



HAL
open science

Dissipative cavities on a floating breakwater, a physical model study

Luis-Fernando Prieto-Lozoya, Dominique Mouazé, Guillaume Carpentier,
Esteban Escobar Valencia

► **To cite this version:**

Luis-Fernando Prieto-Lozoya, Dominique Mouazé, Guillaume Carpentier, Esteban Escobar Valencia. Dissipative cavities on a floating breakwater, a physical model study. Rencontres de l'Ingénierie Maritime 2024, Builders École d'ingénieurs, Jun 2024, Caen, France. hal-04705496

HAL Id: hal-04705496

<https://hal.science/hal-04705496v1>

Submitted on 23 Sep 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Dissipative Mechanisms in Floating Breakwaters

A Physical Model Study

Luis Fernando PRIETO LOZOYA
Coastal and Marine Engineering and Management (CoMEM+)

2èmes Rencontres de l'ingénierie maritime
BUILDERS École d'ingénieurs



Supervisors:

MOUAZE Dominique, M2C
ESCOBAR-VALENCIA Esteban, EGIS
CARPENTIER Guillaume, BUILDERS

Caen, Normandie. France

Abstract

Since the Second World War, the increase in trade has led to a growth in sea transport.. The rapid growth in trade by sea has led to the rapid development of shipping companies and ports. As container ships continue to grow in size, they need to be able to berth in deeper water. A conventional structure (i.e. one laid on the seabed) requires a massive foundation system, the cost of which rises rapidly with depth. From a depth of 20 meters, curves have a clear economic advantage over floating caissons. Furthermore, in the case of the floating body, it can be assumed that the anchoring system remains virtually identical whatever the depth. It seems appropriate to orient the design of floating protection structures to the operating conditions of a port area. A floating breakwater is fairly quick to install, and can be used as a temporary protection structure during storms. The action of a floating system on the environment is limited. Based on the system's geometry, floating caissons have little effect on coastal or tidal currents. It is therefore to be hoped that such a structure will not have a direct impact on pelagic species. Nevertheless, biological studies should be carried out, such as the impact of vibrations generated by the structure on the environment. The quality of the water masses is not adversely affected, as the structure promotes water mass exchange.

The performance (transmitted wave height, limited reflection, contained movements) of a floating system depends mainly on the ratio between the width of the float and the incident wave length. However, other parameters such as flexibility, porosity and geometry can help dissipate the energy of the incident wave.

Despite the combination of the above parameters and the complexity of the geometries tested, it is still impossible to attenuate long waves. In a context of climate change and increasing damage to the coastal zone, the question of how to extend housing and economic activities seaward on large-scale floating systems, while at the same time contributing to coastal protection, needs to be addressed.

The aim of this study is to design, build and test various types of floating breakwaters with different energy dissipation mechanisms. These will consist in distinct designs for the seaward face of the breakwater (such as wave-return gaps with perforations), distinct types of moving parts and internal cavities. For the latter, the flow of incident gravity waves will be redirected and dissipated internally, limiting transmission and loads on the mooring lines. The geometry of these cavities is based on the Tesla valve principle, which favors flow in one direction while slowing it down in the opposite direction. The studies will be carried out in a physical model (wave flume).

Scope of the work

1.1 Objective

The aim of the thesis is to carry-out a comparison study on the hydrodynamic performance of different types of floating breakwaters by means of physical experiments. The main hydrodynamic parameter in question is the wave transmission coefficient. The effectiveness of the structure will be assessed by its capacity to dampen incoming waves through energy dissipation mechanisms. The experimental trials will include combinations of ranging wave heights and periods to determine the structure's behaviour on varying hydrodynamic conditions. Additional analyses may be performed regarding wave reflection coefficient, structure dynamics and mooring forces.

1.2 Relevance of the study

The present study is of significance to the field as it will provide insights on the existing understanding of floating breakwaters, particularly the advantages of specific dissipation mechanisms and their effectiveness under a varying range of wave conditions. The research will also shed new light on new configurations of dissipation mechanisms and their performance when compared to previously studied prototypes in the subject. The outcomes of the study will also be validated against published literature to cross-check the plausibility of the results.

From a practical perspective, research on floating defence structures is important as they may be used *in lieu* of fixed seabed structures to protect the coast. This is particularly advantageous when dealing with increased water depths, where not only the cost of traditional breakwaters becomes significant, but also the challenges on construction and maintenance of the structure. Additionally, floating breakwaters offer a more sustainable approach to coastal defences as they allow for water circulation beneath the floater. As such, it is possible to enclose a coastal basin and protect it from the action of waves without disrupting the existing marine environment of the site. This yields benefits for both the water quality at the shore and local biodiversity. Another benefit of floating breakwaters is their potential use as temporary coastal defence structures due to their relatively fast installation process when compared to other fixed structures. This makes floating breakwaters convenient for temporary deploys during storms or specific seasonal time-frames. Lastly, these structures also provide a more sustainable approach since they can be easily re-positioned or relocated elsewhere for future use, hence fostering circular economy.

Experimental physical studies

2.1 Wave Flume Parameters

The experimental trials will be performed in the wave flume at Jean Chapon Hydraulic Laboratory at BUILDERS in Caen, Normandy. Testing will be mainly focused on regular waves to assess the structures' transmission coefficient under different wave periods. The flume is equipped with a paddle for wave generation. The parameters of the flume are shown in the table below.

Table 2.1: Wave Flume Parameters

Length (m)	10
Width (m)	0.347
Height (m)	0.75
Range of water depths (m)	0.25 - 0.50
Range of wave periods (s)	0.40 - 10
Range of wave heights (m)	0.00 - 0.10

2.2 Floating Breakwater Prototypes

A total of six main configurations will be tested in the wave flume. The primary design is that of a basic rectangular box (RB), after which the rest of the designs are built off of. Maintaining similar dimensions among all models is very important in order to be able to compare their performance at the end of all testing rounds. The rectangular box will also be the main comparison element for each prototype as it will help in assessing the effect of the different additions/arrangements of each model. The sketches of the arrangements are provided in Figure 2.1 below. Minor modifications will be applied to some of these models in an attempt to improve their efficiency, particularly on the models that show the best results.

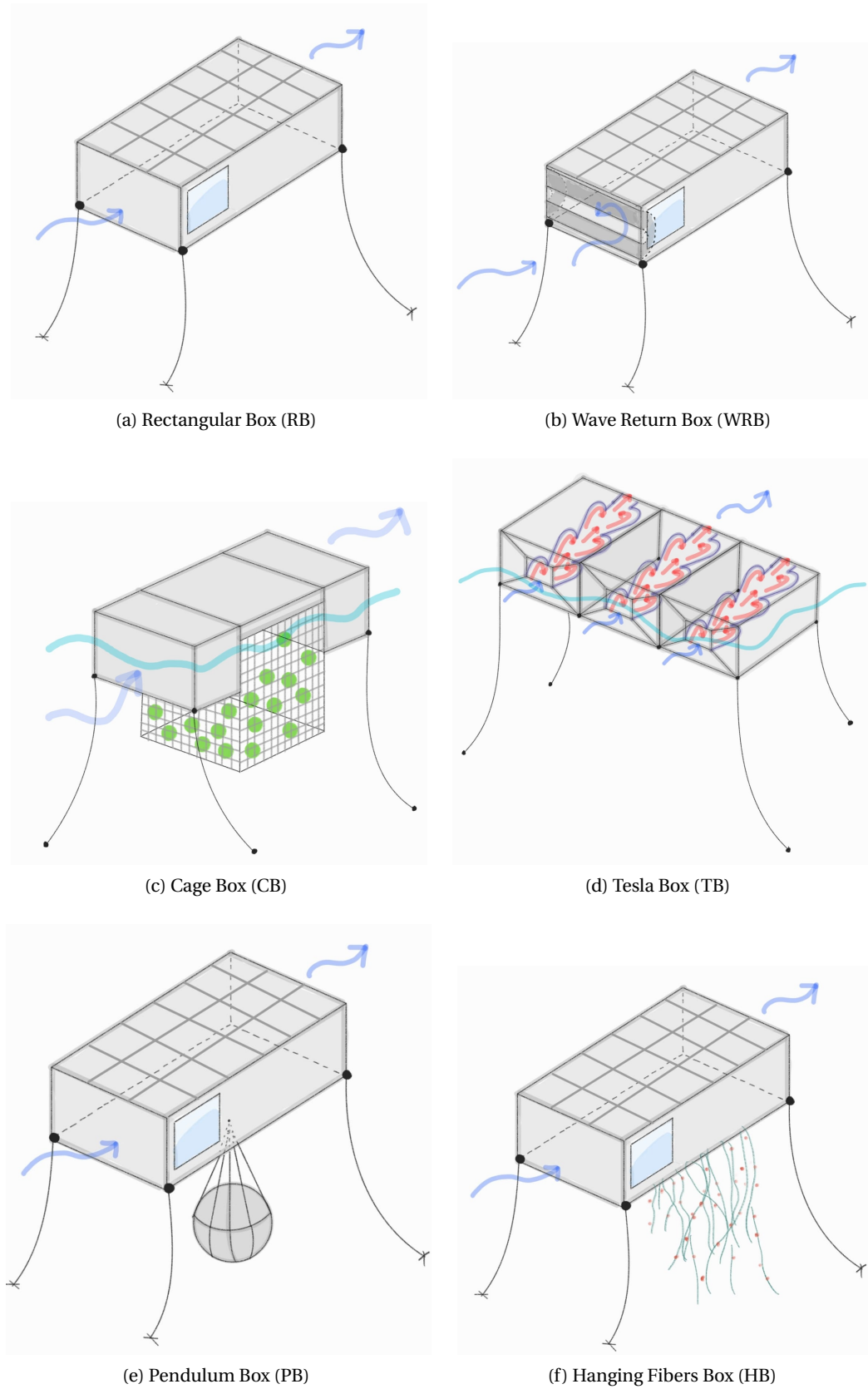


Figure 2.1: Floating breakwater configurations to be tested

Table 2.2: Test matrix for each model displaying wave heights and periods

		H (m)			B/L
		0.2	0.5	0.8	
T (s)	0.6	X	-	-	1.25
	0.7	X	X	-	0.92
	0.8	X	X	-	0.71
	0.9	X	X	-	0.57
	1	X	X	X	0.48
	1.1	X	X	X	0.41
	1.3	X	X	X	0.32
	1.6	X	X	X	0.25
	2	X	X	X	0.19

2.3 Test Matrix

The natural oscillation period of the rectangular box was found to be approximately 1 second based on experimental trials. The test matrix was therefore planned around this value in order to obtain the structures' performance at ranging conditions of short and long waves in comparison to the breakwater's width.

All models will have a width of 0.70m. This parameter was chosen to achieve B/L values between 0.20 and 1.25, where B is the width of the breakwater and L the wavelength of the gravity wave in the flume at each given period. Therefore, short period waves for the models are found below the 1 second period, while long waves are found at periods higher than 1 second.

The test matrix in Table 2.2 provides a guideline to possible number of frequencies to be tested for each model, each of which will be tested at different wave heights. The final number of tests may change based on the amount of prototypes to be analyzed, this will be determined at later stages of the study. However, at least one scenario shall be tested for short waves, resonance and long waves.

A first test run shall be also performed without no structures in the flume, with exception of the dissipative beach at the very end of the tank. Through this initial test, the reflection of both the tank and the dissipative beach shall be quantified in order to better retrieve the wave transmission effect merely associated to the floating structures in the consequent tests.

All wave measurements will be recorded employing gauges, locating them before and after the structure to properly identify the effects of the floaters. The position of the gauges will change depending on the tested wave periods. Data will be processed afterwards to identify incoming, transmitted and reflected waves using specialized software or filtering techniques. It is also expected to find waves generated by the breakwater itself on the leeward side.

2.4 Building of physical models

The main box mentioned above consists of KÖMATEX® PVC-White 662 plates, all of which are glued together with a buoyancy box in the center. See Figure 2.1a. The seaward and leeward faces of the box are detachable, enabling further customization of the box—as required for the wave return box (WRB) shown in Figure 2.1b. The frontal plate in the wave return box may also be altered in terms of porosity to quantify the effect of these cavities in the dynamics of the box.

In regards of the cage box (CB) in Figure 2.1c, additional hooks and rods will be attached as part of the cage's frame. A net will wrap the sides of the cage while the moving balls inside will be made out of lightweight concrete. A similar approach is followed for the pendulum box (PB) and the hanging fibers box (Hb) in figures 2.1e and 2.1f respectively.

The Tesla box (TB) depicted in Figure 2.1d will require a separate model due to the complexity of the cavities inside the floater. In this case, the prototype will be cast in lightweight concrete rather than built with PVC plates. After 3D printing the geometry of the cavities in plastic, the modules can be constructed by casting lightweight concrete around it. The density of the concrete shall be very close to the water's density to favor buoyancy, additional elements may be added when needed to provide the required draft. The lightweight concrete mix design is an important aspect for the model as it will enable the breakwater to float. Failing to determine the appropriate aggregate proportions will result in a non-functional model. Additionally, the model will be also designed to account for rotation of the modules, providing the possibility for testing the valve mechanism in both horizontal and vertical positions.

2.5 Expected outputs and results

After finalizing the tests, comparisons shall be made with the transmission coefficients obtained for each test case, comparing both the behaviour of one single prototype with varying waves as well as performances among all the tested breakwaters. Plots providing the evolution of the transmission coefficients shall be provided with varying ratios of B/L.

In addition, insights shall be given on the reflection coefficient and mooring forces. The dynamics of the floater will also be analyzed through video recordings and motion tracking software, this is particularly important as the motion will directly affect the magnitude of the mooring forces in each of the prototypes. The scope of the study may also include analysis of the models under the action of irregular waves. Despite dealing with completely distinct models, conclusions will be reached on the most promising and feasible designs.