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A study on depositional shoreline forms behind an island

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Introduction

An island creates a shadow zone to waves incident on the shoreline behind it. The combined processes of wave diffraction and refraction occurring in the lee of the island give rise to convergence of longshore currents and resulting longshore sediment transport from both ends of the shadow area. The processes lead to the formation of a salient (Dally and Pope, 1986), a protruding shoreline form behind the island. A salient that connects an island with the mainland is called a tombolo. Engineering-oriented studies on salients and tombolos, associated with detached breakwaters, have been conducted (Dally and Pope, 1986, and literature cited therein). The present study aims to (1) elucidate the formative condition for these shoreline forms through a laboratory experiment, and (2) examine their geometrical relationships using laboratory and field data.

Formative conditions

A wave tank 5 m long, 0.4 m deep, and 1 m wide was used for the experiment. A model beach with an initial bottom alope of 1/10 was set up at one end of the tank and a piston-type wave generator was installed at the other end. The direction of incident waves was perpendicular to the initial shoreline of the beach. Two kinds of well-sorted sand with a different diameter of 0.2 and 0.69 mm were selected for the beach material. A model island, made of an impermeable elliptic cylinder, was placed at some offshore distance (5 to 30 cm) from the initial shoreline, with the major axis parallel to the shoreline. Four kinds of model islands were prepared with different lengths of major axis (5, 10, 15, and 20 cm), but with the same island height which was sufficient to prevent wave overtopping. Breaking wave height ranged from 2.5 to 5 cm and wave period from 0.5 to 1.0 sec. By changing combinations of the sand grain size, island location and size, and wave properties, eighty one experiment runs were performed. The total duration of wave action was two hours for each run. The shoreline configuration was measured after 15, 30, 60, 90, and 120 min wave action. No tidal effect was included in the experiment.

Only data of the experiment runs in which the

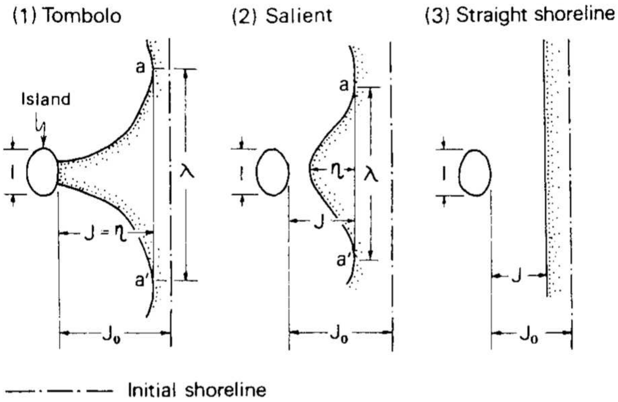

Fig. 1. Definition sketch.

shoreline forms attained equilibrium were employed for the present study. Three distinct beach planforms appeared (Fig. 1): a tombolo, salient, or straight shoreline with no island influence. In Fig. 1, I is the alongshore length of an island; J_o is the offshore distance from the initial shoreline to the island; λ is the width at the root of a tombolo or salient, which is called the "basal width"; η is the projecting length; J is the offshore distance from the equilibrium shoreline to the island; and η and J are measured perpendicular to the

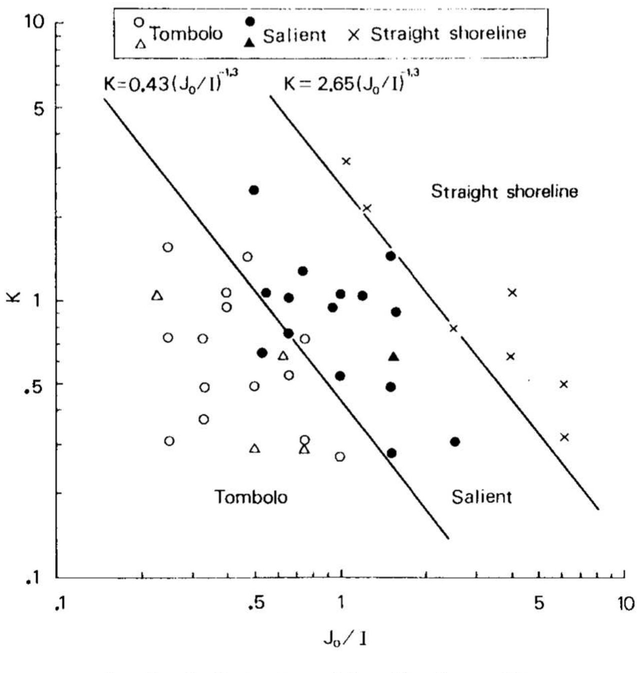

Fig. 2. Delimitation of shoreline forms (1).

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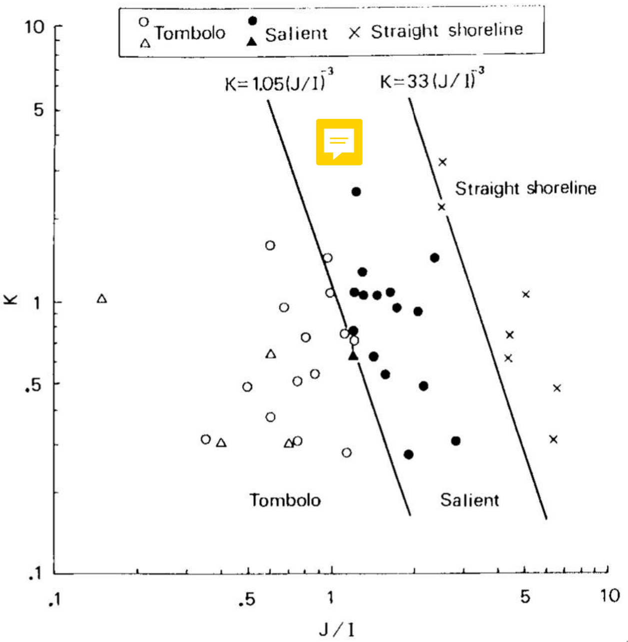

Fig. 3. Delimitation of shoreline forms (2).

a-a' line.

Combinations of dimensionless parameter, K, and J_o/I, or K and J/I were used to examine the formative conditions for three shoreline forms; $K=H_b^2/gT^2D$, where H_b is the breaker height, T is the wave period, D is the grain size of beach material, and g is the acceleration due to gravity. As the value of K increases, the direction of the sediment transport in the surf zone changes from onshore to offshore (Sunamura, 1984, 1986). In this study, the value of K was calculated using H_b-value measured at the initial stage of the experiment. Figure 2 shows the relationship between K and J_o/I; the open and solid symbols denote tombolo and salient formation, respectively, and the circle and triangle symbols indicate the shoreline advance ($J_o \geq J$) and recession ($J_o < J$), respectively. Clear demarcation of the three shoreline forms is seen in Fig. 2. Figure 3 shows the K–J/I relationship. Similar to Fig. 2, three formative regions can be demarcated by the two lines; these lines are steeper than those in Fig. 2. The delimiting lines in Figs. 2 and 3 would probably be changed if data of other experiments with different slopes of the initial beach are used.

Geometrical relationships

The degree of protrusion of tombolos or salients, η/λ, is plotted against J/I using the laboratory data (Fig. 4). Numerals beside the symbols denote the

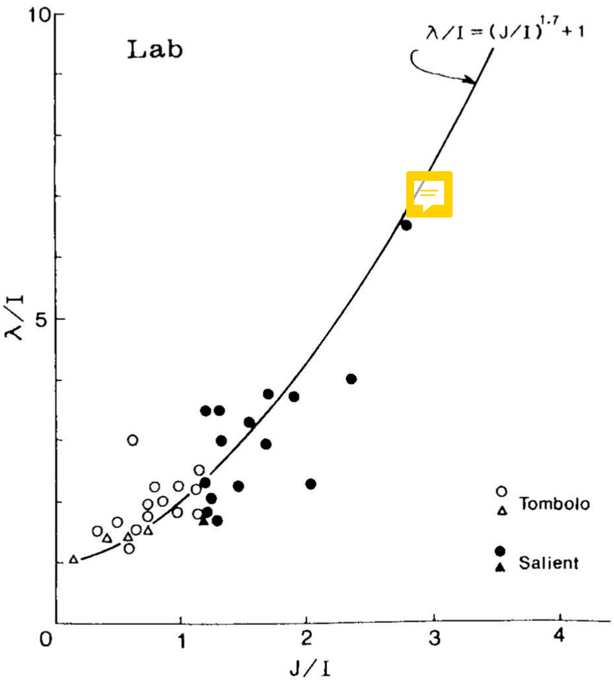

Fig. 5. Laboratory relationship between λ/I and J/I.

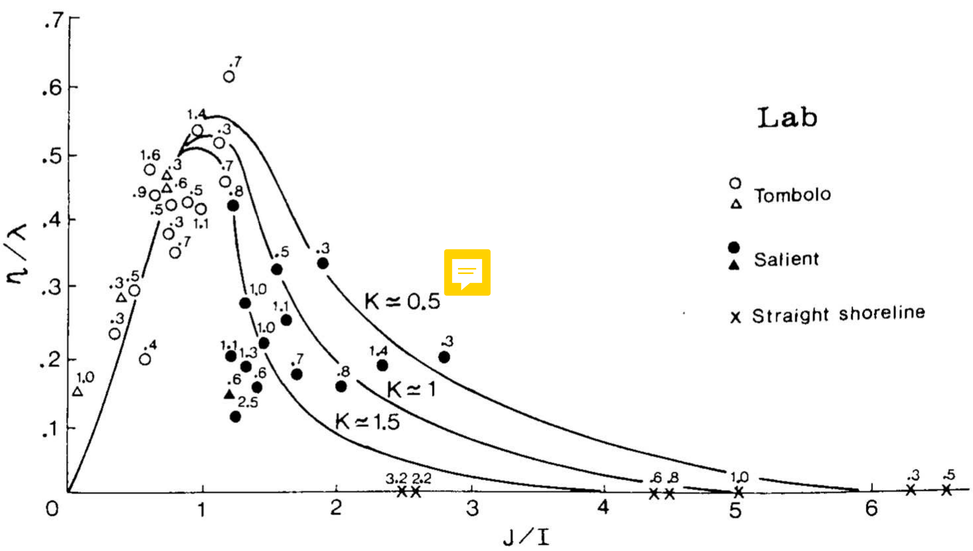

Fig. 4. Laboratory relationship between η/λ and J/I. (Parameter denotes K-value).

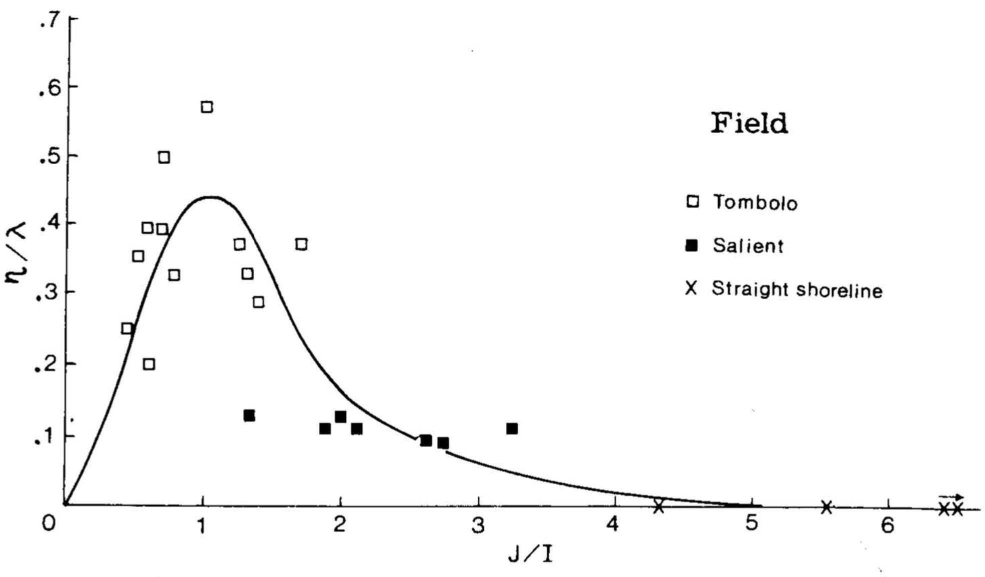

Fig. 6. Field relationship between η/λ and J/I.

values of K. Irrespective of K-values, η/λ monotonously increases as J/I increases for $0<J/I\lesssim 1$. For $J/I\gtrsim 1$, however, η/λ decreases with increasing values of J/I. The decrease in η/λ-values tends to become more significant as K-values increase; such a general trend as illustrated by the curves with different K-values is noticed. Figure 5 shows the normalized basal width of tombolos and salients, λ/I, plotted against J/I; λ/I increases as J/I increases.

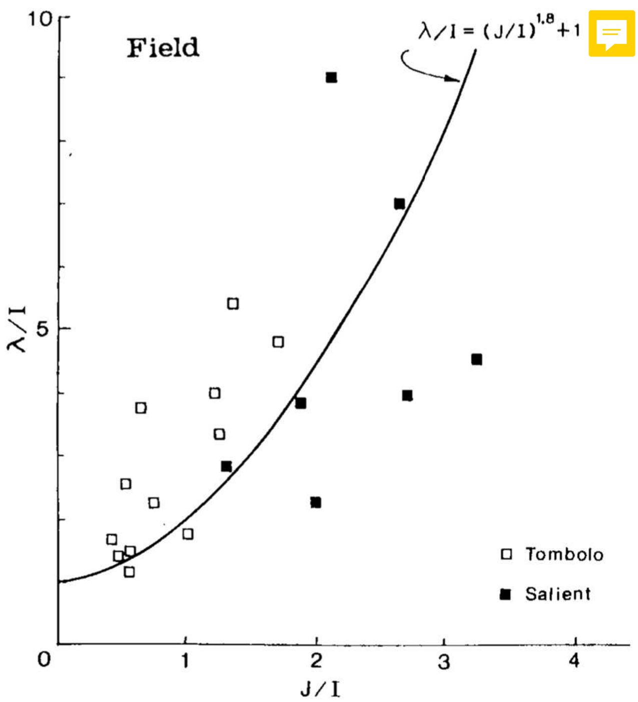

Fig. 7. Field relationship between λ/I and J/I.

Using field data, the η/λ vs. J/I and λ/I vs. J/I relationships are plotted in Figs. 6 and 7, respectively. The field data were collected from Japan (excluding Hokkaido district). Selected were open coasts on which a sandy beach develops behind an island. The quantities I, J, η, and λ, were measured on topographic maps (scale: 1/25,000) published by the Geographical Survey Institute of Japan. Although considerable data scatter is seen in Figs. 6 and 7, general trends similar to those found in laboratory relationships (Figs. 4 and 5) are suggested. Figure 6 shows that a tombolo forms if $J/I\lesssim 1.5$, a salient develops if $1.5\lesssim J/I\lesssim 3.5$, and no island influence appears if $J/I\gtrsim 3.5$. Detail discussion on this point should be made considering K-value for each coast. This is a problem left for the future.

References

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