International Journal of GEOMATE, April 2023, Vol. 24, Issue 104, pp.93-100
ISSN: 2186-2982 (P), 2186-2990 (O), Japan, DOI: https://doi.org/10.21660/2023.104.s8552
Geotechnique, Construction Materials and Environment

STUDY ON SEDIMENT GRAIN-SIZE MEASUREMENT AND CALCULATIONS AT MULTIPLE POINTS ON THE SANDBAR IN CLASS B RIVER

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*Corresponding Author, Received: 18 Nov. 2022, Revised: 12 Jan. 2023, Accepted: 26 Feb. 2023

ABSTRACT: In recent years, flood damage was frequently occurring by the flow rate of rivers has increased due to heavy rains such as typhoons in Japan. Therefore, understanding the particle size distribution of riverbed materials was an important factor 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 heavy sediment 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 twice to see the change in grain size before and after the flood. From the results, the D50 of the sediment collected after the flood tended to be larger than that of the sediment collected before the flood in both the cross-sectional and longitudinal directions. In the depth direction, it was confirmed a layer in which the particle size changes and a layer in which the particle size does not change.

Keywords: Babamegawa River, Sandbar, Particle size, Diameter50, Numerical calculation

1. INTRODUCTION

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 was also used for grasping 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 inathe 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 cross-sectional and longitudinal directions. Sediment was collected twice to see the change in grain size before and after the flood. In addition, the numerical calculation of the studies using the middle basin of the Babamegawa River as the calculation area was a reproduction calculation of the flow in which the roughness coefficient of Manning was changed depending on the location [7], Study on the Behavior of sandbar using UAV (Unmanned Aerial Vehicle) [8][9], but numerical calculations set for the mixed particle size have not been performed. Therefore, numerical calculations were performed using particle size distribution and exchange layer thickness obtained from actual riverbed materials, and the calculation results of uniform particle size and mixed particle size were compared.

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(0~6) in Fig.2(bottom) were surveyed, and the points collected in November 2020 were St.0, and the points collected in 2021 were St.1 to 6. St.1 to 3 were cross-sectional directions and St.4 to 6 were longitudinal directions.

Fig. 3 was shown 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. A flood of river discharge over 40 m^3/s has occurred twice during that period. Sediment samples were collected twice before and after the flood of river discharge 40 m^3/s shown in Fig. 3

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

4.2Particle Size Analysis Results and Discussions

4.2.1 Vertical Direction

Figs. 4 and 5 were shown the grain size accumulation curve and the occupancy of the sample stopped in each sieve of St.0 sediment. When the median diameter(D50) of each hierarchy was compared, it was about 13 to 14 mm in the range of 19 mm in the surface layer and 30 to 70 cm deep. The peak occupancy values were 9.5 to 26.5 mm. The grain size accumulation curve of St.0 did not differ in the grain size accumulation curve in the range of 30 to 70 cm deep. However, when the particle size addition curve of the riverbed material collected from August to November 2021 is seen, the tendency by the depth like St.0 was almost non-existent.

In addition, The thickness of the replacement layer was not formulated. Therefore, the grain size accumulation curve in the middle basin changes greatly depending on the time and position of collection.

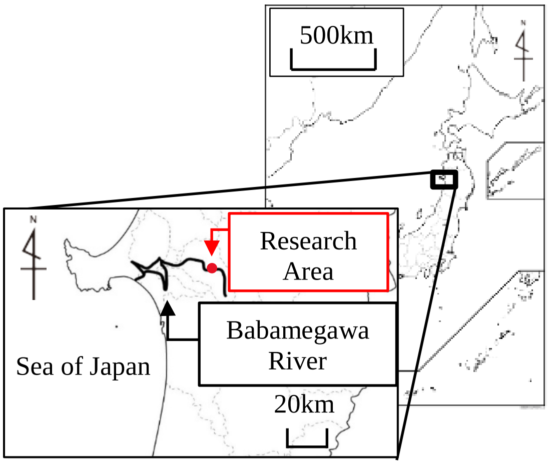

Fig. 1 Study Area.

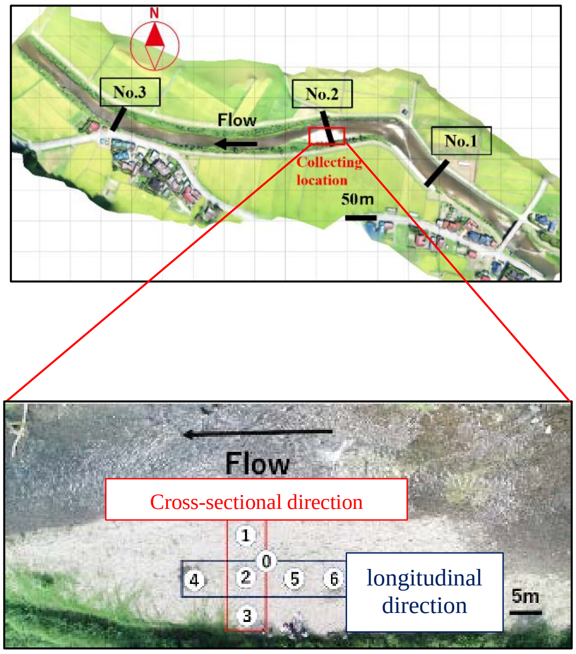

Fig. 2 Aerial photograph by UAV (August, 2021).

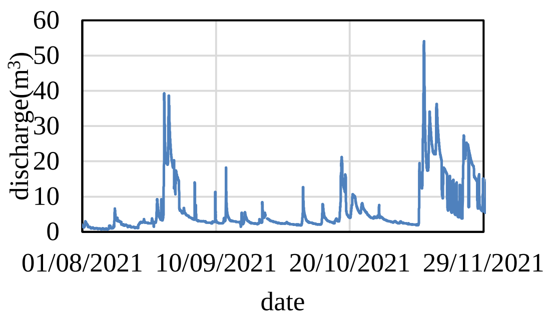

Fig. 3 River discharge variation from August to November, 2021.

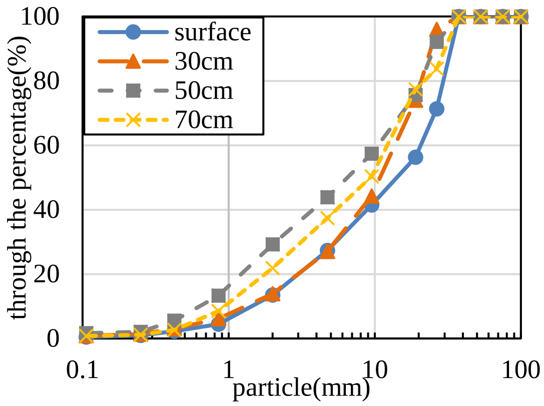

Fig. 4 Grain size accumulation curve at St.0. (November, 2020).

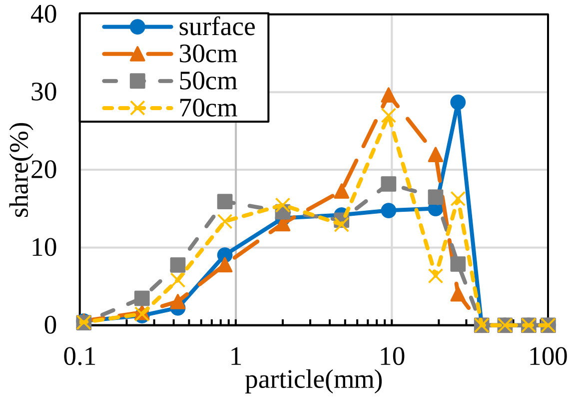

Fig. 5 Occupancy of sediment at St.0. (November, 2020).

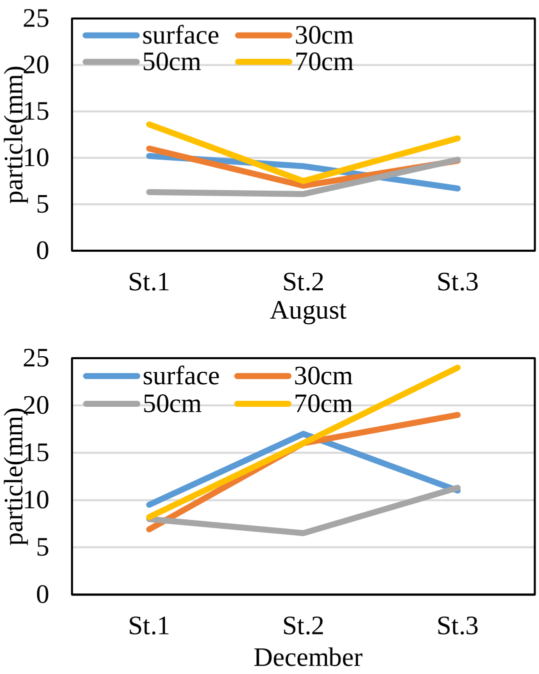

Fig. 6 Cross-sectional direction in 2021(D50).

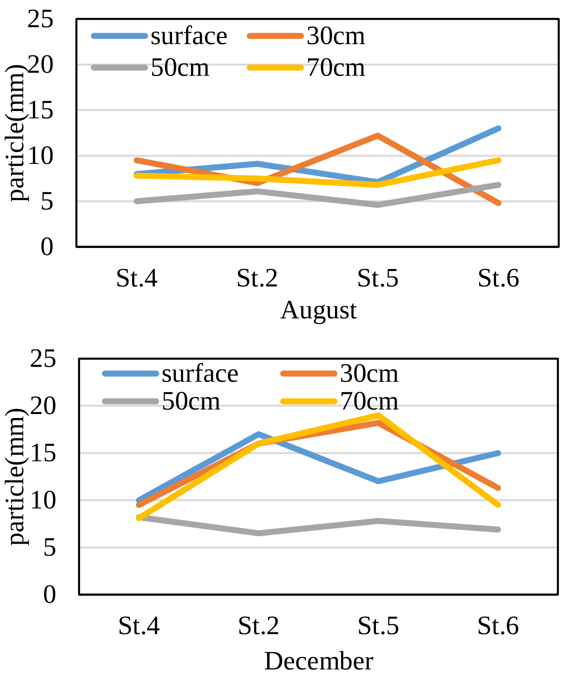

Fig. 7 Longitudinal direction in 2021(D50).

4.2.2 particle size comparison before and after the flood

Fig. 6 was shown D50 in the cross-sectional direction of August and December 2021. St.3, located on the shore, showed a tendency to have a coarser particle size in December than in August at a depth of 30 cm and 70 cm. The D50 of the sediment collected in August ranged from 6.1 to 13.6 mm, regardless of the sampling point or depth. On the other hand, when the sediment collected in December was compared, st.1 was 6.9 to 9.5 mm, and St.2 and 3 were more than 10 mm. D50 after the flood tended to be larger than before the flood. it was thought to be due to the flood of a river discharge of over 40 m^3/s that occurred in the second half of August and the first half of November, and small particles of sediment flowed out of the sandbar. St.3 significantly increased particle size change and became coarser. As a reason, since the shoreside was not flooded at normal times, it was considered that more fine sediment was washed away than at other points.

Fig. 7 was shown D50 in the longitudinal direction of August and December 2021. D50 in August was 5.0 to 13.0 mm, regardless of the location and depth of the collection. On the other hand, D50 in December showed st.4 was 8.1 to 10.0 mm, while St.2, 5 and 6 were 9.5 to 19.0 mm except for a depth 50 cm. D50 was bigger after the flood tendency to become the same as the cross-sectional

Table 1 Particle size input pattern

pattern		Particle size setting	particle size
a	1	Uniform particle size	7.8 mm (2020/10 D50)
	2		14.3 mm (2020/10 occupancy peak)
	3		19.0 mm (2020/11 D50)
	4		23.5 mm (2020/11 occupancy peak)
b	1	Mixed particle size	Deep 50 cm（2020/11）

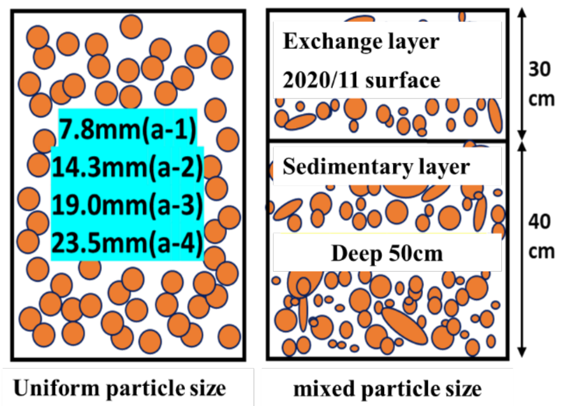

Fig. 8 Setting model

Table 2 Calculation conditions

	Uniform particle size	Mixed particle size
Manning number	riverbed 0.03 other 0.04	riverbed 0.03 other 0.04
Time step	0.1s	0.1s
Exchange layer		30 cm
Sedimentary layer		40 cm
Number of layer thicknesses		25

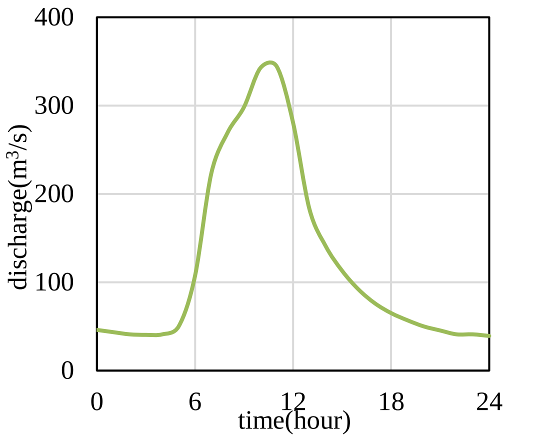

Fig. 9 The boundary conditions at the upstream end

direction, but there was no change as much as the cross-sectional direction.

In the longitudinal direction, the grain size tended to be coarse in the upper part of the sandbar and fine in the middle and downstream areas in the Tamagawa River of the Class A River[11].

4.3 Numerical Calculation

4.3.1 Calculation Model

In this study, the two-dimensional calculation model was used based on the past studies[7-9]. The continuous equations and equations of motion used this time were shown in equations (1) to (3).

$$\frac{\partial h}{\partial t}+\frac{\partial (hu)}{\partial x}+\frac{\partial (hv)}{\partial y}=q+r \quad (1)$$

$$\frac{\partial (uh)}{\partial t}+\frac{\partial (hu^2)}{\partial x}+\frac{\partial (huv)}{\partial y}=-hg\frac{\partial H}{\partial x}-\frac{\tau_x}{\rho}+D^x \quad (2)$$

$$\frac{\partial (vh)}{\partial t}+\frac{\partial (huv)}{\partial x}+\frac{\partial (hv^2)}{\partial y}=-hg\frac{\partial H}{\partial y}-\frac{\tau_y}{\rho}+D^y \quad (3)$$

Where h was the water depth, t was the flow velocity in the x direction, v was the flow velocity in the y direction, q was the amount of inflow by the culvert, gutter, and pump per unit area, r was the amount of rain, g was the gravitational acceleration, H was the water level, τx was the riverbed shear force in the x direction, τy was the riverbed shear force in the y direction, and ν was the density of water.

4.3.2 Calculation Case

The typical particle size used for numerical calculation of uniform particle size was generally using the central particle size D50 of the surface layer. However, the difference was large between the peak value of the occupancy and the D50, and the particle size distribution of the surface layer was different depending on the collection time. In this study, we used the particle size distribution obtained numerical calculations of 5 patterns shown in Table 1 and Fig.8 based on the past study. The input particle size values used the D50 and occupancy peak values of the surface layer of sediment collected in October and November 2020. Table 2 showed the calculation conditions. The boundary conditions at the upstream end (Fig.9) were 24 hour river discharge from 6:00 p.m. 24th to 6:00 p.m. 25th August, 2018 at the Observatory.

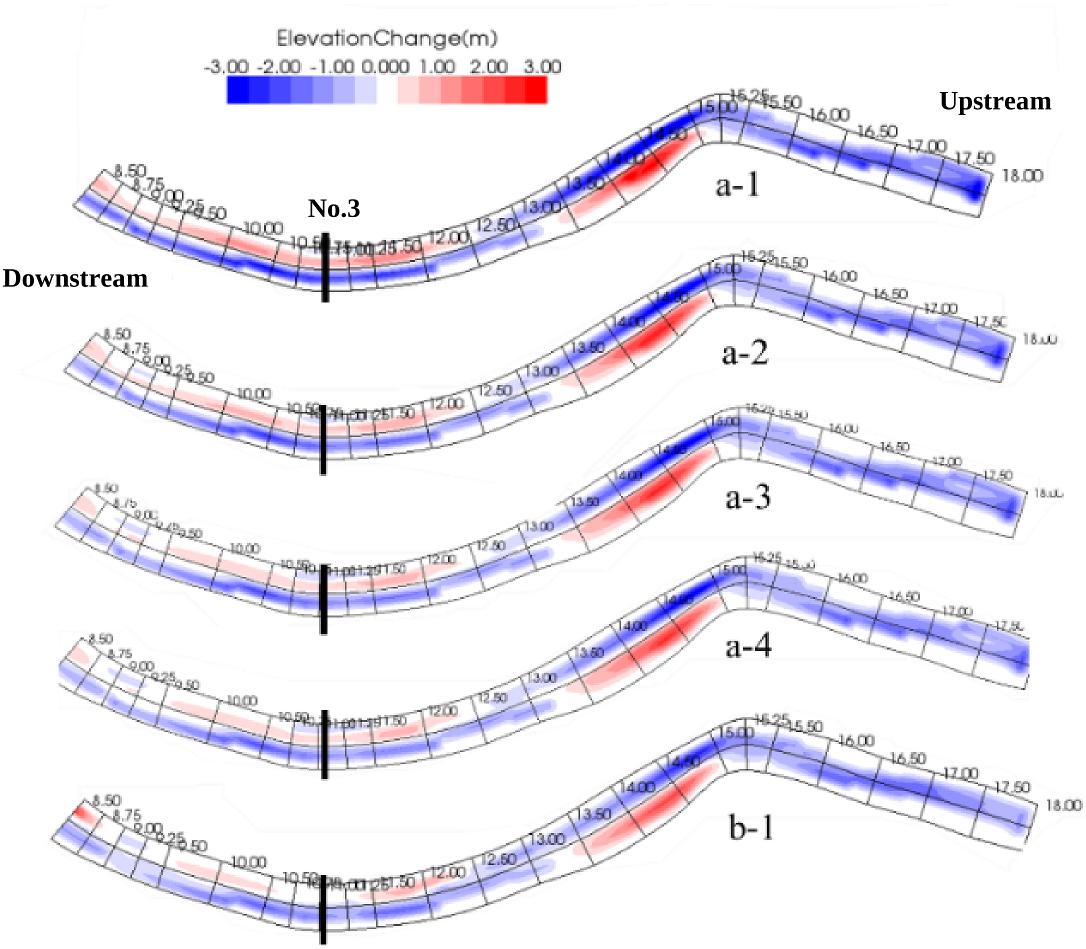

Fig. 10 Elevation change during peak river discharge.

In this study, the longitudinal direction interval was set to 5 m and the cross-sectional direction was set to 10 divisions, and a computational lattice was created using a non-positive lattice.

4.4 Calculation Results and Discussions

Fig. 10 showed the change in the riverbed height at the peak river discharge. The numeral was displayed for each cell relative to the downstream end of the calculation area. The red color of the figure shows sedimentation and blue shows scour. When pattern a was compared as a whole, the larger the particle size, the smaller the fluctuations in the riverbed. However, the tendency of the scoring and deposition was similar regardless of the particle size. On the other hand, the amount of riverbed variation in pattern b was smaller than that of pattern a. And sedimentation was observed on the right bank of pattern a near the line, but no deposition was observed in pattern b.

Upstream and downstream flow velocities in the calculation area were examined. The upstream flow velocity 7 and 11 hours(the peak river discharge) after the calculation is shown in Figs. 11 and 12. The result of the calculation of the uniform particle size up to the peak flow rate (after 11 hours) shows disturbance in the flow even in the straight part, but the flow along the river channel can be seen in the mixed particle size (b-1). In addition, the flow velocity is not generated at the sedimentation point in the contour plot as a whole, and the flow to the right bank side is stronger in the meandering part. Looking at the flow velocity vector around the peak flow rate (11 hours later), it can be said that the flow velocity was faster, and the flow is disturbed than that of the peak time. In addition, the calculation results of uniform particle size (a-1~4) show that the sedimentary part flows to the left bank side.

Downstream flow velocities 11 and 15 hours after calculation are shown in Figs. 13 and 14. There was no difference visible from the flow velocity in numerical calculations of uniform particle size and mixed particle size around the peak river discharge (11 hours later). In addition, the river discharge was almost the same without approaching the size of the

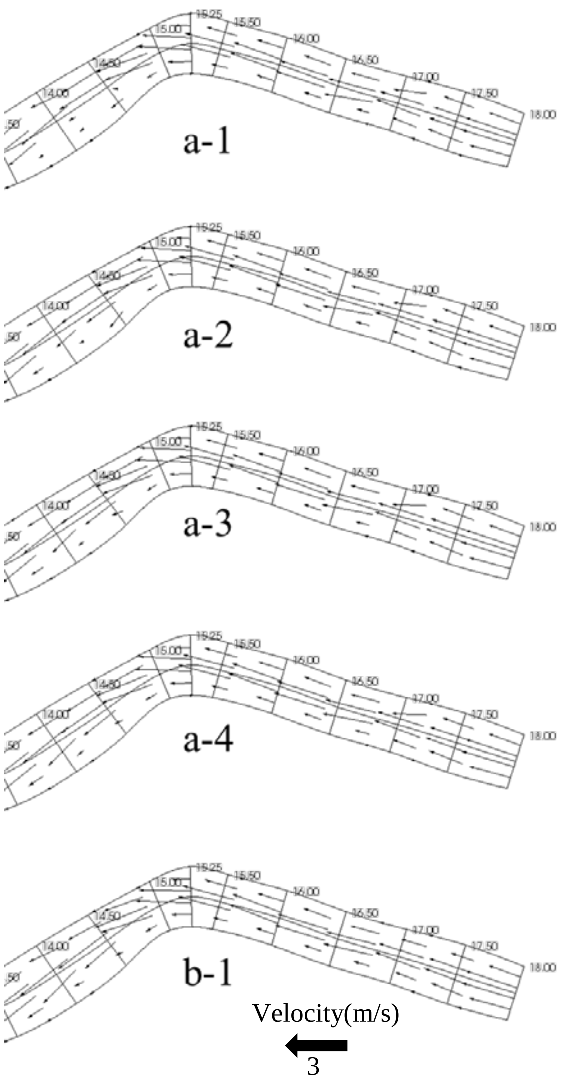

Fig. 11 Flow velocity of upstream (after 7 hours).

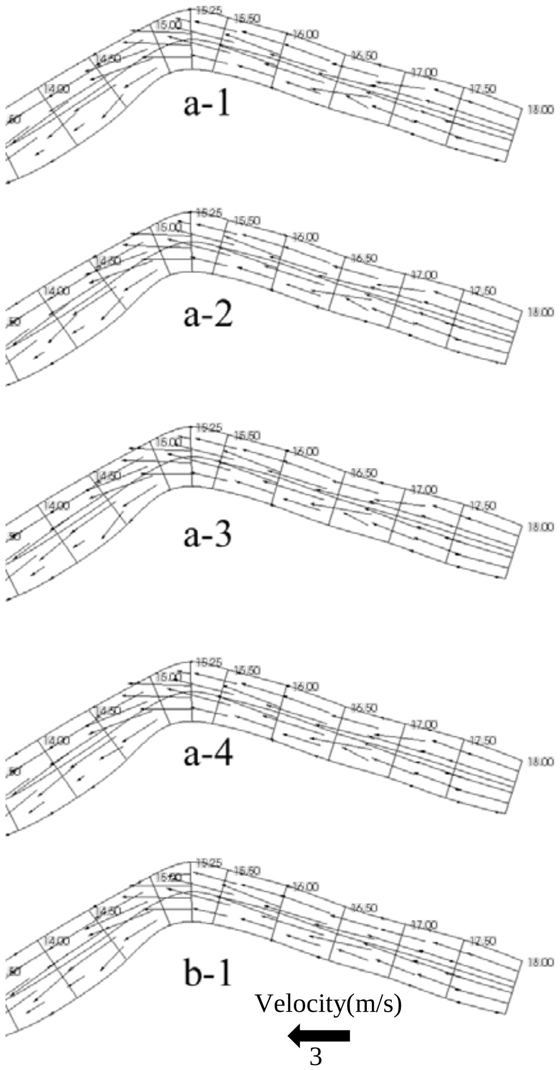

Fig. 12 Flow velocity during peak river discharge of upstream (after 11 hours).

particle size even if it was compared by numerical calculation of uniform particle size. Only the calculation result of the mixed particle size (b-1) after 15 hours, shown in Fig. 14, showed that the flow velocity did not come out on the right bank of the downstream end, and the tendency of the deposition was able to be read.

Fig. 15 shows the calculation results of a-1, a-2, and b-1 in No. 3 and the cross-sectional map of the research area. In the calculation result of pattern a, the scouring in the left bank was seen, while in pattern b, The shape of the riverbed remains the same as the initial state and the riverbed decreased overall. When the survey results were seen, there was no tendency of scouring and sedimentation, and it was the same tendency as pattern b. Furthermore, when a-1 and a-2 were compared, a-1 had a smaller particle size, so the scoring and sedimentation were large.

In the case of numerical calculations in mixed particle size, the entire riverbed sediment not only did the Volume Conservation law hold, but also satisfies the Volume Conservation rule in the soil and sand of each particle size hierarchy constituting the particle size distribution. Therefore, in places where the particle size distribution varies, such as in the middle reaches of rivers, mixed particle size seems to have been able to reproduce the fluctuation tendency.

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.

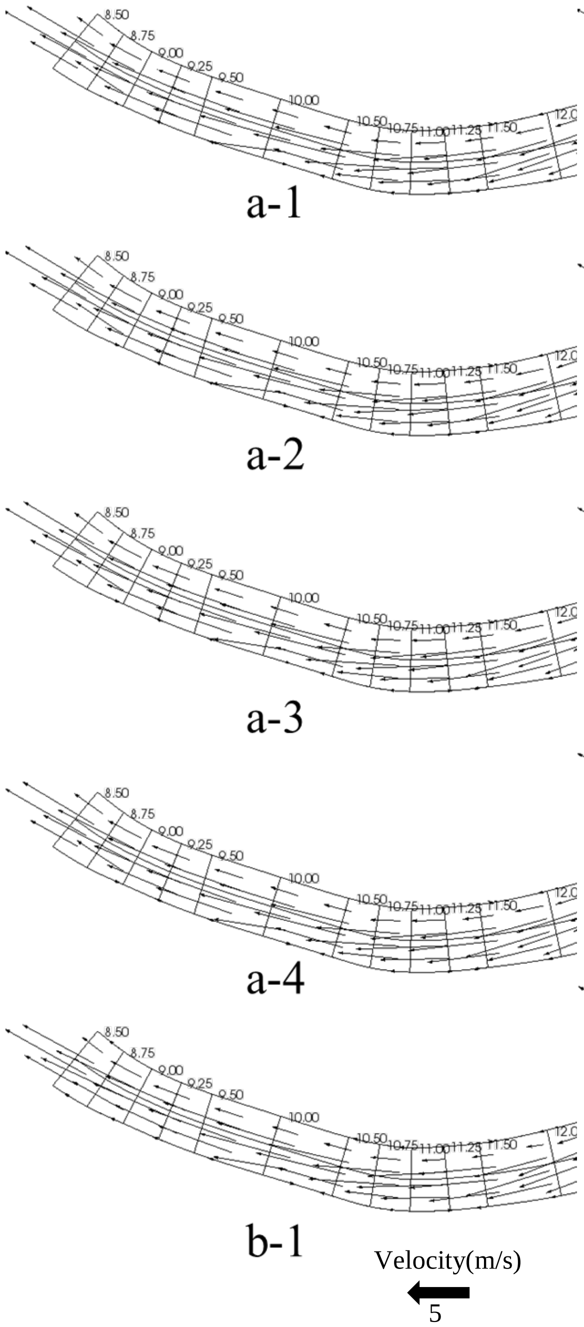

Fig. 13 Flow velocity during peak river discharge of downstream(after 11 hours).

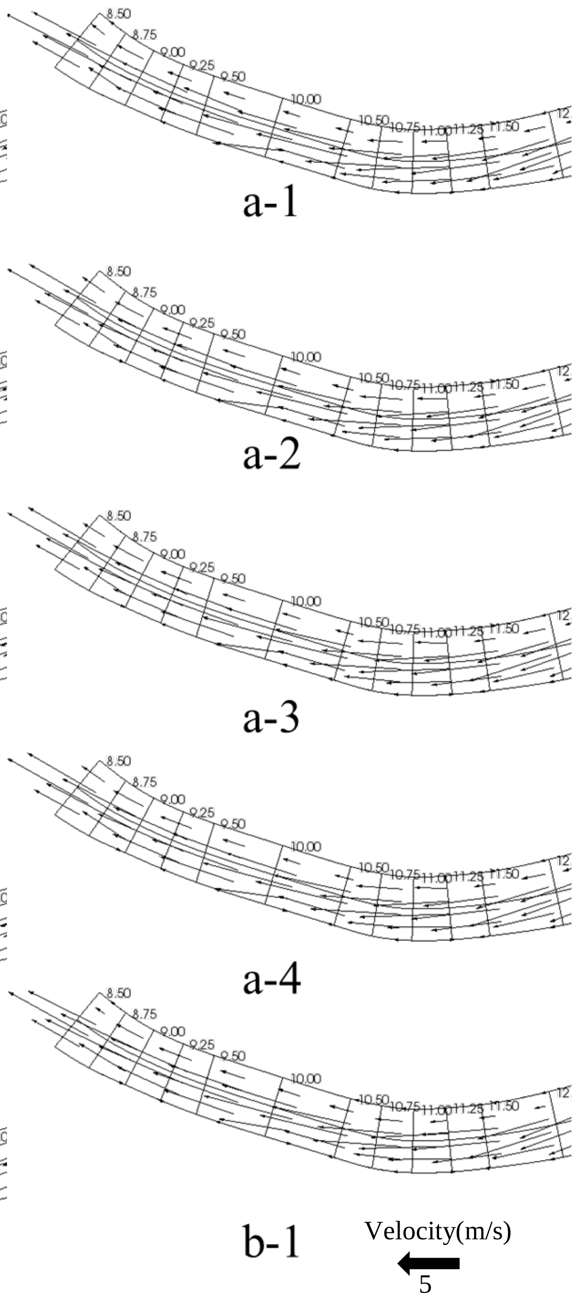

Fig. 14 Flow velocity of downstream (after 15 hours).

And numerical calculations were carried out at the mixed particle size and uniform particle size using the obtained particle size distribution and exchange layer thickness.

As a results of particle size analysis of riverbed materials,

- There was no tendency due to depth at most points, and the exchange layer could not be considered. It was thought to be because the

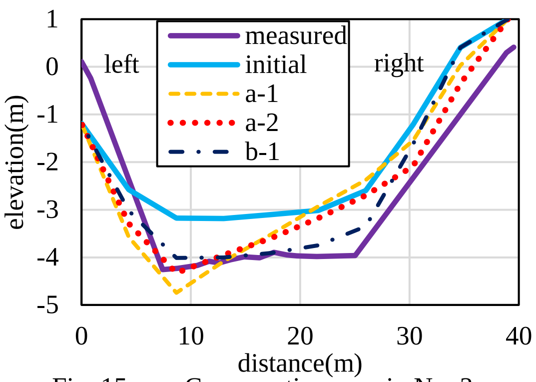

Fig. 15 Cross section map in No. 3

particle size accumulation curve varies greatly depending on the collection time and position.

- Both the cross-sectional and longitudinal directions tended to increase the D50 of the earth and sand collected after the flood than the earth and sand collected before the flood. It seems to be due to the outflow of sediment with a small particle size from the sandbar with a flood flow rate of 40 m^3/s.

As a result of the numerical calculations on sediment transfer at a uniform particle size and mixed particle size using local particle size,

- In the middle river basin, where the particle size distribution varies, it seems that the mixed particle size was able to reproduce the fluctuation tendency of the riverbed rather than the uniform particle size.
- In the case of a uniform particle size assuming all riverbed sediment has the same particle size, the peak value of the occupancy is closer to the setting condition than the D50 value, and it was considered that it approaches the real phenomenon as a result of the calculation.

In this study, the reproducibility of sediment movement was qualitatively improved by calculating the mixed particle size, but it was considered that it is necessary to consider factors other than particle size to quantitatively evaluate it in the future.

6. ACKNOWLEDGMENTS

This research was partially supported by the Ministry of Education, Science, Sports and Culture, Grant-in-Aid for Scientific Research (A), (20H00256, So Kazama)

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