Actions for the Maintenance and Lifespan prolongation of SABO Facilities

Hisashi Watanabe, Professional engineer[1]; Toshio Mori

ABSTRACT

Japan is one of the countries most prone to sediment-related disasters in the world. For centuries, various SABO works, which are measures to counter erosion and control sediment, have been constructed in Japan. In the modern era, countermeasures that protect people from localized sediment-related disasters, such as debris flows or cliff failures, have been emphasized, considering how such disasters actually occur.
Many locations in Japan are prone to sediment-related disasters. Therefore, It is very important to maximize the functionality and extend the lifespan of existing SABO facilities. Our organization, The Sabo Frontier Foundation, evaluates the soundness of SABO facilities and reviews measures to counter sediment-related disasters based on our research.
In fiscal 2015, the Erosion and Sediment Control Department of the Ministry of Japan issued the Manuals, to maintain the functions of existing structures and ensure the future use of those structures. Nation-wide efforts are now being taken in this respect. This paper outlines the two manuals and introduces the actions taken.

KEYWORDS

National Resilience; Maintenance and Lifespan prolongation of SABO facilities; effective use of existing SABO facilities; inspection; soundness evaluation

INTRODUCTION

Japan is one of the countries most prone to sediment-related disasters in the world. For centuries, various SABO works, which are measures to counter erosion and control sediment, have been constructed in Japan. In the modern era, countermeasures that protect people from localized sediment-related disasters, such as debris flows or cliff failures, have been emphasized, based on how such disasters occur.

Many locations in Japan are prone to sediment-related disasters and little progress has been made in the countermeasures taken using SABO facilities, which are at about 20% capacity. It is very important to maximize the functionality and extend the lifespan of existing SABO facilities. Our organization, The Sabo Frontier Foundation, evaluates the soundness of SABO facilities and reviews measures to counter sediment-related disasters based on our research. The issues of maintenance and prolongation of the lifespan of SABO facilities are important globally; some countries have already implemented countermeasures to the problem. In fiscal

1 SABO FRONTIER FOUNDATION (SFF), TOKYO, JAPAN, kenkyu2@sff.or.jp

2015, the Erosion and Sediment Control Department of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT), Japan, issued the "Planning Manual for Maintaining and Prolonging the Lifespan of SABO Facilities" and the "Inspection Procedure Manual for SABO Facilities", to maintain the functions of existing structures and ensure the future use of those structures (these manuals are currently available only in Japanese). Nationwide efforts are now underway in this respect. This paper outlines the two manuals and introduces the actions taken.

PROBLEMS FACING JAPAN

1) Climate of Japan and aggravation of natural phenomena

Japan is part of the Pacific Ring of Fire and much of the terrain is steep and complex. Geologically, volcanic and sedimentary rocks are distributed in a diverse mosaic with many faults. Since the beginning of the Holocene (from approximately 10,000 years ago until the present), Japan has experienced the fourth greatest number of eruptions globally, accounting for 7.3% of all volcanic eruptions. In addition, about 20.5% of all earthquakes with a magnitude of 6.0 or higher have occurred in Japan.

Analysis of the source waters and routes of typhoons, including hurricanes, in the Northern Hemisphere shows that their routes are concentrated in three tracks, one of which leads from Southeast Asia towards the eastern part of the Sea of Okhotsk via the waters near Japan.
In Japan, mountains comprise 61.0% of the total land area, while less than 40% of Japan is habitable. As a result, the population density in the habitable area exceeds 900 people per km^2. Considering the topography, geology, climate, and lack of inhabitable land, it is understandable that Japan is prone to sediment-related disasters.
Recently, typhoons, earthquakes, and volcanic eruptions have increased in scale. In addition, the frequency of localized torrential rain from continuously generated clouds, the so-called "back-building phenomenon", has increased. This has led to large-scale sediment-related disasters, such as those observed in the Niigata Prefecture Chuetsu Earthquake (2004; Fig. 1)

Location	Niigata Prefecture Chuetsu region
Date	October 23, 2004
Scale of earthquake	Magnitude 6.8
Landslide dam was created	45 places
Debris flow	19 places
Landslide	41 places
Criff failure	45 places
Dead	46 people
Injured	4,801 people
House destroyed	2,827 houses
House partially destroyed	12,746 houses
House some damage	101,509 houses

Figure 1: Overview of the damage caused The Niigata Prefecture Chuetsu Earthquake

and extensive sediment-related disasters in the Kii Peninsula (2011, Fig. 2) and Hiroshima (2014; Fig. 3). Consequently, appropriate countermeasures are required to ensure regional safety.

Location	Nara Pref.and Wakayama Pref.
Date	September 2011
Slope failure	About 3,000 place
Landslide dam was created	17 places
Debris flow	59 places
Landslide	16 places
Criff failure	31 places
Dead	72 people
Injured	31 people
House destroyed	369 houses
House partially destroyed	2,901 houses
House some damage	171 houses

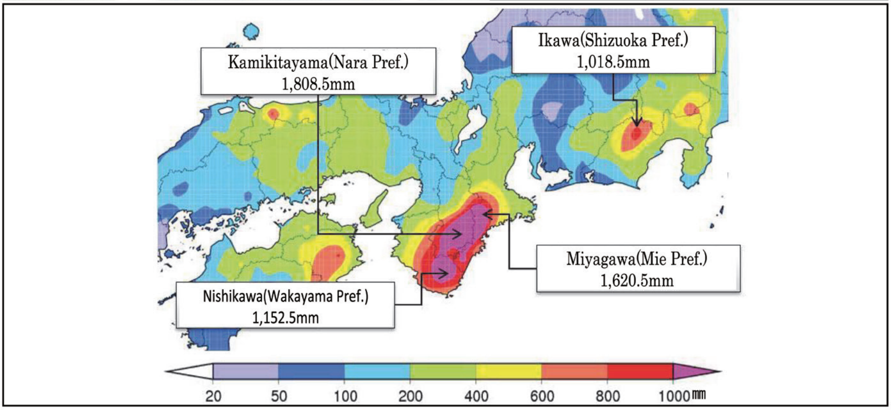


Figure 2: Overview of sediment-related disaster in Kii Peninsula, and Period rainfall distribution (August 30 ~ September 5)

2) Decrease in investment capacity

In Japan, SABO works have been built for a long time. Since 1875, some 90,000 check dams and 10,000 km of channel works have been constructed. Nevertheless, more than 1,000 sediment-related disasters occur annually. Therefore, more structural and non-structural measures need to be taken. Structural measures to deal with natural phenomena include maintaining the “function and performance" of SABO facilities, reinforcing and improving them, and developing new facilities. (here, the “performance of a SABO facility” is defined as the structural safety of the SABO facility, while the “function of a SABO facility” is defined as its ability to prevent sediment-related disasters.) Of those existing, increasing numbers are over 50 years old and it is essential to counteract damage or deterioration of these facilities.

Location	Hiroshima Ctiy, Hiroshima Prefecture
Date	August 20, 2014
Debris flow	107 places
Criff failure	59 plases
Dead	73 people
Injured	39 poeple
House destroyed	123 houses
House partially destroyed	82 houses
House some damage	150 houses

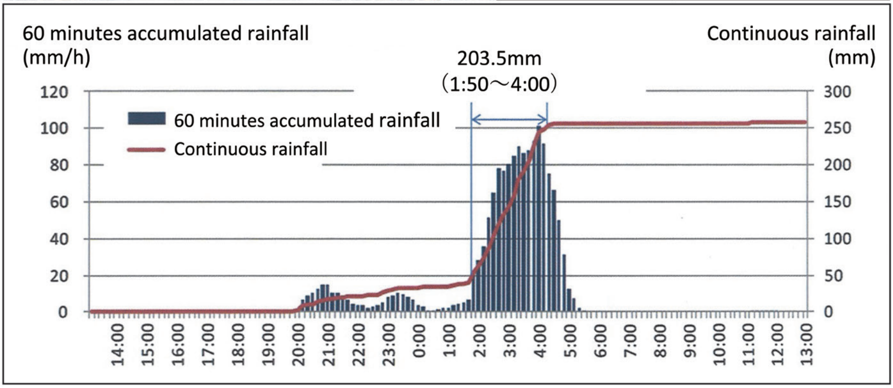


Figure 3: Overview of sediment-related disaster in Hiroshima, and 60 minutes accumulated rainfall (13:00 August 19–13:00 August 20)

There is also an urgent need to update the technical standards of any SABO facility that is "incompatible with the latest technical standards".
However, the increasing costs of social security in Japan make it difficult to increase capital maintenance costs. Therefore, to reduce the total cost of SABO facilities, i.e., the cost of maintaining the installations in an era of limited budgets, SABO facilities must be developed and maintained efficiently and effectively. Their maintenance and lifespan are very important, together with evaluations of their function and performance (see chapter 2 "Evaluating the soundness of a SABO facility" below) and making appropriate repairs and reinforcement when needed.

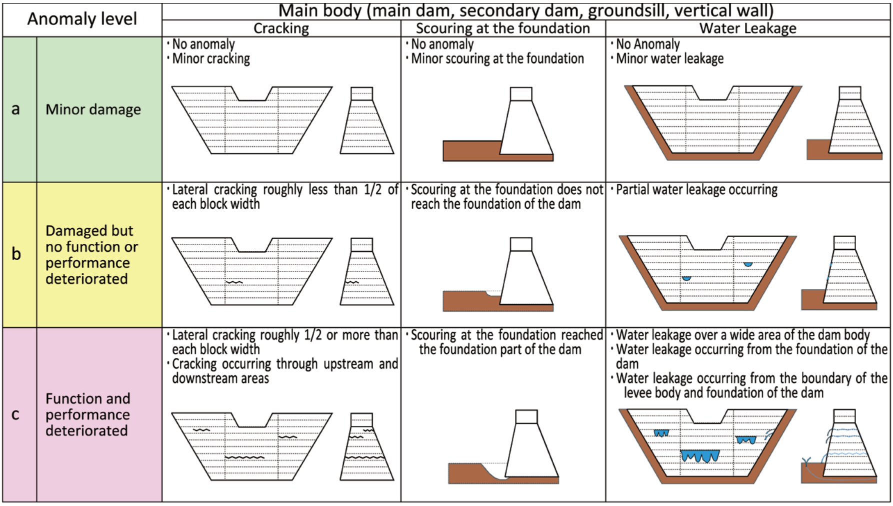
INSPECTION METHODS

1) The contents of manuals

The Erosion and Sediment Control Department of the MLIT issued the "Planning Manual for Maintaining and Prolonging the Lifespan of SABO Facilities", which outlines how to maintain and preserve the functionality of existing SABO facilities. In particular, the sections on the "Inspection of a SABO facility" and "Evaluation of the soundness of a SABO facility" are important considerations in the “Inspection Procedure Manual for SABO Facilities”, which outlines inspection methods.

2) Evaluating the soundness of a SABO facility

First, the soundness and fitness (here, “fitness” is defined as the soundness against aging by weathering) of the SABO facility of interest is evaluated visually. This inspection determines whether any damage or deterioration has occurred in the SABO facility. The effect that the observed damage or deterioration has had on the function of the SABO facilitiy is categorized into one of three grades (e.g., Fig. 4); SABO facilities in the “Anomaly level a” category are excluded from further measures at this stage.



Anomaly level		Main body (main dam, secondary dam, groundsill, vertical wall)		
		Cracking	Scouring at the foundation	Water Leakage
a	Minor damage	･No anomaly ･Minor cracking	･No anomaly ･Minor scouring at the foundation	･No Anomaly ･Minor water leakage
b	Damaged but no function or performance deteriorated	･Lateral cracking roughly less than 1/2 of each block width	･Scouring at the foundation does not reach the foundation of the dam	･Partial water leakage occurring
c	Function and performance deteriorated	･Lateral cracking roughly 1/2 or more than each block width ･Cracking occurring through upstream and downstream areas	･Scouring at the foundation reached the foundation part of the dam	･Water leakage over a wide area of the dam body ･Water leakage occurring from the foundation of the dam ･Water leakage occurring from the boundary of the levee body and foundation of the dam

Figure 4: Example of an evaluation of the level of anomaly by part (source: Inspection Procedure manual for SABO Facilities)

In addition to quantitative information on anomalies detected in the evaluation, factors that may cause damage or deterioration to the facility (such as the structure, material, model or characteristics of the catchment area) are observed, evaluated, or analyzed (Fig. 5). The overall soundness of the facility is evaluated comprehensively based on all this information (Fig. 6).

For example, if the same kind of abrasion of the levee crown has occurred at multiple facilities, an evaluation is made based on the types of internal material (e.g., concrete or rubble concrete). If the same kind of cracking has occurred at multiple facilities, an evaluation is made based on the direction of cracking (e.g., vertical, horizontal, diagonal, etc.). The immediate surroundings of the SABO facility, for example the location and volume of deposited sediment, the stability of the facility site, and the stability of the substrate near the wing of the facility are also evaluated.

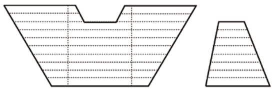
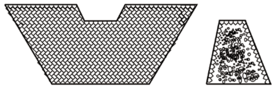
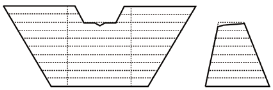
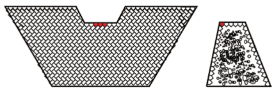
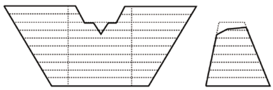
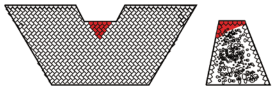
Anomaly level		Abrasion or Corruption of levee crown: Concrete dam	Abrasion or Corruption of levee crown: Masonry dam (Inside:Rubble concrete)
a	Minor damage	· No anomaly · Minor abrasion 	· No Anomaly  *Inside:Rubble concrete
b	Damaged but no function or performance deteriorated	· Abrasion depth in vertical direction roughly less than one lift 	· Some of the crown stone has been lost in the horizontal direction  *Inside:Rubble concrete
c	Function and performance deteriorated	· Abrasion depth in vertical direction roughly one lift or more 	· Some of the crown stones have lost three or more in the horizontal and vertical directions  *Inside:Rubble concrete
Observation point to note		• Abrasion proceeds and the flowing water and sediment are concentrated on levee crown, the progress rate of abrasion is increased • Width, Lentgth, Depth of abrasion must be observed	• Stone of surface of dam has protected the inside of the dam (there many cases of lean concrete),when the internal material is exposed, rapidly function and performance of the dam is decreased • Important to observe outflow status of the stones and filling concrete • If the facility is evaluated as a cultural property, to note to the preservation of its value. (For example, the appearance of the masonry)

Figure 5: Example of the evaluation corresponding to the facility structures, materials, and types (Abrasion or Corruption of levee crown, in Concrete dam and Masonry dam)

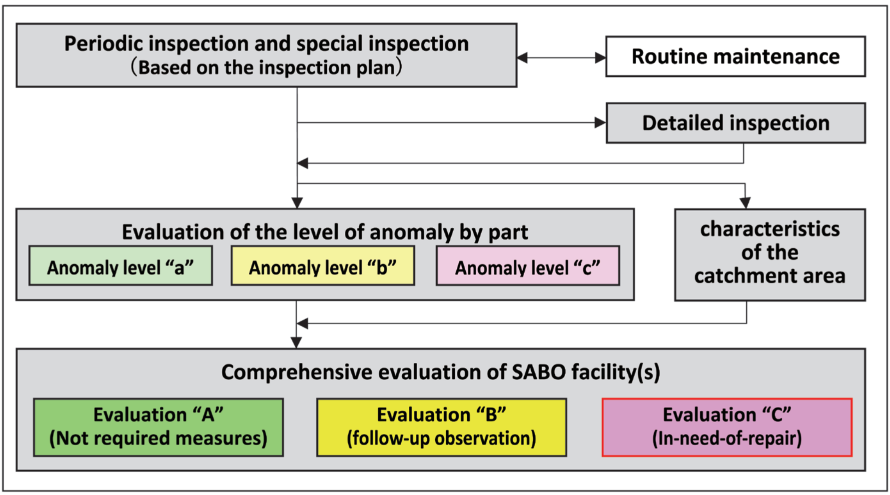


Figure 6: Comprehensive evaluation of SABO facilities

"The Performance of SABO Facilities" will be used to evaluate the suitability of technical standards (safety standards) and as a reference when deciding a measure's priority, such as the placement of conservation targets and SABO facilities, the importance of SABO facilities, the recommended size of facilities, the cost of the countermeasures, and the ease of construction of countermeasures. This will help to prioritize the measures to be taken.

3) In-need-of-repair SABO facilities and follow-up observations

SABO facilities are being classified as those that require urgent repairs (hereinafter "in-need-of-repair" SABO facilities) and those that need follow-up observation (hereinafter "follow-up observation" SABO facilities), based on the soundness evaluation. This classification is used to identify factors that lead to a loss of function and performance of SABO facilities. The personnel undertaking this classification work must have relevant experience or qualifications related to SABO.

For in-need-of-repair SABO facilities, effective repair measures need to be developed based on the characteristics of any damage or deterioration (structure, model, material, catchment area characteristics, etc.). Follow-up observations of SABO facilities will include the implementation of an inspection that can monitor the progress of damage or deterioration (e.g., abrasion of the levee crown, increase or decrease in crack width) and recording of the inspection results. In this way, SABO facilities will be classified into those requiring observation and those requiring immediate measures, so that the limited budget can be allocated efficiently to protect the safety of the region.

	Office S	Office J	Office M	Office Y	Office F	Ave.
Number of SABO dam	242	40	177	238	230	**185**
Number of "In-need-of-repair" SABO dam	17	7	23	29	23	**19**
Ratio	7.0%	17.5%	13.0%	12.2%	10.0%	**11.9%**
Number of "follow-up observation" SABO dam	126	21	143	100	133	**104**
Ratio	52.1%	52.5%	80.8%	42.0%	57.8%	**57.0%**
Typical damage or deterioration that for each office leads to loss of function and performance of the facility (Order of frequency)	1.Scouring at the foundation (Secondary dam) 2.Scouring at the foundation (Side wall)	1.Cracking (Main dam) 2.Cracking (Wing)	1.Scouring at the foundation (Main dam) 2.Cracking (Main dam) 3.Abrasion of levee crown (Main dam)	1.Water Leakage (Main dam) 2.Cracking (Main dam) 3.Abrasion of levee crown (Main dam) 4.Scouring at the foundation (Main dam)	1.Abrasion of levee crown (Main dam) 2.Cracking (Wall) 3.Water Leakage (Main dam) 4.Cracking (Main dam)	

Figure 7: Result of analyzed and evaluation about the soundness of the SABO facilities in five under the direct control SABO works office

In 2014, we evaluated the soundness of SABO facilities under the direct control of five SABO works offices. These investigations showed “abrasion of the levee crown” and “scouring of the foundation of the dam”, typical damage or deterioration that leads to loss of function and performance of the facility. On average, approximately 12% of SABO facilities were “in-need-of-repair” and 58% required “follow-up observations” (Fig 7).

4) A case example

SABO facilities are being repaired to maintain their functions. In addition, their structures are being reinforced and function improved to achieve effective utilization of facilities from the viewpoint of maintenance and prolonging the lifespan of SABO facilities (a reduction of total cost) (Fig. 8).

For example, when a SABO facility suffers from repeated abrasion of the levee crown, it is repaired with granolithic concrete to reduce the repair frequency (L). When an apron and counter dam are constructed to prevent scouring at the foundation (S), appropriate measures are taken using a variety of actions, including widening the dam to improve stability (s1), increasing the crown and wing widths to confer greater protection against debris flow (s2), and raising the dam height to increase the sediment trap capacity of the SABO facility (s3).

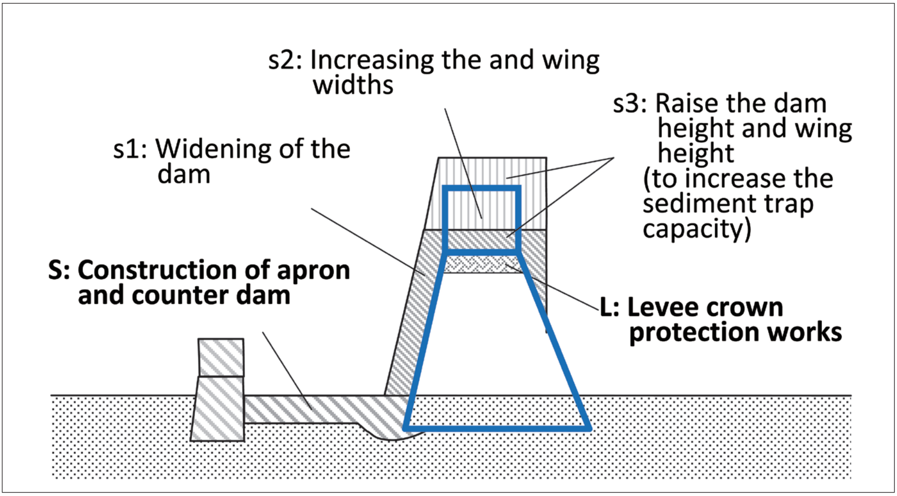


Figure 8: Example of measures in light of Maintenance and Lifespan-keeping of SABO facilities (reduction of total cost)

BUDGET AND SYSTEM

The MLIT established a system that provides for a SABO facility manager who implements a "Maintenance and Lifespan-prolongation Plan" according to the manuals, with a national subsidy to cover part of the work costs in 2015. To take advantage of this system, the prefecture began to create a "Maintenance and Lifespan-prolongation Plan", with a deadline of fiscal 2018. In addition, facilities under the direct control of SABO works undergoing construction and maintenance must be investigated by the end of fiscal 2016, and measures should then be implemented. To contribute to these plans, our organization will study the soundness of SABO facilities and countermeasures for various types of SABO facility.

REFERENCES

- Planning Manual for Maintaining and Prolonging the Lifespan of SABO Facilities: The Erosion and Sediment Control Department of the Ministry of Land, Infrastructure, Transport, and Tourism of Japan (Currently available only in Japanese.)
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