EXPERIMENTAL STUDY ON PROCESS OF EXFOLIATION FROM DRIFTYWOODS IN FLOOD AT OMOTOGAWA RIVER

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ABSTRACT

This paper presents an experimental approach to research the process of exfoliation of bark in a flood. While flowing, bark was stripped by hitting or wearing out gravel rock, and other driftwoods. After that these were found in downstream area in the state of bark stripped completely. Cause of exfoliation was being carried out. However, experiments combining similarity law were few, which the time or length until barks were stripped. Therefore, it was not yet understood the area where driftwoods were transported. Investigation going to upstream of river to identify the source of driftwoods took much time and effort, thus, it is important that process and moments were understood experimentally. Watercourse which flat circular that there was not pumped up was made by us and was composed of acrylic and polyvinyl chloride. Two drainage pumps were used to wash away the things as real floods. In this experiment, driftwood models which cedar rod were flowed with water, sand and gravel. At first, water velocity was measured at some points by use of the current meter. On average, water flowed and mixed with the other things, subsequently, bark was stripped. From this reason, the hydraulic models can be brought back behavior of driftwoods in a real flood.

In this study, process and moments of exfoliation of bark were understood a little. The faster driftwoods were flowed, the earlier barks were stripped. Furthermore, injured models were stripped faster the uninjured models.

Keywords: driftwood, flat rotating channel, stripping, flow time, flood

1. INTRODUCTION

It is frequently occurred flood damage resulting from driftwoods with water and sediment caused by heavy rain (Mizuhara, K., 1979, Kimura et al., 2017). For example, Typhoon No.10 in August 2016 caused flood of Omotogawa River in Iwate (Tsuchiya et al., 2018). This flood caused rapidly rising water level, then it took the lives of nineteen people and damaged town, agricultural land and lifeline. Furthermore, such disaster occurred in other countries. For example, a large amount of driftwoods was come out in the flood of 2005 in Austria and Switzerland (Rudolf-Miklau, Florian et al., 2011). So, study on driftwoods in a flood were conducted. For instance, experiment using steel stakes about driftwood was performed (Harada et al., 2019). On the other hand, risk of driftwood was analyzed (Lukas et al., 2013). And guidelines about driftwood were stipulated by the government in such country (Sabo Planning Division Sabo Management, 2016, Rudolf-Miklau, Florian et al., 2011).

However, study on process of exfoliation of driftwood with time have not been conducted yet. Therefore, driftwood which was drained to downstream area were not able to identify where it had been taken. If exfoliation process in flow-down was cleared up, source area would be estimated and be useful for river management and forestry.

Therefore, in this study, the hydraulic model experiments were carried out using flat rotating channel. It was modeled after Omotogawa River that have been damaged by the flood caused a driftwood in typhoon No.10. The experiments approach to investigate process and time of bark exfoliation from driftwood. It was measured the water level and the flow velocity. It was made by the driftwood models, sediment and water. Exfoliation parts were evaluated quantitatively by analyzing an image and evaluated qualitatively by observing bark.

2. STUDY AREA

The river modeled in this study is Omotogawa River. Figure 1 shows location of Omotogawa River and the measurement station. Omotogawa River is class B River. It flows between mountain over 1000 m altitude in upstream area and flows narrow flatland in midstream and downstream area toward Pacific Ocean while joining some river. The size of catchment area is 731 km^2 and the channel extension is 65 km (Iwate Prefecture, 2019). The survey has been conducted near 14 km from estuary. As a result, it has been obtained the following number. Channel bed profile is 1/666. The width of river is 54 m approximately.

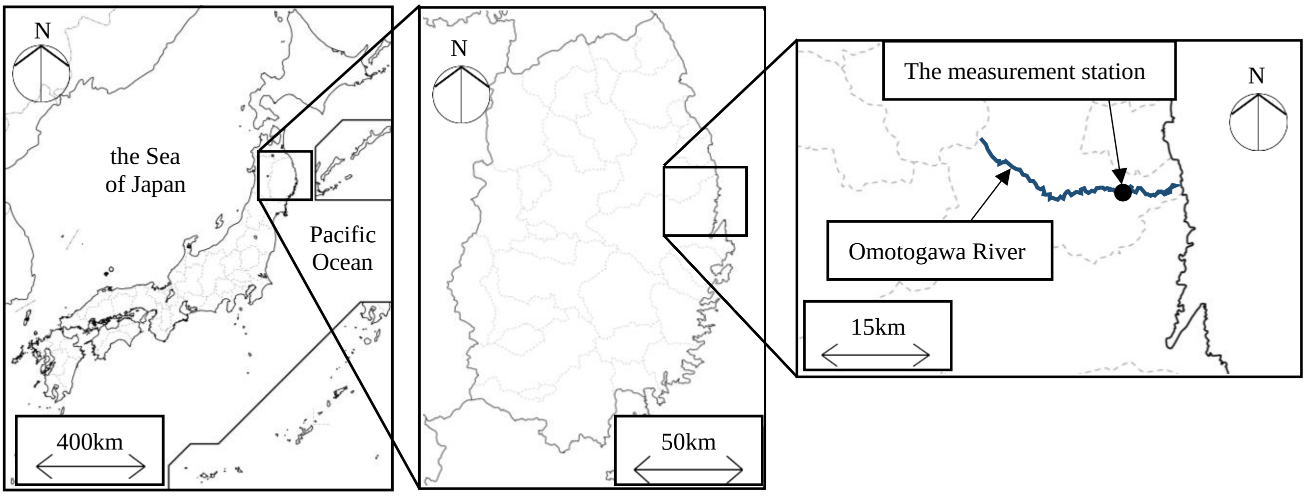

Figure.1 Study area (Omotogawa River).

3. OUTLINE OF EXPERIMENTS

3.1 Flat rotating channel

Experiments were carried out using flat rotating channel. Figure 2 shows the design of this channel. The wall of straight lines and bottom was made of acrylic plates, and the wall of curve lines was made of vinyl chloride pipes. The width of channel is 49.4 cm. The depth is 58.5 cm. The height of walls is 20 cm. The length of Central line in outside channel is 280.0 cm, the length of curves is 81.5 cm, and the length of straights is 58.5 cm. The width of outside channel was 11.5 cm. Water was pumped up by drainage pumps from inside storage area and pass through the hoses, then was came out of releasing points on outside wall. The points were established 5 cm from bottom of channel. Angle of incident is 15 degree. Discharge of each point is 50 ℓ/minute. Moreover, two overflow weirs were established inside wall near the entrance of the straight area in order to keep on flowing without changing water level. Water overflow toward inside and circulate inside and outside. The height of it could be changed 5.5 cm or 7.5 cm. Wire mesh was established above the overflow weirs so that Driftwoods were not flowed to inside with water. The scale was 1/470 by Froude. It was based on the width of Omotogawa River (Nishiwaki et al., 2018) and the width of flat rotating channel.

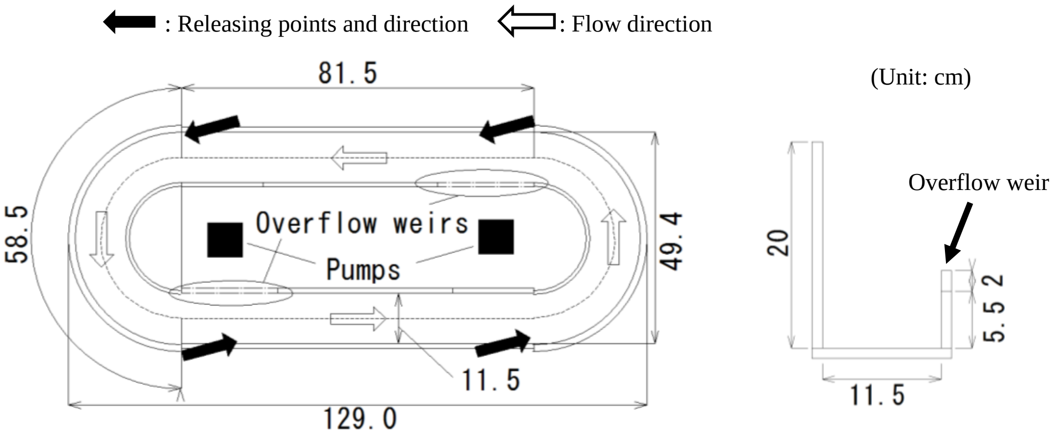

Figure.2 Design of flat rotating channel and sectional view of low wall.

3.2 Sediments

In the Experiments, sediments of Babamegawa River were used. Figure 3 shows Babamegawa River and the measurement station. This river is class B River in Akita prefecture. The size of catchment area is 910.5 km and channel extension is 47.5 km (Akita Prefecture, 2007). A lot of sediments were needed to use in the experiments and this River is nearer than Omotogawa River from Akita University. And furthermore, the grain size distribution of sediment of Babamegawa River and Omotogawa River were discovered by sieved analysis how compliant with JIS A 1204 (Japanese Industrial Standards committee, 2009). Figure 4 shows the grain size distribution curve of each river. It was indicated that grain size distribution of each sediment was similar. For these reasons, Babamegawa River was selected. It was composed of sand and gravel and was occupied with 60 % gravel approximately. Maximum grain size is 31.5 mm, Uniformity coefficient of Omotogawa River is 7.60 and Babamegawa River is 8.13.

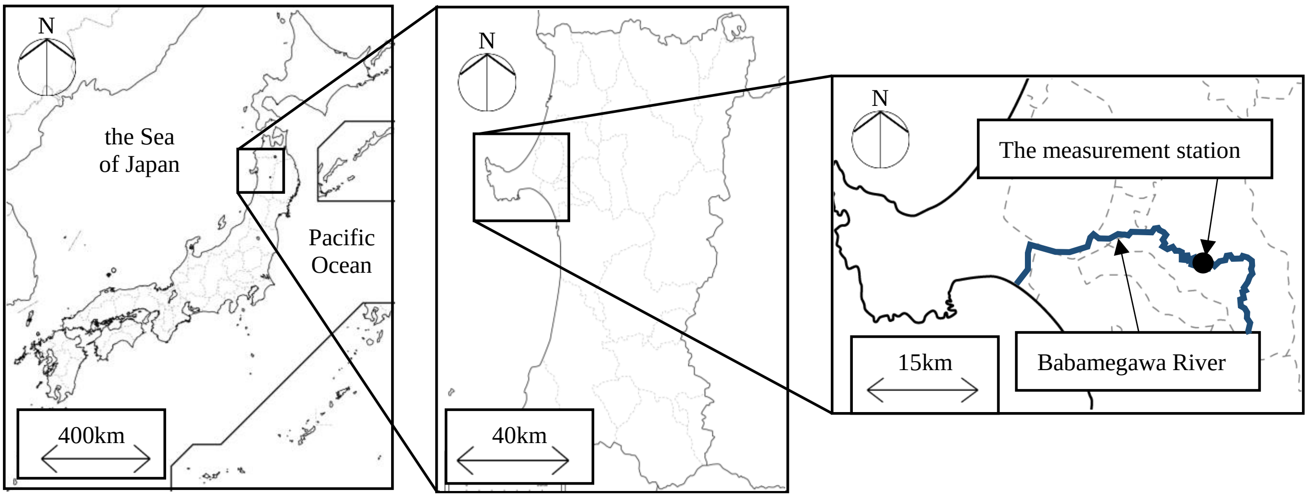

Figure 3. Study area (Babamegawa River).

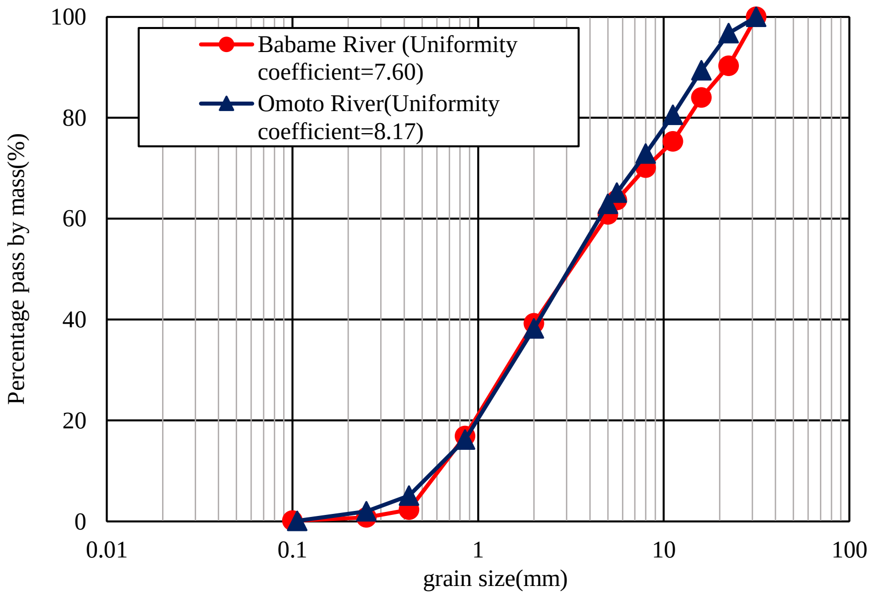

Figure.4 Grain size of distribution curve of each river.

3.3 Velocity in the channel

The experiments were carried out using driftwoods and water or driftwoods, sediments and water. These were put into channel and were poured by pumps. The experiment on driftwoods and water, without sediments (in fresh water), was performed under water level 9 cm (Case A). The experiments on driftwoods, sediments and water were performed under water level 6 cm (Case B), 5 cm (Case C) or 4 cm (Case D). Sand was located at below and gravel was located at above to bring back real riverbed. Thickness of channel bed was set 4 cm approximately.

Velocity in each case was measured using propeller current meter by one-point model. Real velocity in debris flow containing gravel is 3-10 m/s (Ikeya, H., 1999). Therefore, velocity in each case at the experimental channel scale was brought back real phenomenon. Table 1 shows velocity in each case in the channel, velocity converted into real scale and Shields number. It was discovered that sediments in almost all cases were moved in the state of bed-road motion from Shields number.

Table 1. Velocity in the channel, velocity converted into real scale and Shields number.

	Water level (cm)	Velocity in the channel (m/s)	Velocity at real scale (m/s)	Shields number
A	9	0.49	10.62	-
B	6	0.33	7.07	0.0459
C	5	0.36	7.81	0.0563
D	4	0.37	8.02	0.0628

4. EXPERIMENT OF STRIPPING DRIFTWOODS

4.1 Driftwood

Cedar rods were used as Driftwood in the experiments. The length of driftwoods was supposed 25 m. Converted the number into model scale, it was 5.5 cm. The diameter of driftwoods was 6 mm approximately. These used in the wet state to bring back real phenomenon. The specific gravity in this state is 0.92 on average. By the way, the specific gravity in dry state is 0.35 (Ishimaru et al., 2017).

4.2 Experimental method

The experiments were carried out flowing driftwoods and water or driftwoods, sediments and water. These were flowed by pumps. Thickness of sand and gravel was defined 4 cm and water level was based on Table.1. Number of driftwoods was defined 10 in all cases. It was revealed that water was flowed from upstream area near estuary in Omotogawa River at real scale when it was flowed 120 minutes in the channel. In this reason, water flowed 120 minutes in all cases.

Pumps were turned off every 10 minutes until 60 minutes and every 20 minutes next 60 minutes and the driftwoods were analyzed and observed. Evaluation of exfoliation was executed image analysis. First, these were taken the side in the state with focal length constantly from 4 directions. Figure 5 shows example of exfoliation that each area was indicated. Secondly, Stripping area and driftwood area were calculated in each direction and were added up in each area. Finally, stripping ratio was calculated. It was determined that stripping area for driftwood area. Stripping ratio is expressed by equation (1).

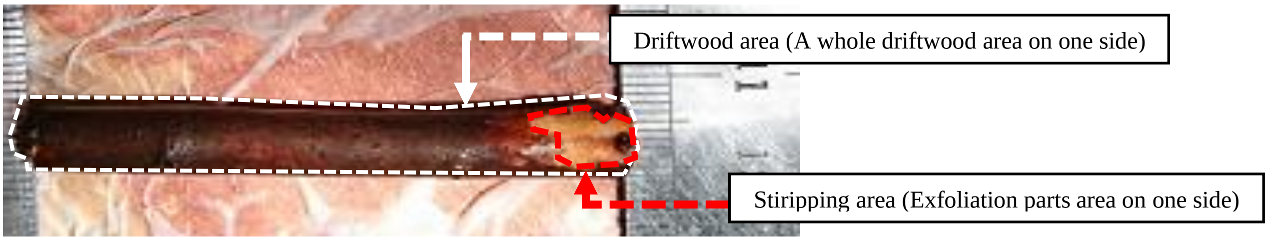

Figure 5. Example of stripping and driftwood area.

$$Stripping\ ratio = \left(\frac{stiripping\ area}{driftwood\ area}\right) * 100 \quad (1)$$

5. RESULT OF EXPERIMENTS AND CONSIDERATION

5.1 Behavior of driftwoods in the channel

Experiment of Case A using a driftwood was executed. Figure 6 shows behavior in the channel in Case A.

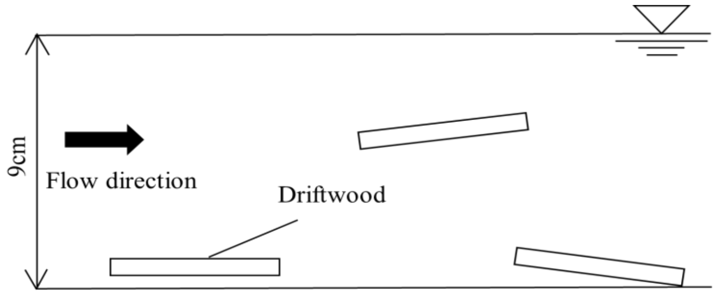

Figure 6. Behavior in the channel in Case A.

It was found that driftwoods tended to be flowed through a section part for the flow direction and be flowed near bottom. These were not flowed while hardening each other.
Case B to D using driftwoods was executed. Figure 7 shows behavior in the channel in Case B-D. It was found that driftwoods tended to be flowed as Case A. These were hit to gravel for a section part or were scraped side part with gravel. Immediately after driftwood hit on gravel, these dodged or span on fulcrum where these hit points. At that moment, it might be hit from behind by others. Gravels were not carried away or even if these were flowed, water level would not be varied. Therefore, Dynamic equilibrium could be kept in the channel.

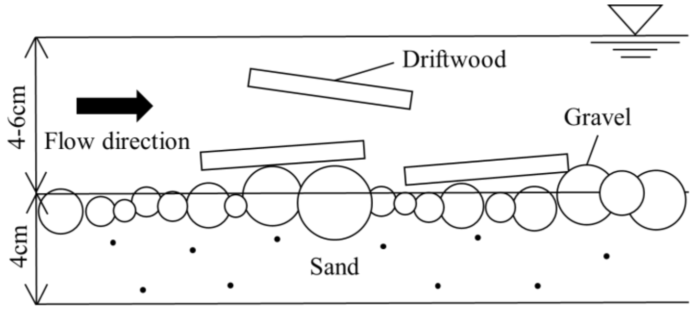

Figure 7. Behavior in the channel in the Case B~D.

5.2 Result of experiment and consideration

Firstly, the driftwoods in Case A was performed analysis. Figure 8 shows stripping ratio results of Case A and driftwood number is observed order. Also, driftwood number is unrelated with rank of stripping ratio. Maximum stripping ratio was 0.11 %. Minimum stripping ratio was 0.00 %. It was found from the result that driftwoods were seldom stripped by hitting bottom, wall and others.

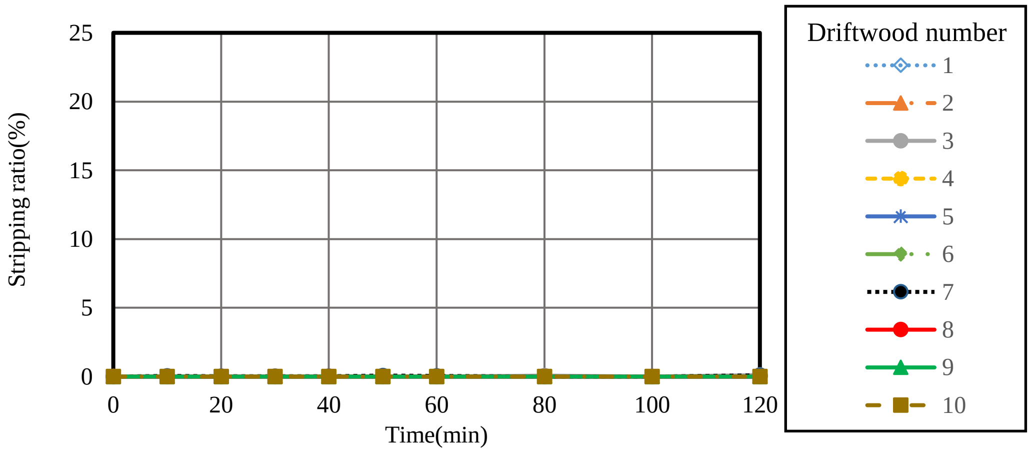

Figure 8. Stripping ratio of Case A. (without sediments, water level=9cm)

Driftwoods of Case B was performed analysis. Figure 9 shows stripping ratio results of Case B.

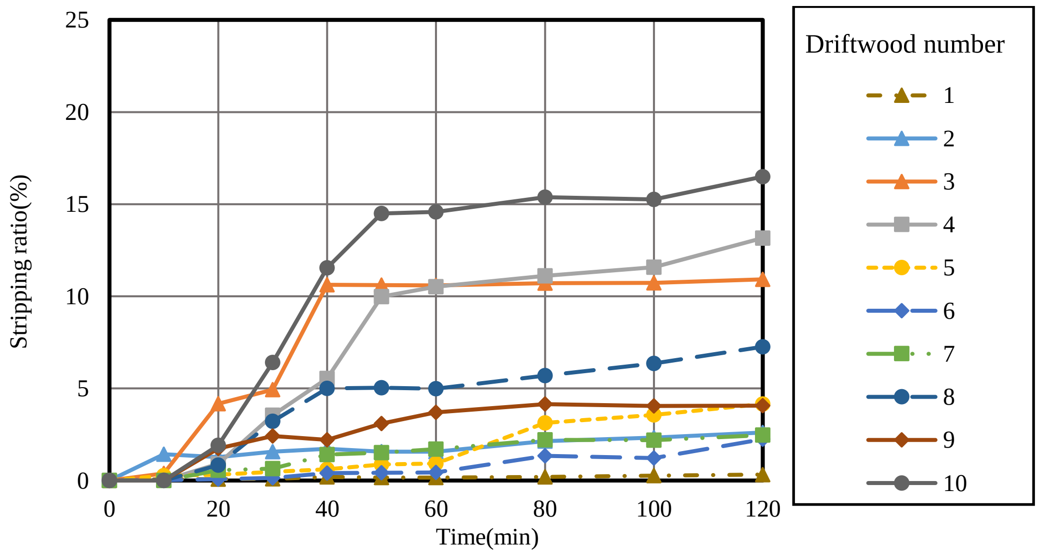

Figure 9. Stripping ratio of Case B. (including sediments, water level=6cm)

Maximum stripping ratio was 16.49 %. Minimum stripping ratio was 0.32 %. Driftwoods already were stripped while it takes 10 minutes. The driftwood of four ranks that stripping ratio was large were stripped mainly 10 minutes to 50 minutes. Regarding 50 minutes later about it, these ratios were raised variously. Exfoliation seldom progressed, slowly and progressed after 100 minutes again.
Driftwoods of Case C was conducted analysis. Figure 10 shows stripping ratio results of Case C. Maximum stripping ratio was 13.73 %. Minimum stripping ratio was 1.39 %. There were two driftwoods that were stripped 20minutes to 50 minutes largely and the way of progress was various. But a lot of driftwood were stripped to only 2 % approximately. Consequently, stripping ratio of Case C tend to be smaller than Case B that water level 6 cm and be smaller unevenness than Case B.

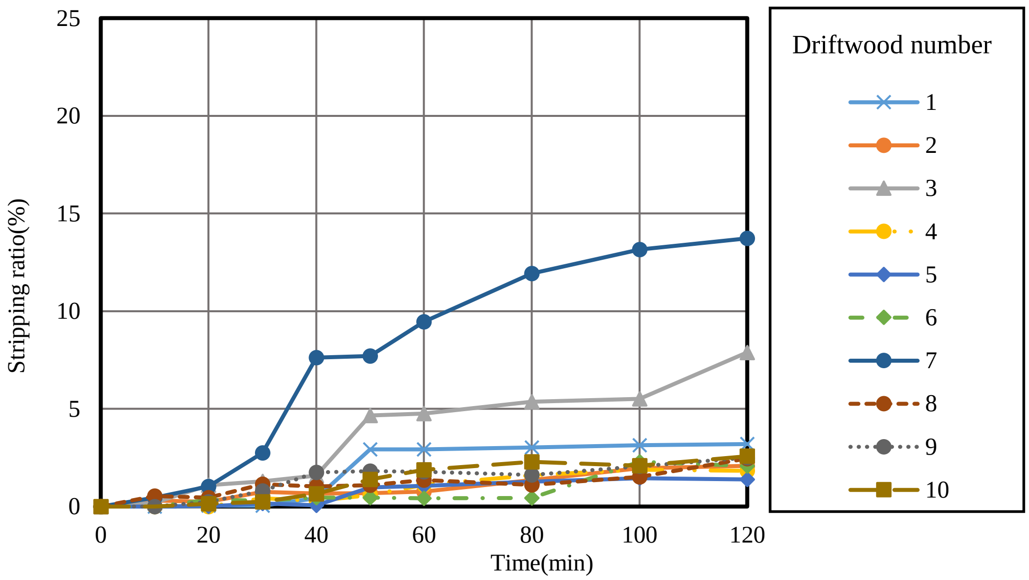

Figure 10. Stripping ratio of Case C. (include sediments, water level=5cm)

Experiment of Case D was conducted analysis. Figure 11 shows stripping ratio results of Case D. Maximum stripping ratio was 20.33 %. Minimum stripping ratio was 0.44 %. The driftwood of two ranks that stripping ratio was large were stripped mainly10 minutes to 60 minutes and were improved after that. But the others were stripped to only 1-2 % approximately. As a result, it was found that stripping ratio was similar tendency to Case C which water level was 5 cm.

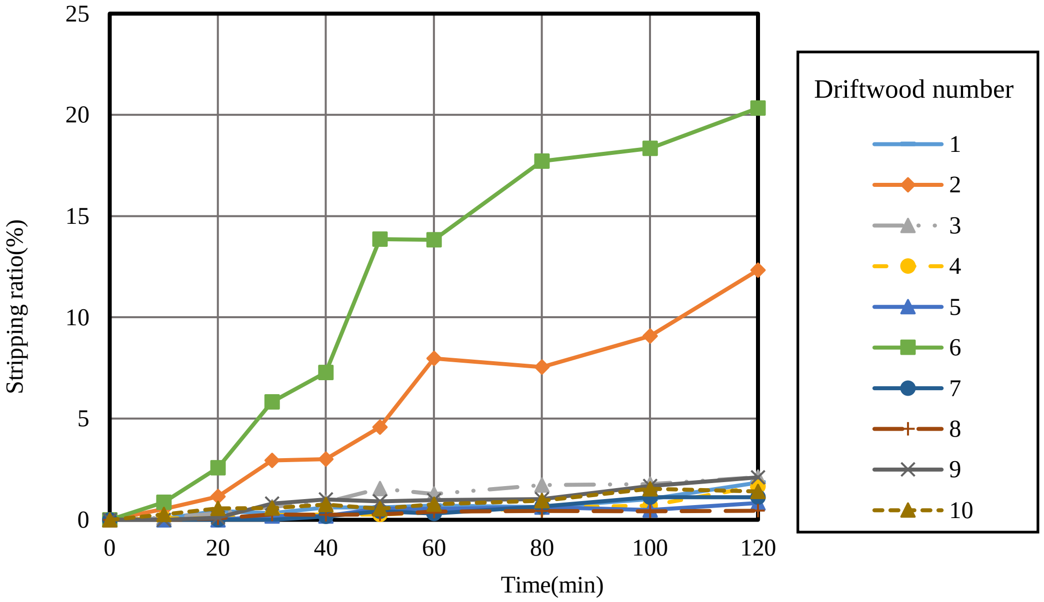

Figure 11. Stripping ratio of Case D. (include sediment, water level=4cm)

Finally, maximum stripping ratios which each case were compered. Figure 12 shows comparison of maximum stripping ratio in each case. The driftwood in Case D was stripped most largely and Case B was stripped secondly.
From these results, characteristic tendencies about stripping ratio and a way of progresses could not be found. It was thought as the reason that indivisual differences, for instance, strength of epidermis was influenced greatly. However, precise factor was not identified yet. Therefore, it is necessary to consider in the future.

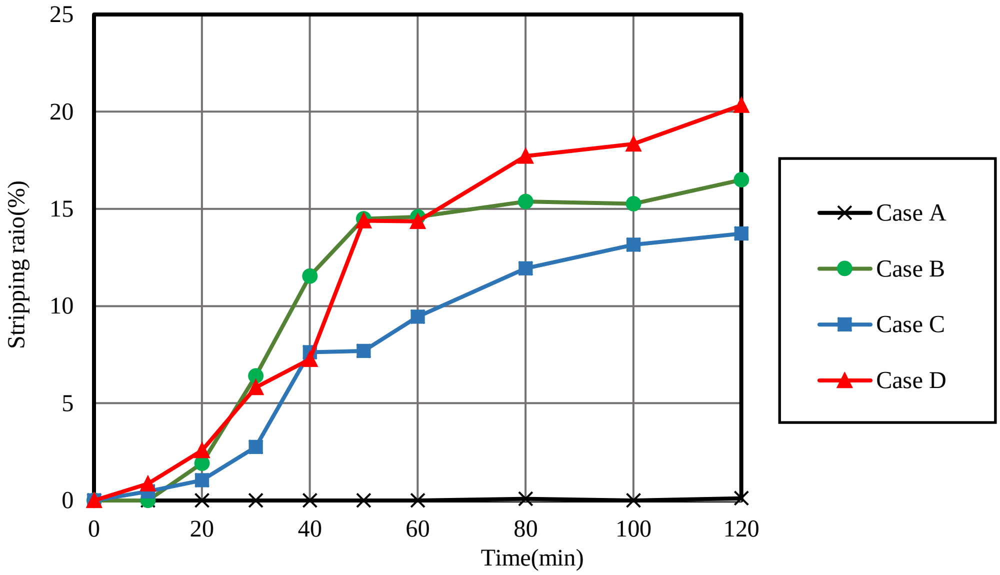

Figure 12. Comparison of maximum stripping ratio.

5.3 Observation of surface

Then, stripped driftwoods were observed about the exfoliation part of surface. Firstly, most barked driftwood in the Case D was conducted over time. Figure 13 shows process of exfoliation.

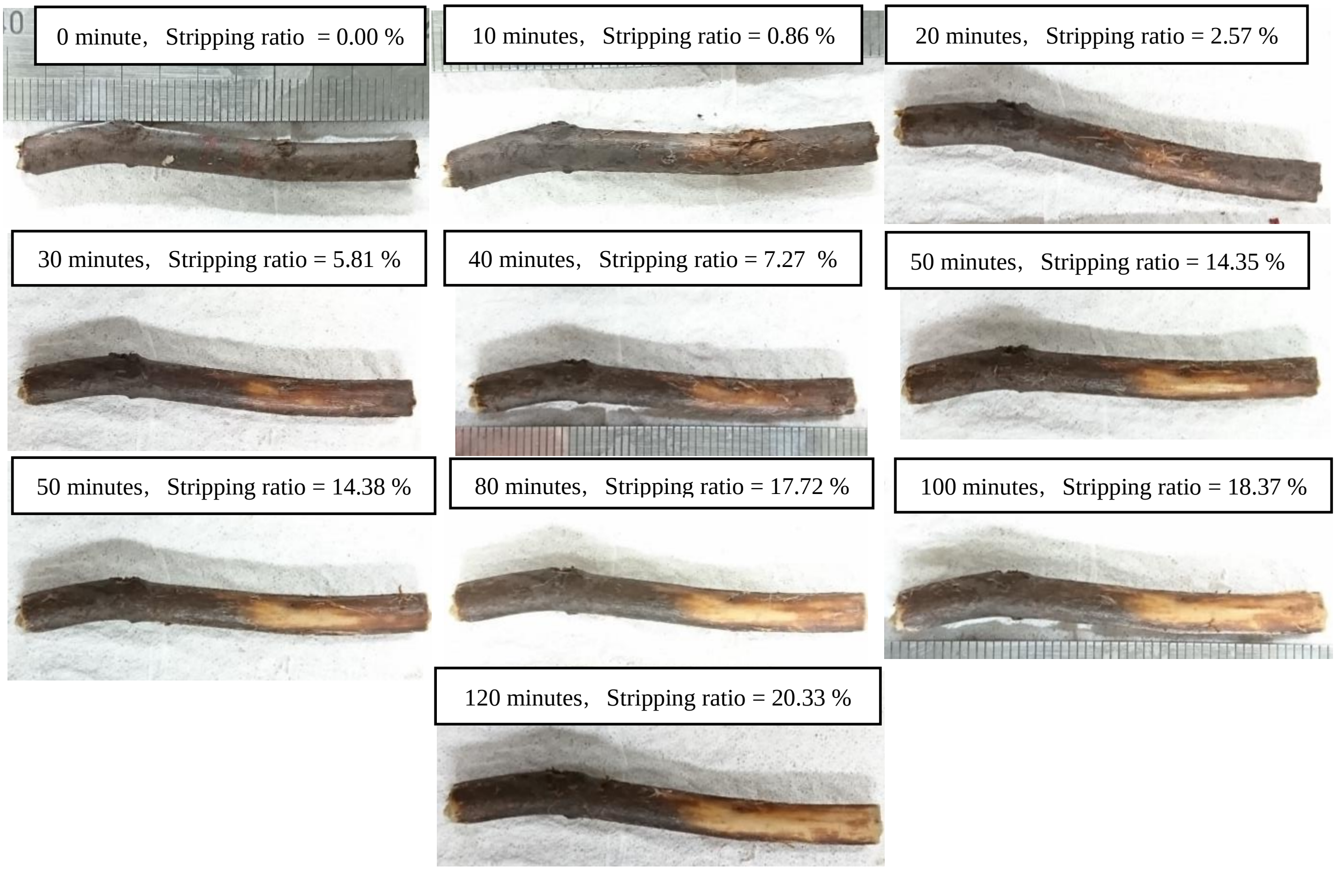

Figure 13. Process of exfoliation of driftwood.

As a result, it was not broken or cracked but was worn away on the side during 10minutes. Therefore, it was found that the side of driftwood was stripped cause of wear by touch with gravels. It could be considered a cause that side of driftwood touched with gravels to scrape. Exfoliation was not spread as circle, but it was progressed mainly in the direction of driftwood length. After having progressed to about half of the full length, exfoliation was extended slowly. By the way, this driftwood was stripped only one place, that is, this driftwood was not peeled off at another.
Observation on all driftwoods about surface were conducted. It was found that everything was not be broken or crack but were worn away in the side, same as driftwood in Figure 11. Furthermore, exfoliations were extended in length direction around the stripped place firstly. These were not peeled off like a circle, this is, circumferential direction. Almost all of driftwoods were stripped only one place. On the other hand, driftwoods which were not seemed to be peeled off at all were discovered that exfoliation was progressed little by little from section part by using image analysis.

6. CONCLUSIONS

In this study, the way and process of exfoliation from driftwood were observed and considered using flat rotating channel. As a result, the following results were obtained.

1) Driftwoods have not been stripped by crashing wall, bottom and driftwoods, when driftwoods were flowed in fresh water.
2) Most of driftwoods which exfoliation progress greatly were wore 10 to 50 or 60minutes mainly, and the way of progress was varied. The reason of this, it was considered that individual difference of the driftwood influence mainly.
3) Driftwoods progressing exfoliation greatly were stripped at the side mainly and tendency stripping from the plural places could not be seen.
4) It was revealed that exfoliation was occurred slightly from section by performing image analysis in the driftwood which exfoliation could not be seen by visual observation.

Further studies are needed in order to investigate influence changing the number of driftwoods, grain size of sediments and the other experimental condition.

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