INVESTIGATION OF QUANTITATIVE SANDBAR MONITORING USING UAV AND SEDIMENT ANALYSIS AT BABAMEGAWA RIVER

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ABSTRACT: Large-scale flood damage was caused one after another by typhoons and heavy rains in Japan. In 2023, Japan's Akita Prefecture suffered severe flood damage due to record heavy rains. Therefore, investigating the mechanism of riverbed variation in rivers was important for flood control planning. It was necessary to understand the particle size distribution of riverbed materials in river planning and sediment outflow forecasting. However, in many cases, the grain size considered in numerical calculations was only for the surface layer because collecting sediment requires heavy labor, and it has not been studied much in the depth direction. In this study, sediment was collected from multiple locations on the sandbar in the middle reaches of the Babamegawa River, which was a class B river in Akita Prefecture. Then, the particle size analysis was performed in the cross-sectional and longitudinal directions. Sediment was collected, and changes in particle size were confirmed before and after the flood. In addition, assessing observations of sandbars using UAV were carried out to evaluate the behavior of sandbars. As a result, it was found that D50 increases or decreases depending on the scale of the flood in both the transverse and longitudinal directions. In the depth direction, changes in particle size were confirmed even at a depth of 70 cm, which was the deepest part investigated in this study.

Keywords: D50, UAV, Babamegawa River, Before and after the flood

1. INTRODUCTION

Akita Prefecture in Japan suffered severe flood damage due to record heavy rains in 2023. Flood damage caused by typhoons and heavy rains has occurred frequently in Japan [1]. The particle size distribution of riverbed materials in river roads was also an important index from the viewpoint of sediment management [2]. In addition, the average particle size obtained from the particle size distribution has also been used to grasp the characteristics of rivers and river planning using numerical calculations in recent years. The particle size distribution of riverbed materials has been widely carried out in past studies [3,4]. However, the collection of sediment was heavy labor, and it was costly to use heavy machines [5]. Therefore, there were many things related to the surface layer of the riverbed in consideration of the particle size. The examination of the riverbed material in the deeper point has not been done much. In this study, sediment was collected from multiple locations on the sandbar in the middle reaches of the Babamegawa River [6], which was a Class B River in Akita Prefecture. Then, the particle size analysis was performed in the crosssectional and longitudinal directions. Sediment was collected twice to see the change in grain size before and after the flood.[7] Previous studies[8] have shown that sediment transport within a river segment can be in equilibrium or non-equilibrium, depending on the amount of sediment entering and leaving the segment. The flow velocity profile with sediment feeding tends to become more slender than that without sediment feeding. In addition, assessing observations of sandbars using UAV were carried out to evaluate the behavior of sandbars. UAVs (Unmanned Aerial Vehicles) were used in a variety of fields. In previous studies [9], monitoring studies using UAVs have been conducted on sandbars formed at the mouth of rivers. The study found that (1) Sandbar area and river mouth width have a positive interrelation between river discharge and cross-shore waves. (2) The sandbar area has a strong negative interrelation between river mouth width. In addition, it is known that the shape of the sandbar changes depending on the season. A typical use is aerial surveying. In this study, the shape, area, width, and length of the sandbar were briefly examined. In addition to this, data on major floods in 2023 were added and summarized. The images taken using the UAV were able to calculate the sandbar area, the length of the sandbar and the width of the sandbar from the topography reconstructed by SfM(Structure from Motion) method. In this study, data from water level stations near the study were used to compare the parameters of the sandbar. In the study, data from water level stations shows that floods occur several times a year. On the Sea of Japan side of Japan, cold monsoon winds receive heat and water vapor from the Sea of Japan and form snow clouds. Especially in Akita Prefecture, sandbars tend to develop due to the influence of snow, which affects the flow of rivers. Therefore, it was important to study the sediment particle size and to study the long term. It was new to consider the sediment grain size before and after the flood and the results of the UAV.

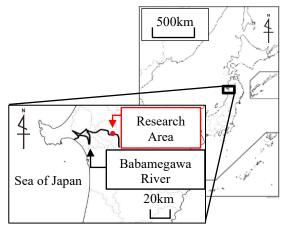


Fig. 1 Study Area.

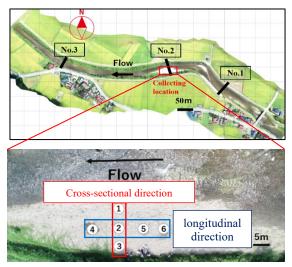


Fig. 2 Aerial photograph by UAV (August, 2021).

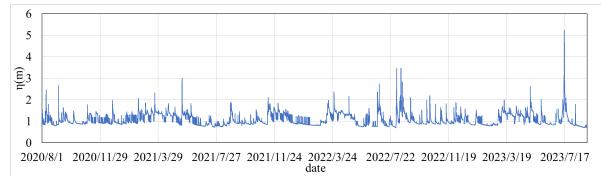


Fig. 3 River discharge variation from August, 2020 to September, 2023.

2. RESEARCH SIGNIFICANCE

This research will lead to the elucidation of the mechanism of riverbed fluctuations in rivers. Examples of elucidation include investigating the particle size of sediment and simulations using numerical calculations. Japan believes that there is an urgent need to review river management due to recent flood damage. The mechanism of riverbed variation has not yet been fully clarified. This research will lead to the understanding of the characteristics of riverbed fluctuations and the establishment of prediction methods.

3. RESEARCH AREA

Fig. 1 was shown that the Babamegawa River flowed into the Sea of Japan and was the largest Class B The calculation area is shown in Fig.2. It was Babamegawa River in Hiranoshita area. The calculated area was an extension of about 850 m section of the Babamegawa River middle basin flat, and the survey data of the river improvement work in 2014 was used for the topographical condition. The river width is about 40 m in all sections, and from the embankment to the riverbed was about 4 m. In this

Study, to compare with the calculated result, three measuring lines (No.1~3) were determined, as shown in Fig.2.

4. RESEARCH METHODS

4.1 Riverbed Material Survey

Riverbed materials were collected from the sandbar, indicated by the red frame in Fig.2(top). All seven stations (1~6) in Fig.2(bottom) were surveyed, and the points collected in 2021[7] and 2022 were St.1 to 6. St.1 to 3 were cross-sectional directions, and St.4 to 6 were longitudinal directions.

Fig. 3 shows the river discharge variation of the Babamegawa River at the Kubo Observatory, which is several kilometers downstream from the survey site, from August to November 2021 and 2022. In 2021/7~11, floods with a water level of about 2 m occurred twice, and in 2022/7~8, there were two days when the flood danger level exceeded 3.4 m and six days when the water level exceeded 2 m. Sediment samples were collected twice before and after the flood.

At seven sites, about 6,000 g of riverbed material

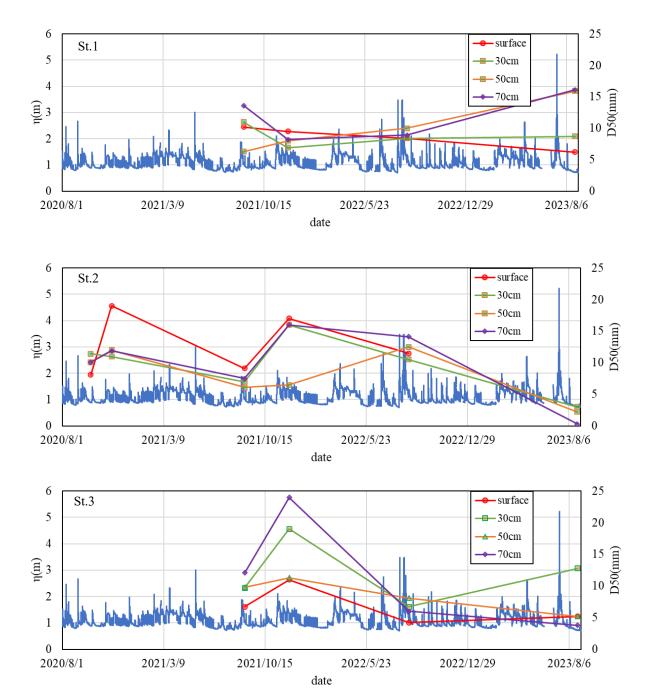


Fig. 4 D50(Cross-sectional Direction)

was collected from each layer, about 50 cm square from four layers of surface layer, depths of 30 cm, 50 cm, and 70 cm. In addition, the collected earth and sediment were dried, and the sifting test was carried out according to JIS A1204 [10] using about 4,000 g as a sample.

4.1.1 Cross-sectional Direction

St.3 was not flooded under normal conditions because it is on the shoreside, but in 2021, a large amount of fine sediment was washed away by the outflow of about 2 m, which increased the size of D50.

However, after the 2022 flood, the D50 level was smaller than before the 2021 flood, and it is thought that coarse sediment was swept away by floods exceeding the flood danger level and intermittent flooding. The D50 after the 2021 flood was $6.9\sim24.0$ mm regardless of the sampling position and depth, but the D50 after the flood in August 2022 was $4.2\sim14.1$ mm, which was the same trend as before the flood in 2021. (Fig.4)

4.1.2 Longitudinal direction

Figure 5 shows the D50 of sediment collected

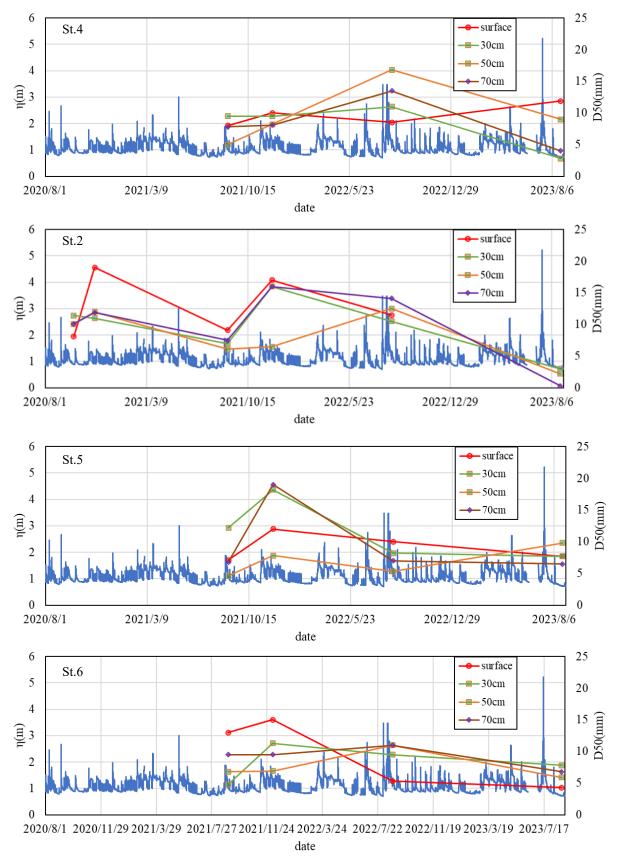


Fig. 5 D50(Longitudinal Direction)

in (a) August 2021, (b) December, 2021, and (c) August, 2022 in the longitudinal directions (St. 4, 2,

5, and 6).
Looking at St.6, which was close to the water

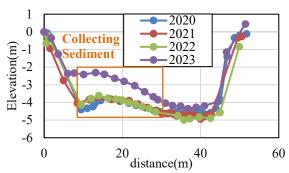


Fig. 6 Cross-sectional survey results of geodesic No.2.

impulse and upstream of the sandbar, there was no change except for the surface layer.

On the other hand, in St.4, there was no change in particle size when looking at D50 in 2021/8 and 2021/12, but after the flood in 2022, fine sediment flowed out due to inundation, and the particle size became coarser. In both the transverse and longitudinal directions, the D50 in 2021/12 tended to be larger than in the pre-flood (2021/8), which was due to the outflow of sediment with a small particle size from the sandbar due to the flood of about 2 m that occurred in the latter half of August and the first half of November. In 2022, the water level was higher than in 2021, and the flood flooded the entire sandbar, so not only fine sediment but also coarse sediment was washed away over a wide area of the sandbar, and as a result, D50 was reduced. Therefore, the size of the water level and the frequency of flooding were greatly related to the change in particle size of the sandbar.

Fig.6 shows the results of geodesic No.2 as a representative of the cross-sectional survey results. The normal water level in the target area was around 0.88 m, and the sandbar was flooded by flooding around 2 m. According to the data of the Kubo Observatory, there were two days when the flood danger water level exceeded 3.4 m during this period, and the water level 2 In Survey 2, where the sandbar exists, sediment was scoured after the flood on the left bank side, and sediment was deposited in the center of the river channel.

4.2 UAV (Unmanned Aerial Vehicle) monitoring

Figure 7 shows an aerial view of the target sandbar. Figure 8 shows the relationship between previous studies 7) $(2017/9/11\sim2018/11/28)$ and the water level $\eta(m)$ and sandbar area A (m^2) on the day observed in this study. The dotted line showed a trendline. When the water level was lower than the normal water level of 0.88 m, the area of the sandbar tended to increase rapidly. Figure 9 shows the relationship between previous studies 7)

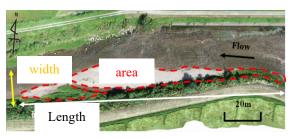


Fig.7 Sandbar area

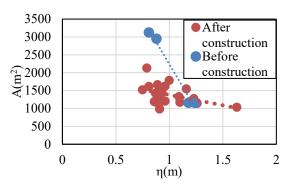


Fig.8 Water level and sandbar area

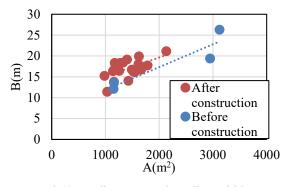


Fig.9 Sandbar area and sandbar width

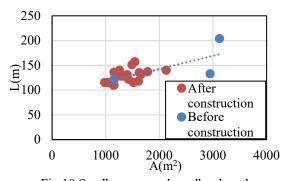


Fig.10 Sandbar area and sandbar length

 $(2017/9/11\sim2018/11/28)$ and sandbar width B(m) and sandbar area A(m²) on the day observed in this study. Figure 10 shows the relationship between previous studies 7) $(2017/9/11\sim2018/11/28)$ and the sandbar length L (m) and sandbar area A (m²) on the day observed in this study. When the width of the sandbar changed by 1 m, the area of the sandbar changed by 100 m^2 , which was proportional. When the sandbar length changed by 1 m, it changed by about 10 m^2 .



Fig.11 Geometry change of sandbar

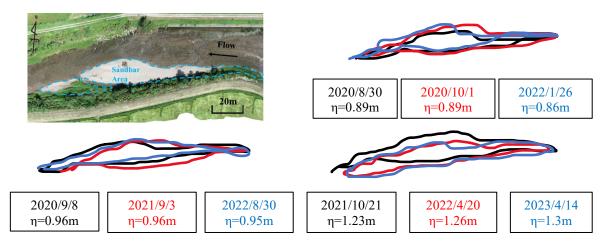


Fig.12 Transition of sandbar morphology

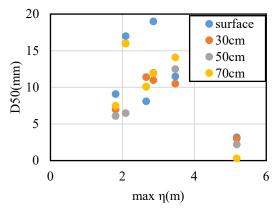


Fig.13 Relationship between maximum water level and D50 at St.2

Looking at the relationship between sandbar width and sandbar area, it was found that the sandbar area increased by 300 m² for every 1 m longer sandbar width. In addition, when the relationship between the sandbar length and the sandbar width was examined, it was found that the sandbar width increased as the sandbar length increased. Therefore, the water level, sandbar width, and sandbar length are all related to the change in sandbar area in the target sandbar. Therefore, it is considered that the runoff and reformation of sandbars occur on the upstream side, where the length of the sandbar changes, and in the center of the river channel, where the width of the sandbar changes.

In the middle basin of the Babamegawa River, which is the subject of the study, it was found that sandbanks were repeatedly runoff and reformed due to the effects of snowmelt and flooding. Sandbar runoff and reshaping are thought to have taken place upstream and in the center of the river channel. In addition, from the results of the cross-sectional survey, sedimentation and scouring were observed in the target sandbar due to flooding caused by heavy rain in August 2022, and it is thought that the influence of the water level and the center of the river

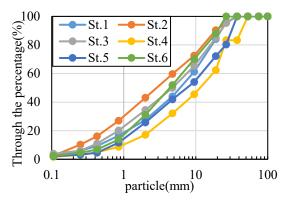


Fig.14 Particle size additive curve by point of surface layer (2023)

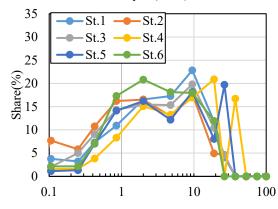


Fig.15 Surface Occupancy by Point (2023)

channel is related to the change in sandbar area.

Fig. 11 shows the shape change of the target sandbar. At the water level of 1.84 m (2022/10/11), the entire sandbar was flooded. At the time of flooding, it began to flood from the upstream side of the sandbar.

Fig. 12 shows the shape of the sandbar when the water level is almost the same. There was no change when the water level was normal, but when the water level was high, the shape of the sandbar changed. In particular, when $\eta = \text{around } 1.5$, sediment was observed in the center of the sandbar from 2022

to2023.

Fig. 13 shows the relationship between the maximum transition in St. 2 and D50. This shows that when the water level is 4 m or less, the D50 increases as the water level rises, regardless of the depth. On the other hand, when the water level reached the flood danger level, there was no relationship.

Figure 14 shows the point-by-point particle size accumulation curve of the surface layer after the 2023 flood. This shows that coarse sediment was swept away at the high altitude of St.2 at the surface layer, and a large amount of fine sediment with a particle size of 10 mm or less was deposited. At the high altitude of St.4, only fine sediment was swept away, and sediment with a coarse particle size remained. In addition, the proportion of sediment with finer particle size was larger in the water barrier such as St.6, and the exchange of sediment was more severe.

Fig. 15 shows the occupancy of particle size in the surface layer of each point. Looking at this, the peak value of the occupancy rate was 2 mm in St.6, which was the finest. The largest was St. 4, located at the bottom of the sandbar. Therefore, it is thought that in this flood, sediment was swept away from the upstream side of the sandbar, and fine sediment was deposited. As a result, fine sediment did not accumulate much on the downstream side of the sandbar, and coarse sediment was occupied. It is thought that there was a sweep of coarse sediment in the surface layer.

5. CONCLUSIONS

In this study, riverbed material was collected from the middle basin of the Babamegawa River in the plane direction and the vertical direction, and the particle size distribution was examined.

As a result of particle size analysis of riverbed materials.

It was found that the size of the water level and the frequency of flooding were greatly related to the magnitude of the particle size change.

Comparing 2023 with 2020 to 2022, it was found that the elevation at the time of sediment collection was different. In the 2023 heavy rains in Akita Prefecture, there was a difference in elevation of up to about 2 m compared to last year due to the particularly large-scale flooding in three years. Here, in 2023, sediment with a small particle size was deposited after the flood, and it is thought that D50 became smaller due to the effect.

In the longitudinal direction, there was no significant change in particle size after large-scale flooding, and the particle size decreased. After the small-scale flood, only sediment with a fine particle size was swept away, and the particle size increased.

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