Form 2

Dissertation Abstract

Report no.	(Course-based) No.1146	Name	A H M Rashedunnabi
Dissertation title	Experimental study on energy reduction of a tsunami current through a hybrid defense system comprising a sea embankment followed by a coastal forest (海岸堤防と海岸林から構成されるハイブリッド防御システムによる津波のエネルギー減衰に関する研究)		

Abstract

※ The abstract should be in keeping with the structure of the dissertation (objective, statement of problem, investigation, conclusion) and should convey the substance of the dissertation

The objective of this study is to investigate the effects of a hybrid defense (combination of a seaward embankment and a landward coastal forest) system on reducing the energy of a tsunami current. Different types of double-layer forests in vertical and horizontal directions were considered for enhancing the mitigation effect of a coastal forest in the hybrid tsunami countermeasure.

Vegetation can act as a bio-shield in disastrous events like tsunamis or storm surges. The effects of a single layer of emergent vegetation against tsunamis have been revealed by extensive research, while the role of a double layer of vegetation (short submerged vegetation coupled with tall emergent vegetation) is still not clearly understood. In this study, vertically double-layer rigid vegetation was selected for increasing the mitigation effect of a tall vegetation. Flume experiments were conducted to investigate the flow structure and energy reduction mechanism of the vegetation models against a high inundating tsunami current (above 5 m in a real scale). It was observed that the energy reduction is highly dependent on the porosity (density) of the short layer. The combined vegetation (double-layer) reduced a significant amount of energy by offering a large water rise in front of the vegetation, very mild water surface slope inside the vegetation, air entrainment within the water surface and creating a low-velocity zone behind the forest. The experiment showed a maximum energy reduction of 52% for the combination of a dense short layer and a sparse tall layer vegetation model.

Moreover, the mitigation by double-layer vegetation was investigated in the experimental flume channel paying special attention to the reduction of velocity and fluid force in and behind the vegetation belt. The double-layer vegetation was shown to produce a large water rise in front of the vegetation, entrain a large amount of air, and create a mixing layer within the vegetation zone. The presence of submerged vegetation and the air bubble flow behind the vegetation protect the ground behind the vegetation from a direct collision with the flowing water and helps in further reducing the velocity. The data showed that a submerged vegetation within an emergent vegetation reduced the maximum flow velocity behind the vegetation around 25%. Moreover, the maximum fluid force reduction behind the vegetation was around 23–29%, in the experimental range of Froude numbers 0.70–0.78.

The 2011 Great East Japan tsunami revealed the limit of using natural or artificial infrastructures as a single tsunami countermeasure. In recent tsunami mitigation strategy, interest in a hybrid defense system (a combination of natural and artificial infrastructures) rather than a single defense structure is growing, and a pilot project has already started in Japan. Clarification of flow structures within the hybrid defense system is necessary for designing an improved mitigation system. In addition, when a hydraulic jump is expected, its position should be restricted to a protected area for the resilience of the hybrid defense system. This study conducted flume experiments to elucidate the mitigation effect of a hybrid defense system comprising an embankment model (EM), followed by different types of single-layer emergent forest models (SLM) or vertical double-layer forest models (DLM). Different types of hydraulic jumps were observed within the defense system. Hydraulic jump position and their characteristics were shown to dominate the energy reduction downstream of SLM or DLM. Experimental results showed that the hybrid defense system reduced the flow energy to 30% and 40% of maximum for SLM and DLM, respectively, compared to only the single EM. Moreover, hydraulic jump occurring position was varying from inside the forest model to the EM toe in the combination of EM and SLM. Whereas, the position of the hydraulic jump was almost controlled near the EM in the combination of EM and DLMs.

A hybrid defense system consisting an embankment model (EM) followed by a horizontally double-layer forest model (HDLM) was also introduced in this study. The HDLM was proposed for enhancing the mitigation capability of a finite width coastal forest, which was constructed by a combination of dense short trees and sparse tall trees. To elucidate the effectiveness, a single-layer forest model (SLM) having sparse tall trees and different arrangements of HDLM (forest width is equal to the SLM) were tested coupled with an EM in an experimental flume against a supercritical flow. A real scale inundating tsunami current was replicated in the flume channel to explore the effects of the hybrid tsunami defense system. Results showed that different types of hydraulic jump were formed in the defense system and energy reduction of the overtopping flow increased by 16-65% compared to the single EM. The SLM was effective to reduce the overtopping energy in the downstream of the defense system but it was not effective to control the occurring position of the hydraulic jump and reduce the flow velocity within the defense structures. On the other hand, the hydraulic jump position was controlled within a specific area in the combination of EM and HDLMs and effectively reduced the flow velocity within the defense system as well as reducing the energy downstream.

This study revealed that; energy reduction of a tsunami current could be increased by a double layer forest. Moreover, forest destruction because of erosion could be minimized due to reducing the velocity near the ground inside and around the forest and fluid force behind it. Besides that, the double-layer forest downstream of an embankment was found to be effective to control the hydraulic jump position around the embankment as well as reducing the overflowing energy downstream. Thus, the resistance of a finite width forest could be enhanced by integrating the short and tall trees. However, the stability of a hybrid defense system against the destructive tsunami forces could be improved by a combination of a protected embankment on the seaward side and a double-layer forest on the landward side. These findings will be helpful for designing an optimum bioshield against tsunamis as well as for the resilience of the hybrid defense structures.

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