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ANALYSIS OF AERIAL PHOTOGRAPHS AND FIELD DATA TO INVESTIGATE THE BEACH CUSP FORMATION

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1. INTRODUCTION

Beach cusps are attractive morphology along sandy coast. They are almost regularly spaced and rhythmic cuspidate features in the swash zone, as shown in **Fig 1**. Scientists in

Fig 1. Beach Cusp, regularly spaced and rhythmic features (Mexico Beach)

the early 1900 found and observed any cuspate pattern on the beach. Since their investigation, many hypotheses and models have been presented.

There are four hypotheses about beach cusps. Edge wave Theory (Guza and Inman, 1975), Self-Organization Theory (Werner and Fink, 1993; Masselink, 1998; Coco et al, 2000), Swash Action Theory (Sunamura, 2000), and Fluid Dynamic Instability Theory (Falques, 1998; Tanikawa and Izumi, 2004). However, the physical mechanism and processes of cusp formation are still largely unresolved. The objectives of this study are: (1) to conduct a study what physical processes which represent the beach cusps formation, and (2) to perform an analysis of those parameters.

2. AERIAL PHOTOGRAPH ANALYSIS

Approximately about 14 years (1992-2005) aerial photographs data over the Sendai coast were analyzed.

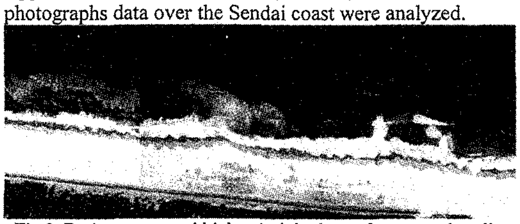

Fig 2. Broken wave and high splash in the surf zone, at shoreline beach cusps appear. (Sendai Coast, January 2002).

Those photos were taken once per 2 months and clearly show whether beach cusps appear or not. Beach cusps could be recognized by their length and time scales. They are not formed in the submerged zones. The cusp spacing is between 10 cm and 50 m. Beach cusps develop in such a short period, they growth times of several hours (Horikawa, 1988). Another information from aerial photograph is the type of the wave breaking when beach cusps appear. Most of wave breaking show a broken wave and a high splash in the surf zone (**Fig 2**). This could be related to the steeper beach condition (Galvin, 1968; Battjes, 1974).

3. FIELD DATA ANALYSIS

A striking characteristic of the nearshore environment is the interaction between fluid and sandy bottom. When water flowing over a sandy bottom, sediment is easily mobilized, resulting in a morphological change. This morphodynamic process is affected by other physical parameters.

3.1. Nearshore Hydrodynamic Condition

Beach cusp evolution is strongly linked to the offshore wave conditions. Nearshore hydrodynamic data were determined for each of the beach cusps events. The angle measured from the line normal to the shoreline. About 82% of the beach cusps events, frequency of perpendicular incoming wave is above 96%. This result corresponds quite well to that obtained by Holland (1998), who said the incident angle is likely an important factor because the potential for the generation of strong alongshore currents is minimized, thereby allowing beach cusps to develop under dominantly cross shore flow.

We need to consider another wave parameter such as wavelength, wave period and wave height. By our study, when beach cusps appear, wavelength is much longer. It is found around 50 - 220 m (**Fig 3**), while condition with no beach cusps take around 50 - 150 m. This indicates that beach cusp will be easily formed when the wave is longer. We also found that wave height at beach cusps appear is higher.

Higher wave will produce stronger wave energy and longer run up at swash zone area. Wave energy when beach cusps formed range around 900-3600 N/m while in another data without cusps formation range between 200-1600 N/m.

Mase et al (1989) present predictive equation for irregular runup on plane, impermeable beaches based on laboratory data $R\max = 2.32 H_0 \xi_0^{0.77}$, where H_o and ξ_0 are the deepwater wave height and surf similarity parameter. From this equation, we simply know maximum run up in beach cusps events ranging 1.64 - 3.45 m. The combination of dominant perpendicular incoming wave with higher wave energy produce greater cross shore actions at the shoreline. These actions may develop some accretion and deposition, and develop rhythmic formation.

The surf similarity parameter, $\xi = \tan\beta (H_0 / L_0)^{-0.5}$ (Battjes, 1974), where L_0 is the deepwater wavelength, was

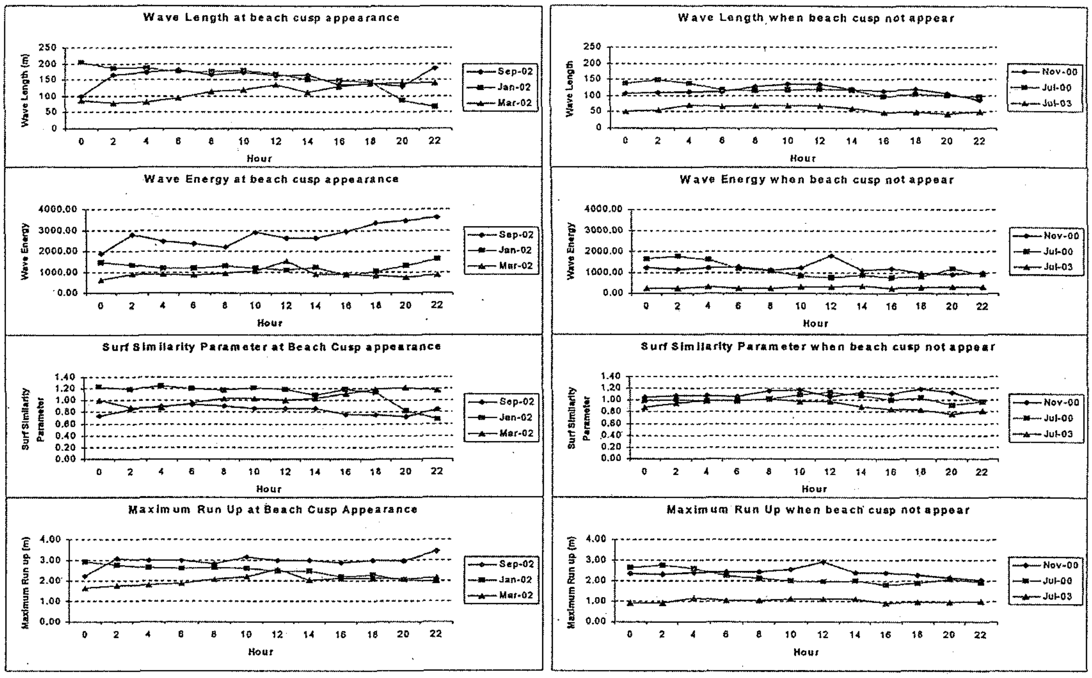

Fig. 3. Wavelength, wave energy, surf similarity parameter, and maximum run up at both events.

used to characterize the surf zone morphodynamic conditions on the steep beach. Surf similarity parameter during cusps formation ranging 0.68 – 1.24. These values indicate a steeper beach and plunging breaking wave type.

3.2. Nearshore Physical Condition

The Sendai Coast is a typical beach which has a relatively steep (1:10) foreshore. Based on field observation at Sendai Coast, we found that beach cusps are not formed in all location along the coast. They are only formed in locations where beach slope is steep enough to produce plunging breaking wave. The plunging breaker is formed when wave energy is released suddenly as the crest curls and then descends abruptly. As it breaks, the crest of the plunging wave acts as a free-falling jet that may scour troughs. Plunging breakers produces the most intense local fluid motions. We could determine plunging breaker as a broken wave and high splash in the surf zone.

4. RESULT AND DISCUSSION

The results of this study support previous study, which said that wave action is the main parameter in the beach cusp development. We can conclude that beach cusp appearance (Ω) is influenced by the wave height (H), maximum run up height (R_{max}), wave energy (E), beach slope ($\tan\beta$), and incoming wave angle (θ).

$$\Omega = f(H, R\max, E, \tan\beta, \theta) \qquad (1)$$

This result agrees with the result proposed by Galvin (1968). We also found that, condition with much higher energy has a greater possibility to form beach cusps.

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