Available online at www.sciencedirect.com
ScienceDirect
Publishing Services by Elsevier
International Journal of Naval Architecture and Ocean Engineering xx (2017) 1—13
http://www.journals.elsevier.com/international-journal-of-naval-architecture-and-ocean-engineering/

Survey of research on the optimal design of sea harbours

Hassan Diab [a,b,*], Rafic Younes [b], Pascal Lafon [a]

[a] *Charles Delaunay Institute, Mechanical System and Concurrent Engineering Laboratory (ICD-LASMIS), UMR CNRS 6281, University of Technologie of Troyes (UTT), France*

[b] *Lebanese University, Faculty of Engineering, Lebanon*

Received 28 January 2016; revised 30 November 2016; accepted 25 December 2016
Available online ■ ■ ■

Abstract

The design of harbours, as with any other system design, must be an optimization process. In this study, a global examination of the different constraints in coastal engineering was performed and an optimization problem was defined. The problem has multiple objectives, and the criteria to be minimized are the structure cost and wave height disturbance inside a harbour. As concluded in this survey, the constraints are predefined parameters, mandatory constraints or optional constraints. All of these constraints are categorized into four categories: environmental, fluid mechanical, structural and manoeuvring.

Keywords: Port management; Harbour; Optimization

1. Introduction

Coastal areas have played a significant role in humanity's progress. Although risks arising from the oceans are sometimes huge, we have found that most of the world's populations live on or near the coast (Creel, 2003; World Resources Institute et al., 1992).

Humans have long tried to benefit from the coast; five thousand years ago (in the 3rd millennium B.C.), the Phoenicians constructed harbours in Tyr and Sidon on the Mediterranean Sea's coast for use in trading (Bosworth, 1915).

A harbour is defined as a place where ships load and unload cargo or shelter from storms (Hornby et al., 1989). At present, there are four major types of harbours according to functionality: fishing, military, pleasure and commercial.

Every type of harbour requires its own design and management considerations. Our interest will be confined to commercial harbours, which constitute the backbone of commercial transport worldwide. As in all commercial sectors, designers and managers always tend to increase the limits of capacity and operating periods of harbours, through optimal forms, design, and management. In addition, protecting a harbour's structures and saving the coastline are two important objectives that demand attention is given to defence structures, including breakwaters.

At present, any system design is an optimization process (Breitkopf and Coelho, 2010). As a consequence, the design of harbours must an optimization problem. In this article, we will outline an optimization problem for defining harbours.

Many researchers have worked on discovering the constraints that menace coastlines, harbours and defence structures to aid ocean and coastal researchers or engineers during the design process.

We will try to summarize what others have done in this field before formulating a breakwater design problem that considers all of the constraints. We will decompose the constraints into four main categories: environmental, fluid mechanical, structural and manoeuvring.

* Corresponding author.
E-mail addresses: hassan.diab.2016@utt.fr (H. Diab), rafic.younes@lsis.org (R. Younes), pascal.lafon@utt.fr (P. Lafon).
Peer review under responsibility of Society of Naval Architects of Korea.

http://dx.doi.org/10.1016/j.ijnaoe.2016.12.004

The environmental constraints cover water quality, water level and ecological life as main environment-related issues.

Among the fluid mechanical constraints, we will first observe the effects of waves, which are considered to be a primary if not the most important constraint. We will proceed further into the world of wave modelling and define its bold lines. We will also discuss erosion and flooding phenomena, water depth and ocean currents.

In addition, regarding structural constraints, we will address both economic and mechanical constraints. Economic constraints comprise the cost, materials, and construction process, whereas mechanical constraints include mechanical stresses, position, dimensions, and the effects of the seismic responses of structures. The problems of the floatability and stability of floating breakwaters will also be considered here.

Furthermore, within the manoeuvring constraints, we will mention the influence of harbour architecture on manoeuvrability. The entrance, fairways and manoeuvring area will be discussed to determine the different factors that affect their designs.

2. Environmental constraints

Many problems in the ocean environment could be studied as water levels rise due to global warming, including water pollution, water quality and ecology. These three issues will be addressed in this section.

In addition, many other environmental problems may exist in certain special cases, including noise and the problem of ice. These problems are less studied. The noise in a chipping port was studied and considered to be a type of pollution in the port area (Kamphuis, 2006). The accelerated growth of brash ice is a problem that port operators confront in the very busy harbour basins of cold regions (Tomasicchio et al., 2013).

Air quality in harbour zones is another environmental problem. To date, this problem has not been considered as a functional constraint on harbour design.

2.1. Water quality

Basin water quality is an important aspect that must be considered in harbour design. Water exchanges produce a flushing action (Neelamani and Rajendran, 2002a). Low rates of seawater exchange between the inside and outside of harbours cause environmental problems that include bad smells and ecological disorders (Vidal et al., 2006). The water quality in a harbour will be affected by the existence of structures because of the influence of those structures on the movements of currents and tides. Predicting this influence using mathematical models before constructing the structures is a method that may be utilized to minimize the consequences of problems (Kantardgi et al., 1995). For example, designing coastal structures, such as Current Deflecting Walls, may be an effective solution that will reduce harbour siltation (Bowman and Pranzini, 2003) because harbour layouts are complex geometries that limit water renovation from the open sea in harbour-enclosed zones (Kamphuis, 2006). In addition, seawater exchange breakwaters have been suggested to address the issue of water quality in harbours (Vidal et al., 2006). World harbours that have only one connection to the adjacent ocean experience severe environmental impacts due to systematic and accidental discharges of polluted waters, which is why multi-connection harbours have been recommended (Vidal et al., 2006).

2.2. Water level

At present, water level is receiving increased interest. Climate change is accelerating rising sea levels (Battjes, 2006; Tomasicchio et al., 2013) and should therefore be taken into consideration when designing breakwater with long lifetimes. A safety factor that accounts for sea level rise must be considered (Suh et al., 2013). Higher water levels increase inshore wave heights in shallow waters (Chini et al., 2010).

Due to rising water levels, the significant wave height, which usually occurs once every 100 years, becomes more frequent, with obvious implications on coastal defence design life (Chini et al., 2010).

2.3. Ecology

The use of coastal structures as breakwaters increases habitat complexity, heterogeneity, and availability by the rapid colonization of sea species in such structures. Breakwaters can be considered as unique and important artificial reef habitats, on which abundant and diverse reef fish communities can develop (Burt et al., 2013). The materials used in constructing those structures significantly influence their role as reef habitats (Burt et al., 2009). To encourage marine life to use them as habitats, the shapes of submerged breakwaters have been studied (Kamphuis, 2006).

The ecological potential of heavily modified water bodies (HMWBs) has been defined to study the influence of the presence of ports on ecological status and to measure physical alterations caused by human activity (Ondiviela et al., 2013).

3. Fluid mechanical constraints

3.1. Waves

Waves have been proven to be the most relevant factor in coastal engineering (Franco et al., 1986), so we have identified a large number of articles that try to model the different types of sea waves or explain their effects.

In addition, most defence structures are built to maintain protection against wave energy (Filianoti, 2000; Hur et al., 2010; Kamphuis, 2006; Tanimoto and Takahashi, 1994; Tomasicchio et al., 2013; Vidal et al., 2006) or to maintain the functionality of harbours by promoting the stability of vessels and ships during accosting and loading/offloading activities (Kamphuis, 2006). Wave-induced ship motion may help cause serious damage to ships, containers and trolleys. It also may increase the duration of the process (Hong and Ngo, 2012). The efficiency of breakwaters decreases when the

Please cite this article in press as: Diab, H., et al., Survey of research on the optimal design of sea harbours, International Journal of Naval Architecture and Ocean Engineering (2017), http://dx.doi.org/10.1016/j.ijnaoe.2016.12.004