Environmental Dialogues between Crown Walls and the Sea

Vicente Negro[1)], Jose Maria del Campo[2*)]

[1)] Universidad Politécnica de Madrid. Profesor Aranguren, 3. 28040 Madrid. Spain, vicente.negro@upm.es;
ORCID: orcid.org/0000-0002-5110-0891
[2*)] Universidad Politécnica de Madrid. Profesor Aranguren, 3. 28040 Madrid. Spain, josemaria.delcampo@upm.es;
ORCID: orcid.org/0000-0002-8284-4527

https://doi.org/10.29227/IM-2025-02-02-100

Submission date: *2025-06-26* | Review date: *2025-08-06*

Abstract

Maritime works have a clear purpose, to reflect or dissipate the high wave energies of seas and oceans to create safe areas of shelter. This involves a large number of natural or artificial materials, both for the submerged and the visible works. In this article we analyze some of the structures that make up these works: blocks, caissons and crown walls, from an environmental and landscape point of view, through a historical study of shapes and colors, as well as their aesthetic and visual integration into the landscape.Both national and international cases are analyzed, of structures of mass concrete or reinforced concrete, with launchings or in flat wall, recessed and in continuation of the monolith, proposing forms in balance, rhythmicity and sustainable. Examples such as Malaga or Tazacorte, with supports similar to Gothic cathedrals or impressive slenderness as in Escombreras, where fibers are used in the external wall, are some of the most notable examples. It concludes with a series of recommendations for the design and execution of these maritime works.

Keywords: *Landscape characterization, Crown Wall, aesthetic, vertical breakwater*

1. Introduction

Breakwaters are very unique works. They embrace the sea to provide shelter and refuge for vessels. Their calm waters facilitate the transfer of goods and passengers at their quays. However, the observer does not perceive their magnitude, grandeur and relationship with the marine environment where they are cemented and supported by a development of large extensions and volumes. The landscape is not perceived at the submerged level, so that the ports are either thin lines on the silver plate of the ocean (the shelter) or large surfaces full of boxes (containers) that allow modal interchange.

In this sense, the perception is centred on the solid reinforced or massed edge, curved or straight, with buttresses or arches, in different shades and shapes, which is the breakwater. A true dialogue with the sea with its buffers and explosions; with its ventilated or hammered breaks, with its forms that are integrated into a balanced and sustainable landscape that strives for sustainable cities and communities (SDG 11) and climate action (SDG 13).

In this sense, this article reviews the solid edge in contact with the sea, developing shapes, proposing a double facing, combining hexagons and cones, controlling the reflections on the headland of the standard vessel, also including new designs with colours in this dialogue that represents the mass of concrete that crowns the sheltering works, what we commonly call docks. This trajectory will show the excellent development of Spanish marine engineering, both at a technical and constructive level, as well as in terms of design, sustainability and landscape. [1], [2], [6]

2. Research methods and development

Spanish engineering has continued to innovate in the design of seawalls. This symbolism has made it possible to play with slenderness, balance stresses and guarantee stabilities in the combination of sea and work. Occasionally, there are some problems that the force of the ocean unbalances the human response. However, new materials and improved coatings will guarantee the prolonged dialogue of the seawall with the sea. [3]

From the play of form that began at the end of the 20th century with the ‘gothic’ of Malaga (figure 1); or at the beginning of the 21st century with the hyper-elliptic of Tazacorte on the island of La Palma (figure 2), the heritage of the Japanese ‘circular’ design of Wakkanai (figure 3) has been enhanced.

The first of these, the Andalusian rib, plays with the strong easterly swells with its curvature. In the second one, the slenderness of the walls, the resistance of the supports, the debate of the forces can be appreciated, being the reflection of a new art more than six centuries later, in the current perception of civil engineering as a landscape. It is a ribbed element that modifies the uniformity of the wall, alternates ellipses and semi-axes [4], shadows, provides structural rhythmicity and modifies and incorporates new components into the design. This double half-axis trellis of ellipse, major and minor, was the precursor of a new form only in the same conical typology when the extension of the port was carried out in 2015 (figure 4).

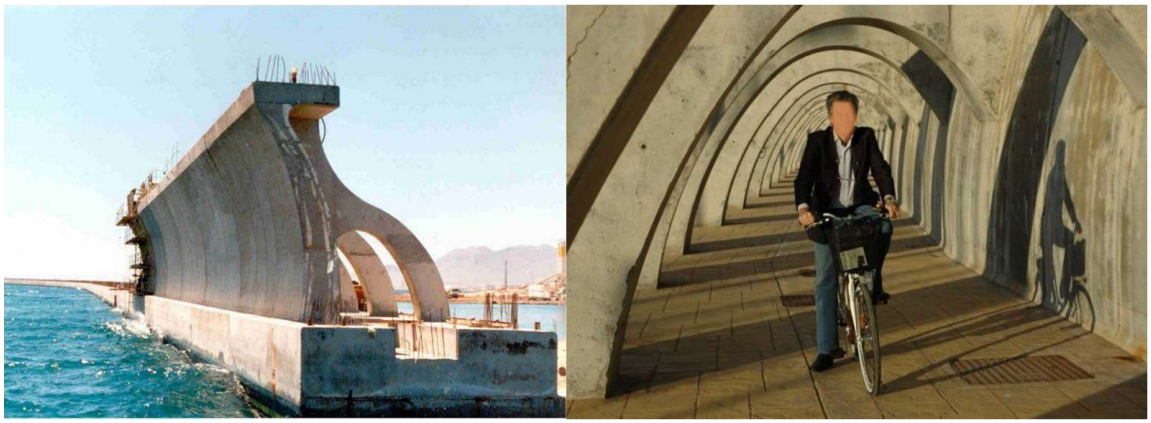

Fig. 1. The slenderness of the Gothic wall (left) and the arrangement of the buttresses with flying buttress-style arches on the breakwater of the Port of Malaga (right)

Fig. 2. Slenderness of the wall (left) and arrangement of the buttresses with half-axes of ellipses in Puerto de Tazacorte (Island of La Palma). First phase (right)

Fig. 3. Wakkanai North Breakwater Dome, Japan (1936)

Fig. 4. Slenderness and layout of the buttresses with uniform ellipse semi-axis in Tazacorte (Island of La Palma). Second phase

The case of the double facing at the Blanes Dam (Girona, Catalonia, Spain, 2010) and the Forum Dam (Barcelona, Catalonia, Spain, 2004) are examples of minimisation of visual intrusion (Figure 5).

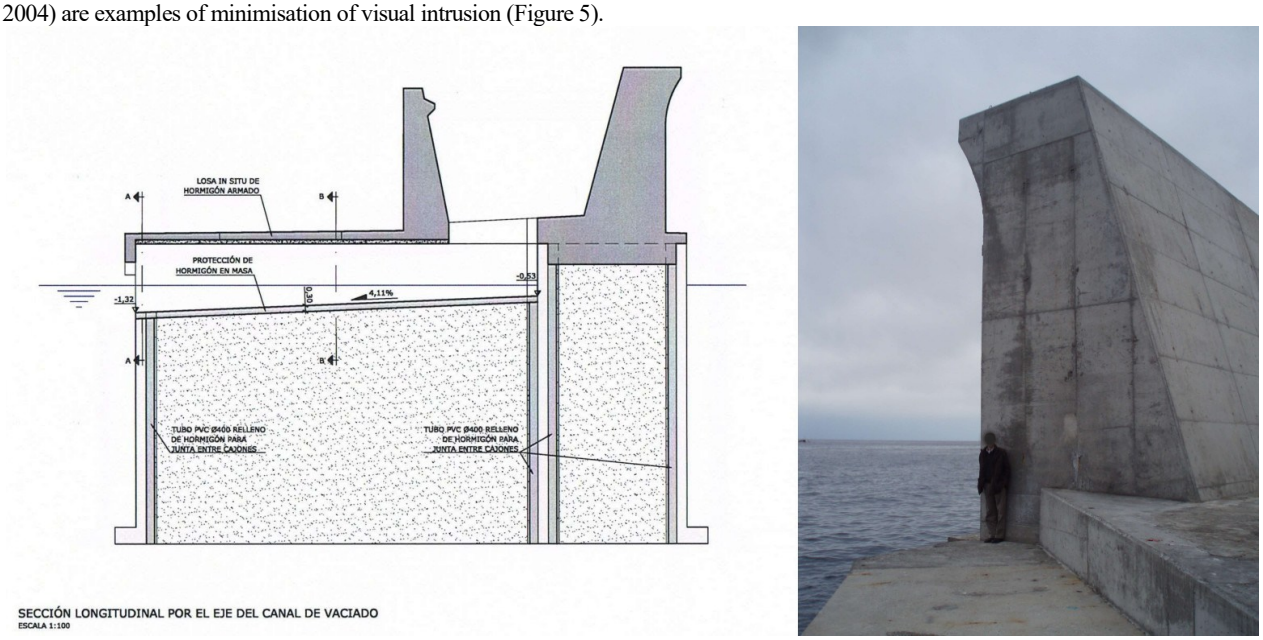

Fig. 5. Slenderness of the double pier and stilling basin in Blanes (Barcelona). Typical section in plan (left) and construction reality (right)

Hexagons built at the same crest height cause the water flow to break rhythmically and asymmetrically. An example of this is the outer seawall of Ciutadella (Menorca, Balearic Islands, Spain, 2008). It consists of a seawall with a reduced crest height to make the city live towards the sea. This design continues the typological and conceptual evolution developed by Suárez Bores in the Cubelles dock (Barcelona) where, in the mid-1970s, he designed and built a low crest height breakwater using diffuser cones that fractionate, launch and disperse the overtopping flows into the air, facilitating aeration (Figure 6). [5]

The Ciudadela breakwater in Menorca has also solved the problem of the long wave of the inner harbour, commonly known as the 'risaga', a long wave of its dock (figure 7).

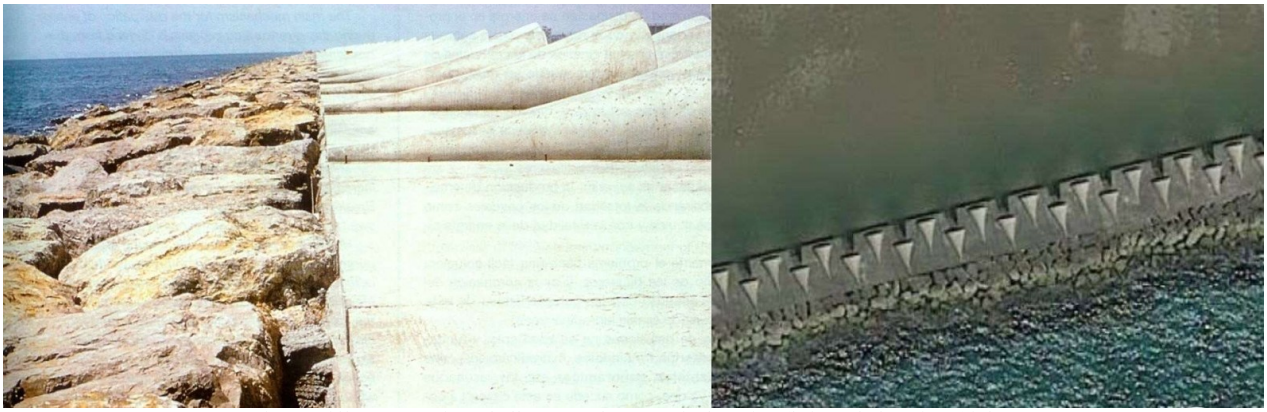

Fig. 6. Diffuser cones in Cubelles, Barcelona. Typical section (left) and plan view (right)

Fig. 7. Port of Ciudadela, Menorca. Curvature of the breakwater (left) and lamination hexagons at the crest (right)

Chambers and buffers are other examples of technological advances, as in the Castellón Dam (Valencian Community, 2012, figure 8) and the "Molhe Norte da Barra do Douro" in Porto (Portugal), which won the National Civil Engineering Award in 2009 and is part of a

set of works at the mouth of the river estuary (figures 9 and 10). [6], [7]

The design of the Modesto Vigueras Dam in Castellón, in addition to guaranteeing structural and functional behaviour by laminating the reflections of the monolith, allows part of its energy to be returned to the sea, playing with the water and the air, forming a harmony that, as in the Basque Country in the Motrico wave power plant, is also called 'the dragon of the sea'. In addition, it meets the criteria of reducing the incident energy in its reflected component, given that the chambers dissipate part of it, and the impact against the wall is laminated between the holes or buffers in the parapet.

Fig. 8. Modesto Vigueras Dam in Castellón. Construction reality (left) and model (right).

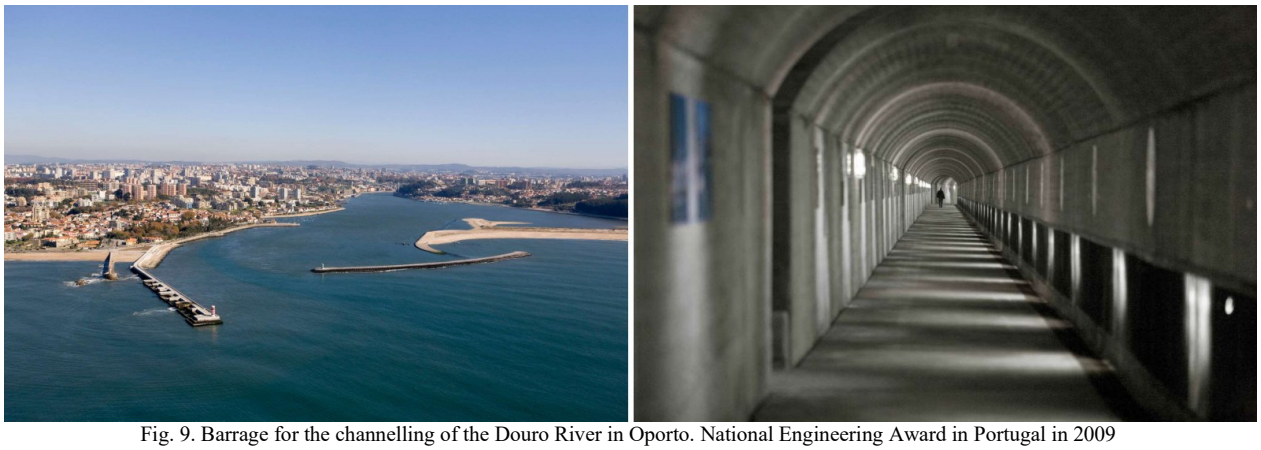

Fig. 9. Barrage for the channelling of the Douro River in Oporto. National Engineering Award in Portugal in 2009

Fig. 10. Barrage for the channelling of the Douro River in Oporto. Plan (left) and temporary operation (right)

One way of constructing curved breakwaters more easily is with circular caissons, as is the case of the Brighton Breakwater (England), or the "Duca degli Abruzzi" in Naples (Italy), or the breakwater of Tangier Med (Morocco), to cite some existing examples in the world (Figure 11 and Figure 12).

The use of colours can be found in the breakwaters of Llanes, La Guardia and Llançà (Spain); the use of different materials in the breakwaters of La Restinga, Mutriku and Zumaia (Spain); and different forms of arrangement in the breakwaters of Ciutadella and Laredo (Spain).

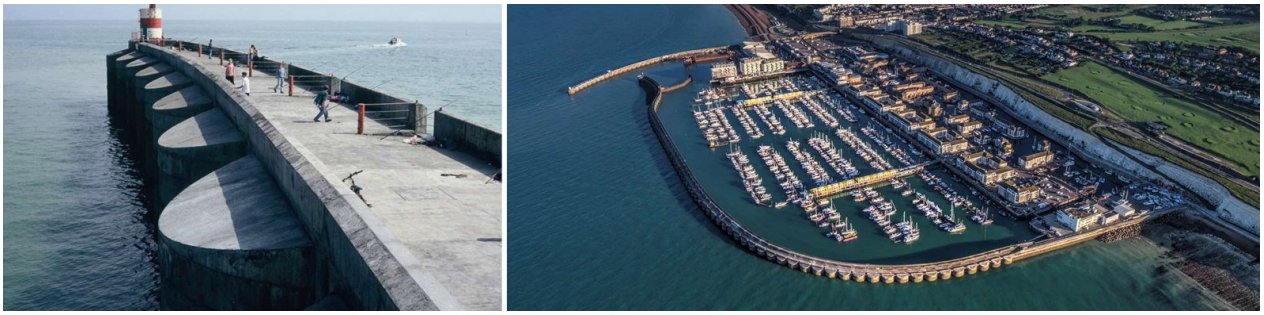

Fig. 11. Cylindrical caisson dock at Brighton Marina, England

Fig. 12. Special cell box dyke and large cells in Tangier Med (Morocco)

In relation to colour, this time in a breakwater breakwater on a slope, at the dawn of this new century the master Ibarrola developed his work 'Los Cubos de la Memoria' (The Cubes of Memory) in the interior and exterior parts of the Llanes Dam in Asturias. In them he reflected human evolution from petroglyphs to present-day civilisation in a new aesthetic use of the protective mantles of the embankment dykes (figure 13). [8], [9]

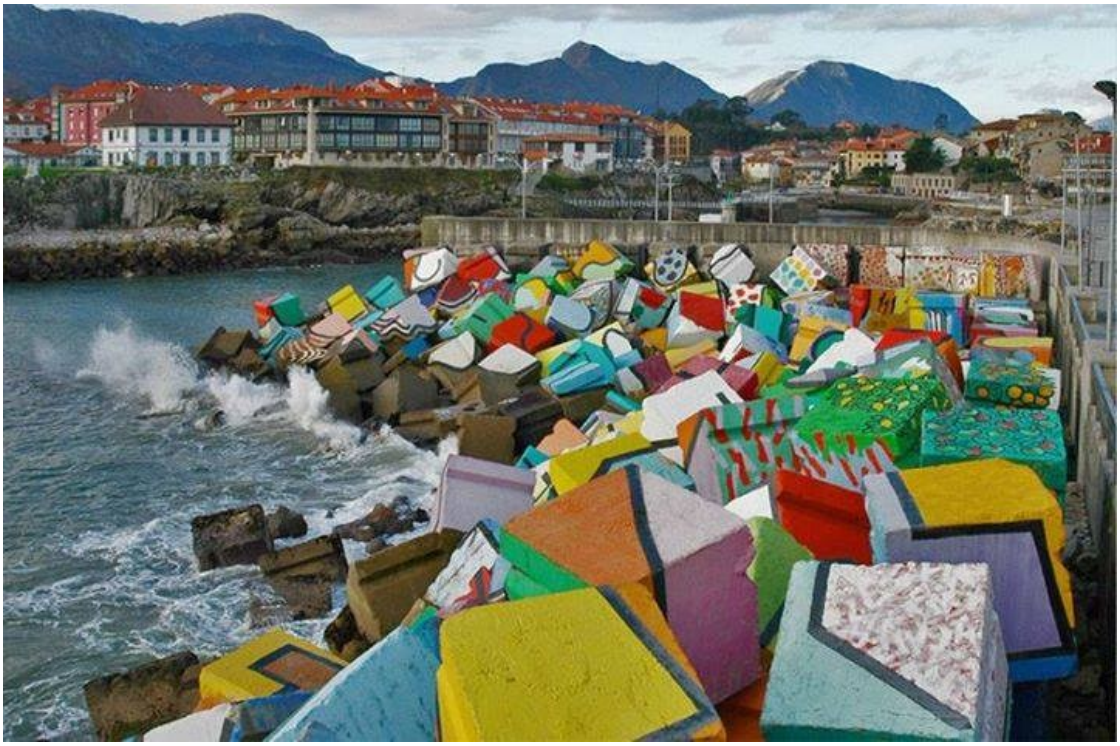

Fig. 13. The Memory Cubes, Llanes, Asturias.

The attached examples allow for the play of colours on the inner parts of the trellises and the use of new materials that facilitate the creation of mosaics on the intrados of the wall. This is the case of La Guardia in Pontevedra, with a notable tradition in the chromatisation of the wall, or the friezes developed in Puerto de la Restinga on the island of El Hierro. This can be seen in Figure 14.

Fig. 14. Crown Wall of La Guardia, Pontevedra (left) and crown Wall of La Restinga, El Hierro (right)

Fig. 15. Painted blocks in Santa Cruz de Tenerife (left) and a trellis with fishing motifs in Llança (Gerona) (right)

At this point in the analysis of this solid edge, slender at its contact with the sea and a fine line that can be seen from a bird's eye view, ideas are interwoven about the massive effect of the seawalls in contrast to the improvement of slenderness by playing with reinforced concrete instead of mass concrete. [10]

Sometimes it is advantageous to use glass-fibre reinforced polyester (GRP), despite its cost, which increases durability and reduces chloride penetration. In this respect, the Spanish technique is also a pioneer, given the work carried out at the end of the decade on the reinforcement of the Escombreras breakwater for the Port Authority of Cartagena by Rover Marítima (Figure 16).

At the present time, the reinforcement of the seawalls with these characteristics represents a value almost eight times higher than the kg of conventional steel, although the minimum useful life exceeds fifty years and means that there are no problems of chloride penetration and generalised corrosion. This has led to visible reinforcements such as those existing on the seawalls in Malaga, Algeciras and Tazacorte, which cause problems both for the construction companies and for the public body Puertos del Estado (State Ports). [11]

Fig. 16. Escombreras sea wall screed with GRP (left) and GRP reinforcement mesh (Escombreras, Murcia) (right).

3. Discussions

Throughout these reflections, the aim has been to raise the need to build seawalls in a sustainable, respectful and environmentally

integrated manner. In addition to this, the way towards aesthetics in the dialogue of a narrow superficial strip that this element represents in comparison with the totality of the maritime work has been added.

A historical and architectural approach has been taken to the form. The use of buttresses in the Malaga Breakwater (Andalusia, Spain, 1998), the so-called 'gothic breakwater' (Gómez, 2001); the use of 'hyperbolic buttresses' in the Tazacorte Breakwater (La Palma, Canary Islands, Spain, 2002 and 2015); and an example of 'circular design' can be seen in the breakwater of the Wakkanai North Breakwater (Japan, 1936). All built in reinforced concrete.

It also links to the case of the double facing in the Blanes Dam (Girona, Catalonia, Spain, 2010) and the Forum Dam (Barcelona, Catalonia, Spain, 2004) that facilitate the minimisation of visual intrusion. The hexagons built at the same crest height cause the water flow to break rhythmically and asymmetrically. An example is the outer seawall of Ciutadella (Menorca, Balearic Islands, Spain, 2008). It consists of a seawall with a reduced crest height to make the city live towards the sea. This reality had already been developed in the sloping breakwaters with diffuser cones in Cubelles, Barcelona (Suárez Bores, 1975).

The chambers and bufadores are other examples of technological advances, as in the Castellón Dam (Valencian Community, 2012) and the 'Molhe Norte da Barra do Douro' in Oporto (Portugal), which is part of the set of works at the mouth of the estuary of the river. Its dialogue with Tazacorte is shown in Figure 17.

Fig. 17. Overtopping at the embankment Duero embankment dam (top) and elliptical shape of the embankment at Tazacorte, island of La Palma (bottom)

One way of constructing curved breakwaters more easily is with circular caissons, as is the case with the Brighton Breakwater (England), or the "Duca degli Abruzzi" in Naples (Italy), or the breakwater at Tangier Med (Morocco), to cite just three of the many examples around the world.

The use of colours can be found in the breakwaters of Llanes, La Guardia and Llançà (Spain) where the master Ibarrola developed the 'Cubos de la Memoria' at the beginning of the 21st century; the use of different materials with GRP reinforcement instead of conventional steel reinforcement (Escombreras, Cartagena, 2017). With less sophistication than in the previous cases, also in the play of colours and shapes can be found cases such as the maritime protection of Santa Cruz de Tenerife or the drawings in symbolic form of the Port of Llançá in Gerona.

This clearly defines the degree of plenitude that Spanish Marine Engineering presents both technologically and artistically. [12]

4. Conclusions

The most relevant conclusions of this research are the following:

- In order to be able to play with aesthetics in the design of a parapet it has to be done in early project phases.
- The slenderness basically requires heavily reinforced concrete XS3 according to CE 2021, with a HA - 35.
- The quantities are well in excess of 100 kg of steel per m3 of concrete.
- New GRP reinforcement increases durability and reduces corrosion due to chloride penetration.
- The design can be realised with curvatures in plan and section, use of materials and colours and lowering of the crown level with juxtaposed elements.

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