Experimental Study of the Use of Stakes to Prevent Driftwood and Natural Debris from Blocking Bridges

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INTRODUCTION

Areas downstream of downpours and floods are often damaged by debris flow and driftwood. The depletion of mountain forests leads to landslides during local downpours, which are induced by global warming; these landslides subsequently cause damage. Recent reports of disasters in Japan showed that bridges can become blocked by driftwood, damaging the bridges and contributing to flooding of surrounding areas. Historically, Japanese bridges have been protected from blockages by stakes that control the flow of driftwood. These stakes have been installed, for example, at the Togetsu Bridge and the Uji Bridge at the Ise Shrine, as shown in **Photo 1**. The stakes also prevent the bridges from becoming blocked by other types of natural debris. Previous studies have described how these stakes function during floods. There are many bridges with narrow intervals between their piers, and we need to prevent the accumulation of driftwood and natural debris at these bridges. Traditional stakes are an effective countermeasure against blockages by debris. However, there are no established design codes relating to the optimal placement of stakes for blockage prevention. Thus, there are different stake configurations at different bridges. For example, stakes were installed at alternating piers of the Togetsu Bridge, as shown in **Photo 1**; whereas at the Uji Bridge, which is also shown in **Photo 1**, stakes were installed at each pier. Furthermore, no studies have been conducted to compare the blockage prevention performance of the different stake configurations, or how their gradient, with respect to the riverbed, affects the accumulation of debris. We conducted a laboratory-based experiment to observe the effects of stakes on the flow of driftwood along rivers. Based on our experimental results, we propose effective stake installation guidelines for the prevention of blockages.

Photo 1 Traditional Japanese technique to protect historical bridges using stakes
(right: Togetsu Bridge, Arashi-yama, Kyoto; left: Uji Bridge, at the Ise shrine, Mie).

EXPERIMENT

We supplied water and driftwood from a waterway flume using the setup shown in **Fig. 1,** and observed the fundamental mechanisms by which stakes prevent driftwood damage. We varied a range of conditions, including the water discharge, driftwood length and diameter, inclination of the stakes relative to the riverbed, and the configuration of the stakes, as shown in **Fig. 2,** to determine the effect of these different parameters on the accumulation of driftwood. Our selection of experimental conditions was informed by a previous study (Ishikawa et al., 1989). We found that driftwood passed between the piers after rotating around the stake, as shown in **Fig. 3**. **Fig. 4** shows the non-capture rate f_{wn}^* obtained using each stake configuration shown in **Fig. 2.** The stakes are configured in a houndstooth arrangement (Type B), proposed in this study. We also investigated the effect of the stake installation interval L_3 (see **Fig. 1**) on the non-capture rate and found that L_3 should be large enough for the driftwood to rotate around the stakes. We determined that L_3 should be 1.5 times larger than the bridge-pier interval, L_2. Having identified the optimal countermeasures for preventing the accumulation of driftwood, we then assessed the efficacy of these countermeasures against other types of natural debris. According to the results of this investigation, the best way to protect bridges is to install stakes vertically, thus diverting both driftwood and natural debris.

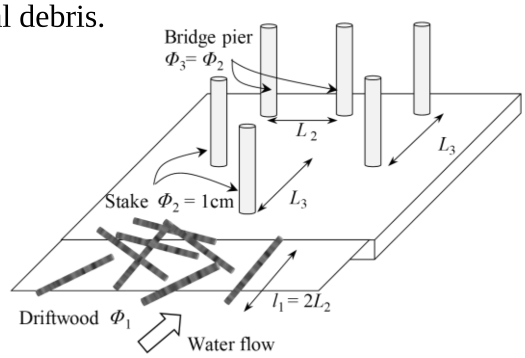

Fig. 1 Schematic diagram of the experimental setup

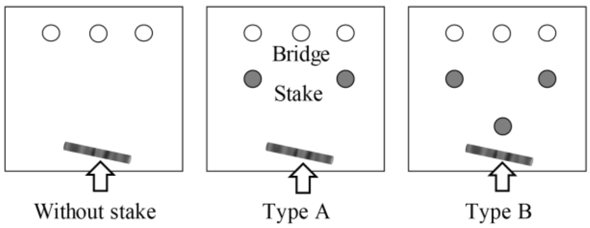

Fig. 2 Stake configurations tested in this study

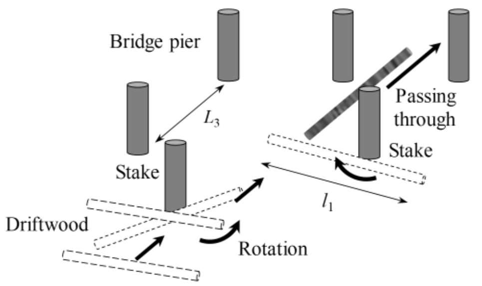

Fig. 3 Driftwood build-up prevention mechanisms

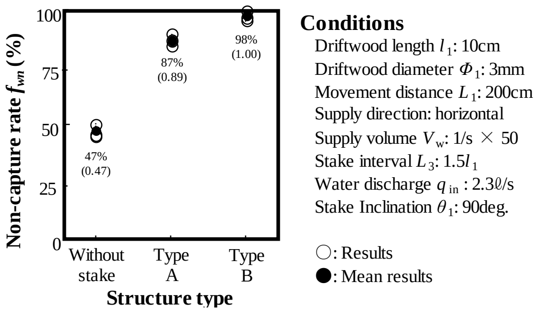

Fig. 4 Effect of stake type on the non-capture rate*

* f_{wn} = number of driftwood pieces passed through bridges V_{wout} / number of pieces of driftwood supplied V_w.

CONCLUSIONS

The driftwood rotates around the stakes, then passes between the bridge piers. The driftwood accumulation prevention performance was affected by the water flow speed, density of the driftwood, inclination of the stakes with respect to the riverbed, and the stake installation interval. We proposed a new houndstooth stake configuration. This acts as an effective countermeasure against blockages by driftwood.

Keywords: Bridge, driftwood, experiment, stake, natural debris