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# TSUNAMI RUNUP ATTENUATION BY ONSHORE OBSTACLES

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## 1 INTRODUCTION

In a time of climate emergency due to global warming, nature-based coastal defence systems are attractive solutions for flood mitigation and adaptation. Coastal forests such as mangroves have received a growing interest for their disaster mitigation effectiveness such as water flow energy dissipation, hence helping communities to become more resilient (Iimura & Tanaka, 2012). The role of coastal forests as a defence measure was highlighted in the aftermath of the 2004 Indian Ocean Tsunami, which claimed the lives of more than 200,000 people and displaced millions more across fourteen countries. Post-disaster damage observations indicated that forests, particularly mangroves, reduced the impact of the tsunami wave in some locations. As a result, significant international relief and reconstruction efforts focused on extensive forest replantation of coastlines (Satake, 2014).

The role of coastal vegetation in reducing the severity of tsunami waves has been studied since. Several studies using physical modelling and computational approaches have provided insights into the wave attenuation provided by coastal vegetation, in terms of relationships between incident hydrodynamic conditions, forest configurations and wave height decay. However, there are still many gaps in knowledge, particularly in quantifying the efficacy of coastal forests in reducing inland hydrodynamic conditions (Tomiczek et al., 2020). It is therefore essential to improve the understanding on how wave heights, velocities and runup are influenced by the characteristics of the “obstacles”, e.g. the forest density, as well as the incident hydrodynamic conditions, e.g. the wave period. This study aims to address these questions conducting physical experiments using the novel pneumatic Tsunami Simulator (TS) developed by HR Wallingford together with UCL (Rossetto et al., 2011).

## 2 EXPERIMENTAL SET-UP

The experiments are performed at a scale of 1:50 using a forest model that is made of wooden obstacles and integrated into a bathymetry made of plywood. Froude scaled tsunami waveforms are generated with periods $T$ in the range of 40 – 230 s and wave amplitudes $a$ between 0.03 - 0.14 m. The waves propagate in a flume 100 m long and 1.8 m wide, with a 1:30 sloping bathymetry that extends onshore over which their runup is recorded. Onshore obstacles are represented by circular cylinders (wooden dowels), with varying diameter $D$ (5, 8 and 10 mm) and inland extension from the still water line (1.33–2 m), as shown in Figure 1. Particularly, tests involved three different obstacle configurations: (a) $D$ = 10 mm, extension = 2 m; (b) $D$ = 8 mm, extension = 2 m; (c) $D$ = 5 mm, extension =1.33 m.

## 3 RESULTS AND PRELIMINARY CONCLUSIONS

Figure 2 shows the $R/a^+$plot for all waves, where $R$ is the run-up height based on the run-up length recorded in the experiments and $a^+$ is the positive wave amplitude. For the latter, data recorded by the long wave gauge located 7.3 m away from the bathymetry toe were used, to minimise the reflection effect observed at the bathymetry toe.

**Figure 1. General arrangement of the experimental set-up (left) and incident wave (right).**

Results show that relative to a smooth slope, these configurations can reduce normalised runup $R/a^+$ by 20% for $T < 100$ s. For $T > 100$ s, $R/a^+$ tends to unity and shows less appreciable reduction compared to the smooth slope. For certain combinations of obstacle geometry and $T$, a small increase in $R/a^+$ is observed.

The long-term aim of this research is to better understand the physical processes associated with the interaction of tsunamis with coastal vegetation, developing a bespoke engineering framework to inform the degree of protection of coastal forests against tsunami, both in terms of tsunami inundation and evacuation time.

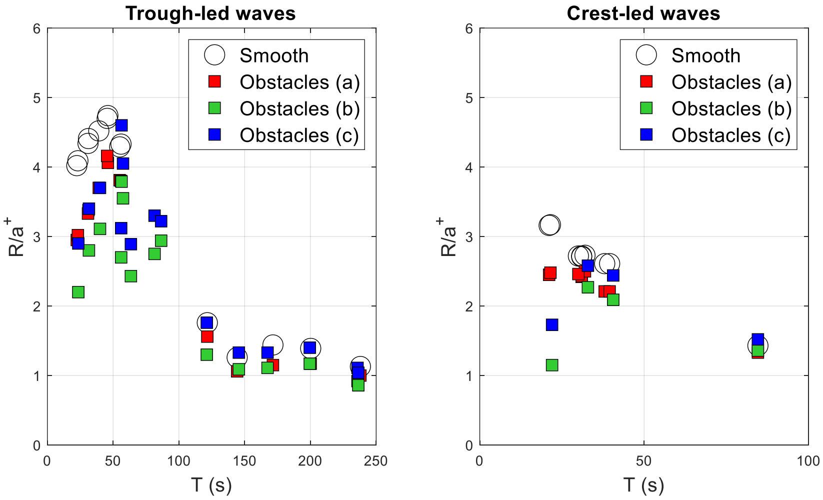

**Figure 2. $R/a^+$ as a function of $T$ for trough-led waves (left) and crest-led waves (right).**

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## REFERENCES

Imura, K., & Tanaka, N. (2012). Numerical simulation estimating effects of tree density distribution in coastal forest on tsunami mitigation. *Ocean Engineering*, *54*, 223–232. https://doi.org/10.1016/j.oceaneng.2012.07.025

McGovern, D. J., Robinson, T., Chandler, I. D., Allsop, W., & Rossetto, T. (2018). Pneumatic long-wave generation of tsunami-length waveforms and their runup. Coastal Engineering, 138, 80–97. https://doi.org/10.1016/j.coastaleng.2018.04.006

Mukherjee, A., Cajas, J. C., Houzeaux, G., Lehmkuhl, O., Suckale, J., & Marras, S. (2023). Forest density is more effective than tree rigidity at reducing the onshore energy flux of tsunamis. *Coastal Engineering*, 182, 104286. https://doi.org/10.1016/j.coastaleng.2023.104286

Rossetto, T., Allsop, W., Charvet, I., & Robinson, D. I. (2011). Physical modelling of tsunami using a new pneumatic wave generator. Coastal Engineering, 58(6), 517–527. https://doi.org/10.1016/j.coastaleng.2011.01.012

Satake, K., 2014. Advances in earthquake and tsunami sciences and disaster risk reduction since the 2004 Indian ocean tsunami. Geoscience Letters, 1(1), pp.1-13.

Tomiczek, T., Wargula, A., Lomónaco, P., Goodwin, S., Cox, D., Kennedy, A., & Lynett, P. (2020). Physical model investigation of mid-scale mangrove effects on flow hydrodynamics and pressures and loads in the built environment. Coastal Engineering, 162, 103791. https://doi.org/10.1016/j.coastaleng.2020.103791