II −23 TSUNAMIS MITIGATION BY USING A GREEN BELT IN INDONESIA -CASE STUDY: PANCER BAY, EAST JAVA-

Tohoku University, Student , ○Hamzah LATIEF
Tohoku University, Member, Fumihiko IMAMURA

1. Introduction

The Pancer bay is selected for study of the inundation model to use a green belt as a coastal protector against tsunamis hazard, because this area is the most damaged area by *the 1994 East Java tsunami,* and good measured data and information are available. This tsunami claimed 136 victims in the Pancer, out of 238 people of the tsunami fatalities in this event, and around 700 houses were heavily damaged.

The Pancer bay is located in the southern part of Eat Java (see Fig. 1) which is typical narrow bay facing directly to the offshore. The mouth of bay is around 3.8 km in width. The beach is stretching around 4.5km in length and 500-700 meter in width, surroundings by hills. The material is dominated by sand with elevation of around 2.0m up to 8.0m. There is a small river behind the village, and the mouth is located at the western part. The daily activities are mostly concentrated at and near of the river mouth because of the presence of a fish market.

Najoan *et al.* (1997) and Maramai and Tinti (1997) measured the tsunami run-up by tracing clear watermarks at some trees and houses. and found the tsunami height above SWL is around 4.0m to 5.0m. The surface height of residential area is about 4.0m and about 20 lines of large trees were located behind the beach, at front of the village. The trees played an important role as natural barriers against the waves. There are three big waves as the tsunami in 1994, the second being the biggest with maximum penetration of about 300m, and up to 500m at the low land. The wave front broke around the last tree line and the wave direction is approximately normal to the beach. So in this case we can apply the mangrove model which can be placed at before breaking wave.

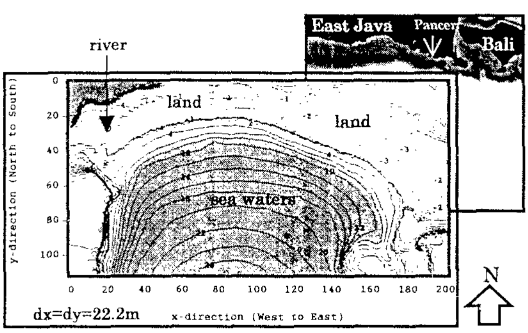

Fig.1 Location of the Pancer Bay

2. Numerical model

The shallow water theory including the effect of virtual mass (C_M) in a two-dimensional problem is used to simulate a tsunami propagation and run-up. The following momentum equation is

$$(1+C_M V_{oc})\frac{\partial M}{\partial t}+\frac{\partial}{\partial x}\left(\frac{M^2}{D}\right)+\frac{\partial}{\partial y}\left(\frac{MN}{D}\right)+gD\frac{\partial \eta}{\partial x}+\frac{gn^2}{D^{7/3}}M\sqrt{M^2+N^2}=0 \quad (1)$$

where: $V_{oc}=V_m/V_w$, V_o is the volumetric occupancy, V_m is the submerging volume of the forest, V_w is the control volume. The depth-integrated continuity and momentum equations are solved by the FDM with the staggered leap-frog scheme.

We used the value of Manning coefficient, *n,* is 0.025 at normal area without land use. However, for the flow through vegetation, we used the formulation of *n* and the impact force as function of volumetric occupancy (Latief, 2000) as follows

$$n=\begin{cases}0.16+0.17V_{oc} & if \quad V_{oc}\geq 0.07\\ 0.03 & if \quad V_{oc}< 0.07\end{cases} \quad (2)$$

$$C_M V_{oc}=\begin{cases}0.067+6.65V_{oc} & if \quad V_{oc}\geq 0.06\\ 1 & if \quad V_{oc}< 0.06\end{cases} \quad (3)$$

where $C_M V_{oc}$ is representative of the impact force and V_{oc} is the volumetric occupancy.

3. Study area and the input tsunami data

The study area is around 4.5x2.5km^2, mostly covering the bay. The number of spatial grid is 202x112 with a square mesh size is 22.2 meter and time stepping is 0.5 sec. The input tsunami data is taken from the CPX4 initial tsunami source (Latief and Imamura,1998) and storing the time series of the computed tsunamis height at the bay mouth (see Fig. 1). We found the maximum wave height is around 2 meter and the wave period is around 20 minute at the bay mouth.

4. Scenario simulations

<u>One-dimensional</u>

There are 5 cases for simulation of 1D-01 up to 1D-05 in Table 1. The case of 1D-01 is one without vegetation; 1D-02 is one with vegetation only considering the *n,* and the case of 1D-03 is the one with vegetation considering the *n* and $C_M V_{oc}$. Both model 1D-02 and 1D-03 use 16% of volumetric occupancy. We also simulate for more dense conditions as shown in models of 1D-04 and 1D-05 with the volumetric occupancy of 40% and 50% respectively (see Table 1). Simulation results of each condition are shown in Fig. 2. The vegetation is designed from the shoreline to the main road (grid 6-16) and along the river (grid 24-27). The forest with 16% of volumetric occupancy can reduce tsunami height around 22% at just behind the forest (see grid 17). The computed results of tsunami run-up are larger than the measured.

Table 1. Scenario simulations for 1D-model and their conditions

Case Model	Manning Coef.		$C_M V_{oc}$	Remarks
	Waters	Vegt.		
1D-01	0.025	0.0	0.0	without vegt.
1D-02	0.025	0.048	0.0	with vegt.(16%), n
1D-03	0.025	0.048	2.8	with vegt.(16%), n, $C_M V_{oc}$
1D-04	0.025	0.084	3.3	with vegt.(40%), n, $C_M V_{oc}$
1D-05	0.025	0.101	4.0	with vegt.(50%), n, $C_M V_{oc}$

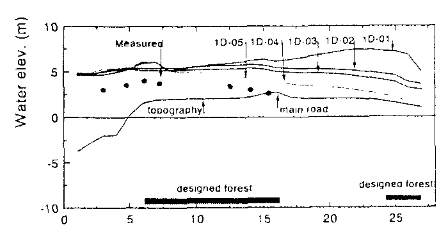

Fig.2 Comparison between computed and measured run-up (1D)

In order to match the computed result with the measured, the input of tsunami data at the open boundary should be reduced around 20% of the previous initial input. Furthermore, the revised results are shown in Fig. 3. The computed results show good agreements with the measured. In the simulation of 1D-03 (volumetric occupancy is 16%) the forest can reduce tsunami height around 43% at just behind the forest. In this case, the tsunami control vegetation could reduce tsunamis more effectively, because the incoming waves are relative small.

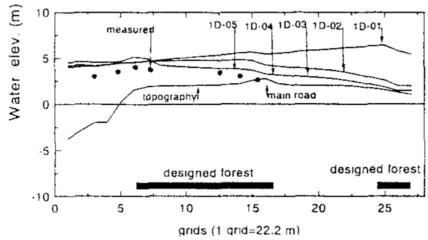

Fig.3 Comparison between computed and measured run-up (reduced 20%)

Two-dimensional

In the case of two-dimensional problem we simulated three conditions; 2D-01 up to 2D-03 in Table 2. The case of 2D-01 is one without vegetation, 2D-02 is one with vegetation but only considering the n, and the case of 2D-03 is one with vegetation considering the n and the $C_M V_{oc}$. Both model 2D-02 and 2D-03 use 16% of volumetric occupancy.

Table 2 Scenario simulations for 2D-model and their conditions

Case Model	Manning coef. Waters	Vegt.	$C_M V_{oc}$	Remarks
2D-01	0.025	0.0	0.0	without vegt.
2D-02	0.025	0.0	0.048	with vegt.(16%), n
2D-03	0.025	2.8	0.048	with vegt.(16%), n, $C_M V_{oc}$.

The simulation results of inundation area with the case 2D-01, 2D-2 and 2D-03 are shown in Fig.4. The inundation areas would be reduced due to effect of the n and $C_M V_{oc}$. This effect is remarkable at the eastern part of the study area, however, small at the western part near to the river mouth because a contribution of discharges through the river can increase the water level at the area. Figure 5 shows the sectional profile of the inundation heights of the case 2D-01, 2D-2 and 2D-03. In the 2D models, the computed tsunami heights show good agreement with the measured data. However, the effect of vegetation did not reduce tsunami significantly, because the discharge trough the river give the effect to increase the water level at behind the forest.

5. Conclusion

The one-dimensional models show that the computed run-up heights are around 20% larger then the measured one, this might be due to the different of hydrodynamics behavior in the real conditions and in the model.

The two-dimensional models show that the forest can reduce the inundation area, due to the effect of the Manning coefficient and the impact force. This effect is remarkable at the eastern part of the study area. The tsunami profile in the two-dimensional model shows that the computed results show good agreement with the measured. However the effect of vegetation reduced tsunami is unclearly, because the discharge penetrated through the river gives contribution to increase the water level at behind the forest.

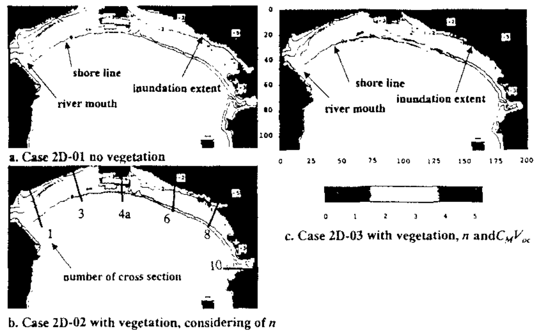

Fig.4 Maximum inundation tsunamis area in the Pancer bay

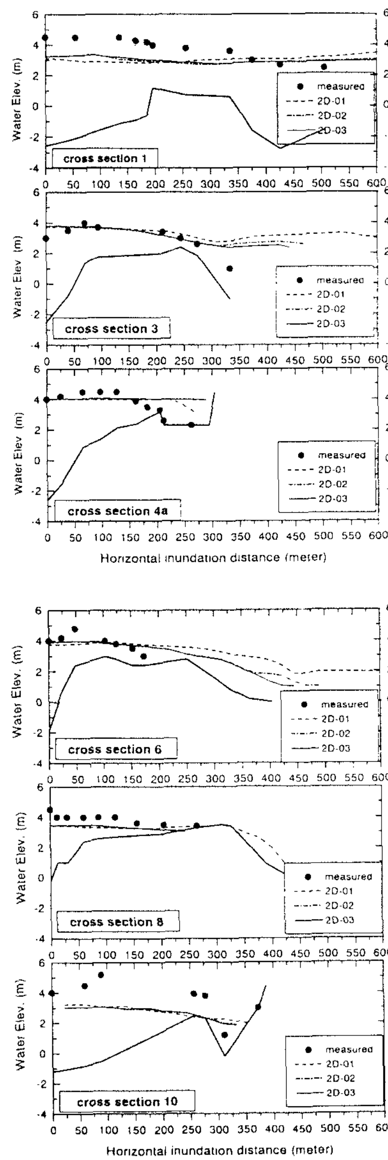

Fig.5 Comparison between computed and measured run-up (2D)

References

Latief, H and F. Imamura (1998), Proc. of 11[th] IAHR-APD, pp.385-394.

Latief, H (2000), Doctor thesis, DCRC, Graduate School of Eng., Tohoku Univ., 110p.

Maramai, A., and S. Tinti (1997) Adv. in Natural and Techn. Hazards Research, Kluwer Publs., pp. 1-20.

Najoan T.F., *et al.* (1997), Puslitbang Air, DPU Bandung, Indonesia No:20/LIT-04/1997.