FIELD STUDY FOR WIND-BLOWN SAND ON THE SWASH ZONE

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PURPOSE OF THE STUDY

Niigata West Coast faces the Sea of Japan and Sado Island is located approximately 45 km to the west from there (Fig.1). This coast has suffered severe erosion since the early 1950s. Hiyoriyamahama beach where is a part of the Coast is a highly erosive beach. For the protection of the beach erosion, the combined shore protection system with the jetty, submerged wide breakwater and beach nourishment have been constructed at the beach (Photo 1). There, strong winds from NW to WNW blow in the winter season and nourished sand has been blown off from the beach. For the prevention of blown off nourished sands from the beach, an attempt to develop an integrate system for controlling the wind-blown sand combined with sand fences, a green belt (an artificial low dune) and a vacancy space (road) has been made. To examine the function of the integrate system under development, extensive field surveys for beach topographical changes, wave runup on the swash zone, wind at the site, waves have been conducted.

The purpose of this paper is to describe the field measurement results.

FIELD MEASUREMENTS

Extensive field measurements were conducted during the winter in 2016 and 2017. Beach topographic surveys using by the Terrestrial Laser Scanner (TLS survey, Leica -made Scan Station P40) were conducted at the beginning and ending of the survey. Table 1 shows the survey dates and methods for each year. The horizontal error in TLS survey is less than 5 mm and the vertical error is approximately 6 mm. The horizontal error in UAV survey is approximately 9mm and the vertical error is approximately 20mm.

The high accurate survey clearly portrayed the detailed terrains and enabled the accurate sand volume calculation. Figure 3 and 4 show the beach terrain, variation of ground heights, and specific Regions B, S & R defined for sand budget analysis at the end of measurement period in 2016 and 2017, respectively. The wind was measured at the site and data observed in the weather station located about 5km from the site (Fig.1, AMeDAS) were also used. The runup waves on the swash zone were photographed by a memo-motion video camera (1 frame/1 second) at the point of 650 shown in Fig. 2 (Fig. 2, Mv). Data for the offshore wave were taken from the observation station, NOWPHAS (Nationwide Ocean Wave information network for Ports and HArborS) of Niigata located around 10 km offshore from the site.

SAND BUDGET ANALYSIS

The sand budget is examined by dividing the beach into following three areas.

Region S is the region surrounded by the beginning survey shoreline and the point where the largest runup wave arrived during the observation period. The maximum runup height is estimated from the video images of the runup waves taken during the observation period and the topographic changes at the beginning and ending survey. The estimated maximum runup heights were about D.L.+2.0m behind the existing detached breakwater and D.L.+2.5m at the opening. The exerting forces in this region were runup waves and wind.

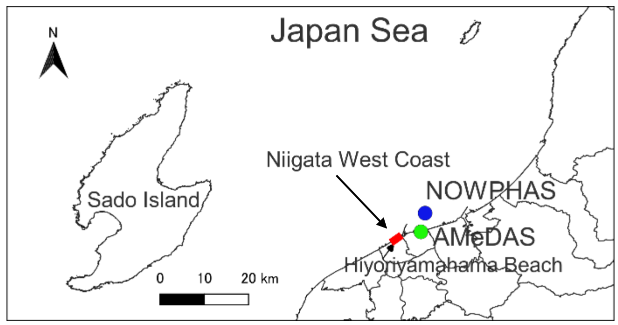

Fig. 1 Location of Niigata West Coast and observation facilities

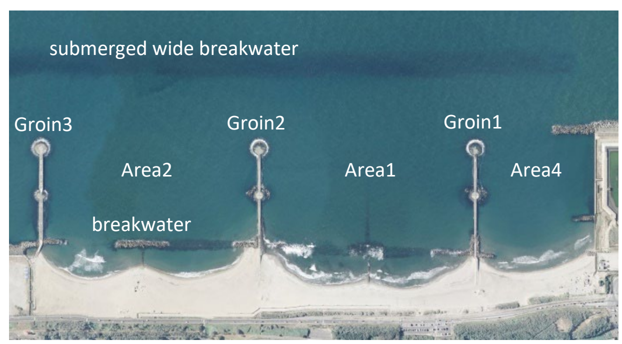

Photo 1 Hiyoriyamahama Beach

Table 1 Survey date and method

	beginning survey	ending survey	survying method
2016	2016 12 19	2017 03 05	TLS
2017	2017 11 21	2018 02 21	TLS

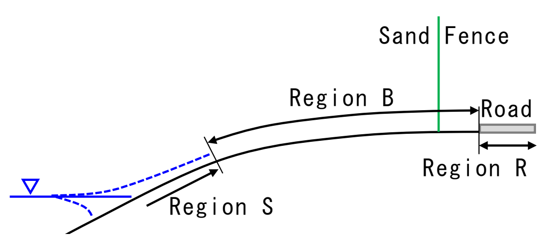

Fig. 2 Region classification for sand budget analysis

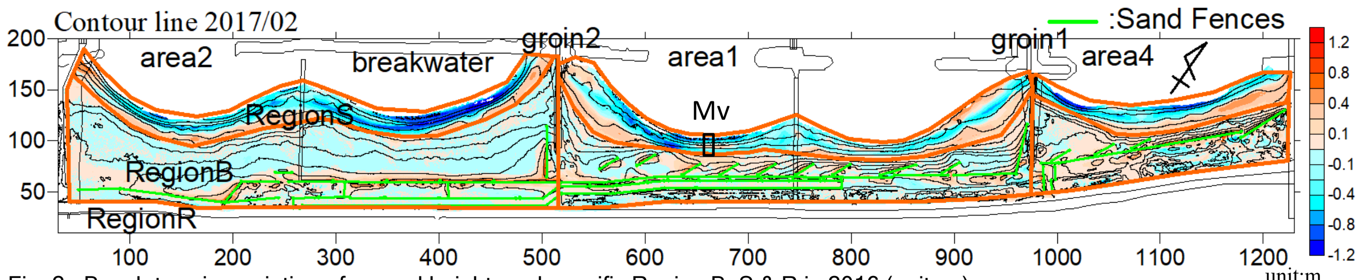

Fig. 2 Beach terrain, variation of ground height, and specific Region B, S & R in 2016 (unit: m)

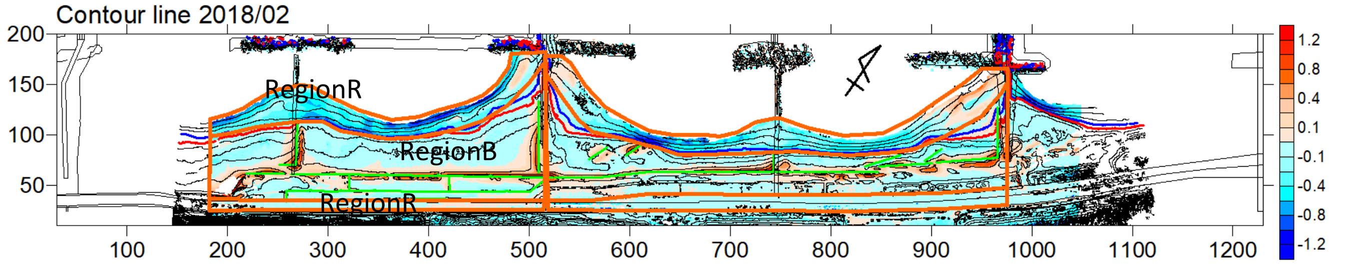

Fig. 3 Beach terrain, variation of ground height, and specific Region B, S & R in 2017 (unit: m)

Region B is the region surrounded by the estimated maximum runup point during the survey period and the seaward edge of the road. In this region, the exerting forces to move the sand are runup waves and wind.

Region R is the road strip adjacent to the landward side of Region B (see Fig.3).

Table 2 shows the change of calculated sand volume in each region. The value for region R in 2016 is an estimate. The amount of sand deposited in region R was estimated to be 0.1 m^3/m, assuming the road shoulder accumulation height as 5 cm and the shoulder width as 2 m. The longshore distances of each area are approximately 470 m for area2, 460 m for area1, and 250 m for area4. The estimated discharge into area R is about 47 m^3 for area2, 46 m^3 for area1, and 25 m^3 for area4. The estimated volume of runoff into area R is about 4.5% of the volume deposited in area B.

The change of sand volume in region B shown in Table-4 is the accumulation, which means that the amount of sand flowing into region B from region S is greater than the one flowing out from region B to the road side (mass conservation law). Region S is the swash zone. The swash zone is wet during stormy weather causing blowing sand by strong winds. This means that the sand is blown out landward by the wind in a wetted swash zone.

The landward side of region R is a steep-sloped hill, and the amount of sand that blows out of region R to the landward side is negligible. The volume of wind-blown sand that has been blown out of region S by the wind is (B+R). The increase in sand volume in region B and region R is the inflow from region S due to the wind. The sand in region S is transported to the landward side by the wind, and the change in S - (B+R) is the amount eroded by the waves.

(B+R)/|S| indicates the rate of erosion by the wind-blown sand in region S. The ratio of erosion due to the wind-blown sand in region S when observing each region indicates the ratio of erosion by the wind increase in the leeward side of the region. The amount of erosion in region S is the one when the ending survey was conducted.

It depends on the sand budget between the swash zone and the offshore area in the region before the survey date. In other words, (B+R)/|S| is not an appropriate indicator to evaluate the amount of sand discharged from region S.

The change in sand volume per unit longshore distance is shown below.

2016：2658 m^3/ 1180 m = 2.25 m^3/m

2017：1959 m^3/ 790 m = 2.48 m^3/m

Table 2 change of sand volume in each region

	Area	RegionS (m^3)	RegionB (m^3)	RegionR (m^3)	Region(B+R) (m^3)	(B+R)/｜S｜	L:Distanse longshore (m)	B+R/L (m^3/m)
2016	Area2	-2652	1021	47	1068	0.40	470	2.27
	Area1	-1348	800	46	846	0.63	460	1.84
	Area4	-716	719	25	744	1.04	250	2.98
2017	Area2	-3110	1174	33	1207	0.39	330	3.66
	Area1	-2291	706	46	752	0.33	460	1.63

The changes of sand volume are those that occurred during the windy season (from mid-December to the early March). The above results indicate that 2-3 m^3/m of sand is discharged from the swash zone to the landward side in one windy season on the Niigata West Coast. Katano et. al. (2021) estimated the amount of wind-blown sand per unit longshore distance during the observation period in area 2 from the amount of accumulation volume around the sand fences installed at the landward edge of the beach.

The values are 4.6 m^3/m in 2016 and 7.5 m^3/m in 2017.The amount of wind-blown sand per unit longshore distance discharged from region R in area 2 is as follows.

2016 : 1068 m^3/ 470m = 2.27 m^3/m

2017 : 1207 m^3/ 330m = 3.66 m^3/m

The ratio of the amount of wind-blown sand generated from region S against the amount of wind-blown sand measured at the land edge is as follows.

2016: 2.27 m^3/m / 4.6 m^3/m = 0.49

2017: 3.66 m^3/m / 7.5 m^3/m = 0.49

This means that about 50 % of the volume of wind-blown sand originates from the swash zone.

WAVE RUNUP HEGHT

The winter high waves on the Niigata West Coast are dominated by the wind waves caused of winter monsoon. Figure 4 shows the relationship between significant wave heights (NOWPHAS) and average wind speed at 2 m above the ground (target wind direction; N235W to N55E, sea to land) for the four-year observation period. It can be seen that the waves on Niigata West Coast are directly related to the average wind speed. The grain size of beach sediment on Niigata West Coast is 0.3 mm, and the critical wind speed at 2m above the ground for generating wind-blown sand is 6.8 m (Bagnold,1954, Zingg, 1952), resulting in a significant wave height of about 2.3 m. During strong winds, the significant wave height increases, the swash zone widens, and the possibility of wind-blown sand in the swash zone increases.

The steel pipes with attached rulers were installed at ground level C.D.L. +1.6 m and C.D.L. +2.4 m at the Mv points shown in Figure-2, and ground deformation was measured at the two points using a video camera. The measurement period was from December 25, 2016 to February 9, 2017.

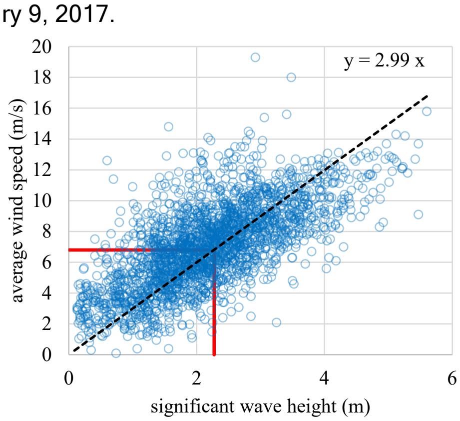

Fig. 4 Relationship between Significant Wave Height and Average Wind Speed (Wind direction: N235W<θ<N55E)

The video images did not show any wave runup at P.2, but traces of wave runup were observed on January 16 and 17, 2017. The maximum wave runup height was estimated to be about C.D.L. +2.5 m. This result is consistent with the maximum runup height estimated from the topographic changes.

The maximum runup wave height in 2017 were calculated using the improved virtual gradient method. The maximum runup wave heights (C.D.L.+2.3 m) estimated by the improved virtual gradient method in 2017 were consistent with the maximum runup wave height (C.D.L.+2.5 m) determined from the topographic change.

RESULTS

High resolution data indicate the following results:

1. The wind-blown sand generates when the wind speed at the height of 2 m on the beach exceeds 6.8 m/s even though the beach sand surface is in the wet conditions. At this time, the significant wave height and the period were 2.3 m and 10.0 sec.
2. The maximum run-up height making up from the topographical data and the runup wave observation was almost matched up with the value estimated by the revised imaginary slope method.
3. The width of the swash zone was about 20m to 40m during stormy conditions higher than the significant wave height.
4. Judging from the sand budget analysis of the beach topography, it became possible to confirm the fact that the wind-blown sand is generated from the swash zone and estimate its volume. The amount of sand blown off from the swash zone during the winter season ranged from approximately 2 to 3 m^3 / m.
5. At the Area 2 shown in Photo 1, the volume of blown sand estimated from the accumulated sand volume around the fences installed at the land side edge of the beach was 4.6 m^3/m in 2016 and 7.5 m^3/m in 2017, respectively. Comparing the ratios of the volume generated from the swash zone and the one measured at the land side edge were 2.27 / 4.6 =0.49 in 2016, and 3.66/7.5=0.49 in 2017, respectively. It results that approximately 50% of blown sand is generated from the swash zone.

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