CHAPTER 166

FIELD OBSERVATION ON SAND RIPPLES UNDER ROUGH SEA STATE

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Abstract

The process of sediment sorting under rough sea state was made clear in the cross-shore direction. Field observation reveals that ripples can be formed under high shear stress in which the Shields number is more than two. The plane bed condition is observed at narrow area of wave breaking. Strong undertow distorts the shape of ripples. The criterion of bed configuration given by Kaneko (1981) is good agreement with the field data which were rearranged with significant wave characteristics. The criterion of Komar and Miller (1975) is also applicable with mean wave ones.

Introduction

In order to develop 3D model of beach processes, it is necessary to get accurate information about sea bottom topography changes, i.e., sediment structure and small scale undulations. The former is the effect of sediment mixture on transport phenomena. In the nearshore environment, sediment sorting is much developed in comparison with that in rivers, but the assumption of uniform sediment in the longshore and cross-shore directions is too rough to predict accurate beach changes. Bottom roughness mainly depends on the formation of wave-formed ripples.

In the field, some observations were conducted at offshore or continental shelf (Forbes et al. 1987, Boyd et al. 1988) and at shallow water environment under moderate wave conditions (Dingler et al. 1976). So far, the measurements were done with the Shields number of less than one. In our observation, simultaneous measurements were also made about waves, currents and sedimentary structures along the T-shaped Observation Pier (TOP) in the surf zone.

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Observations

The field experiments were conducted in December 5 and 6, 1989. The bottom topography was measured with the comb in which 60 fine stings (each sting is 23cm long and 3cm spacing each other) with grease spread on the sting surface can stick the fine sediment in the bed and trace out of the unevenness of sea bottom of 1.8m long in the cross-shore direction. The compass and VTR were also equipped on the instrument to record the overall bottom surface conditions and confirm their accurate direction. The grease can catch the fine sediment after sticking into the bed. The total weight of the equipment is about 100kg.

At the same position, bottom sediment sampling was done with the Smith-Mackintire sampler with which surface layer sediment in around 10cm deep was picked up. The standard sieve analysis was applied to the sampled sediment. Sediment-size distributions and their moments were calculated.

Fig. 1 shows the measuring points and cross-shore changes of mean sediment diameter before and after storms. The maximum significant wave height was 3.34m and its period was 8.64s and the Shields number estimated by small amplitude wave theory was 4.64. The beach profile in the figure was measured in December 5. The formation of shoal was remarkable and in accompany with acceleration of beach erosion due to construction of west breakwater at Naoetsu harbor the beach changed to a wave energy reflected beach. Table 1 shows characteristics of waves, sediment and bottom topography.

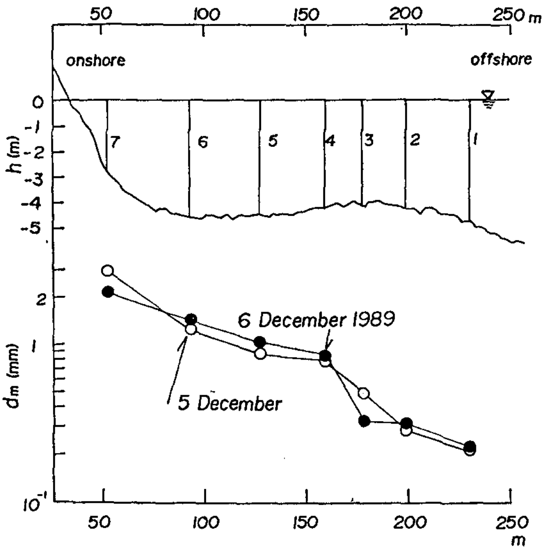


Fig. 1 Measuring points, beach profile and changes of mean sediment diameter in the cross-shore direction

Table 1 Characteristics of waves, sediment and ripples

St.	$H_{1/3}$ (m)	$T_{1/3}$ (s)	H_m (m)	T_m (s)	median diameter $Md\phi$	mean diameter $M\phi$	standard deviation $\sigma\phi$	λ (cm)	η (cm)
1	3.34	8.6	2.02	6.0	2.32	2.27	0.530	P*	—
2	3.11	7.2	1.88	5.1	1.80	1.87	0.535	P	—
3	3.02	7.2	1.84	5.2	0.90	1.08	0.545	P	—
4	3.02	7.2	1.84	5.2	0.13	0.25	0.460	R	—
5	2.72	5.9	1.66	4.1	−0.02	0.21	0.660	R	—
6	3.04	8.8	1.78	6.2	−0.42	−0.16	0.795	R	—
1	2.50	6.2	1.58	4.8	2.26	2.17	0.565	P	—
2	2.50	6.2	1.58	4.8	1.64	1.62	0.665	47.0	4.5
3	2.58	5.6	1.61	4.4	1.59	1.56	0.605	R	—
4	2.16	5.5	1.36	4.4	0.20	0.31	0.435	121.0	8.1
5	2.16	5.5	1.36	4.4	−0.21	−0.085	0.445	91.5	14.4
6	1.99	4.5	1.27	2.9	−0.50	−0.47	0.455	R	—
7	1.98	4.4	1.12	3.0	−0.68	−0.66	0.430	R	—

* R : ripple bed, P : plane bed

Characteristics of sediment

Fig. 2(a) and (b) show the sediment-size distributions with ϕ-scale on a normal probability paper. As already shown in Fig. 1, it was detected that the mean sediment diameter became smaller in the offshore direction and at the end of the TOP the diameter was one tenth of those at the shoreline. Before and after storms, the mean sediment diameter at St. 3 became small and at on and offshore points in the cross-shore direction the sediment changed to rough. This fact shows that relative fine portion of sediment was carried to St. 3 under storm waves. In comparison with Fig. 2(a) and (b), the sediment at St. 3 remarkably became fine after storm. Shirai (1990) has examined annual changes of sediment-size in the cross-shore direction from 1973 to 1979 on the Ogata coast. He pointed out that sediment sorting in a same mother group did not appeared in the field, but eight mother groups of sediment with different mean diameter mixed each other and the four finer sediment groups move in the offshore direction in every storm, even if in summer swell wave conditions. The changes of sediment characteristics in a short-term as shown in Fig. 2 can be regarded as fluctuation of the long-term changes which links to the beach erosion of the Ogata coast.

Characteristics of bottom topography and its classification

The estimation of bottom roughness depend on the formation of ripples which controls wave transformation and nearshore current system. The field data of bottom roughness were collected with the Shields number of more than four. In our data in Table 1, only three cases include the measurement of height and length of ripples, but in other cases sea bottom conditions were only checked with VTR. With the data, the characteristics of bottom topography could be discussed.

(1) Characteristics of bottom topography

Fig. 3(a), (b) and (c) show the bottom topography measured in December 6. The final points of wave breaking were around St. 7, so that it was impossible to measure the bottom topography with the equipment due to rough sediment and washing motion of breaking water. At St. 1, we observed twice. The dominant wave direction was NW, that is parallel to the cross-shore axis of the TOP. VTR recorded as following: St. 1; completely plane bed, Sts. 2 and 3; transition area from ripple bed to plane one. Sts.4 to 6; irregular (three dimensional) ripples. They were called as irregular ripples or cross ripples (Clifton, 1976). The steep slope crest of ripples were recorded at the vicinity of shoreline. This is due to rapid sorting of sediment by breaking waves, and relatively rough sediment at trough of ripples could not be detected by the measuring stings. After the storms the ripple shape could be clearly measured in December 6, so that the scale was listed in Table 1.

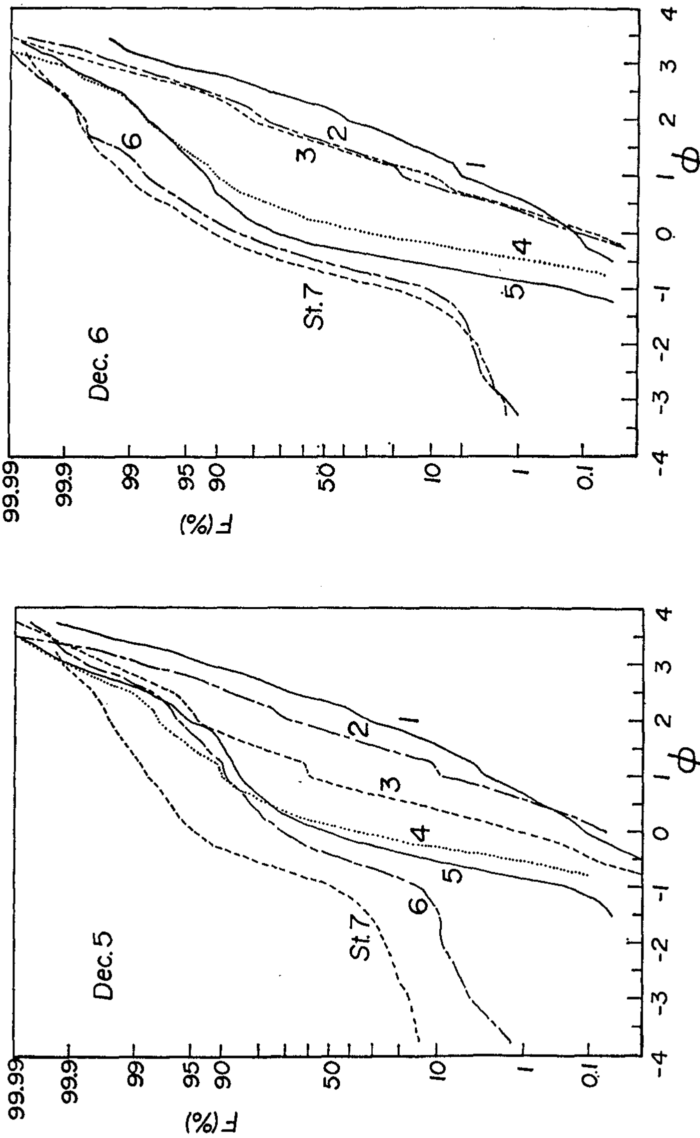
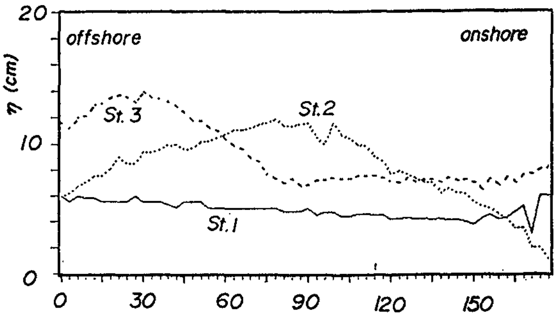
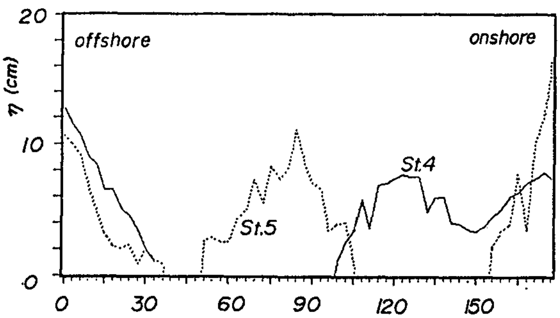


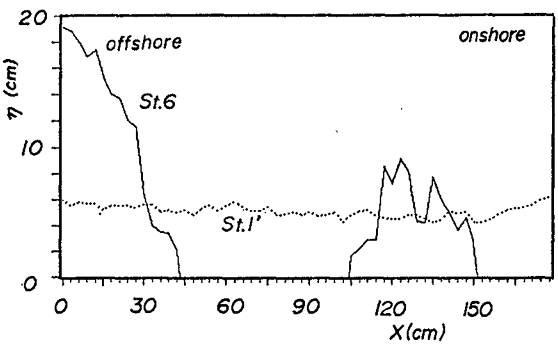
Fig. 2 Sediment-size distributions with ϕ-scale on a normal probability curve



(a) Sts. 1 and 3



(b) Sts. 4 and 5



(c) Sts. 1 and 6

Fig. 3 bottom topography measured

Fig. 4 shows the relationship between d_o/D and $\lambda/\sqrt{D}$, in which d_o; trajectory diameter of water particle motion on the bed, D; sediment diameter and λ; ripple length. This relationship was firstly proposed by Clifton (1976). The former ratio shows the effect of acceleration (Abou-Seida, 1964) and the latter ratio was proposed by Bagnold (1946). The data in the figure were collected in the field by Inman (1957) and Dingler et al.(1976).Three open circles shows our data which were calculated with significant wave characteristics. From this figure, it was found that two of them correspond to suborbital ripples whose length is in inverse proportion to d_o and correlates to D. Another (the data measured at St. 2 in December 6) exhibits longer length of ripples than usual data. Then, the steepness of ripples was shown in Fig. 5 in which u_m; amplitude of water particle velocity on the bed, σ and ρ ; densities of sediment and water respectively. The semi-empirical curve in the figure was proposed by Dingler et al.(1976). The data measured at St. 2 was plotted far from other data set.

The reason of this discrepancy can be recognized as following: At close to St. 2, we had measured flow velocity at the two points of 1.5m and 2.5m from the bottom with ultra-sonic type current meter. On the Ogata coast, easterly swell waves come after storms and strong undertow at the velocity of 0.5 to 1m/s is generated (Tsuchiya et al., 1989). The wave climate in December 6, 1989 was similar to that at the time when the observation of nearshore currents were carried out. Therefore, the undertow may contribute to the distortion and stretching of the ripple profile.

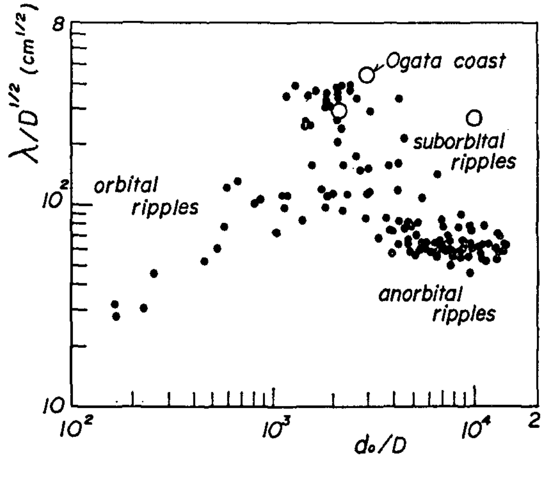


Fig. 4 Relationship between acceleration of wave motion and ripple length (Clifton, 1976)

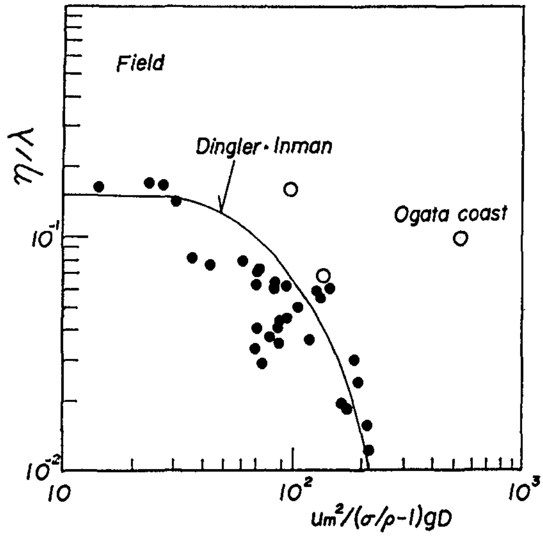


Fig. 5 Relationship between steepness of ripples and dimensionless water particle velocity

(2) Classification of ripple formation

Fig. 6 shows the classification diagram of wave-ripples formation proposed by Kaneko (1981) in which $\delta(=\sqrt{2\nu/\omega})$; laminar boundary layer thickness, ω;wave frequency and open and black circles show ripple and plane bed conditions respectively. Dimensionless parameters were calculated with small amplitude wave theory using significant wave height and its period. The criterion curves were given by Kaneko (1981). The numbers in the figure show the different kind of ripples such as (1): irregular ripples, (2): two dimensional ripples with steep crest and (3): those with round crest. From this figure it was revealed that the boundary between ripple bed and plane bed can be given by the Kaneko's curve. Moreover, as already shown in Fig. 3, the ripples in a shallow water on the Ogata coast are very irregular so that they belong to ripples in area(1). Therefore, Kaneko's criterion is good for prediction of ripple formation. The arrangement with mean wave height and its period was inadequate.

Fig. 7 shows the relationship between sediment-fluid number $D_{\nu*}$ and the Shields number τ_*. In the figure, circles with cross bar correspond to significant waves and $D_{\nu*} = \{(\sigma/\rho)g/\nu^2)^{1/3}D\}$. The empirical curves in the figure show the boundary between plane bed (black circle) and ripple bed (open circle) and were reduced by Tsuchiya et al.(1987) who used the data of Komar et al.(1975) and Nielsen (1979). The curves slightly changes with the parameter of d_o/D and in the

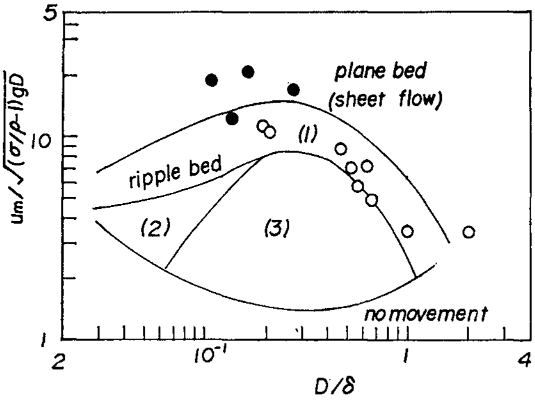


Fig 6 Classification diagram of ripple formation (Kaneko, 1981)

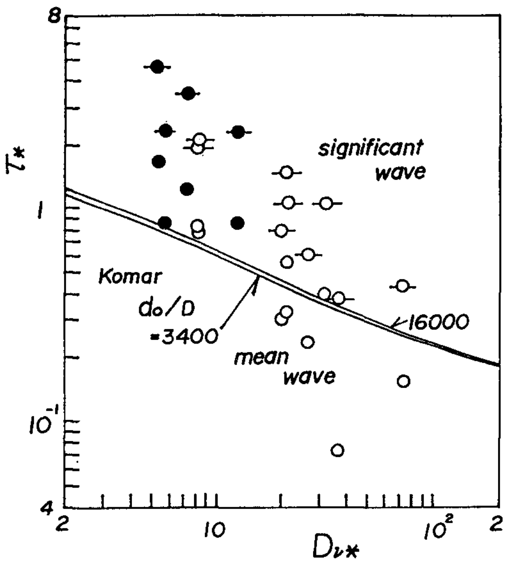


Fig. 7 Classification diagram with sediment-fluid number

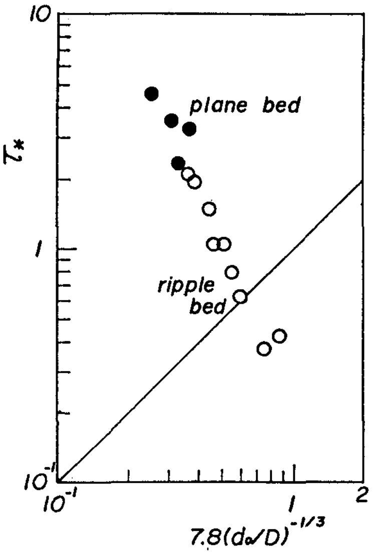


Fig. 8 Classification diagram with wave acceleration

case of calculation with mean wave height and its period, two bed forms can be well divided by the curves.

Fig. 8 shows the criterion of ripple bed and plane bed given by Sato et al.(1987). When we arrange the field data with significant wave characteristics, the criterion can be expressed as,

$$\tau_* = 7.8(d_o/D)^{-1/3} \tag{1}$$

it was found that the curve can not well divide the both bed conditions. The estimation of the Shields number is very difficult in the breaker zone, but Tsuchiya et al.(1987) and Kawata (1989) pointed out that the ratio d_o/D is not effective to classify such bed conditions.

Conclusions

The sediment sorting process and classification of ripple formation were analyzed with the field data under storm wave conditions. The major results of this study to date are as following:

1) On the Ogata coast, beach sediment belongs not to single mother group but to eight mother ones. The finer four groups continuously move in the offshore

direction in every storm, therefore beach erosion has been brought in accompany with sediment sorting process.

2) Kaneko's criterion is good for prediction of ripple formation. Relationship between sediment-fluid number and the Shields number is also good to estimate small-scale bottom topography.

References

Abou-Seida, M.M. (1964)."sediment transport by waves and currents",Tech. Rep. HEL-2-7, Inst. Eng. Res., Univ. of Cal., 34pp.

Bagnold, R.A. (1946)."Motion of waves in shallow water, interactions between waves and sand bottoms", Proc. Royal Soc. London, Ser. A, Vol. 187, pp.1-18.

Boyd, R. et al.(1988)." Time-sequence observations of wave formed sand ripples on an ocean surface", Sedimentology, Vol. 35, pp. 449-464.

Clifton, H.E. (1976)."Wave-formed sedimentary structures: a conceptual model", Beach and Nearshore Sedimentation, ed. R.A.Davis, Jr. et al.,pp.126-148.

Dingler, J.R. and D.L. Inman (1976)."Wave-formed ripples in nearshore sands", Proc. 15th ICCE, pp. 2109-2126.

Forbes, D.L. and R. Boyd (1987)."Gravel ripples on the inner Scotian shelf", J. Sedimentary Peteology, Vol. 57, No. 1, pp. 46-54.

Inman, D.L. (1957)."Wave-generated ripples in nearshore sands", Tech. Memo., No. 100, BEB, pp.66.

Kaneko, A. (1981)."Oscillation sand ripples in viscous fluid", Proc. JSCE, No. 307, pp. 113-124 (in Japanese).

Kawata, Y. (1989)."Law of cross-shore sediment transport on a sloping beach", Proc. Coastal Engineering, JSCE, Vol. 36, pp. 289-293 (in Japanese).

Komar, P.D. and M.C.Miller (1975)."The initiation of oscillatory ripple marks and the development of plane-bed at high shear stresses under waves", J. Sedimentary Peteology, Vol. 45, No. 3, pp. 697-703.

Nielsen, P. (1979)."Some basic concepts of wave sediment transport", Series Paper No. 20, ISVA, Tech. Univ. of Denmark, 160pp.

Sato, S. et al.(1987)."Mechanism of sediment transport under irregular oscillating flow and criterion of ripples disappearance", Proc. Coastal Engineering, JSCE, Vol. 34,pp. 246-250 (in Japanese).

Shirai, T. (1990)."Offshore sediment transport and sediment sorting", unpublished.

Tsuchiya, Y. and M. Banno (1987)."Patterns of littoral drift and their criterion", Proc. Coastal Engineering, JSCE, Vol. 34, pp. 222-226 (in Japanese).

Tsuchiya, et al.(1989)."Long-term observation of nearshore currents at the breaker zone with a ultra-sonic type current meter", Proc. Coastal Engineering, JSCE, Vol. 36, pp. 224-228 (in Japanese).