Field Investigation on Sediment Transport into the Submarine Canyon in the Fuji Coast with the New Type Tracers

Shigenobu Tanaka[1], Koji Yamamoto[2], Hitoshi Ito[3], Toshiharu Arisawa[4], and Toshimitsu Takagi[5]

Abstract

The Fuji coast in Japan is one of the beach which is suffering from coastal erosion. One reason for erosion is seemed to be the offshore sediment transport through the submarine canyon in front of eroded area. The present paper concerns the field investigation in order to confirm the sediment transport into the submarine canyon with two new type tracers. One tracer is the artificial sand and gravel made of the hard plastic. The other is the tracer with an ultrasonic transmitter. These tracers are very effective for tracking the sediment.

1. Introduction

The Fuji coast, facing on the Suruga bay in Japan which has the Suruga trough over 2,000 m depth, is known for one of the most beautiful coast where Mt. Fuji is seen behind (Figs. 1 and 2). The coast is 19 km long between the estuary of Fuji River and Numazu harbor. The coast is made of sand and gravel and the sea bottom has a steep slope, close to 1/2 over 20m depth. In this coast, the longshore sand transport toward east is dominant, which amounts to almost 100,000 m^3/year. The western side of the coast has been suffering from erosion since 1970 as shown in Fig. 3. These reasons are partly reduction of discharged sediment from the Fuji river and stopping the longshore sediment transport by the breakwater of Tagonoura harbor. Since the coastal erosion

[1] Deputy Director, Japan Inst. of Constr. Eng., Tranomon 2-8-10, Minato-ku, Tokyo 105-0001, Japan.

[2] Researcher, River Department, PWRI, Min. of Constr., Asahi-1, Tsukuba, Ibaraki 305, Japan.

[3] Chubu Region Constr. Bureau, Min. of Constr., San-nomaru 2-5-1, Naka-ku, Nagoya, Aichi 460, Japan.

[4] Numazu Constr. Office, Chubu Regional Constr. Bureau, Min. of Constr., Shimokanuki 3244-2, Numazu, Shizuoka 410, Japan.

[5] Coastal Engineering Department, INA Corporation, Sekiguchi 1-44-10, Bunkyo-ku, Tokyo 112-8668, Japan

started, the wave dissipating breakwater has been constructed along the shore. Because of the effect, the backward movement of shoreline stopped. However, the erosion has been spread to the downdrift side of longshore sediment transport. The wave dispersion breakwater might cause the decrease of sediment transport. Recently the erosion occurs from the Outlet 1 to east where is the end of the wave dissipating concrete block. Therefore, the countermeasure is necessary for protection of the eroded beach. To make a plan for countermeasure, the mechanism of sediment movement must be clarified. In this coast the sand transport is dominant toward not only longshore but also offshore because the sediment budget is not maintained along the coast with 15 m or less in depth according to the analysis of topography maps. Particularly a large submarine canyon exists in front of the eroded beach, and its entrance (20m depth) is close to the shoreline (Fig.3). Therefore, there is a possibility of offshore sediment transport through this canyon. Thus, the field investigation on sediment transport was carried out around the submarine canyon with the two types of new tracers.

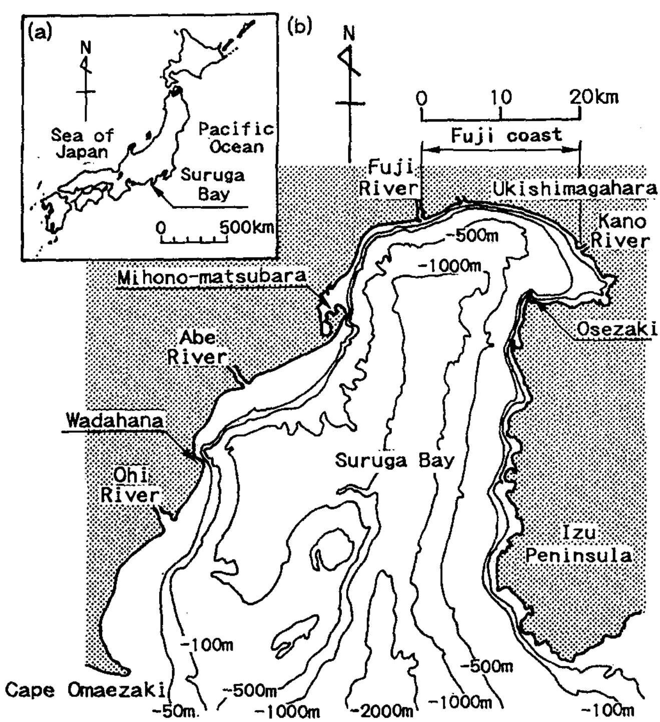

Figure 1 Location map of the Fuji Coast

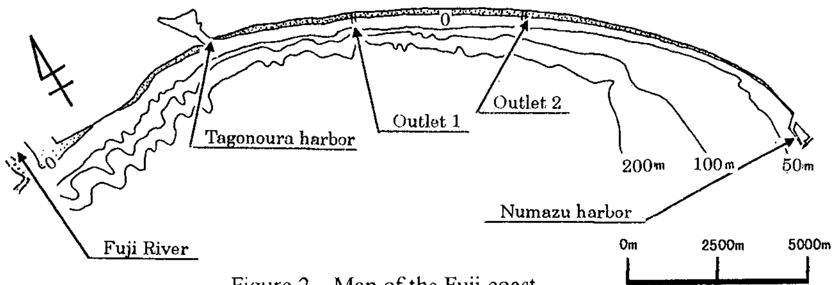

Figure 2 Map of the Fuji coast

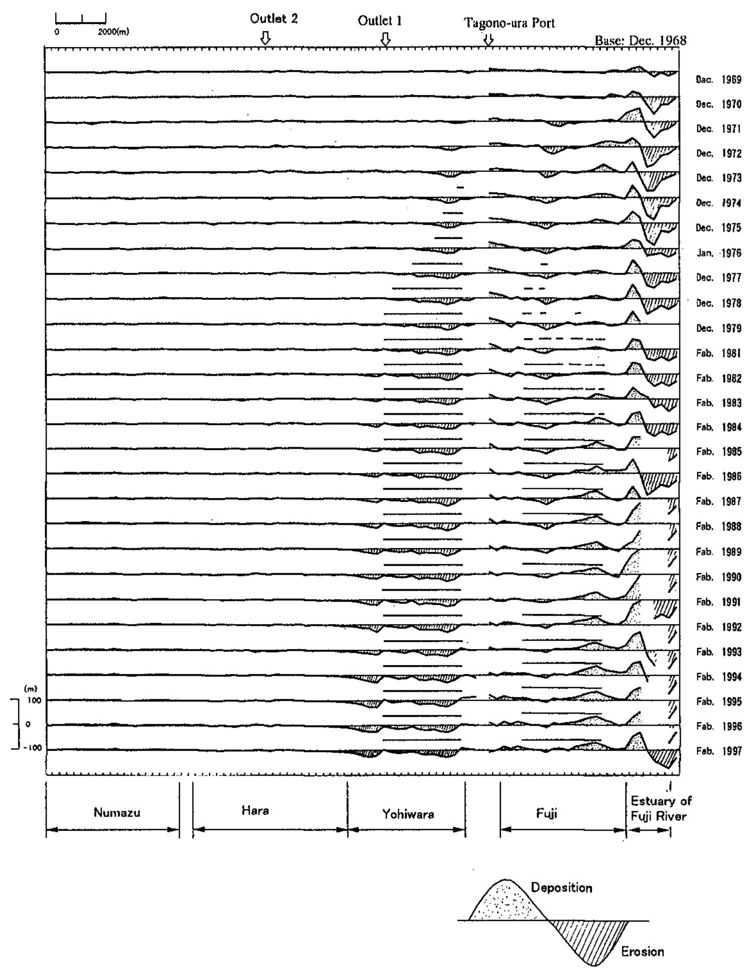

Figure 3 History of the shoreline change

2. Topography around the Submarine Canyon and Characteristics of Sediment

The study coast has very steep bottom, approximately 1/10 from the shore to 20m depth and approximately 1/2 offshore from 20m depth. Especially in front of the Outlet 1 the 20m contour is close to shoreline. These characteristics of topography of Fuji coast are found obviously from the variation of depth contours as shown in Fig.4. According to the topography analysis, the critical depth of topography change is about 14m depth (Fig. 5). The distribution of sediment grain size around the submarine canyon shows in Fig. 6. It is found that the variation of the grain distribution in 50m depth of the canyon from No.48 to 49 is much more than that out of the canyon. This fact shows the movement of sediment even in 50m depth of the canyon.

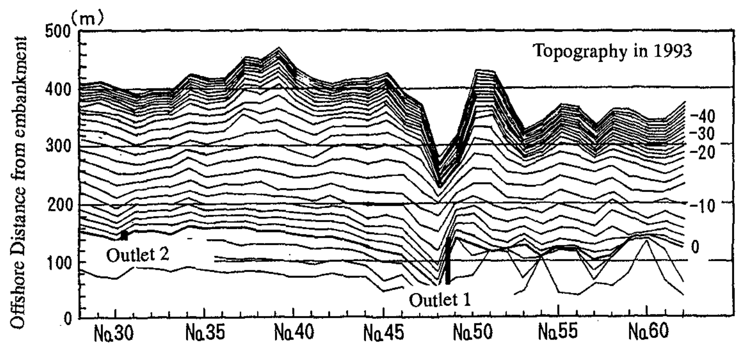

Figure 4. Distribution of topography

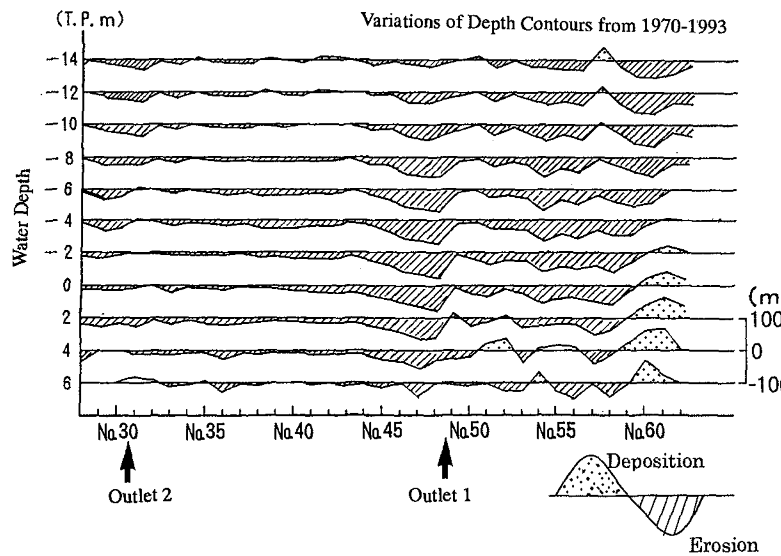

Figure 5. Variations of depth contours

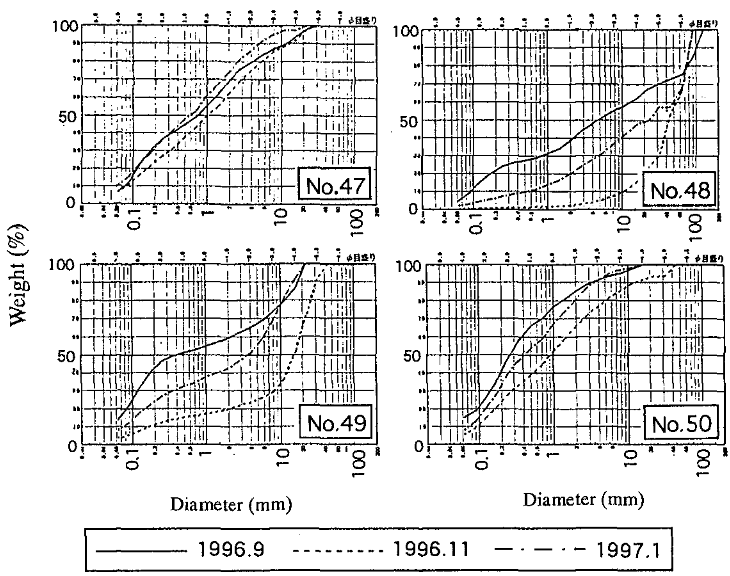

Figure 6. Grain size distribution at 50m depth nearby the submarine canyon

3. Field Investigation Using New Type Tracers

3.1 Artificial gravel tracer (Type A tracer)

The artificial sand and gravel, which are made of the hard plastic, colored pink, with approximately the same density and grain size distribution as the field, were put on the bottom in 16 m depth offshore No.49+125m(Fig.7). Three different sizes of gravel, 1 mm, 10 mm and 50 mm, which are taken as the representative sizes for the field sediment were made (Fig.8, Photo 1). The 100mm tracers as the maximum size in the field were also made. The tracers with 1mm and 10 mm mean diameters were made by crush of the hard plastic panels. The tracers with 50 and 100mm diameter were cast in cup-shaped mold. After mixing these tracers as almost same distribution of grain size as that in the field (Fig.8), three ton of these were put on the bottom in 16m depth offshore to No.49+125 m (Fig.7). On three times tracks including immediately after typhoon, divers collected the sediments of approximately five kilograms weight on the several places of the bottom around the injection place of tracers. The weight of tracers included in the collected sediment was measured in each grain size group.

3.2 Small ultrasonic transmitter(Type B tracer)

The other tracer is the artificial gravel with a small ultrasonic transmitter (Photo 2) that has approximately five months of life (Table 1 and Fig.9). The small ultrasonic transmitter is often used in trace of fish. Three pieces of tracers that have the different

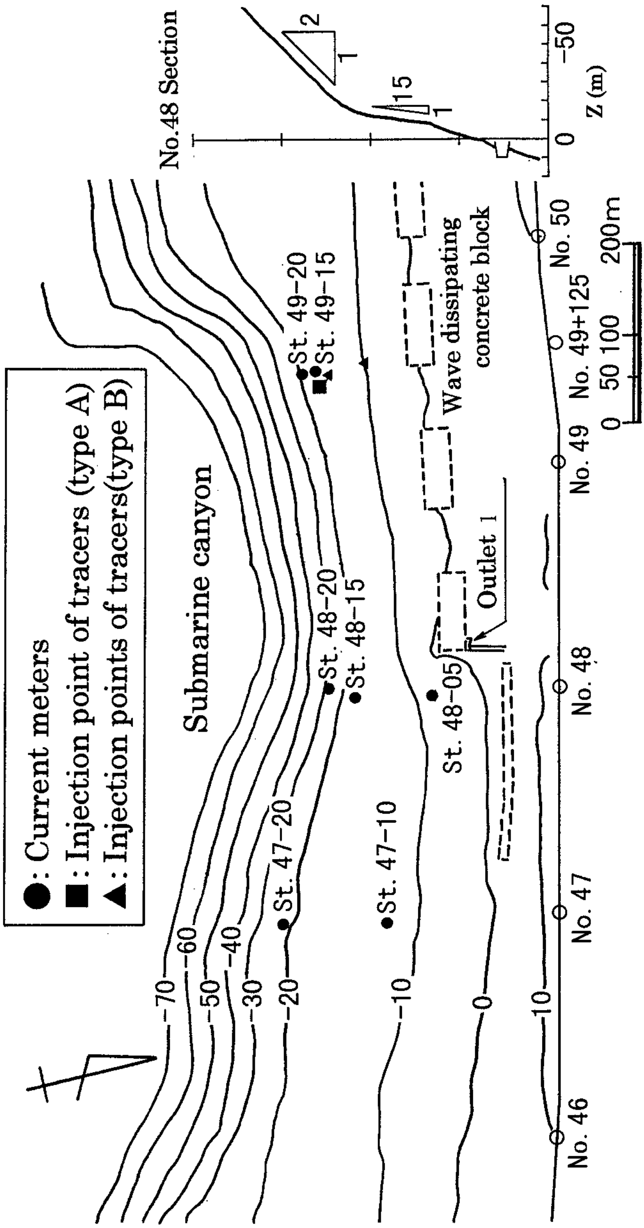

Figure 7 Topography nearby submarine canyon and position of survey equipment

Photo 1 Artificial sand and gravel for tracers

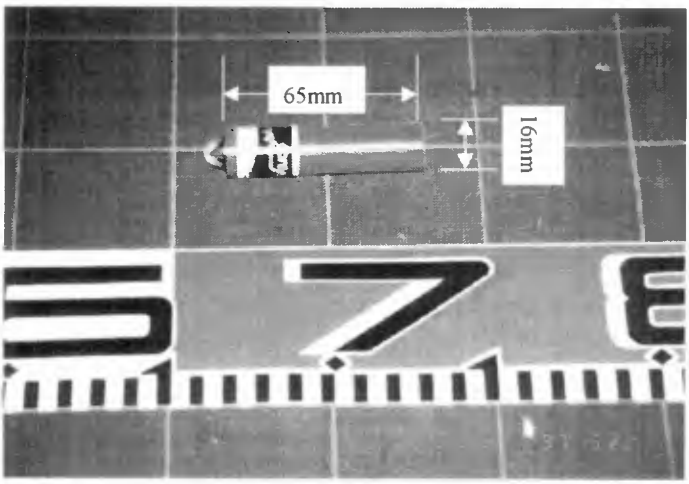

Photo 2 An ultrasonic transmitter

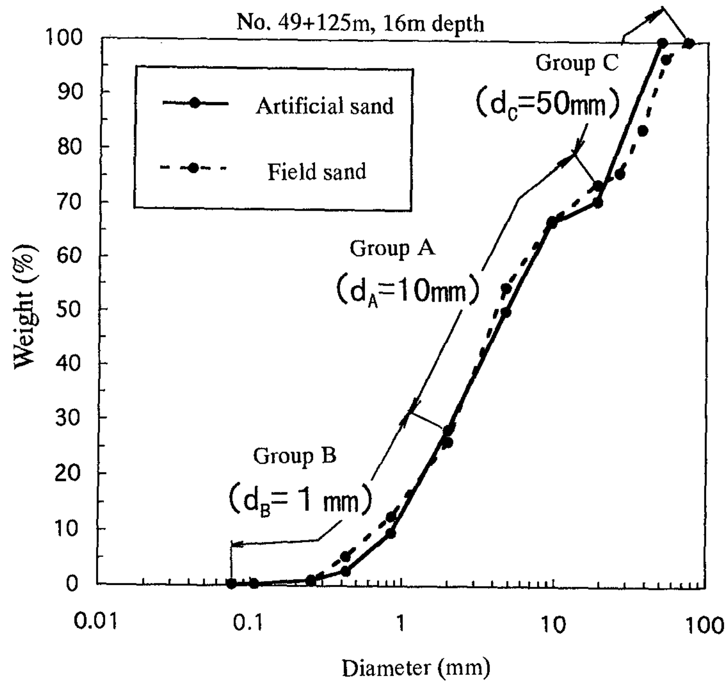

Figure 8 Distribution of artificial and field sands.

Table 1 Characteristics of Small Ultrasonic Transmitter

Parameters	Models
Length/Diameter (mm)	65/16
Weight in water (g)	10
Frequency (kHz)	50,54,60,65.5,69,76.8
Service life (day)	268 (approximately 9 months)
Output (dB)	147
Effective Range (m)	50-800

frequency transmitters were separately put on the bottom each in 10 m and 15 m depth (Fig. 7). By using an ultrasonic receiver fixed on a boat, the position of the tracer with the small ultrasonic transmitter can be searched

4. Tracking of Tracers and the Force of These Movements

4.1 *Wave and current climate*

The history of wave and current climate in St.49-15 from 10 Sept. 1996 to 10 Oct. 1996 is shown in Fig.10. Three typhoons, 9617, 9620, and 9621 attacked this coast on

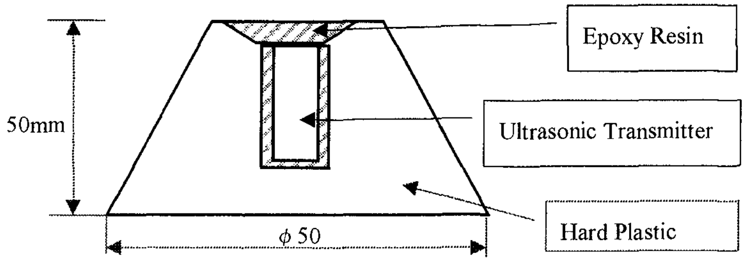

Figure 9 A tracer with ultrasonic transmitter

Table 2 High Wave during Observation by Tracers with Small Ultrasonic Transmitter

Period	$H_{1/3max}$ (m)	$T_{1/3max}$ (s)	Wave direction	Main causes
Nov. 12-13, 1996	3.13	17.6	SW	Typhoon 9624
Dec. 5-6, 1996	4.45	9.2	SSW	Low barometric pressure
Jan. 2-3, 1997	2.57	6.9	SSW	
Jan. 6-7, 1997	2.41	7.2	SSW	

the investigation. Especially the typhoon 9617 caused big waves, about 3.5m height of significant wave and a period of 15 second. Although the velocity of mean current was below 10 cm/s, the orbital velocity of wave was about 1.0 m/s in significant value and 2.0 m/s in maximum value when the maximum wave height 5.25m was recorded. During the tracking of the tracer, type B, the big waves attacked as shown in Table.2. According to the wave data, the wave was coming to the shore from SSW dominantly, which is about 5.0 degree clockwise from the normal direction of shoreline.

4.2 *Tracking results of artificial sand and gravel*

The artificial tracers of the type A were put on 12 Sept. and the tracking of them was carried out three times, 27 Sept. immediately after the typhoon 9617, 9 Oct. and 7 Nov.. The results of tracking of tracers are shown in Fig.11. After the typhoon 9617 the tracers moved toward south along the steepest bottom slope of the canyon. In particular, 100mm tracers were found even in the bottom of 40m depth. Although the sediment could not be collected in 50m depth, divers confirmed the existence of some tracers in it. In addition, any tracer was not found in onshore and longshore from the injection point. The movement of each grain size group of tracers is shown in Fig.12. According to this result, the different movement due to the grain size was not confirmed.

4.3 *Tracking result of tracer with an ultrasonic transmitter*

The tracers with ultrasonic transmitter (Type B) were put on 12 Oct. 1996. The tracking was carried out on 9 Nov. 1996 and 23 Jan. of the next year. The tracking result is shown in Fig.13. On the first tracking, the movement of them was not

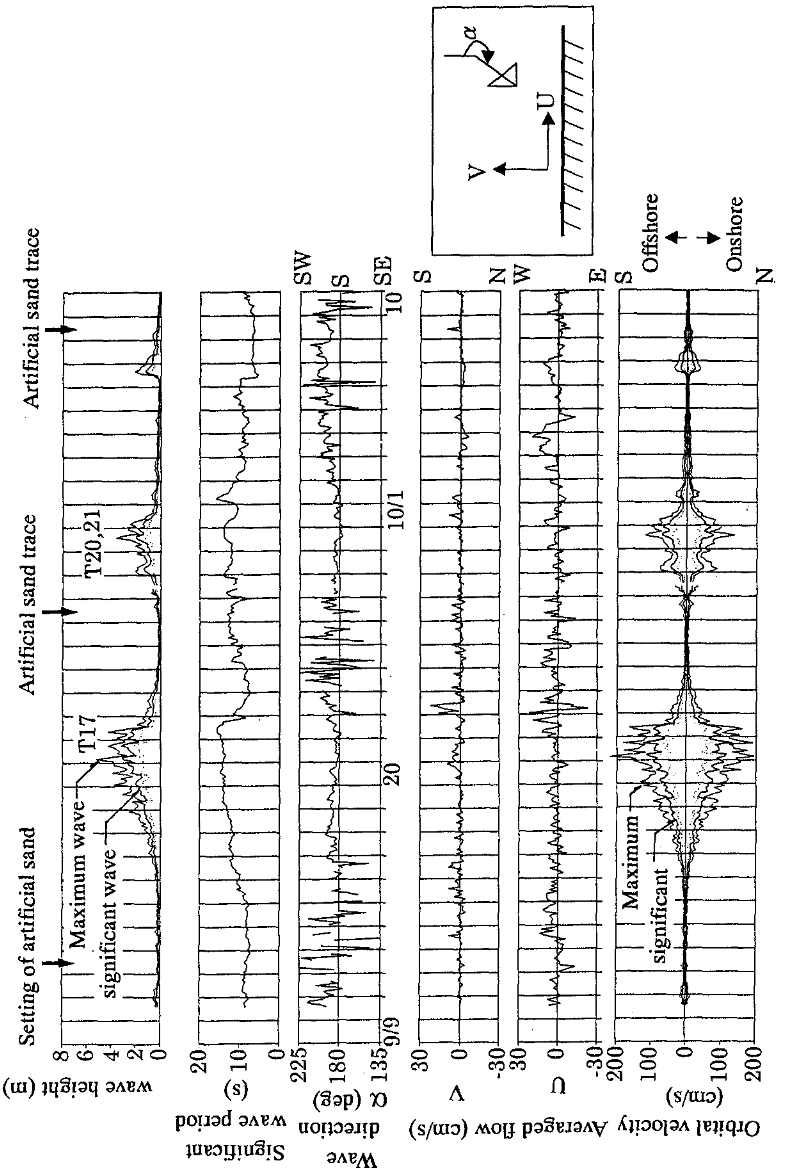

Figure 10 Wave and current at St. 49.5-15

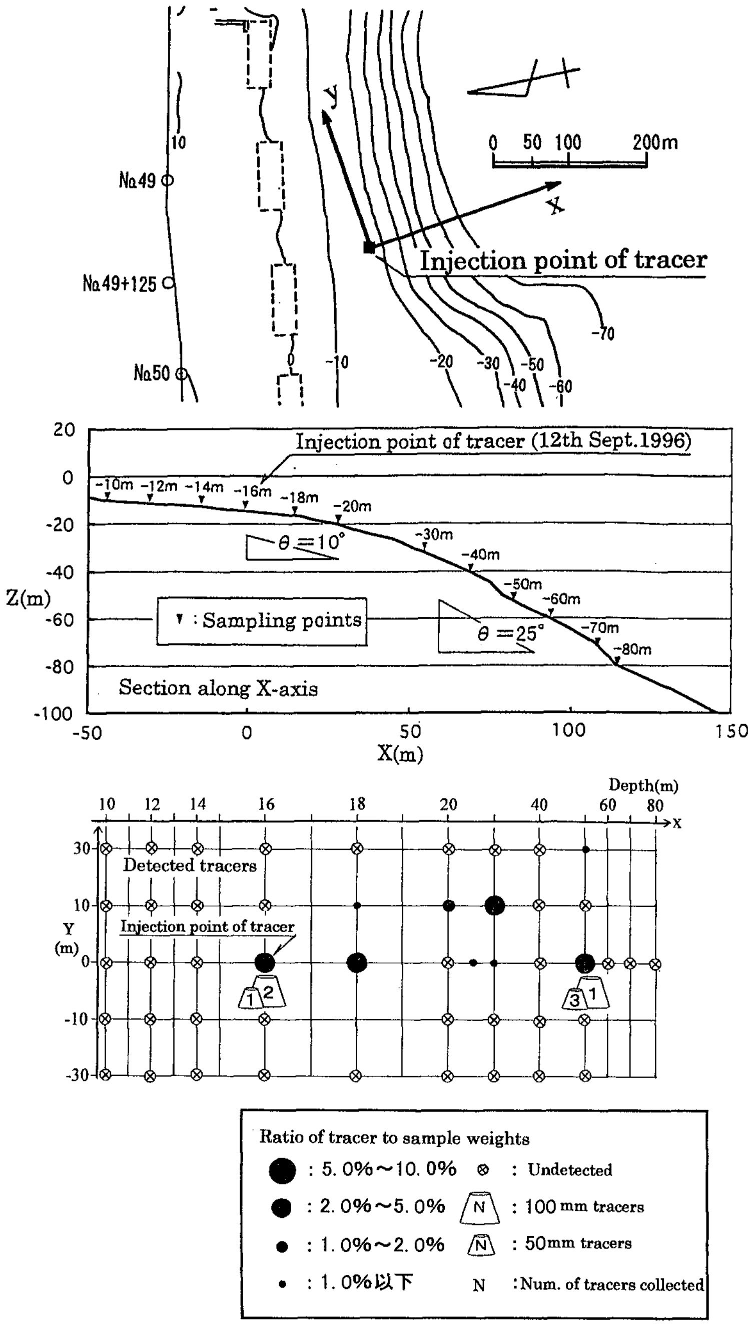

Figure 11 Detected the type A tracers after the typhoon 9617

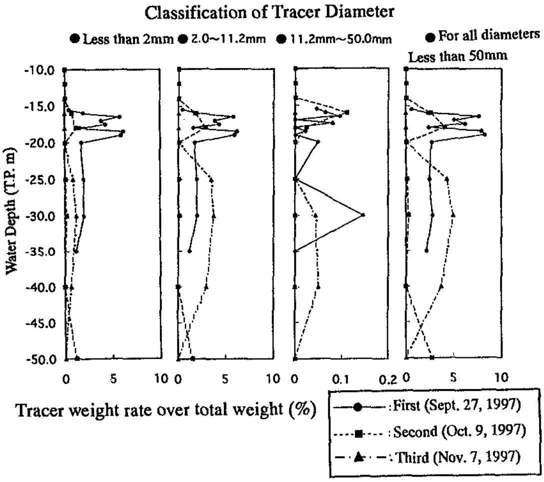

Figure 12 Detected tracer weight rate over total weight (%)

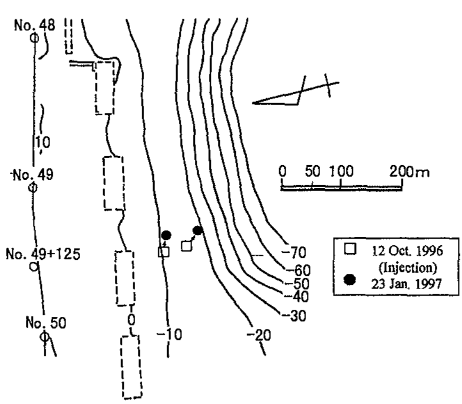

Figure 13 Track of the type B tracers

confirmed. However on the second time, the tracers put on the bottom in 15m depth moved toward offshore about 30m away, and those put on the bottom in 10m depth moved toward both longshore and offshore about 20m far away. The movements of tracers Type A and B injected on 15m depth were toward offshore. However, the movement of tracer type B injected on 10m depth had a longshore component more than that on 15m depth.

5. Mechanism of Sediment Movement on the Steep Bottom

According to the result of the field investigation, it was found that the sediment in 15 m depth where is the entrance of the submarine canyon, moved toward the offshore during the typhoon. The force of the sediment movement is seemed to be the orbital velocity due to wave and gravity because the mean current velocity is not domainant toward offshore. Then using the Shields parameter obtained by the orbital velocity, the stability of sediment was analyzed. On this analysis the critical Shields parameter was revised using Lane's equation (Lane, 1955),

$$K = \Psi_{cs} / \Psi_c = \cos\theta\sqrt{1-(\tan\theta/\tan\varphi)^2} \quad (1)$$

where Ψ_{cs} is the critical Shield parameter on a slope, Ψ_c is the critical Shield parameter on a flat bottom, θ is the angle of bottom slope, and φ is the stable angle of bottom slope. Fig. 14 shows the influence of the bottom slope to the critical Shields parameter with respect to the sediment grain sizes. From this figure, the sediment with 4mm on 1/2 slope starts moving by the half of the critical force at the flat bottom. Fig. 15 shows the histories of the Shields parameters during typhoon 9617 over a range of the grain sizes from 1mm to 100mm. In this case the critical Shields parameter on the flat bottom is 0.05 that is obtained by Madsen and Grant (1976). The bottom slope is 1/6 at the injection point of tracers (Type A). It is found that the sediment with grain size less than 100mm has the possibility of movement at the attack of typhoon. It can be estimated that due to the gravity, the direction of movement is inclined to the offshore with the steep bottom slope.

6. Conclusions

It is found in this investigation that the sediment transport around the 15m depth, partly made of the gravel with 100mm diameter, move toward the submarine canyon when the big waves generated by the typhoons attacked. The force of the sediment movement could be the wave orbital velocities up to 2.0 m/s in typhoon and gravity according to the Shields parameter analysis. By the fact that the averaged offshore velocities are weak, the steep bottom slope determines dominantly the direction of the sediment movement even deeper than 15m around the submarine canyon. Furthermore, the effect of the new type tracers was confirmed in this investigation.

Reference

Lane, E. W. (1955): Design of stable channels, Trans., ASCE, Vol. 120, pp.1234-1279.

Madsen, O.S. and Grant, W.D. (1976): Quantitative description of sediment transport, Proc. 15th Coastal Eng. Conf., ASCE, pp. 1093-1112.

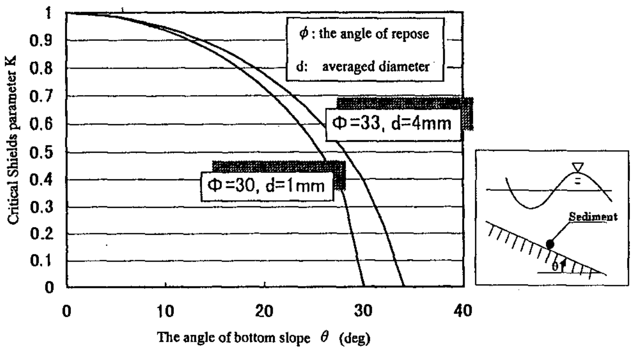

Figure 14 Critical Shields parameter on the slope

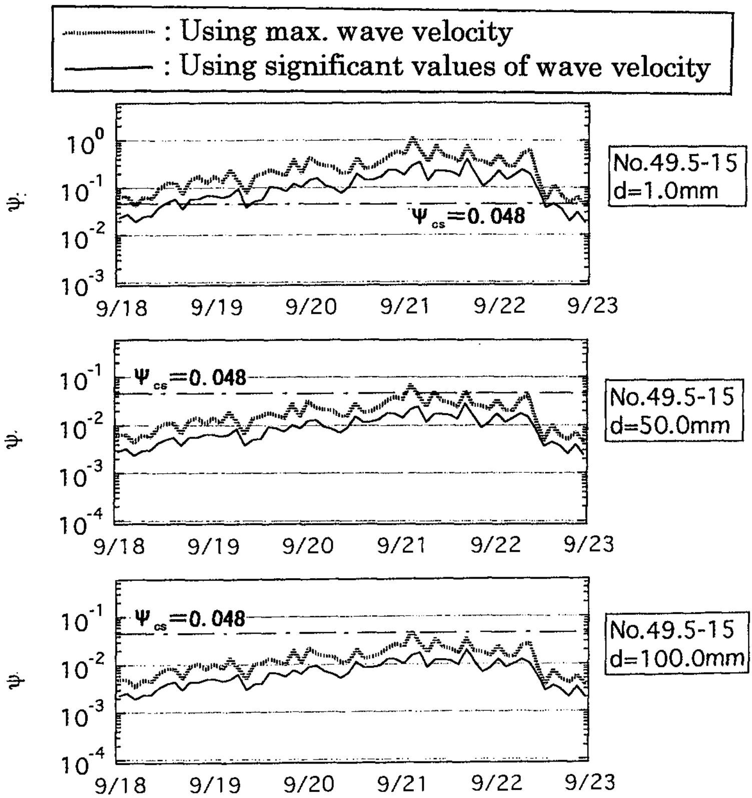

Figure 15 History of Shield parameters during the typhoon 9617