HOKKAIDO UNIVERSITY

A study on characteristics of movement of woody debris mass in debris flows by video footage analysis

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Introduction

- There are several studies on transportation of woody debris in floods.

  e.g. :Haga et al.,2002 Lancaster et al.,2003 Merten et al., 2010
  Mazzorana et al., 2011 Ruiz-Villanueva et al., 2014

- The actual state of transportation of woody debris mass in debris flow hasn't been revealed.

- The purpose of this study is **to clear characteristics of transportation of woody debris mass in debris flows by video footage analysis and preliminary hydraulic flume experiment.**

Methods

- We collected and analyzed seven video footage of woody debris carried on debris flows and sediment flows.

- We conducted **hydraulic flume experiment** in order to confirm the main factors that govern woody debris mass movement.

Definition of woody debris mass Outline (Video footage analysis)

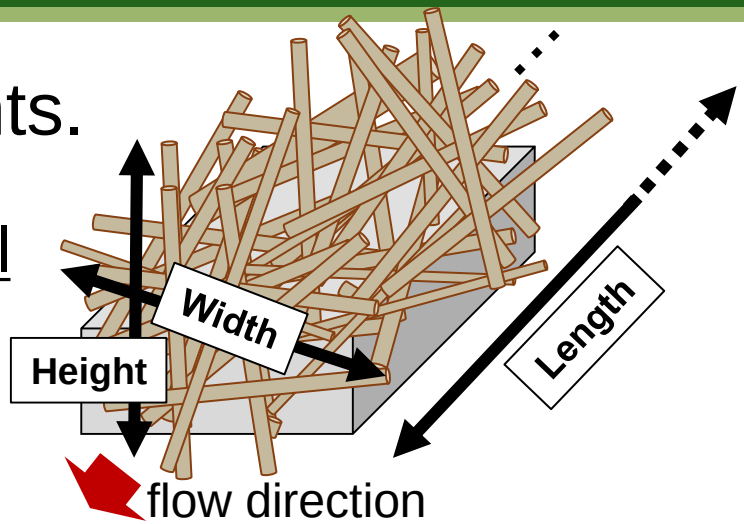
In this study, the part of woody debris entangled with each other near the flow front is called "**woody debris mass**".

9 July, 2014 Nashizawa River, Nagiso town, Nagano prefecture, Japan

Video credit
:Ministry of Land, Infrastructure, Transport and Tourism, Chubu Regional Development Bureau, Tajimi Sabo and National Road Office

Analysis points (Video footage analysis)

- We analyzed the following points.
  - Characteristics of stream channel
    →Gradient, Width, Depth
  - Type of sediment movement
    →Debris flow, Sediment flow
  - Characteristics of sediment movement
    →Flow depth, Flow width, Froude number, Coefficient of velocity
  - Characteristics of "woody debris mass"
    →Width, Height, Length See upper-right figure , Maximum length of woody debris near the flow front of debris flow, Average length of woody debris near the flow front of debris flow



Analysis methods (Video footage analysis)

① During the shooting time, we extracted the time section where the image range did not change.

② We extracted artificial structures (bridges, sabo dam, etc.), heights of revetments and banks, stones, etc. as scales, and measured the length and height with a ruler on the screen by the projection method. If necessary, we measured the distance, width, and altitude of the flowdown section from the google earth image, and the gradient was calculated.

③ The surface velocities of debris flow and sediment flow were calculated by measuring the time between two transverse lateral line sections to the flow direction set in the image with a stopwatch. In this study, the surface flow velocity was considered as the average flow velocity.

Materials (Video footage analysis)

- **Zion National Park, Utah, the United States**

  19 August, 2012 (Uploaded to Youtube)

Video credit : Kent Wilson
Source : Youtube (https://www.youtube.com/watch?v=DNgpI03nWFM)

Materials (Video footage analysis)

- **Southern Utah, the United States**

  30 August, 2013

Video credit : David Rankin
Source : Youtube (https://www.youtube.com/watch?v=aZp_1KtrzjQ)

Materials (Video footage analysis)

- **Utah Road, Utah, the United States**

  16 September, 2015 (Uploaded to Facebook)

Video credit : Christian Brunner
Source : Facebook

Materials (Video footage analysis)

☐ Johnson Canyon, Utah, the United States

16 July, 2018

Video credit : Reed Timmer
Source : Youtube (https://www.youtube.com/watch?v=ORJtxkuD62E)

Materials (Video footage analysis)

☐ British Columbia, Canada

13 July, 2012

Video credit : Global National's Francis Silvaggio and crew
Source : Youtube (https://www.youtube.com/watch?v=n1cCs-S5EKc)

Materials (Video footage analysis)

☐ Nashizawa River, Nagano prefecture, Japan

9 July, 2014

Video credit : Ministry of Land, Infrastructure, Transport and Tourism, Chubu Regional Development Bureau, Tajimi Sabo and National Road Office
Source : Ministry of Land, Infrastructure, Transport and Tourism, Chubu Regional Development Bureau, Tajimi Sabo and National Road Office

Materials (Video footage analysis)

- **Palm Springs, California, the United States**

  14 February, 2019

Video credit : California's Palm Springs Aerial Tramway
Source : Yahoo News

Results (Video footage analysis)

Information about video footage				Characteristics of stream channel			Type of sediment movement	Characteristics of sediment movement					Characteristics of "woody debris mass"				
Location	Date	Video credit	Source	Slope (°)	Width (B1) (m)	Depth (m)		Average velocity (m/s)	Flow depth (h1) (m)	Flow width (B2) (m)	Froude number	Coefficient of velocity	Width (B3) (m)	Height (h2) (m)	Length (L2) (m)	maximum length of woody debris near the flow front of debris flow(L1) (m)	average length of woody debris near the flow front of debris flow(L3) (m)
Zion National Park, Utah, the United States	19 Aug, 2012 (Uploaded to Youtube)	Kent Wilson	Youtube https://www.youtube.com/watch?v=DNgpl03nWFM	indecipherable (mild-slope)	6	3	sediment flow	0.5	0.6	6	0.2		6	1.6	10	2.5	1.8
Southern Utah, the United States	30 Aug, 2013	David Rankin	Youtube https://www.youtube.com/watch?v=aZp_1KtrzjQ	indecipherable (mild-slope)	13.6	3.8	sediment flow	0.4	0.3	13.6	0.2		woody debris mass was not formed			0.4	0.3
Utah, the United States	16 Sep, 2015 (Uploaded to Facebook)	Christian Brunner	Facebook Youtube	indecipherable (a little steeper than horizontal)	3	1.1	sediment flow	2.3	0.4	3	1.2		3	2	7	3	1.3
Johnson Canyon, Utah, the United States	16 Jul, 2018	Reed Timmer	Youtube https://www.youtube.com/watch?v=ORJtxkuD62E	indecipherable (mild-slope)	7	8	sediment flow	0.8	0.6	5	0.3		5	1.2	indecipherable	2	1.5
British Columbia, Canada	13 Jul, 2012	Global National's Francis Silvaggio and crew	Youtube https://www.youtube.com/watch?v=n1cCs-S5EKc	5	indecipherable (overflowed in the alluvial fan)		debris flow	1	1.5	indecipherable	0.3	0.9	18	2	indecipherable	8	5.7
Nashizawa River, Nagiso town, Nagano prefecture, Japan	9 Jul, 2014	Ministry of Land, Infrastructure, Transport and Tourism, Chubu Regional Development Bureau, Tajimi Sabo and National Road Office	Ministry of Land, Infrastructure, Transport and Tourism, Chubu Regional Development Bureau, Tajimi Sabo and National Road Office	4.1	10	3	debris flow	6.5	1.6	10	1.6	6.1	10	2	40	7	4.5
Palm Springs, California, the United States	14 Feb, 2019	California's Palm Springs Aerial Tramway	Yahoo News	8.5	13	3.7	debris flow	10.8	2	13	1.8	6.3	13	1.5	60	4.7	1.3

Results (Video footage analysis)

- The following qualitative characteristics were revealed.
  - Woody debris mass was concentrated near the flow front.
  - A lot of woody debris was distributed on the surface of flow.
  - Woody debris that forms woody debris mass moved with little change in the relative position.
  - When a sediment flow reached the widening part of stream channel and the flow was spread laterally, woody debris mass was broken down and the height of woody debris mass was reduced.

    ⇒ **<u>wood length</u> and <u>channel width</u> are considered to be important parameters of woody debris mass volume.**

Question about “woody debris mass”

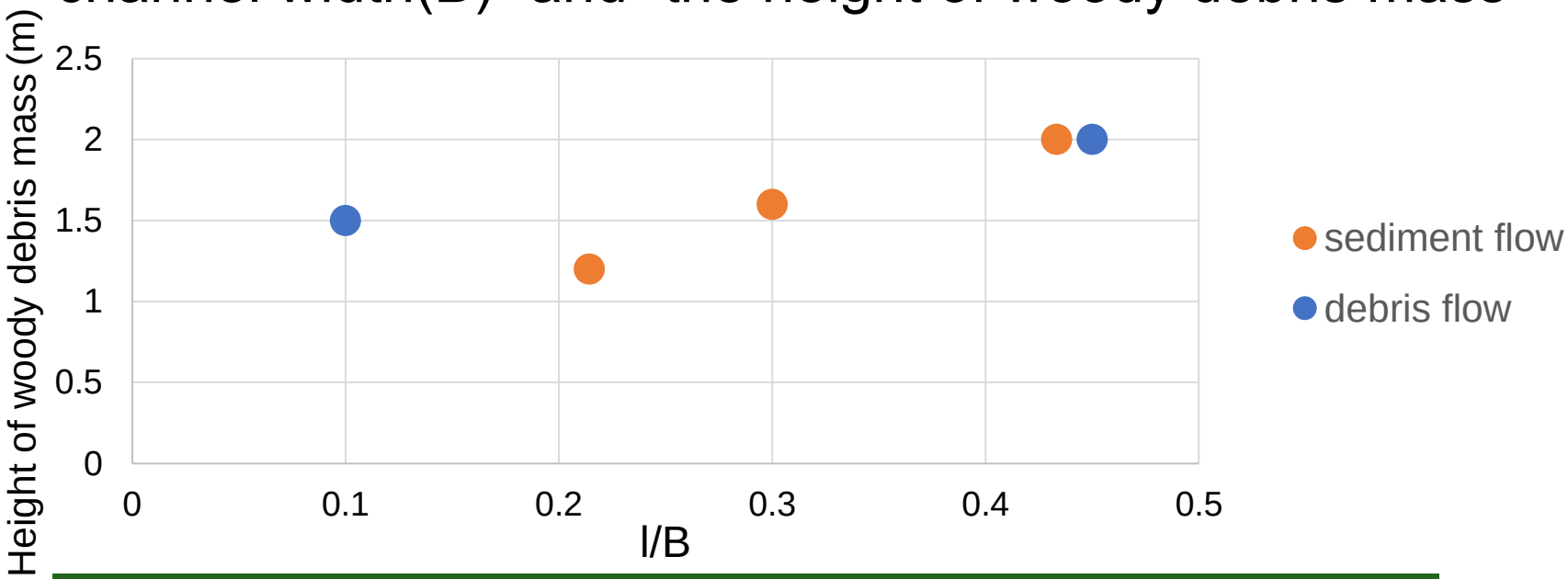
- We noticed that the scale of “woody debris mass” was different for each phenomenon.

What are the factors that determine the scale of “woody debris mass”?

- We rearranged the results of video footage analysis by focusing on the following points.
  - the ratio of the average length of woody debris(l) to the stream channel width(B) →**<u>l/B</u>**
  - **<u>the height of “woody debris mass”</u>** (as an index of scale of woody debris)

Results (Video footage analysis)

- "the ratio of the average length of woody debris(l) to the stream channel width(B)" and "the height of woody debris mass"

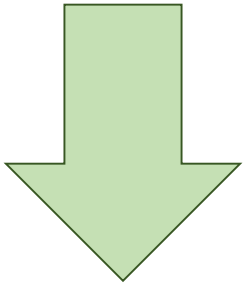


Judging from the sediment flow and debris flow that were analyzed in this study, a **positive correlation** was found.

Objective of hydraulic flume experiment

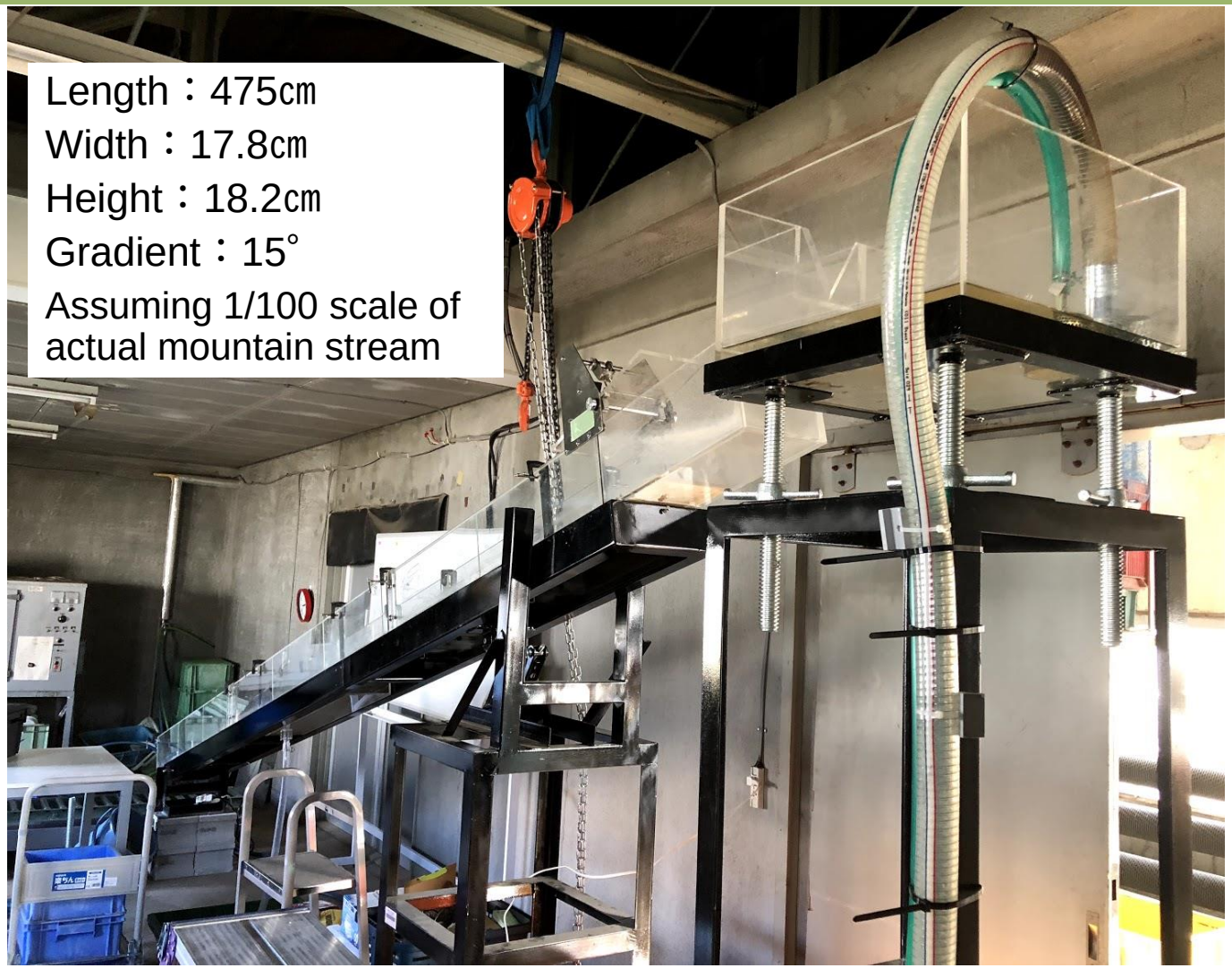
- Formation of woody debris mass

  ⇒ **<u>wood length</u>** and **<u>channel width</u>** are considered to be important parameters of woody debris mass volume.

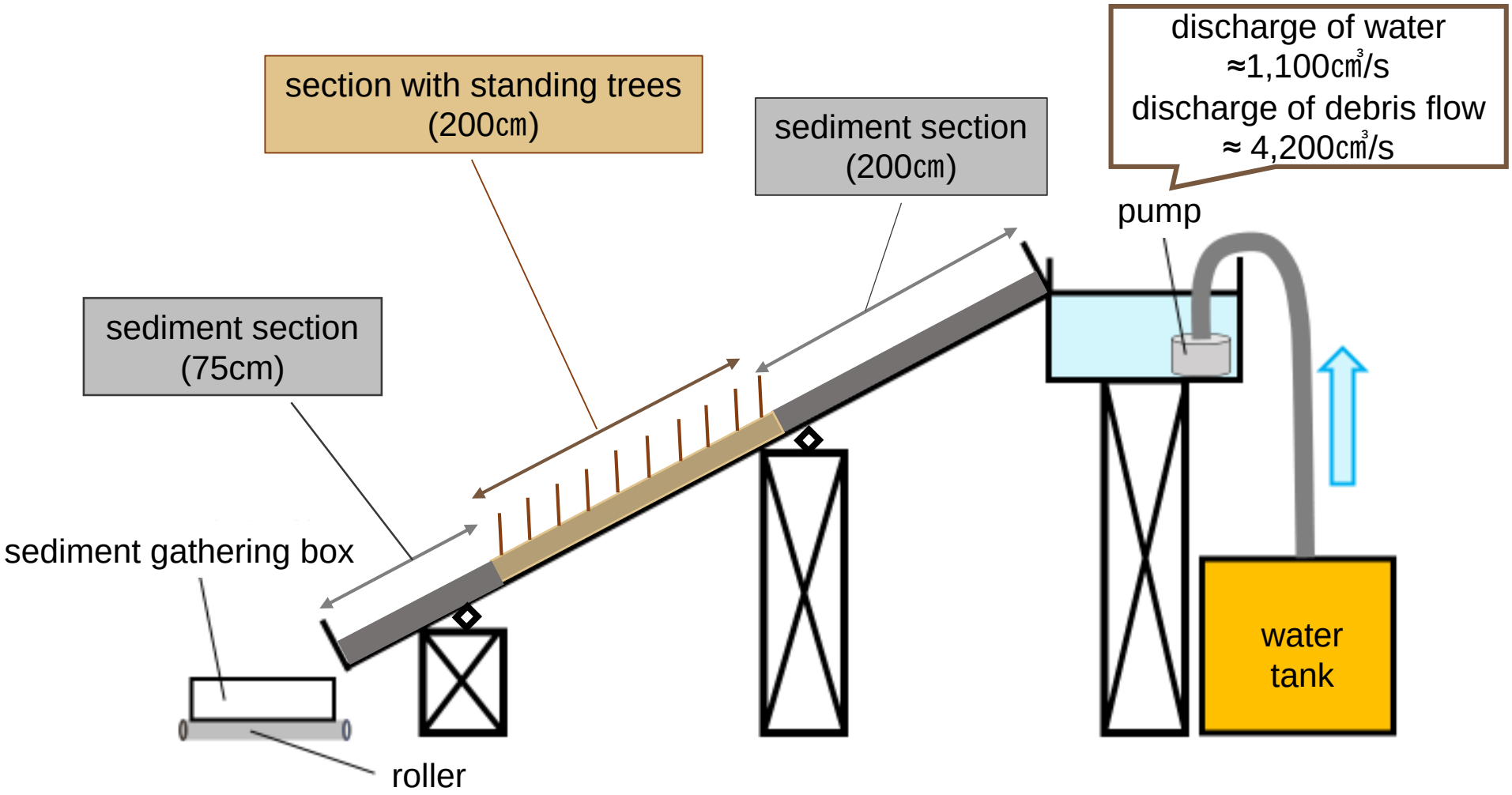


We conducted experiments and compared the results with actual phenomena.

Photo of experimental channel （Hydraulic flume experiment）



Schematic diagram (Hydraulic flume experiment)



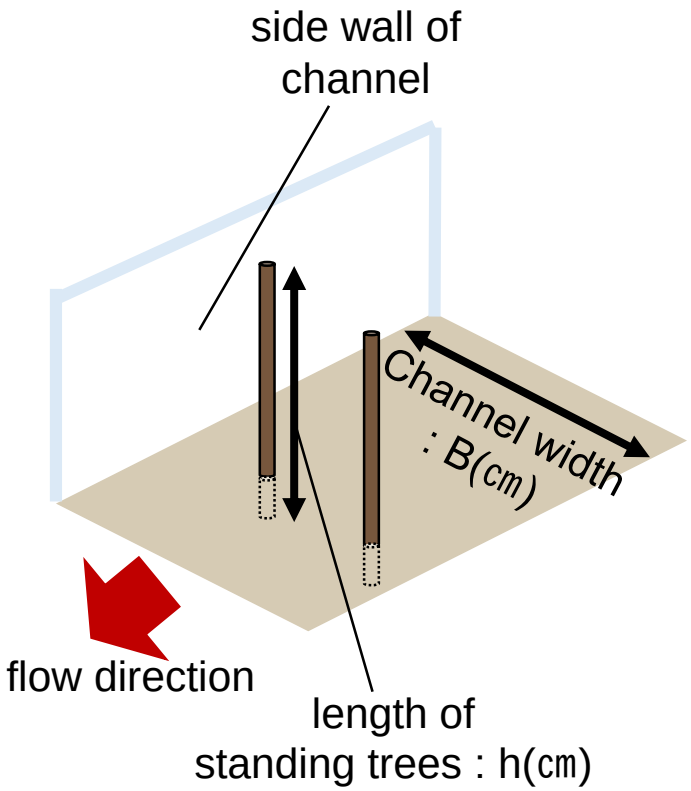
Experimental conditions (Hydraulic flume experiment)

- Length of standing trees (h)
  : **6** types

  4.5cm, 9cm, 13.5cm, 18cm, 20.25cm, 22.5cm

- Number of standing trees (N)
  (Density of standing trees)
  : **8** types

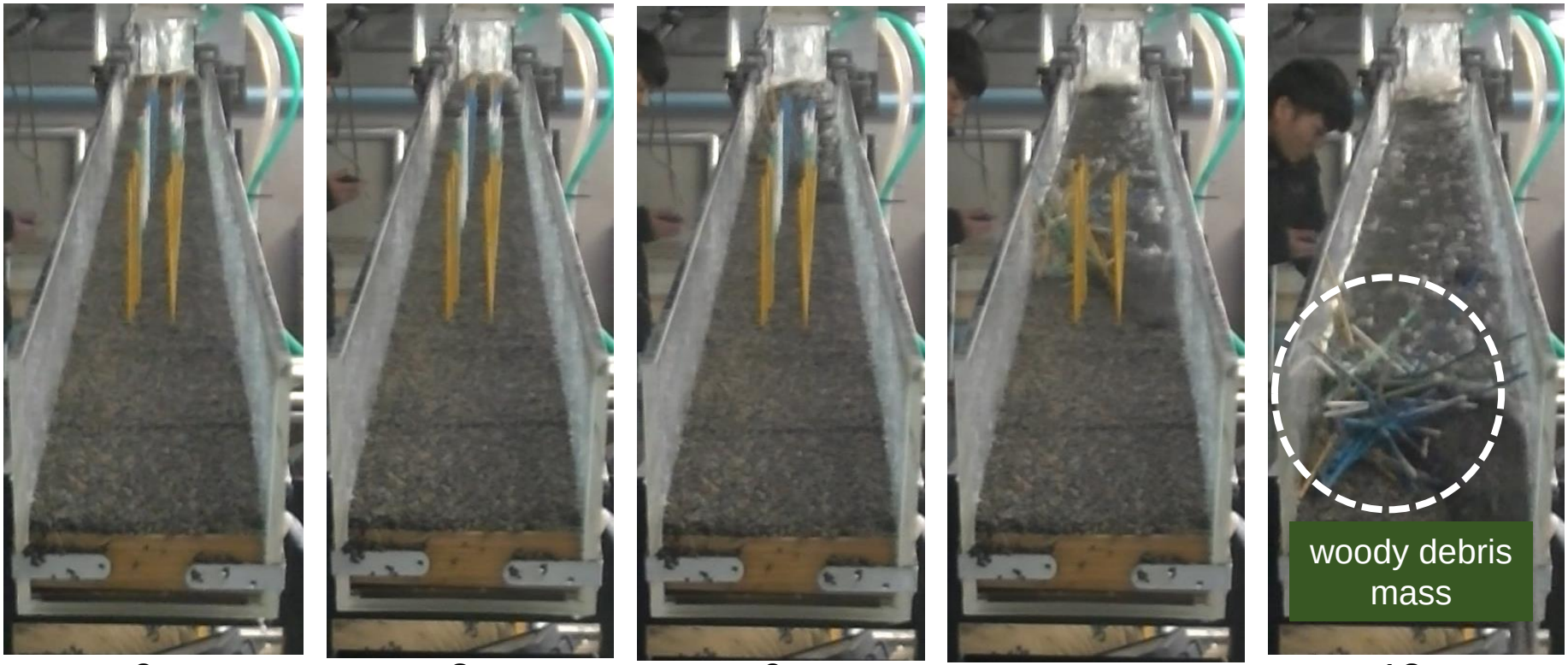
  25, 50, 100, 120, 150, 180, 195, 300



Experiment is conducted by combining the above two conditions.

Results (Hydraulic flume experiment)

- Formation of woody debris mass (h=18㎝, N=100)

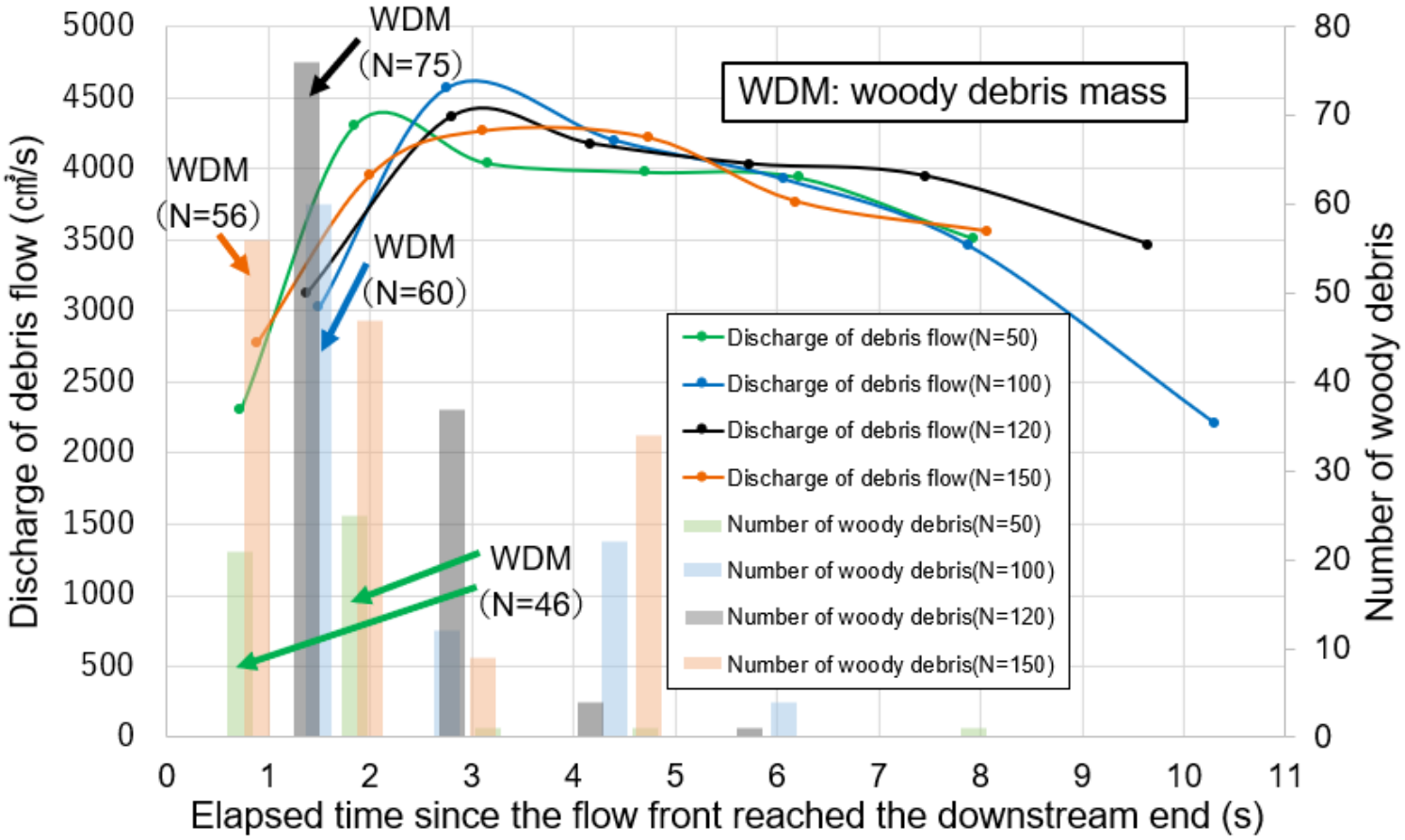


0s 3s 6s 9s 12s

Elapsed time from the start of the experiment

Results (Hydraulic flume experiment)

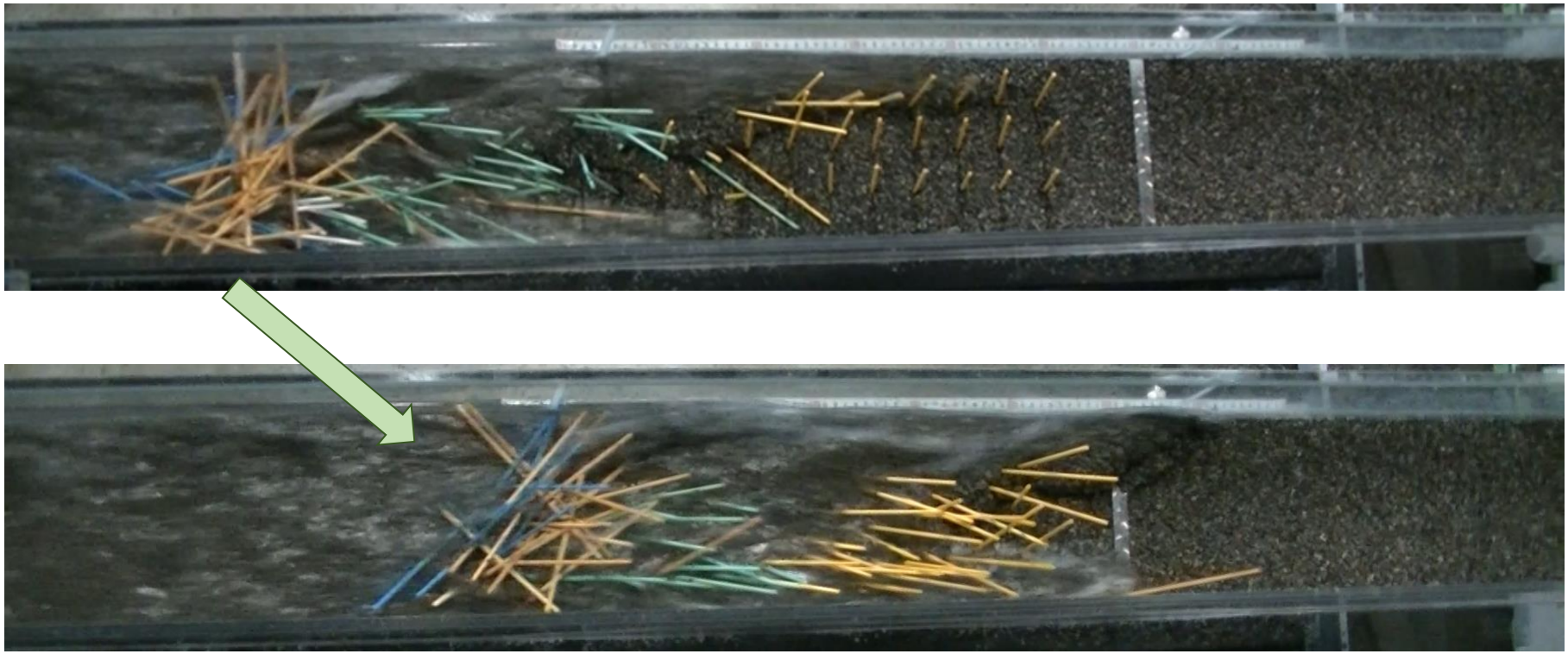
Distribution of woody debris in debris flow



Woody debris mass was formed **near the flow front** of debris flows.

Results (Hydraulic flume experiment)

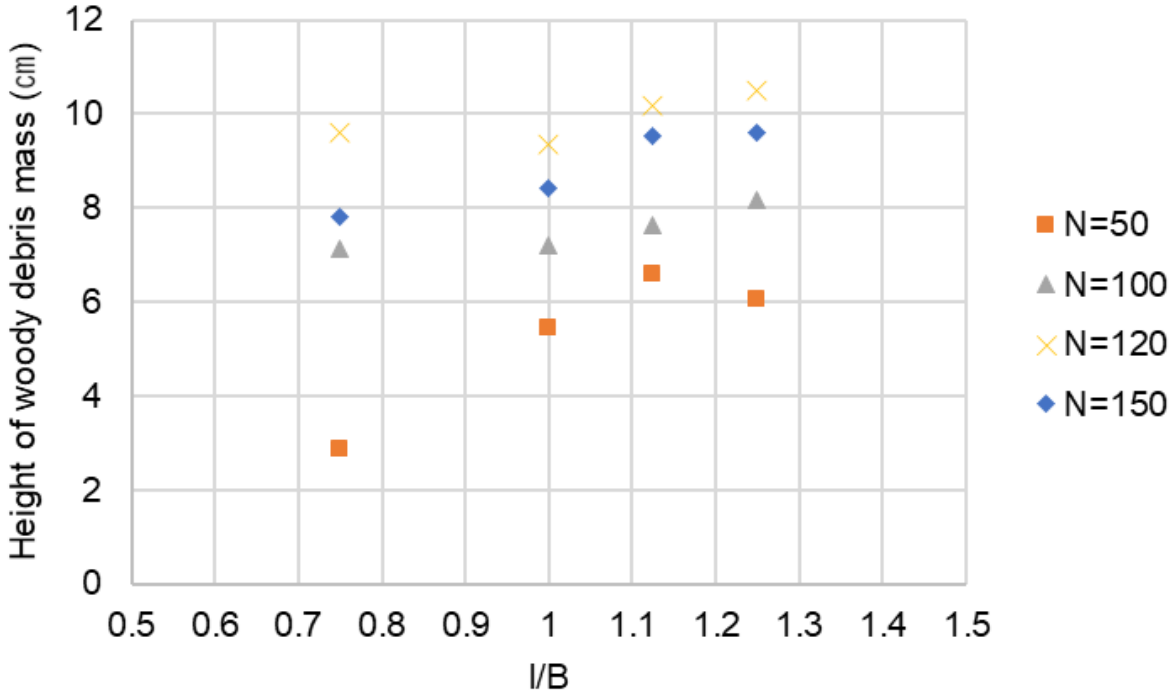
- Position of woody debris mass in debris flow



Woody debris mass moved **with little change in the relative position**.

Results (Hydraulic flume experiment)

- “the ratio of the length of woody debris model(l) to the flume width(B)” and “the height of woody debris mass”



A **positive correlation** was found.

Summary of results (Hydraulic flume experiment)

- Woody debris mass was formed **near the flow front** of debris flow.
- Woody debris mass moved **with little change in the relative position**.
- A **positive correlation** was found between “the ratio of the length of woody debris model to the flume width” and “the height of woody debris mass”.

These results were harmonious with results of video footage analysis.

Discussion

- **Why was a positive correlation found between "the ratio of the length of woody debris model to the flume width" and "the height of woody debris mass"?**
  - The longer the standing tree is, the greater the number of intersections with other woody debris.
  - ⇩
  - More woody debris tends to entangled with each other.
  - ⇩
  - The scale of woody debris mass becomes larger.

Conclusions

- This study was able to clear some characteristics of transportation of woody debris in debris flows by video footage analysis.
  - A lot of woody debris was distributed on the surface of flow.
  - Woody debris that forms woody debris mass moved with little change in the relative position.
  - When a sediment flow reached the widening part of stream channel and the flow was spread laterally, woody debris mass was broken down and the height of woody debris mass was reduced.
  - A positive correlation was found between “the ratio of the average length of woody debris to the stream channel width” and “the height of woody debris mass”.
- Characteristics above are harmonious with results of hydraulic flume experiment.