Design Guideline for Installing a Joined Rigid-Frame Driftwood Entrapper to Existing Sabo Facilities

March 2020

Sabo and Landslide Technical Center (STC)
Joined Rigid Frame Driftwood Entrapper

“Augmentation for Driftwood Entrapment by Joining to Upstream Part of Spillway of an Existing Sabo Facilities”

Compilation of the Design Guideline

Throughout sediment floods disasters nationwide, it has been observed that oftentimes, driftwood inflicts extensive damage. From the aspect of further promoting driftwood countermeasures, many discussions have been held on this matter at the “Study Group on the Development of New Sabo Technology” at the Sabo and Landslide Technical Center. The goal was to make driftwood entrapment work more widespread, and a guideline was created for the design of an effective “Rigid-frame driftwood entrapper,” which is an augmented rigid-frame joined to the upstream part of the spillway of an existing sabo facility.

Regarding driftwood countermeasures, basic concept on planning and design is outlined in the “Technical Code for River Works (Practical Guidelines for Planning) (March 2019, Water and Disaster Management Bureau, MLIT), “Ministry of Construction, Technical Code (Draft) for River Works and Sabo” (May 1997, River Bureau, Ministry of Construction), “Formulation of a Basic Plan on Sabo (Debris Flow and driftwood Countermeasures) (March 2016, National Institute for Land and Infrastructure Management (NILIM), MLIT), “Debris Flow and Driftwood Countermeasures Design Technology Guidelines (March 2016, NILIM), “Design Handbook of Steel Sabo Structures, 2009 version)(Sabo and Landslide Technical Center).

This guideline takes not only the above criteria and guidelines into full consideration, but also expert insight from field surveys, research on driftwood disasters and results from experiments, thereby presenting views and specific figures based on broad-range of specific sites.

March 2019

“Study Group on the Development of New Sabo Technology (Driftwood Countermeasures)”
Takahisa Mizuyama, Chairman

Members of the "Study Group on the Development of New Sabo Technology (Driftwood Countermeasures)"

Chairman	Takahisa Mizuyama (Specially-Appointed Professor, National Graduate Institute for Policy Studies)
Members	Norifumi Hotta (Associate Professor, School of Life and Environmental Sciences, University of Tsukuba)
	Kana Nakatani (Assistant Professor, Graduate School of Agriculture, Kyoto University)
	Hideaki Mizuno (Associate Professor, School of Agriculture and Graduate School of Bioresource and Bioenvironmental Sciences, Kyushu University)
	Toshiyuki Horiguchi (Associate Professor, National Defense Academy)
	Fumitoshi Imaizumi (Associate Professor, Department of Environment Forest Resources Science, Faculty of Agriculture, Shizuoka University)
	Taro Uchida (Head of Sabo Planning Division, National Institute for Land and Infrastructure Management)
	Wataru Sakurai (Researcher, Deep-seated Landslide Countermeasures Division, National Institute for Land and Infrastructure Management)
	Yasuo Ishii (Senior Researcher, Landslide Research Team, Erosion and Sediment Control Research Group, Public Works Research Institute (PWRI))
	Masaki Mizuno (Senior researcher, Erosion and Sediment Control Research Group, PWRI)
	Masaru Kunitomo (Planning Coordinator, Sabo Planning Division, Water and Disaster Management Bureau, MLIT)
	Junichi Kanbara (Head of Sediment Disaster Countermeasures Division, Conservation Group, Water and Disaster Management Bureau, MLIT)
	Masato Jyogasaki (Head of Earthquake and Volcanic Disaster Management Office, Sabo Planning Division, Water and Disaster Management Bureau, MLIT)

[Secretariat]

Sabo and Landslide Technical Center	Yoko Tomita (Planning Department Manager)
	Joji Shima (Deputy Manager, Sabo Technical Research Institute)
	Yuki Igarashi (Chief Engineer, Planning Department)

March 2019

*Listed affiliation is as of the time of the committee meeting

Contents

Chapter 1 Summary

1.1 Purpose of this guideline

With regard to driftwood entrapper, a type of joined rigid steel frame columns, this guideline provides a concise information for the planning and design of the “joined rigid frame driftwood entrapper,” an augmented structure to boost collection of detrimental driftwood by joining a supplemental frame to upstream parts of the spillway of an existing “Sabo” (check) dam (hereinafter, “Joined Frame Entrapper (JFE)”). In designing a rigid frame driftwood entrapper, it is necessary to fully grasp longitudinal and latitudinal stream conditions of each site in addition to optimizing a structural form suitable for types of driftwood movement and to consider whether the design method thereof is to the point. This guideline is expected to facilitate the aforementioned design process.

In various sediment-related disasters nationwide, it has been observed that driftwood exacerbates damage from sediment floods and debris flows. Therein lies the necessity to the compilation of the “Design Guideline for Joined Rigid-Frame Driftwood Entrapper’ (augmented steel frame joined to upper parts of spillway of an existing Sabo facility (check dam)).

1.2 Scope of application and, standards

(1) This guideline applies to the planning, design, and work execution of the Joined Rigid-Frame structures introduced nationwide.

(2) This guideline has been summarized with reference to current relevant laws and regulations, standards, and guidelines. The numerical values indicated in this guideline are general figures listed in existing documents, and numerical values suitable to the on-site conditions have been used in this guideline. Items not listed in this guideline are per the standards and guidelines cited below:

“Technical Code for River Works – Practical Guidelines for Planning” (Water and Disaster Management Bureau, MLIT, March 2019)

“Ministry of Construction Technical Code for River Works and Sabo (Draft) Design Volume” River Bureau, Ministry of Construction, May 1997)

“Formulation of a Basic Plan on Sabo (Debris Flow and Driftwood Countermeasures Volume)” (National Institute for Land and Infrastructure Management, MLIT, April 2016)

“Debris Flow and Driftwood Countermeasures Design Technical Guidelines (National Institute for Land and Infrastructure Management, MLIT, April 2016)

“Design Handbook of Steel Sabo Structures” (Sabo and Landslide Technical Center, 2009 Volume)

(3) For the application of this guideline, if relevant laws and regulations, standards, and guidelines are revised, the revisions shall take precedence.

For the joined Rigid-Frame (JRF), the design methods for steel impermeable Sabo dams are applied correspondingly. Please refer to the “Design Handbook of Steel Sabo Structures” for items not specified in this guideline.

1.3 Purpose of a joined rigid-frame driftwood entrapper

Driftwood entrappers constitute a column of a driftwood countermeasures facility. It is designed to boost the capturing of driftwood which flows down with gravel along the stream in a debris-flow mode, and driftwood which entails floodwater in a bedload-flow mode.

Sediments that flow down with driftwood further exacerbate damage in a sediment flood disaster. Therefore, driftwood trapping functions cannot be separated from sediment flood countermeasures. In planning and designing JRF driftwood entrappers, it is necessary to give careful consideration to the hydraulic-permeability in addition to understanding the structural behavior of steel frames.

Experience indicates that driftwood and sediment/gravel flow down simultaneously and end in clogging depositing downstream, while in certain cases driftwood and gravel flow down separately and come to a halt. In the latter case, gravel sinks on the way it flows downstream whereas driftwood floats further, thereby causing the separation. To effectively reap driftwood, it is essential that through the frame components separation of both water and gravel, and water and driftwood be achieved. At the same time, the vertical protrusion of the trapping frames must exceed the wave height of incoming debris flow or the depth of passing floodwaters.

JRF driftwood entrappers are fundamentally a structure with a hydraulically-permeable steel frames. Considerations will be made on driftwood behaviors according to sediment production and types of sediment downflow.

Photo 1: Driftwood entrapped without overflow

Photo 2: Driftwood entrapped with an overflow

1.4 Functions of driftwood entrappers

There are cases where driftwood flows down together with gravel in the debris flow, and cases where driftwood floats on the water surface separated from gravel. In order to capture driftwood which flows down together with the debris flow, the debris flow itself needs to be captured, and the components used for the driftwood entrappers must be built higher than wave heights of the debris. To collect driftwood floating on the water surface, it is necessary to set heights of the driftwood entrappers so that the rigid frames stand above the water level.

Driftwood structural countermeasures are classified broadly into driftwood preventive works to reduce the occurrence of driftwood before reaching streams and in-stream driftwood entrappers to capture the driftwood that flows down. This guideline outlines the driftwood entrappers, particularly the Joined Rigid Frame Entrapper, which adds a driftwood entrapment function to existing Sabo dams. For driftwood occurrence preventive works, it may be helpful to refer to the conventional sediment erosion and washout management method, such as suppressing the sediment production, expecting plant root systems.

Driftwood entrapment involves capturing driftwood which flows down with sediment washout. However, since the flow type of driftwood varies depending on whether it is in a debris- or bedload flow mode, selection of a facility with entrapment functions suited for the specific conditions is indispensable, with consideration to effective configurations and measurements.

"Formulation of a Basic Plan on Sabo (Debris Flow and Driftwood Countermeasures Volume)," states as follows: "The basic facility required to capture all driftwood flowing down with debris is one with a rigid frame structure." Therefore, for the debris flow stream section, a rigid framed Sabo dam was opted out. In addition, a driftwood entrapment function must be added to a hydraulically-non-consecutive weir/dam (hereafter "HNC"), a man-made waterfall.

For the bedload flow dominant stream section, due to the outflow of floating driftwood on the stream surface, an HNC Sabo dam/weir cannot capture the driftwood (Figure 1). Thus, it is necessary to augment a driftwood reaping function to the facility. Furthermore, a hydraulically-consecutive Sabo dam is also adopted (hereafter "HC"), without regards for sediment, in a mountain stream as a part of driftwood entrapment works (Figure 2).

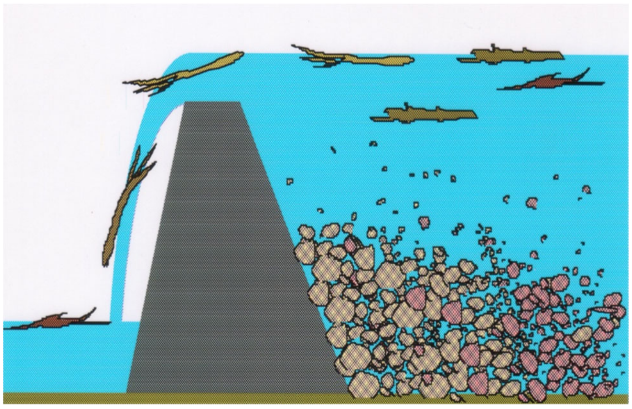


Figure 1: HNC dam with driftwood entrapment in a bedload-flow section

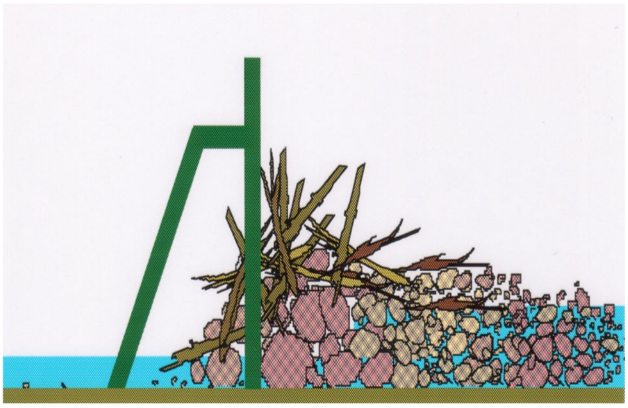


Figure 2: HC driftwood entrapper in a bedload-flow section

(1) Hydraulically-consecutive Sabo dam

In a debris-flow dominant section of streams, a hydraulically-consecutive Sabo dam (HC dam) is built when both debris flow and driftwood are to be captured together. If the framed Sabo dam is selected for the main weir as an erosion and sediment control countermeasure, it is expected to serve as a driftwood countermeasure as well.

Moreover, since driftwood and sediment flow down separately in the bedload flow section, an HC Sabo dam is utilized if driftwood entrapment is needed.

Photo 3: Hydraulically-consecutive Sabo dam that captures both debris flow and driftwood

(2) Partially consecutive Sabo dam

A partially consecutive Sabo dam is suitable when debris flow and driftwood entrapment are planned along with the reduction of detrimental washout of riverbed sediment deposition.

According to the “Formulation of a Basic Plan on Sabo (Debris Flow and Driftwood Countermeasures volume),” “in cases when a substantial change occurs from the normal sediment gradient to the current stream bed gradient or when the sedimentation is elongated, it is necessary to pay attention to the changes in the outflow pattern of the debris flow in the sedimentation range.” Hence, when a partially consecutive Sabo dam is adopted, planning and design must be adjusted according to changes in the outflow pattern in addition to the lower gradient in the sedimentation range of the HNC weir part.

With the partially consecutive Sabo dam, as shown in Photo 4, the opening may sometimes become completely clogged by driftwood and end in impoundment upstream. If debris flow strikes when the HNC part of the Sabo dam is without room for sediment, the gradient of the sedimentation in the frame section may remain moderate, causing a change to a debris flow or a bedload flow up to the upper debris flow range, as driftwood oftentimes captured before sediment. In addition, if the debris flow is captured when the HNC structure of the partially consecutive Sabo dam is empty, the front of the debris flow is to be held at the NC bottom parts, and the HC part drives the subsequent flow safely. Accordingly, when utilizing the partially consecutive type, it is vital to pay close attention to the sediment flow pattern and cross-sectional configuration.

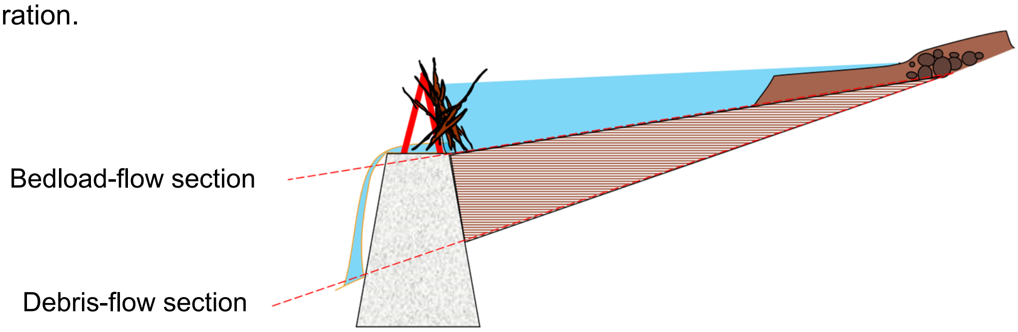


Figure 3: Sediment entrapment functions of the partially Consecutive barrier

View from downstream View from upstream

Photo 4: The opening is being clogged by driftwood, causing impoundment.

1) Cut-out type (reconstruction)

As a method of adding driftwood entrapper to an existing Sabo facility, the spillway can be cut out vertically, and a driftwood entrapper may be joined. The cut-out type can be applied with relative ease up to the sediment surface when the sediment level is not to the edge. It is necessary to set up 2 rigid columns to capture the driftwood, but if the spillway width is adequate and it is difficult to hold space to set up the 2 columns, the spillway must be horizontally widened. In addition, if a cut-out is to be made when the sediment level reaches the planned edge, gravel must be removed from upstream sediment reservoir.

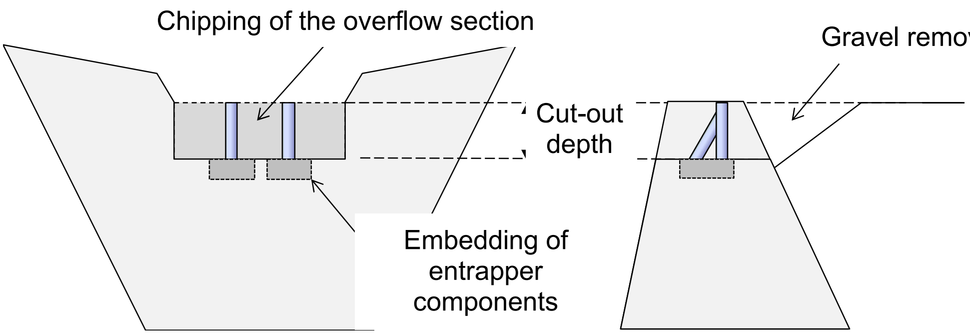


Figure 4: Cut-out type

2) Elevation type (reconstruction)

When installing a driftwood entrapper in the spillway, it is necessary to elevate the wing of weir (sleeve) according to the height to keep the cross sectional area of the spillway. While this method does not require gravel removal, the elevation of the facility height causes the sediment surface to widen, requiring land acquisition. In addition, since there is an increase in design force, weir reinforcement may be required depending on the results of the stability calculation. Furthermore, as with the cut-out method, it may be difficult to keep sufficient space to set up the columns if the spillway is not wide enough.

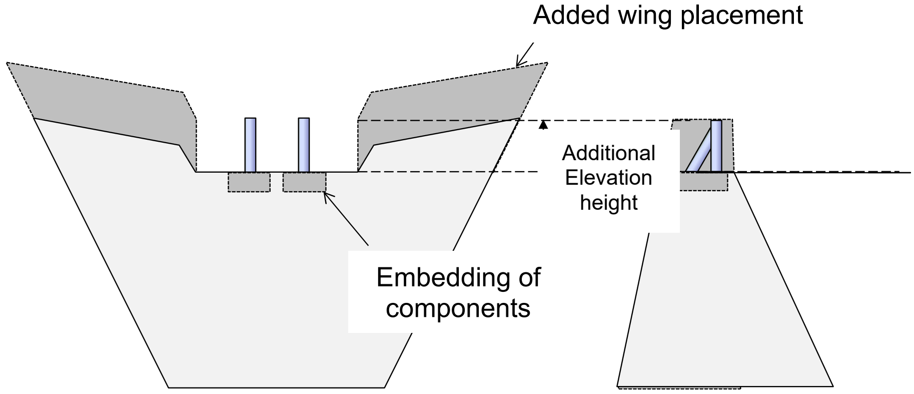


Figure 5: Structural Elevation

(3) HNC Sabo dam + driftwood entrappers

According to the “Guidelines for the Formulation of a Basic Plan for Sabo” (Debris Flow and Driftwood Countermeasures Volume) April 2016,” the planned volume of driftwood entrapment for HNC Sabo dams is obtained by multiplying the planned entrapment volume by driftwood floor-area ratio, with its half of the volume flowing down. In order to reap all planned driftwood safely in an HNC check dam, a driftwood entrapper must be added, excluding cases when the outflow driftwood is allowable or when there is a supplemental driftwood reduction plan.

1) Type of facility to be installed onto the spillway (Sabo Department, Land and Water Bureau, MLIT dated October 20, 2017)

An HC-frame is joined onto the spillway of an existing Sabo weir to reap driftwood driven down separately from sediment. The design concept for installing this driftwood reaping frame onto the spillway of an existing Sabo weir may be applied if all the conditions A to D outlined below are met.

A. The facility is intended for debris flow entrapment and is at the lowest edge of the stream with no fear of additional sediment washout.

B. The height of existing facility is below 15m (in reference to ICOLD classification).

C. The augmented frame planned under the “Debris Flow and Driftwood Countermeasures Design Technology Guidelines” remains below the cross-section of the spillway of the dam subject to the work.

D. The facility is located in a basin with little risk of a large driftwood outflow volume during future floods (not accompanied with debris flows)

Since the joined frame is clogged and impounded with an outflow of sizable driftwood outflow, few streams are suitable to this type of works.

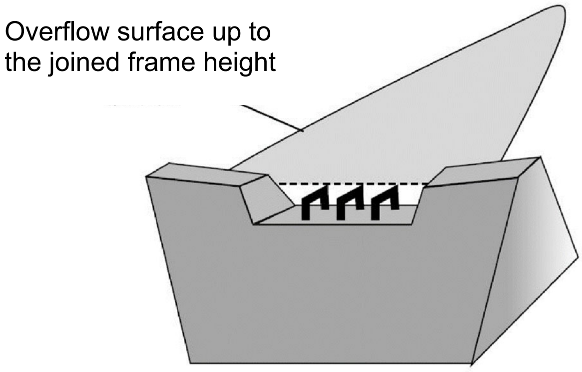


Figure 6: Frame joined onto spillway

2) Joined Rigid-Frame

With the supplemental works of an augmented frame mentioned in the previous section, cautiously, the driftwood entrapment function may be insufficient in catastrophic events where excessive amounts of driftwood are observed during a flood, or when driftwood flows down during a less-than-planned flood event, causing an overflow. Consequently, structural maintenance and driftwood removal become essential, and these methods can only be carried out when the driftwood volume is not overwhelming. On the other hand, the joined rigid frame requires minor modification to the main weir (neither cut-out nor height raising are necessary). It is installed slightly away from the spillway section with reaping frame components positioned so that driftwood does not slip down during a flood. Even if driftwood is captured upstream of the main weir, water and sediment can run through the room between the main weir and the driftwood entrappers, with the spillway fully functioning and not being clogged. As described above, the rigid frame may be joined when 1) installation of new facilities onto the spillway is not possible and when 2) the existing hydraulically non-consecutive Sabo facilities cannot be renovated to a hydraulically consecutive one. For the work method, one way is to install the driftwood entrappers on the sedimented surface of the main weir fully sedimented to level (Figure 7) and the alternate way is to join the frames rigidly onto the upper part of the main weir when its sediment level leaves a margin (Figure 8).

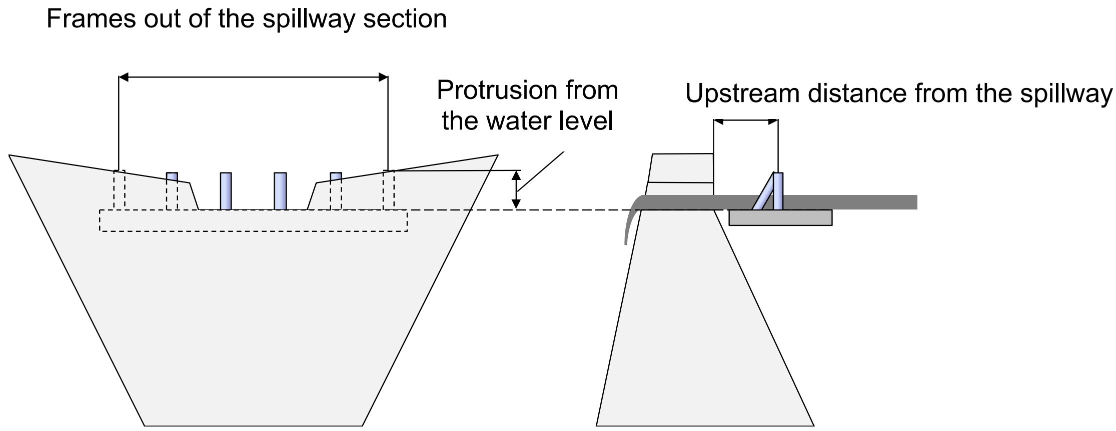


Figure 7: Joined Frame (Without Margin, fully sedimented to level)

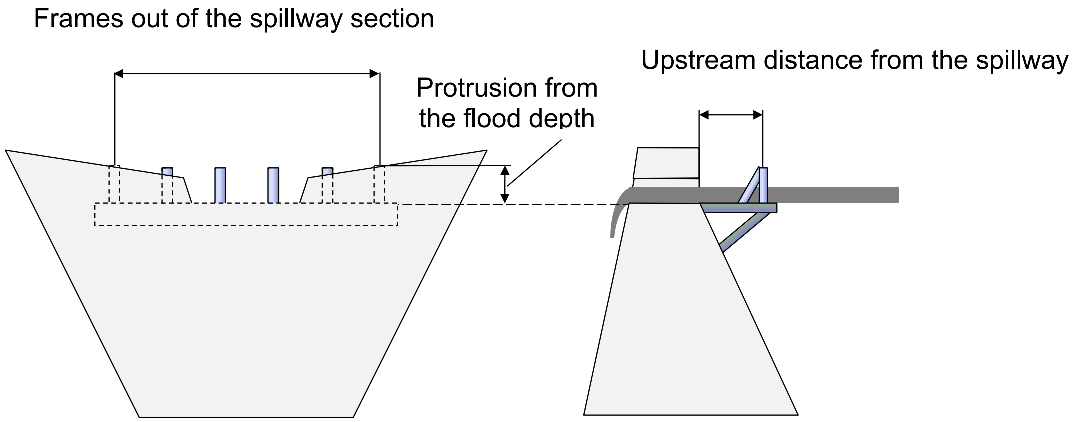


Figure 8: Joined Frame (With Margin, room for further sedimentation)

Photo 5: Up to full-sediment level: Nagaigawa Sabo Dam (MLIT Tone River System Sabo Office)

Photo 6: With margin to the full-sediment level: Futamatasawa No. 2 Sabo Dam (MLIT Tone River System Sabo Office)

3) Rigid frame joined onto secondary weir

Normally, an HC Sabo facility is constructed as a barrier against debris flow. However, when it has been determined that an HNC check dam(Sabo facility) function is necessary, such as when spur-type stabilization is used to mitigate debris flow impacts, driftwood entrapment has been added to lower weir(s). Since the planned entrapment volume of this type is calculated by multiplying the apron area between the main weir and secondary weir by the average driftwood diameter, methods such as widening the area of the apron have been used in newly constructed facilities. However, if this type is joined on an existing weir without consideration to driftwood entrapment, the apron area may be insufficient, and planned driftwood entrapment volume may not be met.

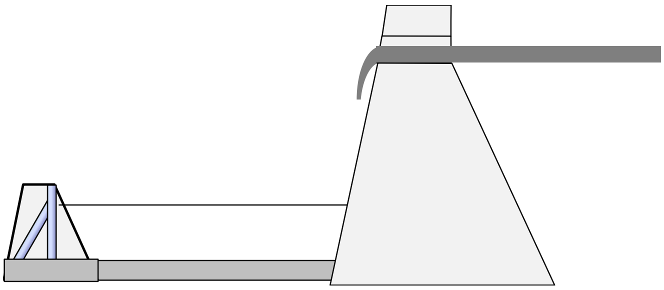


Figure 9: Side-image of frames joined to secondary weir

Photo 7: Driftwood entrapper joined to a secondary weir

Chapter 2 Design of a Joined Rigid-Frame driftwood entrapper

As indicated in the "Technical Code for River Works Practical Guidelines for Planning," "Ministry of Construction Technical Code for River Works and Sabo (Draft) Design Volume," "Guidelines for the Formulation of a Basic Plan on Sabo (Debris Flow and Driftwood Countermeasures Volume," and "Debris Flow and Driftwood Countermeasures Design Technical Guidelines," the basic driftwood countermeasure is a facility with framed barrier-type structures.

Entrapment functions of the stream section along debris flow and bedload flow modes differ according to specific facility. Therefore, adequate consideration must be taken to specific site conditions.

2. 1 Study Procedure

(1) Debris−flow dominant stream section

With existing dams, construction costs and construction period entail the need for gravel removal, cut-out and height raising works. In addition, if the sedimentation is up to the full level, gravel removal is required for supplemental augmentation with a permeable frame, which may present problems for some dams both upstream and downstream. The riverbed upstream may be scoured while sediment supply decreases downstream. Thus, if it is possible to meet the target rate of the planned driftwood entrapment volume calculated in "2.2 Planned driftwood entrapment volume in the debris flow section," the hydraulically non consecutive Sabo dam (HNC) may be chosen for the addition of the frame entrapper. Furthermore, the planned driftwood entrapment volume increases in proportion to the width of the sediment range. Therefore, in catchments where the riverbed gradient is moderate such as in the debris flow sediment-depositing section, HNC weir combined with frame driftwood entrappers have an advantage. However, in cases where the target cannot be met for planned driftwood entrapment volume derived in "2.2 Planned driftwood entrapment volume in the debris flow section," such as in the predominantly debris flow mode stream section or catchments where planned debris outflow volume is excessive, the basic concept is a renovation to an existing HC Sabo dam (or a partially HC Sabo weir/dam).

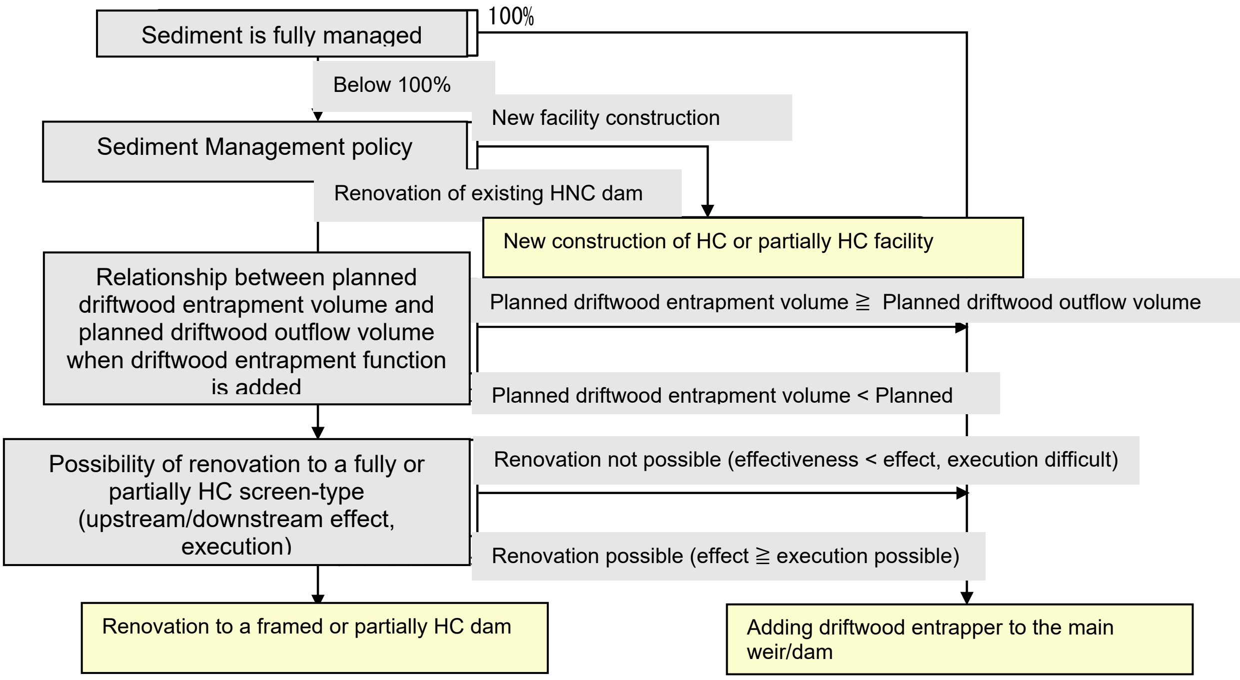


Figure 10: Study procedure of driftwood countermeasures in a basin with an existing HNC check dam (debris-flow dominant stream section)

(2) Bedload-flow stream section

In a bedload flow section, an hydraulically non consecutive Sabo dam (HNC dam) or an elevated-type HC Sabo dam (or a partially HC Sabo dam) is planned. Thus, as a method of adding driftwood entrapper to both new and existing sabo weir/dam, installing driftwood entrapment works directly upstream of the main weir or at the downstream secondary weir may be considered as shown in Figure 11. In the case of installation at the secondary weir, as with the debris flow section, the anterior part of the existing dam does not have a driftwood entrapment function, potentially not being able to capture the driftwood volume sufficiently. To alleviate this issue, if the planned driftwood entrapment volume calculated based on “2.3 Planned driftwood entrapment volume in the bedload flow section” meets the target, the HNC facility may be utilized as a basis with an addition of corresponding joined frame.

With the elevated type of HC Sabo dam as seen as concrete slit, driftwood may slip through the slit. Therefore, a method to prevent the slip-through of the driftwood needs to be devised.

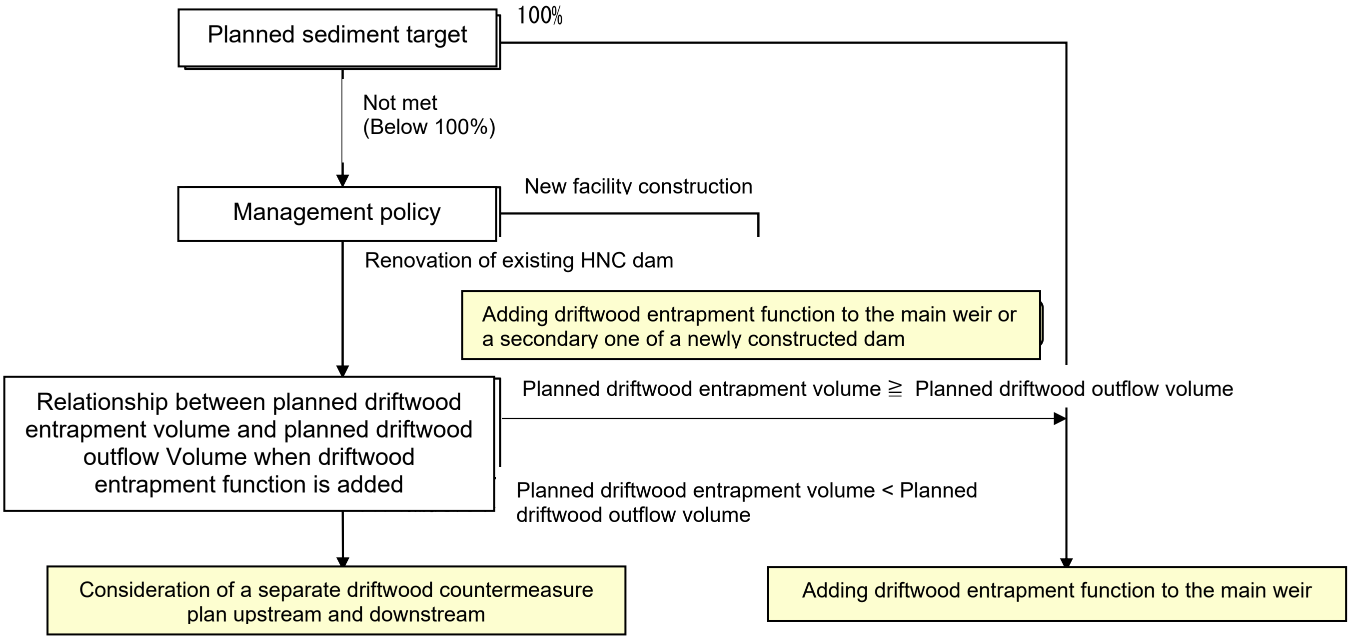


Figure 11: Study procedure of driftwood countermeasures in a basin with an existing HNC Sabo dam (bedload-flow section)

2.2 Planned driftwood entrapment volume in a debris-flow section

In the case of an existing HNC Sabo dam constructed at the most downstream part of the debris flow section with a sediment containment rate of 100%, the planned driftwood entrapment volume of the Joined Rigid Frame which is positioned at upper parts of spillway of the main weir conforms to the attachment "Views on Planning and Design When Auxiliary Structure is Installed to Capture Driftwood at the Spillway of an Existing "Impermeable-type Sabo Dam(HNC)" to the "Specific Methods for the Effective Utilization of Existing Sabo Dams for Driftwood Countermeasures" set forth by the Sabo Department, Water and Disaster Management Bureau, MLIT dated October 20, 2017.

2.2.1 Achieving the sediment containment target rate (target rate =100%)

In the case of an existing HNC Sabo dam installed at the most downstream of the debris flow section with a containment rate of 100%, it is assumed that a portion of the driftwood that flows down with the sediment at the time of the debris flow is separated from the sediment and floats through and down. The upper limit of the volume of driftwood that can be captured with the frame is calculated on the assumption that driftwood will be deposited in a layer on the flood surface when flooding occurs horizontally at the depth of the water level after being raised by the auxiliary structure (Figure 12). At this time, since the depth of the water level of the flood surface is set at the overflow section of the main weir, the depth of the water level after being raised from the driftwood entrapment works is not taken into consideration. To obtain the planned driftwood entrapment volume of the auxiliary structure, of the planned outflow driftwood volume, the volume of driftwood that cannot be captured with an existing hydraulically non consecutive Sabo dam is compared with the upper limit of the driftwood that can be captured by the above auxiliary structure, and the smaller estimation of the two is chosen as the planned driftwood entrapment volume of the auxiliary facility for safety.

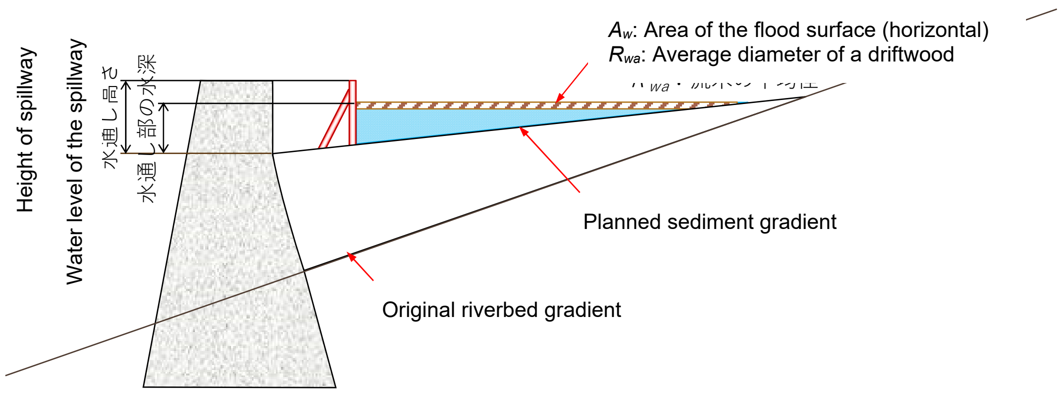


Figure 12: The upper limit of the planned driftwood entrapment volume when installed on a dam with a sediment entrapment containment rate is 100%

2.2.2 Not achieving the sediment containment rate (< 100%)

If the sediment containment target is not met at an existing HNC Sabo dam that has been installed in the debris flow section, the planned driftwood entrapment volume of the Joined Rigid-Frame that is positioned upper parts of spillway of the main weir conforms to the partially HC outlined in the "Guidelines for the Formulation of a Basic Plan on Sabo (Debris Flow and Driftwood Countermeasures Volume). "

However, since it is possible that sediment may slip through between the main weir and the driftwood entrappers, the planned sediment entrapment volume will not be counted in.

If the sediment control rate is below 100% at an existing HNC Sabo dam that has been installed in the debris flow section, the Joined RF will work on the sediment and have the same entrapment form as the partially HNC installed in the debris flow section. Thus, Figure 13 is used as a reference in deriving the planned driftwood entrapment volume. However, since sediment may slip through the spillway of the main weir and the rigid frame, it will not be counted in the planned sediment entrapment volume.

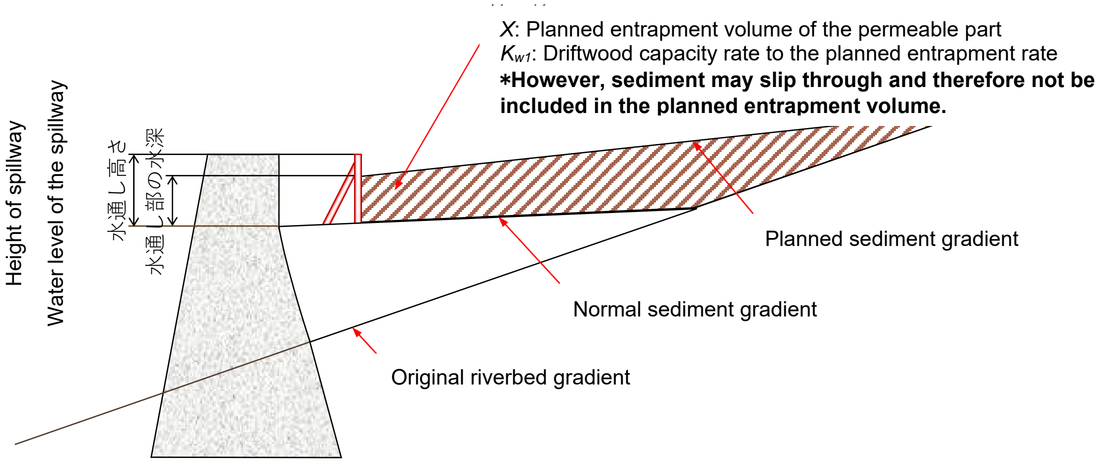


Figure 13: Planned driftwood entrapment volume when installed at a dam with a sediment entrapment containment below the target (<100%)

2.3 Planned driftwood entrapment volume in the bedload-flow section

The planned driftwood entrapment volume of the Rigid frame that is joined to upper parts of the main spillway of an existing HNC Sabo dam that has been installed in the bedload flow section conforms to the attachment “Views on Planning and Design When Auxiliary Structure is joined to Capture Driftwood at the Spillway of an Existing “Impermeable-type Sabo Dam” to the “Specific Methods for the Effective Utilization of Existing Sabo Dams for Driftwood Countermeasures” set forth by the Sabo Department Contact Office, Water and Disaster Management Bureau, MLIT dated October 20, 2017.

However, depending on the stream conditions, the planned driftwood entrapment volume may be estimated for the steel driftwood entrapment works described in Chapter 5 of the “Design Handbook of Steel Sabo Structures.”

The Joined Rigid-Frame is installed on an HNC structure in the dam sedimentation range. Therefore, the concept for the bedload section is applied to the planned driftwood entrapment volume, and the estimated by the equation “area of flooded range A(m2) x average driftwood diameter (m).” Furthermore, depending on the interaction between the spillway width and the weir wings, flooding may occur upstream of the dam (Figure 14) or in an open channel state (when there is a gradient on the water surface) (Figure 15). Hence, the flooded impact is analyzed according to the stream conditions.

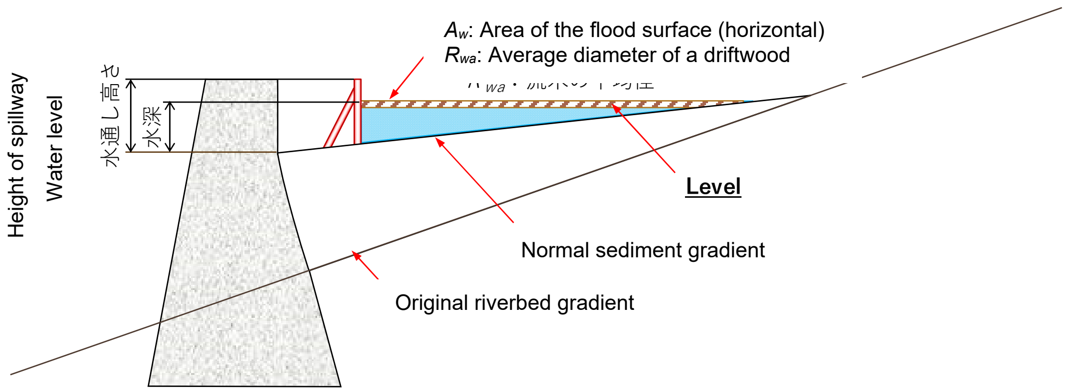


Figure 14: Planned driftwood entrapment volume when the upstream of the dam is under flooding

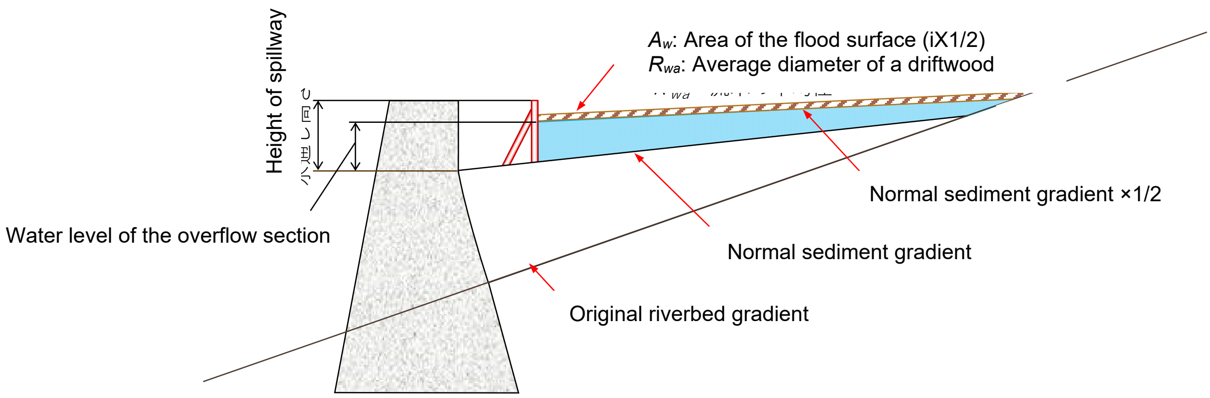


Figure 15: Planned driftwood entrapment volume when the upstream of the dam is in an open channel state (when there is a gradient on the stream flood surface)

Chapter 3 Design of a Rigid-Frame Entrapper

3.1 Application of the steel-frame structure

> The spacing between adjacent columns in the hydraulically consecutive part of Joined Rigid Frame facility must meet the conditions of boulders not blocking the HC structure and at the same time capturing the driftwood.

3.1.1 Spacing between columns in the driftwood entrapper frame

(1) Driftwood length

According to the survey results of the driftwood disaster in Ichinomiya Town, Aso City, Kumamoto Prefecture in July 1990, the sediment washout and driftwood disaster in Ikagawa, Aichi Prefecture in September 1989, and the sediment flood disaster in the northwestern region of Hiroshima Prefecture in July 1988, the length of the deposited driftwood were all roughly 5-meter long.

On the other hand, based on the "Formulation of a Basic Plan on Sabo (Debris Flow and Driftwood Countermeasures Volume)," to practically estimate the maximum length (Lwm(m)) of the driftwood, a comparison is made of the average riverbed width (Bd(m)) where erosion is expected when a sediment washout occurs multiplied by 1.3 with the maximum standing height of the driftwood (Hwm(m)) that flows down from upstream and the smaller of the two figures is opted out. In addition, based on "(Reference) Design of Driftwood Countermeasure Facility at the Bedload Flow Section," the net span between the components in the driftwood entrapment rigid frames at the bedload flow section should be set lower than ½ of the above-mentioned 'Lwn'.

However, with consideration to driftwood that has broken and flowed downstream and to ensure that they are captured, it is recommended that the components are spaced based on the average driftwood length or shorter. From the foregoing, this guideline adopts the driftwood length used in setting the spacing of the components to be the smaller of the generally-accepted 5 m driftwood length according to existing references (p.33-34) and the average driftwood length according to the stream/catchment survey.

(2) Spacing between column components

The spacing of components in the permeable part of the Overhang type must meet two conditions, not allowing boulders to block the hydraulically consecutive part and ensuring that driftwood can be captured.

According to the "Formulation of a Basic Plan on Sabo (Debris Flow and Driftwood Countermeasures Volume)," the net span of components should be below the length of driftwood used in setting the spacing of components (maximum length of driftwood, according to the guidelines) multiplied by ½. This prevents driftwood from rotating downstream and enables gravel to flow through as much as possible. This is instrumental to driftwood entrapment function at the bedload flow dominant stream section.

The basic policy for the spacing between components for the Joined Rigid-Frame is that it is not affected by the spillway and the column lateral spacing should be ½ of the driftwood used to set the components (general driftwood length of average driftwood length based on the stream survey). Additionally, the net span of components is the steel pipe circumference subtracted from the placement span. Concerning the bedload flow dominant stream section, based on the bedload flow that is outlined in 1.2.2 of the Formulation of a Basic Plan on Sabo (Debris Flow and Driftwood Countermeasures Volume)," there must be more than double the maximum size of gravel that is subject to flood transportation.

At the bedload-flow dominant stream section, driftwood is intermixed with gravel and flows down. Since the purpose is to capture the driftwood and not the gravel, the basic policy is to set the spacing of components 2 times more than the maximum gravel diameter so that the clogging “arch action” between the frame components is not exerted.

The spacing of components is either the net steel pipe spacing or the center-to-center steel pipe spacing. However, there is no actual difference in the driftwood entrapment effectiveness between the net steel pipe spacing and center-to-center steel pipe spacing. Thus, center-to-center steel pipe spacing is used in this guideline regardless of the steel pipe diameter to prioritize ease of design and execution and can be placed in 2.0m, 2.5m, 3.0m, and 0.5m increments.

3.1.2 Installation distance from the main weir

> The installation distance from the main weir should enable the entrapment of the driftwood and allow as much gravel as possible to flow down.

The Joined Rigid Frame is installed upstream of the main weir. The installation distance between the main weir and the Joined Rigid Frames should be such that driftwood cannot slip through. Therefore, the frame installation distance should be below ½ of the driftwood length used in setting the column placement span. However, if the distance is to be extended depending on the shape of the main weir, the condition of the sediment range, and workability, auxiliary components for driftwood entrapment may be installed.

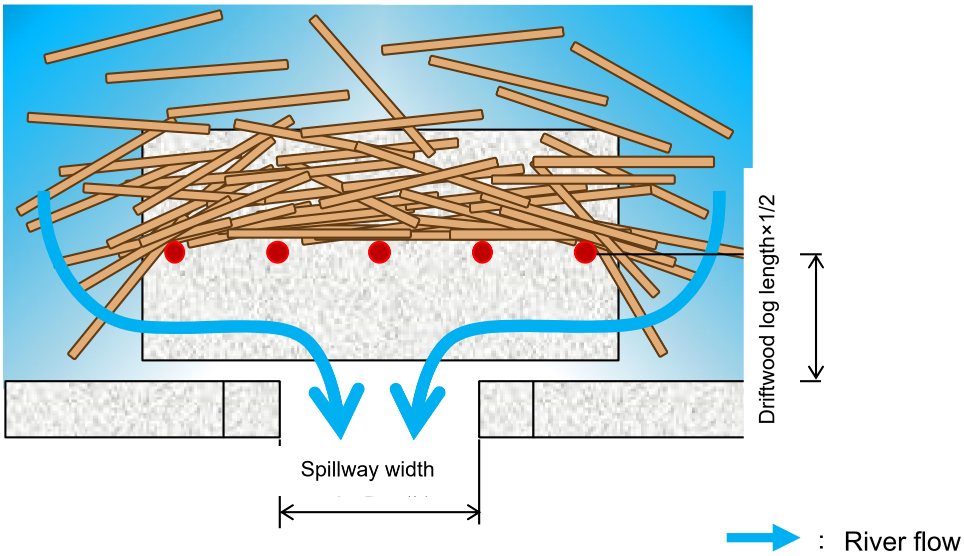


Figure 16: Placement distance from the main weir

3.1.3 Installation extension (across the stream)

The installation extension of the Joined Rigid Frame should be wider than the upper width of the main weir so that the spillway will not become blocked.

Concerning the installation distance of the Joined Rigid Frame, the basic policy is to augment the structure so that there is a protrusion of 1 span (2 columns) between the components both to the right and left of the spillway bed width so that the spillway does not get blocked. However, execution according to on-site circumstances can be made in the cases described below:

- Possibility of stream impounding elevation (if the column comes too close to the right or left bank)
- Possibility of blockage (if the channel width is narrow)
- Upstream geographic features (stream curvature, etc.)
- Upstream structures (sluice gate, fishway, etc.)

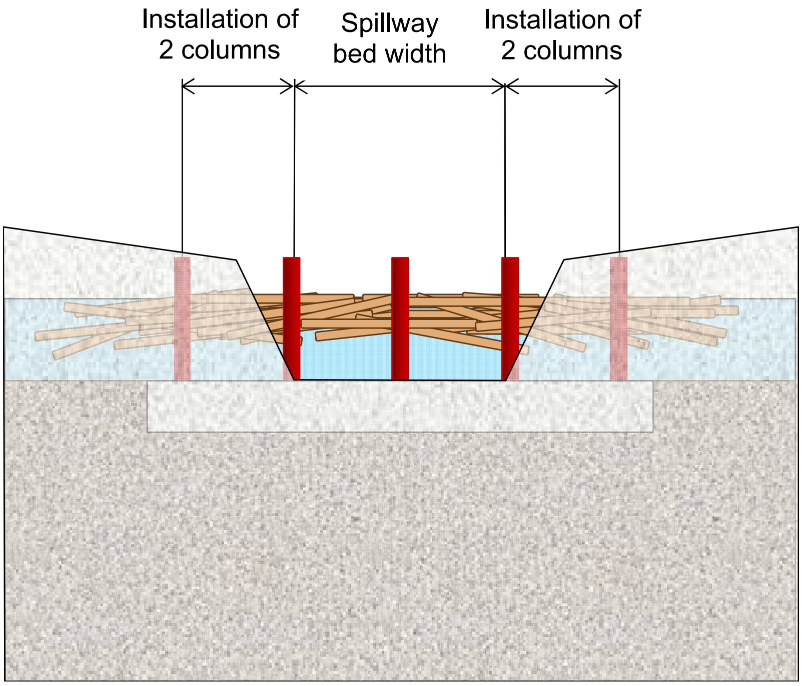


Figure 17: Cross-sectional expanse of the Joined Rigid-Frame driftwood entrapper

Examples of spillway width and installation of components when the center-to-center spacing is set to be 2.5m are shown below.

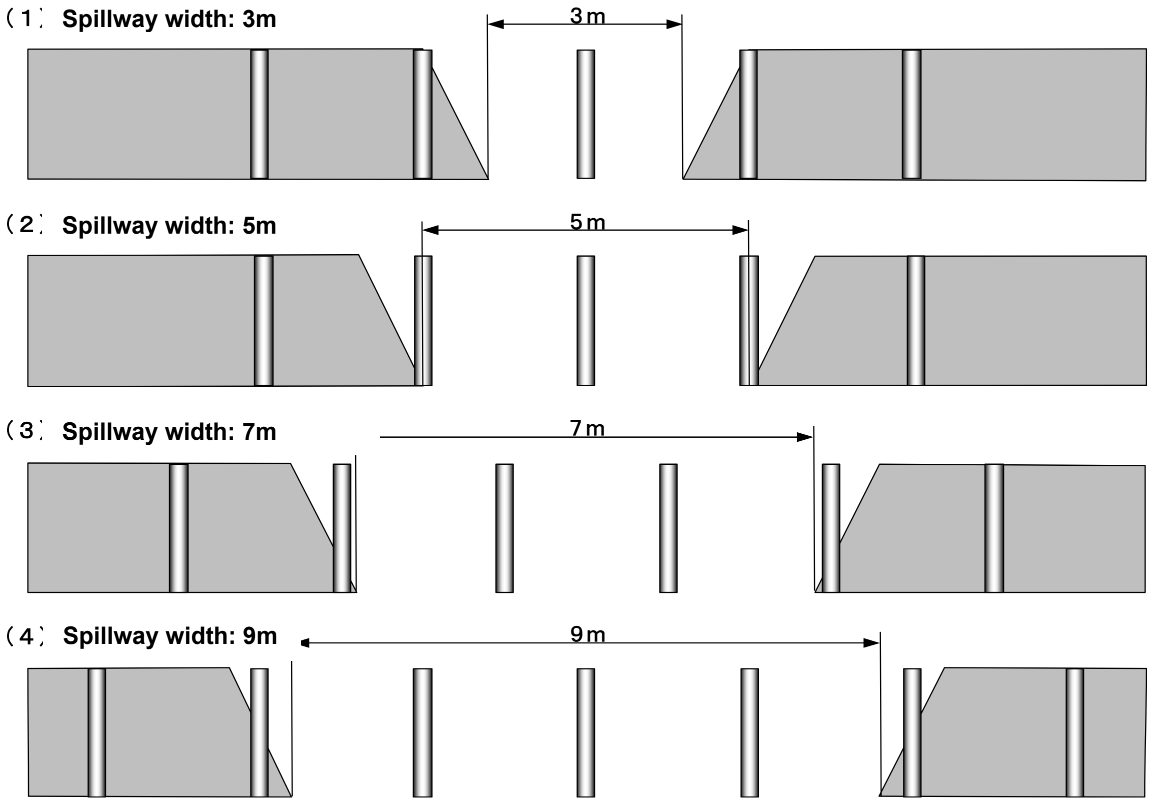


Figure 18: Spillway width and number of columns augmented (example)

3.1.4 Column height

> The columns should protrude above the depth of flood water level to ensure the entrapment of driftwood.

With the Joined Rigid-Frame, due to the wing of the main weir, the depth of the water level is elevated upstream of the spillway. Accordingly, to ensure that driftwood floating down is captured, the components need to protrude from the elevated water level (depth of water level of the overflow section) during a flood. Moreover, if there is a possibility that driftwood flows down with a debris flow, the components need to protrude from the debris flow depth. For that reason, the height of the rigid frame should be set so that it exceeds the cross-section of the spillway (water level + height margin) and with a minimum length of roughly 2.0m and 0.5m round.

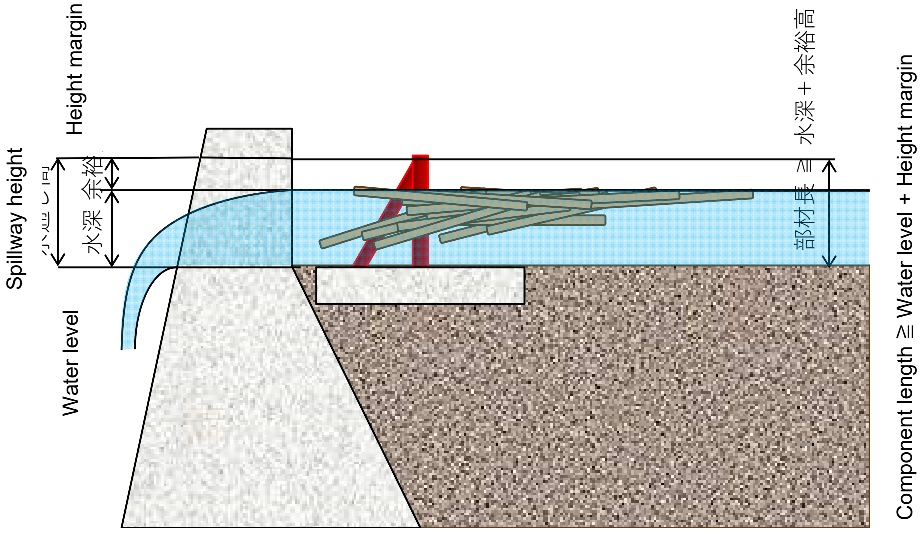


Figure 19: Height of hydraulically consecutive structure

3.2 Estimation of the external force used for the stability analysis in the debris-flow section

The stability and design external force of the Joined Rigid Frame shall be based on the “Debris Flow and Driftwood Countermeasures Design Technology Guidelines.”

3.2.1 Estimation of the fluid force of the debris flow

For the Joined Rigid-Frame, the fluid force of a debris flow is considered since the structure protrudes from the sediment surface of the spillway. The estimation of the fluid force of the debris flow is carried out based on the assumption that a major sediment washout occurs after the reservoir sedimentation level reaches to the full.

The driftwood entrapment components for the Joined Rigid-Frame protrude above the crest of the main levee spillway. Hence, when they are installed at a dam where the sediment containment target is yet to be met, the fluid force of the debris flow is to be considered. In this instance, when the dam is below the full sedimentation level, the fluid force of the debris flow is estimated using the original stream bed gradient. When the dam is without margin to full sedimentation, the fluid force of the debris flow is taken with consideration to the estimated sediment gradient of the dam at the time of the debris overflow.

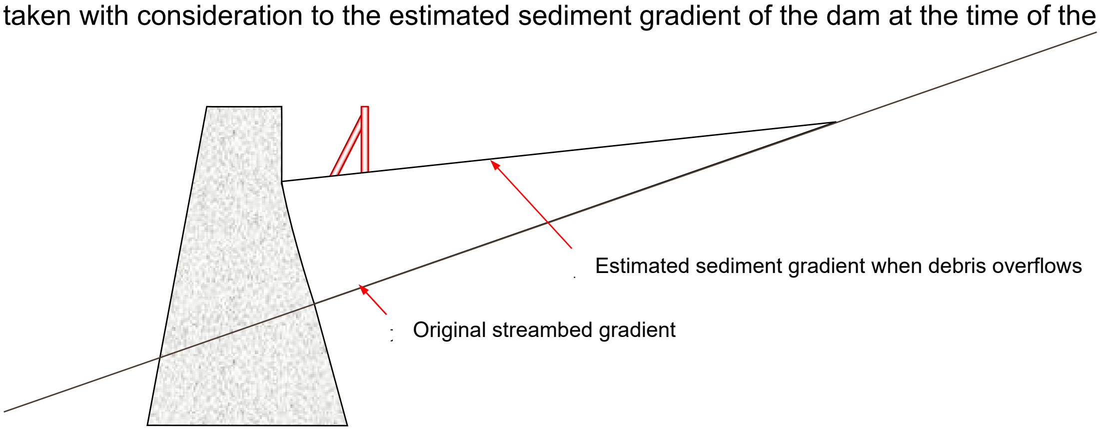


Figure 20: Estimation of various debris flow aspects

3.2.2 Load pattern estimation during debris flow

In the debris flow section when the sediment control rate is 100%, debris flow does not occur.

(1) When the sediment containment target is met (100%)

In the debris flow section when the sediment containment target is met, there is no debris flow load since the sediments will not reach the facility. However, assuming that the HC structure has been blocked, the hydrostatic pressure of the elevated water level area of the main weir spillway is applied.

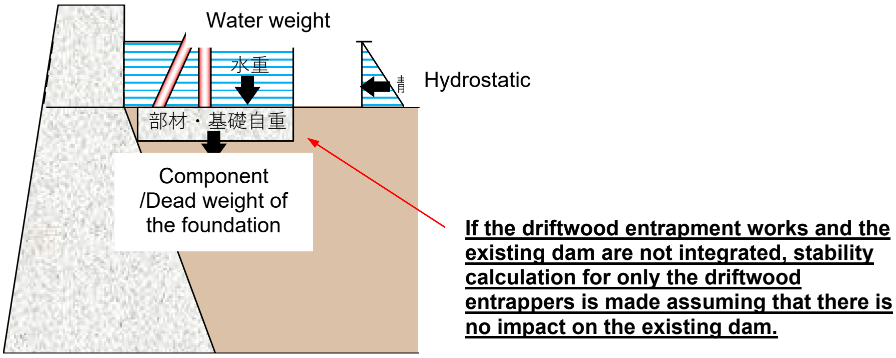


Figure 21: Design external force when joining to a facility with its target fully met (with not margin to full-sedimentation)

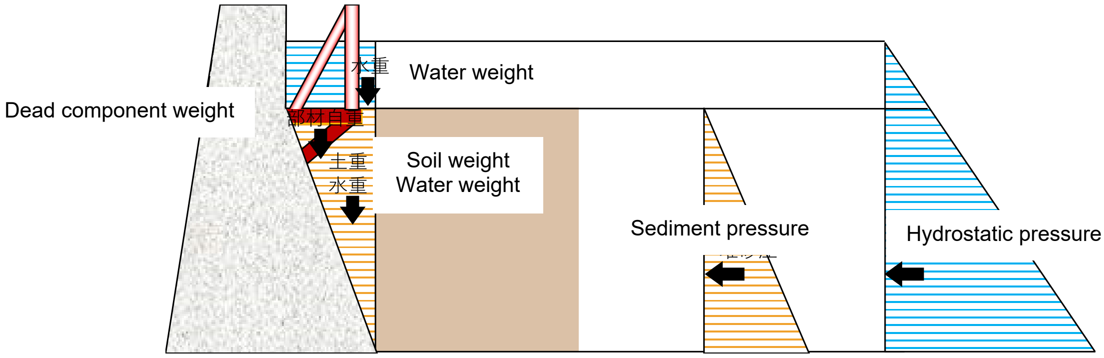


Figure 22: Design external force when joining to a facility with containment target fully met (with a margin to full-sediment level → full-sediment level)

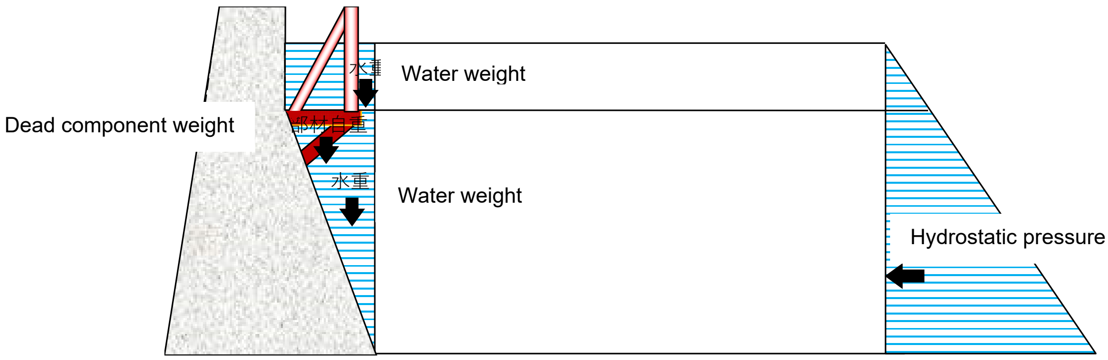


Figure 23: Design external power when joining to a facility with containment target fully met (with a margin to the full-sediment level → below full-sediment level)

(2) When the sediment containment target is yet to be met (<100%)

Concerning the augmentation of the Joined Rigid Frame onto an existing Sabo dam built before 2016, if the stability analysis is made based on the current Debris and Driftwood Countermeasures Technical Guidelines, it may not meet the prescribed safety factor (N). In such cases, the filling concrete of the foundation ground integrated with the main body can be regarded as its part and used to compensate for the would-be stability deficiency. Additionally, if the sedimentation level is to be reached, improvements below the sediment surface can be made to hold stability as part of the main body.

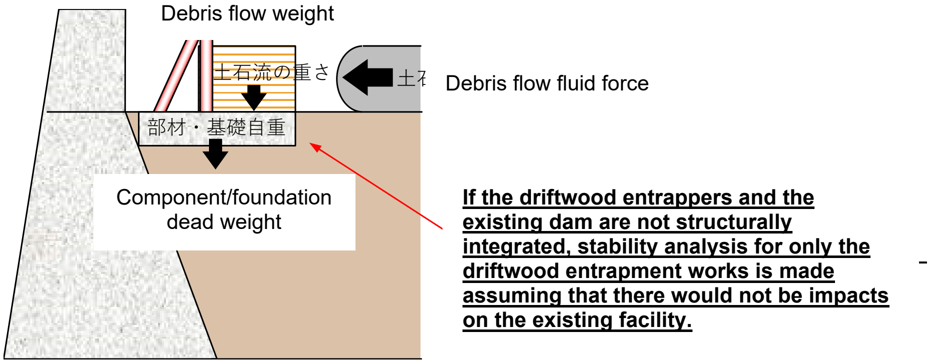


Figure 24: Design external force when joining to a facility with a containment target fully met (without margin to the full-sediment)

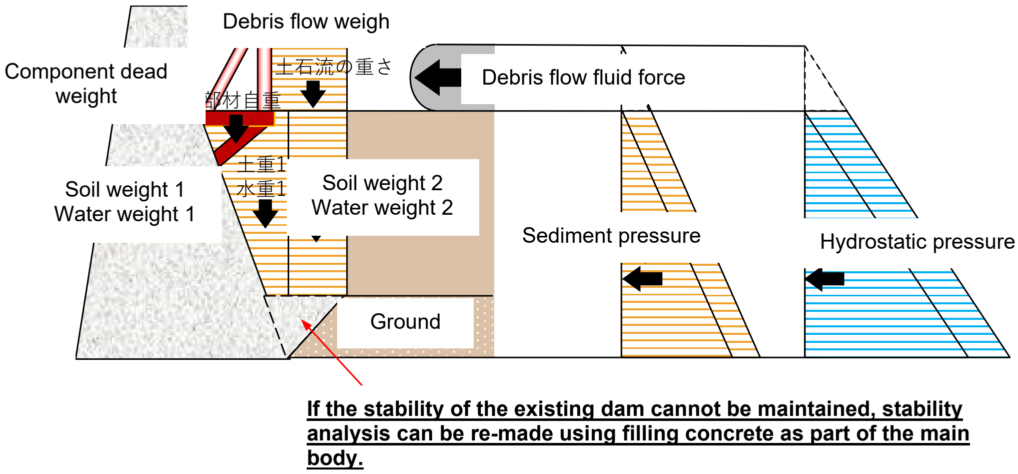


Figure 25: Design external force when joining to a facility with the insufficient containment (<100%)

3.3 Evaluation of the external forces used for stability analysis in the bed-load flow section

The stability of the Joined Rigid-Frame in the bedload flow section is considered based on the condition that the opening is completely clogged by driftwood.

The load used for the stability analysis for the Joined Rigid-Frame in the bedload flow section is based on the assumption that the upstream of the dam is flooded due to overwhelming amounts of driftwood flowing out through the overflow parts, with hydrostatic pressure applied laterally downstream-wise.

Sediment pressure is not taken into account because the net spacing of the components for the rigid-frame expanse is set with enough room to avoid entrapment of boulders.

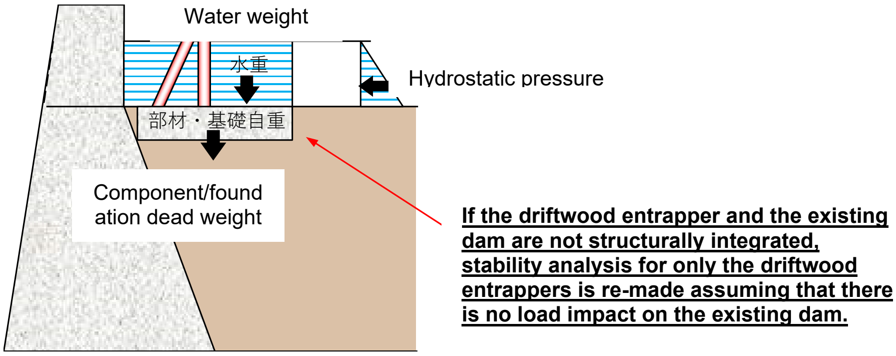


Figure 26: Under a full sedimentation condition (without margin to the full-sediment)

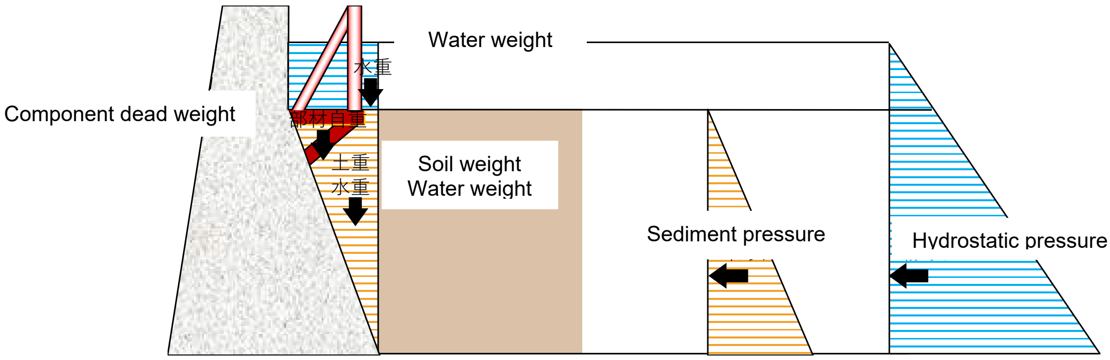


Figure 27: When full-sedimented starting from less-than full level (less-than full-sedimentation → full-sedimentation)

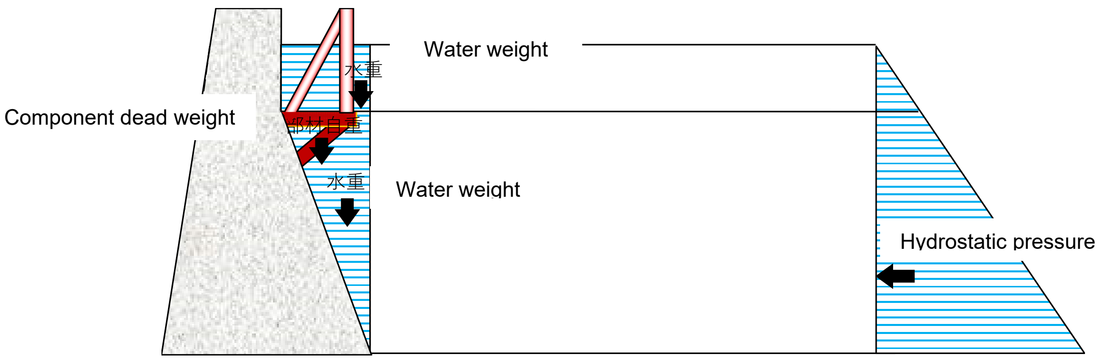


Figure 28: In a below-full-sediment level (less-than full-sedimentation←→full-sedimentation)

3.4 Structural analysis of the joined rigid-frame entrapper components

> The design external force that is considered in the structural study is based on “Debris Flow and Driftwood Countermeasures Design Technology Guidelines,” and a structural analysis is carried out for the impact force of the load, gravel, and driftwood used in the stability analysis. Verification methods for the components based on the Design Handbook of Steel Sabo Structures is to be used.

The structure for the Joined Rigid-Frame is the same as the Hydraulically consecutive Sabo dam (HC dam). Therefore, safety may be ensured if the verification of the components is conducted based on the Design Handbook for Steel Sabo Structures. However, the prerequisite for the efficacy of this verification is that the connection of the various components of the steel pipe frame is upheld and not excessively deformed. It is also based on the premise that the load is transferred to the bottom slab concrete through the steel pipe frame without fail. If other connecting methods, load setting method, or structural analysis method is used, separate modes of verification are additionally needed, thereby requiring engineering sound safety to be held for the respective methods.

3.5 Safety Analysis for the Non-Overflow Section

The safety and design external force for the main body of the non-overflow Section is based on "Debris Flow and Driftwood Countermeasure Design Technology Guidelines." However, the analysis for the debris flow fluid force is per 3.2.1 Estimation for the Fluid Force of the Debris Flow.

(Reference Materials)

1) Uchiogi T., Shima J. (1996): Design Methods for Wood-Debris Entrapment, INTERPRAEVENT, Tagungspublikation Bd.5

2) Hisashi Osumi, Hiroshi Kokuryo, Hajime Shibuya, Satoshi Katsuki, Takahisa Mizuyama "Observations-Driftwood and Standing Tree Surveys in Shobara District, Hiroshima" Japan Society of Erosion Control Engineering Annual Conference Summary, 2012

3) Hiroshi Kokuryo, Hisashi Osumi, Joji Shima, Keisuke Yoshida, Takahisa Mizuyama "Factual Survey on the Design of Driftwood Entrapment Works" Japan Society of Erosion Control Engineering Annual Conference Summary, 2013

4) Joji Shima, Takahisa Mizuyama "Method of Adding Driftwood Entrapment Functions onto Full-Sediment Impermeable-type Sabo Dams" Japan Society of Erosion Control Engineering Annual Conference Summary, 2017

5) Hideki Yamauchi, Joji Shima, Koji Iizuka, Hiroshi Kokuryo, Akira Tsuiki, Toshiyuki Horiguchi, Takahisa Mizuyama "Impact of the Opening Width on Driftwood Entrapment Functions in Steel Permeable-type Sabo Dams" Japan Society of Erosion Control Engineering Annual Conference Summary 2018

6) Hiroshi Kokuryo, Tsukasa Sasaki, Keiji Tamura, Koji Hiroi, Joji Shima "Proposal on Driftwood Countermeasures Works to Add to Existing Impermeable-type Sabo Dams" Japan Society of Erosion Control Engineering Annual Conference Summary, 2018

7) Kazuo Yoshida, Shizuka Matsumoto, Yoshifumi Satofuka, Sho Takayama, Ryosuke Sakamoto, Joji Shima, Takahisa Mizuyama "Experimental Research on Adding Driftwood Entrapment Functions onto Existing Concrete Dams" Japan Society of Erosion Control Engineering Annual Conference Summary, 2018

8) Shizuka Matsumoto, Kazuo Yoshida, Kimihiro Nagao, Joji Shima, Takahisa Mizuyama "Debris Flow Entrapment Status of the J-Slit Dam (Yunoki River) During the Northern Kyushu Heavy Rainfall in July 2017" Japan Society of Erosion Control Engineering Annual Conference Summary, 2018

References

[Reference 1] Survey results for driftwood length

The survey results and achievements concerning the length of driftwood are summarized.

[Reference 2] List of references regarding driftwood (International Journal of Erosion Control Engineering)

Theses and disaster reports concerning driftwood contained in the International Journal of Erosion Control Engineering published between 1989 and 2018 are organized into a list.

[Reference 3] Construction Example (without margin to full sedimentation level)

Photos of the construction example of the joined rigid-frame type (full sedimentation).

[Reference 4] Construction Example (with margin to full sedimentation)

Photos of the construction example of the joined rigid-frame (yet to be fully sedimented).

[Reference 5] sabo Technical notes (driftwood entrapment construction)

(General Incorporated Association) These are the technical notes concerning driftwood entrapment construction published in “sabo” magazines by Sabo & Landslide Technical Center. Please take into consideration the notes are from the magazines originally published and may have a little discrepancy to the content in this guideline.

[Reference 1]　Survey results for driftwood length

According to survey results of the driftwood disaster in Miyamachi, Kumamoto, in July 1990, the sediment and driftwood related disaster in Iko River, Aichi, in September 1989, as well as the Sediment related disaster in the northwestern area of Hiroshima in July 1988, the most common length of driftwood appears to be around 5m.

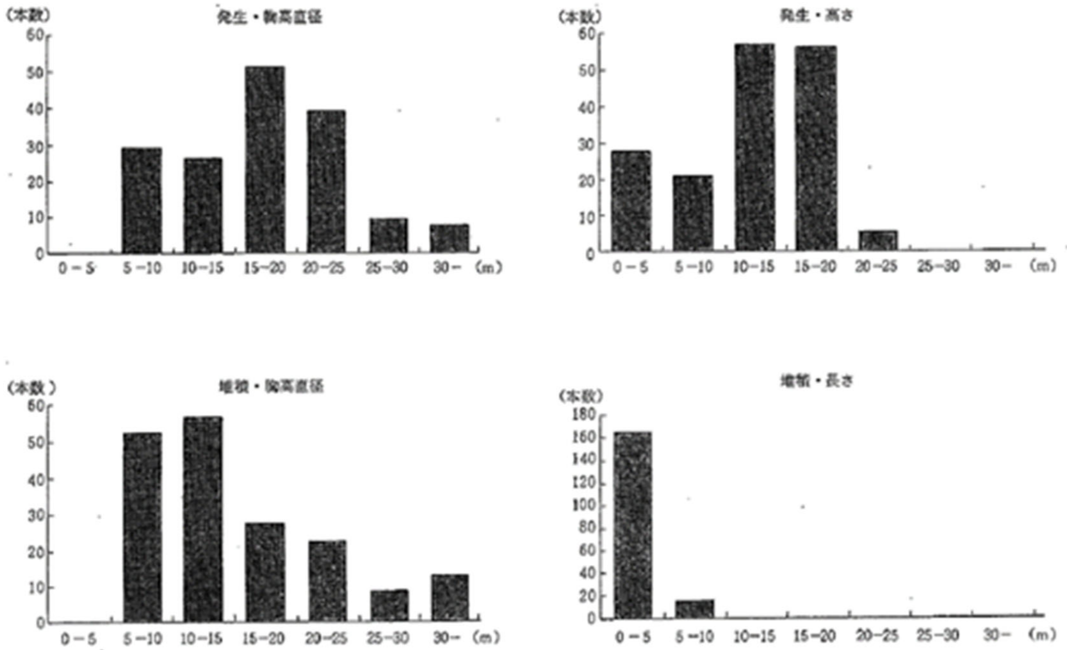


Figure 1: Frequency of length and diameter of standing and piled logs at chest height in the Koe and Higashidake rivers
(From issue 3026 of the Public Works Research Institute)

Figure 1: Survey results for Miyamachi, Kumamoto, in July 1990

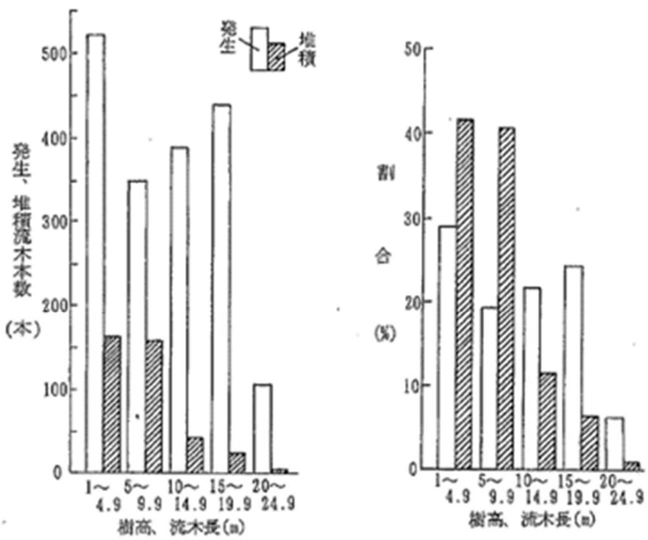


Figure 1:Frequency of length of standing and piled logs
(From issue 2833 of the Public Works Research Institute)

Figure 2: Survey results for sediment and driftwood related disaster in Iko River, Aichi, in September 1989

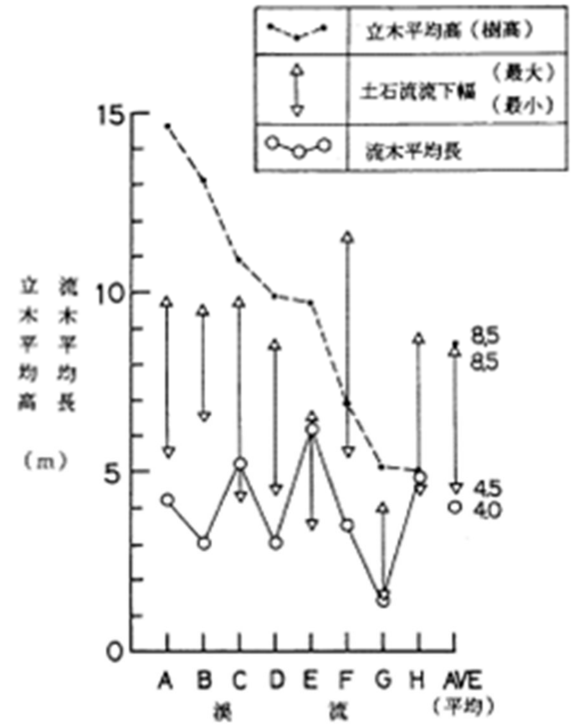


Figure 1: Length and width of driftwood
(From Ishikawa, Mizuyama, Fukuzawa 1989)

Figure 3: Survey results for the sediment related disaster in the northwestern area of Hiroshima in July 1988

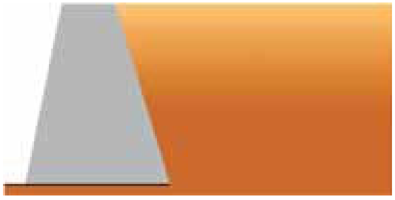
[Reference 2]　List of references regarding driftwood (International Journal of Erosion Control Engineering)

No	Author	Title	Year	Vol.	Issue No.	Page
1	Yoshiharu Ishikawa, Takahisa Mizuyama, Makoto Fukuzawa	Generation and Flow Mechanisms of Floating Logs associated with Debris Flow	1989	42	3	4-10
2	Yoshiharu Ishikawa, Takahisa Mizuyama, Nobuhide Asai	An Experimental Study on Displacement of Steel Beams due to Impact of Floating Logs	1990	42	5	11-20
3	Yoshiharu Ishikawa, Takeshi Shida	Mud flow-floating log Disasters in Ichinomia Town, Kumamoto Pref. on July 2nd, 1990	1990	43	2	63-66
4	Kazuki Matsumura, Yoshiro Hashida, Shun-ichiro Kasai	Effect of Trapping Floodwood by Grid Type Sabo dam	1990	43	3	9-12
5	Tomomi Marutani, Mio Kasai	Spatial Change of the Strength of Woody Debris Accompanied with Sediment Storage	1995	47	6	3-7
6	Nobutomi Osanai, Shinya Hiramatsu, Yoshiharu Ishikawa	Present Conditions on Effects and Maintenance System of Floating Log Prevention Structures	1998	50	6	48-51
7	Yukitada Ozaki, Yoshinori Kamogawa, Takahisa Mizutani et al.	A Debris Flow with Woody Debris Trapped by a Steel-pipe Gridded Sabo Dam	1998	51	2	39-44
8	Yasuo Miyabuchi, Akira Shimizu, Yasuhiro Ogawa	Storage of Woody Debris and Sediment in a Mountain Stream, Northern Kyushu, Southwestern Japan	1999	52	1	21-27
9	Takashi Yamada, Yasuhiro Doi, Noriyuki Minami et al.	Woody debris trapping by impermeable type Sabo dam	1999	52	3	18-23
10	Yasuhiro Doi, Noriyuki Minami, Takashi Yamada et al.	Experimental Analysis of Woody Debris Trapping by Impermeable type Sabo Dam filled with Sediment	2000	52	6	49-55
11	Noriyuki Minami, Takashi Minami, Yasuhiro Doi et al.	Woody debris trapping by impermeable type Sabo dam	2000	53	3	62-63
12	Noriyuki Minami, Yasuhiro Doi, Takashi Yamada et al.	Report of woody debris disaster at Yosasa River in August 1998 in Tochigi prefecture, Japan	2000	53	4	44-51
13	Tomoyuki Noro, Hideaki Mizuno, Taro Uchida et al.	Sediment related disasters caused by heavy rainfalls in Niigata, Fukui and Tokushima in July and August 2004	2004	57	3	47-52
14	Hajime Sato, Yu Nagasaka, Tatsuhiro Asai et al.	Quantification of the woody debris in Appetsu river basin by Typhoon 0310, Etau	2006	58	6	11-17
15	Kenji Yamada, Yu Nagasaka, Hajime Sato et al.	Quantitative study of the area of damage and the amount of lost or trapped timber in a riparian forest in the Appetsu River basin caused by Typhoon 0310	2006	59	1	13-20
16	Masahiro Katatani, Takashi Yamada	Study on new type slit Sabo dam development for reduction of slit blockade by drift woods	2006	59	1	23-31
17	Kota Kikuchi, Yoshiharu Ishikawa, Katushige Shiraki	Characteristics of large woody debris transportation and deposition by rainfall in the Kanaso Creek, Miyake Island	2007	60	3	38-43
18	Hajime Shibuya, Daisuke Haraki, Satoshi Katsuki	Experimental study on trap performance of grid shape check dam on debris flow with woody debris	2009	62	1	66-73
19	Osamu Shimizu	Wood debris transport processes and formation and failure of wood debris dams in mountain channel networks	2009	62	3	3-13
20	Hajime Shibuya, Satoshi Katsuki, Hisashi Ohsumi et al.	Experimental study on woody debris trap performance of drift wood capturing structure	2010	63	3	34-41
21	Hajime Shibuya, Satoshi Katsuki, Hisashi Ohsumi et al.	3D-DEM simulation on trap performance of drift wood capturing structure	2011	63	6	13-22
22	Hajime Shibuya, Satoshi Katsuki, Hisashi Ohsumi et al.	Investigation of drift wood caused by heavy rain at Shobara, Hiroshima on July 16, 2010	2011	64	1	34-39

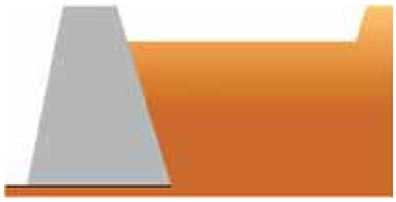
23	Kazuki Matsumura, Masaharu Fujita, Takashi Yamada et al.	Sediment disasters due to typhoon No. 12 at 2011, occurred in Kii peninsula	2012	64	5	43-53
24	Tetsuya Kubota, Takashi Jitousono, Osamu Shimizu et al.	Debris disasters induced by heavy rainfall in Northern Kyushu District in July 2012	2012	65	4	50-61
25	Hajime Shibuya, Satoshi Katsuki, Hiroshi Kokuryo et al.	Experimental study of load for steel frame check dam caused by debris flow with woody debris	2012	65	1	54-61
26	Yoshiharu Ishikawa, Akihiko Ikeda, Yoshiaki Kashiwabara et al.	Debris Disasters caused by Typhoon Wipha (T 1326) in Izu Oshima on Oct. 16, 2013	2014	66	5	61-72
27	Satoshi Katsuki, Hajime Shibuya, Nobutaka Ishikawa	Woody debris analysis around structures in river by using 3-dimensional DEM	2015	67	6	78-85
28	Kazuki Matsumura, Yuji Hasegawa, Masamitsu Fujimoto et al.	The debris flow occurred in the Tanba city by the typhoon No. 11 in 2014	2015	68	1	60-67
29	Hajime Sato, Tomoyuki Abe, Kazuhiro Minamino	The estimation of woody debris flow based on the moving pattern of river woody debris	2015	68	3	31-38
30	Yuji Hasegawa, Kana Nakatani, Yoshifumi Satofuka et al.	Experimental study on debris flow deposit dam formation and outburst process	2016	69	2	19-23
31	Takehiro Sakaguchi, Kazuo Tsutsui, Tsuneshi Nishioka et al.	Observation of the movement of sediment and driftwood in Araki river basin in Wakayama	2016	69	3	75-80
32	Ryoichi Ohno	A driftwood simulator in three dimensions using particle-based method	2016	69	4	16-20
33	Ryuhei Tateishi, Toshiyuki Horiguchi, Nobutaka Ishikawa et al.	Experimental study on blockage of drift wood roots and sediment by steel open-type Sabo dam	2017	70	2	11-18
34		Report of the first emergency investigation team for the sediment-related disasters after a heavy rainfall in Northern Kyushu in July 2017	2017	70	3	
35	Tomomi Marutani, Masahiro Kaibori, Takashi Jitousono et al.	Sediment-related Disasters by a heavy Rainfall in the northern Part of Kyushu-Island, Japan in July 2017	2017	70	4	31-42
36	Osamu Shimizu, Ryuhou Kodama, Mio Kasai	Proposal of a new idea for designating hazard areas based on travel distance of sediment and woody debris discharged from rainfall-induced landslides in Aso caldera walls	2018	70	5	3-14

[Reference 3] Construction Example (without margin to full sedimentation)

01
Pre-construction



02
Bedding excavation



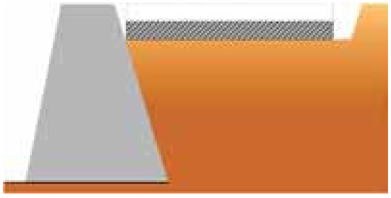
03 Plate bearing test to ensure the bearing capacity

04
Formation work

05
Concrete cast, first layer

06
Concrete cured

07
Completion of the 1st layer



08
Parts delivered

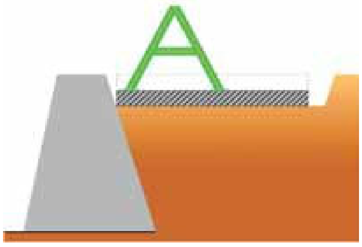
09 Parts settled in

Lifted up with a crane

10 Anchor bolts fixed

Secured with anchor bolts above the leveling mortar.

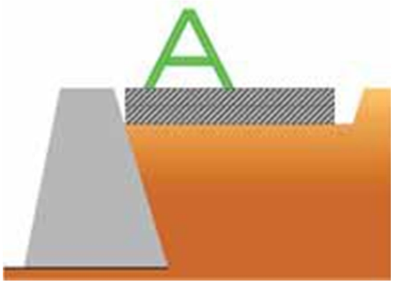
11 Completion of joining works



12 Concrete cast

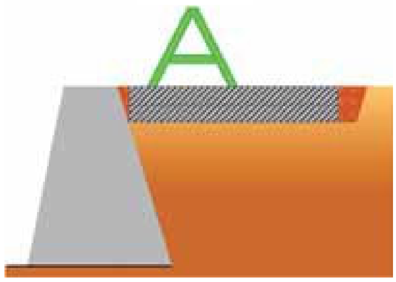
13 Concrete cured with plastic sheet

14 Concrete casting completed



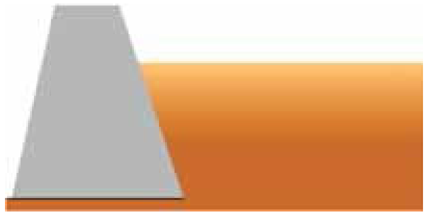
15 Back filling and restoration

16
Completion



[Reference 4] Construction Example (with margin to the full sedimentation level)

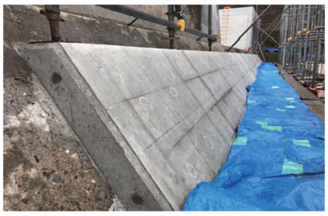
01
Before construction



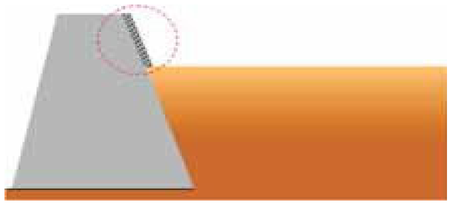
02
Chipping of existing structure

03 Formwork for filled-in concrete

04 Casting filled-in concrete



05
Concrete work finished for adjustment



06
Anchor bolts drilled

07 Anchor bolts installed

Zinc Aluminum alloys are used for the anchor bolts.

08 Mortar insertion to joints of anchor bolts

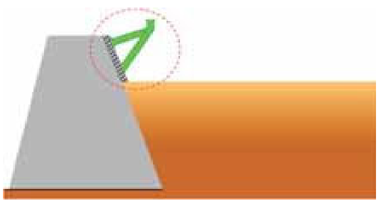
09 Anchor bolts set in

10 Scaffolding setup/parts delivery/lower part installation

11 Anchor bolts encapsulation check Scaffolding setup/parts delivery/lower part installation

The parts are secured to the existing dams using anchor bolts.

12 Lower columns installation settled

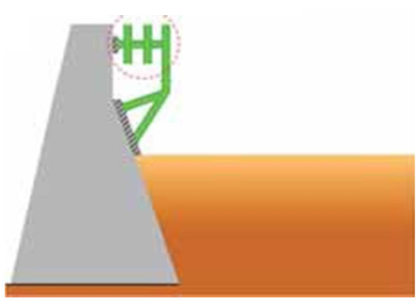


13
Center upper-part installation

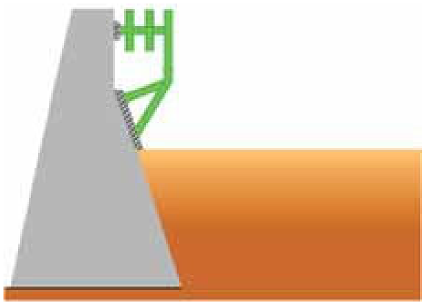
14 Edge-installation conditions #1

15 Edge installation conditions #2

16 Edge modified concrete installation



17 Completion



(On-site painting finished)

Photos provided by
Steel Sabo Structure Research Society

[Reference 5]
Technical note

Regarding steel Sabo structures 9

Driftwood entrapment construction

Joji Shima
Sabo & Landslide Technical Center
Deputy Director of the Sabo Technology Research Institute

1. Introduction

Driftwood occurs along with the yield and discharge of sediment after heavy rainfall and has been inflicting further landslide damage. Methods to install a driftwood entrapment function between debris flow sections include the method to use the steel permeable Sabo dam or the driftwood entrapment structure in the secondary levee of an impermeable type Sabo dam. Regarding driftwood countermeasures, although a "driftwood countermeasure policy (proposal)" was created after the driftwood disaster in Aso Ichinomiya in 1989, the main content was about installing a structure to the secondary levee. While lattice structure dams and B-type slit dams existed at the time for the use of catching debris flow, these steel permeable Sabo dams were not designed to catch driftwood. Today, it is often thought to be "an open-type=driftwood entrapment structure" as it is well known that steel permeable Sabo dams capture driftwood well. However, as steel permeable Sabo dams were not well known at the time, adding a driftwood entrapment structure to the secondary levee of the impermeable-type Sabo dam was the only method used. Although this driftwood entrapment structure is the type to be installed in the bedload flow section, as the capture of upstream debris is done in the main levee, the driftwood entrapment structure dealing with the bedload was installed in the secondary levee with the assumption that everything below the main levee including the front levee area flows down. (photo-1)


D type slit


h type slit


△ type slit

Photo 1 Several driftwood Entrapment structures attached to the secondary levees

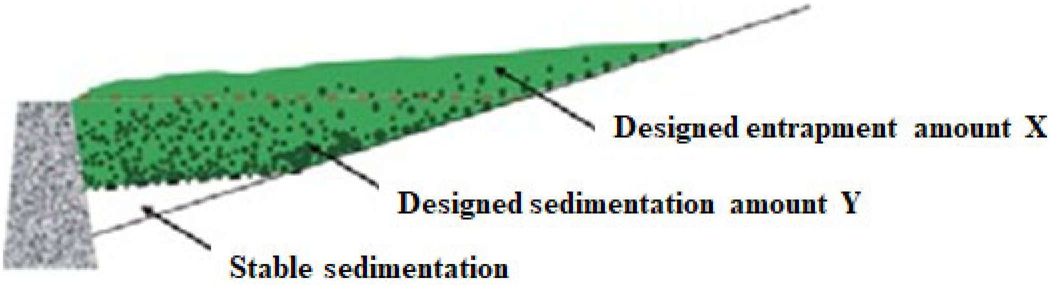
Later, when the steel permeable Sabo dams started to be installed all over the country as an entrapment in upstream areas also increased. When observing the entrapment forms, driftwood is always captured in the opening (photo-2). This shows that the effect of driftwood entrapment for the steel permeable Sabo dams has been recognized. As shown in the "April 2016 Technical Guidelines for the Design of Debris and Driftwood Countermeasures", as the main levee can also be a driftwood countermeasure if it is a steel permeable Sabo dam, the use of the method to install driftwood entrapment structures in the impermeable Sabo dam will likely decrease.

However, adding the driftwood entrapment function to impermeable Sabo dams requires significant renovation work. Therefore, we will introduce an example of adding driftwood entrapment function to the impermeable Sabo dam.

2. Driftwood entrapment ability of the impermeable Sabo dams

According to the "April 2016 Guidelines for Formulating Basic Sabo Plans (Debris and driftwood countermeasure)", the planned amount of captured driftwood in the impermeable Sabo dam is either 1) half the amount of planned captured sediment multiplied by the driftwood volume ratio or 2) 2% of planned captured sediment, whichever value is smaller (Figure 1). When adding the driftwood entrapment function to the impermeable Sabo dam, the entrapment function is sufficient if half of the driftwood flows through. However, if it is to capture the amount of driftwood that occurred in the heavy rain in northern Kyushu, it must be upgraded to the permeable type.

Photo 2 Steel open type Sabo dams capturing driftwood



1) 0.5 x Kw0 x (X+Y)
KW0 : Driftwood volume ratio to the planned flow amount
2) KW1 x (X+Y)
KW1: Driftwood volume ratio to the planned captured amount (2%)

Figure-1 Planned amount impermeable type driftwood entrapment

As a current way to add the driftwood entrapment function in the impermeable Sabo dam, it is common to either install a driftwood entrapment in the secondary levee or create a cutout in the water flow section of the main levee and install it there. If it is installed in the secondary levee, the distance between the main and secondary levee is considered the bedload flow section and the amount of captured driftwood is calculated by multiplying the area of the water cushion by the driftwood diameter (Figure 2).

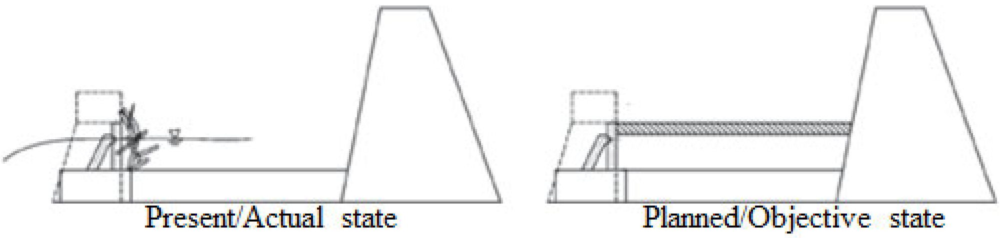


Figure-2 Driftwood entrapment of secondary levees

s

The water cushion is usually designed to be bigger if it is designed with the purpose of capturing driftwood. However, since existing facilities were not designed with this purpose, the area of the water cushions may be insufficient. Although traction is supposed to happen from below the main levee, the driftwood entrapment situation is different to what is pictured in the guidelines. When looking at the entrapment of driftwood with the structure installed in the secondary levee, it is rare to see driftwood floating in the water cushion, it seems closer to the image of the debris flow section rather than the bedload flow section, and the driftwood is captured in a way that obstructs the permeable columns (Photo 3).

Photo 3 Driftwood captured by the driftwood entrapment structure of the secondary levee

In reality, when floating logs get captured by the driftwood entrapment structure, logs around the entire permeable surface and not only on the water surface are captured. In the case of secondary levees, this tendency is stronger as the structure has a water level difference between the top and bottom section. Although the guidelines show that the bigger the area of the water cushion the bigger the amount of driftwood captured, in reality, entrapment structures with a more effective height capture more driftwood (Figure 2)

Furthermore, unlike sediment, driftwood can be captured by the entrapment structure even if it is above the water flow. If the amount of driftwood is small, the logs are captured with sediment up to the top of the water flow of the levee, if the amount of driftwood increases, the logs can be captured considerably higher than the top of the water flow (Photo 4). In other words, driftwood is captured even if it is higher than the height of the facility.

Going back to our previous topic, although the amount of planned driftwood entrapment amount may seem insufficient when the entrapment structure is installed to the secondary levee of an existing levee, a larger amount can be captured in reality. However, in order to expect more than the planned amount, columns used for the entrapment structure must be above the surface of the water. If it is under water, driftwood will flow past and the entrapment structure will not be fully functioning.

Photo 4 Yakata River (Wood, Hita City, Oita)

(1) Cutout type

As a method to add the entrapment structure to the existing Sabo levee, the driftwood entrapment can be installed into the cutout in the water flow section. The photo is the N type slit developed specifically for an existing levee (Photo 5). When installing this type, stones must be removed if it is full of sediment. When improving the impermeable type, the space to put 2 stakes may be hard to secure if the water flow area is narrow. In addition, pressure must be increased if the bed width of the upper and lower areas are narrow, which is usually done together with the reinforcement work of the levee. Therefore, the driftwood entrapment function can be added when repairing/reinforcing old levees.

Photo-5 N type slit (cutout type)

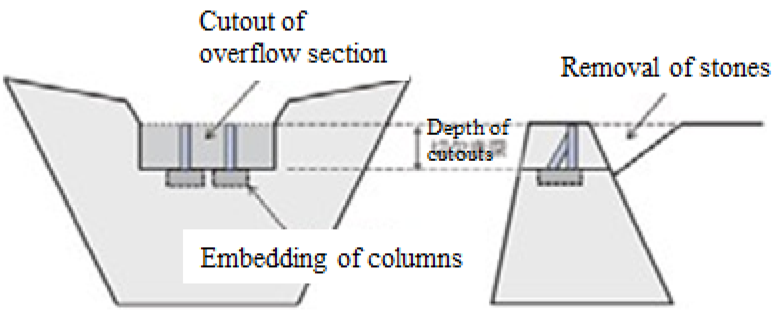


Figure -3 Cutout type

(2) Elevation type

Stones must be removed when installing the cutout type in levees that are filled with sediment. Therefore, there is a way to install the entrapment structure in the water flow section and raise the sleeve part according to the height of the structure. Although this method does not require removing the stones, it is higher in cost as the sediment surface widens and more space must be newly secured. Additionally, as the external force also increases, according to the stability calculations, improvements such as levee widening may become necessary. Also, just as in the case of the cutout type, space for the stakes may be difficult to secure if the water flow width is narrow.

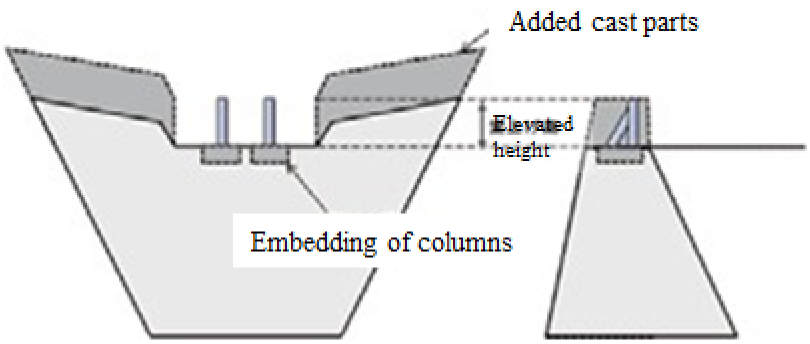


Figure-4 Elevation type

3. Function of the Overhang type

In both the cutout and elevation types, renovations of the main levee is necessary. However, one method that requires minimal changes to the main levee, which does not lower the water flow function of the main levee, and adds the driftwood entrapment effect will be introduced below (Figure 5).

In this method, instead of installing the driftwood entrapment structure in the water flow of the main levee, it is installed in a position further up from the water flow in a way that logs cannot slip through. As a function to capture driftwood, it is ideal if gravel flows past while driftwood is captured. However, when logs are caught, gravel is easily caught along with them. It is hard to make the structure function together in this way. Therefore, the idea is to place the entrapment structure in the higher part of the water flow of the main levee to make sure the gravel can flow through the gap. Although the width of the entrapment structure should be as wide as possible in order to sufficiently utilize the driftwood entrapment effect, existing impermeable types often have a narrow water flow. Therefore, the installed driftwood entrapment structure will be made wider than the width of the water flow section. For example, if placed as shown in figure 6, the apparent water flow width is “water flow width x 2 + driftwood length x (1/3~1/2) x 2” which means that sufficient width to capture driftwood can be secured. In this way, the downstream cross section can be maintained without being limited by the form of the water flow or obstructing the water flow of the main levee even if there is a large amount of driftwood captured.

Figure-5 Joined Rigid Frame type (image)

As there is no need to fit the columns within the water flow cross section, the columns of the driftwood entrapment structure (effective height) can be set to a height that easily protrudes above the water surface. Although the columns for the structure must be above the water, as this type has no sleeve part as seen in figure 7, the flow will go sideways and, even if the structure gets clogged, it won’t overflow from the sleeves if it is within the planned scale.

Another advantage is that by having columns protruding beyond the width of the water flow part, the main levee itself is not hit with the debris flow and the sleeve part that is easily damaged can be protected. As the main levee is not affected even if the driftwood entrapment structure itself is damaged by debris flow, the function of the levee can be maintained while the entrapment structure is repaired. Items and forms to consider when designing a structure is shown below.

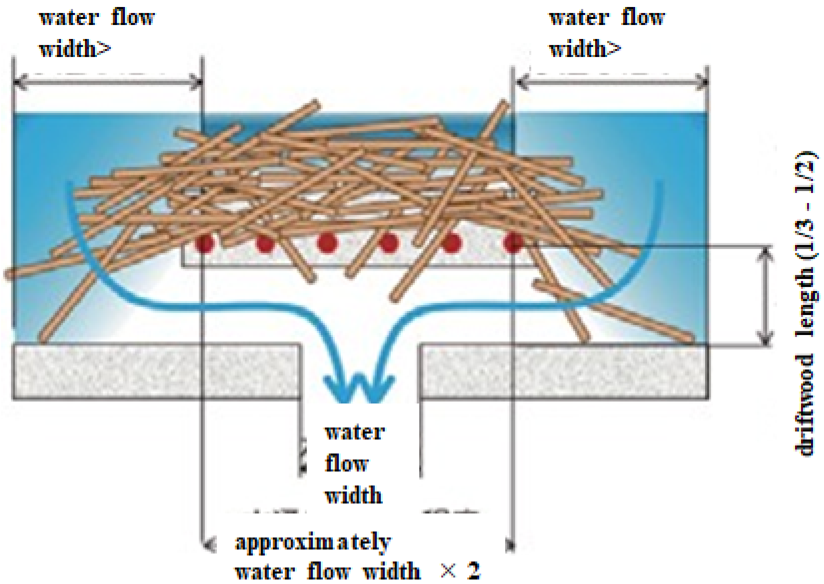


Figure-6 Planar view

(1) Length of driftwood and part spacing

The length of driftwood is used to set the part spacing and this is set to 1.3 times the valley exit in the guidelines. For example, if the valley width is 10m, the spacing should be 13m. Although it is possible to flow down at this length in the debris flow section, it will break and half in size several times as it flows downstream. However, as it does not continue to half in size, the minimum size would be about 4~6m. Therefore, if the driftwood length is assumed to be about 4~6m, the part spacing should be 2~3m. The levee can get clogged if the spacing is too narrow while logs can flow through if it is too wide. If driftwood is assumed to break, results show that 2~3m is considered the appropriate part spacing. Although it is a good idea to set it according to each driftwood length when designing a new structure, as the aim here is to avoid unnecessary costs as it is an addition to an existing levee, it is also possible to standardize and simplify the design by limiting it to several patterns.

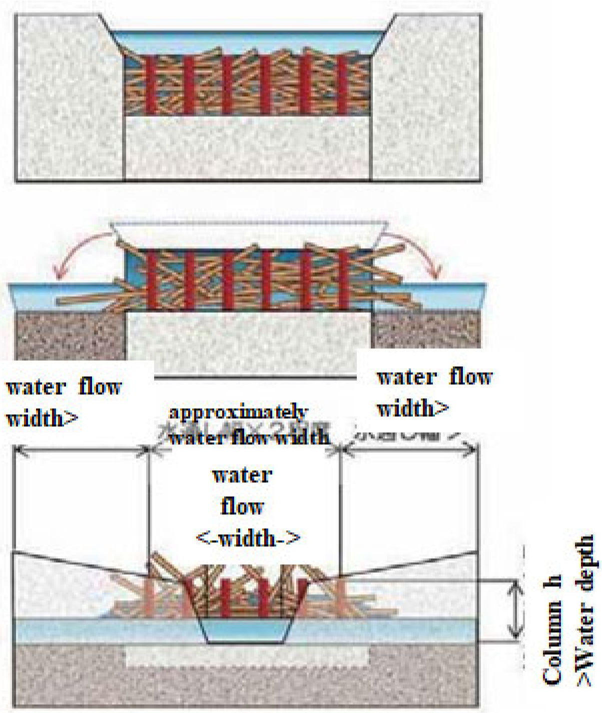


Figure-7 Front view

(2) Distance from the water flow section

As this type of driftwood entrapment structure is installed away from the water flow part, some have pointed out that the logs may float through the gap. Excluding very short logs and foliage, driftwood will be captured if the gap is 2~3m (1/2~⅓ of the driftwood length). However, if sediment and driftwood overflow above the sleeve part as seen in the heavy rainfall in Northern Kyushu last year, the driftwood entrapment structure will not function. In order for the driftwood entrapment function to work when the water is flowing above the sleeve, the scale must be big enough that it protrudes out of the water. However, as long as the permeable part installed is based on the design water level, the parts of the entrapment structure will never be higher than the sleeve. Although is it difficult to assume such a large scale, even if the planned scale is surpassed, while it cannot be guaranteed, the entrapment function can be given an allowance when the distance is set to sleeve part+1m. The function of the driftwood entrapment structure can work the better it protrudes out of the water.

(3) Overhang length from the water flow section

If both sides of the opening have a non-overflow part, the opening will be blocked by driftwood and boulders, and sediment as well as grain and sand will also be caught in the gaps in the same way as the impermeable type. As a result, even though it is a permeable type, water will flow over the sediment surface (Photo 6). The partial permeable type is the same. Because the cutout type and elevation type are both partial permeable types, a water flow cross section is installed on top of the opening with the assumption that driftwood will block the opening if it is caught.

Photo 6 Surface water flowing over sediment

The Overhang type installs the entrapment slightly upstream of the water flow part of the main levee but does not install a non-overflow part (sleeve). By doing this, driftwood is captured at the opening but water and sediment go around it and flow down water flow part. As the elevation of the height due to a blocked opening does not need to be considered, the impact scale on the upstream area remains the same before and after the structure setup. Additionally, since the water level is almost the same, the design external pressure is also the same. Therefore, the function that only catches driftwood can be added without changing the plan or design of the main levee. In order to utilize this function properly, the gap between the Overhang part and the banks on left and right should be wider than the water flow width. If the length of the levee is larger than the ratio of the water flow width, this gap will be difficult to secure. However, it will be rare for this to happen as the impermeable type has a narrow water flow compared to the levee.

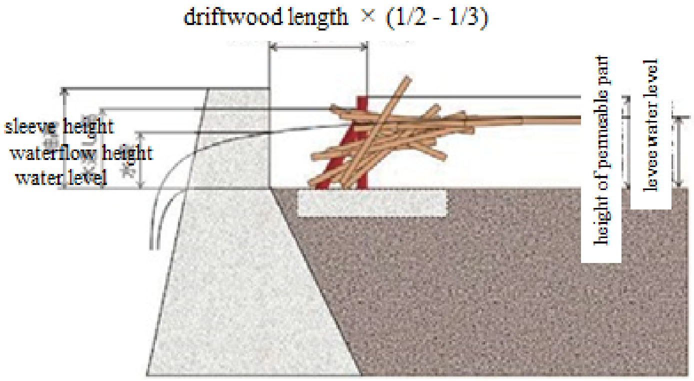


Figure-8 Lateral view

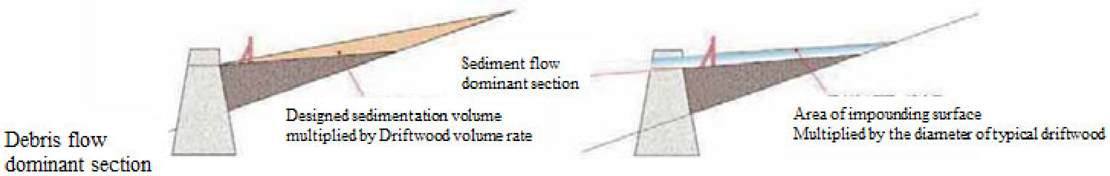


Figure-9 Lateral view

(4) Height of the permeable part (part length)

In order to capture driftwood securely, the columns of the structure must protrude out of the water. While the driftwood entrapment structure in the guidelines stipulate a height of “water level + driftwood diameter x 2 + levee height raised by columns”, when looking at the reality of entrapment, driftwood diameter and the levee height raised by columns are all within the range of error so it is better to plan for the structure to sufficiently protrude out of the water surface according to the actual circumstances. The ideal protruding height should be around 1m. From entrapment examples, even if the accuracy is determined to the cm unit level, this will not have an impact on the actual entrapment function. Therefore, the height of the permeable column should be set by adding a margin to the overflow water level and making it equal to or higher than the water flow height.

4. Planned amount of captured driftwood

Regarding the impermeable Sabo dam, at least half of the planned maximum driftwood entrapment amount flows down from the water flow part. The purpose of the Overhang type is to catch the other half of the driftwood that is not trapped in the impermeable Sabo dam. Concerning the amount of planned driftwood entrapment amount for the Overhang type, driftwood will not flow down to the levee by traction as this type is only effective as an entrapment structure after the impermeable Sabo dam is full (Figure 8). Although the planned driftwood entrapment amount of the bedload flow section (flooded area x driftwood diameter) may be closer to real situations, considering that the permeable type will be installed in the debris flow section, it will be acceptable to have it as the

water only upstream sediment + flowing water

Photo 7 Hydraulics model test

planned sediment entrapment amount x driftwood volume ratio of the impermeable type (Figure 9).

5. Load diagram

Regarding the impermeable Sabo dam, stones in the upstream section must be removed to secure sediment entrapment capacity and there is a possibility that the bedload flow section is not filled with sediment. Therefore the load diagram shows cases where it is placed on the sediment bed of the levee as well as when it is placed on the main levee. Photo 7 shows the hydraulics model test.

Figure-10 is the load diagram for the debris flow section. When placed on the sediment bed of the levee, it is the same stability calculations as the single installation of the permeable type and the dimensions of the base concrete plate buried in the sediment bed is calculated. However, since the top of the main levee is downstream and will not be scoured, the sediment pressure of the sediment bed does not need to be considered.

When placing it to the main levee, the load operating in the Overhang type is operating in the main levee as a fulcrum reaction force through steel columns as there is no base concrete plate. Here, the fluid force of the debris flow operates above the top of the water flow, and will be greater than the load in the overflow area (same as in the non-overflow area). When directly placing it on the main levee, the design of the attachment column is required.

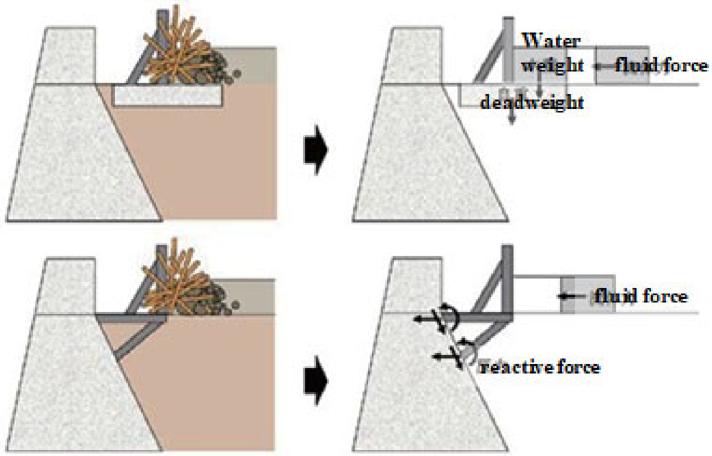


Figure 10 Load diagram (debris flow section)

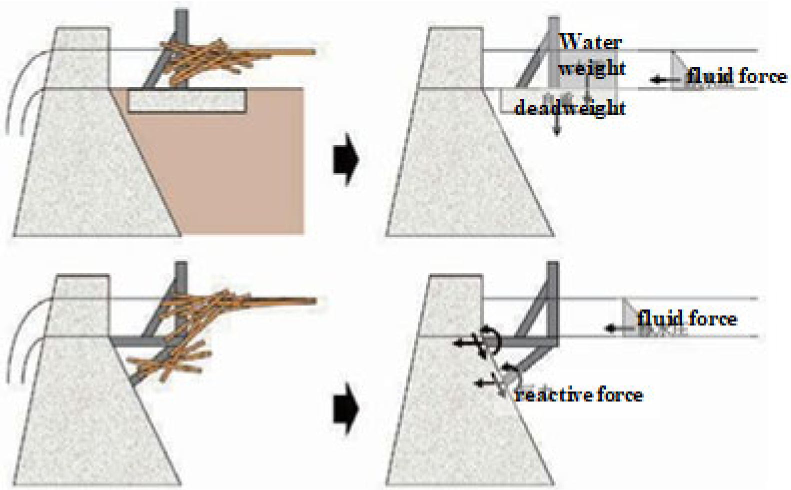


Figure 11 Load diagram (Sediment flow section)

FIgure-11 is the load diagram for the bedload flow section. Although the load is hydrostatic pressure, since the sleeve has depth raised by the levee, water levels upstream and downstream are actually the same and cancels out the hydrostatic pressure. However, the stability calculations for the bedload flow section is conducted as it is possible for the levee to be raised after catching driftwood even after the peak of a flood.

6.Conclusion

As debris flows down along with driftwood, this is a cause for furthering the damage caused by sediment related disasters. Therefore, the driftwood entrapment function cannot be ignored in debris flow countermeasures. While other driftwood countermeasures do not need to be considered if steel permeable Sabo dams are selected in the future, currently, as there are still many impermeable Sabo dams utilized as a debris flow countermeasure, it is necessary to attach a driftwood countermeasure function to the dams. Although adding a steel permeable dam would improve the entrapment function of both sediment and driftwood, this requires both construction time and costs. The method to add the driftwood entrapment function introduced here will assist the promotion of driftwood countermeasures as it can easily add the entrapment structure to existing impermeable Sabo dams.

*This article is an addition to the “Center Activity Report” presented at the Sabo Technology Achievement Reports Meeting held on November 14^{th}, 2018.

Joined Rigid-Frame Driftwood Entrapper Design Guidelines

March 31st, 2020

Publisher: Sabo and Landslide Technical Center
Level 5, Sabo Kaikan Building 2-7-5 Hirakawa-cho, Chiyoda-ku, Tokyo
Phone 03-5276-3274
Printing company: Nissei Eblo Inc
1-18-17 Nishi-Shinbashi, Minato-ku, Tokyo
Phone 03-5157-1271