Maintenance of Historical Sabo Facilities by the Tateyama Mountain Area Sabo Office - An Evaluation of the Soundness and Utility of Sabo Facilities -

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In the middle reach of the Joganji River, the Hongu Sabo Dam, which is as important as the Shiraiwa Sabo dam installed in Tateyama Caldera, is installed. More than 80 years, Hongu Sabo Dam has been proteced the Joganji River basin from a sediment-related disaster. And it was designated as an important cultural property in 2017. In this paper, I introduce the inspection and soundness evaluation of Hongu Sabo Dam carried out based on the "Planning Manual for Maintaining and Prolonging the Lifespan of Sabo Facilities" issued by Ministry of Japan in 2014. And also I introduce the utilization of the Hongu Sabo Dam in recent years.

Key words: Historical and cultural value; Maintenance; Rubble concrete; Soundness evaluation; Utilization of sabo dams

1. Introduction

Sabo work in Tateyama started in 1906. The initial sabo works were undertaken by Toyama Prefecture, and were continued by the Japanese Government as of 1926. Over the past 90 years, the techniques used in sabo works have advanced considerably; some of the sabo dams in Tateyama are made of materials, structures, and construction methods that are now obsolete. Several sabo dams have been certified as cultural properties by the Agency for Cultural Affairs, based on their historical or cultural value.

This paper examines recent efforts by the Tateyama Mountain Area Sabo Office to maintain the Hongu Sabo Dam, a large sabo dam located in the middle reach of the Joganji River that has been designated a cultural property

2. Outline of the basin and its two main sabo facilities

2.1 The Joganji River

The Joganji River, controlled by the Tateyama Mountain Area Sabo Office, is one of the steepest rivers in Japan. It flows 56 km from the mountainous area 3,000 m in eastern Toyama Prefecture to Toyama Bay. Its average bed slope is about 1/30.

During the 1858 Hietsu earthquake (7.1 magnitude), the massive Tonbi landslide occurred, originating at the Tateyama Caldera (**Fig. 1**). About 400 million m^3 of sediment were accumulated, of which 200 million m^3 flowed down the mountainside. As a result, 140 people died and 8,945 people were injured.

After this disaster, the Joganji River became prone to sediment-related disasters. In the Tateyama Caldera, 200 million m^3 of sediment remains. During heavy rainfalls, accumulated sediment flows into the downstream reaches of the Joganji River.

Fig. 1 Tateyama Caldera

2.2 Two main sabo facilities of the Tateyama Mountain Area Sabo Office

Modification of the Joganji River began during the Meiji era to protect the Joganji River Basin from sediment-related disasters. However, disasters continued to occur despite these efforts. Therefore, in 1906, Toyama prefecture started sabo works in the upstream area of the Joganji River.

Direct control over the sabo works was given to the Ministry of Home Affairs (now the Ministry of Land, Infrastructure, Transport and Tourism, MLIT) in 1926. Two of the main sabo facilities on the Joganji River were constructed to protect the basin from sediment disasters. One is the Shiraiwa Sabo Dam (**Fig. 2**), which is located at the exit of the Tateyama Caldera in the upstream portion of the Joganji River. The other is the Hongu Sabo Dam (**Fig. 3**), which was constructed in the middle of the Joganji River.

Shiraiwa Sabo Dam was built to stabilize the hillside of the Joganji River upstream area (Tateyama Caldera) and to prevent erosion of the river bed. From October 1929 to December 1939, the main dam and counter dams 1 and 2 were constructed. Counter dams 3–7 were constructed after 1951 to prevent riverbed degradation, completing the dam in its current form. Hongu Sabo Dam was built for the prevention and adjustment of sediment discharge in the midstream area of the Joganji River, 26.8 km from the estuary. From April 1935 to December 1937, the main dam and counter dams 1 and 2 were constructed. Counter dam 2 was modified and counter dams 3–5 were created after 1947, producing the current dam structure.

Thus, the Shiraiwa Sabo Dam and Hongu Sabo Dam have protected the Joganji River Basin from sediment disasters for a long period of time. These dams, designated as "particularly technically superior" and "highly historical", are important cultural sabo facilities in Japan.

Fig. 2 Shiraiwa Sabo Dam

3. Hongu Sabo Dam

3.1 Hongu Sabo Dam specifications

Hongu Sabo Dam is a main check dam that was constructed from 1935 to 1937 in the midstream area of the Joganji River (26.8 km from the estuary), for the prevention and adjustment of sediment discharge.

Its height is 22.0 m, and its crest length is 107.4 m, a total of 23,500 m^3 of concrete was used in the construction of the dam body, with a sediment trap capacity of 5 million m^3 (Japan’s largest). It has five counter dams.

Hongu Sabo Dam was built before the existence of the materials and machine tools now used for dam construction. To save cement, which was then prohibitively expensive, stone material was used for the outside of the dam (front and crest) and rubble concrete was used for interior construction.

Fig. 3 Hongu Sabo Dam

3.2 Hongu Sabo Dam construction

Since 1926, when construction began on Shiraiwa Sabo Dam, sabo works in Tateyama have been controlled by the Ministry of Home Affairs (now the MLIT). The construction of Shiraiwa Sabo Dam took many years. During this time there was a collapse of the Onigajo rock wall downstream of the dam. As such, Shiraiwa Sabo Dam cannot solely prevent all sediment-related disasters in the Joganji River Basin.

Similarly, heavy rainfall of 400 mm per day occurred in the upper part of the Joganji River in 1934, and a large disaster occurred in the Joganji River Basin destroying 1,080 m of the revetment in ten places. Following the disaster, a river improvement project was initiated, and Hongu Sabo Dam was constructed.

3.3 Dam construction features

During the construction of the Hongu Sabo Dam

(**Figs. 4** and **5**), large tower cranes, chutes, and rubble concrete were introduced. These were state-of-the-art equipment, materials, and methods for the period. Despite its size, the dam was completed in less than 2 years.

Hongu Sabo Dam demonstrates the technical level of sabo facilities during the early Showa period and is a valuable example of early construction methods. In November 2017, the dam was designated an important cultural property among Japanese sabo facilities.

Fig. 4 Large tower cranes and chutes (1935)

Fig. 5 Hongu Sabo Dam construction (1936)

4. Maintaining and prolonging the lifespan of sabo facilities

4.1 Deterioration of physical infrastructure

In Japan, a large amount of physical infrastructure such as roads, bridges, river management facilities, and quay walls was constructed during the high growth period following World War II. These facilities will approach 50 years of age within the next decade. Within 20 years, 60% of Japan’s sabo facilities will exceed 50 years of age. Therefore, there is concern that these sabo facilities will deteriorate.

4.2 Approach of the MLIT Erosion and Sediment Control Department

In this context, an accident occurred in which a tunnel ceiling board fell on the Chuo Expressway, a major Japan highway, in December 2012. The MLIT created a maintenance action plan to prolong the lifespan of physical infrastructure in September 2013. To prevent sediment-related disasters, the Ministry ordered all sabo offices in Japan to create their own plans to prolong the lifespan of sabo facilities, based on the Ministry’s action plan.

The MLIT Erosion and Sediment Control Department issued a manual to help sabo office facility managers investigate the soundness of existing facilities and to create plans to maintain the function and performance of the facilities in good working order over a long period (**Fig. 6**).

4.3 Actions taken at the Tateyama Mountain Area Sabo Office

The Tateyama Mountain Area Sabo Office has implemented a plan to maintain and prolong the lifespan of sabo facilities in accordance with manuals issued by the Ministry.

The plan defines countermeasures according to the soundness of the sabo facility. Therefore, it is extremely important to accurately evaluate the soundness of the target sabo facilities during planning.

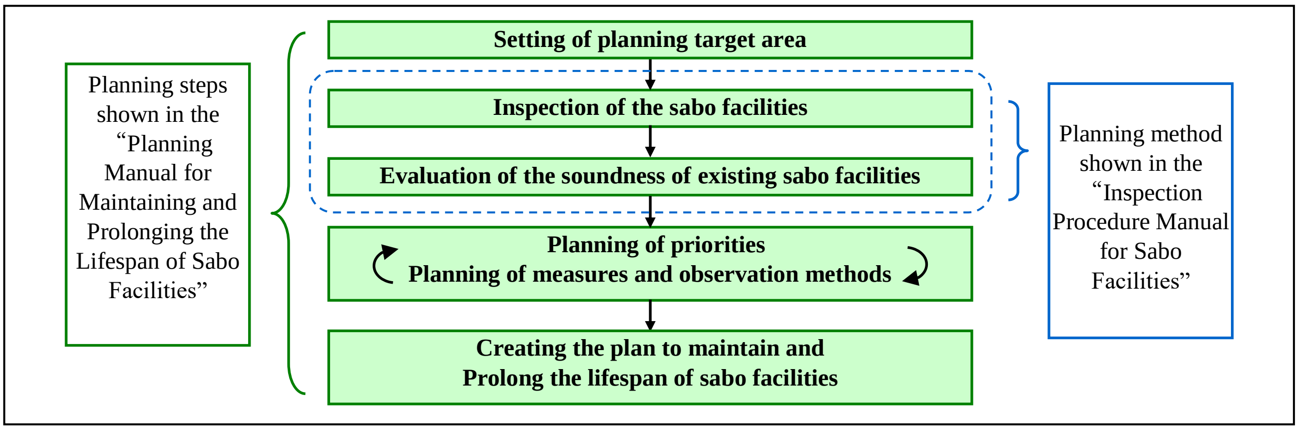

Fig. 6 Manual contents

5. Characteristics of sabo facilities and soundness evaluation

5.1 Rubble concrete check dams

Hongu Sabo Dam is a check dam with a rubble concrete structure (**Fig. 7**). The rubble concrete within such a dam may be of poorer quality and therefore weaker than modern ready-mixed concrete. However, if the outer material (e.g., stone) is undamaged, the dam will not fail catastrophically. In other words, the soundness of rubble concrete dams depends largely on the state of the outer materials

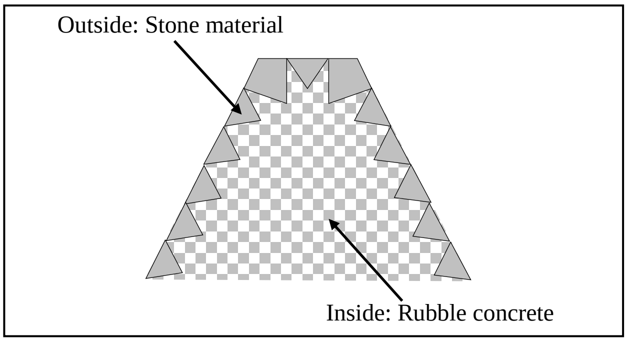

Fig. 7 Check dam with rubble concrete structure

Hongu Sabo Dam is a large-scale check dam constructed in the middle reach of the Joganji River. Recent inspections have found that some stone was missing or abraded at the crest of the dam, exposing the material in the interior (**Fig. 8**).

Fig. 8 Deterioration at the crest of the dam

The sediment trap capacity of Hongu Sabo Dam is 5 million m^3 (Japan's largest), such that the loss of facility functions can have an enormous influence downstream. Hongu Sabo Dam has also been designated an important cultural property; thus, the cultural value of the facility must be preserved when repairs are undertaken. In general, when an important cultural property is repaired and/or reinforced, it is necessary to consult with the Agency of Cultural Affairs to preserve the value of the property. Therefore, immediate inspection of the Hongu Sabo Dam was necessary, to evaluate its soundness and to judge whether the repairs were necessary.

5.2 Information necessary for evaluating the soundness of a facility

When the soundness of a sabo facility is evaluated, basic information about the planning and design of the facility is collected through a literature survey. Next, an inspection of the sabo facility is conducted to evaluate the extent of the deterioration.

Water flows continuously over the Hongu Sabo Dam; thus, damage to the outer stones at the crest or front of the dam cannot be examined during a normal inspection. In addition, it is difficult to implement large-scale river diversion for inspections, in terms of both time and budget.

Further, documents containing information about the design of the Hongu Sabo Dam were burned during the Toyama air raid during World War II. Thus, we could not obtain information about the materials used to construct the interior of the dam.

5.3 Inspection based on the importance of the facilities

To maintain the disaster-prevention function of the dam, preserve its value as a cultural property, and determine the soundness of the sabo facilities within a short time and at low cost, a survey was conducted (**Table 1**).

Table 1 Detailed inspection items for historical sabo facilities

Item No.	Investigation method	Investigation aims	Supplemental information
i	Boring investigation (includes laboratory investigations)	Physical properties of the internal material of the dam and sedimentation area	Six representative locations
ii	Detailed visual inspection	Damage or deterioration of the outer stone material	Divert the flow Rappel down the dam
iii	Elastic wave exploration	Density of the internal material	Eight representative sections

i. Boring investigation

Boring investigations were conducted at four locations (**Fig. 8** and **9)** at the crest of the dam where the interior rubble concrete was exposed. Water leakage and internal cracks were investigated within the borehole using a borehole video camera. Rubble concrete collected from four locations on the body of the dam permitted an evaluation of its physical properties in a laboratory investigation. The sedimentary area was also investigated at two locations, including observations of the sediment condition and water level.

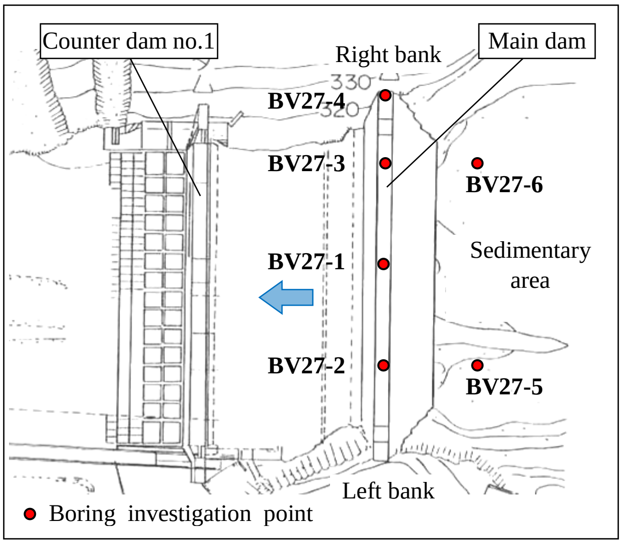

Fig. 9 Boring investigation point

ii. Detailed visual inspection

To confirm the material, color, shape, arrangement, and condition of the stones used at the crest and downstream of the Hongu Sabo Dam, a detailed visual investigation was conducted (**Fig. 10**).

Hongu Sabo Dam is a check dam with historical and cultural value and has been designated a culturally important sabo facility. Maintaining the original appearance of the facility as much as possible is a priority during maintenance and repair.

Therefore, a detailed visual inspection was conducted, and all stone materials used in the crest and downstream of the Hongu Sabo Dam were investigated.

During this inspection, a small-scale diversion of the river was carried out, exposing the stone materials for assessment. To conduct the inspection safely and in detail, and to accurately record the results of the inspection, engineers with climbing skills were added to the inspection team.

Fig. 10 Detailed visual inspection

iii. Elastic wave exploration

The boring survey was carried out at only four locations on the Hongu Sabo Dam; these measurements may not have been representative of the internal conditions of the dam. Therefore, to supplement the results of the boring investigation, an elastic wave exploration was performed, which permitted easy, non-destructive evaluation of the dam body.

The elastic wave exploration was conducted along eight lines (eight sections) as shown in **Fig. 11**.

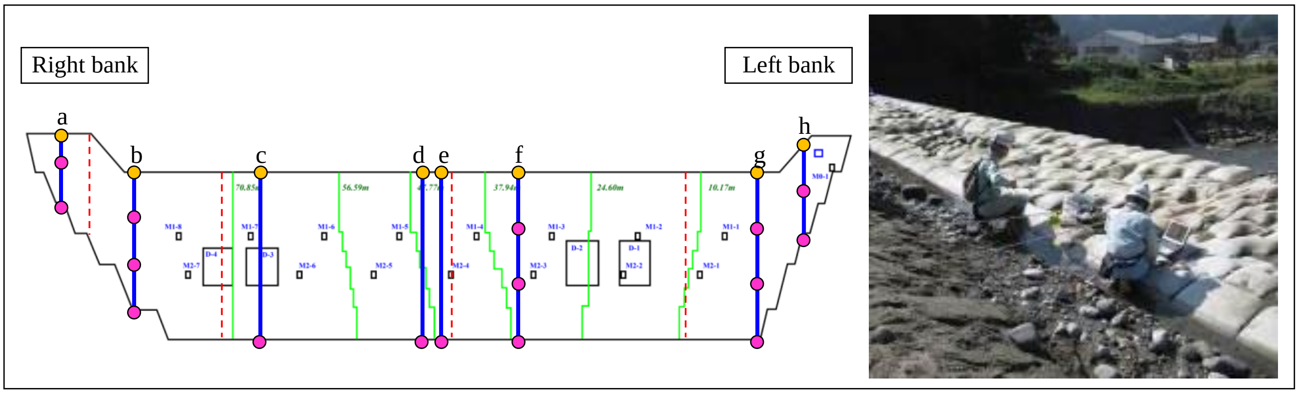

Fig. 11 Elastic wave exploration

6. Results and evaluation

6.1 Inspection results

i. Result of the boring investigation

Rubble concrete within the Hongu Sabo Dam consists mainly of 3- to 4-cm gravel and stones (rubble) with diameters ranging from 10 to 30 cm. The boring core did not exhibit many cracks, and almost no cracks were found by the borehole video camera (**Fig. 12** and **13**). The aggregate and cement in the rubble concrete were firmly adhered, unweathered, and hard. Therefore, the condition of the rubble concrete within Hongu Sabo Dam was determined to be in good condition (**Table 2**).

Fig. 12 Example of a boring core picture (BV27-1 0.0–10.0 m)

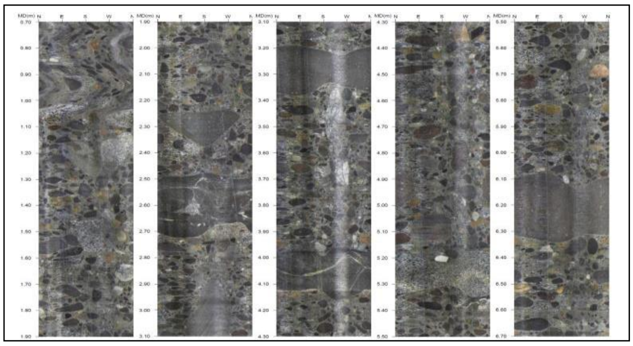

Fig. 13 Example of borehole camera images (BV27-1 0.7–6.5 m)

Table 2 Example of laboratory investigation results for concrete (BV27-1 4.2–5.0 m)

Classification	Symbol	Unit	Concrete
Wet density	ρt	g/cm^3	2.324
P wave velocity	V_P	km/s	4.50
S wave velocity	V_S	km/s	2.40
Dynamic Poisson ratio	V_d	–	0.301
Dynamic shear modulus	G_d	MN/m^2	13386
Dynamic elastic modulus	E_d	MN/m^2	34830
Uniaxial compressive strength	Qu	MN/m^2	24.6
Modulus of deformation	E_{50}	MN/m^2	10250
Tensile strength	σ_t	MN/m^2	3.55

ii. Results of detailed visual inspection

As a result of detailed investigation, the material, color, shape, and arrangement of the stones used in the crest and downstream of Hongu Sabo Dam were confirmed. The following signs of deterioration were also detected (**Table 3**, **Fig. 14**–**16**). The stone at the crest of the dam and the mortar in the joints were abraded. No damage to the stone on the upstream or downstream sides of the crest of the dam was detected. Seven central rows of stone and mortar at the crest of the dam were missing, over a maximum area of 2 m × 2.5 m and a depth of 0.4 m.

In the past, abrasion countermeasures were implemented downstream of the Hongu Sabo Dam; abrasion was found to have occurred again in a downstream part of the dam.

Table 3 Major deterioration detected in Hongu Sabo Dam

Position	Major deterioration
Crest of dam	Abrasion of stone material Missing stone material
Downstream of dam	Missing stone material Missing mortar Re-abrasion of repaired concrete Re-scoring at repaired concrete Leak

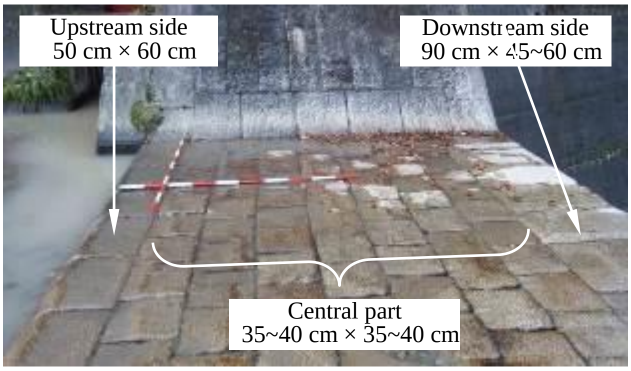

Fig. 14 Stone material on the crest of Hongu Sabo Dam

Fig. 15 Stone material downstream of Hongu Sabo Dam

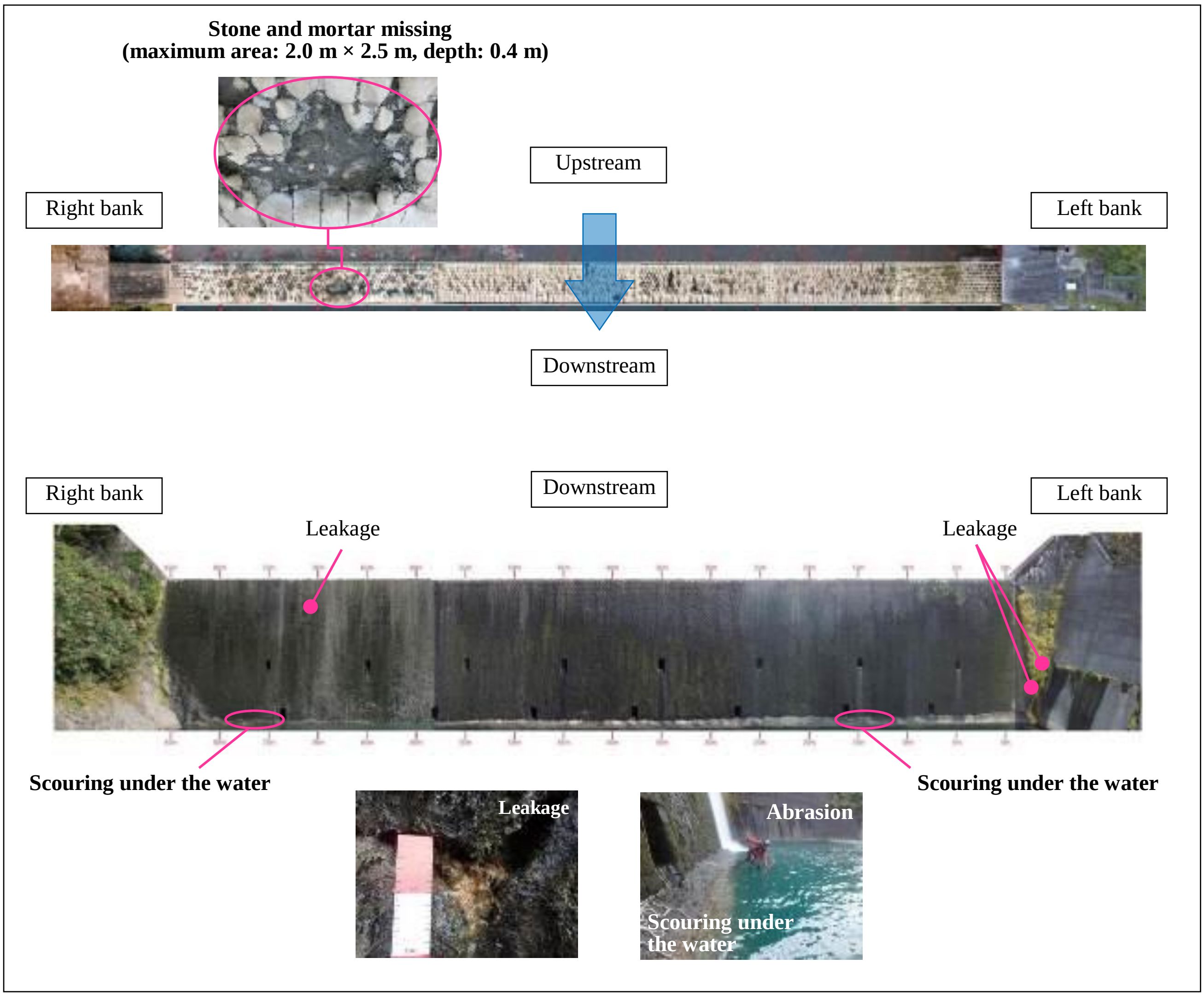

Fig. 16 Main deterioration on the crest and downstream of Hongu Sabo Dam

iii. Results of elastic wave exploration

The threshold value for elastic wave velocity indicating soundness in modern ready-mixed concrete is 3.5–4.5 km/s.

Hongu Sabo Dam, as an 80-year-old rubble concrete structure, was expected to have a low elastic wave velocity. However, contrary to expectation, the elastic wave velocities exceeded 4.4 km/s in all sections. From these results and those of the aggregate and cement that form the rubble concrete of the dam interior, the dam materials remain firmly adhered to each other and are considered to be hard.

6.2 Soundness evaluation of Hongu Sabo Dam

As a result of the boring investigation, visual inspection, and elastic wave exploration, two types of damage were identified: missing stone material and mortar at the crest of the dam, and re-abrasion of repaired concrete downstream of the dam, which has the potential to cause loss of function in terms of sediment-related disaster prevention. However, the results of the boring investigation and elastic wave exploration indicated that the fine rubble concrete within the dam was of good quality, like that of modern ready-mixed concrete.

Dam scouring does not reach the foundation of the dam. Therefore, the probability of loss of sediment-related disaster prevention function at Hongu Sabo Dam was estimated to be low.

The performance (stability) of the Hongu Sabo Dam cannot be verified precisely because the ground-bearing capacity of the dam site and the stability at the time of design remain unknown. However, we estimate that the dam is at low risk of suddenly losing sediment-disaster prevention function, due to the results of a recent stability check of the facility and because stability was not lost during a major flood in 1969.

6.3 Timing and method of measurements

Damage or deterioration in Hongu Sabo Dam detected during the inspection described in this report will continue to be monitored. Rubble concrete within Hongu Sabo Dam was determined to be in good condition. As such, the dam did not require immediate repair. In the future, extensive damage or large missing stone sections upstream or downstream of the dam crest will initiate repair actions beginning at the dam ends (**Fig. 17**).

Downstream of Hongu Sabo Dam, abrasion and scouring have not progressed to the dam foundation and thus do not require immediate repair.

Hongu Sabo Dam is a facility with historical and cultural value and was designated an important cultural property in November 2017. Therefore, it is necessary to maintain both the disaster-prevention function and cultural property value of Hongu Sabo Dam throughout repairs.

The Tateyama Mountain Area Sabo office plans to establish a conservation and management plan for Hongu Sabo Dam.

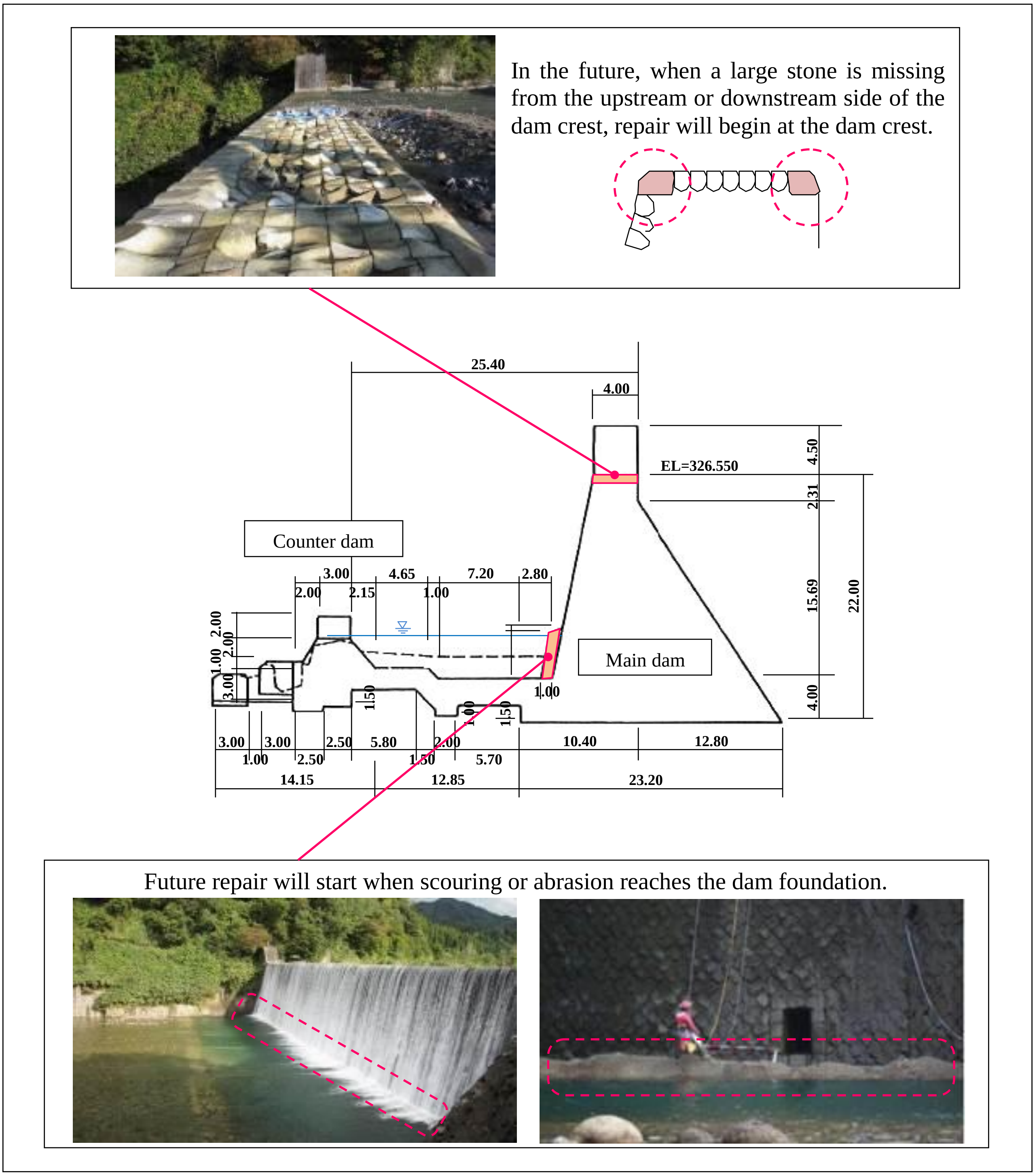

Fig. 17 Timing of repair measures

7. Utilization of Hongu Sabo dam

7.1 Effect of sabo works

In Japan, many sabo facilities were constructed more than a century ago to recover devastated mountains and prevent sediment-related disasters. These sabo facilities were created using contemporary technologies for the time and remain in use to the present day as disaster-prevention facilities.

The MLIT and Agency of Cultural Affairs created a Committee on the Preservation and Utilization of Historical Sabo Facilities in December 2002 to preserve and utilize sabo facilities of historical value. In May 2003, these organizations established guidelines for the preservation and utilization of historical sabo facilities. According to these guidelines, it is important to consider metrics of visitor experience, as described by the words "see", "learn", and "know" when establishing practices for sabo facilities (**Fig. 18**).

The Tateyama Mountain Area Sabo Office, in cooperation with the Tateyama Caldera Sabo Museum, has been conducting an experiential learning tour to teach the history of past disasters and the function and effects of sabo facilities. Hongu Sabo Dam is a major site for experiential learning tours, because it is a large-scale check dam with Japan's largest sediment trap capacity (5 million m^3). Its placement in the middle reach of the Joganji River, one of the steepest rivers in Japan, provides relatively easy access

Fig. 18 Experiential learning

7.2 Improvement around the Hongu Sabo Dam

The area around the Hongu Sabo dam is designed such that elementary school students can engage in outdoor activities and be in direct contact with the water (**Fig. 19**).

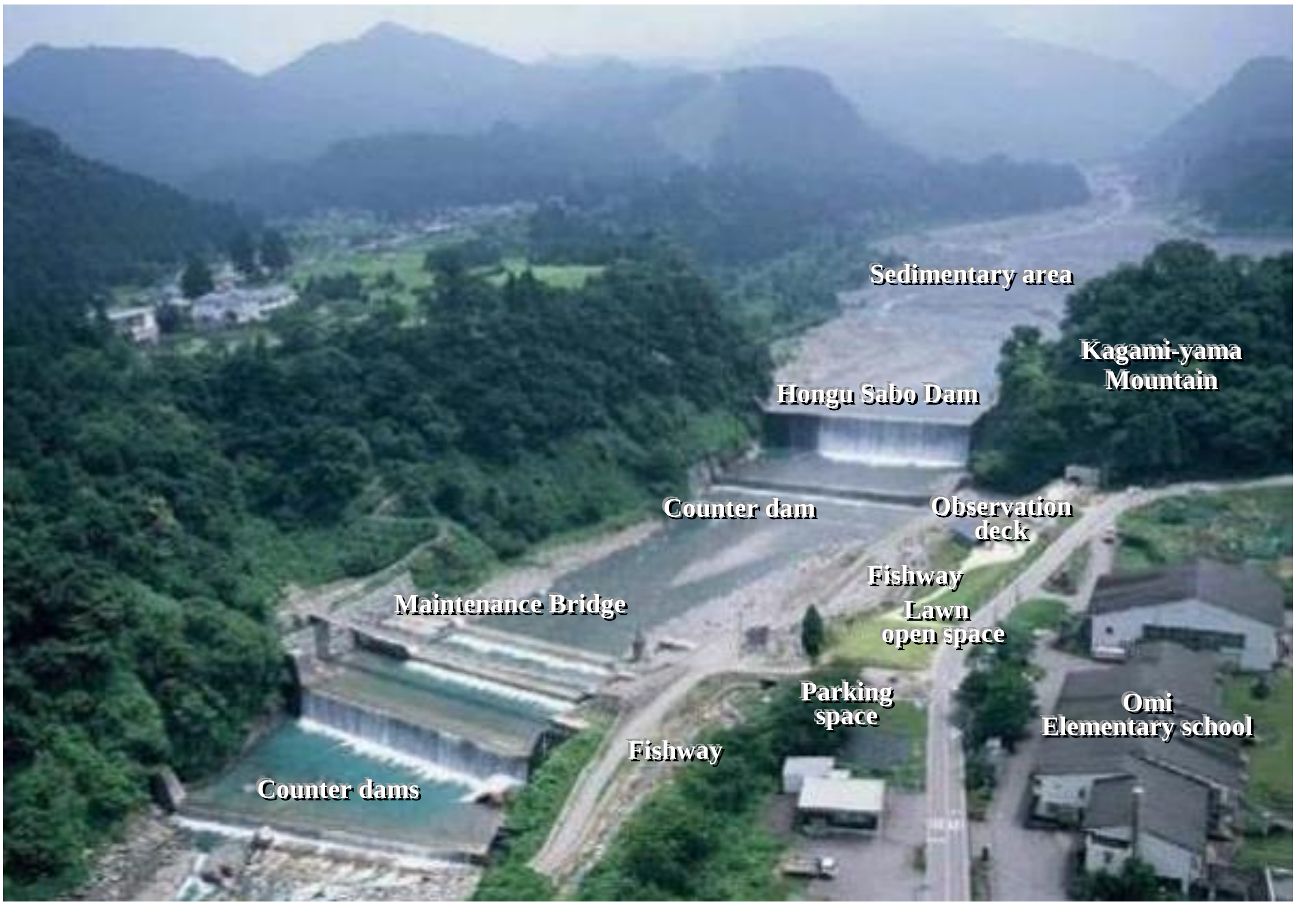

Fig. 19 Environmental improvement around Hongu Sabo Dam

Improvement is based on the subsidy system for improving the hydrophilicity of rivers, and facilities have been developed, including an observation deck, maintenance bridge, lawn, and fishway.

The Tateyama Mountain Area Sabo Office and Tateyama Caldera Museum also dispatch instructors upon the request of users who wish to engage in outdoor activities and learn about sabo works around Hongu Sabo Dam.

The Tateyama Mountain Area Sabo Office, in cooperation with regional residents and construction workers, conduct safety inspections and cleanup activities several times per year in the area surrounding Hongu Sabo Dam. In addition, the Tateyama Mountain Area Sabo Office sometimes holds public discussions with local residents on the subject of future dam maintenance and management and better ways to revitalize regional communities..

7.3 Utilization of the facility as a regional resource

The historical sabo facility has academic value with respect to its technology and design philosophy, landscape/environmental value for its contribution to the abundant natural ecosystem in the middle mountains, and public relations value due to its contribution to the conservation and modernization of parts of these lands. It is important to disseminate these values widely.

The Tateyama Mountain Area Sabo office has held an informal meeting to educate local residents about the value of Hongu Sabo Dam, so that they can utilize Hongu Sabo Dam as a regional resource (**Fig. 20**).

Fig. 20 Informal meeting with local residents

8. Conclusion

In recent years, the environments surrounding sabo works have changed greatly. The maintenance costs of sabo facilities are expected to increase.

To maintain and improve the safety of these regions in the future, new and existing sabo facilities must be utilized effectively, especially the historical sabo facilities, to convey the risk of sediment-related disasters, inform the public of the valuable role of sabo works in disaster prevention, and determine how best to use sabo facilities as regional resources. All of these aims require the cooperation of regional communities.

It is our hope that this report will contribute to the achievement of these goals

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