RIP CURRENT MEASURED AT URADOME BEACH TOTTORI, JAPAN

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Four different types of rip currents were observed in the field observations of near shore current at Uradome Beach Tottori, Japan. One was the rip current occurred in the shallower region of the opening of the two submerged breakwaters. Second one was the rip current appeared suddenly on a relatively straight part of the shoreline and continued for only ten min. at the maximum. Third and fourth were the rip currents occurred from the embayment and apex of the shoreline. Among them, the generation of rip currents except for the second one can be reproduced by the numerical model.

1. Introduction

In Japan, it is reported that about 200 lives were lost during swimming and surfing every year. It is said that more than 1/2 of these fatal accidents were caused by the rip current. Rip current also plays important role in sediment transport in shallow water region and stabilization of bottom topography.

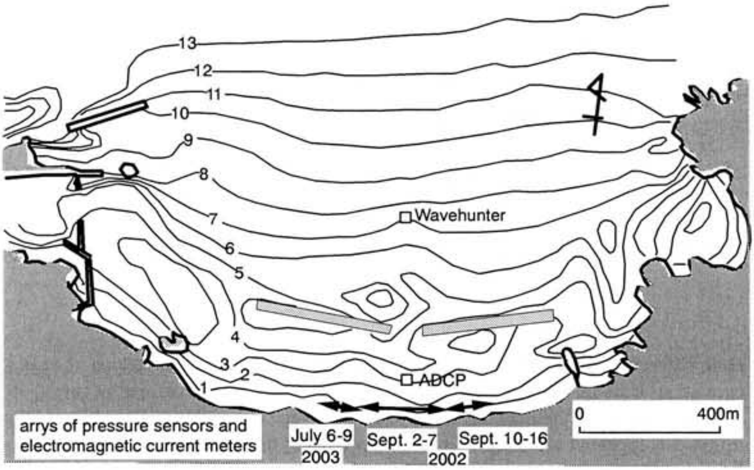
Therefore, many studies have already been carried out (Bowen 1969, Komar 1971, Sonu 1972, Tam 1973, Noda 1974, Hino, 1974, Dalrymple 1975, Damgaad 2002). However it is not easy to predict or find out rip current in the actual field beach. At Uradome Beach, there were four accidents caused by the rip current during swimming for the past five years.

The aim of this study is to investigate the occurrence condition of rip current and characteristics of generated rip currents at Uradome Beach. We also examine whether we can predict the generation of rip current at Uradome Beach by the numerical simulations.

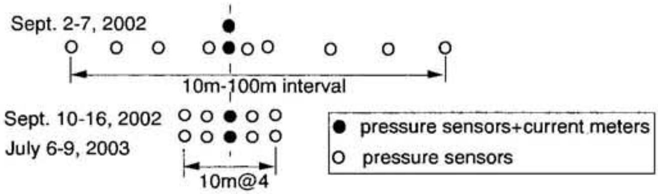
2. Field Measurements at Uradome Beach

2.1. *Outline of Uradome Beach*

Field measurements were carried out at Uradome Beach in Tottori, Japan in 2002 and 2003. The beach is a beautiful pocket beach of the length about 1.6km surrounded by headlands as shown in Fig. 1(a). Two submerged breakwater were constructed at the depth about 5m to prevent from beach erosion. The length of the breakwater is 400m, the crown width is 30m and crown height is DL-2.0m.



(a) Bottom profile of Uradome Beach



(b) Arrangement of pressure sensors and current meters

Fig 1. Profile of Uradome Beach and arrangement of sensors

The bottom slope is relatively gentle, about 1/50 near the shoreline and bed material is fine sand of the mean grain size about 0.02cm. The spring range of this beach is less than 30cm.

For the past five years, there were four accidents during swimming. In July 2001, nine students were caught by the offshore-directed current and two were drowned. The bodies were found at the east end of the west submerged breakwater. It is reported that the observed significant wave height was 2m at the accident.

2.2. *Measurements of waves and nearshore currents*

Field measurements of nearshore current were carried out in September 2002 and July 2003. Incident waves were measured by an ultrasonic wave gauge (Wavehunter) set at the depth of 7m and ADCP was set just behind the opening of the two submerged breakwaters at the depth of about 3m to measure the offshore directed mean current velocity.

We also set 10 pressure sensors to measure surface displacement and two electro-magnetic current meters (ECM) in the very shallow water region. The arrangements of these sensors are shown in Fig.1(b). We determined the arrangements of these instruments in a very shallow water region to estimate the direction of low frequency wave motion by using a so-called MUSIC spectrum (Fujii et al 2002).

Flow pattern of near shore currents were observed by the local remote sensing using balloon. The balloon is about 10m long and 2.5m high and is installed by a remotely operated video camera. When the wind velocity was less than 10m/s, the balloon was moored at about 100m to 200m high above the ground according to the resolution of the image we needed. Flow pattern of rip currents were recorded by tracing the trajectory of the sea-marker, a fluorescent tracer, injected in the rip current.

As for the bottom topography, we could not measured exactly because the speed of the change in water depth was extremely rapid e.g. 0.4m/day. The bottom topography shown in Fig. 1 was measured on September 2001.

3. Results of Field Measurements

3.1. *Measured incident waves and mean current*

Characteristics of the incident waves measured at the depth of 7m in September 2002 and July 2003 are shown in Figs.2(a) and 3(a). Figures 2(b) and 3(b) are the mean current velocities at about 2m above the bottom measured by the ADCP set at the depth of 3m. Wave directions shown in Fig.(c) are measured clockwise from the north. In Fig.(d), N-S comp. (E-W comp.) roughly corresponds to the cross-shore (longshore) component of the mean current and positive offshore (west ward). The horizontal axes of these figures start at the noon of each day.

In 2002, large waves of wave heights higher than 1.5m appeared twice. Wave direction of these high waves was almost perpendicular to the shoreline. When the incident wave height became larger than 1m, offshore-directed current appeared. In 2003, waves of wave height higher than 1m were observed twice. Wave directions of those waves were not perpendicular to the shoreline and offshore-directed current did not grow significantly.

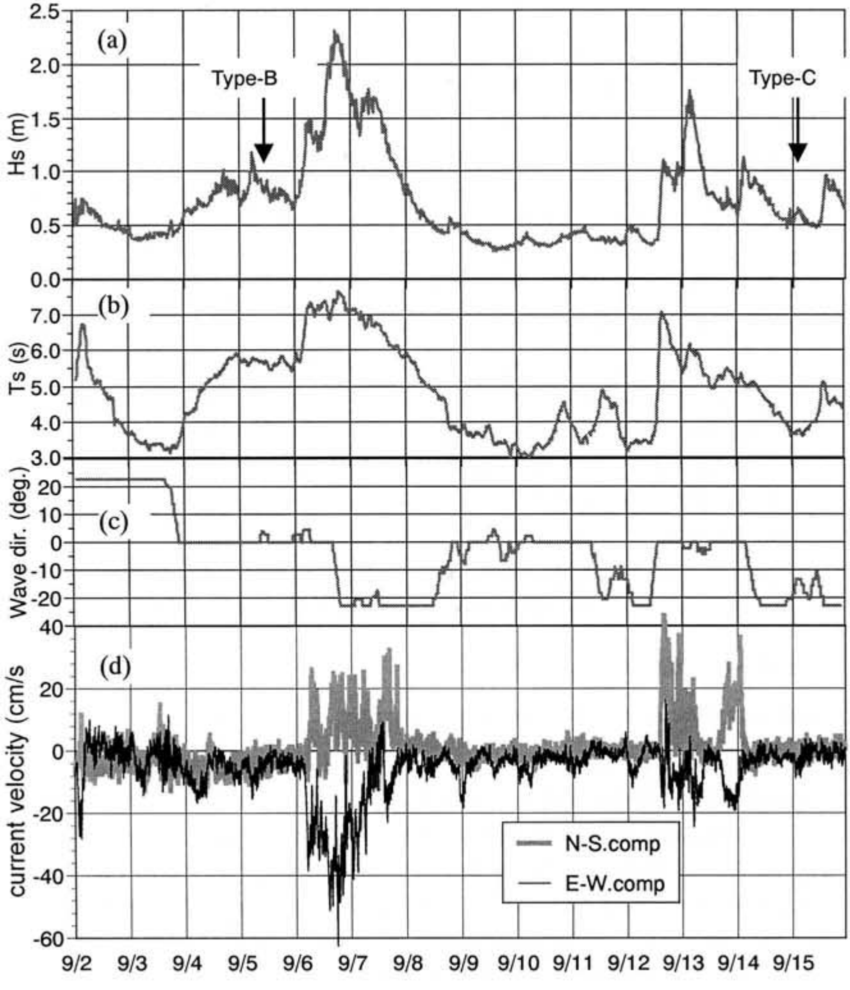


Fig.2 Characteristics of incident waves and mean current in September 2002
((a) Significant wave height, (b) Period, (c) Wave direction and
(d) Mean current velocity)

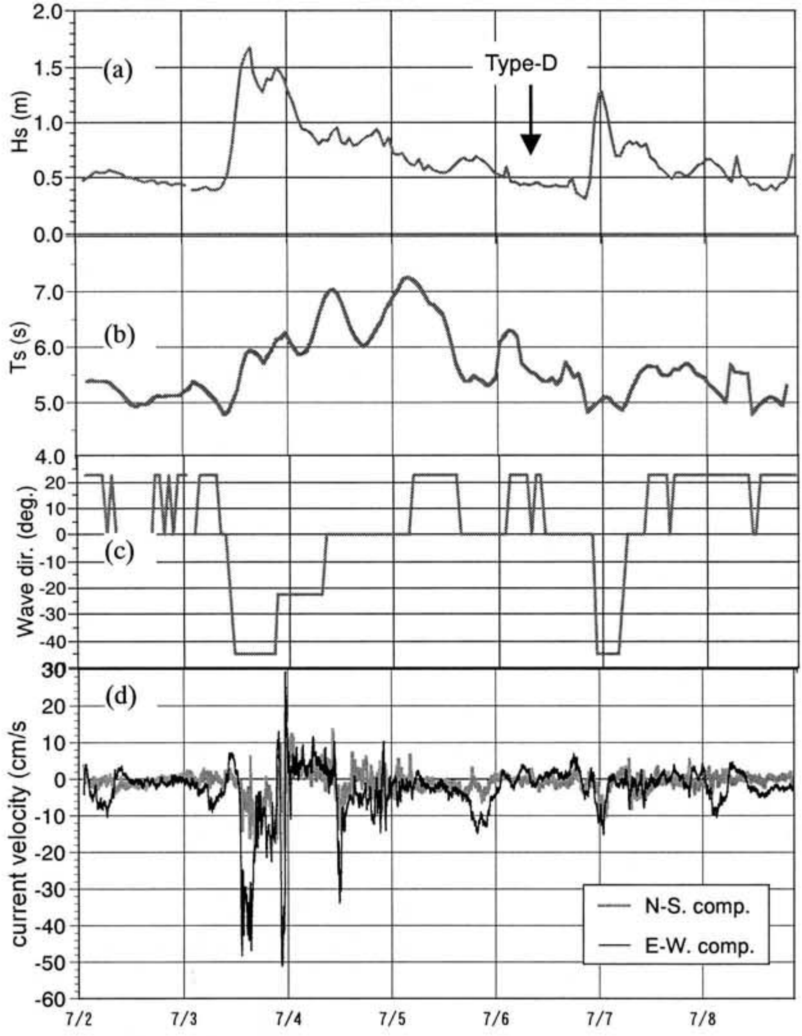


Fig.3 Characteristics of incident waves and mean current in July 2003
((a) Significant wave height, (b) Period, (c) Wave direction and
(d) Mean current velocity)

3.2. *Measured offshore-directed currents*

The following four different types of offshore-directed mean currents from Type-A to Type–D were observed at the place shown in Fig.4:

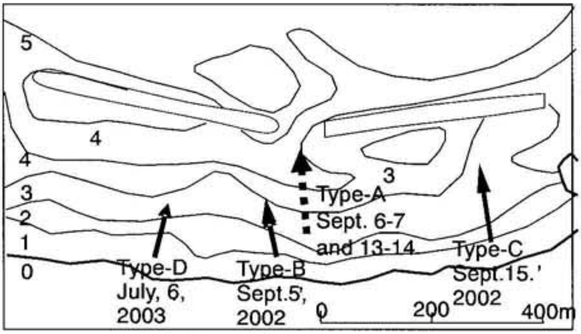


Fig.4 Places of rip current generation

Type-A (Offshore-directed flow from the shallow water region to the opening of the submerged breakwaters):

The offshore-directed current of this type became significant in the case of the normal wave incidence of the wave height larger than 1m as shown in Fig.2(d). In such cases, wind velocity was larger than 10m/s and we could not use our local remote sensing system to record the flow pattern.

Type-B (Rip current on the relatively straight part of the shoreline where there was not any significant longshore gradient of the bottom topography):

Figure 5 shows the captured video image of this type of rip current recorded on September 6, 2002 when the incident wave height was about 0.6m.

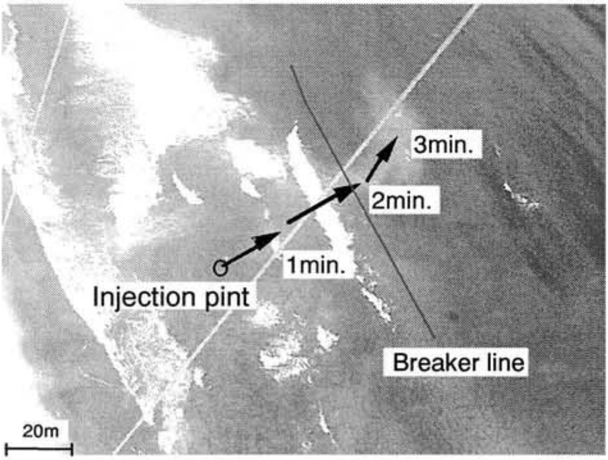


Fig.5 Flow pattern of rip current of Type-B

This rip current appeared suddenly on the relatively straight part of the beach and flowed through the mean breaker line. However, it continued for only 10min.

Type-C (Rip current from the embayment of the shoreline):
Figure 6 shows the trajectory of the sea-marker in the rip current recorded on September 15, 2002. Although this current appeared when the incident wave height was less than 1m, it continued for more than two hours. The average velocity estimated from the motion of the sea-maker reached 0.8m/s.

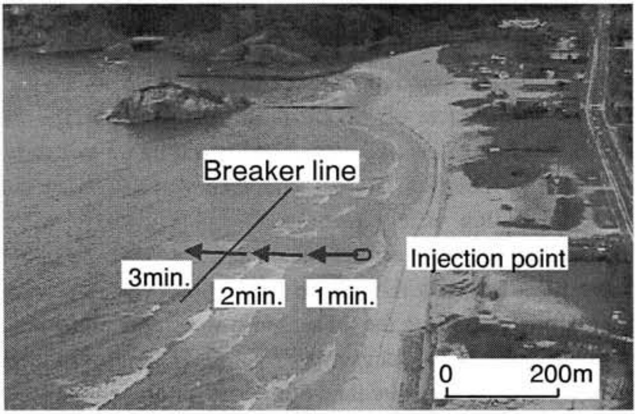


Fig.6 Flow pattern of the rip current of Type-C

Type-D (Rip current from the apex of the shoreline):
In the morning of 6 July 2003, the rip current appeared at the apex of the shoreline. Figure 7 is the captured image of video.

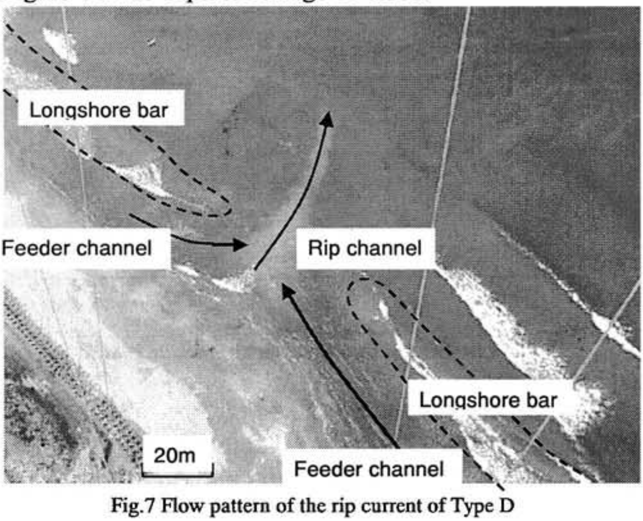


Fig.7 Flow pattern of the rip current of Type D

In this case, clear feeder channels were formed in the both side of the apex and there was a typical rip channel in front of the apex. This rip current continued for more than 3 hours until the direction of incident wave changed from north to northwest as shown in Fig.3(c). Soon after the change in the incident wave direction, the rip current disappeared.

Although the rip currents shown in Figs.5 and 6 flowed keeping away from EMCs we set in the very shallow water region, we could measured the main flow velocity of the rip current shown in Fig.7 by ECMs.

4. Possibility for Predicting Generation of Rip Current

A series of numerical simulations is carried out to examine the possibility for predicting the generation of rip currents measured in the field. In the numerical model, we first calculated wave field based on an unsteady mild slope equation to determine radiation stresses and then wave-induced currents were calculated based on shallow water equations.

The first calculation was carried out on the bottom topography shown in Fig.1(a) to reproduce the offshore-directed current of Type-A. The contour lines in Fig.1(a) were drawn based on the measured water depth along the survey line set at the interval of 50m in the longshore direction. Therefore, the smaller scale variations in the bottom topography than 50m were smoothed out.

Figure 8 is the calculated wave-induced current vectors under the condition of incident wave height 1.5m, period 6.5s. The wave direction is the north. Clear current of the velocity about 0.3-0.4m/s toward the northwest direction is generated in the landward of the opening of the submerged breakwaters.

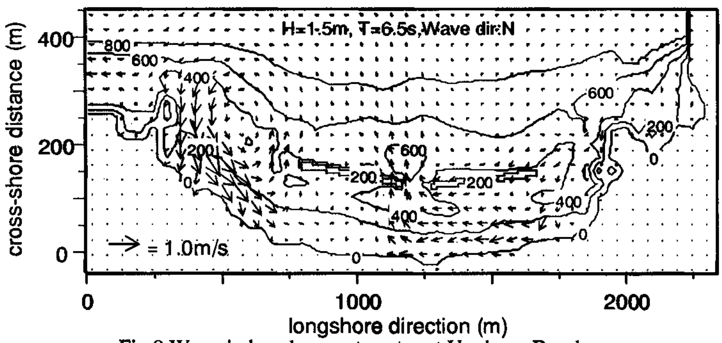
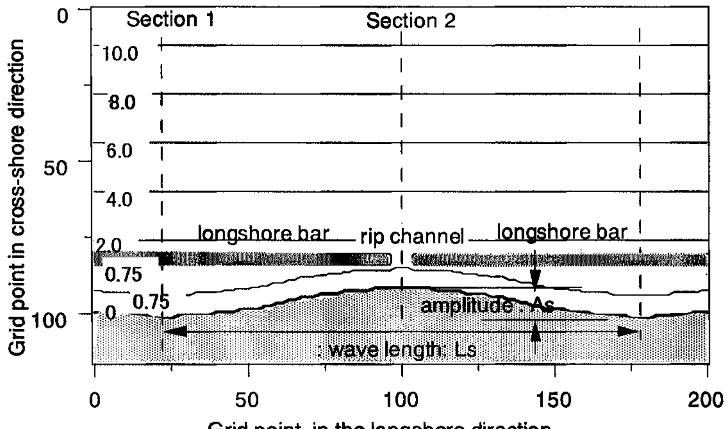


Fig.8 Wave-induced current vector at Uradome Beach

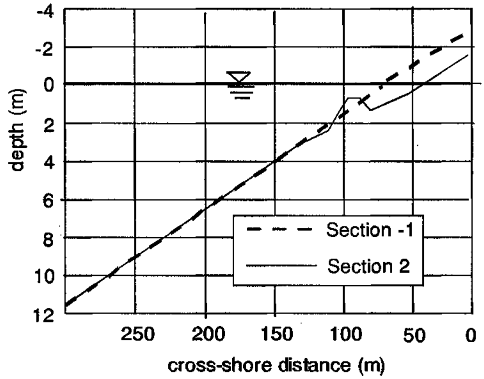
It is confirmed that this offshore-directed flow becomes strong as the increase in the incident wave height and disappears when the incident wave direction shifts to NNW. These results correspond to the measured flow by

ADCP. Strictly speaking, this is not a rip current. However, such kind of offshore-directed current is important to keep the swimming beach safe.

Then the authors examined the possibility for predicting the occurrence of rip currents from the embayment (Type-C) and the apex (Type-D) of the shoreline numerically. However, we could not measure the bottom topography exactly where the rip current happened. Therefore, the authors carried out calculation on the model bottom topography with wavy shoreline as shown in Fig.9.



(a) Plane view of the model bottom topography with longshore bar



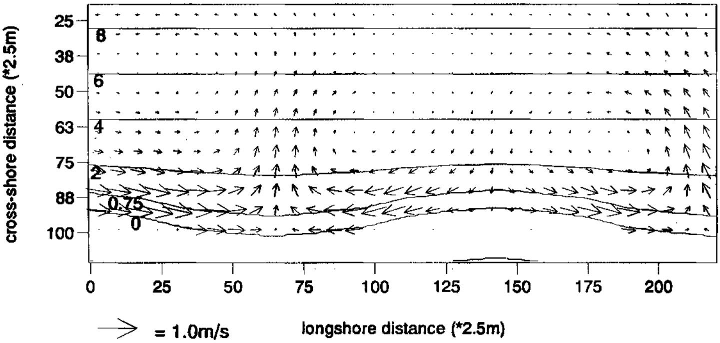
(b) Cross-shore profile of the model beach

Fig.9 Model bottom topography with wavy shoreline

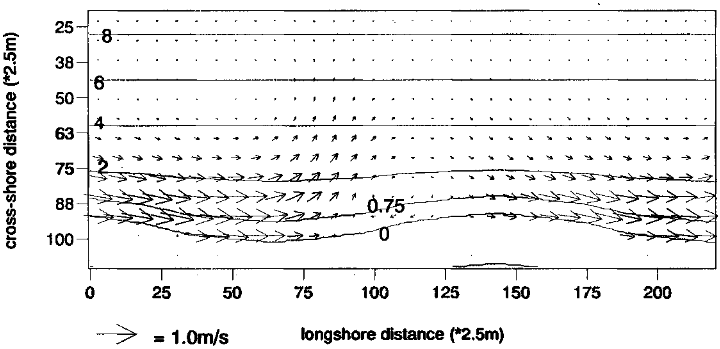
Figure 9(a) illustrates the plane view of the model bottom topography. The rip current from the embayment was calculated on the simple wavy shoreline and the rip current from the apex was calculated on the topography with the longshore bar and the rip channel in front of the apex. Figure.9(b) is the cross-shore bottom profile s with longshore bar along Section 1 and Section2 in

Fig.9(a). In the calculation, an isotropic grid system of grid space 2.5m is used. Consequently, the wavelength of the shoreline is 375m, the amplitude is 25m and the mean bottom slope is 1/20.

Figure 10 shows the calculated wave-induced current vector on the wavy shoreline without bars under the condition of normal wave incidence (Fig.(a)) and oblique wave incidence (Fig.(b)). The incident wave height and period are 1m and 3s and incident wave angle is 10° to the normal to the shoreline in the case of oblique wave incidence. As can be seen from Fig.10(a), the rip current of Type-C occurs from the embayment in the case of normal wave incidence. Even in the case of oblique wave incidence, the rip current still appears as shown in Fig.10(b). This means that the rip current of this type weakly depends on the wave direction.



(a) Wave-induced current in the case of normal wave incidence

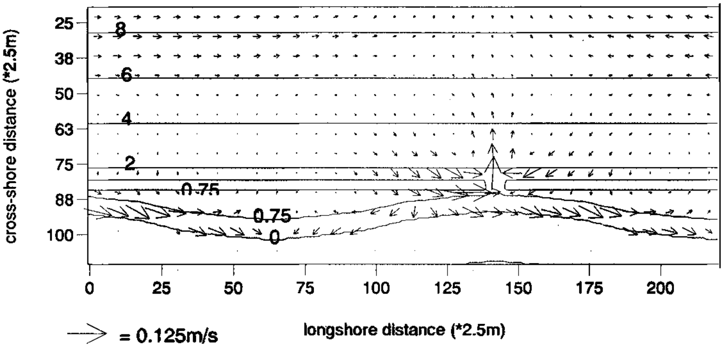


(b) Wave-induced current in the case of oblique wave incidence

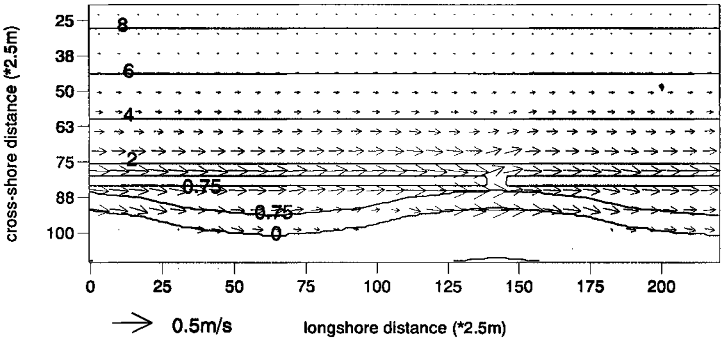
Fig.10 Wave-induced current on wavy shoreline without bar

Figure 11 is the calculated result on the bottom topography with bar and rip channel under the condition of normal wave incidence (Fig.(a)) oblique wave incidence (Fig.(b)). Incident wave conditions are the same as those shown in Fig.10. In the case of normal wave incidence shown in Fig.11(a), rip current of

Type-D occurs from the apex of the shoreline through the rip channel However, in the case of oblique wave incidence shown in Fig.11(b), rip current does not appear. These results correspond to the measured rip current on the bottom with feeder channel and rip channel system.



(a) Wave-induced current in the case of normal wave incidence



(b) Wave-induced current in the case of oblique wave incidence

Fig.11 Wave-induced current on wavy shoreline with bar and rip channel

Until now, we cannot reproduce the generation of the rip current of Type-B that appears suddenly on a relatively straight beach by the numerical simulation. This may come from the fact that all irregularities of the incident waves (irregularities in wave height, period and directional spreading) are not taken into account in our numerical simulation.

The offshore-directed current of the velocity larger than 0.5m/s often appeared in the recorded time series of the EMC at very shallow water region. However, such kind of offshore-directed flow continued for only ten minutes at the maximum. Figure 12 shows an example of the time series of the velocity of such kind of offshore-directed flow measured at the depth of about 0.7m in September 2, 2002. Again, N-W comp. in the figure corresponds the cross-shore component and positive offshore.

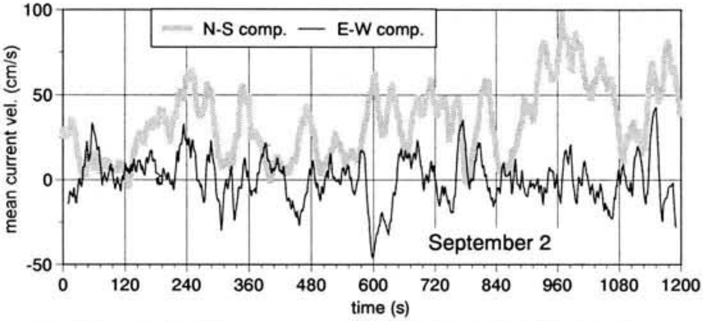


Fig. 12 Example of measured time series of offshore-directed current

The authors examined the occurrence conditions of these unsteady cross-shore current in relation to the surface displacement in a low frequency region, mean surface gradient around the EMC, and so on. However, we could not explain the mechanism of the generation of rip current of this type.

5. Conclusions

In the field measurements of nearshore currents at Uradome Beach Tottori, Japan, four different types of offshore-directed mean currents were observed:

From the shallow water region behind the opening between the two submerged breakwaters, offshore-directed current is often generated. This current becomes significant as the increase in the incident wave height. This offshore-directed current depends on the wave direction and can be reproduced exactly by the classical numerical simulation.

From the embayment of simple cuspate topography, rip current usually appears and continues for a fairly long time. From the apex of cusp with feeder channel and rip channel system, in this case rip channel is usually formed in front of the apex, strong rip current occurred and it continues for a long time and deeply depends on wave direction. These rip current resulting from the bottom topography can also be reproduced by the numerical simulation.

Even on a straight beach, rip current appears suddenly and continues only ten minutes at the maximum. This kind of rip current is dangerous for the swimmers who are not good at swimming. However, it is not easy to detect this kind of rip current and unfortunately, we can not explain the mechanism of the generation of this kind of rip current

Acknowledgments

A part of this study was supported by the Ministry of Education, Science, Sports and Culture, Japan, Grant-in-Aid for Scientific Research (B)(2), 15360266. Further support has been given by Japan Coast Guard in the field works.

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