CHAPTER 169

A FIELD EXPERIMENT ON THE FORMATION OF BEACH CUSPS

Michio Sato* Keiji Kuroki† Tomoaki Shinohara‡

Abstract

This paper describes an attempt at investigating the actual time scale needed to form beach cusps, and the issue whether beach cusps are accretionary features or erosional ones. Data was collected through a field experiment. The experiment was conducted by tracking the process of beach cusp formation on a beach face, which had been flattened in advance by erasing previously formed beach cusps with a bulldozer. New beach cusps gradually developed with every high tide and attained a similar size to the previous ones after three tides.

INTRODUCTION

Beach cusps have been concerns of many researchers. Main interests seem to have been directed to the aspects on the basic origin and what control their rhythmic spacing.However,in spite of numerous contributions on the subject,contradictory observational results and views in many aspects of beach cusp formation have prevented us from grasping beach cusps in their totality.

It seemed to us that to accumulate measured field data on cusp formation,especially the one which relates the cusp origin to wave conditions, was indispensable. In conducting field measurement, care must be taken to the point whether the waves being measured are the ones which are actually building the cusps or not,as has been pointed out by Johnson(1919). In other words,we should know about the actual time scale needed to form beach cusps.

Smaller cusps are known to be built and eliminated in a relatively short time;in one tide cycle at most(e.g.Longuet-Higgins and Parkin(1962); Komar (1973)). However,the time seemed too short for the formation of beach cusps with spacings of 15 to 20m which the authors sometimes saw. Then,a field experiment was planned to investigate this point.

*Professor, Department of Ocean Civil Engineering, Kagoshima University, 1-21-40 Korimoto, Kagoshima-shi,890 JAPAN

†ECOH Co.,Ltd.,Minami-Senju 1-59-7,Arakawaku,Tokyo,116 JAPAN

‡Sankyu Co.,Ltd.,Mita 1-4-28,Minatoku,Tokyo,108 JAPAN

The purpose of this paper is to describe the attempt at investigating the actual time scale needed to form beach cusps, and the issue whether beach cusps are depositional features or erosional ones.

FIELD EXPERIMENT

LOCATION OF STUDY The experiment was carried out from 18 to 21 December,1980 at Motte Beach, Kagoshima Prefecture, Japan(Figure 1). The beach is a part of sandy beach which extends 8.2km north-north west from the foot of Mt.Kaimon-dake and is exposed to the action of waves from the East China Sea.

Figure 2 shows the cross sectional profile of the center of study area. The beach face had steep slope of over 1/10 and a terrace of of 20m wide followed.Beach material was well sorted sand with the median diameter of 0.7mm and the sorting coefficient,introduced by Trask,of 1.29 on average.

PRELIMINARY SURVEY The spacing of the beach cusps previously formed was measured over the 500m beach area and was 15.2m on average. The variation of the measured cusp spacing and cusp height along the beach are shown in figure 3. The cusp spacing ranged between 7m to 26m and the histogram is shown as well in the figure.

Though the spacing is widely distributed, the variation of it along the shore seems to have a definite tendency that the spacing increased with the alongshore distance from 100m to 400m,then,decreased abruptly due to the appearance of a small cusp in the middle of pairs of cusps and their growth to the size which determines the spacing. The similar variation seemed to repeat along the beach.

Therefore,our impression was that the broad distribution of cusp spacings in the histogram did not mean the lack of regularity in the spacing of cusps but it was due to the alongshore variation in the cusp spacing controled by a certain mechanism.Nishi and Sato(1991) pointed out that one unit of the spacing variation corresponded to the spacing of a giant cusp based on the photograghs taken from the top of Mt.Kaimon-dake for six years period.

The variation of the height seemed to increase slightly with the increase of cusp spacing.

The experimental site was the center of the measured area.

FIELD CONDITIONS DURING THE EXPERIMENT During the experiment, tides were semidiurnal with maximum range of 2.7m, and waves of about 0.5m in significant wave height with periods of 6.5-8.5sec acted on the beach continualy (Figure 4). The maximum breaking wave height was about 1m.The change of wave height during the experiment was small though the period changed in the range from 6.5sec to 8.5sec. Wave incidence was almost

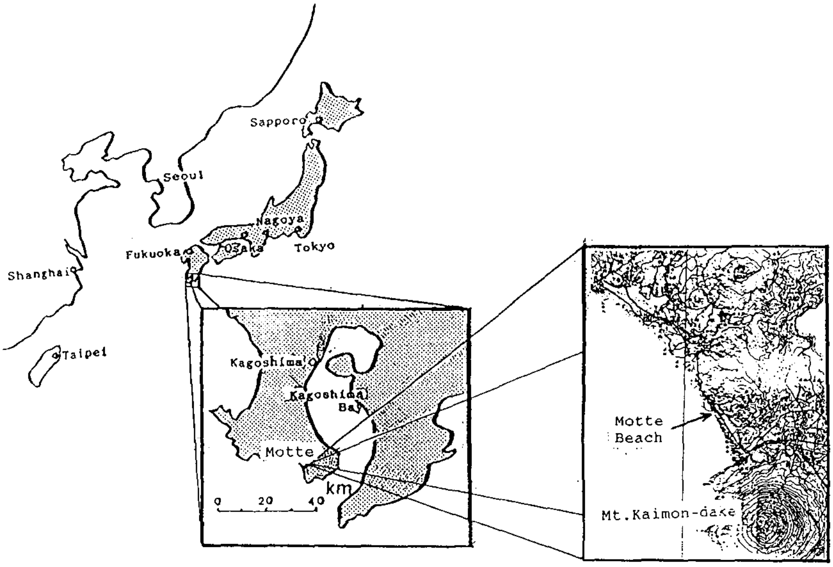

Figure 1: Location of study area

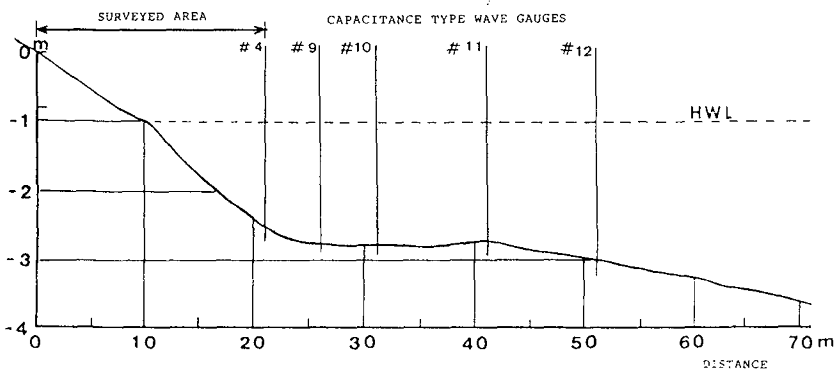

Figure 2: Cross section of the beach

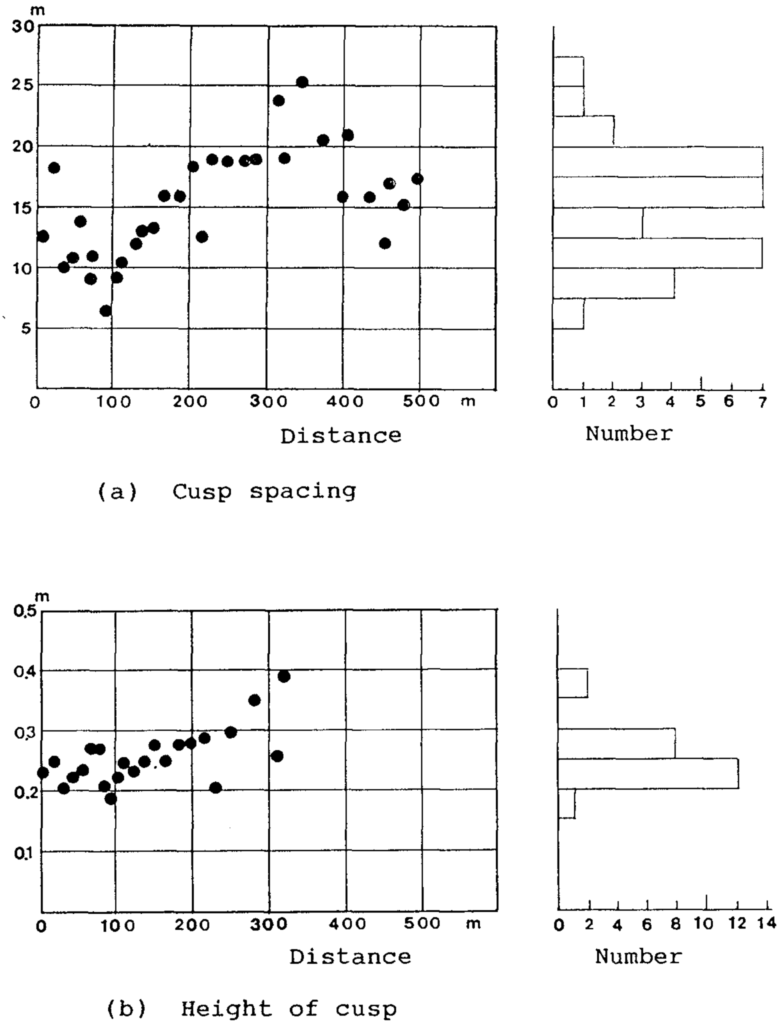

Figure 3: Alongshore variation of cusp spacing and height

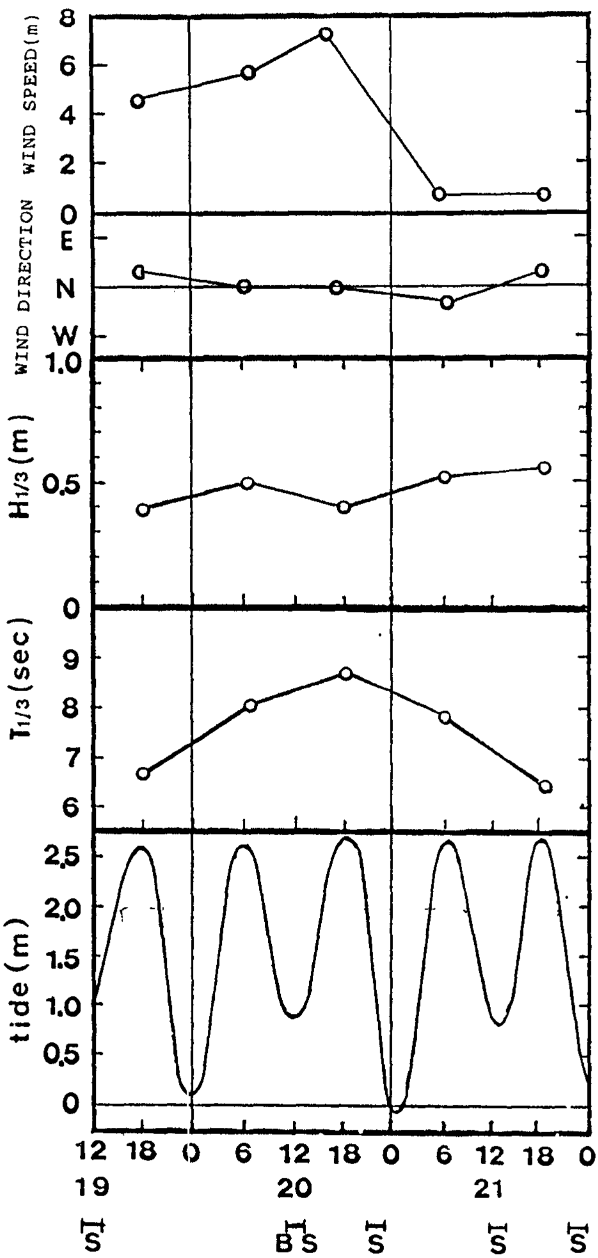

Figure 4: Field conditions durıng the experiment

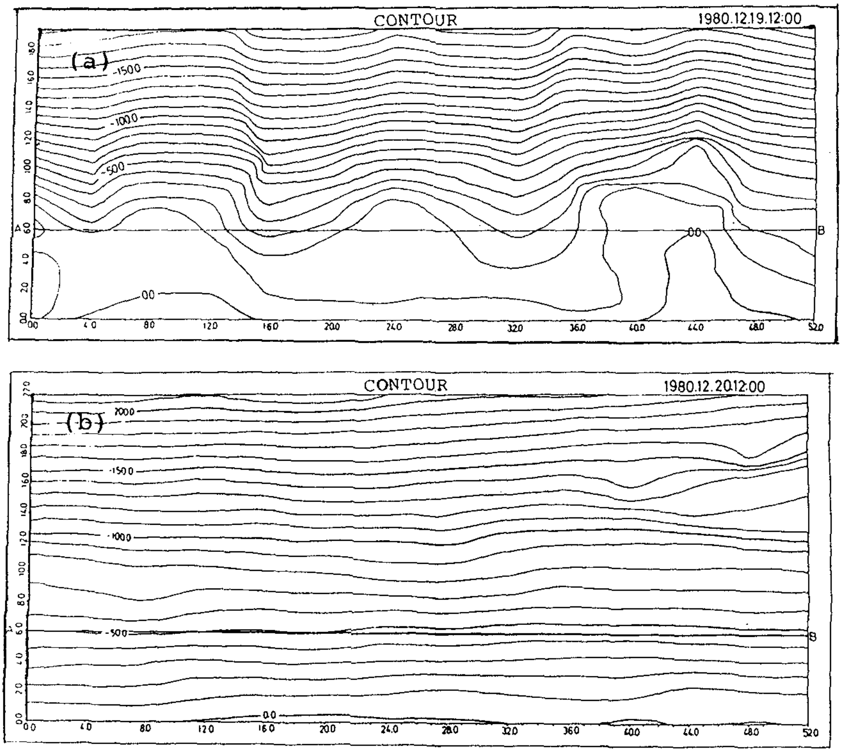

Figure 5: Contour maps of original cusp and topography just after the bulldozing

normal to the beach.North wind of 4 to 7m/sec blew on December 19 and 20,but it almost ceased on the following day.

ORIGINAL CUSP Prior to the experiment, the area of both the beach cusp field and the foreshore zone,in a 60m alongshore section,was surveyed at the grid points. The alongshore increment was 4m and the on-offshore one was 1.5m. Elevation of each grid point was acurately measured using a precision level. Figure 5-(a) shows the survey of original beach cusps. Contours were drawn every 0.1m. Cross sectional profile along a line AB parallel to the shoreline is shown in figure 10. We can recognize 3 cusps in this area.

EXPERIMENTAL METHOD On the following day,the alongshore area of over 100m including the surveyed part was flattened by a bulldozer during low tide(Figure 6). Figure 5-(b) is the contour map just after being flattened. Three cusps in figure 5-(a) were completely erased.

After that 168 iron rods, 2m in length, were driven into the beach face at intervals of 4m parallel to the shoreline, and at 2m intervals perpendiular to the shoreline. This made a grid system of $52m \times 22m$ shown in figure 7.

Repeated levelings of the beach face were carried out every low tide by measuring the amount of the rod exposed. And,in the day time,the subsidence of the iron rods was checked with a level.

Waves were measured with 12 capacitance type wave gauges during every high tide.Eight of the wave gauges were arranged parallel to the shoreline,and the rest were arranged perpendicular to it. The arrangements are shown in figure 7 and figure 2.

In order to track sediment movement, tracer technique was applied by using dyed sand with fluorescent color as the tracer. Two 30 liter buckets of dried sand were dyed red and green,respectively. At 5:30pm December 20,1980,they were placed on the beachface; red sand at grid point(4,4) and green sand at(9,9) in figure 7. Sampling of about 300 gram of beach materials was done at the grid points at 1:00pm and 10:30pm December 21,1980. All samples were dried and examined for fluorescent coated particles using ultra-violet lamp. The centroids of the distribution maps of dyed sands were tracked by

$$x = \frac{\sum_{i=1}^{n} m_i x_i \Delta x \Delta y}{\sum_{i=1}^{n} m_i \Delta x \Delta y}, \quad y = \frac{\sum_{i=1}^{n} m_i y_i \Delta x \Delta y}{\sum_{i=1}^{n} m_i \Delta x \Delta y}$$

where (x, y) is the position of the centroid, Δx and Δy denote the grid intervals,(x_i, y_i) is the distance between the origin(i.e.the place where the tracer was deposited initially) and i-th grid point,and m_i is the number of fluorescent coated sand particles found per $1{,}000cm^2$.

RESULTS

The development of beach cusps after bulldozing can be seen in a series of contour maps(Figures 8). Contours were drawn every 0.1m as well as in figure 5. Figures 9-(a,b,c) show the difference in height between the beach profile just after bulldozing and those after each high tide. Shading in the figures mean eroded part.

In Figure 8-(a),the contour map drawn based on the survey after one high tide from the bulludozing,we can not recognize any cusps. After two high tides,three cusps with a similar spacing to the original ones appeared on almost the same position(figure 8-(b)). And after three high tides they finally attained a similar size to the original cusp formation(figure 8-(c)).

Figures 10-(a,b) are the cross sectional profile along a line A-B parallel to the shoreline of the flattened beach face just after bulldozing and in the course of the development,respectively.

Figure 6: Bulldozing

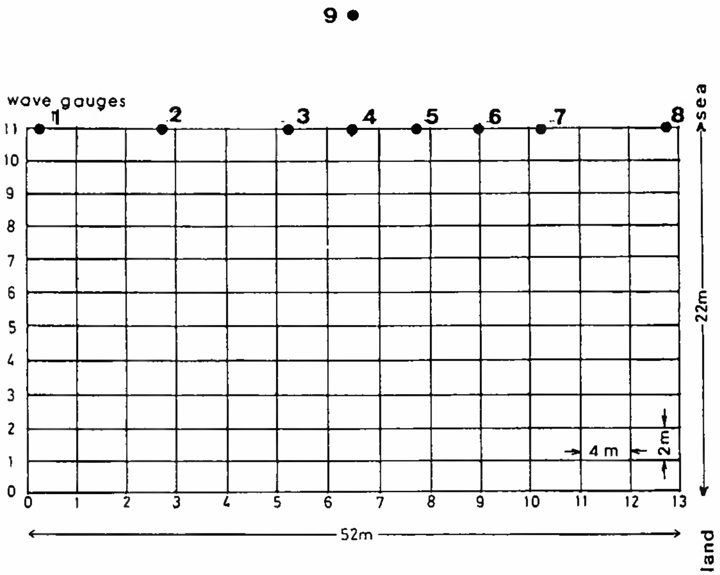

Figure 7: Grid system and arrangement of wave gauges

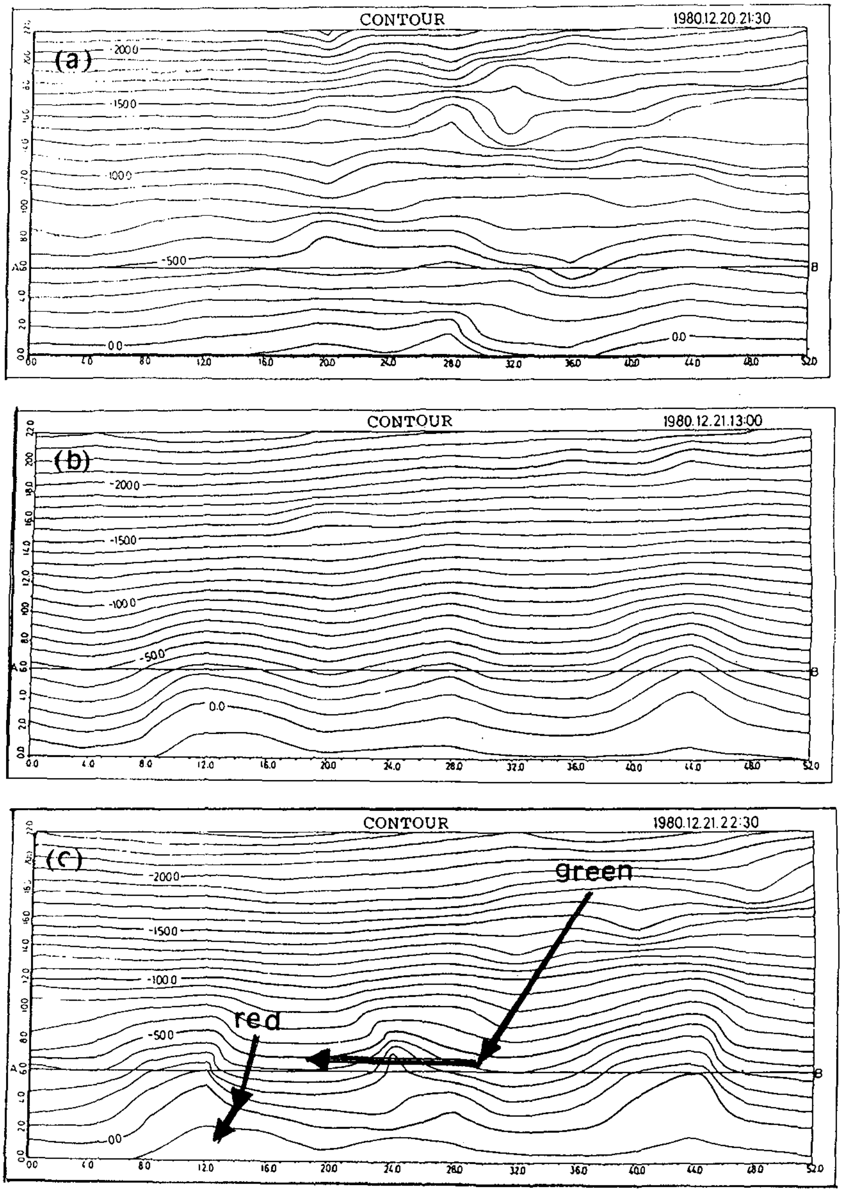

Figure 8: Development of cusps(contour maps)

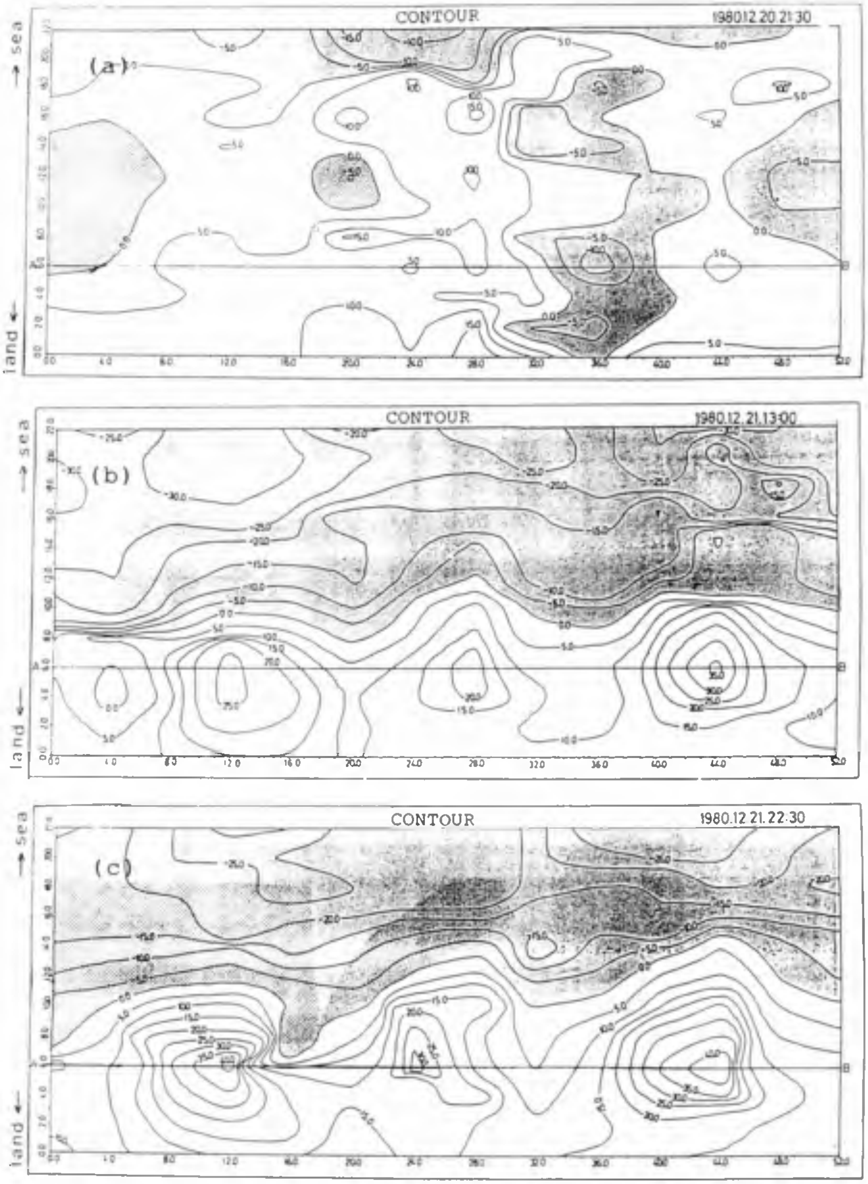

Figure 9: Development of cusps(topographical changes from the flattend contour map)

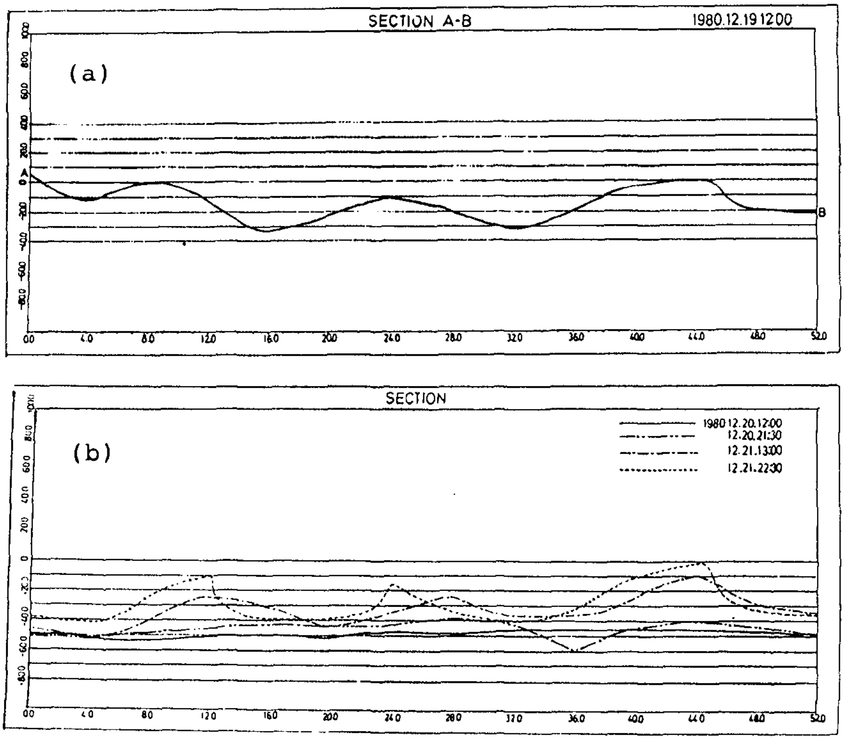

Figure 10: Cross sectional change along the line parallel to the shoreline

It can be seen from these figures that new beach cusps gradually developed. This gradual development was in constrast to the observation of smaller cusp formation(e.g. Longuet-Higgins and Parkin(1962);Komar(1973)). Figures 9-(b) and (c) indicate that sand carried landward from the lower foreshore zone accumulated even in the bay position of the newly formed beach cusps. This is backed up by the trace of dyed sand shown by arrows in figure 8-(c).Thus,beach cusps are purely accretionary features with the horns experiencing more deposition than the bays.

Samples of beach materials were analysed with sieves. Median grain size and sorting coefficient of each sample were obtained. The median diameters ranged from 0.5mm to 1.1mm and the average was 0.7mm as shown in figure 11.In this figure,Δh is the difference in height between the profile just after being flattened and the one after three high tides. Negative Δh corresponds to the lower foreshore part,and larger positive Δh means cusp horns.This figure shows that the sediments of lower foreshore were coaser than cusp area,it also

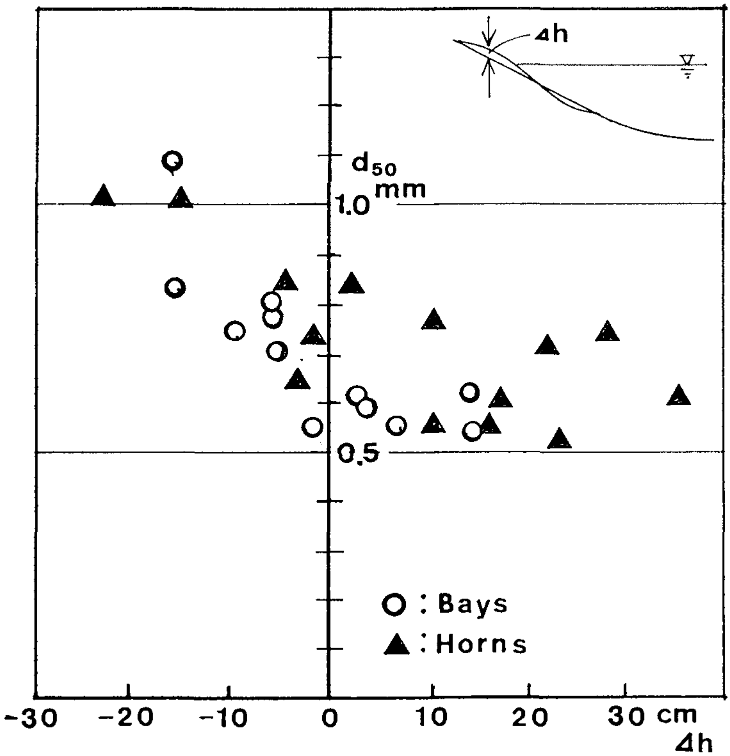

Figure 11: Sediment grain size

shows the median diameters of sediments of cusp horns were slightly larger than the ones of bays.

As to the sorting coefficients,they ranged from 1.14 to 1.8 and the average was 1.29. In lower foreshore area,the sorting coefficients showed larger values;but they were smaller and in cusp and bay field compared to the lower foreshore.

These results add support to the description by King(1972),Williams(1973) and Komar(1973).

Lastly, it may worth to note about the variation of the density of beach materials in cusp field. When we were pulling out the iron rods from the beach, we found that the rods in cusp area were easily pulled out,but those in bay area were hard to be pulled out and some of them needed two or three persons to be removed. No one realized the difference when we drove the rods into the beach. This seemed to mean that the sediments in bay area became dense and the ones in cusp area became loose as the cusps developed. The difference of the density of sediments between bay area and cusp area causes the difference of permeability. The difference of permeability has been pointed out by many authors. And the reason has been considered to be the difference in composition of beach materials(Longuet-Higgins and Parkin(1962)). However,even if there is not definite difference in composition of beach materials between cusps and bays,the difference of density,which is due to the difference of compaction,seems to be a reason of the difference in permearbility.

CONCLUSION

A field experiment was conducted by tracking the process of beach cusp formation on a beach face, which had been flattened in advance by erasing previously formed beach cusps with a bulldozer. New beach cusps gradually developed with every high tide and attained a similar size to the previous ones after three tides.

Sand carried landward from the lower foreshore zone accumulated even in the bay position of the newly formed beach cusps. This is backed up by the trace of dyed sand.Thus,beach cusps are purely accretionary features with the horns experiencing more deposition than the bays.

The sediments of lower foreshore were coaser than cusp area,and the median diameters of sediments of cusp horns were slightly larger than the ones of bays.

The sorting coefficients ranged from 1.14 to 1.8 and the average was 1.29. In lower foreshore area,the sorting coefficients showed larger values;but they were smaller in cusp and bay field compared to the lower foreshore.

REFERENCE

Dean,R.G. and E.M.Maurmeyer,1981 *Beach cusps at Point Reyes and Drakes Bay Beaches,California*,Proc.17th ICCE,pp.863-884

Flemming,N.C.,1964 *Tank experiment on the sorting of beach materials during cusp formation*,J.Sed.Petrology,Vol.34,pp.112-122

King C.A.M.,1972 *Beaches and Coasts(2nd ed.*, Edward Arnold(Publishers) Ltd.,London,570p

Komar P.D.,1973 *Observations of Beach Cusps at Mono Lake,California*,Geol. Soc. Amer. Bull., Vol.84,pp.3593-3600

Longuet-Higgins M.S. and D.W.Parkin,1962 *Sea waves and beach cusps*, Geogr. Jour., Vol.128, No.2,pp.194-201

Nishi,R. and M.Sato,1991 *Photographic observation on cusps and wave fields*, Proc.Coastal Eng.,JSCE,Vol.38,pp.296-300

Otvos,E.G.,1964 *Observations of beach cusps and pebble ridge formation on the Long Island Sound*,J.Sed.Petrology,Vol.34,pp.554-560

Schwaltz,M.L.,1972 *Theoretical approach to the origin of beach cusps*, Geol. Soc. of America Bull.,Vol.83,pp.1115-1116

Seymour,R.J. and Aubrey,D.G.,1985 *Rhythmic beach cusp formation:a conceptual synthesis*,Mar.Geol.,Vol.65,pp.289-304

Sunamura,T.,1989 *Sandy beach geomorphology elucidated by laboratory modelling*,Chapter 6 of *"Applications in coastal modeling"*, V.C.Lakhan and A.S.Trenheile (editors), Elsevier, Amsterdam,387p.

Williams A.T.,1973 *The problem of beach cusp development*,J.Sed.Petrology Vol.43,pp.857-866