_{max}	void ratio in the loosest state
e_{min}	void ratio in the densest state
E_P	passive earth pressure (kN/m)
E_s	energy absorbed by the fender (kJ)
F	required buoyancy of the floating body (kN)
F	fetch (m)
f	friction coefficient
f	frequency (Hz)
f_c	Corner frequency
F_d	wave drift force per unit width (kN)
F_{eff}	effective fetch (km)
F_n	lateral force acting on the hull of a ship (N)
f_t	design tensile strength of a stabilized body (kN/m^2)
F_U	uplift acting on the bottom surface (kN/m)
F_W	wind drag force (kN)
G	shear modulus of elasticity (kN/m^2)
G	center of gravity
g	gravitational acceleration (980 cm/s^2)
G_0	shear modulus of elasticity (kN/m^2)
GM	distance between the gravity center and metacenter of the ship (m)
$\overline{GM}$	distance between metacenter and center of gravity (m)
GT	gross tonnage of the ship (ton)
H	height of incident waves
H	horizontal force acting on the unit (kN),
H	thickness of a consolidation layer (m)
H	wall height (m)
H	water depth (m)
h	a damping constant
h	head loss (cm)
h	thickness of a concrete slab (cm);
h	layer thickness (m)
h	water depth (m)
h'	freeboard (m)
h'	water depth at the bottom of caissons (m)
H_0	deepwater wave height (m)
H_0'	equivalent wall height (m)
H_0'	equivalent deepwater wave height (m)
h_1	water level in front of the structure (m)
$H_{1/3}$	significant wave height (m)
$H_{1/20}$	highest one-twentieth wave height (m)
H_b	breaking wave height (m)
h_b	water depth at an offshore distance of 5 times the significant wave height from the front face the upright wall (m)
h_c	required crown height above water level (m)
H_D	wave height used in performance verification (m)
h_f	height of footing (m)
H_i	horizontal force distributed to each pile (N/m)

Symbols	Definitions
H_i	incident wave height (m)
h_i	thickness of the ith layer (m)
H_{max}	maximum wave height (m)
h_w	difference between a residual water level and a tidal level (m)
I	geometrical moment of inertia (m^4/m)
i_0	pile deflection angle (rad)
I_r	iribarren number
I_σ	influence value
K	coefficient of earth pressure
K	modulus of elasticity of ground (N/mm^2)
K	spring constant of the piled pier (kN/m)
K	the rebound rate (m)
k	coefficient of permeability (cm/s)
k	increase rate of c_u
k	coefficient of lateral subgrade reaction (MN/m^3)
k	horizontal seismic coefficient
k	lateral resistance coefficient of the ground ($kN/m^{2.5}$ or $kN/m^{3.5}$)
k	coefficient of permeability (cm/s) or (m/s)
k'	apparent seismic intensity
K_0	coefficient of earth pressure at rest
K_{30}	coefficient of bearing capacity corresponding to the loading plate with a diameter of 30 cm (N/mm^3)
K_{75}	the coefficient of bearing capacity corresponding to the loading plate with a diameter of 75 cm (N/mm^3)
K_a	coefficient of the active earth pressure
k_{CH}	coefficient of lateral subgrade reaction (kN/m^3)
K_d	diffraction coefficient
k_h	seismic coefficient
k_h'	apparent horizontal seismic coefficient
K_{Hi}	horizontal spring constant of pile (kN/m)
K_i	relative stiffness (m^3)
K_P	coefficient of passive earth pressure.
K_R	reflection coefficient
K_r	refraction coefficient
K_s	shoaling coefficient
k_s	horizontal shear modulus (kN/m^3)
k_v	coefficient of vertical subgrade reaction (kN/m^3).
L	embedment length of a pile (m)
L	wave length (m)
l	embedment depth (m)
l	span (m)
L_0	deepwater wavelength (m)
L_1	design service life (year)
L_a	length of the berth (m)
lg	length of the ground chain (m)
L_{pp}	length between perpendiculars of the ship (m)
L_t	wavelength of transverse waves (m)
M	metacenter
M	overturning moment (kN·m/m)
M	required mass of rubble stones or concrete blocks (t)
M	resistant moment due to friction on wall surfaces with fillings (kN·m/m)
M	stable mass of rubble stones or other armor material (t)
m	adjustment factor
m_B	adjustment factor for bearing capacity of foundation
M_H	horizontal maximum bending moment (kN·m)
M_p	rotation moment

Symbols	Definitions
M_s	mass of the ship (t)
m_v	coefficient of volume compressibility (m^2/kN)
M_w	mass of the water body (t)
N	SPT-N value.
$\bar{N}$	mean SPT-N value
N	number of waves
n	porosity of the ground (%)
n	stress sharing ratio = ($n=\Delta\sigma_s/\Delta\sigma_c$)
n	Young's modulus ratio (= E_s/E_c)
N_{ef}	effective number of waves
N_q, N_r	bearing capacity coefficient
N_S	stability number of the armor units
P	tractive force (kN)
P	concentrated load (kN)
P	exceedance probability of permissible rate of overtopping
P	horizontal load (kN)
P	load intensity (kN/m^2)
P	maximum rainfall (mm)
P	total uplift (kN)
P	wind energy per unit cross-sectional area (W/m^2)
p	a reduction rate
p	air pressure (hPa)
p	cumulative percentage (%)
p	subgrade reaction (kN/m^2)
p'	increment of consolidation pressure (kN/m^2)
p_1	wave pressure at the still water level (kN/m^2)
p_2	wave pressure at the sea bottom (kN/m^2)
p_3	wave pressure at toe of the upright wall (kN/m^2)
p_a	intensity of the wave pressure (kN/m^2)
P_B	buoyancy (kN/m)
p_c	air pressure at the center of typhoon (hPa)
p_{dw}	dynamic water pressure (kN/m^2)
P_H	horizontal wave force (kN/m)
P_k	external pressure to cause buckling (kN/m^2)
p_{max}	maximum tsunami wave pressure (kN/m^2)
P_p	resultant passive earth pressure (kN/m)
P_U	uplift force (kN/m)
P_V	resultant vertical earth pressure (kN/m)
p_w	residual water pressure (kN/m^2)
q	a seepage flow rate per unit width (cm^3/s/cm)
q	loaded weight (kN/m^2)
q	velocity pressure (N/m^2)
q_d	design value of foundation bearing capacity considering buoyancy of submerged part (kN/m^2)
q_u	unconfined compression strength (kN/m^2)
$\overline{qu}$	mean unconfined compression strength (kN/m^2)
q_{uc}	standard design strength (kN/m^2)
Q_x	longshore sediment transport rate (m^3/s)
R	radius of circular slip failure (m)
R	radius of cylindrical cell (m).
R	rainfall intensity (mm/h)
r	radius of gyration of area (mm)
R_f	fluid pressure force (kN)
R_{fk}	characteristic value of the skin friction force of a pile (kN)

Symbols	Definitions
RWL	residual water level (m)
S	settlement (m)
Sg	specific gravity (ton/m^3)
S_r	specific gravity relative to water
$S_u(f)$	frequency spectrum (m^2/s)
T	tension force of the tie member (kN)
T	tractive force (kN/m)
T	wave period (s)
t	consolidation time (min)
t	design working life (y)
t	plate thickness (mm)
t	rainfall duration (min)
t	temperature (°C)
t_0	start time of secondary consolidation (d)
T_1	return period (year)
$T_{1/3}$	significant wave period (s)
U	average degree of consolidation
U	flow velocity (m/s)
U	ship speed (m/s)
U	utilization factor
U	wind velocity (m/s)
U_{10}	average wind velocity at the standard height of 10 m (m/s)
U_C	velocity of the currents (m/s)
V	current velocity (m/s)
V	displacement volume (m^3)
V	wind velocity (m/s)
v	the Poisson ratio
V_b	berthing velocity of the ship (m/s)
V_g	velocity of gradient wind (m/s)
V_i	amplitude of each tidal constituent
V_p	longitudinal wave velocity (m/s)
V_s	transverse wave velocity (m/s)
W	self-weight (kN)
W	wind load(N)
w	water content (%)
w	deflection (m)
w'	saturated unit weight (kN/m^3)
w_0	equivalent unit weight (kN/m^3)
w_0	unit weight of sea water (kN/m^3)
W_i	wheel load (N)
w_i	load intensity (kN/m)
w_i	saturated unit weight (kN/m^3)
WL	water level (m)
y_0	displacement (m)
Z	section modulus (mm^3)
α	factor for an effective cross-sectional area
α	wave pressure coefficient of hydrostatic pressure (= 1.1)
α	constant determined by bottom shape (1.00 for rectangular shape and 0.588 for round shape)
β	characteristic value of a pile (m^{-1})
β	drift angle (rad)
β	incident wave angle (°)
γ	density of seawater (t/m^3)
γ	unit weight of soil (kN/m^3)

Symbols	Definitions
γ'	unit weight of fill (kN/m^3)
γ_i	structure factor
γ_S	load factor
γ_t	wet unit weight (kN/m^3)
γ_w	unit weight of water (kN/m^3).
δ	angle of wall friction
Δc	increases in strength (kN/m^2)
Δe	change in void ratio
Δp	pressure increment (kN/m^2)
ΔS	residual settlement (m).
ε_{50}	strain at $q_u/2$ in unconfined compression test
k_{h_k}	characteristic value of a seismic coefficient for verification
ζ	correction coefficient
η	inundation depth of tsunami standing wave in front of upright walls (m)
η^*	wave pressure acting height above the still water level (m)
θ	1/2 of the target beam angle
θ	angle between a slip surface and a horizontal plane (°)
μ	heaving ratio
μ	plasticity rate
μ	static friction coefficient
μ	friction coefficient
ν	Poisson's ratio
ρ	density (t/m^3)
ρ	flexibility number (m^3/MN);
ρ_0	density of sea water (t/m^3)
$\rho_0 g$	unit weight of seawater (kN/m^3)
ρ_s	soil particle density (t/ m^3)
ρ_w	density of seawater (t/m^3)
σ	normal stress on a shear surface (kN/m^2).
σ_t	secondary stress (N/mm^2)
σ_y	yield stress (N/mm^2)
τ	shear strength (kN/m^2)
ϕ	angle of shear resistance (°)
ϕ	angle of shearing resistance of soil (°)
θ	angle between the bottom face of a segment and a horizontal plane (°)
ω	similarity number
ω	surcharge per unit area (kN/m^2)
δ	angle of wall friction (°)
ρ_a	density of air (t/m^3)
ρ_0	density of seawater (g/cm^3)
σ	dynamic water pressure
σ	standard deviation
σ_y	yield stress (N/mm^2)
τ	average shear strength on a slip surface (kN/m^2)
$\partial p/\partial r$	pressure gradient (kg/m^2/s^2)

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