GUIDELINE FOR DRIFTWOOD COUNTERMEASURES (PROPOSAL)

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Sediment Control (Sabo) Division
Sediment Control (Sabo) Department
Ministry of Construction

Part I

GUIDELINE FOR DRIFTWOOD COUNTERMEASURES (PROPOSAL)

Planning

CONTENTS

1. GENERAL

*** Driftwood countermeasures are to be implemented in basins where there is believed to be the danger of driftwood flowing down with other debris and sediment, for the purposes of protecting human life and property as well as the natural environment.**

Comments

In recent years much driftwood has combined with debris and sediment, due to heavy downpours over mountain rivers, to result in disastrous damage and loss of life in the lower reaches of rivers. Recent attention has therefore been focused on driftwood countermeasures aimed at driftwood transported by debris/sediment waterflows.

In Japan, in general there are many cases where the catchment area of mountain rivers is covered by forest. In these areas there are cases where, due to slope failure, sediment and driftwood are washed out and are carried downstream. Such driftwood clogs narrows in the river course or bridge or culvert sites giving rise to flooding, bridge damage or destruction and sometimes resulting in considerable loss of life and property. Based on observations of past experiences it is clear that the greatest damage has occurred when the outflows have been accompanied by driftwood and the countermeasures should thus be aimed at the linking the measures for debris/ sediment and driftwood outflows.

2. BASICS OF DRIFTWOOD COUNTERMEASURES

2.1 Basics of Driftwood Countermeasures

*** The driftwood means standing trees, fallen trees, felled trees, etc. that may flow out when a hillside collapse, a riverbank collapse, or a debris flow occurs and the resulting sediment flows out.**
The basics of driftwood countermeasures are to prevent the outflow of driftwood that may give damage to the downstream area as well as to capture the flowed-out driftwood in the mountain streams which are designated for sabo works implementation.

Comments

Restraint of driftwood means to prevent the production of driftwood that occurs when the sediment is produced. Entrapment of driftwood means to prevent fallen trees and felled trees accumulated on the hillside slopes from flowing into the mountain streams using sabo facilities, as well as to stop driftwood in the mountain streams from flowing down further and let it deposit using sabo facilities.

The process of driftwood countermeasures consists of surveys conducted on driftwood in the target basin, formulation of a countermeasure plan based on the survey results, and implementation of sabo works and management. The flow of driftwood countermeasures and points of note are shown in Figure 1.

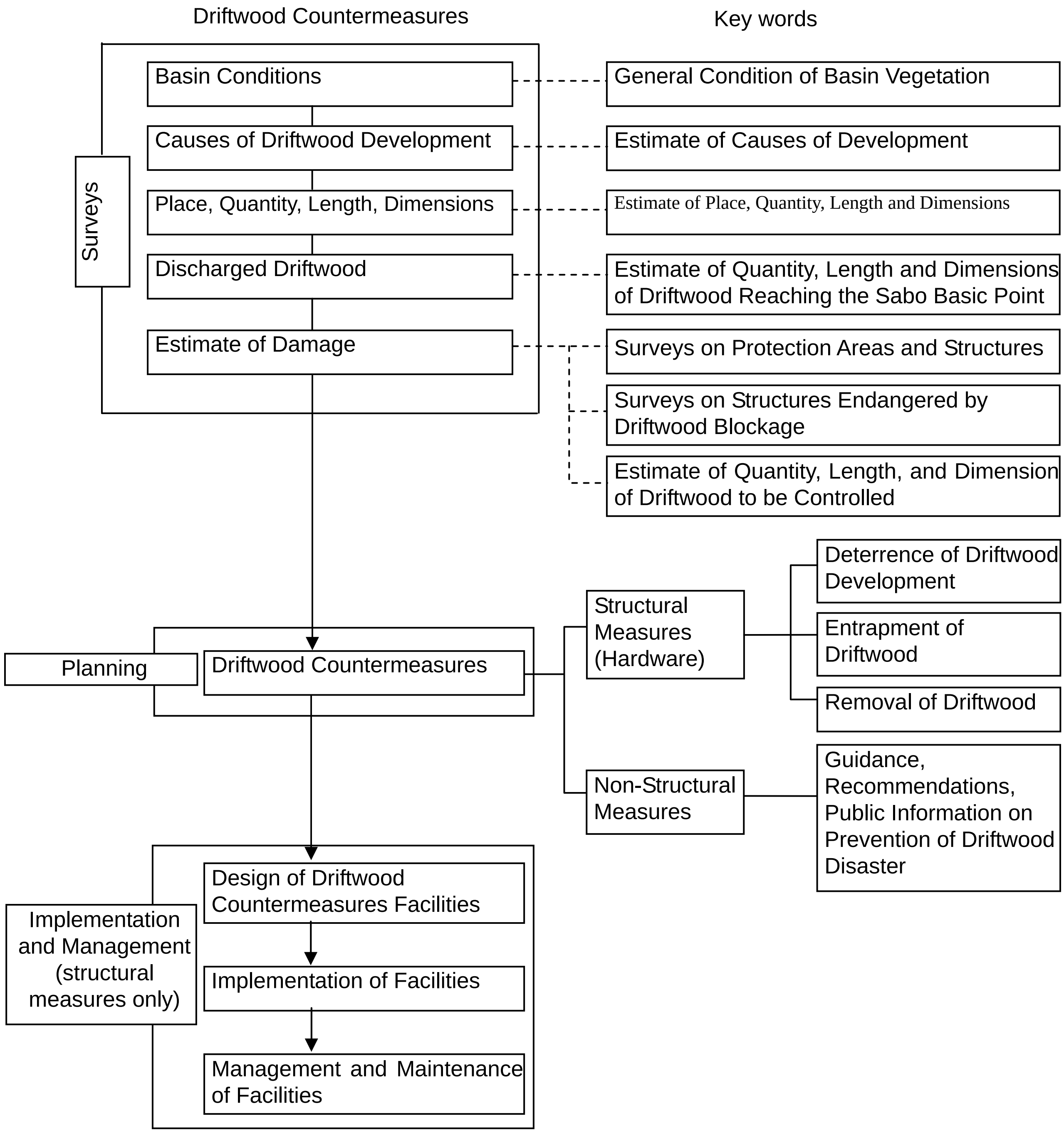


Figure 1. Flowchart of the Driftwood Countermeasures

2.2 Basic Point for Planning

*** The basic point for driftwood planning is the position at which the driftwood quantity to be handled in the driftwood countermeasure plan is determined. The basic point for the driftwood countermeasure plan is placed upstream of the target protection area.**

Comments

In general, the basic point for driftwood planning is placed at the position of the basic point for sabo planning (including an auxiliary basic point) or the basic point for debris flow planning (hereafter referred to as the "sabo basic point for planning").

2.3 Quantity of Driftwood for Planning

*** When planning driftwood countermeasures, the driftwood quantity that may flow out to the sabo basic point shall be determined by evaluating the topography, geology, forest morphology, past records, results of field survey, and other data comprehensively.**

Comments

The driftwood quantity for planning is expressed by the actual volume of driftwood. It is estimated based on the assumption that facilities for restraining the occurrence of sediment and driftwood, for storing and regulating discharged sediment, and for capturing driftwood, do not exist in the basin.

The driftwood quantity resulting from standing trees shall be estimated from the survey of the basin conditions and the potential collapsible area specified in the sabo plan (potential collapsible hillside area + potential collapsible bank area) when it is judged that the composition of forests such as the species, age, volume of trees existing in the hillside slopes and valleys susceptible to a slope failure or a bank failure would not show any significant change with time. If all the forests in the basin are of the same age, the driftwood quantity shall be estimated by presupposing the forest morphology of 10 years later from the present state of the forest. Depending on the composition of a forest, the standard quantity of standing trees by tree species which is determined for each region can be used as a reference, instead of the survey results on the present conditions of the basin.

The driftwood quantity produced from fallen trees, felled trees, and accumulated trees on the streambed can be estimated by measuring their length and diameter in a field survey. However, trees that are artificially cut for lumbers and other purposes are not included in this estimation.

The outflow percentage of driftwood to the exit of a valley must be determined through a survey, but one report says that it is approximately 0.8～0.9 when no driftwood countermeasure facilities are installed[1).

3. SURVEYS FOR DRIFTWOOD COUNTERMEASURES

3.1 General

> *** In order to implement driftwood countermeasures effectively and logically, it is necessary to estimate the possible extent of damage due to driftwood, based on the results of investigations on prevalent conditions of the basin, causes of development, place and yield and the dimensions of the driftwood.**

Comments

The flowchart and related notes for driftwood countermeasures are shown on Figure 1.

When examining driftwood countermeasures, first it is necessary to deepen the knowledge of forest morphology by carrying out surveys on the conditions existing in the basin concerned. Next, it is essential to determine the yield and development of driftwood through comprehensive interpretation of the results of “Basin Situation Survey” to be mentioned in more detail later.

Furthermore conduct surveys to estimate the places of development and 0.quantity of driftwood, and surveys to estimate the quantity and dimensions of driftwood that is likely to be washed out and carried downstream.

Based on these results, having carried out the assessment of the damage due to driftwood, it is necessary to formulate appropriate measures in the light of the quantity, dimensions and possible damage due to the driftwood.

3.2 Survey of Basin Conditions

> *** Investigation in the upper reaches from the sabo basic point should be made for the topography, geology, vegetation, land use and distribution of sediment control and driftwood countermeasure facilities, while other investigations of the lower reaches from the sabo basic point are required to determine the circumstances prevailing in the areas to be protected.**

Comments

Among the factors involved in this survey, emphasis must be placed on the survey of the vegetation, in particular on artificial forests, (same-age forests), and the situation regarding its cropping age. If there is a scheme for land exploitation for the basin concerned, a survey of future land use must be carried out.

3.3 Survey of Causes of Driftwood Development

*** It is necessary for a designer of driftwood countermeasures to infer the cause of driftwood generation or development from a comprehensive point of view or from the results of a "Basin Situation Survey".**

Comments

It is important to estimate the cause of driftwood development in order to estimate the area of development, quantity and dimensions of the driftwood, as well as the possible downstream damage. In cases where the topography of the basin is steep and the ground is weak, in the event of a heavy downpour slope collapse and debris flow are likely to occur felling trees and carrying them into the river channels. In addition, significant information can be obtained from previous examples of driftwood damage.

The causes of driftwood development are tabulated in Table 1. Apart from the causes so far considered, driftwood can also originate from the felling of lumber for logging purposes, but for the sake of convenience this will not be considered here. In other words, the countermeasures considered here are in response to occurrences resulting from hillslope collapses or the breakout of debris flows.

Table 1. Causes of Driftwood Development

Origin of Driftwood	Causes of Driftwood Development
Standing Trees	1) Slide of Standing Trees from Slope Collapse 2) Slide and flow of Standing Trees with Occurrence of Debris Flow 3) Outflow of Standing Trees due to Bed / Bank Erosion with Debris Flow 4) Outflow of Standing Trees due to Bed / Bank Erosion with Floodwater
Discharge of Fallen Trees (Previously Fallen)	5) Outflow of Fallen Trees Due to Flooding and Debris Flow, Insect Damage or Tree Disease. 6) Further Movement of Fallen Trees in River Channels Due to Flooding and Debris Flow 7) Outflow of Fallen Trees Produced by Avalanche Followed by Floodwater or Debris Flow. 8) Outflow of Fallen Trees Produced by Volcanic Eruptions Followed by Floodwater or Debris Flow.

3.4 Survey on Source area, Quantity, Length, Diameter of Driftwood

*** Surveys shall be made on the source area, quantity, length, diameter, etc. of the driftwood existing in the target basin through the reconnaissance of hillside slopes, aerial photograph reading, and interpretation of past disaster records, and by taking into account the causes of driftwood development.**

Comments

(1) Causes and source area

The causes of driftwood development and the source area shall be inferred through the reconnaissance of the target basin, reading of aerial photographs, and interpretation of past disaster records.

(2) Estimation of driftwood quantity by the survey of basin conditions

The length, diameter, and quantity of driftwood shall be estimated based on the causes of driftwood development and the source area which are obtained from the above survey.

For this survey, the direct survey method is adopted in principle, which is to survey directly the quantity, length, and diameter of trees and driftwood existing in the areas susceptible to driftwood production (hereafter referred to as the "Direct survey method on the present conditions").

The direct survey method on the present conditions is classified into two types of surveys: one is to survey all the trees and driftwood existing in the possible range of driftwood development (hereafter referred to as the "Total survey method"); the other is to survey some representing areas in the possible range of driftwood development (hereafter referred to as the "Sampling survey method"). In practice, however, the sampling survey method is usually adopted because the survey range is often too wide if the total survey method is adopted. To employ the direct survey method, it is necessary to find a possible source area at which driftwood may be produced due to a collapse or a debris flow. In the case of debris flows, the occurrence range and the flow range are usually inferred using the method specified in the "Guideline for Debris Flow Countermeasures (Proposal), Part I, Division 2, Item 2.4.1 - Design Sediment Discharge". If the occurrence range and the flow range of a collapse or a debris flow triggered by rainfall is identified using this method, then it becomes possible to estimate the quantity, length, and diameter of the potential driftwood by the survey of the quantity (number and volume) and length of standing trees, fallen trees, and the deposited driftwood existing in those ranges. As the methods for this survey, the

reconnaissance method and the aerial photograph reading are available. Normally, they are used in combination.

First, using topographical maps and aerial photographs, the density of trees (rough estimation), tree height, and tree species existing in the possible occurrence range and flow range of a collapse or a debris flow are estimated. Then, using the obtained results, the possible occurrence range and the flow range are sectioned into several areas by vegetation and forest morphology. Next, the sampling survey (range: 10 m × 10 m) is conducted in each area through a site reconnaissance, and the number of trees, tree species, tree height, tree diameter at the breast height, etc. are found. To be specific, the following items are surveyed in the reconnaissance.

[1] Density or number of trees:

number of standing trees, felled trees, fallen trees, and driftwood per 100 m^2

[2] Diameter:

diameter of standing trees at their breast height; average diameter of felled trees, fallen trees, and driftwood

[3] Length:

height of standing trees; length of felled trees, fallen trees, and driftwood

The quantity of driftwood can be calculated using the following procedures and equations. If the possible range of sediment yield due to a collapse or a debris flow is made up of multiple forest morphologies, the driftwood yield quantity (Vg) shall be calculated by each forest morphology and then totaled. The width and length of a 0-order valley or a collapse site shall be obtained in accordance with the "Guideline for Debris Flow Countermeasures (Proposal), Part I, Division 2, Item 2.4"

$$Vg = \frac{(Be \times Le)}{100} \times \Sigma V \quad \cdots\cdots (1)$$

$$V = \pi \cdot h \cdot d^2 \cdot f/4$$

***Vg*: yield quantity of driftwood (m^3)**

***Be*: width of 0-oder valley or collapsed site (m)**

***Le*: length of 0-oder valley or collapsed site (m)**

***V*: volume of a single tree; Σ V is the volume of trees per a sampling area of 100 m^2 (m^3).**

h: height of tree (m)

d: diameter of tree at the breast height (m)

f: breast height factor (See Table 2)

Table 2 Breast height factor for trees [2)]

Tree height (m)	Group 1	Group 2	Group 3	*hf* (Group 3)	Tree height (m)	Group 1	Group 2	Group 3	*hf* (Group 3)
5	0.6550	0.6529	0.6517	3.3	25	0.5066	0.4874	0.4524	11.3
6	0.6191	0.6138	0.6064	3.6	26	0.5054	0.4859	0.4505	11.7
7	0.5954	0.5878	0.5759	4.0	27	0.5043	0.4846	0.4487	12.1
8	0.5786	0.5692	0.5538	4.4	28	0.5032	0.4833	0.4470	12.5
9	0.5660	0.5552	0.5371	4.8	29	0.5023	0.4822	0.4454	12.9
10	0.5562	0.5442	0.5238	5.2	30	0.5014	0.4811	0.4440	13.3
11	0.5483	0.5354	0.5131	5.6	31	0.5005	0.4801	0.4426	13.7
12	0.5421	0.5282	0.5042	6.0	32	0.4997	0.4791	0.4413	14.1
13	0.5365	0.5221	0.4966	6.5	33	0.4990	0.4782	0.4401	14.5
14	0.5320	0.5169	0.4902	6.9	34	0.4983	0.4773	0.4389	14.9
15	0.5281	0.5124	0.4846	7.3	35	0.4976	0.4765	0.4378	15.3
16	0.5247	0.5085	0.4796	7.7	36	0.4970	0.4758	0.4367	15.7
17	0.5217	0.5050	0.4753	8.1	37	0.4964	0.4750	0.4357	16.1
18	0.5191	0.5020	0.4714	8.5	38	0.4958	0.4743	0.4348	16.5
19	0.5167	0.4992	0.4679	8.9	39	0.4953	0.4737	0.4339	16.9
20	0.5146	0.4968	0.4647	9.3	40	0.4948	0.4731	0.4330	17.3
21	0.5127	0.4945	0.4618	9.7	41	0.4943	0.4725	0.4321	17.7
22	0.5510	0.4925	0.4591	10.1	42	0.4938	0.4719	0.4314	18.1
23	0.5094	0.4907	0.4567	10.5	43	0.4934	0.4714	0.4306	18.5
24	0.5080	0.4890	0.4545	10.9	44	0.4930	0.4708	0.4299	18.9

(Note)
- **Group 1** Silver fir, Sakhalin fir
- **Group 2** Japanese cypress, Sawara cypress, Hiba arborvitae, Japanese parasol fir
- **Group 3** Japanese cedar, Pine tree, Momi fir, Japanese hemlock, and other coniferous trees and broadleaf trees
- **hf (Group 3)** height of tree obtained from the breast height factor

(3) Estimation of driftwood yield quantity based on the past data

If driftwood was caused near the target basin in the past and its data are available, the driftwood yield quantity per unit basin area (u m^3/km^2) is obtainable from the data. Then, using that value, the driftwood yield quantity in the target basin can be estimated by the following equation.

$$Vg = u \times A \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (2)$$

A: area of a basin (km^2)

As a reference, survey results of past driftwood cases which were caused by debris flows are shown in Figures 2 and 3. These figures respectively show the driftwood yield quantities in both coniferous and broadleaf forests, and the relationship between the yield quantities of driftwood and sediment.

The area of a basin here means the area along the mountain stream in the range having a streambed gradient of 5 ° or more and mostly covered with a coniferous or broadleaf forest.

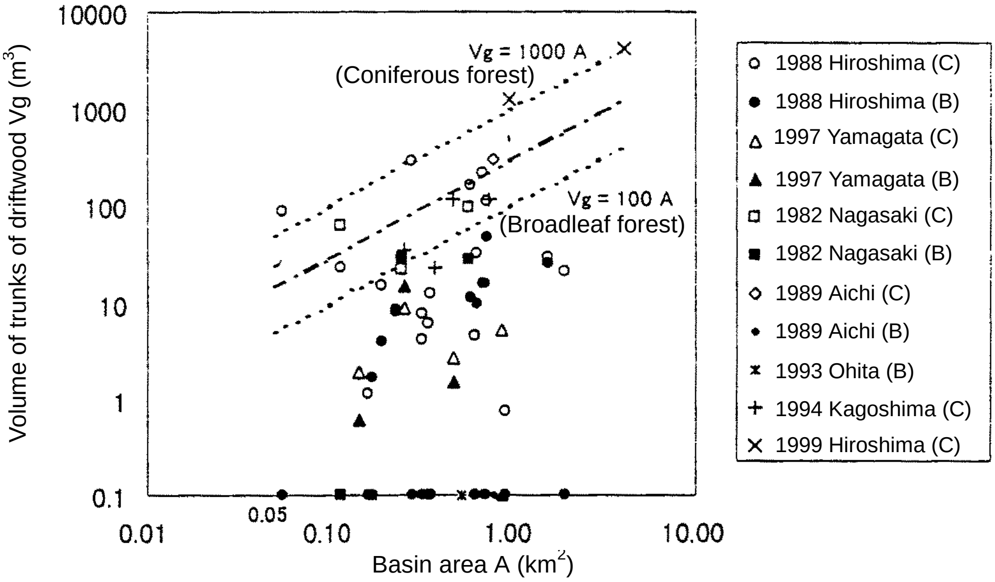


Figure 2 Basin area and volume of trunks of driftwood

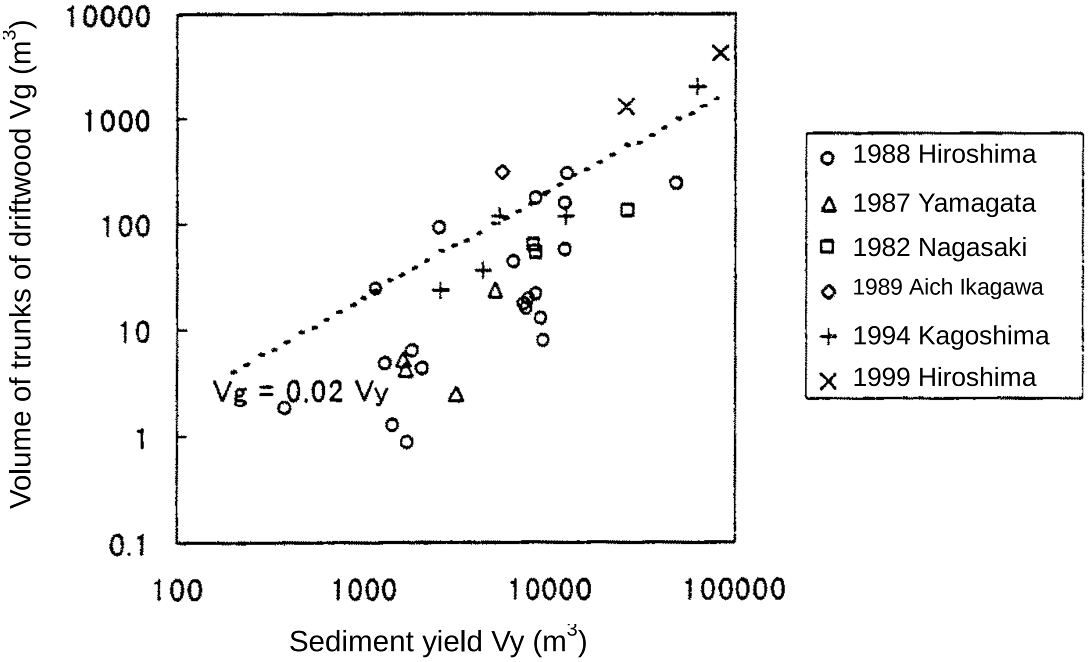


Figure 3 Sediment yield and volume of trunks of driftwood

3.5 Estimation of Driftwood Outflows

*** For the establishment of driftwood countermeasures it is necessary to estimate the probable amount and dimensions of driftwood likely to reach the sabo basic point based on the amount and dimensions of driftwood at the origin.**

Comments

The quantity of driftwood reaching the sabo basic point based on the quantity at source can be estimated from the probable ratio of runoff/delivery downstream as introduced in Section 2.3.

Regarding the design of driftwood facilities, and in particular driftwood entrapment works it is important to know the maximum probable length and diameter of driftwood to be encountered, (out of all the driftwood the largest 5% are taken, and the corresponding length is defined as the "Maximum Length of Driftwood").

As for the maximum length of driftwood that can be expected to flow to the outfall of a valley, the following equation can be used:

When

when $h_{max} \geq 1.3$ Wav $l_{max} \cong 1.3\ W_{av}$

when hmax < 1.3 Wav $l_{max} \cong h_{max}$

where: l_{max} = max length of driftwood

W_{av} = average width of expected debris flow

h_{max} = max height of stumpage from upstream

The maximum diameter of the driftwood (d_{max}') can be assumed almost equal to the maximum breast height diameter of the standing trees at source, (from the breast height diameter taken with the trunk number analysis, the maximum diameter that occupies 5% can be used).

3.6 Types of Damage due to Driftwood Outflows

*** Estimate the damage to various facilities located in the protection area based on the quantity and dimensions of driftwood that will flow to the lower reaches.**

Comments

After assuming the probable quantities and dimensions of driftwood that will flow down toward the lower reaches where facilities to be protected exist, the damage likely to be sustained can be estimated (Sections 3.2-3.5 inclusive).

The clogging of bridges/box culverts or other narrows by the outflow of driftwood accompanied by sediment is likely to result in debris/sediment flooding that could lead to extensive property damage, the blockage of roads and possible loss of life.

4. FACILITIES FOR DRIFTWOOD COUNTERMEASURES

4.1 Driftwood Control Methods

*** Countermeasures against driftwood consist of those using facilities and those not using facilities, but the basic principle is the countermeasures using facilities. Driftwood countermeasure facilities have a close relationship with debris flow control facilities.**

Comments

Countermeasures using facilities are broadly classified into two types: works for preventing the occurrence of driftwood (driftwood restraint works); and works for preventing driftwood from flowing down to the lower reaches by capturing it in the mountain stream or river (driftwood entrapment works). These facilities have a close relationship with the facilities for sediment control. The countermeasures not using facilities include the establishment of a warning and evacuation system.

When formulating a facility plan for the debris flow section, coordination must be secured between the driftwood countermeasure facilities and sediment control facilities because both of them capture driftwood and sediment simultaneously in this section, never driftwood only or sediment only in this section. Coordination shall be secured by the following method.

(1) The quantity of driftwood restrained or captured by the sediment control facilities is evaluated.

(2) When the driftwood control percentage is below 100%, installation of driftwood countermeasure facilities is planned.

(3) The sediment quantity captured by the facilities which are added as the driftwood countermeasure facilities is evaluated.

(4) The sediment control percentage is estimated by adding the sediment quantity captured by the added driftwood countermeasure facilities. If the sediment control percentage exceeds 100%, the number and the size of sediment control facilities under planning shall be changed.

4.2 Driftwood Countermeasure Facilities

*** Driftwood countermeasure facilities must be planned to take into account the behavior of driftwood during the occurrence and outflow of sediment.**

Comments

The facilities for restraining driftwood occurrence are mainly consist of slope stabilization works which are primarily installed in the source areas of driftwood and sediment such as a collapsible slope; revetment works, groundsill works, sabo dam works which are installed in the section where debris flows occur, flow, and deposit (hereafter referred to as the debris flow section); and the torrent conservation works and revetment works which are installed in the section where sediment is transported in the state of bed load (hereafter referred to as the bed load section). If it is assumed that the main sabo dam can capture the entire sediment of a debris flow, the driftwood entrapment works installed at the secondary sabo dam in the debris flow section are treated as the works installed in the bed load section.

The facilities for entrapping driftwood mainly consist of driftwood catching works which are installed on the hillside to prevent the accumulated driftwood from entering into the mountain stream; permeable sabo dams and partially-permeable sabo dams which are primarily installed in the debris flow section; impermeable sabo dams + driftwood catching works (installed at the secondary sabo dam, etc.), permeable sabo dams, and sand retarding area (including sand catching works) + driftwood catching works, which are primarily installed in the bed load section.

Figure 4 shows the types of general driftwood countermeasure facilities. Figure 5 shows the concept of layout of driftwood countermeasure facilities.

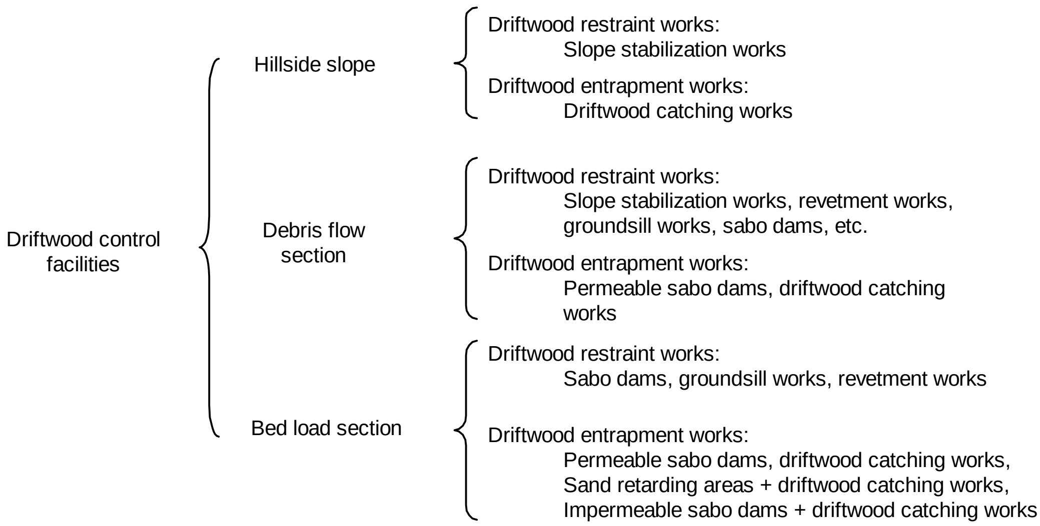


Figure 4 Types of driftwood countermeasure facilities

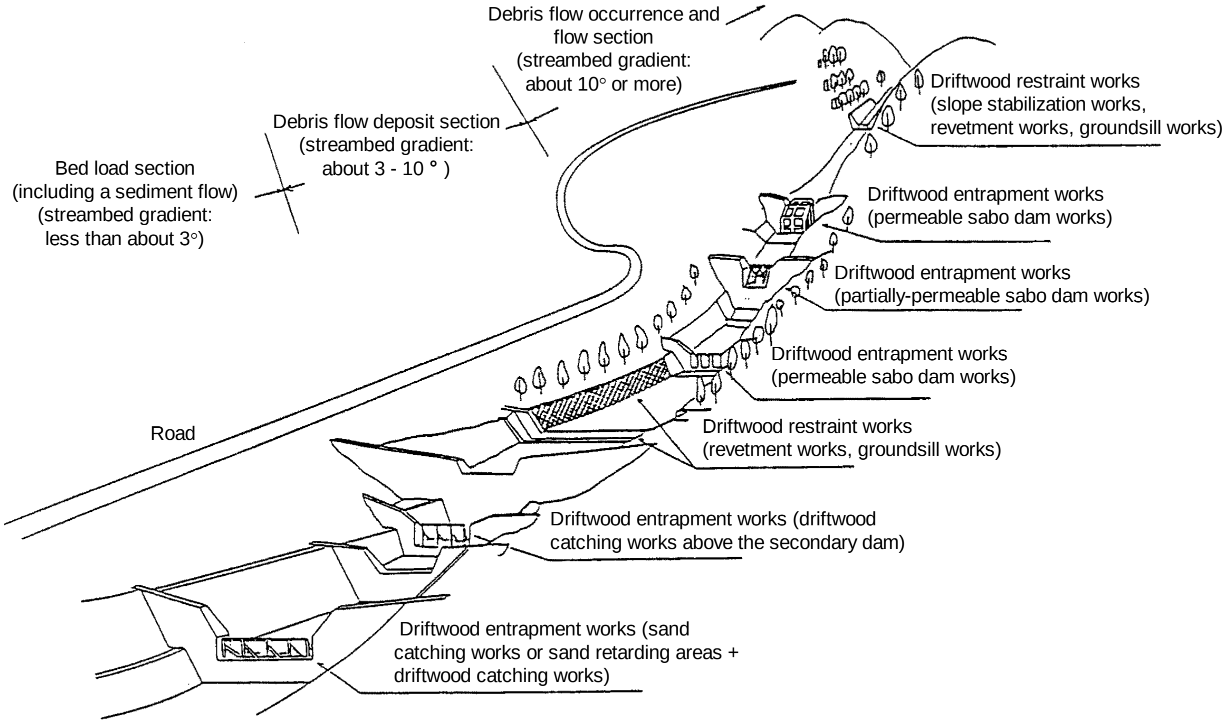


Figure 5 Concept of layout of driftwood countermeasure facilities

4.3 Planning of Driftwood Restraint Works

*** The driftwood restraint works are installed for preventing the production of driftwood by arresting collapses and erosion on the hillsides and stream banks. These works shall be planned for sediment yield areas and driftwood source areas.**

Comments

The driftwood restraint works consist of slope stabilization works for preventing hillside collapses to restrain the production of driftwood which will flow out together with sediment; and revetment works and groundsill works for preventing the production of sediment from stream banks and stream beds. These works shall be planned to have coordination with the facilities for sediment yield restraint which are installed by sabo plans.

4.4 Planning of Driftwood Entrapment Works

*** Driftwood entrapment works are installed for capturing driftwood on the hillside slopes and in the mountain streams and river courses. Care must be taken when planning installation of these works because their capturing mechanisms differ in the hillside slope, debris flow section, and bed load section.**

Comments

(1) Installation position of driftwood entrapment works

On the hillside slope where trees having a fear of flow-out such as wind-fallen trees are accumulated, driftwood catching works are installed to prevent those trees from flowing into the mountain streams.

In the debris flow section where driftwood is assumed to flow down with a debris flow, both of them are captured together by the permeable sabo dam or other works.

Driftwood that flows down in the bed load section and driftwood that is produced in the lower reaches are captured by driftwood catching works plus sand retarding works or by driftwood catching works installed at the secondary sabo dam.

(2) The effective entrapment quantity by driftwood entrapment works

The effective entrapment quantity of driftwood by the entrapment works installed in the debris flow occurrence section, flow section, and deposit section to capture driftwood that flows down together with debris flow, is obtained as the actual volume of driftwood (Vr) by multiplying the apparent entrapment volume (Vd) by the driftwood area ratio (β).

$$Vr = Vd \times \beta$$

$$Vd = h \times W \times (2\text{-}3) \times 1 / I \times H$$

Where

h : height of driftwood catching works (m)

W: average width of water impounding area or sedimentation area in the upstream of driftwood catching works (m)

I: gradient of original riverbed in the upstream of driftwood catching works

H: height of driftwood catching works from the original riverbed measured at the center of the works (m)

(Reference)

The driftwood area ratio (β) differs by the type of sabo facility, but the following value has been obtained for the permeable sabo dams from the actual driftwood entrapment in the past disasters.

Permeable sabo dams: $\beta \leq 30\%$

The data on the driftwood area ratio of impermeable sabo dams in the debris flow section is very limited, but one case showed that it is about 3% when the dam is filled up with sand. According to a model test conducted by the Public Works Research Institute (PWRI), the driftwood area ratio is in the range of 1-9%, particularly 2-5%, when the driftwood length is greater than 1.3 times the spillway width. The driftwood area ratio (β) to the entrapment volume of an impermeable sabo dam must be derived based on the past entrapment cases, but *β* = 2% may be used when no entrapment cases are available in the target stream.

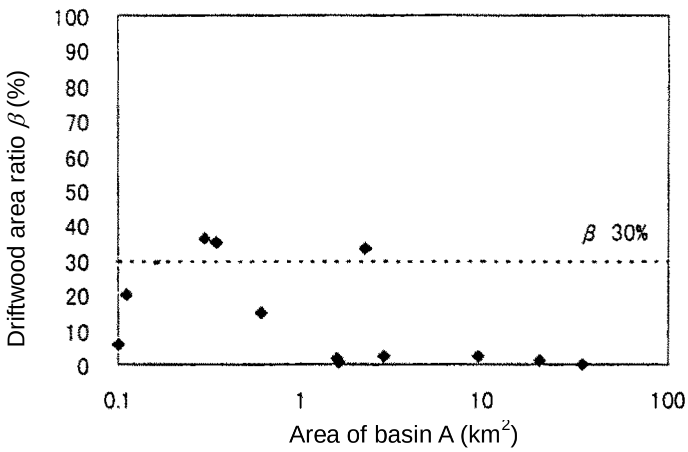


Figure 6 Driftwood area ratio to the entrapment volume at the permeable sabo dam

The sediment volume (*Vs*) deposited in the apparent entrapment volume (*Vd*) in the upstream of the driftwood catching works shall be estimated using the following equation.

$$Vs = Vd \times (1-\beta)$$

In the case of driftwood entrapment works installed in the bed load section, the driftwood quantity captured by driftwood catching works shall be calculated based on the assumption that (one layer of) driftwood covers the entire sedimentation surface, because driftwood tends to pile up to some extent near the driftwood catching works although some space remains between each piece of driftwood. On the other hand, the project area of the captured driftwood is calculated as the sum of the mean length of a piece of driftwood (l_{av}) × mean diameter of a piece of driftwood (d_{av}).

Using these values, the area of the sedimentation area or the impounding pond (A_d) above the driftwood catching works which is necessary for capturing the design driftwood entrapment quantity is estimated by the following equation.

$$A_d \geq \Sigma\, (1_{av} \times d_{av})$$

The actual volume of driftwood deposited in the sedimentation area or the impounding pond (V_{r2}) is obtained by the following equation.

$$V_{r2} \approx A_d \cdot d_{3v}$$

It is assumed that the impermeable sabo dam has no driftwood entrapment effect in the bed load section, because driftwood will be separated from sediment and flow downstream on the surface of flowing water in this section.

5. MAINTENANCE AND MANAGEMENT OF DRIFTWOOD COUNTERMEASURE FACILITIES

5.1 Inspection and Survey on Changes in Basin Conditions

*** When forest conditions at the driftwood source area appear to be undergoing significant change, further complementary inspections or additional surveys are necessary in order to determine what measures need to be taken to cope with the new situation.**

Comments

At the major origin of driftwood development, in the upper reaches of the catchment basin, the forest trees undergo natural growth year by year, but significant changes occur as the result of logging, reforestation, typhoon damage, mountain fires, volcanic eruptions, or insect damage causing trees to fall and wither. In order to cope with such natural phenomena, it is necessary to carry out special inspection surveys in addition to routine inspections, in particular after the occurrence of some event that could be considered to have some effect on the situation regarding driftwood development. Based on the results of such complementary surveys, a check should be made of whether initial planning is adequate in the light of these results and if necessary an increase in the capability of facilities made to control driftwood outflows.

5.2 Inspection and Repair of Driftwood Countermeasure Facilities and Removal of Driftwood

*** To ensure that the driftwood facilities are functioning adequately, it is necessary to take the necessary measures in accordance with the results of routine inspections or inspections after a large flood. In particular it is essential to remove entrapped driftwood, debris/sediment or other rubbish from the facilities, and if necessary, to remove remnants of driftwood accumulating on the riverbed.**

Comments

After the installation of driftwood facilities, periodic inspection and maintenance of these facilities are necessary to keep them effective. Besides these periodic inspections special surveys in the wake of a big flood have to be carried out to determine the necessity of removal of clogged driftwood and any repair needed in such things as the steel members of structures.

In addition, it is necessary to remove driftwood accumulating on riverbeds or banks that is in danger of flowing down in the event of flooding and causing serious damage.

Part II

GUIDELINE FOR DRIFTWOOD COUNTERMEASURES (PROPOSAL)

Design

CONTENTS

1. BASICS OF DESGIN

*** Driftwood countermeasure facilities shall be designed to provide functions necessary for driftwood countermeasures as well as to be safe against run-off of debris flows, floods, and others. The permeable type driftwood countermeasures need safety verification of both the entire structure and the constituting members.**

Driftwood countermeasure facilities shall be designed using an appropriate design method in consideration of their installation position, either in the hillside slope, the debris flow section, or the bed load section.

Comments

(1) Functions and design conditions of driftwood countermeasures

Driftwood countermeasure facilities shall be designed to exhibit their intended functions fully, such as prevention of driftwood development and entrapment of driftwood, as well as to be safe against run-off of debris flows and flood flows.

The design conditions required for driftwood countermeasures in the mountain streams differ by their installation position, either in the upstream section where both driftwood and debris flow run down together as a unity (the debris flow section), or in the downstream section where driftwood and large-sized sediment flow down separately (the bed load section), because the flow type of driftwood differs in those sections. Accordingly, when designing driftwood countermeasures, it must be identified first which section the planned installation position belongs to, either in the debris flow section or the bed load section. In the case of driftwood entrapment works, the driftwood capturing effect and design external forces differ in those two sections, because both driftwood and sediment are captured together in the debris flow section but they are captured separately in the bed load section.

In terms of design, driftwood countermeasures are classified as follows.

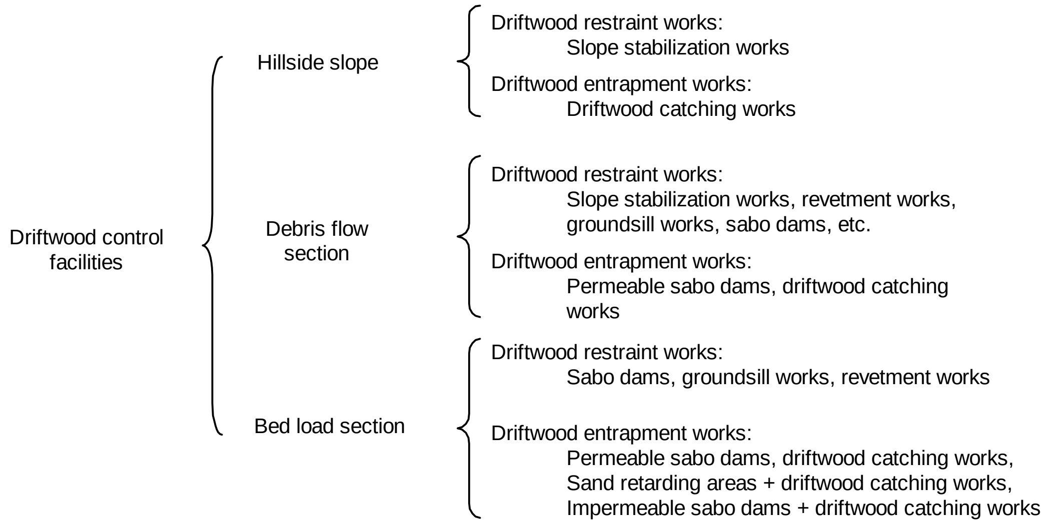


Figure 1 Types of driftwood countermeasures

(2) Distinction of the debris flow section and the bed load section

In general, the debris flow reach section is considered as the section having a riverbed gradient of I ≥ 3° (approximately 1/20). However, it is desirable to identify the range of debris flow section and the bed load section by examining the sediment transport mode based on the records of past disasters and survey results of streambed deposits in and around the target stream. In the case of volcanic sabo areas and debris flow-prone areas, the distinction of the sections shall be determined from past disaster data which are obtainable relatively easily in these areas. If such data are not available in the volcanic sabo areas, the debris flow reach section can be made to I ≥ 2° (approximately 1/30).

(3) Applicable design standard

For the structural design of driftwood countermeasures, the following design standards which are established for other sabo facilities shall be adopted.

[1] In principle, driftwood entrapment works in the debris flow section shall be designed based on the "Guideline for Debris Flow Countermeasures (Proposal), Part II, Division 2 - Debris Flow Entrapment Works".

[2] In principle, revetment works and training dikes used as the driftwood restraint works in the debris flow section shall be designed by adopting the "Guideline for Debris Flow Countermeasures (Proposal), Part II, Division 3 - Debris Flow Training Dike".

[3] In principle, driftwood entrapment works in the bed load section shall be designed based on the "River/Sabo Engineering Standards, Ministry of

Construction (Proposal), Planning Edition, Chapter 12 - Planning of Sabo Facilities, and Design Edition, Chapter 3 - Design of Sabo Facilities".

[4] In principle, revetment works and channel works used as the driftwood restraint works in the bed load section shall be designed by adopting the "River/Sabo Engineering Standards, Ministry of Construction (Proposal), Planning Edition, Chapter 12 - Planning of Sabo Facilities, and Design Edition, Chapter 3 - Design of Sabo Facilities".

[5] When groundsill works are used as the driftwood restraint works, they shall be designed to have the structure that does not directly receive the impact forces of the collision of driftwood and boulders, and the fluid dynamic forces of a debris flow. Therefore, only the hydrostatic pressure shall be considered as the external force acting on the groundsill works. Other designs in the debris flow section shall be carried out in accordance with the "Guideline for Debris Flow Countermeasures (Proposal), Part II, 2.6 - Structure of Impermeable Sabo Dam", and other designs in the bed load section shall be carried out in accordance with the "River/Sabo Engineering Standards, Ministry of Construction (Proposal), Planning Edition, Chapter 12 - Planning of Sabo Facilities, and Design Edition, Chapter 3 - Design of Sabo Facilities".

[6] When retaining wall works are designed as the slope stabilization works, stability of the target slope shall be evaluated adequately by taking into account the weight of trees existing on the slope and other factors. For the planning and design of slope stabilization works, the "River/Sabo Engineering Standards, Ministry of Construction (Proposal), Planning Edition, Chapter 12, Division 7 - Hillside Works, and Chapter 5 - Design of Steep Slope Failure Prevention Facilities" shall be adopted.

2. SELECTION OF WORKS FOR DRIFTWOOD COUNTERMEASURES

*** When determining the type of works installed as the driftwood countermeasures, the most effective works for the required functions and the safest works for the design conditions of the installation location shall be selected.**

Comments

(1) Driftwood restraint works

Sabo dams, groundsill works, revetment works, slope stabilization works, etc. are installed as the driftwood restraint works. The functions and features of these works are described in the "River/Sabo Engineering Standards, Ministry of Construction (Proposal), Planning Edition, Chapter 12 - Planning of Sabo Facilities, and Design Edition, Chapter 3 - Design of Sabo Facilities" and the "Guideline for Debris Flow Countermeasures (Proposal)". When selecting the works to be installed as the driftwood restraint works, the appropriate type shall be selected in consideration of the causes of driftwood occurrence, topography and geology of the site, and buildablity of works.

(2) Driftwood entrapment works

Various types of works have been developed as the driftwood entrapment works[1).

Each of them has distinctive features, and appropriate works shall be selected in consideration of the installation location, the flowing mode of sediment and driftwood, the dam height, construction conditions, etc.

3. DRIFTWOOD COUNTERMEASURES IN THE DEBRIS FLOW SECTION

3.1 Scale of Debris Flow

*** Upon designing driftwood control structures the scale of the debris flow incorporating the driftwood must be considered.**

Comments

The scale of debris flows (Planned Quantity of sediment outflow, peak discharge flows, velocity, flow depth, unit weight) is, in general, calculated based upon “Guideline to Debris Flow Countermeasures (Proposal), Part I, 2.4 - Quantity of Sediment.” While the quantity of debris flow with driftwood may be estimated by adding the water discharge (Refer to Part I, 2.3)to the sediment discharge. For simplicity the influence of driftwood on the velocity, peak discharge, flow depth and unit weight may be ignored and it may be further assumed that the velocity of driftwood will be equal to the average velocity of debris flows.

3.2 Design of Driftwood Entrapment Works

3.2.1 Investigation of Stability of the Entire Structure

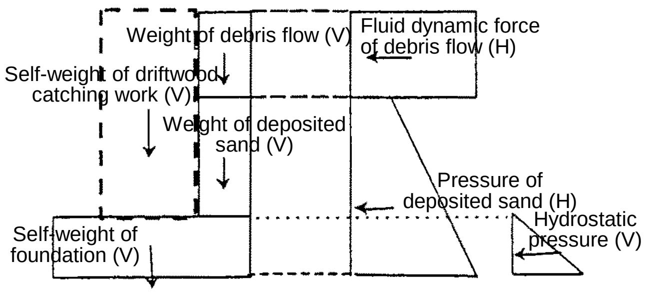
*** Regarding the stability of the structure, driftwood entrapment works shall be designed to be stable even under the conditions that they are clogged with driftwood and others during a flood flow and a debris flow.**

Comments

In principle, safety of the entire structure of driftwood entrapment works in the debris flow section shall be investigated based on "Guideline for Debris Flow Countermeasures (Proposal), Part II, Division 2 - Debris Flow Entrapment Works" and other standards, and the safety factor shall be made to 1.2. The most stringent load conditions are the combination shown in Figure 2.

When the upper face of the foundation is as high as or lower than the design riverbed height, the hydrostatic pressure shall not be taken into account as a design external force by considering that hydrostatic pressures acting on the upstream and downstream sides of the foundation maintain a balance.

(Permeable type steel driftwood entrapment works)

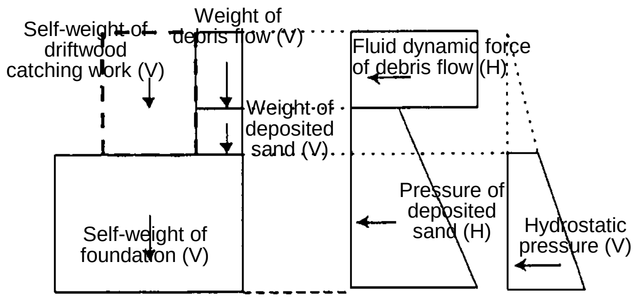


Load combination for stability calculation of the permeable type steel sabo dam

Dam height	Design load
Less than 15 m	Fluid dynamic force of debris flow Self-weight of deposited sand Hydrostatic pressure (foundation area)

(Permeable type concrete driftwood entrapment works*)

*** A driftwood entrapment structure is installed at the concrete sabo dam [See Part I, Figure 5 - Driftwood entrapment works (partially-permeable sabo dam)]**



Load combination for stability calculation of the permeable type concrete sabo dam

Dam height	Design load
Less than 15 m	Fluid dynamic force of debris flow Self-weight of deposited sand Hydrostatic pressure

Figure 2 Design external forces acting on the driftwood entrapment works in the debris flow section

The dam height of driftwood entrapment works including the foundation area shall be less than 15 m in principle.

The impermeable section of the foundation is constructed integral with the permeable section, and it requires enough thickness to disperse and equalize the load acting on the permeable section and to transfer it as the load lower than the allowable bearing capacity of the ground. Therefore, the thickness of the foundation is determined in consideration of the structure and shape of the permeable section, properties of the foundation ground, necessary embedment depth, etc.

When a driftwood entrapment structure is installed at the secondary sabo dam in the debris flows section and the main dam in that section is unable to capture all of the debris flow, safety of the structure must be secured by investigating its stability not only during a flood but also during a debris flow. As the load conditions of a debris flow for this investigation, those shown in Figure 2 shall be used. The attributes of a debris flow used for this investigation shall be those used for the design of the main dam. As the riverbed gradient used for the calculation of the wave height and velocity of a debris flow, the design sedimentation gradient shall be used.

3.2.2 Details of Structure

* When designing the details of driftwood entrapment facilities, it is necessary to examine the design of the structure to ensure that it is safe in both the unclogged and clogged case.

Comments

For the examination of the safety of each component of driftwood entrapment facility (spillway section, crown width, body slope downstream side, foundation, stability and configuration of wings, apron protection works), should be performed under the provisions of “Guideline to Debris Flow Countermeasures (Proposal), Chapter Ⅱ, 2. - Debris Flow Entrapment.”

The spillway section of the driftwood entrapment facility should be positioned on top of the permeable section, allowing for the overflow of debris flow due to clogging. (Refer to River/Sabo Engineering Standards, Ministry of Construction (Proposal), Survey Edition, Chapter 12, 2.5.9. - Driftwood Entrapment).

In debris flow sections, as the object is to entrap driftwood together with debris flow, it is necessary to give arrange openings of slits as wide as 1.5 times the size of the largest boulder expected in the debris flow but less than 1/2 the length of the longest piece of driftwood.

When the wing portion of the driftwood entrapment facility is made of concrete, it is necessary to examine the safety factors with respect to driftwood and boulder collision in which considerable impact forces are entailed.

3.2.3 Investigation of Safety of Constituting Members

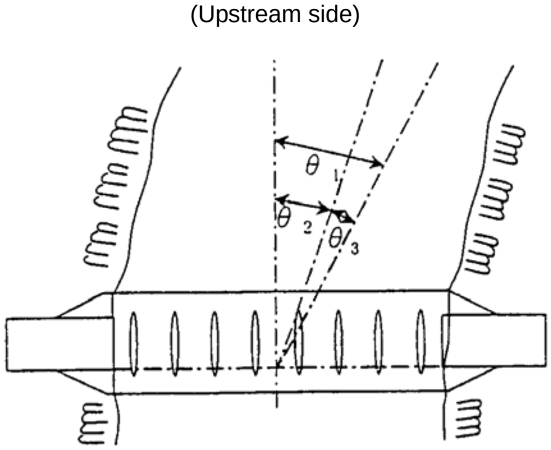
* As the permeable section of driftwood entrapment works is constituted of the members having a small cross section, they shall be designed to secure safety in addition to securing the safety of the entire structure (See Part II, Item 3.2.1).

Comments

The members constituting the permeable section shall be designed to be safe against the out-of-plane loads and collision loads of driftwood and boulders in addition to the design loads shown in Figure 2.

The axis of the sabo dam at the bend section of a river is made to be perpendicular to the river course on the downstream side. Therefore, the axis of the sabo dam becomes eccentric to the center of stream on the upstream side. Then, by estimating this eccentric angle and by

taking into account the discrepancy in the centers of gravity of boulders/driftwood contained in the debris flow and the members at the permeable section when they collide, the "θ_3" in Figure 3 is determined.



$\theta_1 = \theta_2 + \theta_3$

θ_1 : eccentric angle of a debris flow to the dam

θ_2 : angle between the center of stream of a debris flow and the axis of the dam

θ_3 : eccentricity of collision angle due to the discrepancy in the centers of gravity of driftwood/boulders and the members of the permeable section when they collide

Figure 3 Out-of-plane loads acting on the members of the permeable section

This Item (Item 3.2.3) shall also be applied to the design of driftwood entrapment structure which is installed at the secondary dam in the debris flow section when the main dam in that section is assumed to be unable to capture all of the debris flow.

3.3 Design of Driftwood Restraint Works

* **Driftwood restraint works shall be designed to prevent collapse of slopes and erosion of stream banks, to perform driftwood restraint functions effectively, and to be safe against debris flows and flood flows.**

Comments

Driftwood restraint works (slope stabilization works) installed for the prevention of slope failures shall be designed in accordance with the "Guide to the Hillside Protection Works (Proposal)" (prepared by the Sediment Control Division, Sediment Control Department of the Ministry of Construction).

Driftwood restraint works (stream bank works, groundsill works, sabo dams, etc.) for the prevention of stream bank erosion shall be designed in accordance with the "River/Sabo Engineering Standards, Ministry of Construction (Proposal)" and "Guide to the Riverbank Protection Works (Proposal)" (prepared by the Sediment Control Division, Sediment Control Department of the Ministry of Construction).

4. DRIFTWOOD COUNTERMEASURES IN THE BED LOAD SECTION

4.1 Scale of Flood and Sediment Flow

*** Driftwood countermeasure facilities to be installed in the river course and its vicinity in the bed load section shall be designed to allow safe flow-down of floods and sediment flows by taking their scale and other factors into account.**

Comments

In principle, the scale of a flood (peak flow, flow velocity, water depth, sand content, etc.) that occurs under a heavy rain shall be investigated in accordance with the "River/Sabo Engineering Standards, Ministry of Construction (Proposal), Survey Edition, Chapter 5 - Run-off Calculation, Chapter 6 - Roughness Coefficient and Calculation of Water Level; Planning Edition, Chapter 12 - Planning of Sabo Facilities; and Design Edition, Chapter 3 - Design of Sabo Facilities".

The flow velocity and water depth of a flood and a sediment flow shall be calculated from the flow rate containing sediment by using Manning's equation. In this calculation, the effect of driftwood on the flow velocity and the water depth is not taken into account. The flow velocity of driftwood is assumed as 1.2 times the mean flow velocity of a flood flow or a sediment flow, because it is considered roughly equal to the surface flow velocity of those flows.

4.2 Design of Driftwood Entrapment Works

4.2.1 Height of the Permeable Section

*** The height of the permeable section of driftwood entrapment works shall be made higher than the sum of the water level raised by the installation of a driftwood catching structure and the height necessary for capturing driftwood.**

Comments

The permeable section of driftwood entrapment works shall be designed to avoid clogging by boulders, and its height shall be made higher than the sum of the water level raised by the installation of a driftwood catching structure and the height necessary for capturing driftwood. This concept is shown in Figure 4. The determination process is show below.

h_s : water level raised by the installation of a driftwood catching structure

Δh : height necessary for capturing driftwood

H_s : height of a driftwood catching structure (permeable section)

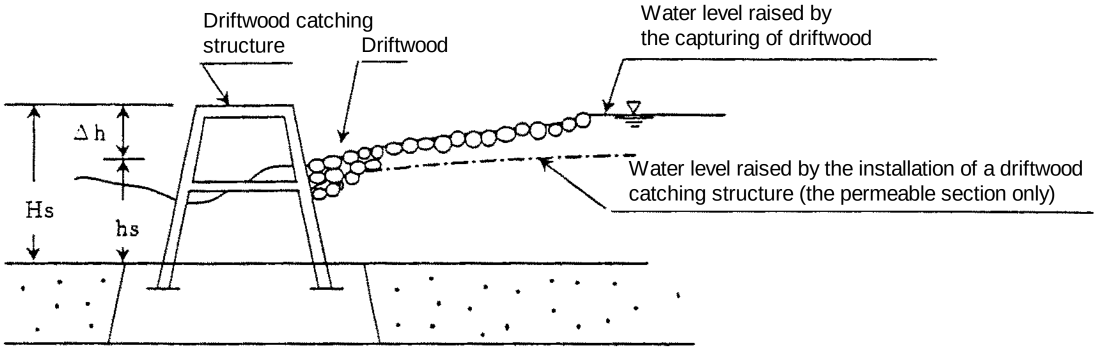


Figure 4 Schematic of the permeable section height (H_s) of the driftwood entrapment works installed in the bed load section

(1) Calculation of the rise of water level

[1] Water depth before water rise (h) and mean flow velocity (v)

Configuration of the open channel:

obtained from the flow rate that contains sediment using Manning's equation.

Configuration of the dam:

obtained from the flow rate that contains sediment using an equation for dams.

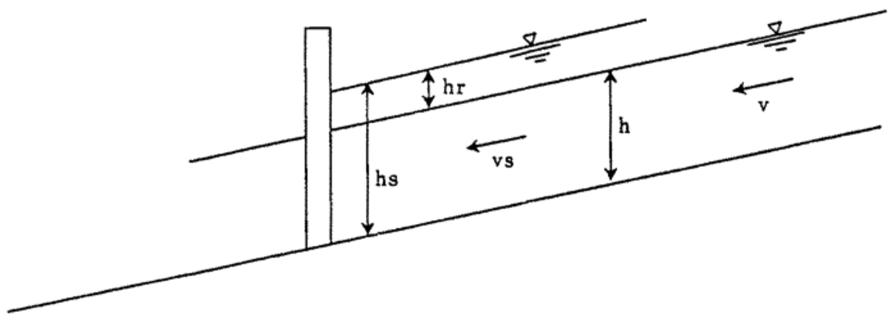


Figure 5 Water level raised by the installation of a driftwood catching structure

[2] Water level raised by the installation of a driftwood catching structure

In the bed load section, most of driftwood flows downstream on the surface of a sediment flow or a flood flow. Therefore, when installing a driftwood catching structure in this section, its height must be higher than the water level of a sediment flow or a flood flow raised by the installation of the structure.

The water level raised by the installation of vertical members only can be calculated using the following equation[2).

$$h_r = \beta \sin\theta \cdot \left(\frac{t}{d}\right)^{4/3} \frac{v^2}{2g}$$

where h_r **: water level raised by the vertical members of a driftwood catching structure (m)**

β**: factor of the sectional shape of vertical member**
(β ≈ 2.0 for steel pipe; β ≈ 2.5 for angular steel pipe; β ≈ 3.0 for H section)

θ**: inclination angle of vertical members to the river bed on the downstream side (°)**

t **: diameter of vertical member (m)**

d **: clear spacing between vertical members (m)**

v **: flow velocity on the upstream side (m/s)**

[3] Water depth after the rise of water

$$h_s = h + h_r$$

$$V_s = \frac{Q}{h_s \cdot B}$$

where Q**: design flow rate**

V_s**: mean flow velocity after the rise of water**

B**: flowing width**

(2) Necessary height of driftwood catching structure (Hs)

Assuming that a driftwood catching structure will not be clogged by sediment or boulders, the height of the structure shall be determined as the sum of the water depth raised by the installation of the structure (h_s) and the height necessary for capturing the driftwood (△h). The value of △h shall be at least twice the diameter of the largest driftwood because pieces of driftwood may be piled when they are captured.

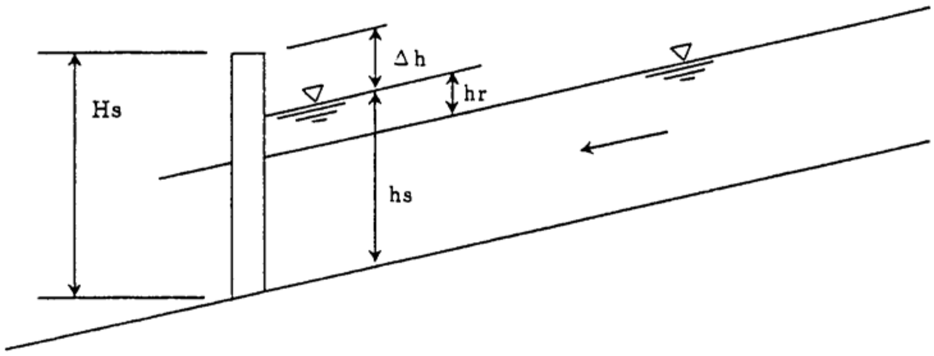


Figure 6 Necessary height of the permeable section when there is no fear of clogging

4.2.2 Clear spacing between members at the permeable section

(1) Maximum size of boulders transported by bed load

The maximum size of boulders that flow down in the bed load section shall be determined using the following method by referring to the critical grain size carried by the critical tractive force.

[1] Square of the critical friction velocity for the average grain size (d_m), U_{*cm}^2

This is obtained from the equation below[3].

$$U_{*cm}^2 = 0.05 \cdot (\sigma / \rho - 1) \cdot g \cdot d_m$$

where
- d_m : average grain size of riverbed materials
- σ: density of sand and gravel, usually 2.60-2.65
- ρ: density of muddy water, usually 1.00-1.20
- g : gravity acceleration

[2] Square of friction velocity, U_*^2

This is obtained from the equation below.

$$U_*^2 = g \cdot h \cdot I$$

where
- h : water depth
- I: gradient of riverbed

[3] Square of the friction velocity ratio, U_*^2 / U_{*cm}^2

This is obtained using the values of [1] and [2].

[4] Using Fig. 7 below, d_i / d_m is obtained as the value when the U_{*ci}^2 / U_{*cm}^2 in the ordinate becomes equal to U_*^2 / U_{*cm}^2 which is derived in [3]

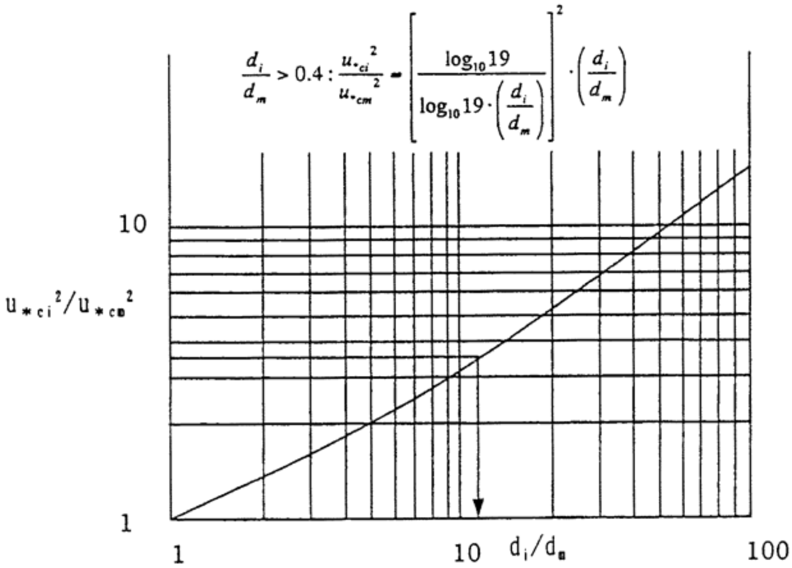


Figure 7

[5] The critical grain size for movement d_i is obtained from d_i / d_m which is obtained in [4] and the average grain size d_m which is obtained from the in-situ test, etc.

(2) Clear spacing of members at the permeable section

To prevent clogging of the permeable section, the clear spacing of the members at the permeable section shall be determined so that the maximum size of boulders obtained above will satisfy the following condition.

$D \geq 2\, d_i$

D : clear spacing of the members at the permeable section

d_i : maximum size of boulders

To capture driftwood, the clear spacing of the members at the permeable section shall be made to the value that satisfies the following equation.

$1/2\, L \geq D$

L : maximum length of driftwood

The clear spacing of the members shall be determined in the range that satisfies the above two equations.

4.2.3 Investigation of Stability of the Entire Structure

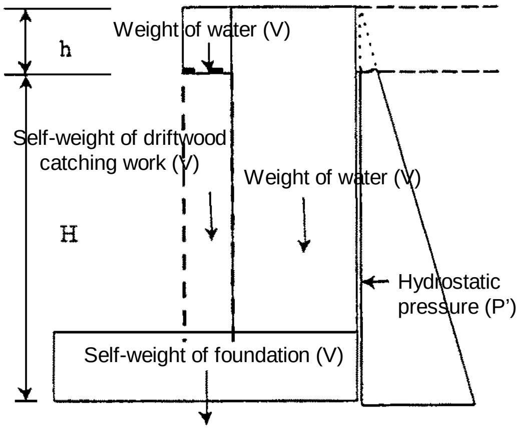
*** Regarding the stability of the structure, driftwood entrapment works shall be designed to be stable even under the conditions that they are completely clogged with driftwood or others.**

Comments

In principle, stability of driftwood entrapment works installed in the bed load section shall be investigated based on the "Technical Standard on River Sabo Works, Ministry of Construction (Proposal), Planning Edition, Chapter 12 - Planning of Sabo Facilities; and Design Edition, Chapter 3 - Design of Sabo Works." The dam height of driftwood entrapment works, including the foundation area, that are installed singly shall be less than 5 m (approximately the height of groundsill works) in principle. When the dam height exceeds 5 m, structural stability shall be investigated by taking the following points into account.

- **The spillway width shall be made wider to reduce the water depth so that the height of the permeable section of the driftwood entrapment structure can be made lower as much as possible.**
- **When a large head is caused between the crown of the foundation and the riverbed on the downstream side due to the thickness of the foundation, or when a large head is caused to the overflow water due to the height of the driftwood entrapment structure, installation of apron protection works shall be considered to secure stability.**

If the driftwood catching works in the bed load section are clogged with driftwood, hydrostatic pressure will act as shown in Figure 8. In this case, the magnitude of hydrostatic pressure is affected by the clogging density (α) at the permeable section. Here, assuming that the permeable section is completely clogged, a hydrostatic pressure of α = 1.0 (unit weight of water: r_w = 1.2 t/m^3) is presumed to act. In the case of permeable type driftwood entrapment works installed in the bed load section, the sedimentation pressure shall not be taken into account because the structure is designed not to capture boulders and gravel.



Load combination for stability calculation in the bed load section

Dam height	Design load
Less than 5 m in principle (including the foundation)	Water pressure under flooding, self-weight, and sedimentation pressure

$P = 1 / 2r_w \{(H + h) \cdot \alpha\}^2$

α: hydrostatic pressure factor determined by the clogging density of the permeable section (α = 1.0)

Figure 8 Clogging of driftwood entrapment works in the bed load section

4.2.4 Investigation of Safety of Constituting Members

*** The members constituting the permeable section of driftwood entrapment works in the bed load section shall be designed to be safe against water pressure and collision of driftwood.**

Comments

As the permeable section of driftwood entrapment works in the bed load section has a small cross section and is not a gravity type, just like the driftwood entrapment works installed in the debris flow section, safety of the members constituting the permeable section shall be verified through structural calculation.

The surface flow velocity is used as the flow velocity for the calculation of driftwood collision and it is obtained by the following equation. The impact force is calculated by assuming that driftwood flows down with its longitudinal axis in parallel to the stream of water and collides against the permeable section.

Vss = 1.2 Vs

where Vss : surface flow velocity

Vs : mean flow velocity

4.2.5 Design of sections other than the permeable section

*** Other sections of driftwood entrapment works shall be designed to be safe even under the conditions that the works are clogged with driftwood or others. Stability of those sections against impact forces from the collision of driftwood shall also be investigated.**

Comments

The stability of each section (spillway section, width of the crown, slope on the downstream side, foundation, wing structure, apron protection works, etc.) of driftwood entrapment works shall be investigated based on the "River/Sabo Engineering Standards, Ministry of Construction (Proposal), Planning Edition, Chapter 12 - Planning of Sabo Facilities; and Design Edition, Chapter 3 - Design of Sabo Facilities". In other words, the spillway section, width of the crown, slope on the downstream side, foundation, and apron protection works shall be designed by assuming the situation that the upstream side of driftwood catching structure (permeable section) is completely clogged with driftwood and water is unable to flow down, which means to assume the situation that the structure becomes an impermeable type sabo dam.

The spillway section of the driftwood entrapment works shall be placed above the permeable section in principle as a provision for the overflow of a sediment flow or a flood flow when the permeable section is clogged with driftwood (River/Sabo Engineering Standards, Ministry of Construction (Proposal), Planning Edition, Chapter 12, 2.5.9 - Driftwood Catching Works).

4.3 Design of Driftwood Restraint Works

*** Driftwood restraint works in the bed load section shall be designed to exhibit bank erosion restraint functions effectively and to be safe against floods.**

Comments

Driftwood restraint works in the bed load section are to be installed at the same position with revetment works and channel works and to perform the same function with those works. Therefore, design of driftwood restraint works shall be carried out in accordance with the "River/Sabo Engineering Standards, Ministry of Construction (Proposal, Design Edition, Chapter 3 - Design of Sabo Facilities)".

5. INSTALLATION OF DRIFTWOOD CATCHING WORKS AT THE SECONDARY DAM

* **When driftwood catching works are installed at the secondary dam as an addition to the driftwood entrapment function of the existing main sabo dam or because of topographical limitations or restriction on land use, they shall be designed in accordance with the design method for the bed load section.**

6. DRIFTWOOD CONTROL FACILITEIS ON THE HILLSIDE SLOPE

6.1 Driftwood Outflow Phenomenon

*** Driftwood control facilities installed on the hillside slope are intended for the prevention of sediment production and the outflow of trees which fell in the past and accumulated there. Therefore, debris flow discharge and flood discharge are not considered in the design of these facilities.**

6.2 Design of Driftwood Entrapment Works

*** Driftwood entrapment works shall be designed to secure stability even under the conditions that the permeable section is clogged and driftwood and sediment are deposited on the upstream side of the permeable section.**

Comments

Stability of the entire structure and the constituting members of driftwood entrapment works installed on the hillside slope shall be investigated by considering the sedimentation pressure only, because these works are intended for the prevention of outflow of trees that fell in the past, and because neither a debris flow nor a flood flow flows down the slope in a concentrated manner.

6.3 Design of Driftwood Restraint Works

*** Driftwood restraint works shall be designed in accordance with the design of steep slope failure prevention works.**

Comments

Driftwood restraint works installed on the hillside slope are intended for restraining the production of driftwood that occurs with the collapse of a hillside slope. Therefore, the type and design of those works are the same with those of steep slope failure prevention works.