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Port Designer's Handbook

Third edition

Carl A. Thoresen

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Foreword

This third edition of the handbook on modern design and construction of port and harbour engineering will, in my opinion, give harbour colleagues around the world an opportunity not only to study the Norwegian practices and solutions in the design and construction from traditional berth structures to complicated oil and gas berths, but also gain knowledge and a general understanding of the design of port and harbour constructions.

The invitation to write the foreword to the third edition of the *Port Designer's Handbook*, which has been updated to cover new port developments and standards, provides the ideal opportunity to express my belief that harbour experts around the world should write and share their knowledge and information more frequently with their colleagues.

This new edition will contribute and make available new information based on the author's long experience and knowledge to others within the harbour and port sector, so that the field can continue to develop.

I feel, therefore, that this handbook will be invaluable to practising harbour and port engineers and to postgraduate and senior university students of the state of the art.

Kirsti L. Slotsvik
Director General of the Norwegian Coastal Administration

Preface and acknowledgements

The purpose of the third edition of the *Port Designer's Handbook* is to update its coverage, particularly with regards to the berthing of large vessels and the design and construction of berth structures due to new developments in the construction and use of new materials. Over the last 5–10 years there has been considerable improvement and much new thinking in the design and construction of port and harbour structures. The main aim of the third edition is not to explain the full scope of port design and construction but to give guidelines and recommendations to try to deal with some of the main new items and assumptions in the layout, design and construction of modern port structures, and the forces and loadings acting on them.

The use of new concrete technology for berth structures in the marine environment is dealt with in detail, as well as the types of deterioration and methods of repair of these structures. Safety considerations and maintenance problems have also been covered in detail.

The book is mainly based on the author's more than 45 years of experience gained from practical engineering and research from more than 800 different small and large port and harbour projects both in Norway and abroad. He worked as the chief engineer and was technically responsible for the port and harbour division in the largest Norwegian consulting company Norconsult AS. After retiring, he started his own office, PORT-CAT.

The book includes material from many lectures held by the author over the years on berth and port structures at the Norwegian University of Science and Technology, and at the Chalmers University of Technology, Sweden, as well as on postgraduate courses arranged by the Norwegian Society of Chartered Engineers.

Over the last 10 years or so, the growing interest in the design of port and harbour structures has produced a huge number of research reports and technical papers and amount of information, especially from the International Navigation Association (PIANC). Much of this latest information has been evaluated and summarised in this handbook.

The author hopes that the contents of the book will make it a readable and useful handbook that provides practical guidance for port engineers who are responsible for the design of port and harbour structures, and that it will contribute to further development of the subject. Many of the subjects mentioned in the text are worthy of further study, and there are further reading lists at the end of each chapter to direct the reader to other detailed sources of information.

Finally, the author would like to express his deepest thanks to the many friends and colleagues who have contributed with helpful encouragement, information, comments and suggestions to this third edition. Particular and sincere thanks go to the following persons, whom the author has drawn upon for their experience and knowledge and for their input to the following chapters, and therefore deserve to be mentioned for their contribution to the book:

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Senior Geotechnical Engineer Bjørn Finborud, Norconsult AS, Norway: Chapter 1.

Senior Geotechnical Engineer Odd Gregersen, Norwegian Geotechnical Institute, Norway: Chapters 1 and 11.

Senior Port Consultant George R. Steel, Scott Wilson Group, UK: Chapters 1 and 13 and co-author to Chapter 20.

Special Adviser Arne Lothe, Norconsult AS, Norway: Chapters 1 and 2.

Professor Shigeru Ueda, Tottori University, Japan: Chapters 4, 14 and 21.

Project Manager Sergi Ametller, Panama Canal Enlargement, Grupo Unidos por el Canal, Panama: Chapter 2.

Professor Knut V. Høyland, The Norwegian University of Science and Technology, Norway: Chapter 2

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Chief Engineer Trygve Isaksen, Norconsult AS, Norway: Chapter 19.

In addition, thanks go to the following friends and colleagues whom I have known for many years and have had the privilege of exchanging experiences with in the field of port and harbour engineering for this book:

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Thanks are also due to ICE Publishing for all their help and assistance during the preparation of the typescript for the third edition of the *Port Designer's Handbook*.

About the author

Carl A. Thoresen graduated from the University of Strathclyde, Glasgow, in 1963. During more than 45 years as a professional consulting engineer he has been involved in practical engineering and research for over 800 different small and large port and harbour projects both in Norway and overseas as the Chief Engineer and responsible consultant for the largest Norwegian consulting company, Norconsult AS. For the last decade he has run his own company, PORT-CAT. In addition, he has worked for the Norwegian Agency for International Development, the World Development Bank, the Asian Development Bank and the African Development Bank.

The projects he has overseen include waterways, complicated oil and gas harbours, commercial multi-purpose and container terminals, breasting and mooring dolphins, lighthouses, breakwaters, ferry berths, fishing harbours, marinas and small craft harbours. His involvement on these projects has included planning, technical and economic evaluations, design, preparations of tender documents, tender evaluations and negotiation, construction supervision, maintenance and rehabilitation work.

He is the author of the books *Port Design: Guidelines and Recommendations* (published 1988) and *Port Designer's Handbook* (first edition in 2003, reprint in 2006 and a second edition in 2010), and the co-author of *Norwegian Recommendations for Waterfront Structures* and the *Norwegian Recommendations for Concrete Construction in Water*.

He has been a member of many official technical committees for harbour design, constructions and waterfront structures, and actively involved in the PIANC's various working groups, including:

- Working Group 145, 'Berthing Velocity and Fender Design'
- Working Group 135, 'Design Principles for Container Terminals in Small and Medium Ports'
- Working Group 116 (chairman), 'Safety Aspects Affecting the Berthing Operations of Large Tankers to Oil and Gas Terminals'
- Working Group 48, 'Guidelines for Port Construction Related to Thrusters'
- Working Group 33, 'Guidelines for the Design of Fender System 2002'.

Over the years he has presented many lectures on berth and port structures at the Norwegian University of Science and Technology, the Chalmers University of Technology, Sweden, and on postgraduate courses arranged by the Norwegian Society of Chartered Engineers.

He has been an active participant in around 30 international conferences. He has written some 50 papers and articles on port and harbour planning, berth and fender design and construction, and marine repair and rehabilitation works.

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Chapter 1
Port planning

1.1. Introduction

The advantages and disadvantages of various berth alternatives for accommodating all types of ship in a port cannot be assessed in detail without well-developed and well-defined port plans. All port plans represent a set of compromises between several goals. This chapter evaluates the activities necessary for the preparation of a detailed port plan, and discusses the criteria that form the basis of the planning, from the open sea, through the approach channel, the harbour basin, the berth and the terminal, as indicated in Figure 1.1.

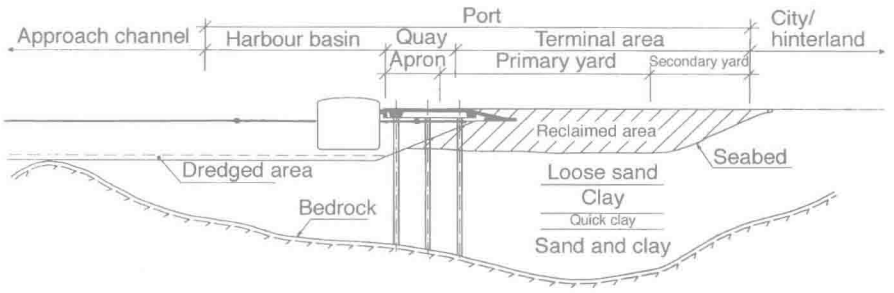
The port authority and its consulting engineer should identify the activities necessary to establish the terms of reference for the engineering planning and to specify the work to be executed by, for example, the consulting engineer, the contractors and the port operator, within the fixed margin of expenditure.

1.2. Planning procedures

There are many activities, all of which have to be recorded, clarified and assessed. Essential basic information includes, among other things, data on the physical and technical conditions in the development area and information obtained from experienced port users. A checklist for the planning of port developments should cover at least the following main items:

(a) resolution by the port authority to start planning
(b) selection of the consulting engineer
(c) scope of work:
    (i) introduction
    (ii) background
    (iii) scope of project
    (iv) basic data
(d) registration of users:
    (i) public
    (ii) private
(e) recording of users' needs:
    (i) types of port and berth structures
    (ii) traffic statistics
    (iii) types and specifications of ships
    (iv) coastal areas and maritime conditions
    (v) berth and land area requirements
    (vi) growth factors
(f) impact study
(g) site evaluation:

Figure 1.1 The activities that need to be investigated



(i) existing areas
(ii) potential areas
(iii) natural conditions
(iv) relationship with neighbours

(h) layout plan
(i) economic analysis
(j) work schedule.

The items listed above are outlined in the following sections, in order to describe the various activities that require closer study and assessment in connection with proper port planning. But one should always remember that ports often define their own needs. Some ports are predominantly bulk ports, others are high-value cargo ports and others are multi-purpose ports, etc. Depending on the character of existing traffic and expectations about future potential, the port's needs and future capacities will vary. A port usually exists in a dynamic business and social environment, and therefore the needs of the port can change rapidly over short periods of time.

1.2.1 Resolution to start planning

After engaging a consultant, but before the planning starts, it is essential that the client or the authority concerned has prepared a project plan stating clearly the conditions and target of the planning or the work to be done.

The planning and implementation of a project for a new port or for a major port extension can be subdivided into the following main phases:

(a) project identification study
(b) preliminary planning study:
  (i) reconnaissance mission
  (ii) fact-finding mission
  (iii) feasibility study
  (iv) appraisal mission and study
(c) detailed planning work:
  (i) inception planning
  (ii) interim planning
  (iii) final planning and report

(d) pre-engineering work:
    (i) design criteria and structural specifications
    (ii) preliminary cost estimate
    (iii) final pre-engineering report
(e) detailed engineering work:
    (i) design calculations
    (ii) tender drawings (formwork drawings)
    (iii) technical specification for construction
    (iv) bill of quantity
    (v) tender evaluation
(f) construction work:
    (i) construction drawings
    (ii) construction supervision
(g) project completion report.

One of the most important tasks is probably the preliminary planning study, which serves the purpose of verifying whether a suggested project is really justified from an economic point of view and whether it can be implemented at a reasonable cost under safe technical conditions. The most convenient site for the suggested works should be tentatively selected, or alternative locations suggested. A preliminary plan of the port, an approximate cost estimate and an economic and financial evaluation should form the final part of a preliminary study report.

The results of the planning study for the port development should, therefore, always be summarised in an action-oriented programme containing an evaluation of the following:

(a) operational analysis
(b) technical analysis
(c) economic analysis
(d) financial analysis.

The fate of the project will depend on the conclusions of the preliminary report. The general character of the port, the layout of the port facilities, and their capacity and extent are determined in the preliminary plan, notwithstanding such modifications or corrections that may be made afterwards. The preparation of a preliminary study should, therefore, be entrusted to port planners with the widest possible range of experience, both in technical planning and in port operation under various conditions, and a thorough understanding of economic and transportation problems. When the general conclusions of the preliminary study have been approved and its recommendations accepted, the next predominantly technical phase of the planning will include all necessary field investigations and the detailed design.

1.2.2 Selection of the consulting engineer (planners)

It is a fact of life that the competition for consultancy business in the harbour sector is now tougher than it has ever been. It is therefore necessary for consultancy companies to be highly specialised in the use of the latest technical skills and development tools. The company's past experience and performance as a whole, the experience of the leading personnel who will be involved in the project, and the company's proposed methodology are important factors for the client to consider when selecting a consulting engineer.

As a basis for selection, the consulting engineers must enumerate and describe the projects they have undertaken, naming previous employers for reference. They should also indicate the general manpower

available (e.g. graduate engineers), whether they can step-up planning and design if so desired by the client, and whether they can mobilise divers (frogmen), an underwater camera, a diver's telephone outfit, etc., to carry out underwater investigations and supervision.

A client should always make sure that the personnel named in a proposal will also form the project team working on the project. If a team member is replaced, the client should always demand that the new team member have at least the same qualifications as the original team member.

The Federation International des Ingenieurs-Conseils, **FIDIC**, has the following policy statement:

> A Consulting Engineer provides a professional service. A Client, in selecting a Consulting Engineer, is selecting a professional adviser. The Consulting Engineer's role is to put expert knowledge at the disposal of his Client. On engineering matters, he serves his Client's interests as if they were his own. It is essential that he should have the necessary ability. It is equally important that the Client and Consulting Engineer should proceed on the basis of mutual trust and co-operation. In the professional relationship, the Consulting Engineer identifies with his Client's aims.

It is in the client's interest to select the most qualified and experienced company and to negotiate a fair price for the consultancy services. Saving 1 or 2% of the project cost on engineering is penny-wise and pound-foolish.

Payment for consultancy services can be defined in the following ways:

(a) payment on a time basis
(b) payment of a lump sum, based on either:
    (i) the consulting engineer's estimate of the work involved, or
    (ii) a generally accepted fee scale
(c) payment as a percentage of the cost of the works.

Direct expenses, such as travel costs, hotels, etc., are normally reimbursed separately. The fee for the consultancy service itself is normally invoiced at agreed intervals.

Some international development banks select the consulting engineer after what was previously called **the two envelope system**. The consulting engineer is requested to submit its proposal for consulting services in one technical envelope and one financial envelope. The technical proposal should be placed in a sealed envelope clearly marked 'technical proposal' and the financial proposal should be placed in a sealed envelope clearly marked 'financial proposal'.

The **technical proposal** should contain the following:

(a) The consulting company's general expertise for doing the work. If the company does not have the full expertise, the company can be associated with another company. For work in a developing country it is considered desirable to associate with a local company.
(b) Any comments or suggestions on the terms of reference (TORs) and a description of the methodology (work plan) the consulting engineer proposes for executing the services, illustrated with bar charts of activities and the graphics of the type used in the critical path method (CPM) or programme evaluation review technique (PERT).
(c) The estimated number of key professional staff required to execute the work according to the TORs. The composition of the proposed engineering team, and the task which would be

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