

## **Modelling of a Wave Energy Harnessing Breakwater**

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### **ABSTRACT**

The wave energy production through a system of a breakwater and a Low Head Turbine in the port side, is investigated by means of a mathematical model. The model simulates the propagation of a linear wave along a 1-D wave channel towards a hollow wave-absorbing breakwater further processing the wave. The breakwater presents an opening to the sea with a crest at a fixed elevation above the MSL, leading the overtopping water masses to a reservoir in its interior. As the reservoir is filled, it discharges water to a Low Head Turbine inside the port basin. The research goal is to maximize the mechanical power entering the port basin where the LHT is safely placed, producing electricity under a piezometric head of the order of 1- 4 m, depending on the wave climate in the region. The aim of this work is to optimize the relation of the parameters influencing the producible power, i.e. to maximize the head and the mean discharge towards the LTH, (minimizing its variation with time). The optimization is investigated numerically on the basis of the values of the above parameters.

**KEY WORDS:** mathematical modelling; wave propagation; breakwater; wave energy; Low Head Turbine

### **INTRODUCTION**

During the last three decades considerable research has been conducted in the directions of a) the determination of the overtopping discharge over the crest of a coastal defense structure and b) the safe and efficient harnessing of the wave energy, especially via Low Head Turbines (LHT). The first led to important correlations between the height of the crest of the coastal structure ( $R_c$ ), its surface slope and the wave characteristics (mainly the  $\xi$  parameter). The most recent findings have been reported by Hedges and Reis (2004) and are compiled in the Coastal Engineering Manual (2003). That discharge, variable during the wave period obtains considerable values and it is a threat to the coastal communities attacked by water masses. The same discharge, if properly collected and returned to the sea can become from a threat to an invaluable natural energy resource.

The research related to the wave energy production after the daring

open sea prototypes that have been proved too weak before extreme waves conditions, soon led to the conclusion by Bruun and Viggooson (1977) that the most safe way of harnessing and exploiting water waves consists of collecting it to a coastal reservoir and returned to the sea via a Low Head Turbine. This idea is actually applied to the offshore Danish prototype, the “Wavedragon” ([www.wavedragon.net/](http://www.wavedragon.net/)).

Low head turbines design, started from the classical water mills and continue developing for the exploitation of river and tidal flows in renewable energy production ([www.esha.be/fileadmin/esha\\_files/documents/workshops/hidroenergia/E\\_S1\\_Leclerc.pdf](http://www.esha.be/fileadmin/esha_files/documents/workshops/hidroenergia/E_S1_Leclerc.pdf), [www.esha.be/fileadmin/esha\\_files/documents/workshops/Lausanne/2L\\_Denis\\_1\\_.pdf](http://www.esha.be/fileadmin/esha_files/documents/workshops/Lausanne/2L_Denis_1_.pdf)).

Those two sources of invaluable scientific experience can naturally be combined with the modern breakwater construction technology, i.e. the caisson type breakwater, to produce a “Wave Energy Harnessing Breakwater”.

That type of breakwater facing seas with rather strong wave climate can become a wave energy producing device incorporating in the same technical configuration the two missions, the wave protection and the energy production.

This idea was recently tracked to a certain extent by the Korean Coastal Research Institute (2005) and some experimental results were combined with theoretical analysis.

The scope of the present study is to organize a numerical model describing initially in 1-D the process of wave masses attacking a hollow breakwater, overtopping its crest, storing and exploiting them as far as it concerns their mechanical energy, and to present some results applicable to the design of that type of breakwater in order to optimize its efficiency.

### **THE MATHEMATICAL MODEL**

For the 1-D case the mathematical model used to describe the wave propagation towards the coastal structure and the runup-overtopping is the classical 1-D nonlinear shallow water equation model effectively applicable according to recent research findings Shiach et al. (2004).