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TECHNICAL COMMUNICATION

Re-examination of Breaker-Type Classification on Uniformly Inclined Laboratory Beaches

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ABSTRACT

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Results of 150 runs of a wave-flume experiment using sloping bottoms with various gradients ranging from 1/20 to 1/0.5 indicated that the demarcation of breaker types can be described by the equation, $H_0/L_0 = N (\tan \beta)^n$, where H_0/L_0 is the deep-water wave steepness, β is the slope angle, and N and n are coefficients: $N = 2.4$ and $n = 1.8$ are given for the boundary between spilling and plunging breakers; $N = 0.19$ and $n = 2.5$ for plunging-collapsing boundary; and $N = 0.074$ and $n = 2.4$ for collapsing-surging boundary. The surf similarity parameter, ξ_0 was found to represent these three boundaries: they were given by $\xi_0 = 0.5$, 2.5, and 3.7, respectively.

ADDITIONAL INDEX WORDS: *Surf similarity parameter, breakers, wave-tank experiment.*

INTRODUCTION

IVERSEN (1952a) first classified the type of breaking waves into three: spilling, plunging, and surging breakers. GALVIN (1968) defined a fourth, using the term "collapsing" for a type intermediate between plunging and surging.

Through his wave-tank experiment, IVERSEN (1952b) indicated that the breaker type depends on the deep-water wave steepness and the beach slope. Since then, a considerable number of studies concerning the classification of breaker types have been carried out (*e.g.*, HAYAMI, 1955, 1958; GALVIN, 1968; WEGGEL, 1972; IWAGAKI *et al.*, 1974; BATTJES, 1974; GAUGHAN & KOMAR, 1975; SAEKI *et al.*, 1975, 1976). These studies, except for Galvin's, have been performed under the condition of bottom slopes gentler than 1/10.

Figure 1 is a plot of the breaker-type boundaries proposed by previous studies. This figure shows that there are remarkable discrepancies in the boundary between spilling and plunging waves and also in the boundary between plunging and surging or collapsing waves. The reason for these discrepancies seems to stem mainly from different criteria used to classify breaker types, as already pointed out by SAEKI *et al.* (1976).

GALVIN (1968), who introduced collapsing breakers and performed wave-flume experiments using three beach slopes with a gradient of 1/20, 1/10, and 1/5, did not define the boundary between collapsing and surging breakers, probably because of insufficient number of data obtained from his steep slope experiments. Gal-

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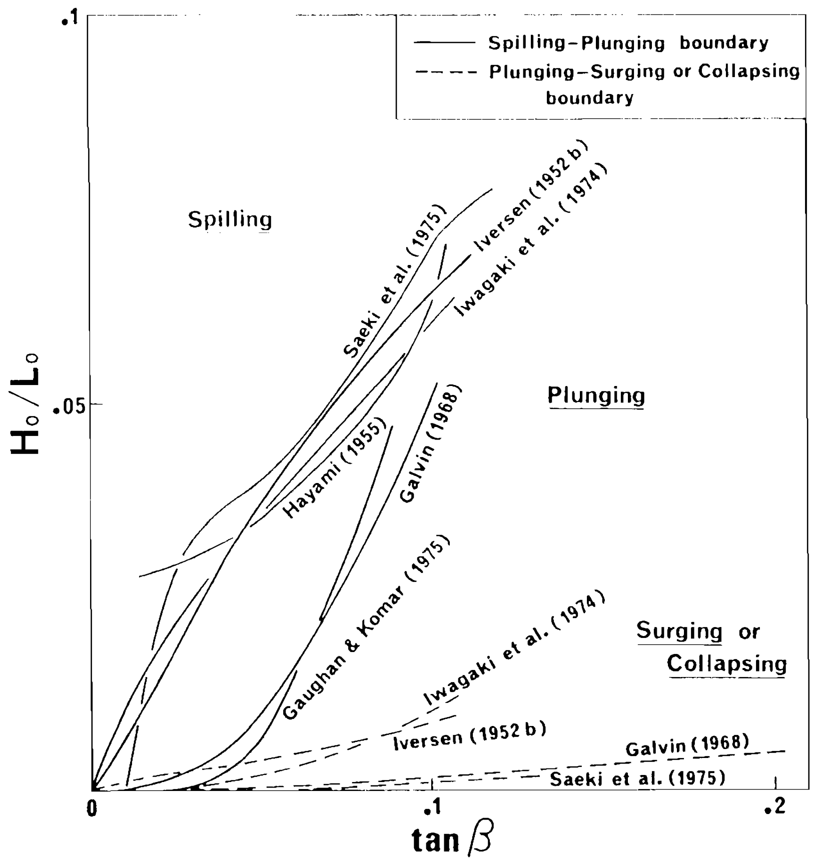

Figure 1. Comparison of breaker-type boundaries.

vin's study is the only one that has dealt with types of breaking waves on a beach slope greater than 1/10. It should be noted that no explicit demarcation has been made between collapsing and surging breakers as shown in Figure 1.

Nevertheless, it has been believed that studies on the classification of breaker types was complete. This assumption is evident from the fact that no studies on breaker-type classification have been conducted since 1976.

Using Galvin's data, BATTJES (1974) represented the boundary of breaker types in terms of the surf similarity parameter, ξ_o (= tan β/ $\sqrt{H_o/L_o}$), where β is the beach slope angle, H_o is the deep-water wave height, and L_o is the deep-water wavelength. His result was: $\xi_o = 0.5$ for spilling-plunging boundary and $\xi_o = 3.3$ for plunging-collapsing or surging boundary. These values are today widely used to demarcate breaker types. The boundary between collapsing and surging breakers, however, has not been quantitatively determined.

The type of breaking wave, which characterizes the nearshore wave field, is of vital importance for coastal processes studies. Breaker types are indicative of an interrelationship between input waves and bottom topography. Rocky coasts have nearshore slopes with a wider range of gradients from gentle to almost vertical. Bottom shopes of sandy coasts are usually gentler, but the gradient of shingle beaches composed of cobbles or boulders is considerably steep. KING (1959, p. 322) and SHEPARD (1963, p. 171) reported that gradients between 1/3 and 1/2 are found on some shingle beaches.

The previous breaker-type classifications seem to be inapplicable to the littoral environment with such steep slopes.

Although (1) waves are random in nature and (2) the beach is not smooth and generally not uniformly inclined, breaker types under simplified laboratory conditions should be explored before approaching the more complicated natural phenomenon. Using uniformly sloping, smooth bottoms with a wide range of gradients, a laboratory study was conducted in a flume with a monochromatic wave generator, aiming to (1) re-evaluate the previous breaker-type classifications, (2) scrutinize breaker types on slopes steeper than 1/10, and (3) propose a new classification, which will be applicable to beaches with any gradient.

LABORATORY EXPERIMENTS

Laboratory experiments were conducted in a two-dimensional wave flume 12 m long, 0.2 m wide, and 0.4 m deep. The wave flume was equipped with a plunge-type wave generator at one end, and a uniform, smooth, impermeable slope was placed at the other end. Slopes with eleven kinds of gradients ranging from 1/20 to 1/0.5 were employed in the experiment. The water depth at the toe of the slope was 25 cm and kept constant. One hundred fifty runs of experiment were tested combining the slope gradient, wave height (1.5–12 cm), and wave period (0.6–2.8 sec).

During each experimental run, the behaviour of breaking waves was recorded using a video-camera operated at a tape speed of 30 frames/sec and a shutter speed of 1/500 sec. Pictures reproduced were used for the determination of breaker types. A capacitance-type wave gauge was installed in the offshore with a constant water depth of 25 cm to measure input waves.

DEFINITION OF BREAKER TYPES

According to GALVIN (1968), the principal justification for introducing collapsing as a separate type and restricting the meaning of surging was that untrained observers can easily distinguish collapsing from surging breakers. This enables a more precise classification of breaker types. This study employed GALVIN's (1968) criterion, which is described as follows.

In spilling breakers waves gradually peak until their crest becomes unstable and cascade down producing bubbles and foam. In plunging breakers the shoreward face of waves becomes vertical, curls over, and the overturned crest plunges into the water ahead. In collapsing breakers the crest of waves peaks up as if they plunge, but then the base of the deforming wave rushes up the beach as a thin layer of water, so that the crest collapses and disappears. In surging breakers the form of waves remains smooth with no marked crest, and they slide up the beach with only minor production of foam and bubbles.

RESULTS

The analysis of data obtained in this study indicated that (1) the present results and GALVIN's (1968) dots are in good agreement for the spilling-plunging boundary, and (2) a definite demarcation can be made between plunging and collapsing breakers, and between collapsing and surging breakers. Breaker-type boundaries are indicated by the solid curves in Figure 2; they can be expressed by:

$$H_o/L_o = 2.4\,(\tan \beta)^{1.8} \quad \text{for spilling-plunging boundary} \tag{1}$$

$$H_o/L_o = 0.19\,(\tan \beta)^{2.5} \quad \text{for plunging-collapsing boundary} \tag{2}$$

$$H_o/L_o = 0.074\,(\tan \beta)^{2.4} \quad \text{for collapsing-surging boundary} \tag{3}$$

Two dashed lines are also plotted in this figure. One is the straight line that shows MICHELL's (1893) limiting wave steepness for breaking, $H_o/L_o = 0.142$; and the other is the curve that indicates MICHE's (1951) theoretical relation for the boundary between partial and total reflection of waves, $H_o/L_o = \sqrt{2\beta/\pi} \cdot \sin^2\beta/\pi$. This relation is found to be well concordant with the boundary between plunging and collapsing breakers, Eq. (2), when the bottom shope is small (*i.e.*, $\tan \beta \leq 0.6$).

Figure 3 shows that the breaker-type boundaries elucidated by this study can be adequately expressed in terms of the surf similarity parameter, ξ_o, ie.,

$$\begin{aligned} \xi_o &= 0.5 && \text{for spilling-plunging bondary} \\ \xi_o &= 2.5 && \text{for plunging-collapsing boundary} \\ \xi_o &= 3.7 && \text{for collapsing-surging boundary} \end{aligned} \tag{4}$$

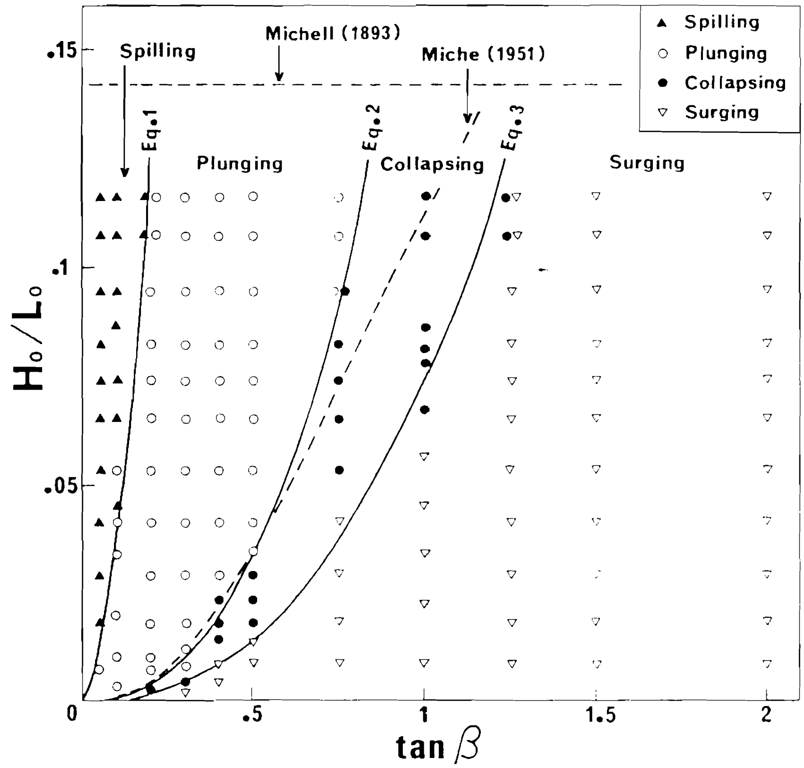

Figure 2. Demarcation for breaker types

The ξ_0-value for spilling-plunging boundary in this study is the same as that of BATTJES' (1974).

CONCLUDING REMARKS

The spilling-plunging boundary obtained here was accordant with Galvin's. The demarcation for collapsing and surging breakers was clearly defined. A new classification for breaker types (Figure 2), each breaker-type boundary being given respectively by Eqs. (1), (2) and (3), was proposed with an applicability to uniformly sloping bottoms with any gradient. This classification can be expressed in terms of the surf similarity parameter (Eq. (4)). Miche's breaking criterion was found to be concordant with the boundary between plunging and collapsing breakers, Eq. (2), when tan β is less than 0.6.

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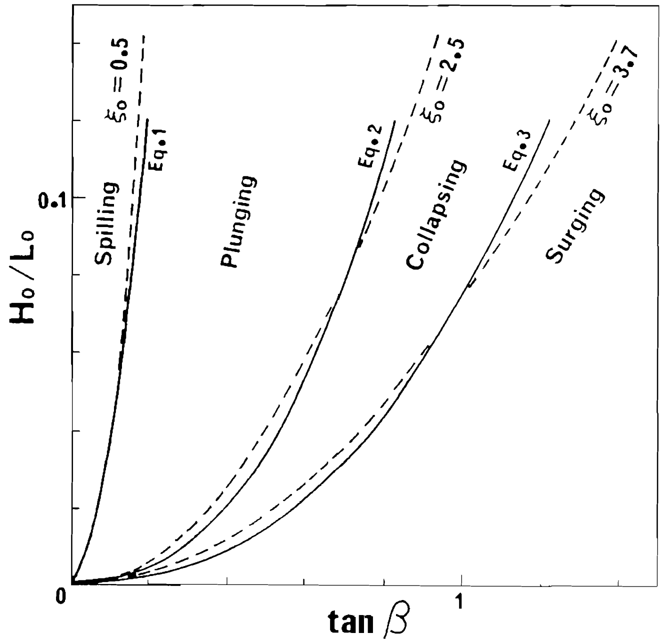

Figure 3. Comparison of Eqs. (1) through (3) and ξ_0-values.

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□ RÉSUMÉ □

Les résultats de 150 expériences effectuées en cuve à houle dont le fond varie d'une pente de 1/20 à 1/0,5 indiquent que la différenciation des types de brisant peut être décrite par l'équation Ho/Lo = $N (\tan \beta)^n$ ò Ho/Lo est la cambrure de la houle en profondeur infinie, β la pente, N et n des coefficients. N = 2,4 et n = 1,8 pour la limite entre déferlement déversant et déferlement plongeant; N = 0,19 et n = 2,5 pour la limite entre déferlement plongeant et brisant etN = 0,0074 et n = 2,4 pour celle entre déferlement croulant et régénération. Le paramètre de similarité du déferlement est donné par ξ_0 respectivement égal à 0,5, 2,5 et 3,7.—*Catherine Bousquet-Bressolier, Géomorphologie EPHE, Montrouge, France.*

□ ZUSAMMENFASSUNG □

Die Ergebnisse von 150 Durchläufen eines Experiments im Wellenkanal, bei dem mit Beckenböden unterschiedlicher Neigung (1/20–1/0,5) gearbeitet wurde, zeigten, daß die Grenzen für verschiedene Typen von Brechern durch die Gleichung $H_0/L_0 = N(\tan \beta)^n$ beschrieben werden kann. Dabei sind H_0/L_0 die Steilheit der Tiefwasserwelle, β der Neigungswinkel des Beckenbodens, N und n Koeffizienten. Ermittelt wurden: N = 2,4 und n = 1,8 als Grenzwerte zwischen Schwall- und Sturzbrechern, N = 0,19 und n = 2,5 als Grenzwerte zwischen Sturz- und Kollapsbrechern und schließlich N = 0,074 und n = 2,4 als Grenzwerte zwischen Kollaps- und Reflexionsbrechern. Der Brandungsparameter ξ_0 repräsentiert diese drei Grenzen ebenfalls, und zwar bei ξ_0 = 0,5, 2,5 bzw. 3,7.—*Helmut Brückner, Geographisches Institut, Universtät Düsseldorf, F.R.G.*

□ RESUMEN □

Los resultados de 150 pruebas en un experimento en canal de oleaje, utilizando fondos con pendientes variables desde 1/20 a 1/0.5, indicaron que la delimitación de los tipos de rotura puede ser descrita por la ecuación, $H_0/L_0 = N(\tan\beta)^n$, donde H_0/L_0 es el peralte en profundidades indefinidas, β es el ángulo del fondo con la horizontal y N y n son coeficientes: los valores de N y n que se obtuvieron para las transiciones entre los tipos de rotura son los siguientes: decrestamiento-voluta: $N = 2.4$, $n = 1.8$; voluta-colapso: $N = 0.19$, $n = 2.5$ y colapso oscilación: $N = 0.074$, $n = 2.4$. Se encontró que el parámetro de Iribarren, ξ_0 representa estas tres transiciones, dadas por $\xi_0 = 0.5$, 2.5 y 3.7, respectivamente.—*Department of Water Sciences, University of Cantabria, Santander, Spain.*