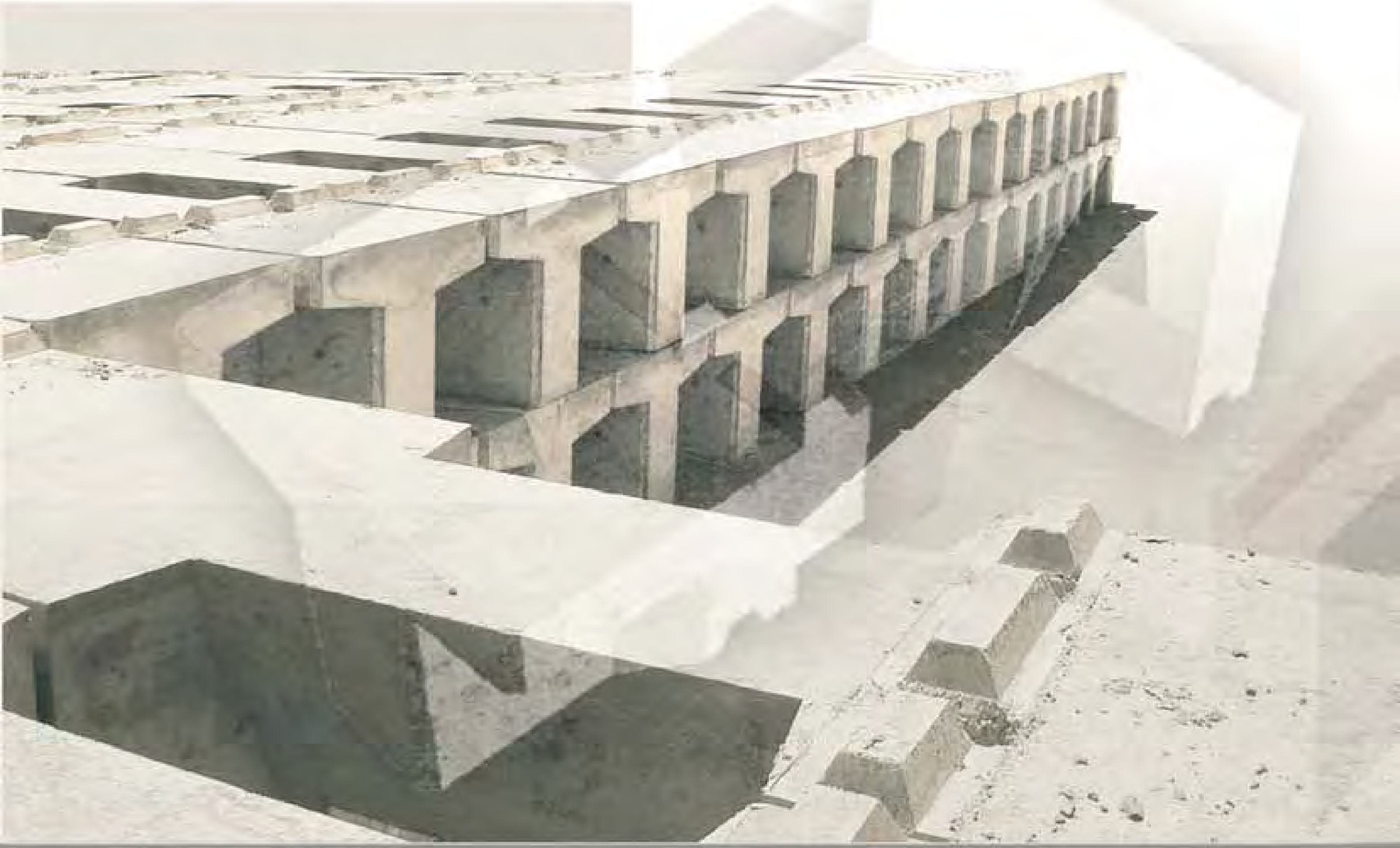
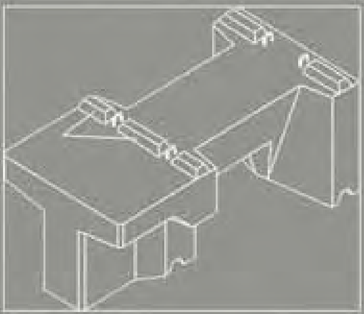
BARA

GUER Ingeniería

FEDER





BARA

TO IMPROVE EXPLOITATION CONDITIONS ON QUAYS WITH VERTICAL SEAWALLS

BARA UNIT

(Patent number P200000215)

BARA Unit

INTRODUCTION

The energy of a wave crashing against a land border - whether it might be a breakwater, a dock or just a bank - goes through a process of greater or smaller transformation, basically according to that border's geometrics and characteristics, and to the surge's own characteristics, as well. Generally speaking, it can be supposed that a part of that energy will be dissipated in the very process of impact or go into the structure of the border. Another part of that energy will go through the structure or bordering its limits and, finally, another part will be reflected to the water as a new wave. In theory, the energy of the reflected wave could be equal to the incident one in the case of a perfect reflective border. But in reality, it is always minor because of energy dissipation in the process, due to turbulences or to friction with the faced object or the sea bottom.

This loss of energy produced in the process of reflection is normally represented through the reflection coefficient (Kr) -which relates the typical wave height or incident surge (Hi) with that of the reflected wave or surge (Hr) - through the following expression:

$$K_r = \frac{H_r}{H_i}$$

Generally speaking, the reflection of a wave on the seawalls of maritime or river structures is, in most cases, an undesirable circumstance. It can even negatively influence the operating conditions, structural resistance, security, quality or any other kind of projected activity. Though in some isolated cases this statement might not be true (e.g. by-pass catalysts), the general intention is to reduce the reflection as much as possible, that is to say, to obtain a low reflection coefficient. This is achieved by enhancing those processes that dissipate the wave energy, divert it or produce a controlled phase-lag.

More precisely, wave reflection usually has a negative connotation in actions of port and coast engineering, due to the following reasons:

- Navigation and vessel manoeuvring in rivers, canals and port zones.
- Vessel movements into mooring docks.
- Efficacy in loading-unloading operations of merchandise.
- Security in case of uplifts or floods on docks and banks.
- Security with respect to erosion processes on the structure base that can provoke its destruction.
- Stability of beaches.

- Stability of river banks.
- Resistance or stability of maritime structures.
- Protection of the vital conditions of sea and river environments.

Therefore, it is not surprising that the investigations on the reflection phenomenon and on the methods to decrease its intensity have been intensified over the years. This way, several solutions have been developed, that consist of adapting the border structures in a way to obtain higher energy dissipation in the process. The type of flexible structures with a sloped seawall has, as it is generally recognised, a better behaviour than those typologies based on monolithic units with almost vertical walls. The use of natural breakwaters to build the coating layers is, in most cases, the most economical solution to this problem. Artificial units with different geometrics provide the possibility of location in zones with surge of greater energy. The reflection coefficients for this kind of structures are usually within the range between $0.20 < Kr < 0.50$. The lower limit can be achieved by creating slightly perched beaches with granular material ($m < 0.20$), where, by enlargement of the waves' run-up/run-down phases, by turbulences or by percolation, reflection coefficients even lower than 0.20 are possible.

Nonetheless, in many cases - especially those related with port operations - the border functionality requires vertical geometrics on its seawall facing the water. Such is the case, for example, of port quays and or some promenades, sea shores or river banks. For these cases different kinds of solutions have been developed as well, each of them conceived to diminish the energy of the incident wave by generating hydraulic turbulences and to dissipate the energy of the reflected wave, altering its phase and direction.

Within this concept we can divide different kind of seawalls into those made with caissons with one or several inner chambers, those constructed by joint prefabricated elements forming channels or inner chambers, or those constructed by juxtaposition of linear elements (piles, sheets, plates, etc.), which produce vertical or horizontal openings through which surge is more or less transmitted. On the other hand, we could also mention solutions based on formation of platforms with piles, under which there is a sloped breakwater or caissons or ditches filled up with granular material. In the first, energy dissipation occurs in the same way as with a sloped structure, while in the latter there is greater turbulence coming from the granular filling.

One of the main limitations of every developed system is the narrow range of characteristics of the incident wave within which they are significantly effective. It is the different wave period, rather than a different wave height, which determines more clearly the efficacy of reflection reduction systems. This limitation is, moreover, doubly important since high periods – during which the developed systems are the least efficient - coincide with those of highest intensity and seriousness, causing the engineering problems mentioned before.

There are several procedures to diminish wave energy incident on the seawalls of a dock or a navigation channel, that range from the traditional structure of a sloped breakwater, to the use of prefabricated elements with shapes especially conceived to dissipate energy. The use of either of those solutions is clearly conditioned by the characteristics of the site in question (depth of the natural terrain), as well as by the wave conditions (wave height, period and wave length) incident on the structure.

The solutions of pre-fabricated pieces or perforated blocks have shown their best behaviour in B/L relationship around 0.20.

It must be stressed that, though the placing of absorbent elements in the dock seawalls has an extremely positive result (reduction of reflections), it can also have a negative effect, when big vessels moor on the dock. In the case of vessels of great length and draught (practically reaching the dock depth), whenever the surge crashes into the vessel towards the dock, the water gap between the hull and the vertical wall of the dock (*see figure 1*) performs a "mattress" effect on the ship movements due to the narrow space left for the water to move under the hull and on the sides.

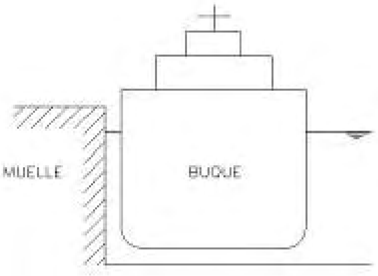


Figure 1. “Mattress” Effect on big vessels

On the contrary, in hollow docks or with slope piles under the structure, this effect, benefiting for the vessel’s immobility, would be lost with the possibility for the water to move through holes in the wave screen. This would provoke greater mobility in the vessel and less “mattress” effect. Movements like pitch and yaw are the most affected due to this cause.

Nevertheless, this is a punctual situation, only referring to the case of big vessels which, due to their hull shapes and their adjustment to the berth, make it difficult for the water to get out of the gap between the hull and the sea wall. Therefore, it is not significant for middle sized or smaller vessels, which do not occupy the whole of the berth of the structure or whose hull is not square.

BARA UNIT

1.- Description

The BARA unit *(figure 2)* is the first unit developed in Spain to reduce wave reflections on the exterior wall of docks.

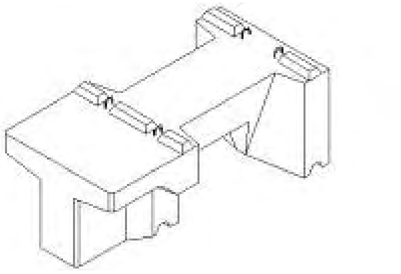
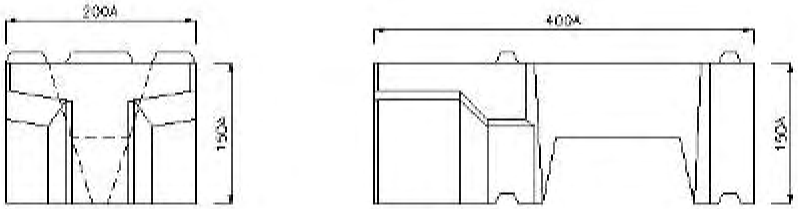


Figure 2. General view of the BARA unit.

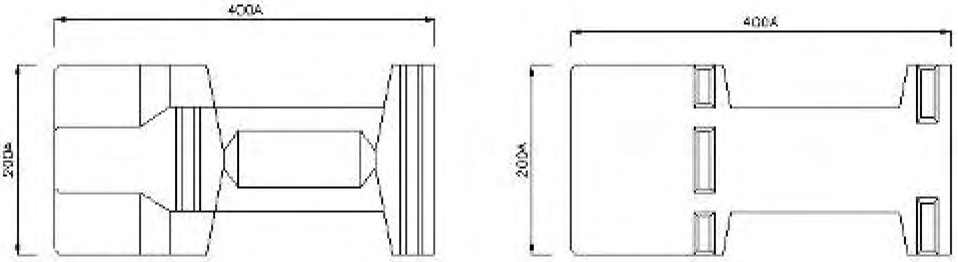
The BARA unit has a defined structure for being designed within a parallelepipedic block. Its dimensions are 1.5 high, 2.0 wide and 4.0 long. The size of this unit can vary, always keeping this proportion, in order to adequate its behaviour to the characteristic incident wave period in each case.

To describe it formally, each unit can be parted into three zones *(see figure 3)*:



Frontal Section view

Cross Section view



Bottom Section view

Top Section view

Figure 3. Plant and section views of the "BARA unit"

- The back side, joined to other units, will form a containment wall for the back terrains forming a continuous wall.
- The front side presents a smooth front wall nucleus, two top wings and a sloped diaphragm in the rear.
- The intermediate zone is formed by a union beam between these two previous zones which, with its smaller transverse section, will create an inner chamber for the water to calm down.

“BARA” storage

Figure 4 shows different views of the BARA unit, with its following characteristic parts:

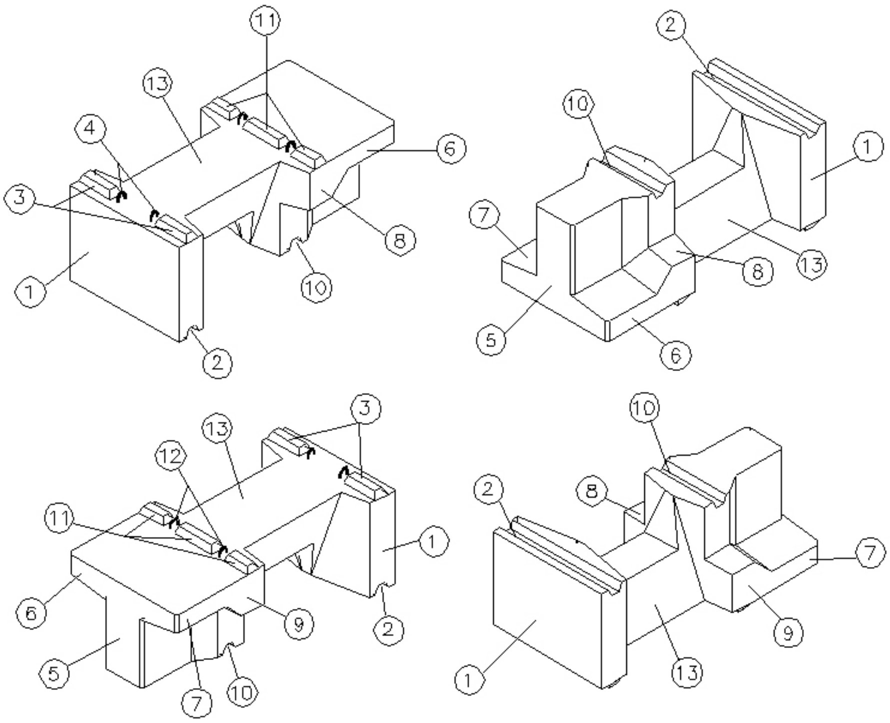


Figure 4. Views of BARA unit

- 1: Back, wall.
- 2: Back, slot.
- 3: Back, bubbles.
- 4: Back, clamps.
- 5: Front, wall.
- 6: Front, top right wing.
- 7: Front, top left wing.
- 8: Front, right diaphragm.
- 9: Front left diaphragm.
- 10: Front, slot.
- 11: Front, bubbles.
- 12: Front, clamps.
- 13: Intermediate part, beam.

The units are placed one on top of the other (*see figure 5*) or alternatingly (see figure 6); in both cases the connection between the units is achieved by fitting the bubbles into the slots, which each unit has on its top and bottom, respectively. The reduction of incident wave energy is the same by placing the units either way; therefore, there is no advantage to arrange them in one way or the other. However, in case of using the alternative placement (*see figure 6*), half BARA units are needed, or even parallelepipedic solid blocks – with half the width of the others- to be placed on the ends of the BARA seawall structure.

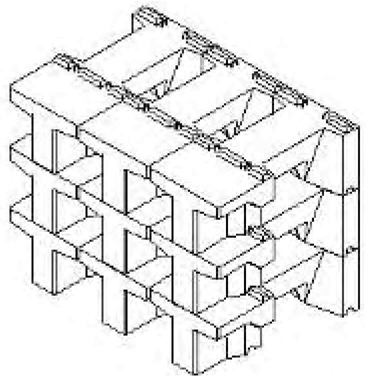


Figure 5. Superimpose placement

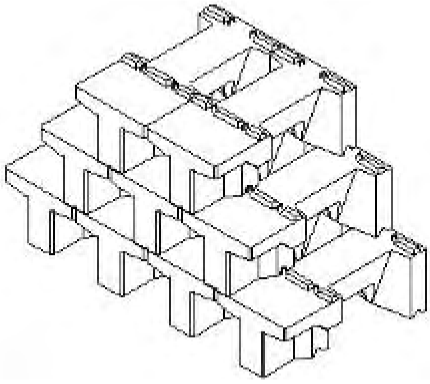


Figure 6. Alternating placement

Superimpose placement of BARA unit

2. Properties

A group of BARA units, once settled, forms an inner chamber which, due to the particular design of each unit, is connected both laterally and vertically with the top and bottom rows. This way, the reflection on the seawall of the structure is reduced, due to the following facts:El conjunto de piezas, una vez colocadas, conforma una cámara interior que, debido al singular diseño de cada unidad, se encuentra comunicada tanto lateralmente como con las hileras superior e inferior. De esta forma se consigue una atenuación de las reflexiones en la pared de la estructura, motivada por los siguientes fenómenos:

- Phase lag on the reflection damping
- Turbulences in the inner chamber
- Constriction of the water flow on the centre diaphragm
- Destruction of the orbital particle movement
- Phase lag with respect to the water level

The efficiency in the energy reduction will depend on the incident wave characteristics, especially on its period (T). The relationship between the characteristic length of the BARA unit (B) and the wave length (L), which is a variable that depends on the wave period, has a particular effect on the reflection coefficient (Kr) obtained.

3.- Fabrication and placement

The material to produce BARA units is concrete. Its type, characteristics and resistance are determined, in each case, by the corresponding regulations. The BARA unit's design includes a reinforced top front zone armoured with gridiron, as well as longitudinal bars and rings all along the unit's central body (see figure 7), with the objective to avoid the appearance of fissures in those parts and make the unit stronger to resist the tensions when hoisted and placed. Once the BARA unit is placed in its definite position, the structure can resist the different forces that act on it by its own weight and the reinforced parts have lost their resistance function.

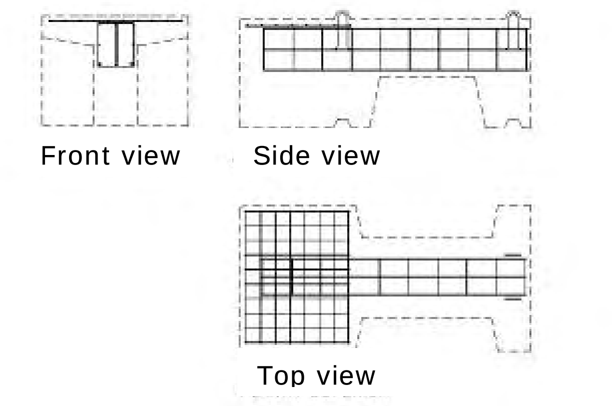


Figure 7. Armour distribution

Each unit is moulded individually by means of formwork. The concreting is done continually and in horizontal layers; the unit's design allows its regular and homogeneous concreting and easy de-moulding.

BARA unit, Concreting and transport of BARA units

In particular cases, after a previous analysis of the efforts the units are going to go through especially during their placement, the moulding of the BARA unit can be done without the armouring or by adding alternative material to the concrete.

The placement of BARA units requires a crane. Therefore, there are four clamps of corrugated steel to sling it correctly; these are situated between the bubbles - which are designed to fit into the slots of the next BARA unit above – without exceeding the height of those (*see figure 4*), so that they will not hinder the placement of the units.

Placement of the “BARA” unit

Before placing the first row of units, a breakwater has to be built as a bearing structure, its surface filled with gravel to level it. The BARA units have to be placed on a rigid basis; that is why there must be a concrete layer on top of the breakwater, either submerged or with a prefabricated concrete layer approximately 0.50 m thick. The construction of a quay made of BARA units is executed by sections. The different rows of units of one section are placed and on top of them another concrete layer which holds neighbouring units together, in a certain way. On the back of the structure, filling materials could be placed between the structure and the adjoining wall. To illustrate this, some practical examples are given in chapter 4.3.

Filling materials on the structure's backside

A quay or structure built with BARA units only needs a reduced volume of concrete, since each piece has a real concrete volume equivalent to 48.67% of the one the virtual rectangular prism within which the BARA unit was designed would require.

Taking into account everything specified before and due to the fact that each wave period will need a determined size for its correct behaviour - the longer the periods, the bigger the units – the size of the BARA unit differs according to the situation of the projected structure. Chart 1 shows different dimensions of BARA units, always respecting the ratio 1.5/2.0/4.0, with its corresponding weights (with a supposed concrete density of 2.35 T/m³). The pieces are named by their length in decimetres. This classification is not complete, since there may be as well intermediate sizes, as long as ratio of length (L), breadth (B) and height (H) is maintained.

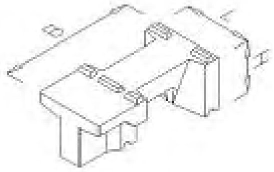
Unit	H (m)	L (m)	B (m)	CONCRETE VOLUME	Weight (t)	CAPTION
BARA 200	0,75	1,0	2,0	0,73	1,7	
BARA 300	1,125	1,5	3,0	2,46	5,8	
BARA 400	1,5	2,0	4,0	5,84	13,7	
BARA 500	1,875	2,5	5,0	11,41	26,8	
BARA 600	2,25	3,0	6,0	19,71	46,32	

Chart 1. Dimensions, volumes and weights of different BARA units

4.- Test

The tests performed with BARA units show a good behaviour in ranges of short periods, between 2 and 5 seconds, with a minimum value for B/L=0.18, while for bigger values, its functional performance tends to be like that of a completely reflecting vertical seawall, especially when the periods are longer. *(figure 13)*

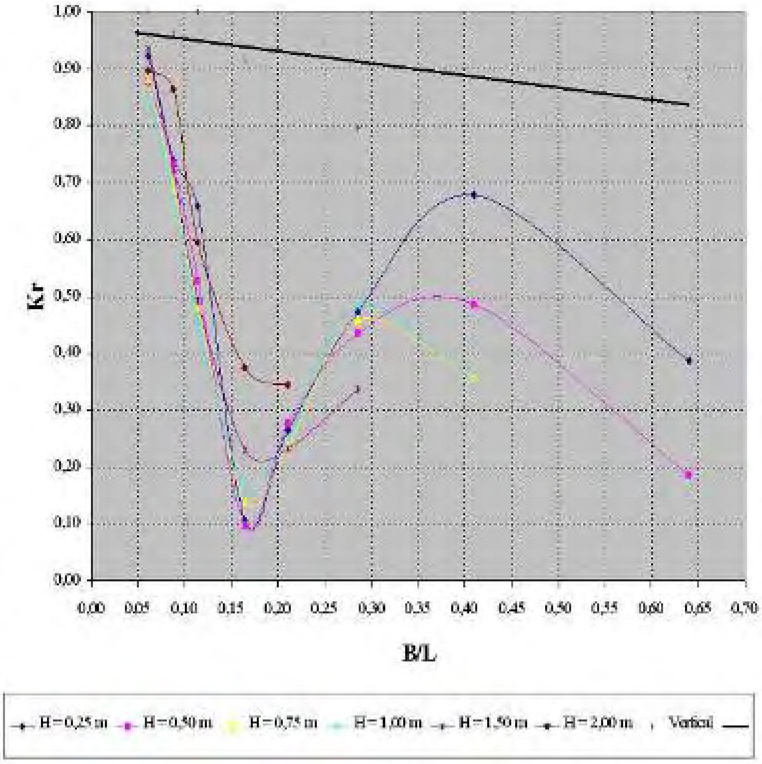
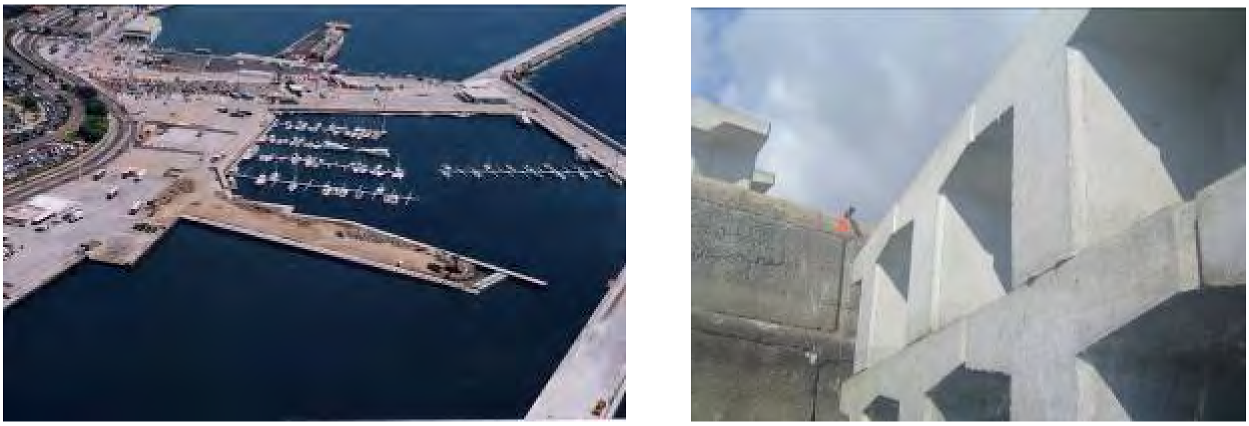


Figura 13. Reflection coefficients obtained during the tests

Tests of BARA units

The range between 2.0 and 5.0 is considered especially adequate for quays where vessels of medium or smaller size usually operate (fishing boats, sport boats, ferries, fast ferries, etc.). Such period values are considered extremely dangerous for these size ships, since they coincide with the ships' own oscillation frequency, which is a fact too common to risk. On the other hand, surges with these periods are the ones which are usually generated inside the quays, due to the effect of the wind on the water mirror, or even simply by vessel navigation nearby or inside the port.



Placement of "BARA", inside the port

For all these reasons, it can be particularly benefiting to use BARA units in ports and marinas harbouring vessels with significant problems due to the water agitation.

5.- Aplicaciones

En cuanto a las posibles aplicaciones para la pieza “BARA” se mencionan las siguientes posibilidades:

1.- Construction of docks or port seawalls affected by surges of different origins and in those where it is convenient to keep a limited level of agitation.

In Figure 14 you can see a view a structure of 4 m long BARA units, leaning against a submerged concrete wall built on site. Concerning the concept and construction techniques, the solution is similar to the type section of conventional gravity docks.

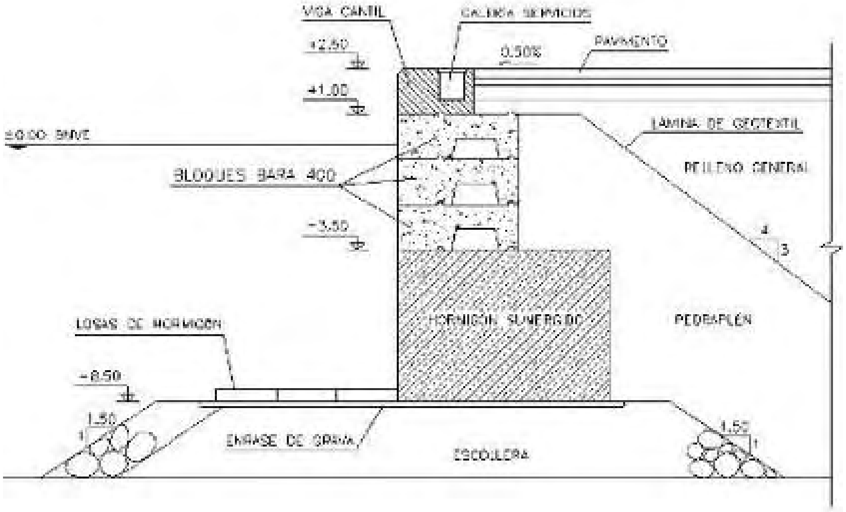


Figure 14. BARA units in gravity docks

In figure 15 you can see the use of BARA units combined with the traditional solution of floating caissons for big draught docks. Taking into account the range of efficiency and the dimensions of BARA units, it is not advisable to use them as unique construction element of quays with big draughts. It is possible, however, to take advantage o the BARA unit’s anti-reflecting characteristics, combining them with other solutions, to allow the construction of docks of bigger draught.

Such a combination could be the solution shown in figure 15, which consists of placing four rows of BARA units on the outer cell of a floating caisson. A concrete cap would be placed under the blocks to avoid the loss of the granular filling from the cells.

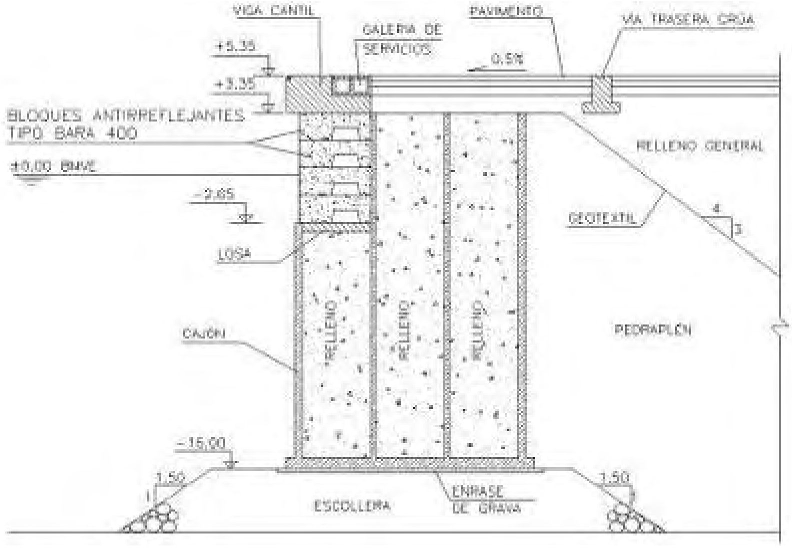


Figure 15. BARA units combined with floating caissons

Figure 16, on the other hand, shows a possible use of BARA units in combination with piles: the units would be settled behind the piles with the double objective of diminishing the wave reflections under the gangplank and serving as a containment wall for the filling material on the back of the BARA structure.

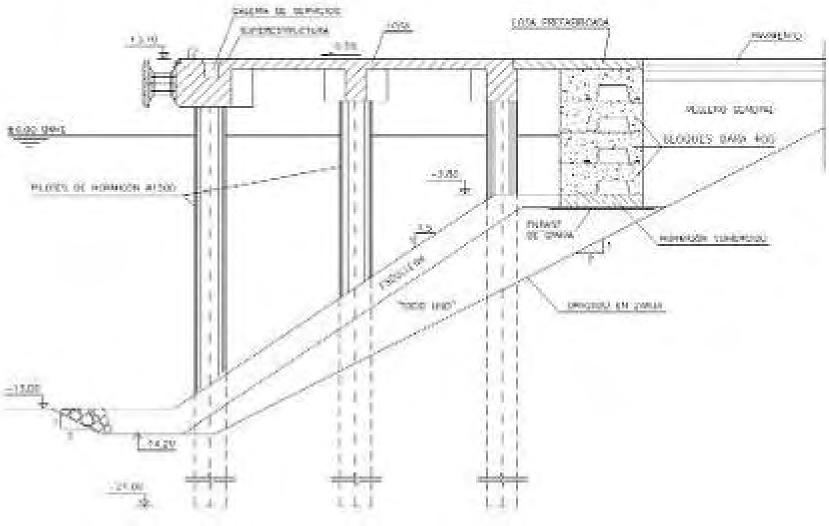


Figure 16. BARA units combined with piles

2.- Construction of seawalls on mooring quays affected by streams or surges, caused by vessel propellers or nozzles, which can damage their structure or undermine their foundations.

This is an especially interesting application in the case of mooring ferries or fast ferries, which, whose special propellers create important surges on the vertical walls which are directly transmitted to the structure’s foundations. This might harm the foundations and ruin it completely. By placing BARA units on the mooring dock facing the vessels, the propeller surge will be dissipated within the inner wall chamber and thus avoid the phenomenon of hollows at the bottom mentioned before.

Moreover, the fact that ferries or, even better, fast ferries need moderate draughts for operating (quays 4 m deep), makes the BARA unit the ideal construction element for this kind of wharf.

Construction of docks and port seawalls affected by waves

3.- Construction of exterior seawalls on port docks and other maritime works to avoid any manoeuvring problems in the area near the structure, due to the wave reflection.

Figure 17 shows a cross section of a breakwater that protects an interior wharf against the action of the surge. The fact that the ships approaching the wharf are usually affected by the wave reflection on the breakwater itself has led the authorities to look for some option to reduce this effect as much as possible.

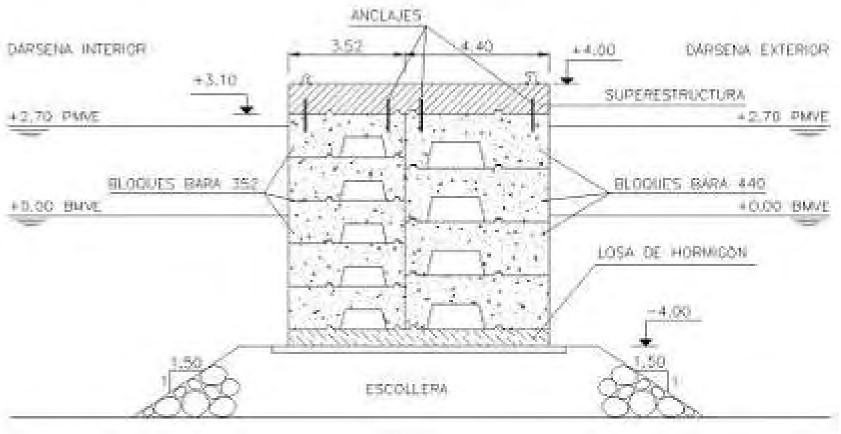


Figure 17. BARA units on a protection breakwater

The BARA units used for the construction of the breakwater are different sizes on each side, because the exterior seawall has to face waves of longer periods than the interior one; by adapting the size of the pieces to the wave period, the efficiency of the system is higher.

BARA units on gravity dock

4.- Construction of seawalls on maritime or lagoon working sites to avoid erosion problems on neighbouring coasts or river banks, due to the reflection of incident surge on them.

5.- Construction or covering of river banks where it is convenient to reduce the reflected wave energy or the longitudinal surge on the riverbed.

BARA units in Valencia Port

6.- Construction of sea banks or promenades on the back zones of beaches where it is convenient to reduce the risk of erosion due to storm wave reflection, or for aesthetical reasons.

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