Coastal erosion. Geometric detached breakwaters indicators for preventing the shoreline erosion

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ABSTRACT

The coastline today is undoubtedly in a precarious situation. Many beaches are suffering from erosion and the obvious environmental and landscape degradation of many coastal stretches are problems. Coastal Engineers are spending time in solving. With this in mind, different protection methods have been used over time, most based on the artificial nourishment of beaches and on building structures such as groynes and detached breakwaters. Detached breakwaters are artificial structures, generally parallel to the coastline, inspired on the working of natural formations, protecting a certain stretch from wave action and being able to create accretion areas. This is why these structures have been in general use with different results, since the 1970s, in countries such as Japan, the USA, Israel, Spain, Italy and Australia.

The study undertaken for this research centres precisely on this type of structure, with the purpose of providing an overall view of the state-of-the-art in this field and a conceptual model for preventing the coastal erosion. In addition, the effects of a detached breakwater on the shoreline for a series of prototypes on the Spanish coastline and whether the empirical relations given by different researchers for classifying the shoreline's type of response were fulfilled for them all or not, were researched. The result of this work showed how sensitive the shore's response is in relation to the non-dimensional B/X monomial (where B is the length of the detached breakwater and X its distance to the initial coastline) and the range of figures proposed for classifying the shore's response based on that monomial.

DEVELOPMENT OF THE RESEARCH

The study of detached breakwater influence on the shoreline was confined to a single descriptive, geometric and measurable aspect: the ratio between the length of the detached breakwater and the distance from the initial shoreline (non-dimensional monomial B/X or length/distance), taking as such the dry beach line just before being affected by a detached breakwater.

It was seen during the review of the State-of-the-Art that there is a large range of figures proposed for classifying the type of shoreline response based on the B/X monomial that could be basically explained by the importance of surrounding conditions, which are not taken into account in this type of empirical relation, mainly incident wave characteristics because the shore's response to a detached breakwater or system of detached breakwaters noticeably sensitive to states of the sea and, consequently, the problem of determining such becomes highly complex. This is why a certain littoral area was chosen for the study, in an endeavour to eliminate dispersion though average states of the sea, to the greatest extent possible, as represented by wave height, period, wave direction and the average reference level. (figures 1 and 2)

After checking the geometric empirical relations for classifying the shore's type of response to a detached breakwater or system of detached breakwaters as taken into consideration in this study, the general estimation of the geometric model B/X as proposed for the case of the Catalonian coastline, (no tide) could be: (Table 1)

Tombolo:	$B / X \geq 1.3$
Salient or hemitombolo:	$1.3 > B / X > 0.5$
Sandy point or nil response:	$0.5 \geq B / X$

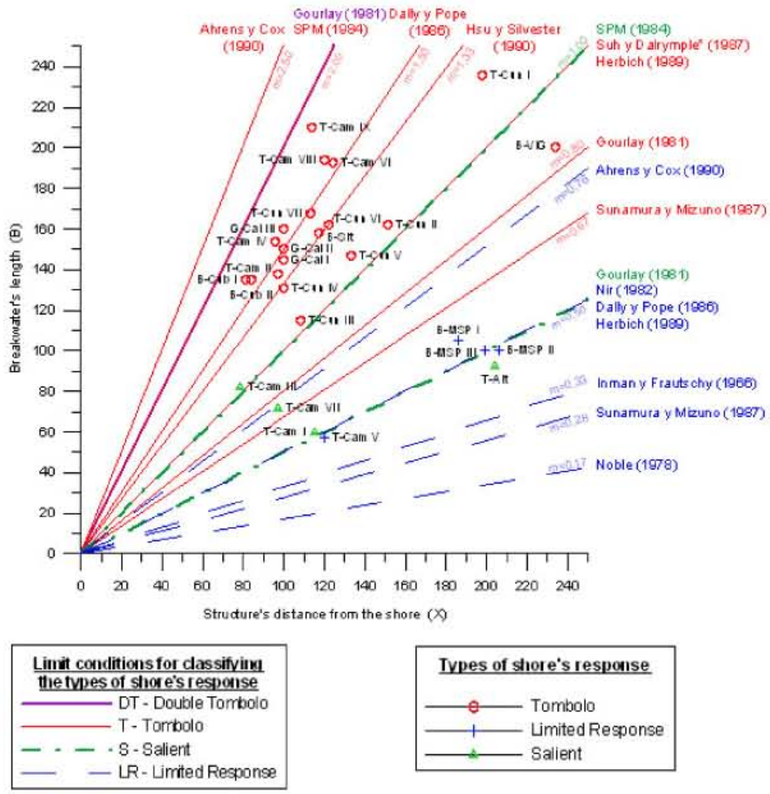

Table 1. First research results

Figura 1. San Antonio de Calonge Beach (Gerona)

Figure 2. Terranova Beach, Sitges (Barcelona)

An extensive database on detached breakwaters was gathered in the research, analyzing the normal wave actions, the geomorphologic conditions and the littoral processes. The method tries to combine these three aspects to predict and prevent the coastal erosion (figure 3 and tables 2, 3 and 4).

Figure 3. Design conditions and definition sketch of a salient

Design conditions. Environmental actions	
Local Wave climate. Normal conditions	H_{12} Significant wave height exceeded twelve hours, m
	T_s Significant wave period, s
	L_0 Wave length in deep water conditions, m
	H_{12}/L_0 Wave steepness, -
Normal tide	Astronomical tide. The method is used with tidal range less than one metre

Table 2. Design conditions. Wave climate in normal distribution

Design conditions. Geomorphologic conditions	
Beach Characteristics	m_t Theoretical slope of the submerged beach, m
	D_{n50} Nominal diameter of sand, mm
	S Relation between the mass density of sand and the mass density of water, -

Table 3. Design conditions. Geomorphologic conditions

Design conditions. Littoral processes	
Sediment transport	d_{sa} Littoral depth, Hallermeier, 1983, m $d_{sa} = \frac{2.9 \cdot H_{12}}{\sqrt{(S-1)}} - \frac{110 \cdot H_{12}^2}{(S-1) \cdot g \cdot T_s^2}$
	d_c Closure depth, m; $d_c = 2 \cdot d_{sa}$
	X_{sa} Width of the surf zone, m; $X_{sa} = d_{sa}/m_t$
	Iribarren Number, $NI_0 = m_t/(H_{12}/L_0)^{1/2}$

Table 4. Design conditions. Littoral processes

According to the natural and physical conditions fitting with the database of the Spanish Mediterranean Detached Breakwaters, *Negro et al* suggest a method following several steps.

- The wave steepness must be less than 0.034, $H_{12}/L_0 < 0.034$

- Following the figure 4, and with the Iribarren Number in deep water conditions, it is possible to obtain a previous range of the geometric factor, B/X
- According the shore response, it is possible to make more precise the range of the geometric factor

• **Tombolo, B/X > 1.67**	
• **Salient**	Well developed, B/X between (1,14; 1,67) Y/X > 0.50
	Small development, B/X between (0,56; 1,14) Y/X < 0.50

Table 5. Range of the geometric factor

- Using figure 5 and the value of X_{sa} (width of the surf zone), according the B/X interval, it is possible to fix the relative position of the detached breakwater, $X < X_{sa}$; $d < d_{sa}$ and $d_{sa} < d < d_c$

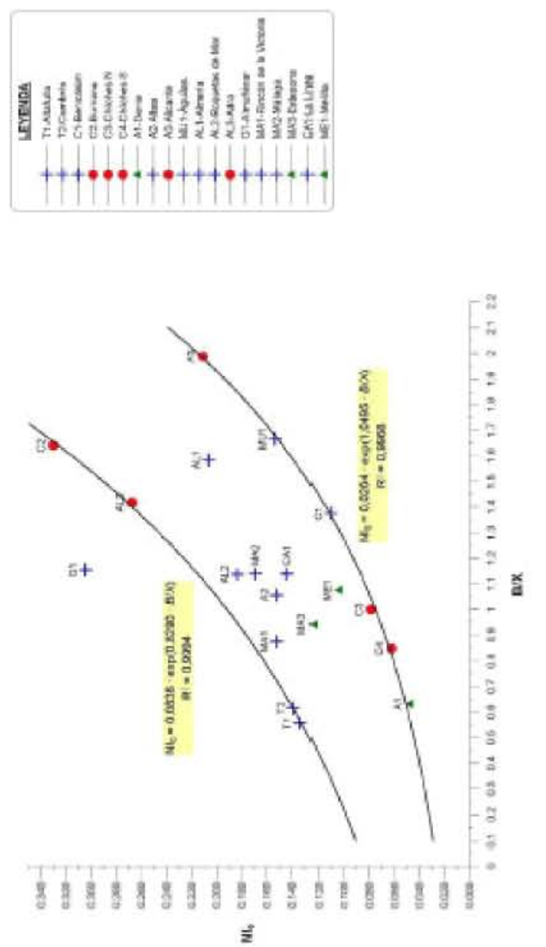

Figure 4. Iribarren Number versus Geometric factor

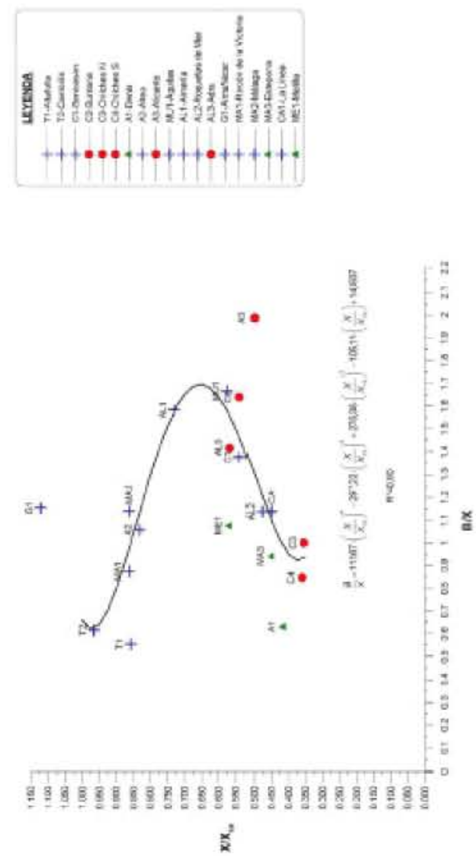

Figure 5.Relation between X/X_{sa} and the geometric factor B/X

CONCLUSIONS

The study of detached breakwater influence on the shoreline was confined to geometric and measurable aspect (B/X); wave climate governing parameters (H_{12}, T_s, θ, H_{12}/L_0), the dynamic processes (d_{sa}, d_c), the behaviour of the coast (Y/X, X/X_{sa}), and the size of sediment (D_{n50}) and beach slope (m_t). The method proposed by the authors tries to resolve the design of this structure commonly used in coastal engineering, using the tables and figures presented above.