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EVALUATION OF THE FUNCTION OF SLIT SABO DAMS THROUGH HYDRAULIC MODEL EXPERIMENTS

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ABSTRACT
Sabo dams (check dams) are grouped into the closed type and the slit type. The closed type sabo dams do not discharge sediment downstream until they become full of sediment. When they become full of sediment, they control the amount of outwash in accordance with the gradient of the sedimentation slope. On the other hand, the slit type sabo dams discharges sediment downstream during the usual small scale floods, while it dams up and catches sediment to control the amount of outwash during large scale floods are not planned. Moreover, the slit type sabo dams are considered to be preferable environmentally because the direct connection between the upstream and downstream areas of the channel is maintained so that fish can pass through the dam freely. In this study, in order to determine the appropriate width of the slit of the slit sabo dams to promote the effective catching of bed load sediment during large scale flood, examples of hydraulic model experiments are described using topographic models that reproduced a field model. The results are summarized as follows: Even if the total width of the slits is appropriate, the amount of controlled sediments changed with the difference in the width of each slit. Moreover, paying attention to the open rate of slit sabo dams and the occurrence of dam-up, height and length of dam-up were investigated experimentally by changing the open rate. The results are summarized as follows: Whether dam-up occurrence depends largely on the open rate, and the smaller open rate causes dam-up to occur more easily.

Key words: hydraulic model experiments, controlled sediment quantity, slit sabo dam, dam-up

INTRODUCTION

In Japan, the distance from a torrent, which is the source of a sediment yield, to its exit in mountain areas is short in comparison with other countries. Consequently, once an inundation occurs, a large quantity of outwash will cause a disaster in the downstream basin. In order to prevent the disasters, sabo dams have been installed. At present, slit type sabo dams are mainly used in Japan to control the quantity of outwash during inundation, and to permit the outwash to pass through their slits.

The slit type sabo dams installed in traction flow river sections usually permit sediment to run downstream through their slits, while they dam-up the flow of sediment and catch the sediment therein temporarily during the inundation controlling the quantity of downstream outwash. After that, the outwash caught in the slit type dam is discharged during the depletion of the river or the occurrence of a medium or small floods thereby controlling the

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quantity of outwash. Moreover, since the slit type sabo dams are capable of securing a smooth flow between the upstream and downstream areas of the channel, they have the advantage of permitting fish to pass through the dam freely and hence are preferable from an ecological environmental point of view. The selection of the slit width is important for the control of the outwash.

This study provides examples of hydraulic model experiments carried out in Japan using topographic models and numerical calculations to determine the arrangement of the slit sabo dams and their slit widths so as to enable them to catch sediment effectively in traction by inundation. Taking these and previous existing studys (Mizuyama et. al., 1991) into consideration, we further introduce the knowledge acquired so far and the problems which confront us concerning the function of slit sabo dams.

Moreover, we examined the determination of proper slit width which plays an important role in the aforementioned problems. Therefore, we paid particular attention to the relationship between the open rate of a slit sabo dam and the occurrence of dam-up. We varied the open rate to examine whether dam-up occurred also experimentally.

EXPERIMENTAL EXAMPLES OF SLIT SABO DAMS

The essential purpose of the topographic model experiments is to confirm whether planned sabo dams can bring about the sediment control effect expected. These topographic model experiments were also carried out to determine the appropriate scale and arrangement of the slit type sabo dams. What we describe here, however, pays particular attention to the sediment control function of the slit sabo dams. Therefore, we do not mention the actual scale and arrangement of the sabo dams constructed at the building site. The following shows examples of topographic model experiments and numerical simulations of slit sabo dams, and based upon the results obtained, discussions of the function of the slit sabo dams.

(1) Sabo dam No.3 of the Kotaki River

① Summary of the basin

The Kotaki River is the left tributary to the Hime River in Nagano Prefecture (Fig.1 and Table.1). At present, Sabo dam No.2 of the Kotaki River is constructed at a point about 6.5km upstream from its junction with the Hime River. This sabo dam is a slit type sabo dam having 2 gates with slit widths of 2.5m, and it is located in the lowest reaches of the Kotaki River. Planned sabo dams No.1 and No.3 of the Kotaki River will be located at points downstream about 700m and upstream about 850m from the existing sabo dam No.2 of the Kotaki River, respectively. Sabo dams No.1 and No.3 of the Kotaki River are the same in scale as the existing sabo dam No.2. These sabo dams are planned to be of slit type.

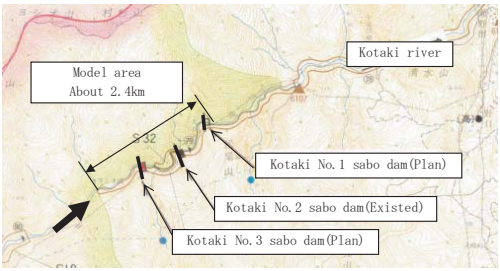

Fig.1 Location of geomorphic model

Table 1 Field dimensions

Items	Dimensions
Catchment area	37.7km^2 (at Kotakigawa No.3 sabo dam)
Extension of basin	13.3km (In model area : 2.4km)
Average riverbed gradient	1/7.2 (In model area : 1/26)
Design discharge(Return period is 100 years)	362m^3/s (Mixing ratio of sand is 10%)
Diameter of sediment	Average grain diameter (d_m) is 26.9cm, 90% grain size is 80.0cm

② Summary of the experiment

The sections set up for the topographic model experiment (scale of 1/50) are installed in areas ranging from about 850m upstream from sabo dam No.3 on the Kotaki River to about 2.4km downstream from sabo dam No.1 on the Kotaki River. In order to clarify the sediment control function of these three consecutively constructed sabo dams, the planned flow rate (100 year maximum probability flow rate, with a peak flow rate of 362m^3/s) was set up in repetition 3 times so that sabo dam No.1 of the Kotaki River located at the lowest reaches of the river could store a full load of sediment during peak flood periods. Particularly, in order to investigate how the sediment control function of the slit type sabo dam changes with varying flood hydrographs, the experiment was conducted so that the flood hydrograph of a 10-year maximum probability flow rate (peak flow rate of 229m^3/s) was repeated 8 times so that the total quantity of supply sand volume(549,000 m^3) becomes the same as that of the planned for flood hydrograph. The dimensions of the slit sabo dams used in the experiment are shown in Table.2.

Table 2 Dimensions of slit sabo dams

Dam No.	Width of slit (m)	Height of slit (m)	Number of slit	Planned control sediment volume at sabo dam (m^3)
No.1	1.5・2.0・2.5	10.5	2	98,000
No.2	2.5	10.5	2	137,000
No.3	2.5	12.0	2	131,000
	5.0	8.0	1	
		12.0		40,000

③ The relationship between the slit width of the sabo dam located at the farthest upstream area and the quantity of sediment controlled

The quantity of sediment controlled is defined as the total cumulative quantity of sediment removed during washaway of initial riverbed. In this experimental condition, the maximum cumulative quantity of sediment occurred after washaway following the last of 3 peak flood hydrographs.

Fig. 2 shows a comparison of the quantity of sediment controlled after a flood occurred 3 times. In one case where sabo dam No.3 which is located most upstream on the Kotaki River has 2 gates with slit widths of 2.5m and in the other case where the sabo dam has 1 gate with a slit width of 5.0 m. Even with the total width of the slits of the dams bring the same in these two cases, since in the case of sabo dam No.3 having one gate with a slit width of 5.0m, the flood is liable to be concentrated on the 1 gate, the sediment control quantity decreases in comparison with the other dam having 2 gates. However, there was not much difference in controlled sediment quantity between sabo dams No.1 and No.2 located downstream.

In the case of one gate with a slit width of 5.0m, because sediment was constantly flowing out of the sabo dam through out the rise of flood, and little accumulated sediment remained in the sabo dam, there was no surge of outwash during depletion. It can be considered that because no rapid increase in cumulative sediment could be observed in sabo dam No.3, sediment flowed out of sabo dam No.3 without accumulating in the sabo dam. Furthermore, it can be thought from these results that changes in controlled sediment quantity of the sabo dam on the upper reaches side influence the entire amount of controlled sediment in a sabo dam group directly.

④ The relationship between the differences in flood hydrographs and the cumulative sediment quantity

The controlled sediment quantity as determined by the hydrograph of a flood of 10 years annual flow was compared with that of the hydrograph of a flood of 100 years annual flow under the condition where the total quantity of quicksand is the same. As a result of the comparison, it was found that there was a remarkable difference in the controlled sediment

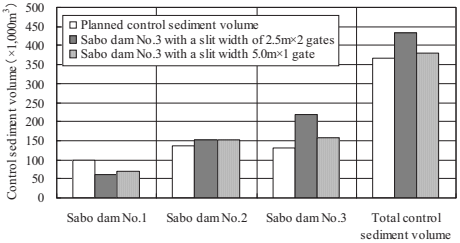

Fig.2 Control sediment volume of each sabo

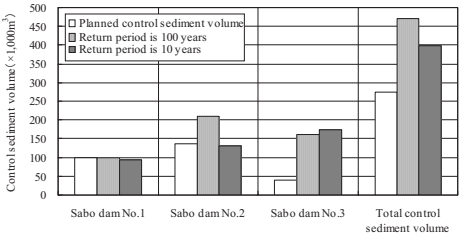

Fig.3 Control sediment volume of each sabo

quantity of sabo dam No. 2 in terms of the hydrograph of a flood of 10-year annual flow and that of the 100-year annual flow, whereas there was no remarkable difference in the controlled sediment quantity of sabo dams No.1 and No.3 (Fig.3).

Fig. 4 shows the changes in the amount of outwash from these three sabo dams. The amount of outwash from sabo dam No.2 decreases in terms of the hydrograph of a flood of 100 years annual flow. The reason for this can be considered to be that the river channel in the upstream basin of sabo dam No.2 is wide, and the flood spread out over the entire river channel, where the sediment accumulated as flux increased.

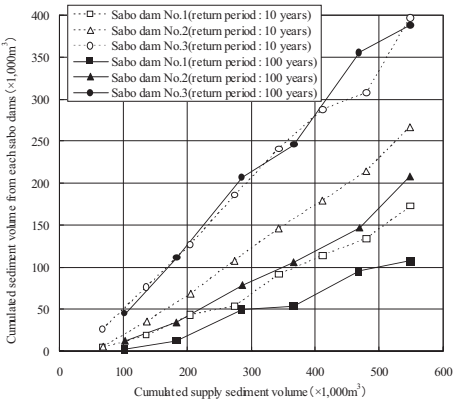

Fig.4 Cumulated sediment volume from each sabo dams

⑤ Conclusion

It was found from these experiment results that the sediment control of the section where slit type sabo dams are consecutively installed is influenced greatly by the sediment control of the slit sabo dam installed on the upstream side. Moreover, it was shown that the controlled sediment quantity of the sabo dam installed in the middle of the river channel changes with the differences in the hydrographs of the floods and the topographic conditions of the river channel.

(2) Tsunoura sabo dam

① Summary of the basin

The Tsunoura sabo dam is a slit type sabo dam planned to be installed about 1.7km upstream of the existing Setokura sabo dam which is installed at the junction of the Jyouganji and the Syoumyou Rivers (Fig.5). The Karatani sabo dam was installed about 0.5km upstream and the Tsunoura slit type sabo dam was installed about 0.5km downstream of the spot of the planned slit type sabo dam. The field dimensions of the site and dimensions of these sabo dams are shown in Tables 3 and 4.

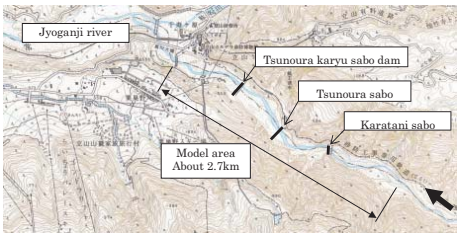

Fig.5 Location of geomorphic model

Table 3 Field dimensions

Items	Dimensions
Catchment area	129.75 km^2(at Tsunoura sabo dam)
Extension of basin	25 km(at Tsunoura sabo dam)
Average riverbed gradient	About 1/28
Design discharge(Return period is 150 years)	2,060 m^3/s (Mixing ratio of sand is 15%)
Diameter of sediment	Average grain diameter (d_m) is 27.8cm, 90% grain size is 65cm

Table 4 Dimensions of slit sabo dams

Name	Case	Width of slit (m)	Height of slit (m)	Number of slit	Width of waterway (m)	Planned control sediment volume (m^3)
Tsunoura	A	4.0	8.0	6	110	332,422
	B	8.0		3		
Tsunoura karyu (Existed)		16.0	8.0	2	110	189,000

② Summary of the experiment

The area used for the topographic model (scale 1/70) is about 2.6km long, ranging from the upper end of the upstream deposition area of the Karatani sabo dam about 840m from the Karatani sabo dam to the Senjugahara groundsill No.1 about 750m downstream of the Tsunoura lower sabo dam. The quantity of sand to be supplied for the experiment was determined to be as much as the original bed slope (1/28) of the upstream area of the Karatani sabo dam could support. The total amount of supply sand for the planned hydrograph of a flood is 801,900 m^3. The average grain size of sand used for the experiment is 27.8cm. After the planned hydrograph of a flood was discharge at a flow rate of a 150 year maximum probability flow rate (2,060 m^3/s : sediment concentration 15%), small and medium floods with a 10 year maximum probability flow rate (900m^3/s) were discharge twice (Fig.6).

③ Changes in the cumulative sediment quantity

Fig.6 shows the change in the amount of accumulated sediment (total) toward the initial riverbed in each sabo dam for every flood. Under the present experimental conditions, the upper sabo dams had more accumulated sediment than the lower sabo dams for every flood regardless of the difference (with equal total slit width) in the slit width of each upper sabo dam.

The amount of accumulated sediment of the upper sabo dam during the period of the small and medium floods tended to decrease after the first peak of the small and medium floods. This tendency was more remarkable for case B (slit width of 8.0m). It was also confirmed that if the total slit widths of two the sabo dams are equal and the slit width of each gate is wide, the sediment accumulated in the sabo dam having wider slits tends to flow out easily during a planned flood even if the bed gradient is as low as about 1/50.

④ Comparison of the cumulative sediment quantity between the upper and lower sabo dams

Fig.7 shows the ratio of the amount of cumulative sediment accumulated in the lower sabo dam to that accumulated in the upper sabo dam during every flood (the lower sabo dam /upper sabo dam). It can be seen in Fig.7 that the ratio of the amount of sediment accumulated during the plan flood decreases from a peak ratio of 0.7～0.9 to a ratio of about 0.3 obtained after the flood. It is shown that the sediment accumulation ratio of the upper sabo dam is greater than that of the lower sabo dam even after the peak as well.

The ratio of the amount of cumulative sediment during the period from the planned flood to the small and medium floods tends to get closer to 1. It is considered that sediment flows out from the upper sabo dam and is deposited in the lower sabo d am. This tendency is more remarkable in case B (with a slit width of 8.0m).

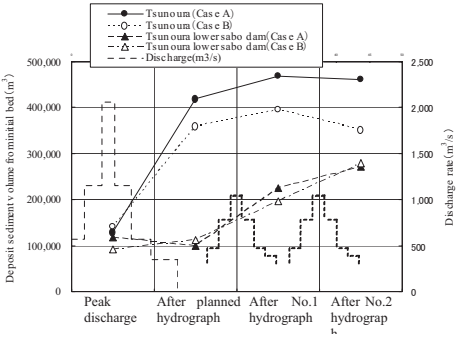

Fig.6 Cumulated deposit sediment volume at each hydrograph

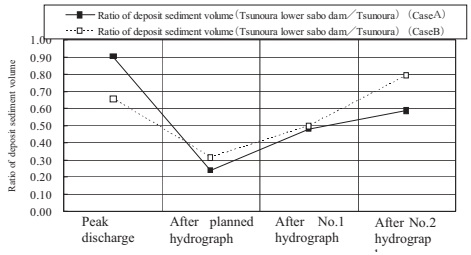

Fig.7 Ratio of deposit sediment volume between the upper sabo dam and the lower sabo dam

⑤ Summary of numerical calculations

A one-dimensional riverbed variation was calculated. The section on which the calculation was carried out is the same as was done in the experiment. For calculating the traction sediment discharge, we chose the Ashida-Takahashi-Mizuyama formula where the coefficients in the sediment transport formula have been revised, taking the conformity with the experimental result of case A into consideration. The existence of suspension sediment was not taken into consideration. Table.5 shows the condition of numerical calculations. The hydrograph of the flood was made to run at a 100-year maximum probability flow rate.

Table 5 Calculating conditions

No.	Average grain diameter of supply sediment(cm)	Total supply sediment volume(m^3)
1	27.8	801,900
2	10.0	1,718,500
3	1.0	2,664,900

⑥ The relationship between grain size and the ratio of the maximum quantity of cumulative sediment to the quantity of quicksand

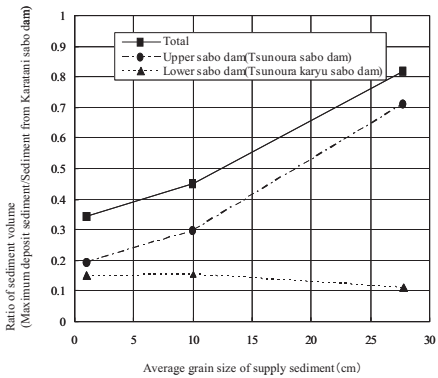

Fig.8 Relationship between average grain size and maximum deposit sediment volume

Fig.8 shows the ratio of the maximum quantity of cumulative sediment to the quantity of supplied quicksand for differences in the grain size of supplied quicksand in the original plan (The total slit width of the upper sabo dam is 24m.). A tendency can be seen that the ratio increases with the increase in grain size. It is considered that the reason for this is that the outflow in the sediment accumulation area of the upper sabo dam was suppressed more by the armoring-coat during the depletion of the flood as the grain size is becomes rougher. This is because the maximum quantity of cumulative sediment of each sabo dam occurs when the supply of quicksand with dm= 1.0 cm reaches a peak and after the flood is supplied with quicksand with dm= 27.8cm.

⑦ The relationship between the grain size and the slit width of the upper sabo dam

Fig.9 shows the ratio of the maximum quantity of cumulative sediment to the quantity of quicksand in cases where the total slit width of the upper sabo dam was changed. The ratio decreases as the total slit width of the upstream sabo dam becomes wider. This tendency is remarkable as the grain size is rougher. If the total slit width is wider, the length of the dam-up area becomes shorter and the spread range of cumulative sediment increases. Further, it can be considered that the amount of outwash from the upper sabo dam increased because the range of the occurrence of the armoring-coat also becomes narrower during depletion. In addition, this ratio in the lower sabo dam was not as great as that in the upper sabo dam.

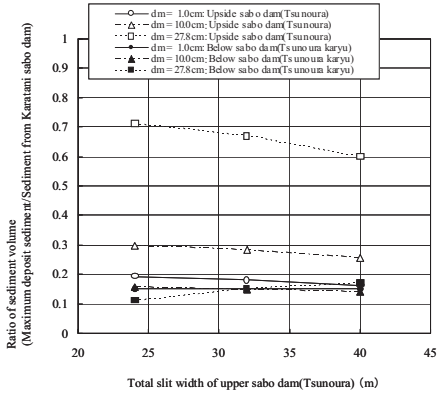

Fig.9 Relationship between total slit width of the upper sabo dam(Tsunoura) and ratio of sand volume (Maximum deposit sediment volume/Supply sediment volume from Karatani sabo dam)

⑧ Conclusion

The expansion of the slit width per gate and that of the total slit width stimulates the outflow of cumulative sediment. It was also confirmed that as outwash from the upper sabo dam increased, cumulative sediment in consecutively installed lower slit sabo dams also increases. Furthermore, from the present investigation, a tendency could be identified that as the grain size of the supplied bed material is rougher, sediment is more liable to be accumulated in the upper sabo dam.

(3) Functions of the slit sabo dam resulting from the topographic model experiment and future problems

From the topographic model experiments and calculations of the consecutively installed slit sabo dams, the following results were obtained as enumerated below:

a. The controlled sediment quantity of the slit sabo dam increases as the slit width per gate is narrower even if the total slit width is constant.
b. The difference in the hydrograph of a flood affects the controlled sediment quantity of the slit sabo dam.
c. The expansion of the slit width per gate and that of the total slit width stimulates the outflow of the accumulated sediment.
d. As outwash from the upper sabo dam increases, cumulative sediment in consecutively installed lower slit sabo dams also increases.
e. As the grain size of the supplied bed material is rougher, sediment is more liable to be accumulated in the upper sabo dam.

From the present experiment results, it has become clear that the slit width affects the amount of controlled sediment greatly. Therefore, in order to clarify how the controlled sediment quantity of the slit type sabo dam varies with the difference in the slit width, we executed as the first stage of systematic investigation a fundamental experiment to know the relationship between the occurrence of dam-up and the slit width.

EXPERIMENTAL STUDY ON DAM-UP BY SLIT TYPE SABO DAM

① Purpose

From the stand point of sediment control throughout the basin, there is a recent tendency to adopt a slit type sabo dam so that the type of sediment which is not likely to cause disasters can be allowed to flow out as much as possible. Accordingly, slit type steel sabo dams having an opening rate (total slit width / basin width) smaller than the conventional, the large underdrain sabo dam having a large opening rate, etc. have been developed and widely used. The slit type steel sabo dam having a small opening rate, however, is considered to have a bad point in that the steel sabo dam with a small opening rate may cause not only the clogging of the openings, but also dam-up, thereby resulting in catchment. Therefore, we experimentally examined the occurrence of dam-up in debris flow sections by changing the opening rates.

② Summary of the experiment

The experimental channel is a rectangular straight open channel 10m long and 30cm wide with a variable slope. A sabo dam model was installed in the channel as shown in Fig.10. Sands with a grain size of 1.0mm for experimental sediment were pasted on the riverbed board for roughness. The sabo dam model was installed a distance of 1.5 m from the end of the lower reaches of the channel. We set up two different cases of channel slopes at the sabo dam installation point (hereinafter referred to as installation slope); case A where the installation slope was made to conform to the channel slope and case B where the installation slope is fitted at level. The reason for establishing these two cases is that both execution examples can be actually seen in the field. The members used for the sabo dam model were steel columns with a diameter of 2.5 cm each and were set up upright in a line in a direction crossing the channel. Moreover, all these column members constituting the sabo dam model were set up tall enough to be able to prevent overflow in all the cases.

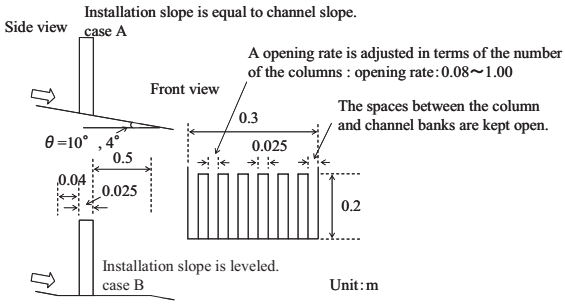

Fig.10 Slit sabo dam models

The channel slope was set up to 4 and 10 degrees, and the discharge rate of the flood was set up to a range from 1.0 to 5.0 ℓ/s at an intervals of 1.0 ℓ/s. The opening widths between the column members were adjusted in terms of the number of column members (0,5, to 11) and in a range from 0.08 to 1.00. Further, the channel slope was set up to the range of slope generally considered to be a debris flow section. h_1 is the uniform flow water depth in the rapid flow section on the upper reaches of the channel, h_2 is the depth of the opening section in the area immediately upstream of the slit sabo dam, and the length of dam-up (L) is the distance from the hydraulic jump start position that can be observed in the left bank of the waterway to the area immediately upstream of the slit sabo dam. Fr_1 is Froude numbers corresponding to h_1, respectively. The experiment was started by setting up the installation slope of the dam models, the channel slope, and the opening rate, and the discharge rate was increased starting from 1.0 to 5.0 ℓ/s at intervals of 1.0 ℓ/s. When the depth of the opening section h_2 reached below the critical depth (h_c) in the area immediately upstream of the slit sabo dam, the value of h_2 was set up to the dam-up occurrence limit, and no experiment was carried out on a flood with the discharge rate greater than the dam-up occurrence limit. The experiment parameters are shown in Table. 6.

Table 6　Experimental condition

Discharge rate（ℓ/s）	channel slope (degree)	installation slope	opening rate
1.0 - 5.0	4，10	channel slope（case A） leveled（case B）	0.08 - 1.00

③ Experiment results

Fig.11 shows the experiment results on the occurrence or non- occurrence of dam-up. Mark ○ in the figure indicates the occurrence of dam up and mark × the non-occurrence of dam-up. According to Fig.11, dam-up occurs when both the opening rate and Fr_1 are small. Moreover, it is obvious that dam-up occurrence conditions differ with the installation slopes of the dam models. It can be seen that when the installation slope of the dam models are leveled, dam-up occurs easily. For example, as far as this experiment concerns, in case A dam-up does not occur when the dam-up occurrence condition is greater than an opening rate of 0.33, and in case B dam-up does not occur when the dam-up occurrence condition is greater than an opening rate of 0.50.

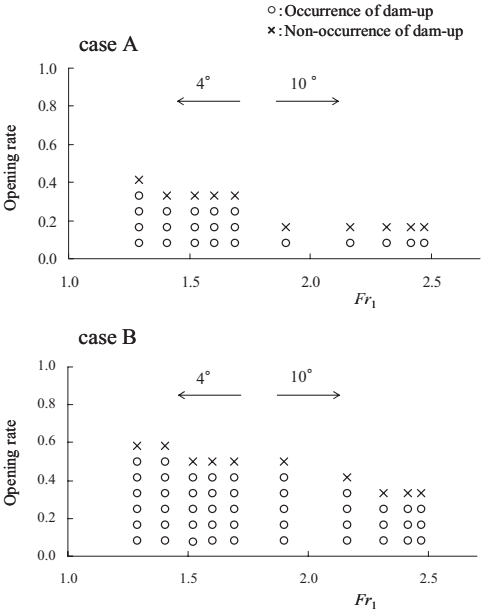

Fig.11　Occurrence and non-occurrence of dam up

Fig.12 shows the experiment results on the depth of the opening section (h_2) located in the area immediately upstream of the slit sabo dam in the case whe re the opening rate is 0.08 and 0.17. Critical water depth (h_c) in Fig.12 show s the numerical value corresponding to the discharge rate in the case where the ch annel width is set to 30cm. However, dam-up does not occur under the condition where the depth of the dam-up increases in the area immediately upstream of the slit sabo dam was plotted below critical depth h_c. It is understood from F ig.12 that although dam-up depth h_2 increases with the increase of the discharge rate in the area immediately upstream of the slit sabo dam, h_2 does not depend on the channel slope, but rather depends on opening rates of 0.08 and 0.17, and further that the rate of increase of h_2 increases as the opening rates increase. Moreover, it is understood that the depth of dam-up h_2 in the area immediately upstream of the slit sabo dam is little affected by the installation slope of the slit sabo dam model, except that the experimental conditions (▲ and △) differentiate the occurrence or non-occurrence of dam-up in cases A and B. Namely, when dam-up occurs, the depth of dam-up h_2 depends

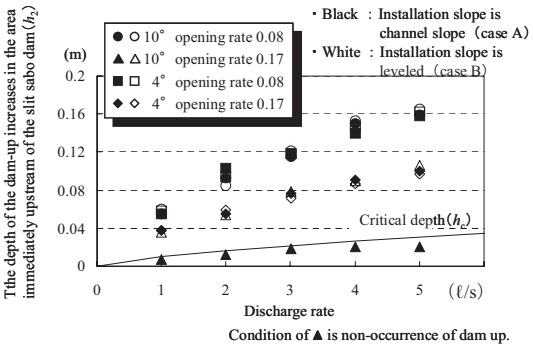

Fig.12　Water depth of dam-up (Opening rate 0.08 and 0.17)

largely on the opening rate only as long the discharge rate is the same. This means that if the conditions for the occurrence of dam-up can be understood under each experimental condition, h_2 can be determined by the discharge rate and opening rate regardless of the channel slope and the installation slope of the slit sabo dam model.

Fig.13 shows the relationship of the dam-up length (L) under the same condition as that of Fig.12. Like h_2, the dam-up length in the area immediately upstream of the slit sabo dam also grows large with an increase in the discharge rate. Moreover, the dam -up length becomes longer as the channel slope becomes gentler. The dam-up length in case B is longer than that in case A. Further, the rate of increase to the discharge rate of flux in case B is also greater than that in case A.

Figs.14 and 15 show the results of case B on dam-up depth h_2 and length L at an opening rate of 0.25 in the area immediately upstream of the slit sabo. As also shown in the Fig.11, it is understood from Fig.14 that dam-up occurs for all discharge rates. Moreover, when the discharge rates are 4ℓ/s and 5ℓ/s, there is a difference in experiment results between the channel slope and the installation slope. Especially, dam-up depth h_2 with a channel slope of 10 degrees in the area immediately upstream of the slit sabo dam is greater than the value of h_2 with a channel slope of 4 degrees. The same is true of the dam-up length L. As Fig.15 shows, under the condition that the channel slope of 4 degrees and discharge rates are 4 ℓ/s and 5 ℓ/s, the dam-up length L becomes longer than that with a channel slope of 10 degrees and discharge rates of 4 ℓ/s and 5 ℓ/s. The water surface shapes under the conditions given in Fig.14 and Fig.15 are shown in Photo 1 and Photo 2, respectively. Broken lines in Photo1 and Photo 2 are the water surface shapes at the left bank of the channel. As Photo 1 and Photo 2 show, the downstream end of the hydraulic jump reaches the dam slit position under the conditions where the channel slope is 4 degrees and discharge rates are 4 ℓ/s and 5 ℓ/s. Moreover, under other conditions, the hydraulic jump is formed at the end of the back water of the dam-up. It is estimated that when the discharge rate is raised more, dam-up will no longer occur. This estimation suggests that the raising of the discharge rate corresponds to a

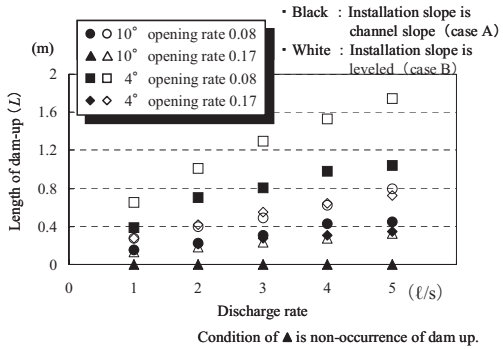

Fig.13 Length of dam-up (Opening rate 0.08 and 0.17)

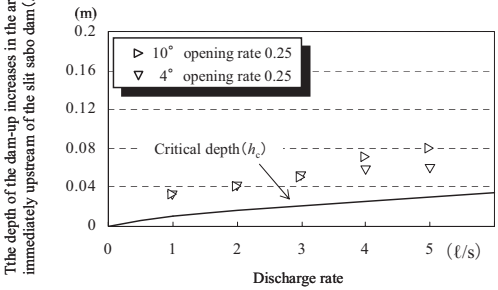

Fig.14 Water depth of dam-up(case B, Opening rate0.25)

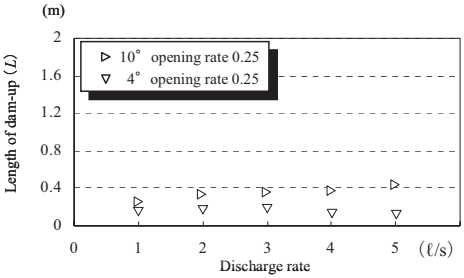

Fig.15 Length of dam-up(case B, Opening rate0.25)

transition process to the non-occurrence of dam-up caused by an increase in discharge rate (for the increase in Fr_1) when paying attention to terms of case B in Fig.11 where the opening rate is 0.33 and the channel slope is 10 degrees.

Figs.16 and 17 show the relationship between the ratio of water depth (h_2/h_1) and the opening rate in each slope. In Figs.16 and 17, water depth ratio h_2/h_1 is shown for reference in indicating the occurrence or non-occurrence of dam-up.

Figs.16 and 17 show that dam-up depth h_2 which causes dam-up depends little on either the channel slope or the installation slope in the experimental channel, but depends nearly on the opening rate only. Water depth ratio h_2/h_1 increases as the opening rate increases, and in the same opening rate, the water depth ratio increases as Fr_1 increases.

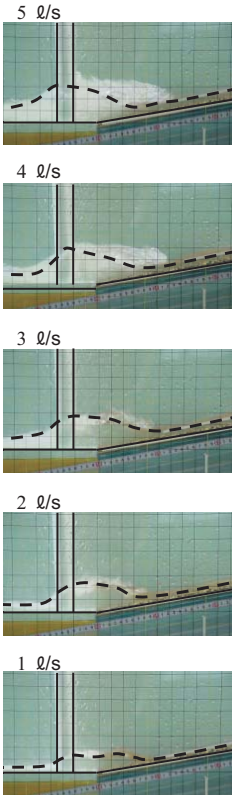

Photo 1 Dam-up by the slit dam (case B, Opening rate 0.25, Slope 10°)

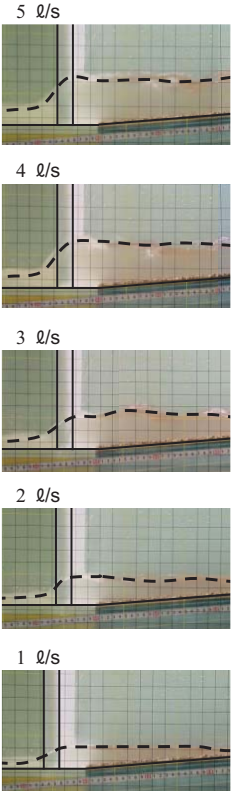

Photo 2 Dam-up by the slit dam (case B, Opening rate 0.25, Slope 4°)

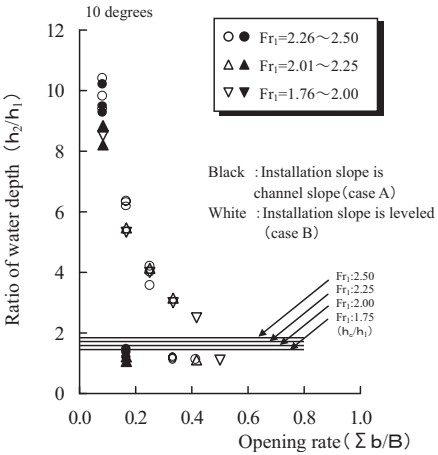

Fig.16 Relation between ratio of water depth and opening rate (Slope 10 °)

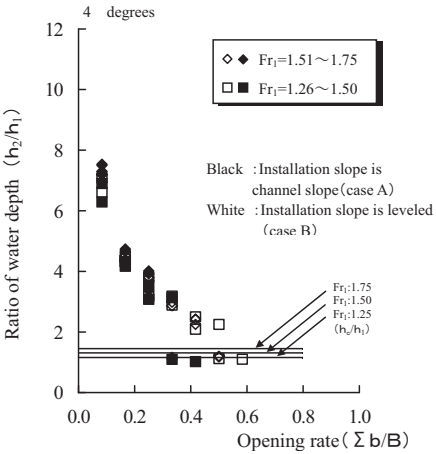

Fig.17 Relation between ratio of water depth and opening rate (Slope 4°)

④ Conclusion

Paying attention to the opening rate of slit sabo dams and the presence or absence of the occurrence of dam-up, we changed the opening rates in the rundown reaches of debris flow to examine experimentally the presence or absence of the occurrence of dam-up and the degree of occurrence. The results are enumerated as follows:

a. Whether dam-up occurs or not depends largely on the opening rate, and the smaller opening rate causes dam-up to occur more easily.
b. When the installation slope of the dam models is leveled, the marginal discharge rate causing transition from the occurrence of dam-up to non-occurrence grows large. Specifically dam-up occurs easily by leveling the installation slope of the dam models.
c. Moreover, when the installation slope of the dam models is level, dam-up length L becomes large for the same hydraulic condition and the same h_2.
d. When dam-up occurs, dam-up depth h_2 increases in the area immediately upstream of the slit sabo dam and dam-up length L also becomes greater as the flow discharge rate increases. However, it can be expected that when the flow discharge rate is increased even more, transition from the occurrence of dam-up to the non-occurrence of dam-up will occur.
e. When transition from the occurrence of dam-up to the non-occurrence of dam-up occurs, the downstream end of the hydraulic jump reaches the dam slit position.

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