ANALYSIS OF WAVE RUN UP DYNAMICS AT JOGEHAMA BEACH JAPAN

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The big wave suddenly invaded to the beach, and three children were carried off to the sea by the wave though they played on the beach. The beach characteristic topography has the cusp topography and steep slope. This study tried to comprehend the reason why this accident occurred. Firstly, this study comprehended the wave condition when the accident occurred. Secondary, this study made the survey about the geographic feature of the beach. And this study obtained the geographic data for the numerical simulation from the aerial photograph which were taken by Drone. Finally, this study comprehended the wave dynamics on the beach by the numerical simulation. This study simulated the wave dynamics by the horizontal two dimensional numerical model and the vertical two dimensional numerical model.

Keywords: wave run up; cusp topography; drone; aerial photography; numerical simulation; Niigata prefecture; Japan sea

Introduction

The accident that three children and two adult males who tried to rescue the children died occurred at Jogehama beach Japan in 2014 (see Fig.1). The wave run up to 28m from the shoreline when the accident occurred. The beach was known in the around area for the small cusp topography and steep slope. Therefore, the beach was the swimming prohibited area, and they played on the beach when the accident occurred. However, the big wave suddenly run up to the beach, and the children were swept out to sea. Our group reproduced the wave run up condition by the numerical simulation, and comprehended about the wave run up speed and the water level. This time, we tried to know whether the same phenomenon occurs or not at other coast area in Niigata prefecture.

Firstly, we comprehended the wave condition when the accident occurred. In this case, we used vertical two dimensional model, CADMAS-SURF2D. After comprehending the accident occurred condition, the wave run up condition was comprehended by changing the wave height and the period. According to the result, when the wave height will be about 1m, adults will fall down in the wave run up area. Secondary, we tried to extract the same beach with Jogehama. As the result, some beaches were extracted. According to the result, we went to the extracted beaches, and confirmed that the wave run up conditions were same with Jogehama beach.

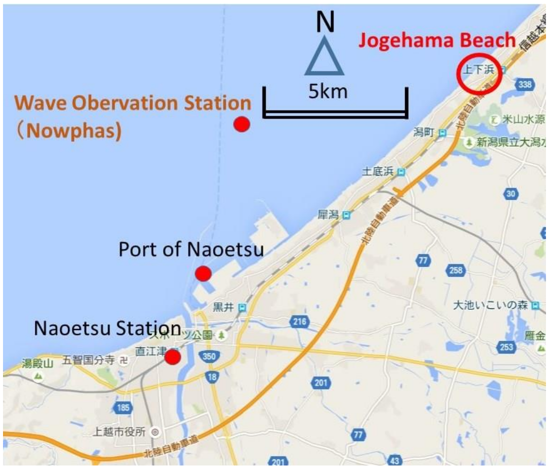

Figure 1. Location of the field

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Figure 2. Compare Distance of Wave Run Up at Accident Date and Field Survey Date.

Compare Wave Run Up due to Wave Period

Inukai et al.(2017) comprehended the wave dynamics on the beach when the accident occurred. Fig.3 shows the relationship between the significant wave heights and the periods in past 5 years. The wave was observed at the Nowphas Wave Obervation Point (MIG, 2012)(see Fig.1). The figure shows when the accident occurred, the wave heights (1.2m) was not high, however the period (7.9 seconds) was large in this wave height division. Therefore, we tried to comprehend the wave run up condition of the other wave period. In this case, we used CADMAS-SURFD2 (CDT, 2001). CADMAS-SURF 2D is supplied by Coastal Development Institute of Technology (CDT). This model solves the Navier-Stokes equation and continuity equation, and also employs volume of fluid (VOF) method to solve the temporal elevation of free surface. This study set the channel length as 190m, and used the anisotropic mesh. In this case, the grid size was set as 10cm in horizon and 5cm in vertical. The wave was entered at the edge of the channel. The wave height was 1.2m only, however the periods were changed as 5.5s, 6.5s and 8.5s. The topographic data that was used to this simulation, was made by UAV (Inukai, 2015).

Fig.4 shows the maximum water level, and maximum run up/downward velocity at 5m point from the shoreline. Furthermore, Fig.5 shows the same results at 10m point from the shoreline.

Both figures show that the maximum run up velocity increases proportionately with the period, however the downward velocity was almost constant. We considered these reasons as follows: the run up current velocity increased due to the incident wave, however the downward current was the gravity flow. Particularly, the water level when the wave period was 6.5s became the maximum height (Fig.4). The wave behavior when the period was 6.5s shows in Fig.6. Figure shows that the water level increase due to collide the incident current and the downward current.

Fig.7 shows the change of wave run up distance due to change the period. Figure shows that the distance of wave run up proportional the wave period. To verify the exactness of result, we compared with the results of equation (1) about the maximum run up height at every period (Maze, 2006). Where, R: Run up height, T: Period, H: Incident wave height, θ: bottom slope, α: constant (=0.405).

$$\frac{R}{H} = \frac{\alpha \tan\theta}{(H/T^2)^{1/2}} \quad (1)$$

This equation calculates the run up height at the uniform slope. In this case, we assumed the bottom slope as 1/4 from the shoreline until 3m depth (Fig.8). Fig.8 shows that the both results are almost same, and we think that the result of the numerical simulation can comprehend the phenomenon qualitatively.

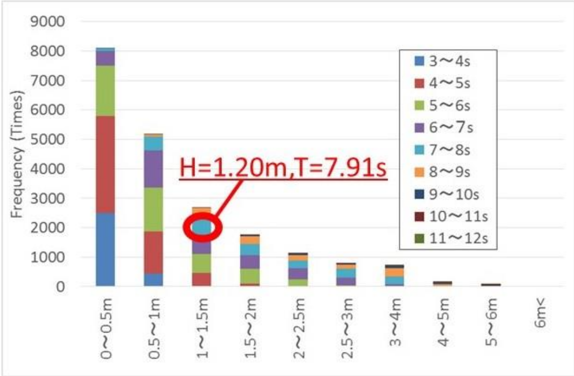

Figure 3. Relationship between Significant Wave Height and Period (Nowphas: Port of Naoetsu, 2007-2011).

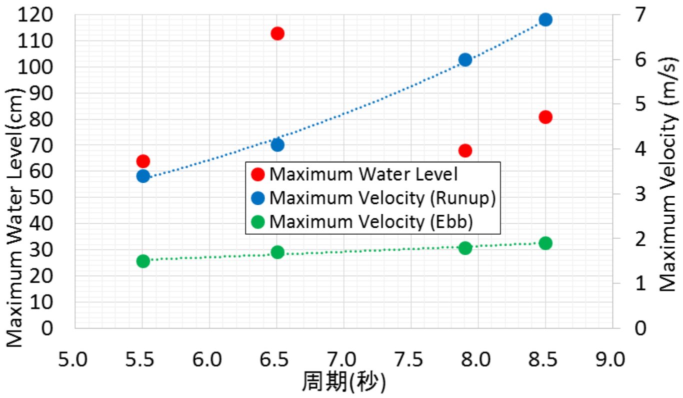

Figure 4. Change of Maximum Water Level and Maximum Velocity (Wave Height:1.2m, 5m from shoreline).

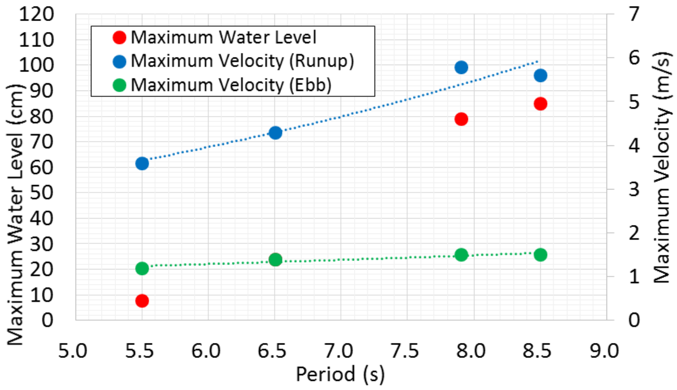

Figure 5. Change of Maximum Water Level and Maximum Velocity (Wave Height:1.2m, 10m from shoreline).

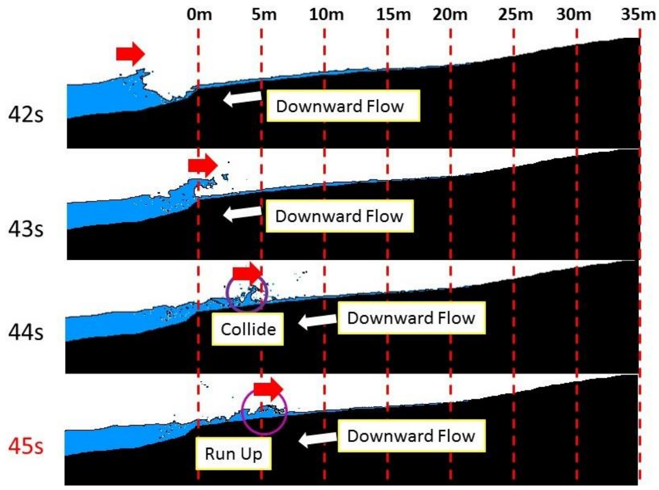

Figure 6. Wave Run Up (jogehama, Wave Height:1.2m, Period:6.5s).

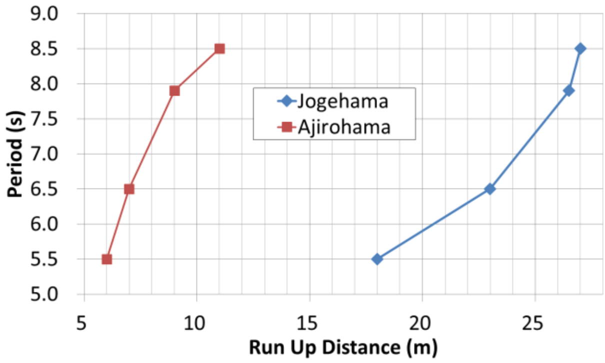

Figure 7. Change of Wave Run Up Distance (Wave Height:1.2m).

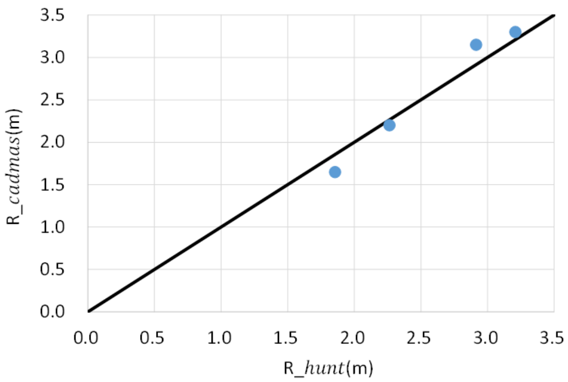

Figure 8. Compare Wave Run Up (Simulation and Equation).

Compare Run up Behavior at Steep Slope and Gentle Slope

Preceding chapter, we comprehended the dynamics of wave run up at the 1/7 slope beach. However, we tried to comprehend the dynamics of wave run up at steep slope beach in this chapter. Fig.9 and Fig.10 shows the Ajirohama beach as a steep slope beach. The slope angle of this beach is about 1/80. Our group measured the topography at the field, and simulated the wave dynamics. The wave condition was set as wave height 1.2m and period 7.9s. The result was compared with the result of 1/7 slope beach. In this case, we set the channel length as 390m, and the grid data as 25cm in horizontal, 5cm in vertical. The wave was entered at the end of the channel (depth was 4.9m). Fig.11 shows the depth change of Jogehama beach and Ajirohama beach. In Ajirohama case, the wave run up short and the wave dynamics at 5m point from the shoreline could not recorded. Therefore, we use at the shoreline data, and we compared with the Jogehama and Ajirohama data of the water level and the velocity at the shoreline. Fig.12 shows change of the water level, and Fig.13 shows change of the velocity. Fig.14 shows the wave dynamics at Ajirohama Beach. Furthermore, Fig.7 shows the wave run up distance.

The wave motion of Ajirohama (Fig.14) decreased less than the result of Fig.6 (Jogehama). The maximum water level at Jogehama was about 190cm (Fig.12), however at Ajirohama was about 35cm. The maximum velocity at Jogehama was about 4m/s (Fig.13), however, at Ajirohama was about 1m/s. The wave run up distance at Jogehama was about 26m (Fig.7), however at Ajirohama was about 9m.According to the above results, the water level, the velocity and the run up distance decreased less than Ajirohama. Therefore, we think, the wave run up accident will not occur at Ajirohama beach.

Figure 9. Location of Ajirohama Beach (Google Map).

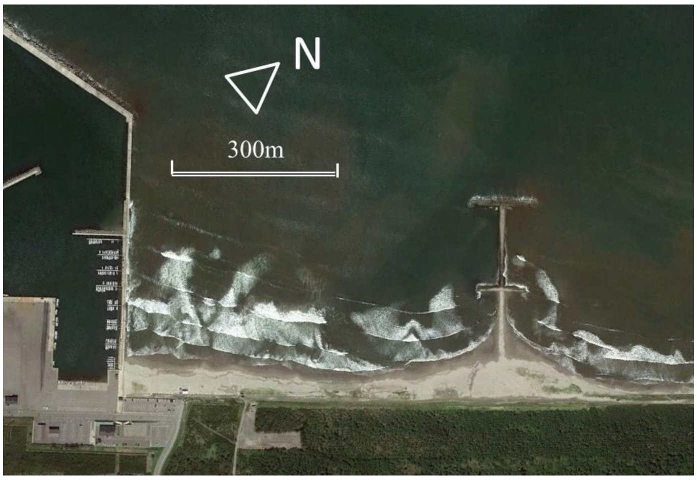

Figure 10. Ajirohama Beach (Google Earth).

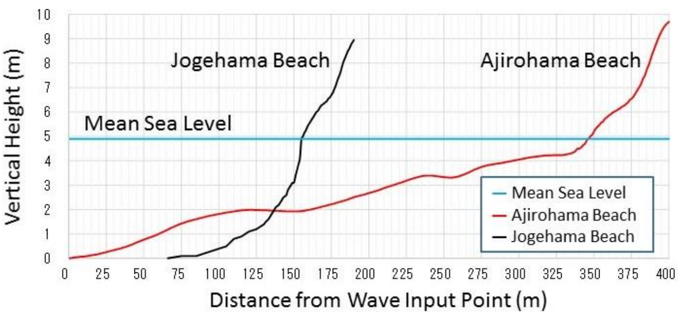

Figure 11. Compare Bottom Slope (Jogehama and Ajirohama).

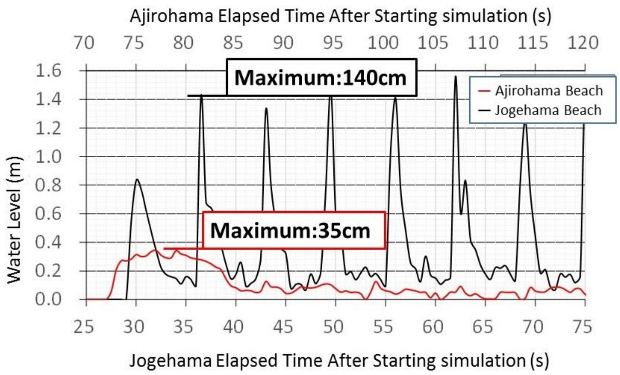

Figure 12. Change of Water Level (on Shoreline).

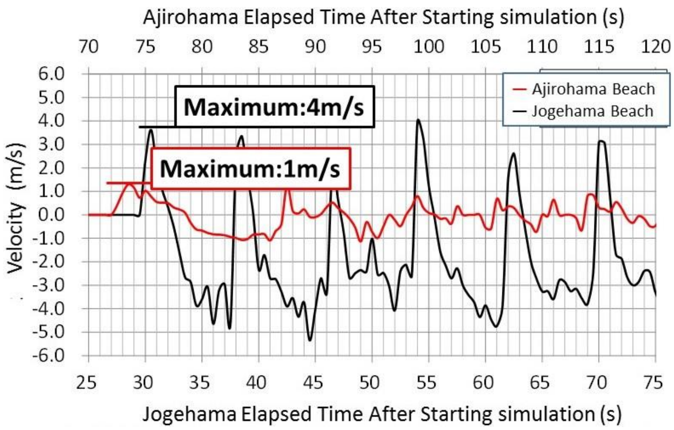

Figure 13. Change of Velocity (on Shoreline).

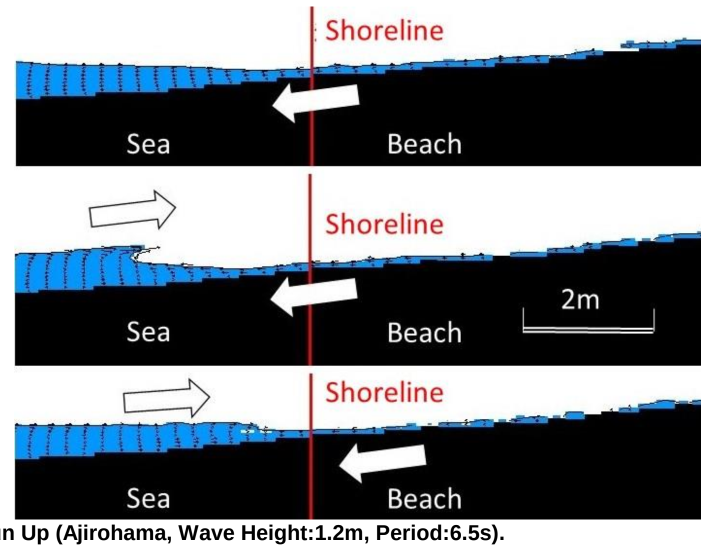

Figure 14. Wave Run Up (Ajirohama, Wave Height:1.2m, Period:6.5s).

Risk Estimation of Jogehama Beach

In, preceding chapter, we comprehended the velocity and the water level of run up wave, however, this chapter, we tried to estimate the risk allowances of Jogehama beach. Asai (2009) estimated the risk allowance of walk in the water flow due to the experiment. As the result, the risk allowance was decided by the relationship between the water level and the velocity (Fig.15). Fig.15 shows that the adult person becomes “walking difficulty”, when the water level becomes 30-40cm or the velocity becomes about 2m/s.

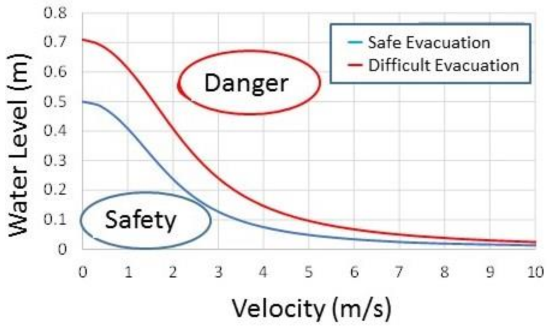

Figure 15. Relationship between Risk allowance and Level, Velocity.

Table 1. Definition of Risk Allowance.

Risk Allowance	Detail
1	Possibility of Child Fall Down
2	Possibility of Adult Fall Down
3	Almost Certainly Adult Fall Down

Table 2. Estimate Risk Allowance at Jogehama Beach (5m from shoreline).

Incident wave height (m)	Period (s)			
	5.5	6.5	7.9	8.5
0.5	15 (1.3)	17 (1.8)	21 (3.0)	21 (4.2)
0.75	34 (2.4)	28 (2.6)	45 (3.3)	58 (4.4)
1.0	64 (2.6)	72 (3.9)	80 (4.4)	94 (4.9)
1.2	64 (3.4)	111 (4.1)	68 (6.0)	81 (6.9)
1.5	69 (3.9)	95 (5.1)	70 (7.0)	84 (5.4)

Water Level (cm), (Velocity (m/s))

Takahashi (1992) shows the safety of the people on breakwater against overtopping waves due to the relationship between the height of people and the water level. According to the results, 1m tall people was fallen down due to 30-40 cm the overtopping level.

The following table summarizes the above descriptions (Table 1.). Furthermore, the risk degree at every wave heights was estimated by the run up velocity and water level at 5m point from the shoreline, these were simulated by changing the wave period. Table 2. shows the risk degree that has the relationship between the run up velocity and the water level. Table 2. shows, when the wave height become over 1m, the risk degree become 3. This means that the adult people possible fall down over 1m wave height.

Risk Estimation in Niigata prefecture

In preceding chapter, we comprehended the risk degree at Jogehama, however, this chapter, we estimated the risk degree due to change the bottom slope and the wave period. And we tried to pick up the beach in Niigata prefecture that has same condition with Jogeama beach. In this case, we set the wave height as 1m.

Firstly, we assume the bottom slope as uniform gradient, and we got the run up velocity and the water level by the simulation due to change the slope and the wave period. And we estimated the risk degree by the according results. Table 3. shows the result at 5m point from the shoreline. Table shows that the risk was estimated as “Danger” at over 6s period when the slope was 1/10. When the wave height is 1m, the over 6s period wave constitutes over 50%. Therefore, when the wave height becomes over 1m, there is possibility of occur the run up wave that push the adult people down.

Take this result into consideration, we tried to pick up the over 1/10bottom slope beach in Niigata prefecture. In this case, we use AW3D30 – 30m grid space data set (JAXA, 2016). Fig.16 shows the part of the result. The figure shows the result of circumference of Kasiwazaki city, where is near to the

Table 3. Estimate Risk Allowance at every bottom slope (Incident Wave Height: 1m).

Bottom Slope	Period (s)			
	5.5	6.5	7.9	8.5
1/10	20 (2.6)	35 (2.8)	40 (5.2)	47 (6.4)
1/20	14 (0.9)	15 (1.7)	20 (2.1)	22 (2.3)
1/30	13 (1.0)	14 (1.1)	16 (2.5)	18 (2.2)

Water Level (cm), (Velocity (m/s))

accident occurred place. The figure shows that there are some picked up beach in this area even Jogehama beach. Fig.17 and Fig.18 show the satellite images of the picked up beach.

Both images show that there are the protected beach by some structures, the artificial reef, the offshore breakwater and etc.

Photo 1. and Photo 2. show the wave run up situations at the picked up beach. Furthermore, Photo 3. shows the wave run up situation at Jogehama beach. Every photo were taken in same day. The wave condition was follows: the significant wave height was 1.4m and the period was 5.4s. This wave was observed at Port of Naoetsu where locates the 20km west from the filming location. For reference, the wave condition when the accident occurred was follows: the significant wave height was 1.2m and the period was 7.9s. The Photos show that Yoneyama beach and Kakizaki-Chuo beach were protected by offshore breakwater, however the incident wave broke near the shoreline, and the wave run up on the beach. These phenomena were same with Jogehama beach (accident occurred beach). From the above result, we think that the wave run up at the picked up beaches, and there is the possibility of occurring the accident same with Jogehama beach. Therefore, we need to pay attention to prevention of the accident.

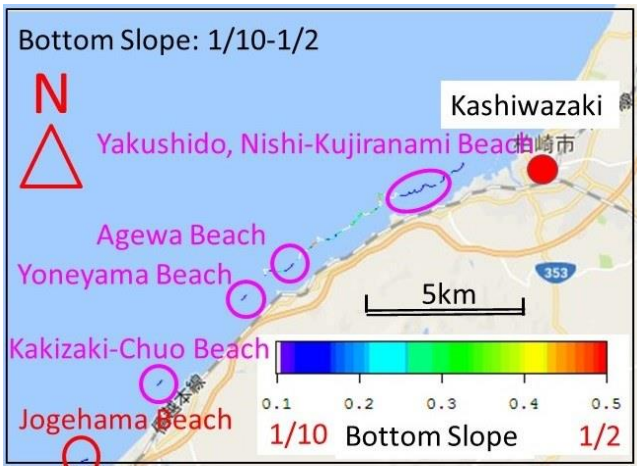

Figure 16. Picked Up Beaches (nearby Jogehama) (Google Map).

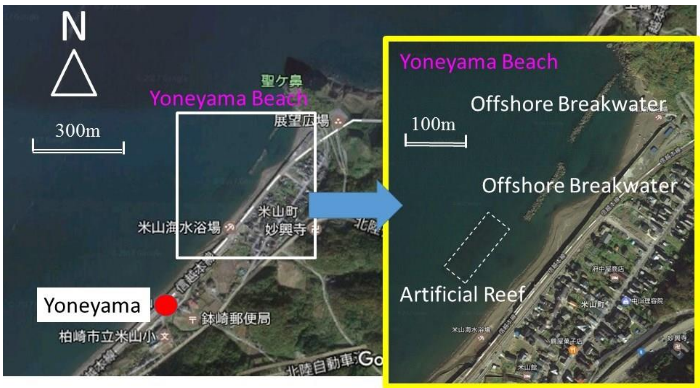

Figure 17. Picked Up Beach (Yoneyama Beach)(Google Earth).

Photo 1. Picked up beach (Yonayama beach, 8th May, 2017, Significant wave height:1.4m, Period:5.4s).

Figure 18. Picked Up Beach (Kakizaki-Chuo Beach) (Google Earth).

Photo 2. Picked up beach (Kakizaki-Chuo beach, 8th May, 2017, Significant wave height:1.4m, Period:5.4s).

Photo 3. Picked up beach (Jogehama beach, accident occurred beach, 8th May, 2017, Significant wave height:1.4m, Period:5.4s).

Conclusion

We comprehended the wave run up dynamics by the numerical simulation due to change the bottom slope and the wave condition. Furthermore, we estimated the risk allowance using the run up velocity and the water level. From these results, the risk about the fall down of the adult person is high when the wave height becomes over 1m at Jogehama beach. Furthermore, when the bottom slope becomes over 1/10 and the wave height becomes over 1m, the risk about fall down of the adult person is high. Referring to the results of above thing, other beached were picked up in Niigata prefecture.

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