An Experimental Study of Solitary Waves through Layered Coastal Vegetation

Shawn Y. Sim¹, Yao Yao², Zhenhua Huang¹,²*, Ka Sim Lee² and Joann Y. R. Chan²

¹Earth Observatory of Singapore, Nanyang Technological University, Singapore, Singapore
²School of Civil and Environmental Engineering, Nanyang Technological University, Singapore, Singapore

ABSTRACT

In this paper the effects of layered coastal vegetation on long wave (solitary wave) propagation were investigated experimentally in a long wave flume. This layering vegetation is represented by an open gap in a patch of vegetation that lies perpendicular to the flow direction. Solitary waves with different heights were used to simulate the leading tsunami waves. Results on the wave transmission, reflected waves, and waves within the gap in a patch of vegetation are discussed.

KEY WORDS: Coastal vegetation; tsunami mitigation; wave scattering; shore protection; solitary wave.

INTRODUCTION

The 2004 Indian Ocean tsunami made the world realize the devastating potential of tsunamis. With a death toll of more than 200,000; it is considered one of the most serious catastrophes in the present day. As a result, there is a necessity to find means to mitigate the impacts of tsunamis.

One viable way to attenuate tsunami wave is through turbulence generated by trees in mangrove forests. Danielsen et al. (2005) pointed out that the presence of mangroves along Cuddalore, Tamil Nadu, India shielded several villages from the 2004 tsunami. However, the unshielded villages were not so fortunate. They were either badly damaged or completely destroyed. Dahdouh-Guebas et al. (2005) also noted that besides mangroves, other coastal vegetation types such as salt marshes and vegetated sand dunes also serve a similar purpose. These natural coastal structures provide a form of additional roughness that affects both the transmitted surface elevation and velocities (Struve et al., 2003). Although there are still doubts on the effectiveness of mangroves (Overdorf and Unmacht, 2005), there is still a general consensus that mangroves do play a part in reducing tsunami impacts. However, this does not pertain to the specific mechanisms that they play. The variation in mangrove settings is one area that can be looked into (Dahdouh-Guebas and Koedam, 2006). Few research groups have already conducted several experiments and numerical simulations to investigate the effects of mangrove settings by having a streamwise gap in a mangrove model (Naot et al., 1997, Nepf et al., 1997, Struve et al., 2003). Thuy et al. (2009), conducted more research on this topic by producing numerical simulations on run-up that include several cases of open gaps within the mangrove forest. These include two cases with parallel gaps between the mangrove model. These gaps may represent roads or pathways parallel to the shore. However, little has been done to experimentally investigate the effects of a tsunami based on such settings. Moreover, such experimental investigation could extend to that of coastal cities where other than the shape difference between the mangrove trees and buildings, could lead to a preliminary representation of the buildings and help us to understand the flow patterns within.

In this paper, the experimental results of solitary wave propagation in a patch of vegetation with different open gaps perpendicular to the flow direction are presented. Due to the fact that tsunamis are long waves with periods in the order of half-hour (Munk, 1951), solitary waves were used to model the leading tsunami waves. This is because solitary waves can appropriately model some important aspects of the coastal effects of tsunamis well (Synolakis, 1987). In this paper only variations in the surface elevation is recorded under different test conditions.

MANGROVE MODEL STRUCTURE

In the experiments, two mangrove with different arrangements of cylinders, named Model A and Model B were used. Model A has a staggered arrangement whereas Model B has a regular arrangement. Both of them are made of Perspex. Mangrove trees were represented by tubes with 1 cm outer diameter and fixed to a bottom plate (Fig. 1). Model A and Model B have porosity of 0.825 (Fig. 2) and 0.913 (Fig. 3), respectively.

Figure 1 Mangrove Model B