uniform conditions together with a constant bottom slope, m :

$$\bar{D} = \frac{1}{xb} \int_0^{xb} D(x)dx \qquad (1)$$

$\bar{D}$ being the average (cross-shore) value for D , and xb the width of the surf-zone. It is shown that this value is easily related to the dynamic state via the Iribarren's parameter Ir (or Irb when referring to breaking conditions), defined as:

$$Ir = m / (H/Lo)^{1/2} \qquad (2)$$

where m is the bottom slope (assumed to be constant through surf-zone), H wave height and Lo the deepwater wave length.

To get a better insight of the relationship between D and the dynamic state, a non-dimensional value, $\hat{D}$, is defined, refering $\bar{D}$ to an order of magnitude rate of wave energy dissipation Do:

$$Do = \rho g \frac{Hb^2}{T} \qquad (3)$$

where T is the wave period, g is the gravity acceleration and ρ is the water density.

Do may be obtained from dimensional analysis or bore (hydraulic jump) dissipation theory. This reference value can be also obtained via an energetic balance in the surf zone, relating eddy viscosity coefficients to wave energy dissipation:

$$D <> \text{Stress x velocity} \qquad (4)$$

Characteristic stresses for this problem are, typically, the Reynolds stresses (related to eddy viscosity coefficients):

$$\tau_r = - \rho \overline{u'v'} = - \rho A \frac{dV}{dx} \qquad (5)$$

where A is the eddy viscosity coefficient, and u', v' are the (x,y) components of the turbulent velocity. The eddy viscosity coefficient has the dimension of a typical length times a typical velocity:

$$A \sim l \cdot V' \qquad (6)$$

Following (Harris et al, 1962) typical scales for length and velocity can be respectively H and H/T . The eddy viscosity coefficient must therefore be of order H^2/T .

The characteristic velocity, V', is assumed to be a typical scale of the turbulent velocity, that can be related, in the surf zone, to the shallow water wave celerity:

$$V' \simeq \hat{B}\,(g\ hm)^{1/2} \qquad (7)$$

where $\hat{B}$ is a dimensionless constant accounting for breaker type (therefore related to Ir) and hm is an average or characteristic depth through the surfzone.

The energetic balance can be set as in (Battjes, 1975):

$$\frac{\text{Rate of wave energy dissipation}}{\text{Area}} = \frac{\text{Rate of turbulent energy produced}}{\text{Area}} =$$

$$= \frac{\text{Rate of turbulent energy dissipated}}{\text{Area}}$$

(neglecting bottom friction, percolation or any other dissipation phenomena than turbulence).

From this and (5):

$$D < > \text{Stress} \cdot \text{velocity} = \rho A \frac{dV}{dx} \cdot V' \qquad (8)$$

Following the control volume approach presented in (Losada, S.Arcilla and Vidal, 1986) to estimate the partial derivative in (8), the rate of wave energy dissipation can be written as follows:

$$D = \rho A \frac{Vlb}{xb} \cdot \hat{B}\,(g\ hm)^{1/2} \qquad (9)$$

Vlb being the longshore current velocity at the breaker line, depending on wave, beach and dynamic state parameters.

Assuming (Losada, S.Arcilla and Vidal, 1986) that A , $\hat{B}$, and other parameters involved in the Vlb formulation (γ,Kr,etc.) are Ir functions, it is easy to show that:

$$\frac{D}{\rho g A} = F\,(Ir) \cdot \cos \Theta b \qquad (10)$$

where Θ is the angle of wave incidence.

In this dimensionless equation F(Ir) is a known function that comes from the formulation used to evaluate Vlb. If we choose (Losada, S.Arcilla and Vidal, 1986), F(Ir) can be written as follows:

Author	$\hat{D}$	Free parameters and order of magnitude or suggested values
Longuet-Higgins, 1970	$\frac{(2\pi)^{1/2}}{8} \gamma^{1/2} Irb$	---
Losada, S.Arcilla and Vidal, 1986	$\frac{(2\pi)^{1/2}}{8} \gamma^{1/2} (1-Krb^2) \cos\theta b \; Irb$	---
Dally, Dean and Dalrymple, 1984	$\frac{(2\pi)^{1/2}}{8} \gamma^{1/2} Irb$	---
Battjes, 1978	$\beta \cdot \frac{B \gamma_B^4}{4\,(0,7 + 5m)}$, $\beta = 0,1134$	$B \sim O(1)$ or $B\gamma_B^4 \sim O(1)$
Battjes and Janssen, 1978	$\frac{1}{xb} \int_0^{xb} [\frac{\alpha}{4} Qb \cdot (\frac{Hm}{Hrms})^2] \, dx$	$\alpha \sim O(1)$
Stive, 1982	$\beta \cdot \frac{\gamma}{4} \cdot A_\varepsilon \; Ad$	$A_\varepsilon \sim$ 2tanh (5 Iro) or 2tanh (5 Irb) if Irb < 0,4
Svendsen, 1984	$\beta \cdot \frac{\gamma}{4} \cdot As \; [(1+\gamma \frac{\eta c}{H})(1+\gamma(\frac{\eta c}{H} - 1))]^{-1}$	$As \sim O(1)$
Guza and Thornton, 1985	$\frac{1}{xb} \int_0^{xb} [\frac{3(\pi)^{1/2}}{16} \cdot B^3 \gamma (\frac{Hrms}{Hb})^2] \, dx$	$B \sim O(1)$ or $B^3 \sim O(1)$

Table 1. Expressions of non-dimensional average rate of wave energy dissipation, D, as functions of Irb dependant variables, for various analytical models.

$$F\,(Ir) = \frac{\hat{B}\,.\,\tilde{A}}{4\quad(2)^{1/2}}\,.\,\gamma^{1/2}\,.\,(1-Kr^{2})\;m^{2} \qquad (11)$$

where Kr is the reflection coefficient and γ is the breaker index.
Then, assuming that $A \simeq H^2/\,T$, it follows that:

$$\frac{D}{\rho g\;H^2/T} = F\,(Ir)\;.\;\cos\theta b \qquad (12)$$

and the reference rate of wave energy dissipation, Do, can be correctly expresed by $\rho g\;H^2/T$.

Using this reference value, average non-dimensional expressions for the rate of wave energy dissipation can be obtained for all formulations considered, even though some of them require numerical evaluation. These expressions are shown in table 1, together with their free parameters, suggested values for them, and range validity. The dimensionless $\hat{D}$ values are known functions of parameters that depend on Ir. It follows that $\hat{D}$ itself is a function of Ir for all models.

The only formulation including reflection and large angles of wave incidence, without any free parameters, and being valid for the whole range of Ir values, is that of (Losada, S.Arcilla and Vidal, 1986). It will be, therefore, compared to other models to enlarge their range of validity via an estimation of their free parameters as functions of Ir. Values of Kr are taken from (Battjes, 1974). The comparison is made numerically in all cases using laboratory and field data taken from:

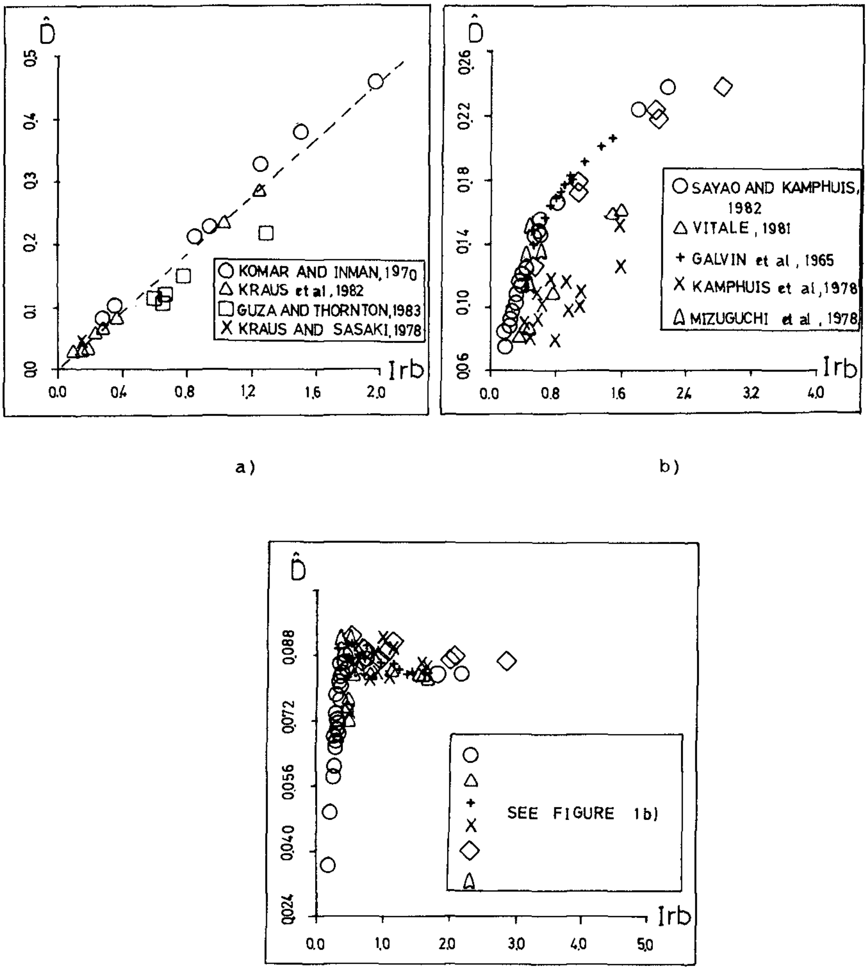
Laboratory (Putnam, Munk and Traylor, 1949) (Galvin and Eagleson, 1965) (Mizuguchi et al., 1978) (Kamphuis and Readshaw, 1978) (Vitale, 1981) (Kamphuis and Sayao, 1982)

Field (Komar and Inman, 1970) (Kraus and Sasaki, 1978) (Kraus, Isobe et al, 1982) (Guza and Thornton, 1983)

Results from (Losada, S.Arcilla and Vidal, 1986), (Battjes and Janssen, 1978) and (Guza and Thornton, 1985) are shown in figures 1a to 1c, as an example of the results of some of the models analysed.

To test the models, wave, beach and dynamic state measured parameters are used to estimate the average non-dimensional rate of wave energy dissipation. It is shown that $\hat{D}$ is greater for laboratory than for field data, because viscosity and bottom efects are overestimated in laboratory tests.

The adjustment of free parameters as Ir functions is shown in Table 2. Figures 2a to 2c illustrate the results for (Battjes and Janssen, 1978), (Stive,1982) and (Guza and Thornton, 1985) models, being an example of the fit made for all models.



c)

Figure 1. Results of non-dimensional average rate of wave energy dissipation ,$\hat{D}$, for:

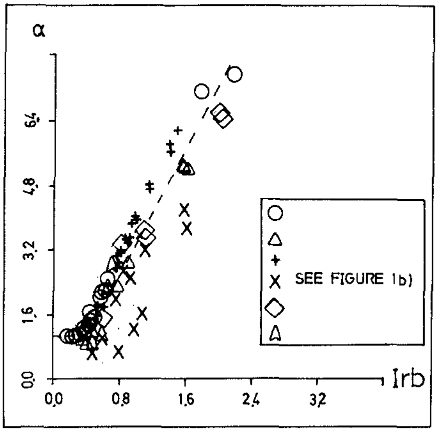
a)(Losada,S.Arcilla and Vidal,1986) model.Field data.

b)(Guza and Thornton,1985) model.Laboratory data.

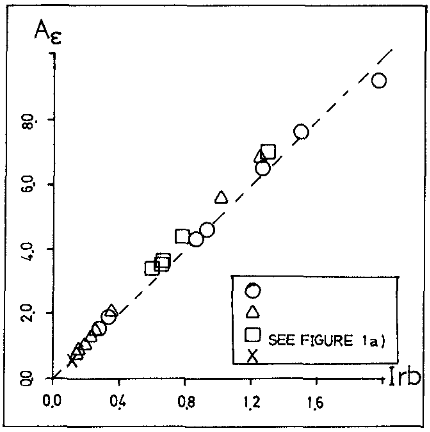
c)(Battjes and Janssen,1978) model.Laboratory data

Author	Free parameter	Initial value of original range of validity	Proposed adjusted value Laboratory		Proposed adjusted value Field	
Battjes, 1978	8	1.... 2	5.875 Irb		4.800 Irb	
(regular waves)	$8\,\gamma_B^4$	1.... 2	$12.862\ Irb^2$		$7.706\ Irb^2$	
Battjes. Janssen, 1978	α	0(1)	1.000	Irb $\leqslant$ 0.4	1.100	Irb $\leqslant$ 0.4
(irregular waves)			3.680.Irb	Irb > 0.4	2.583.Irb	Irb > 0.1
Stive. 1982	A_ε	A_ε = 2 tanh (5Iro)	4.24 Irb		5.000 Irb	
Svendsen, 1984	As	1	5.100 Irb		8.000 Irb	
Guza , Thornton, 1985	8^3	0(1)	1.875 Irb		2.474 Irb	

Table 2. Expressions of free parameter adjustements for all analytical models. obtained by comparison to (Losada and Sanchez-Arcilla and Vidal, 1986) formulation.



a)



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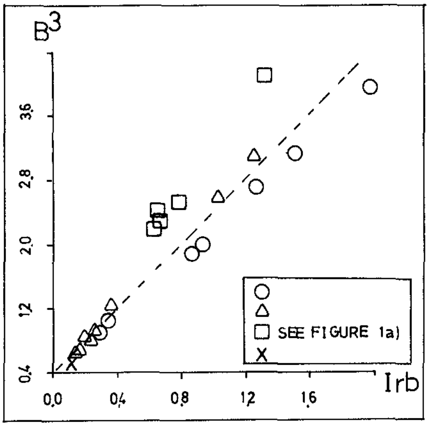


c)

Figure 2. Results of the adjustment of the free parameters:

a) α (Battjes and Janssen,1978),laboratory data

b) A_ε (Stive,1982),field data

c) B (Guza and Thornton,1985),field data

as functions of the Iribarren's parameter Irb

As final remark, a bell-shaped behavior is expected for $\hat{D}$ vs Ir due to:

- incipient spilling breakers, corresponding to low Ir values, produce small dissipation per unit horizontal area (wide surfzone together with a small depth affected by turbulence)

- collapsing-surging breakers, in the higher Ir range, produce small dissipation per unit horizontal area (highly reflecting beach conditions).

- maximum dissipation corresponds to late spilling and plunging breakers, generating maximum turbulence

3. Longshore Current Velocity

Analytical (state-of-the-art) models for the longshore current velocity are based on time and vertically-integrated conservation equations for stationary and longshore uniform conditions with constant beach slope. Most of them also use shallow water linear wave theory.

All formulations depend on two poorly known coefficients, each representing one of the two main retarding terms considered in the momentum balance equation:

- cf, bottom friction coefficient

- M, lateral mixing coefficient, related to eddy viscosity

From the given definition for Iribarren's parameter Ir, (2), an Ir-dependent expression for Vlb may be obtained for each of the selected longshore current velocity models (Table 3). These equations depend on Ir directly or via other parameters related to it (γ, Kr, etc).

From these expressions and order of magnitude considerations, a reference velocity Vo can be defined to obtain a non-dimensional value for Vl:

$$Vo = \frac{Hb}{T} \sin \theta b \qquad (13)$$

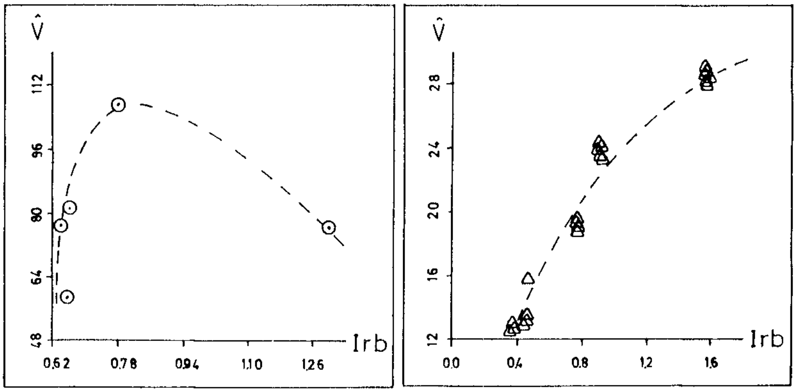
$$\hat{V} = Vl/ Vo = \frac{Vl}{(Hb/T \ . \ \sin \theta b)} \qquad (14)$$

Testing these formulae with the set of data mentioned in section 2, general trends for a relationship between Vlb and Irb may be obtained (an example of them being figure 3):

- lower values of Vlb appear associated to incipient spilling breakers (low range of Irb values)
- stabilized or decreasing values for collapsing-surging breakers (high values of Irb)
- maximum values for Vlb are attained for late spilling and plunging

Author	$\dot{V} = V_{lb} / V_o = V_{lb} / (H_b/T \cdot \sin\theta_b)$	parameters
Longuet-Higgins, 1970	$\frac{(50\pi^3)^{1/2}}{16} \cdot \frac{\gamma^{1/2}}{c_f} \cdot [P\,(1-P_1)(P_1-P_2)]^{-1} \cdot I_{rb}$	$P = \frac{\pi N_m}{\gamma c_f}$, $P_1 = -3/4 + (9/16+1/P)^{1/2}$ $P_2 = -3/4 - (9/16+1/P)^{1/2}$
Losada, S.Arcilla and Vidal, 1985	a) linear bottom friction law : $\frac{3\,(2\pi)^{1/2}}{18} \cdot \gamma^{1/2}\,(1 + 3/5\,\sin^2\theta_b)^{-1} \cos\theta_b\,(1-K_{rb}^2)\,I_{rb}$ b) cuadratic bottom friction law: $\frac{(\pi)^{1/2}}{2} \cdot K \cdot \left(\frac{(1-K_{rb}^2)\,\gamma}{m\,c_f\,\sin\theta_b\cos\theta_b}\right)^{1/2}$	$K = V_{lb}/V_m = O(1)$ $V_m = V_{mean}$
Liu and Dalrymple, 1978	$\pi \cdot \frac{(\pi)^{1/2}}{2} \cdot \gamma^{1/2} \cdot \frac{1}{m\,\sin\theta_b} \cdot I_{rb} \cdot f_{11}\left(\frac{\sin\theta_b}{c_b}, gh_b, \gamma\right)$ $\left(\frac{\pi}{2}\right)^{1/2} \cdot \gamma^{1/2} \cdot \frac{1}{m\,\sin\theta_b}\, I_{rb} \cdot f_{12}\left(\frac{\sin\theta_b}{c_b}, gh_b, m, f\right)$	$V_l << U_m$ $V_l >> U_m$
Kraus and Sasaki, 1979	$\frac{(50\pi^3)^{1/2}}{16} \cdot \frac{\gamma^{1/2}}{c_f} \cdot f_{ks}(\sin\theta_b, P, Q)\,I_{rb}$	$P = \frac{\pi}{2}\,\Gamma\,\frac{m^*}{c_f}$; $Q = \frac{\pi}{2}\,\Gamma\,\frac{m}{c_f}$ m* : modified bottom slope (accounting for set-up)
Madsen, 1978	$\lambda \cdot \frac{(50\pi)^{1/2}}{8} \cdot \frac{\gamma^{1/2}}{f} \cdot f_m(P)\,I_{rb}$	$P = \frac{\pi\gamma m^*}{f}$
Komar, 1970	$1.35\,(\pi)^{1/2}\,\frac{\gamma^{1/2}}{m} \cdot I_{rb}$	
Bijker, 1976	$\frac{(25\pi^3)^{1/2}}{8} \cdot \frac{C}{(g\gamma f_w)^{1/2}}\,I_{rb}$	C : Chezy coefficient
Guza and Thornton, 1985	$\frac{23\,(2)^{1/2}}{20}\,\frac{\gamma^{1/2}}{c_f} \cdot \frac{a^{1/5}\,h_b^{9/10}}{H_b}\,\left[1 - h_b^{23/4}\left(\frac{1}{h_o^{23/4}} - \frac{a}{y_o^{5/2}}\right)\right]^{-6/5} I_{rb}$	; $a = \left(\frac{23}{15}\left(\frac{g}{\pi}\right)^{1/2} \frac{\gamma^4 m}{B^3}\,T\right)$

Table 3. Non-dimensional longshore current velocity at the breaker line for all models considered.



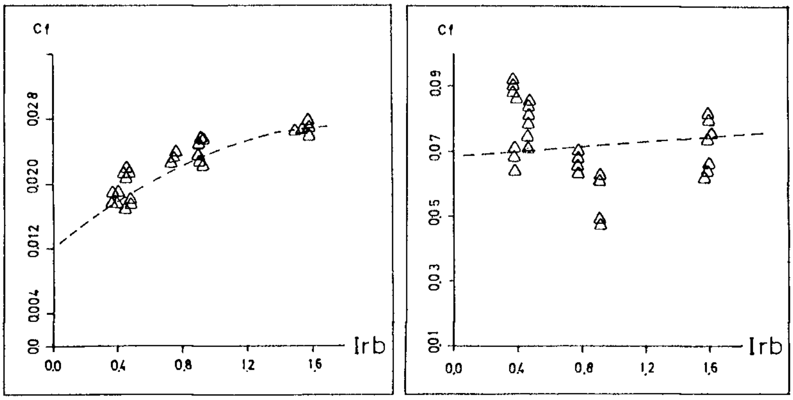
a) b)

Figure 3.

Non dimensional longshore current velocity at the breaker line vs Irb

a) field data taken from (Guza and Thornton, 1985)

b) laboratory data taken from (Vitale, 1981)



a) b)

Figure 4.

Calibration of bottom friction coefficient , Cf, as a function of Irb for:

a) (Losada, S. Arcilla and Vidal, 1986) model

b) (Guza and Thornton, 1985) model

using (Vitale, 1981) laboratory data.