Ports and Terminals

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Preface

Former students from Delft University of Technology, who followed the lectures Ports and Waterways in the Master Hydraulic Engineering will recognize this text book as one of the readers they had to digest. It was, and will be, used in that course, but as there has been also much interest from other universities and practitioners in the Netherlands and in many other countries, it has ultimately led to this ”upgrade”.
The contents of this book is the combined result of the work experience of both authors in port planning and design and their consecutive part-time position in the chair of Ports and Waterways in the Faculty of Civil Engineering and Geosciences at Delft University of Technology. Throughout the 33 years of our tenure the new developments in practical engineering and results of academic research were merged in subsequent editions of the reader. In that respect we also like to acknowledge the many contributions from colleagues and researchers to the document and the valuable information from many PIANC Working Group reports.
During the years the cover page evolved, from a stern white sheet with only the title, author and course-code, into a colourful page with the aerial photograph of the Port of Rotterdam as background, which is still shown on the present cover. The reason for this is not difficult to guess: at one glance one sees the channels and basins and all different types of terminals, which are treated in the book. But more importantly the Port of Rotterdam has become a highly valued partner for the University and the Civil Engineering Faculty in particular, providing training places and guest lecturers on specialized subjects, and collaborating in a joint Research Program.
However, this does not mean that the text is focused on the planning and design of very large ports and sophisticated terminals only. On the contrary, much of our experience related to smaller ports and ports in developing countries has been included in the book, thereby also referring to valuable - be it a little outdated - sources such as the UNCTAD Handbook on Port Development. In other words, the book is aimed at guiding planners and designers of any type of port facility, all over the world.

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Contents

List of Symbols

Parameter	Unit	Description
a	m	vertical motion due to wave response
A	m^2	surface area
A_{cfs}	m^2	surface area of the CFS
A_{ch}	m^2	chamber floor area (horizontal); channel wet cross-sectional area
A_{gr}	m^2	gross storage area
A_L	m^2	longitudinal above water area
A_s	m^2	vessel cross-sectional area in the plane of the water surface; used in squat calculation
A_T	m^2	transverse above water area
A_{TEU}	m^2	required area per TEU inclusive op equipment travelling lanes
B_s	m	beam; width of a ship at the midships-section
c	m/s	celerity of an individual wave in unrestricted water
C	t/yr; TEU/yr	design annual throughput
c_a	$m^{-1}s^{-1}$	factor of bottom jet depending on the quay wall slope
c_a	m/s	apparent wave celerity
c_b	t/yr; TEU/yr	berth productivity; berth productivity per year
C_B	-	block coefficient
c_c	TEU	parcel size; the number of TEU (un)loaded per call
C_c	-	configuration coefficient; current force coefficient
C_c	currency	present day value
C_e	-	eccentricity coefficient
C_m	-	added mass coefficient
C_{mx}; C_{my}	-	virtual mass coefficients
C_r	m/yr	resiltation factor
C_s	-	stiffness coefficient
C_s	-	stiffness coefficient
$c_{s/h}$	t/hr	unloading rate per ship per hour
C_t	currency	annual costs in year t
C_w	-	waterplane area coefficient
D	m	draught; depth of non-moving ship; ship draught (for condition considered)

d_{50}	m	average grain size diameter; characteristic diameter bottom protection
D_{pl}	m^3	water displacement
DWT	t	deadweight tonnage
E	J	impact energy
f	Hz	actual wave frequency
F	N	force
f_{area}	-	ratio gross area over net area
f_{bulk}	-	bulking factor
f_r	-	irregularity factor for vessel arival
f_{TEU}	-	TEU-factor
GRT	1	gross register tonnage (volume in units of 2.83 m^3)
h	m	water depth; water level above undisturbed level; head-water thickness
h_{berth}	m	water depth at the berth location
h_f	m	freeboard
h_{gd}	m	guaranteed depth (with respect to a specified reference level)
h_{net}	m	remaining safety margin or net under keel clearance
h_{over}	m	overdepth
h_s	m	average height of the cargo in the storage or CFS
H_s	m	significant wave height
h_T	m	tidal elevation above reference level, below which no entrance is allowed
i	-	rate of discount (usually true interest, that is the actual interest minus the inflation component)
k	m	radius of gyration of the ships mass around the c.g.
k	-	blockage coefficient ($=A_s/A_{ch}$)
k_p	kN/m	pile stiffness
L	m	wave length
L_b	m	required berthing quay length for resting of vessels
L_B	m	length of basin or slip
L_{BP}	m	length between perpendiculars
L_{OA}	m	length over all
L_q	m	quay length
L_s	m	ship length; main vessel length
L_{st}	m	stopping distance
M	t	mass of the ship in tonnes
M	kNm	moment
m_b, m_s	-	occupancy rate of berth, respectively storage
m_c	-	acceptable average occupancy rate
n	-	number of berths
∇	m^3	water displacement

$N_{20'}$	-	number of TEU's
$N_{40'}$	-	number of FEU's
N_c	-	number of container movements per year per type of stack in TEU's
N_{cb}	-	number of cranes per berth
n_{dc}	day	number of days comprising a fishing cycle
n_{dr}	day	number of resting days in a fishing cycle
n_{du}	day	number of unloading days in a fishing cycle
N_{gs}	-	number of gangs per ship
n_{hd}	-	number of unloading hours in a day
n_{hy}	-	number of operational hours per year
NRT	1)	net register tonnage (expressed in units of 2.83 m^3)
N_s	-	number of ships
N_{sa}	-	number of vessels abreast
N_{sr}	-	number of vessels at rest
N_{sy}	-	number of ship calls per year
P	W	power
P	t/hr	(un)loading productivity per handling entity (crane, gang, pumps)
r	m	distance between c.g. of the ship and the point of first contact during berthing
r_{st}	-	ratio of average stacking height and nominal stacking height (0.6 to 0.9)
s	m	squat
s	m	space between vessels
$S(t)$	-	quantity of containers still on terminal; total number unloaded containers
$s_{\max}$	m	maximum sinkage (fore or aft) due to squat and trim
T_a	s	apparent wave period
T_B	t	total bollard pull
t_d	day	dwell time
$t_{d,\max}$	day	maximum dwell time (e.g. time within which 98% of containers have left the terminal)
T_n	s	natural periods of oscillation (nth harmonic)
T_p	s	peak waver period
U, u, V	m/s	water velocity; current velocity
u_b	m/s	velocity near the bed
v	m/s	approach velocity of ship's centre of gravity at time of impact
V	m^3	contents of 1 TEU container
V_c	m/s	average current velocity over the underwater part of the hull
V_d	m^3/yr	average annual volume of resiltation

V_{eff}	m/s	ship speed with respect to channel bottom (design entrance speed)
V_{min}	m/s	minimum ship speed for rudder control
V_s	m/s	sailing speed
V_{wv}	m/s	wind velocity
V_{wd}	m/s	transverse speed of ship as a result of wind drift
w	kg/m^3	specific weight of seawater
W	m	average width of canal; width
W_a	m	additional width
W_b	m	bank clearance
W_{bm}	m	basic widthv
W_{eff}	m	channel width in unrestricted shallow water
W_p	m	separation distance
$W_{shelter}$	m	sheltering width in the wave direction
y_p	m	pile deflection
y_f	m	fender compression
z	m	vertical distance compared to undisturbed water level (up is positive)
α	$^\circ$	angle between wave direction and ship axis
α_{axis}	$^\circ$	angle between current and channel axis
β	$^\circ$	drift angle
γ	$^\circ$	angle
Δ	-	relative density (=$(\rho_s - \rho_w)\ /\rho_w$)
Δ	t	ship displacement in tons
θ	$^\circ$	angle interference peaks
θ_c, θ_w	$^\circ$	angle between current and ship axis, respectively between wind and ship axis
ρ_{air}	kg/m^3	density of air
ρ_{cargo}	kg/m^3	density of the cargo as stowed in the ship or stacked in the storage
ρ_w	kg/m^3	density of water

[1] actually a ton-force (a non-SI unit), but in practice referred to as "ton".

Chapter 1

Introduction

By nature port planning is a multidisciplinary activity. It involves expertise in the field of transport economics, shipping, nautical matters, safety and logistics. But also knowledge of waves and currents, sediment transport and coastal morphology, dredging and land reclamation, and design of breakwaters and quays. Hence port planning is teamwork. But within this team the port planner plays a central role in developing the concepts and obtaining the required expertise at the right time. Most port planners are civil engineers with hydraulic engineering training and experience. But they need to have two important qualities in addition to that:

(i) a basic understanding of the other disciplines involved
(ii) creativity

The first quality is needed to direct the work done by these experts and to integrate the results into a balanced design of the port lay-out. The integration process itself is the creative part of the work: after having determined the basic dimensions of approach channel and turning basins, of quays and terminals and of the corridors for hinterland connections, there are often many ways to physically arrange them into a port lay-out. Here the second quality mentioned above plays a crucial role in developing the right one.

The first part of this book (Chapter 1 through 6) is aimed at providing the basic elements to perform this planning process. In Chapter 7 the detailed planning of container terminals is treated, including the logistic process. Further attention is paid to design aspects, typical for such terminals. The objective is to provide the basis for an all-round port engineer, somebody who can participate in the design of any given type of port or terminal.

Chapters 8-14 present the planning aspects of other types of terminals.