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Thesis Outline

Mangroves are well-known as a natural coastal barrier. In the past, mangrove forests saved many human settlements from storm surges, tsunamis, and high waves. In addition, mangroves act as huge carbon sinks and are a vital part of the coastal and marine ecosystem. Mangrove restorations have been implemented in many countries, but the success rate was low. It often fails during the initial stage of plantation due to various counter-environmental impacts. In particular, high waves can cause the failure of young seedlings. Our field study revealed that mangroves are particularly vulnerable in the early stage of their growth (few months old), while half-year or older plants can withstand moderate waves sufficiently. The mangrove growth test was conducted at the field site and suggested that direct planting of seedlings at the restoration site was preferable compared to nursery plantings. A manual wave generating test was conducted at the site and showed that mangroves about one month old subjected to a wave height of 10 cm were bent and submerged in water. On the contrary, mangroves older than a half year were undamaged by similar wave action. As a result, a portable reef was proposed to act as an effective wave attenuator to facilitate the growth of young mangrove seedlings. However, after six months of growth, mangrove plants become resistant to normal wave conditions; thus, the service period of the portable reef system can be set as short as six months.

The water and wave parameters were derived from the field study and implemented in the analytical design of the portable reef. A portable reef was designed using the conventional design expressions of rubble-mound breakwaters. The cross section of the portable reef was calculated by applying the existing formulas considering the local tidal and wave conditions. The wave dissipating performance of the reef was also examined by the CFD model using olaFlow/OpenFOAM, followed by its validation. Numerical analysis was performed on four different shaped mounds with a cross-sectional area of approximately 1 m2 to investigate wave transmission. Wave dissipation efficiency was found to be high, with more than 50% in all geometrical mounds. Although the present structure has a small cross-sectional shape compared to conventional breakwater, there is a clear consistency in terms of wave transmission ratios. Therefore, it can be expected that a portable rubble-mound reef will sufficiently reduce wave energy before reaching mangrove plants.

When studying the portable reef, it is important to focus on the changes in the characteristics of both the wave periods and wave heights. The portable reef should be small enough to be installed by the local community itself. Thus, experiments using a large wave flume were conducted to investigate the performance of portable reefs. A series of experiments were carried out to verify the wave dissipating effect and wave characteristics of a real-scale reef. Portable reefs were tested for wave height reduction and variations in the characteristics of the wave periods. Overtopping waves gave rise to short-period waves behind structure and expected to increase the oscillations of young mangroves. Low-crest reefs are likely to cause mangrove oscillations due to the turbulence generated behind the reef, especially where tidal levels are high and overtopping is significant. Experiments with different water depths suggested that overtopping waves can be avoided if the crest of the portable reef is sufficiently high. Factors such as the range of tidal levels, characteristics of wave periods, and permeability of the structure should be considered in its design and placement, which effectively prevents the loss of young mangroves due to wave forces.

Studies on the oscillatory characteristics of a young mangrove using an elastic model were demonstrated in a small-scale experiment. A young mangrove model made of flexible olefin resin was tested with a small wave flume placed behind porous and nonporous reefs, and its oscillation was precisely measured with a high-speed camera. The experiments produced several new findings. At the higher water depth, overtopping of waves resulted in short-period waves behind the reef causing resonant oscillations in response to the natural oscillation of the mangrove model. Higher plant oscillations appeared to adversely affect the mangrove plant. Both the permeable and impermeable block structures exhibited good performance in reducing the oscillation of young mangroves. Impermeable block structures are also advantageous for reducing the oscillation of young mangroves but are not always recommended as they are heavy and difficult to carry around, can inhibit seawater exchange, and block sediment inflow. Therefore, we recommend a permeable structure of small stones or blocks for portable reefs. The optimal shape should be designed based on reliable data on local wave conditions, tidal range, and topography to avoid strong turbulence and short-period waves behind the reef, which would effectively prevent the loss of young mangroves due to waves.