Debris Flow Capture Investigation of Steel Open-type Sabo Dams around Mt. Aso, JAPAN

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The northern Kyushu area was hit by heavy rain from July, 2012. In particular, in Aso district of Kumamoto prefecture, many sediment disasters occurred, and more than 20 people died. On the contrary, disaster mitigation effects caused by Sabo facilities have also been reported [*Kasai*, 2006],[*Ozaki*, 1998], [*Sato*, 2001], [*Yoshida*, 2011]. We investigated capturing capacities of 12 sets of steel open-type Sabo dams within the outer crater rim of Mt. Aso. The results of our investigation show that many dams captured sediment and woody debris. In particular, steel open-type Sabo dams showed the largest capacity to capture woody debris. This paper presents the results of these investigations.

Key words: steel open-type Sabo dam, debris flow, capture investigation, woody debris, Mt. Aso

1. INTRODUCTION

The northern Kyushu areas in Kumamoto, Oita, and Fukuoka prefectures were hit by heavy rain from July 11 to 14, 2012, and the rainfall was described as the most intense at the time. In particular, in Aso district of Kumamoto prefecture, the maximum hourly rainfall reached 108 mm, and a maximum daily rainfall of 508 mm was observed. Consequently, many sediment disasters occurred, and more than 20 people died in Aso district.

Aso District, which sustained heavy damage, was subject to debris flow and woody debris as a result of the torrential rains in July 1990, which claimed eight lives. Sabo facilities were established within the outer crater rim of Mt. Aso after the disaster as part of disaster- related urgent Sabo projects. Steel open-type Sabo dams were also included. Twelve sets of steel open-type Sabo dams were established within the outer crater rim of Mt. Aso. These steel open-type Sabo dams are shown in **Fig. 1** and **Table 1**. A follow-up investigation of capturing capacities of these dams was conducted by the Research Association for Steel Sabo Structures in October 2012.

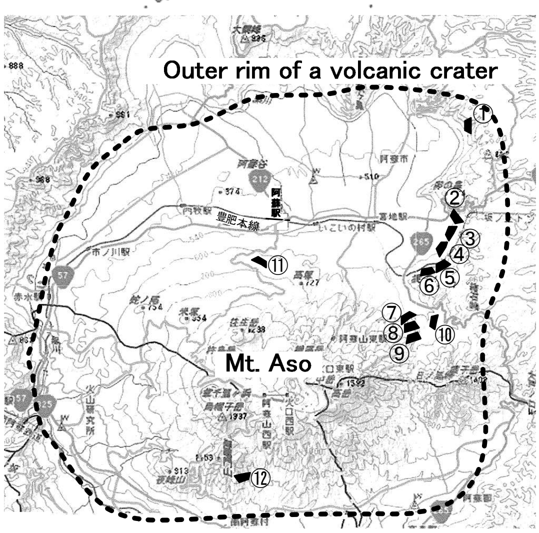

Fig. 1 Map of steel open-type Sabo dam in Aso caldera

Table 1 List of steel open-type Sabo dam in Aso district

Name of Dams	Type	Dam Height	Slit Height	Slit Width	Completion Year	GIS Data	
① Shioi river	Secondary	5.7 m	3.0m	10.0m	1991	32° 57’39.27″N	131° 09’09.08″E
② Hattanda river	Secondary	–	3.0m	10.0m	1991	32° 56’21.11″N	131° 08’57.96″E
③ Mamefuda river	Secondary	10.0m	3.0m	7.0m	1991	32° 55’56.80″N	131° 08’50.29″E
④ Hebonoki river	Secondary	8.0m	3.0m	12.0m	1991	32° 55’43.79″N	131° 08’44.98″E
⑤ Koga fall	Secondary	9.5m	3.0m	10.0m	1992	32° 55’22.24″N	131° 08’36.32″E
⑥ Yoroizuka river	Secondary	7.5m	3.0m	10.0m	1993	32° 55’22.07″N	131° 08’24.33″E
⑦ Furue river 9	Main	10.5m	8.0m	12.0m	1991	32° 54’33.38″N	131° 08’01.63″E
⑧ Furue river 2	Main	10.5m	8.0m	21.0m	1991	32° 54’27.97″N	131° 08’08.25″E
⑨ Furue river 11	Secondary	–	4.5m	–	1992	32° 54’21.76″N	131° 08’15.88″E
⑩ Furue-Hakoishi	Secondary	–	–	–	–	32° 54’30.76″N	131° 08’15.25″E
⑪ Koga river	Main	11.0m	8.0m	8.0m	2004	32° 55’34.07″N	131° 04’39.15″E
⑫ Kari river	Main	14.0m	6.0m	16.0m	–	32° 51’09.02″N	131° 04’07.48″E

2. EFFECTS OF STEEL OPEN TYPE SABO DAMS

This investigation, as well as an interview survey that was conducted, reveal that while the amount of captured debris varied, all dams captured woody debris or sediments and demonstrated their effectiveness in mitigating or preventing damage. The main examples of their effectiveness are presented below.

2.1 Ichinomiya Shioi District

The Shioi river dam, which is a steel open-type Sabo dam with 3 m height, was established as the secondary dam of a concrete closed-type dam. The main dam was completely filled with sediments, with boulders exceeding 3 m in diameter present at a few locations. The secondary dam was also filled with a large amount of woody debris and sediment, as shown in **Photos 1** and **2**.

However, owing to the large amount of sedimentation, sediment discharge to the downstream area occurred from the top edge of the steel dam, as well as from the service road on the left bank. Unfortunately, this resulted in damage caused by sediments downstream, but we presume

Photo 1 Capture of sediment and woody debris (Shioi river dam)

Photo 2 The situation of down stream (Shioi river dam)

that the facility reduced the damage to the downstream areas.

2.2 Ichinomiya Koga District

An investigation was conducted on three steel open-type Sabo dams located on the Hebonoki river, at Koga Fall, and on the Yoroizuka river. At the Hebonoki river, a steel open-type Sabo dam composed of a steel structure with 3 m height was established as the secondary dam. Woody debris that overflowed the main dam was captured by this steel open-type Sabo dam, as shown in **Photos 3** and **4**.

No discharge of sediment or woody debris downstream was confirmed, and this dam, together with the main dam, is considered to have demonstrated significant effectiveness.

On the other hand, captured woody debris reached the top edges of dams at both the Yoroizuka river and Koga Fall. In both places, sediment overflowed into the downstream area owing to the large amount of sediment flow that occurred and cut off the rails on the JR Hohi Line. However, woody debris was definitely captured and the dams are considered to have demonstrated disaster mitigation effects for downstream areas.

Photo 3 Capture of sediment and woody debris (Hebonoki river dam)

Photo 4 Capture of sediment and woody debris (Hebonoki river dam)

2.3 Furue River

Three medium to large steel open-type Sabo dams have been established on the Furue river as main dams(**Table 1**). From downstream to upstream, these are known as the Furue river No. 9, Furue river No. 2 (8m high steel structures in both cases), and Furue river No. 11 dams (4.5m height). The three dams were almost fully heaped up, with their openings blocked by woody debris and shrubs accompanied by sediment comprising primarily fine sand that was captured almost up to the top (refer to **Photos 5** and **6**). Damage resulting from sediment floods involving woody debris that reached the vicinity of National Road No. 57 occurred during the disaster of 1990, but no floods occurred downstream by the effects of these dams at this time(refer to **Fig. 2**).

(a) The situation of open part

(b) The situation of upper stream

Photo 5 Capture of sediment and woody debris (Frue river No.9 dam)

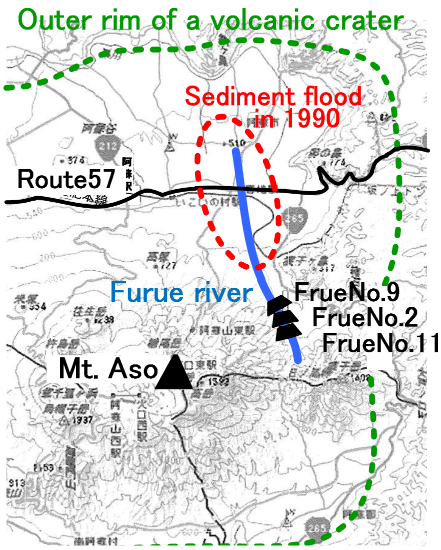

Fig. 2 Map of drainage area of Frue river

(a) The situation of open part

(b) The situation of upper stream

Photo 6 Capture of sediment and woody debris
(Frue river No.2 dam)

In steel open-type Sabo dams, sediments can usually pass through to the downstream areas except during debris flow. Generally, the capacity of sediment entrapment was high when the size of the dam was large, and this allowed the dam to have a damage-mitigating effect on downstream areas.

3. INVESTIGATION OF SOUNDNESS

After debris removal was completed at the Shioi river, Hebonoki river, Koga Fall, and Yoroizuka river dams, an investigation was once again conducted to determine the soundness of the steel structures of these dams in February 2013. The investigation was done to determine the following items: (1) overall and local deformation of steel members, (2) looseness of bolts, and (3) corrosion and abrasion. The results of the investigation confirmed the soundness of all these dams. On this occasion, all the dams had their openings blocked by woody debris, which is presumed to have played the role of a buffer. No deformation or indentation was confirmed on the steel members. In addition, the paint coat on the steel members was almost intact, and no abrasion was confirmed (refer to **Photos 7** and **8**).

(a) Before woody debris removal

(b) After woody debris removal

Photo 7 The situation of woody debris removal
(Hebonoki river dam)

Photo 8 Investigation of soundness

However, at the Shioi river dam, a number of bolts at the top edge were damaged by overflow. These are not structural materials, so their damages had no impact on the strength of the dam.

4. JAPANESE MANUAL OF TECHNICAL STANDARD FOR ESTABLISHING SABO MASTER PLAN

In Kumamoto prefecture, the steel open-type Sabo dams began to be built after debris flow disaster in 1990 at Aso district. In Japan, test construction of the steel open-type Sabo dams was performed in the 1970s, and in the 2000s, the dams began to be used in many mountain streams. Many effects of debris flow disaster prevention by the steel open-type Sabo dams have been reported. As a result, the manual of technical standard for establishing Manual of technical standard for design SABO facilities against debris flow and driftwood was revised in March 2007[*National Institute for Land Infrastructure Management*, 2007]. One of the most important changes is that the function of steel open-type dams to capture debris flow /woody debris has been shown more clearly.

Generally, three functions required of debris flow/woody debris control structures: "capture of woody debris", "maintenance of entrapment function" and "conservation of mountain stream environment". Steel open-type Sabo dams possess all these functions. The following introduces some actual cases which exhibit those functions.

4.1 Capture of woody debris

Photo 9 shows a case where a large amount of woody debris was captured by an steel open-type Sabo dam. A number of closed-type dams are installed upstream from this dam, and they capture gravel and sediment, but they fail to capture almost all woody debris, and thus it is captured by this downstream open-type steel Sabo dam.

Photo 9 Capture of woody debris （Kitazato river dam）

4.2 Maintenance of entrapment function

Photo 10 illustrates a picture of an open-type steel Sabo dam taken from the downstream side a few years after it was completed. This dam was designed prior to the recent manual revision, but because it is the dam furthest downstream, the steel pipe spacing was set to 1.0 times the maximum gravel size. It is confirmed from the photograph that an upstream side entrapment function can be maintained even with a dam which improves capture functionality in this way.

Photo 10 Maintenance of entrapment function （Suganumadani dam）

4.3 Mountain stream environment

Photo 11 Conservation of mountain stream environment （Sanbonmatsu dam）

Photo 11 shows a case where a steel open-type Sabo dam has been installed. The foundation of the steel open-type Sabo dam is installed in line with the current river bed. Therefore, aquatic creatures can freely come and go, and effects on the ecosystem are minimized. Cases have also been reported where deep and shallow areas are naturally formed upstream from a dam where there have been no debris flows for a few years, and fish are living there.

5. CONCLUSIONS

The results of the investigations confirm the high capacity for woody debris capturing of steel open-type Sabo dams. Furthermore, in the future dam, the maintenance of entrapment function, which is another feature of steel open-type Sabo dams, was effective in capturing a large amount of sediment and had contributed to suppressing river floods in downstream.

On the other hand, Manual of technical standard for design SABO facilities against debris flow and driftwood was revised in March 2007. Steel open-type Sabo dams will be increasingly important as debris flow and woody debris control structures, from now on.

We expect that steel open-type Sabo dams continue to contribute to suppressing and mitigating disasters caused by the debris flow and woody debris.

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REFERENCES

Kasai, S., Mizuyama, T. and nagaki,S. (2006): Debris Flow control with steel open-type Sabo dam constructed at base point, Journal of the Japan Society of Erosion Control Engineering Vol.59 No.4, pp. 48-53 (in Japanese).

National Institute for Land Infrastructure Management. (2007): Manual of technical standard for design SABO facilities against debris flow and driftwood, (in Japanese).

Ozaki Y., Kamogawa, Y., Mizuyama, T., Kasai, S. and Shima, J.(1998): A Debris Flow with Woody Debris Trapped by a Steel-pipe Gridded Sabo Dam, Journal of the Japan Society of Erosion Control Engineering Vol.51 No.2, pp. 39-44 (in Japanese).

Sato, K., Uehara, S., Mizuyama,T. and Kasai, S. (2001): Structural behavior of open type dam hit by stony debris flow, Journal of the Japan Society of Erosion Control Engineering Vol.53 No.6, pp.61-65 (in Japanese).

Yoshida, K.,Yamaguchi, M. and Mizuyama, T. (2011): Field survey on the capture of debris flow with steel open Sabo dams, Journal of the Japan Society of Erosion Control Engineering Vol.63 No.5, pp. 43-46 (in Japanese).