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DESIGN METHODS FOR WOOD-DEBRIS ENTRAPMENT

ENTWÜRFE VON AUFFANGSTRUKTUREN FÜR TREIBHOLZ

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Abstract: Measures against wood-debris are taken to prevent human lives, properties and living environment from being damaged by wood-debris. This paper describes the basic ideas for wood-debris control to determine the fundamental values for planning to design proper scale of facilities which may effectively function.

Zusammenfassung: Gegen das Treibholz, das jeder Erdrutsch mit sich bringt, werden verschiedene Maßnahmen getroffen, um Menschenleben , Güter und die natürliche Umwelt überhaupt vor den dabei vorausgesehenen Katastrophen zu schützen. Die vorliegende Arbeit legt einige Grundkonzepte für die zur Planung und zum Entwurf effektiver Auffangstrukturen erforderlichen Untersuchungsmethoden dar. Diese Konzepte gelten auch den Ermittelungsmethoden, die optimale Größe der jeweiligen Auffangstruktur betreffen.

Introduction

In the torrents of mountainous regions, a large number of wood-debris are carried away with sediment flow during torrential rains, which, flowing down torrents and river channels, can congest in narrow spots of streams or around bridge sites and road culvert boxes. This causes inundation's of sediment, which can seriously do damage to roads and houses, and destroy human lives.

In such torrents as lots of wood-debris are feared to be being carried downstream with sediment or debris flow, it is naturally desirable to take countermeasures for checking as well as the measures against debris flow so that they might be checked in the upstream. However, since there is a limitation in preventing wood-debris generation at the site the countermeasures against wood-debris should be devided into twocategories:one is to prevent the generation of wood-debris itself at the origin sites and the other is to trap the wood-debris flowing downstream. In this report we shall deal with the latter and introduce the estimation methods of fundamental values for planning and designing wood-debris entrapment facilities.

1. Practices of wood-debris entrapment facilities

We have Set up the principle to adopt and develop a "permeable type" of wood-debris entrapment structure, which will allow an ordinary floodwater to pass down with safety and yet effectively function against such a big flood as carrying wood-debris.

In a debris-flow-segment of devastated torrent we make a point to build up such structures as having the function to control the debris flow as well as entrap the wood-debris since the flood wood, boulders and sediment will flow down in a form of aggregate coalescence. We can introduce some examples of check dams coping with debris flow as well as providing with wood-debris entrapment.(Photo.1, Photo. 2)

Meanwhile, in such a small basin that merely one check dam seems to be enough for controlling the debris flow and there are some private houses immediately downstream the envisaged dam site, we use a main dam as "impermeable type" of wood-debris entrapment facility and set out "permeable type" of facility on the sabo-dam.

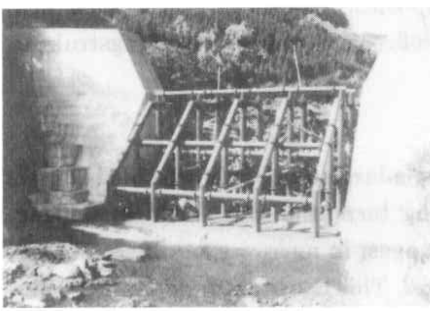


Photo.1 Wood-debris entrapment facility (the downstream)
Foto.1 Auffanganlage für Treibholz (Oberlauf)

Photo.2 Wood-debris entrapment facility (the upper-stream)
Foto.2 Auffanganlage für Treibholz (Unterlauf)

2. Surveys for planning

2.1. Survey items and methods

In order to improve the effectiveness and rationality of the plans for wood-debris entrapment, it is necessary to estimate a probable volume of wood-debris including the length and diameter of floodwood which will flow down until a certain point in question.

As to the survey methods, first, a field research, in proportion to usual survey method for debris flow, is needed to estimate the possibility of land-slide and debris flow occurrence and the extent of landslides or debris flow hazards.

Next, estimation is made on the volume, length and diameter of living trees and fallen trees in the debris flow hazards.

In this kind of survey, it is essential to use a method of aero photo-interpretation together with field survey. In the case where a field research is difficult, however estimation of wood-debris volume may be done by using the method indicated as the following.

2.2. Estimation of wood-debris volume

2.2.1. Estimation method using the amount of sediment yield

According to the studies on the major disaster precedents, the relation between sediment yield and expected wood-debris volume can be expressed by the following formula.

$$V_g = 0.02\ V_y$$

where, V_y: sediment yield (m^3), and V_g: wood-debris volume (m^3).

2.2.2. Estimation method using forest area

According to the studies of the major disaster precedents, the relation between forest area and floodwood volume can be expressed by the following formula.

A coniferous forest : $V_g = (10\text{ to }1000)\ A_f$

A deciduous forest : $V_g = (10\text{ to }100)\ A_f$

where, A_f: forest area (km^2), and V_g: wood-debris volume (m^3).

In estimating wood-debris volume, the formula for a coniferous forest is usually used. Only in the case where the occupation rate of a deciduous forest is assumed rather large, the one for a deciduous forest to be taken into consideration.

2.2.3. Estimation of wood-debris outflow volume

Wood-debris outflow volume can also be obtained by multiplying the estimated volume of wood-debris volume by outflow rate. The outflow rate can be obtained from the previous surveys of disasters in the subject basin or similar basins. When no reference case is found, the rate may be assumed 0.9 for small torrent (in sediment-flow section) and 0.8 for large torrent (in sediment-flow section).

2.2.4. Estimation of the length and diameter of floodwood

The length of floodwood which is expected to flow into the planned spot can be estimated not only by the result of wood-debris survey but also by the total study on the width of a river bed and the trace of previous flood marks in the upstream of planned spot. When a field survey is difficult or none of disaster record is found, the relation as shown below may be available in terms of rough estimation.

When $L_{max} \geqq 1.3\ W_{av}$, $L' \fallingdotseq 1.3\ W_{ax}$

When $L_{max} < 1.3\ W_{av}$, $L' \fallingdotseq L\ m_{ax}$

where, W_{av}: average width of debris flow, L_{max}: maximum height of a living tree, and L': maximum length of floodwood.

The diameter of floodwood to flow into a planned spot is supposed to be equal to that of a living tree measured at the height of 1.2m above the ground. Such living-trees may be chosen as objective trees to fall down to become floodwood in the upstream.

3. Plans for wood-debris entrapment facilities

3.1. Estimation of wood-debris entrapment capacity

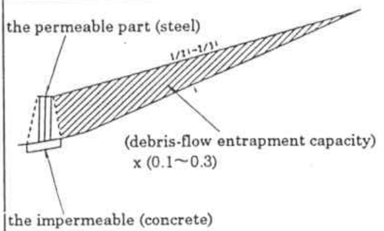
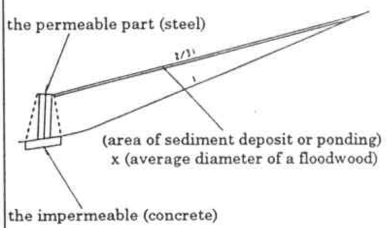
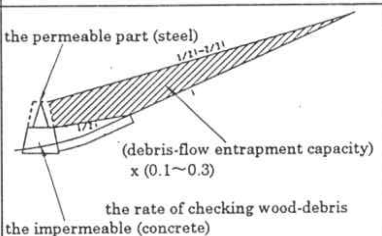
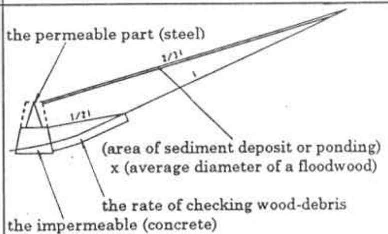
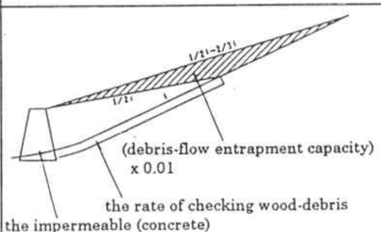
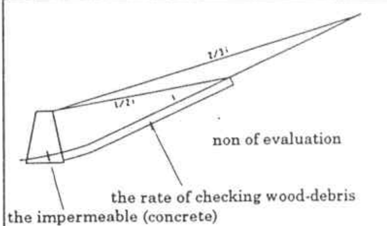
Table 1 is the exemplification of how to estimate the expectable entrapment capacity of wood-debris, depending upon morphological division of debris/sediment transport.

For permeable type of wood-debris entrapment facility (dam) located in the 'debris-flow section' of stream, we assume that the entrapment capacity of wood-debris is 10 to 30% of that of debris-flow check dam, since this type facility naturally entraps debris and wood-debris as the same time. For the same type facility located in the 'sediment-flow section' of stream where the wood flows down in floating condition, we also assume that the wood stuck (in one layer) over the sediment deposit or water ponding extent.

As for the impermeable type facilities such as gravity-type concrete dams set out in the 'debris-flow section' it is true that they also entrap wood-debris, but we set an assumption that the volume is to be less than 1% of sediment entrapment capacity. Like wise, for the impermeable type facilities located in the 'sediment-flow section' we don't evaluate the function to entrap the wood-debris.

Because the calculation methods of entrapment efficiency are the empirical ones based on the results of limited field surveys, they are only the tentative. Further surveys and studies are naturally essential.

Table 1 Wood-debris entrapment capacity
Tabelle 1 Auffangkapazität für Holzrümmer

	debris-flow section	sediment-flow section
permeable type		
partially permeable type		
non-permeable type		

3.2. Design for wood-debris entrapment facilities

The clearance and height of entrapment slits are designed basically according to the ideas as the following.

3.2.1. The clearance of entrapment slits

To trap wood-debris safely and effectively, it is necessary to consider the length of wood flowing down, the size of boulders contained in debris flow, and the types of a flow before deciding the clearance of entrapment slits. Figure 1 shows the relationship between the clearance of entrapment slits and the decreasing rate of sediment outflow obtained by a hydraulic experiment on debris flow. It is understood from Figure 1 that when the clearance of slits is smaller than 1.5 times the maximum diameter of boulder, the slit is exactly clogged, while when the clearance is larger than 2.0 times, the peak discharge volume of sediment flow decreases and the slit is not clogged completely. This indicates that the clearance of slits should be less than 1.5 times the maximum diameter of boulder so long as we intend to trap the debris/sediment, and for the purpose of merely trapping large boulders or decreasing the peak sediment discharge the clearance should be about 2.0 times the maximum diameter of boulders in debris-flow.

P : maximum sediment outflow
P_0 : maximum sediment outflow without structure
b : clearance of slits
d_{max} : maximum diameter of boulder

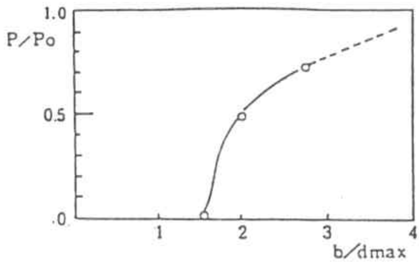


Fig. 1 Relationship between the clearance of slits and the decreasing rate of sediment outflow

Abb. 1 Verschlußlochgröße und Re-duktion der maximalen Geschiebetransportrate

1) In debris-flow section

In debris flow section, where wood-debris and boulders or sediment are trapped together, the clearance of slits can be designed as about 1.5 times the maximum diameter of boulders contained in the debris-flow, and as about 1/3 to 1/2 the length of the longest floodwood (Figure 2.)

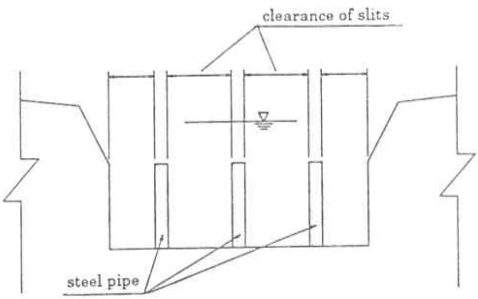


Fig.2 Clearance of slits
Abb.2 Zwischenraum der Spalte

2) In sediment-flow section

In sediment-flow section, it is necessary for the slits to trap the wood-debris firmly as well as to allow the sediment to pass down as far as possible and thereby to prevent the slits from getting clogged. The clearance of the slits, therefor, should be larger than about 1.5 times the maximum diameter of boulders, and yet smaller than 1/3 to 1/2 the length of longest floodwood.

3.2.2. Height of slits

1) Debris flow section

Since the wood-debris and sediment flow down, getting coalesced in one body as mentioned before, a dam to trap or control debris flow also functions as a wood-debris entrapment facility. Therefore the height of wood-debris entrapment structure is to be designed in connection with the planned entrapment capacity of a debris control dam.

2) Sediment-flow section

In sediment-flow section, most of wood-debris flow down in a state of floating on the stream surface around. Upon designing the height of wood-debris entrapment structures we should consider the swell-up of water-level due to slit/boom structure and occasional clogging of slit/boom section due to boulders, at first. Necessary height of slits to trap wood-debris should be much higher than such water-level. Empirical formula we obtained is shown in the following(Figure 3.)

$H_s = h_s + h_d + \Delta h$

Here, H_s: height of slit (m)

h_s: water depth in swell-up due to wood-debris (m)

h_d: 1.5 times the maximum diameter of boulders

Δh: allowance depth, 2.0 times the minimum diameter or floodwood or 1.0 (m)

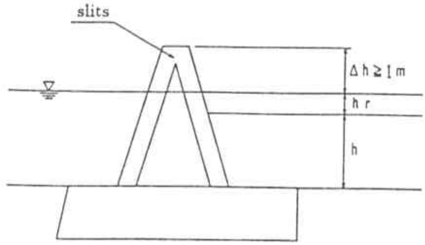


Fig.3 Height of slits
Abb.3 Höhe des Spaltbereiches

In addition, the minimum height of the slits is provided as 3m to prevent wood-debris caught by the boom from being carried away again by subsequent flows. In the above formula, Δh is the allowance depth for the fear of slit clogging which would happen at the lower part due to sediment accumulation.

4. External forces for slits design

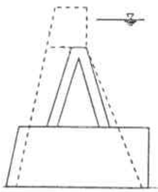
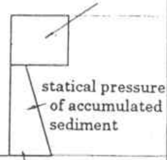
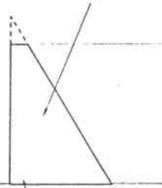
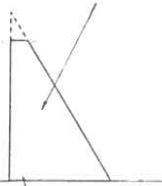
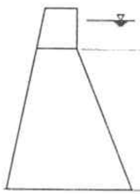
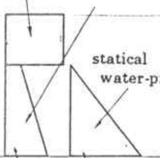
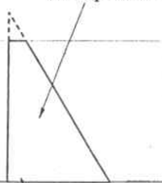
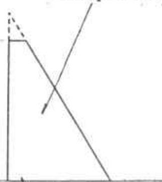
In designing the sections of structure we assume certain external forces acting on the structure.

As seen on Table-2, we take 1) the fluid pressure of debris-flow as well as statical pressure of accumulated sediment for the case in which debris-flow attach is anticipated in the 'debris-flow section' of torrent, but for the case of flood situation we just take the statical water-pressure.

As for the 'sediment-flow section' we merely assume 2) the statical water-pressure.

Table 2 External forces for slits design

Tabelle 2 Das Spaltdesign beeinflussende externe Kräfte

type	debris-flow section		sediment-flow section
	the case of debris-flow	the case of flood	the case of flood
permeable type 	 fluid pressure of debris-flow statical pressure of accumulated sediment $\gamma = 1.8\,t/m^3$	 statical water-pressure $\gamma = 1.2\,t/m^3$	 statical water-pressure $\gamma = 1.2\,t/m^3$
impermeable type 	 fluid pressure of debris-flow statical pressure of accumulated sediment statical water-pressure $\gamma = 1.0\,t/m^3$ $\gamma = 1.1\,t/m^3$	 statical water-pressure $\gamma = 1.2\,t/m^3$	 statical water-pressure $\gamma = 1.2\,t/m^3$

Conclusion

After the windfall tree disaster which had attacked Kyushu area in 1992, we have built up a number of wood-debris entrapment facilities there and they have effectively functioned to prevent the disasters coming from wood-debris outflow. Also they have not suffered seriously so far. However, the estimation methods for the capacity and the design methods which we introduce in this report are largely based on empirical judgments.

We would like to continue further surveys and studies through field surveys and hydraulic experiments to establish more effective design guidelines.

<Reference>

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1) Guidelines for Wood-debris Control (draft), Oct. 1990.
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3) Manual for the Design of Steel-made Sediment-Control Structures.
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