

## CHAPTER 107

### Barcelona's littoral regeneration looking forward to the Olimpic Games. Numerical model

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#### 1.- ABSTRACT

The modern technique of Coastal Engineering has enabled the succesful modification of the environment, the recuperation and the stabilization of those sandy areas which due to human action, were in a process of regression and erosion. This work developes a mathematical and numerical model to adjust and analyze the variations between the dissipative profiles and the reflectives ones. The research also emphasizes the enveloping profile to calculate the stable behaviour of the beach.

#### 2.- INTRODUCTION

After several series of observations to get data about bathymetry topography, location of sand, the littoral process, sea, swell, tides, the longitudinal and onshore-offshore current, the authors analyzed the conditions of the progressive erosion of our shoreline during the last decades. Considering these series of initial conditioners, the design criteria were developed in a mathematical and numerical model divided in the following chapters:

- a) Variations between the dissipative and reflective profiles.
- b) Incipient motion on a granular bed in water waves.
- c) The depth at breaking and the signigicant wave height.
- d) Beach profiles.
- e) Numerical model to adjust. Enveloping profile in

$$x/x_{m\acute{a}x} \quad d/d_{m\acute{a}x}$$

### 3.- VARIATIONS BETWEEN THE DISSIPATIVE AND REFLECTIVE PROFILES

Equilibrium profiles have been studied extensively through the history of coastal engineering. For many years it has been held that the steepness  $H_0/L_0$ , the ratio of the deep water waves of the wave height and wave length divided the bar and berm profiles; the dimensionless fall velocity  $H_0/T_w$ , the erosion parameter  $Q/H_{0d}$ , the grain size  $D_{50}$ , the depth  $d$ , and the relations between the steepness and the fall velocity separate the dissipative and the reflective profile.

The numerical model calculates the beach profile shape depending of wave climate and the variations with  $H_0$ ,  $L_0$ ,  $\gamma_s$ ,  $\gamma_w$ ,  $D_{50}$  data.

In Table 1, the authors include the initial variables and the design criteria.

### 5.- THE DEPTH AT BREAKING AND THE SIGNIFICANT WAVE HEIGHT

A large number of factors influence the shape of beach profiles in nature. The series of observations to get data about bathymetry are considered the design criteria to establish the refraction, diffraction and the breakpoint.

The depth at breaking and the relationship with the significant wave height, type of breaker, broken wave and the accreting, transition and eroding beaches correspond with the occurrence of surging, plunging and spilling breakers respectively.

The authors analyze the different criteria and adjust several ones to compute the break point and the type of breaker.

In table 2, they include the variables and the design criteria. Numerical model uses the following formulae:

- Munk
- Weggel
- Gumbak
- Goda

TABLE 2. MODEL OF WAVE BREAKING

-	Boussinesq	(1881)	$H/d = 0,73$
-	McGowan	(1881)	$H/d = 0,781$
-	Michell	(1893)	$H/L = 0,127$
-	Gwyther	(1900)	$H/d = 0,83$
-	Miche	(1944)	$H/d = 2 H/L/\text{arcth}(7,04 H/L)$
-	Davies	(1951)	$H/d = 0,83$
-	Packham	(1952)	$H/d = 1,03$
-	Yamada	(1957)	$H/d = 0,828$
-	Laitone	(1962)	$H/d = 0,7273$
-	Lenau	(1966)	$H/d = 0,827$
-	Horikawa-Kuo	(1966)	Grafico
-	Kishi-Saeki	(1966)	$H/d = 5,618 m^{0,40}$
-	Camfield-Street	(1967)	$H/d = 0,75 + 25 m - 111 m^2 + 3.870 m^3$ $0 \leq m \leq 0,045$
-	Galvin	(1969)	$\frac{H}{d} = \frac{1}{B - \tau iK}$  $B = 1,40 - 6,85$ $\tau = 4 - 9,25 i$ $0 \leq K \leq 2 ; K \approx 1$
-	Collins	(1969)	$H/d = 0,72 + 5,60 m$
-	Bryar-Smith	(1970)	$H/d = 0,86$
-	Grimshaw	(1971)	$H/d = 1,21$
-	Strel Koff	(1971)	$H/d = 0,85$

Weggel	(1972)	$\frac{H}{d} = \frac{b}{1 + a/\sqrt{gT^3}}$ $b = \frac{1,56}{1 + e^{-19,5i}}$ $a = 43,70 (1 - e^{-19i})$
Goda	(1975)	$K_s H_0; D/L_0 \geq 0,20$ $H_{1/3}$ $m \ln (B_0 H_0 + B, d), B_{\max} H_0, K_s H_0$
Gumbak	(1977)	$\frac{H}{d} = 0,80; \quad Ir < 0,20$ $\frac{H}{d} = 0,87 \quad Ir > 0,63; \quad 0,20 \leq Ir \leq 0,66$ $\frac{H}{d} = 1,20; \quad 0,66 \leq Ir \leq 2,20$
Ostendorf-Madsen	(1979)	$H/d = 0,829$
Ostendorf-Madsen	(1979)	$H/d = (0,80 + 5m)^2 \quad H/L / \operatorname{argth} (7,14 H/L)$ $m < 0,10$ $H/d = 0,13^2 \quad H/L / \operatorname{argth} (7,14 H/L)$ $m > 0,10$

## 6.- BEACH PROFILES

To find a connection between the depth, the wave height and length, the grain diameter, the dimensionless fall velocity and to evaluate the response of the beach, the bar or berm profiles the researches have been studied the problem through the history of the Coastal Engineering. The lineal relation, the adjustment of storm profiles by cubic parabolas, the location of the inflection point and the shoreline process of regression are the problems to analyze and resolve.

In table 3, the authors include the state of art and they develop a mathematical and numerical model to determine the variations between bar and berm profiles. Considering the initial data:

- Beach shape
- Motion initiation by oscillatory flow
- Break point
- Beach profile

The numerical model evaluate in 600 points in  $x$  and depth the value of each profile, the risk of failure depending of the grain size and wave climate, and the enveloping profile of the stable beach.

The mathematical curve adjusts the stable beach, the validity of each one (Bruun, Larras, ...) and with the initial data the defensive barrier that we need is created an artificial beach. We shall emphasize the enveloping profiles in dimensionless parameters:

$$x/x_{\text{máx}}$$

$$d/d_{\text{máx}}$$

TABLE 3. BEACH PROFILES

- Bruun (1954, 1956, 1978, 1986)  $x = L_0 \sqrt{2\pi y} \left( 2 \left( \frac{2\pi y}{L_0} \right) + \frac{1}{3} \left( \frac{2\pi y}{L_0} \right)^2 + \dots \right)$

$$y < L_0/8 \quad y^{3/2} = px$$

$$y^{5/4} = px$$

$$y^{3/2} = px$$

- Keulegan y Krumbein (1949)  $y = px^{4/7}$

- Inmann y Bagnold (1963)  $y = px$

- Larras  $\frac{y}{L_0} = k \left( \frac{x}{L_0} \right)^m$

$$k = f(H_0, L_0, D, \xi, \xi_0)$$

$$m = g(H_0, L_0, \xi, \xi_0)$$

- Sitarz (1969)  $x = ay^2 + x_0$

$$a = f(D, H_0, \xi, \xi_0)$$

$$x_0 = g(A_1, H_0, D, \xi, \xi_0)$$

$A_1$  43,50 Berm

66 Bar

75 Nature

- Dean (1973)

$$y = A_D x^{2/3}$$

$$A_D = \frac{24}{5} \frac{f(D)}{f g \sqrt{g} \lambda_b^2}^{2/3}$$

$f(D)$  = Energy wave regime

$\lambda_b$  =  $H/d$  breaker point

- Vellinga (1982,19854)

$$y \frac{7,60}{H_{0s}} = 0,47 (7,6/H_{0s})^{1,28} x$$

$$x (W_f/0,0268)^{0,56} x + 18 \frac{1}{2} - 2,00$$

$$y = 0,70 \left(\frac{H_0}{L_0}\right)^{0,17} w_f^{0,44} x^{0,78}$$

$H_0 = 7,6$  m

$T = 12$  sg

$D_{50} = 0,225$  mm

- Sunamura (1980, 1984)

$$y = 0,75 \left(\frac{D}{H}\right)^{0,25} \left(\frac{L}{H}\right)^{0,15} x$$

- Horikawa (1980, 1984)

$$y = 0,21237 H^{-0,50} D^{-0,25} T^{-0,50} x$$

- Sayao (1982)

$$y = 0,082 x^{0,633} D_{50} = 0,225 \text{ mm}$$

- Hattori y Kawamata (1982)

$$y = p x^{2/3}$$

$$\frac{H_0}{L_0} \text{tg } B \frac{w_f}{gT} = k$$

**Beach profile shape**

**TABLE 1. Dissipative and reflective profile**

-	Jonson (1952)	$0,025 < \frac{H_o}{L_o} < 0,030$	
-	Saville (1957)	$0,025 \approx \frac{H_o}{L_o}$	
-	Iwagaki-Noda (1962)	$\frac{H_o}{L_o}, \frac{H_o}{D_{50}}$	
-	Sitarz (1963)		< 0,60 Berm
		$\frac{H}{T (g (s - 1) D)^{1/2}}$	
			> 0,60 Bar
-	Nayak (1970)	$\frac{H_o}{L_o}, \frac{H_o}{D_{50}}, \frac{\gamma_s}{\gamma_w}$	
-	Dean (1973)		< 0,85 Berm
		$\frac{H_o}{T_w}$	
			> 0,85 Bar
			> T/2 Bar
		tf	
			< T/2 Berm
		$\frac{H_o}{L_o} > 1,70 \frac{\gamma_w f}{gT}$	Bar

- Van Hijum (1974)  $\frac{H_o}{L_o} > 2,50 \frac{D_{90}}{H_o}$  Bar  
 $< 0,54$  Berm  
 $\frac{H_o}{T_w D_{50}}$   
 $> 0,54$  Bar
- Sunamura y Horikawa (1974)  $\frac{H_o}{L_o} > 4 \text{ tg } \alpha^{-0,27} \left(\frac{D}{L_o}\right)^{0,67}$  Bar
- Dalrymple y Tompson (1976)  $\frac{Q}{H_o d_i}$  erosion parameter
- Hattori y Kawamata (1980)  $< 0,50$  Berm.  
 $\frac{H_o}{L_o} \text{ tg } B$   
 $\frac{w}{gT}$   
 $> 0,50$  Bar.
- Gourlay (1980)  $< 1,55$  Berm  
 $\frac{H_o}{T_w}$   
 $> 1,55$  Bar

Marine sand,  $D_{50}$  0,20 a 0,30 mm.

$< 0,40$  Berm

$$\frac{H_0}{T_w}$$

$> 0,40$  Bar

$D_{50} \approx 2 \text{ mm.}$

Wang (1981)

$$I_w = \frac{H_b^{\frac{1}{2}}}{g^{\frac{1}{2}} T \operatorname{tg} \alpha}$$

$I_w \downarrow$  Berm

$I_w \uparrow$  Bar

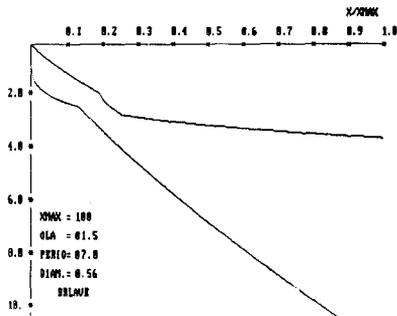
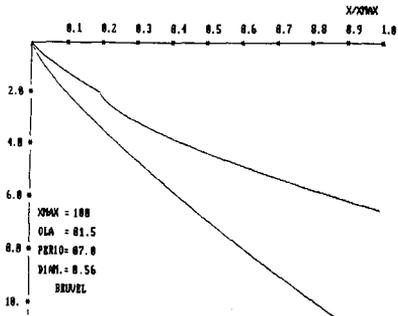
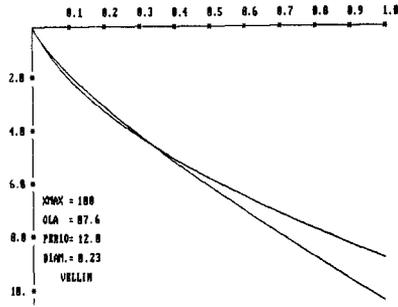
#### 4.- INCIPIENT MOTION ON A GRANULAR BED IN WATER WAVES

Motion initiation on a granular bed by oscillatory flow is of great importance to coastal engineers, it is a necessary condition for bed erosion and to determine the changes onshore-offshore in beaches, to establish the failure and to use in different beach profiles.

The numerical model adjusts three formulae in this case:

- Swart  $u = 4,58 D_{50}^{0,38} T^{0,043}$
- Hallermeier  $u = \left( 8 \left( \frac{\gamma_s}{\gamma_w} - 1 \right) g D_{50} \right)^{\frac{1}{2}}$
- Vellinga  $\log \left( \frac{1}{w} \right) = 0,476 (\log D)^2 + 2,18 \log D + 3,190$

- Readshaw (1982)  $y = 0,112 x^{0,98} \quad D_{50} = 0,56 \text{ mm}$
- Bailard (1981)  $y = p x^{\frac{1}{2}}$   
 $y = p x^{2/7}$
- Sayao (1982)  $y = A x^n \quad n > 1, D_{50} > 0,60 \text{ mm}$   
 $n < 1, D_{50} < 0,60 \text{ mm}$
- Garau (1974-1984)  $m_o = 0,075 + 0,035 L_n D_{50}$   
 $m_s = 0,025 + 0,010 L_n D_{50}$   
 $m_p = 0,0223 + 0,005 L_n D_{50}$   
 $t_g = m = 0,138 + 0,056 L_n D_{50}$
- Garau-Friedman  
(stable beachline)  $m_{sa} = (0,0255 + 0,010 L_n D_{50}) \frac{1}{K_a^{1,11}}$   
 $m_{oa} = (0,075 + 0,035 L_n D_{50}) \frac{1}{K_a^{1,22}}$



## 7.- SUMMARY AND CONCLUSIONS

The modern Technique of Coastal Engineering has enabled the successful modifications of the environment and the recuperation and stabilization of those sandy areas which due to human action were in a process of regression and erosion.

The research has developed the mathematical adjustment of curves to the storm profile and the berm profile according to Bruun, Vellinga, Larras, Sitarz ... and the behaviour of the beaches of Barcelona in which both human action (growing, construction, harbour works...) and maritime actions (sea movements) have produced a remarkable backward movement and regression.

The numerical model is able to analyze the variations between the dissipative profiles and the reflective ones, and to make the enveloping profile in

$$x/x_{\max}$$

$$d/d_{\max}$$

Which will enable us to adjust a stable profile to the beach.

The behaviour of the beaches of Barcelona may consider as fossil ones, near the breaker zone and with  $D_{50}$  between  $0,16 \text{ mm} \leq D_{50} \leq 2 \text{ mm}$ .

The numerical model was developed in the University of Madrid and the results were analyzed by experimental data for the beach profile tests in the Spanish Center of Investigation (CEDEX, CEPYC. Madrid).

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