DYNAMICS OF TSUNAMI DRIFTED WOOD DEBRIS UPON COLLISION WITH FINITE LENGTH FOREST – A FLUME EXPERIMENT

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1. INTRODUCTION

Tsunami is one of the most vulnerable natural hazards in the world. It causes a huge amount of both tangible and intangible damage, including loss of life, destruction of property and goods, economic instability and demolition of the social environment. The tsunami caused by the Great East Japan Earthquake on 11 March 2011 shattered most of the coastal forest thus producing large amount of drift wood. This tsunami drifted debris has the potential to collide with buildings causing secondary damage to them, even at times igniting fire. So, there is dire need to limit this debris, both effectively and economically. The aim of this research is to deeply investigate the complex flow structure of finite length forest upon its collision with wood debris considering (1) patterns of debris accumulation, and (2) density of forest.

2. EXPERIMENTAL PROCEDURE

Fig. 1 shows the experimental water flume setup. The laboratory experiments for 6 different cases (Table 1) were conducted in water flume (constant bed slope 1/2400) that is 5m in length, 0.7m in width and 0.5m in height at Saitama University. The water depth opted in the experiment was 2.5cm, 3.5cm and 4.5cm setting Froude number equal to 0.63,0.68 and 0.70 respectively. The rectangular shaped forest model was mounted on the water flume bed at 2.7m from the upstream inlet and in the middle of the width of the stream. The width of coastal forest in x and y direction is selected in such a way that it results in forest's aspect ratio equal to 1.65. The density of coastal forest is chosen considering the forest characteristics of investigated sites (Tanaka et al., 2013). The driftwood model used in this study has a specific gravity of 0.7-0.8, thus it was inundated before the experiment and arranged to be 0.83-1.05 (about the specific gravity of raw wood).The driftwood motion was recorded in a video system and the location in plan and section was investigated by video analysis.

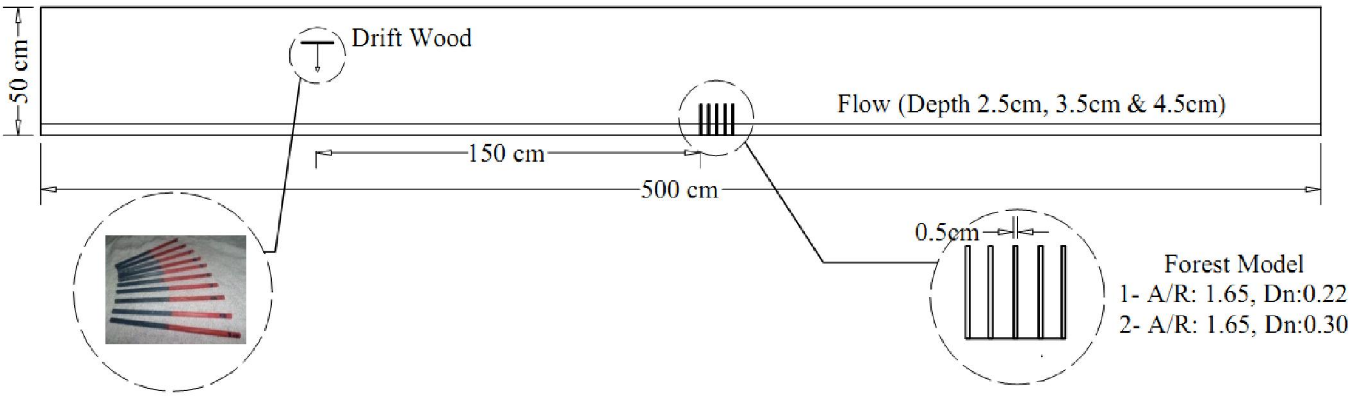

Fig 1: Experimental set-up for investigation of debris collision with the forest

Table1: Experimental Conditions

Case No.	Froude Number	Forest Size (cm)	Aspect Ratio (A/R)	Density of Forest (Dn)	Size of Driftwood (cm)	No. of Specimens tested	No. of Specimens observed as Pattern 'c'
1	0.70	16 x 9.7	1.65	0.22	12.5x0.5	50	45
2	0.68	16 x 9.7	1.65	0.22	12.5x0.5	66	56
3	0.63	16 x 9.7	1.65	0.22	12.5x0.5	55	45
4	0.70	13 x 7.9	1.65	0.30	12.5x0.5	54	46
5	0.68	13 x 7.9	1.65	0.30	12.5x0.5	58	44
6	0.63	13 x 7.9	1.65	0.30	12.5x0.5	62	58

3. RESULTS AND DISCUSSIONS

3.1 Patterns of debris deposition

Tsunami drifted wood debris is likely to be deposited where it hits the obstruction i.e forest. The set of debris were made to float with its longitudinal axis perpendicular to flow. Several deposition patterns were observed depending on the

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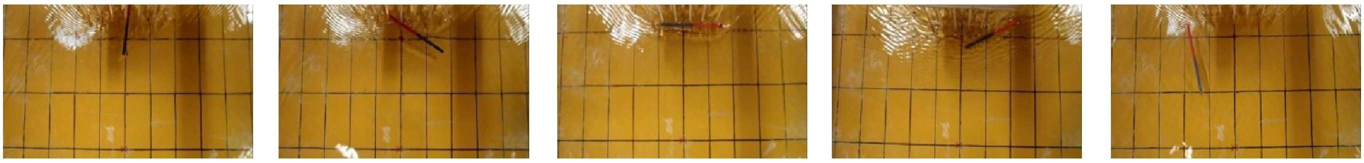
collision angle and position of release. Five different patterns were mostly identified in the current experimental study as shown in Fig 2. However pattern 'c' in Fig 2 is the most critical as it poses immense overturning force on the trees. The critical bending moment for knocked over trees greatly depends upon the height of attached debris from the ground surface; greater the height greater will be the bending moment. Therefore, inland forest designed to trap tsunami drifted debris must catch maximum debris at the foot of trees.



(a) (b) (c) (d) (e)

Fig 2: Patterns of debris interaction with forest (a) Passed between trees, (b) Trapped between trees, (c) Held parallel to the front line of trees, (d) Pivoted with outer tree, (e) Passed beyond forest after hitting outer trees.

3.2 Effect of Density of forest on debris accumulation

Fig.3 clarifies the relationship between forest density and height ratio (h_d/h_0) which is the ratio of debris accumulation height to water depth. The trend lines are plotted by taking the mean values of height ratio for the three groups of specific gravity. When the spacing between trees is increased i.e. forest density is decreased, the height ratio becomes large due to easily passage of tsunami flow through the inside of forest. For nearly the same aspect ratio, the overall trend shows that by increasing the forest density the height ratio is decreased. However, due to complexity of behavior, the trend is not similar for all three groups of specific gravity and Froude number (Fr), a ratio of inertial and gravitational forces. It is, however, more prominent for higher value of Froude number. Table 2 shows the percentage of debris which falls below half of the depth of water after collision. It can be elucidated from the current results that for high Froude number flow, dense forest is recommended for the debris to accumulate at the foot of trees.

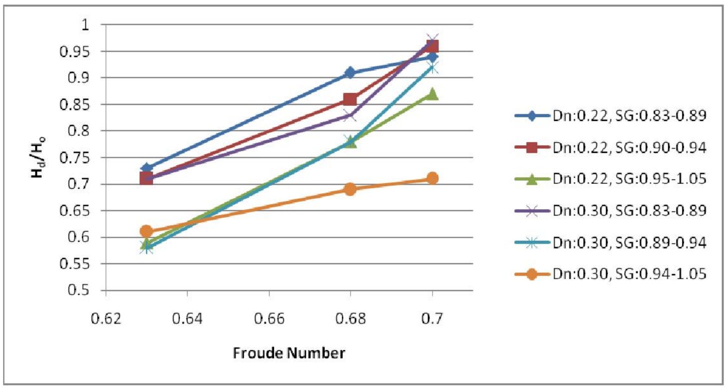


Table 2: Debris falling more than 50% of water depth with Aspect Ratio 1.65

Forest Density	Fr. No.	SG:0.83-0.89	SG:0.90-0.94	SG:0.95-1.05
Dn:0.22	0.70	0%	0%	13%
	0.68	4%	7%	23%
	0.63	36%	43%	69%
Dn:0.30	0.70	0%	11%	35%
	0.68	18%	35%	46%
	0.63	38%	64%	50%

Fig 3: Ratio of debris accumulation to water depth against different forest densities

4. CONCLUSIONS

Laboratory experiments were carried out to investigate patterns of debris accumulation and density on a limited length inland forest to trap debris. The results of this study can be summarized as follows:

(1) Five major patterns of debris accumulation were identified in the present study. The debris attaching perpendicular to the stream flow and parallel to the front line of trees is the most critical because it exerts enormous overturning pressure on the trees.
(2) While keeping the aspect ratio constant and increasing the density of forest, the amount of debris falling below half of the water depth increases and is seen to be effected by Froude number. Higher Froude number yield clear results while with decreased Froude number mix behavior is seen with varying densities.

More experimental study is required for high Froude number flow in order further investigate the phenomena.

5. ACKNOWLEDGMENTS

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6. REFERENCE

Tanaka N., Yagisawa J. and Yasuda S., 2013. Breaking pattern and critical breaking condition of Japanese pine trees on coastal sand dunes in huge tsunami caused by Great East Japan Earthquake, Natural Hazards, 65, 423–442.