

Multidisciplinary Optimization of a Moored Rectangular Floating Breakwater

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ABSTRACT: The design optimization of floating breakwaters implicates solving a multidisciplinary problem consisting from three parts. The first one arises from the interaction of linear waves with a moored floating breakwater with a leeward boundary composed from a vertical wall. The second covers the dynamical behaviour of the structure; while the third concerns its structural mechanics. Next, the optimization problem is summarized by designing an optimal resistive breakwater with a minimum weight. The imposed constraints cover the floating condition, the stability, the maximum wave height in the port side, and the limitations for the mechanical stresses.

KEYWORDS: Floating breakwater; Wave modelling; Optimization; Structural resistance.

INTRODUCTION

Over the past two decades, interest in the study of the behaviour of floating breakwaters, FBWs, has increased owing to the requirement for the development of large number of new marinas and recreational harbours. The lower initial investment and the mobility of the structure of FBWs is attractive to the designer, where they are evaluated as a viable alternative when the cost of a fixed structure exceeds the economic return to be gained at that location and especially in sites with a large water depth and worse bottom foundation conditions.

As a result of all these positive effects, many types of floating breakwaters have been developed as described by McCartney (1985); however, the most commonly used type of floating breakwaters is the one that consists of rectangular pontoons connected to each other and moored to the sea bottom with cables or chains. Many studies have been directed towards the performance of floating breakwaters and its motion responses to understand their behaviour due to sea waves. For example, Drimer et al. (1992) presented a simplified analytical model for a floating rectangular breakwater in water of finite depth. Lee (1995) presented an analytical solution to the heave radiation problem of a rectangular structure, and he calculated the generated waves, added mass, damping coefficients and the hydrodynamic effect of the submergence, width of the structure. Hsu and Wu (1997) developed the boundary element method and applied it to study the heave and sway problem in a bounded domain (floating breakwater with a sidewall in the leeward side), which describes the real problem of breakwaters appearing in ports. Sannasiraj et al. (1998) adopted a two-dimensional finite element model to study the behaviour of pontoon-type floating breakwaters in beam waves, also Williams et al. (2000) investigated the

hydrodynamic properties of a pair of long floating pontoon breakwaters of rectangular section. Lee and cho (2003) developed a numerical analysis using the element free Galerkin method and mainly concerning the influence of mooring line condition on the performance of FBWs. Shen et al (2004) studied the effects of the bottom sill or the topography change on the hydrodynamic and transmission coefficients by a semi analytical method. Gesraha (2006) investigated the reflection and transmission of incident waves interacting with long rectangular floating breakwater with two thin sideboards protruding vertically downward, having the shape of the Greek letter Π .

Yet none of these studies have been discussing the structural design of floating breakwaters or more even optimizing its shape. On the other side, optimization of fixed breakwaters has been previously discussed by Ryu et al. (2005) but focused on minimizing the cost function imposed to structural failure constraints, and also by Castillo et al (2006) for composite breakwater types and similarly concerning the minimization of initial/construction costs subjected to yearly failure rate bounds for failure modes. Therefore, in this paper the study is directed towards optimization of floating breakwaters to reduce its weight, or to represent a new resistive form, in accordance to the physical and mechanical constraints.

The present paper represents a comprehensive study on the behaviour of a real pontoon-type floating breakwater appearing in ports; represented by floating structures oscillating on water surface of finite deep water and one side of the boundary with vertical sidewall. It is different to the problems of structures oscillation with unbounded domain, since a ship parked in the port is affected by the reflected waves by the vertical sidewall and also by the resonance bands occurring in this enclosed port region. It starts with a hydrodynamic modelling of the floating breakwater in order to be able to detect its performance and the water elevation in the port side. Then, it proceeds forward towards imposing an optimization problem to obtain a resistive form with a minimum weight, satisfying the relevant constraints outlined by: minimum wave height in the port, floating, stability, and mechanical resistance.

HYDRODYNAMIC MODELLING OF FLOATING BREAKWATERS

Formulation of boundary value problem

Fluid is assumed to be ideal, flow is considered as irrotational, so we can apply a linear wave theory. The motions are assumed to be small, so