WAVE ATTENUATION IN MANGROVE FORESTS: AN INVESTIGATION THROUGH FIELD AND THEORETICAL STUDIES

Thesis submitted by
Richard Michael Brinkman BSc (Hons) *Flinders University*
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James Cook University

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Richard Brinkman
October, 2006

1 ABSTRACT

Mangroves are woody forests that exist at the confluence of the marine and terrestrial environments. These forests are highly biologically productive and play a key role in supporting coastal food chains, and trapping and stabilizing coastal sediments. Mangroves are also known to dissipate significant amounts of wave energy over relatively short distance, which has significance in the area of coastal protection. However, understanding the quantitative effects of mangrove vegetation in reducing surface wave energy has, until now, received very limited research interest. This study presents a field and theoretical investigation of the attenuation of random, wind–induced surface wave energy in mangrove forests. Field observations of wave processes in mangrove forests were undertaken at three study sites with different wave energy regimes. At each site, an array of wave gauges was placed along a transect aligned with the dominant wave direction to measure changes in wave characteristics as waves propagated shoreward through the mangroves. Mean rates of attenuation of total wave energy and significant wave height observed at the three sites averaged 1.5% m^{-1}, and 1.1 % m^{-1} respectively. Attenuation rates are found to be frequency related, with preferred attenuation of shorter period waves. Field data also indicate an increase in the energy transmitted into the forest with increased water depth.

Two theoretical approaches were developed to investigate and model the attenuation of wave energy for waves propagating through mangrove forests: In the first theoretical approach, the water depth in the mangrove forest was assumed constant, and the wave motion was described by a set of amplification factors for individual spectral components. The second approach was developed for a mangrove forest with arbitrary bathymetry, and in this case the wave motion within the forest was determined by solving the mild slope equation with dissipation. Both approaches investigate energy dissipation in the frequency domain by treating the mangrove forest as a random media porous to wave energy, with certain characteristics determined using the geometry of mangrove vegetation. Also, both cases employ modified drag co-efficient to introduce the dependence of the drag coefficient on the spatial density of the vegetation.

Theoretical results from the model with constant water depth show good qualitative agreement with the key wave propagation features identified in the field data, with predicted rates of wave energy attenuation controlled primarily by prescribed vegetation characteristics. Results from the model with arbitrary bathymetry demonstrate that the model was able to reproduce observed rates of wave energy attenuation. Wave energy attenuation was shown to depend strongly on the spatial density of the mangrove vegetation and its structural arrangements, and on the spectral characteristics of the incident waves. Wave energy attenuation was also found to be a function of water depth, with increased energy transmitted into the forest with increased water depth, due to the non-uniform vertical structure typical of mangrove vegetation.

The results of this study demonstrate that it is possible to numerically model the dominant energy dissipation processes and thus predict attenuation of surface wave height within mangrove forests. The ability to predict the attenuation of surface wave energy due mangroves has relevance in the field of costal protection. A model developed in this thesis is applied to assess the theoretical performance of a temporary coastal protection measure using bamboo, and evaluate its cost effectiveness compared to other accepted low-cost measures for attenuating wave energy. The proposed design of a bamboo wave attenuation structure is significantly cheaper than other published designs, for an equivalent level of energy attenuation.

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Declaration

I declare that this thesis is my own work and has not been submitted in any form for another degree or diploma at any university or other institution of tertiary education. Information derived from the published or unpublished work of others has been acknowledged in the text and a list of references is given.

Richard Brinkman
October, 2006