Effectiveness of the unique topographic as mitigation against tsunami hazard
- A case study: Lampon and Pancer, Banyuwangi, Indonesia -

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1. Introduction

Indonesia is located between two continents, two oceans, and three ground plates: Eurasia, Indo Australian and the Pacific. Due to this geographical position, Indonesia is a country with a high risk for natural disasters, like earthquakes, tsunami waves, landslides, volcano eruptions, hurricanes and storms. Java Island is situated on the Indo-Australia plate, which makes this island abundant with beautiful undulating mountains and valleys. At the same time, this location means great volcanic and earthquake activity.

In developing countries, budgets for tsunami hazards are very limited. Therefore, topographic re-construction can be used as alternative mitigation against tsunami and other natural disaster cause of sea wave. They are cheap, easy, and useful the other hand the existing topographic condition does not provide maximum protection from tsunami. This study is based on Lampon and Pancer beach tsunami experience in Banyuwangi 1994.

The main purpose of this study is to investigate effectiveness of the unique topographic as mitigation against tsunami hazard. This study is used a two-dimensional numerical wave based on a VOF method in order to compute interaction between bore wave propagation and the unique topographic. The numerical simulation investigated here is verified by comparing the numerical results on the normal condition by several cases such as seawall, dig, dig dump, dump dig and combination all of cases. The numerical results furthermore reveal that the interaction of wave and the unique topographic caused the difference of water levels and have a strong effect on water surface elevation and water particle velocity after over top the unique topographic in several measures point.

2. Tsunami in Banyuwangi 1994

The elevation of the residential area in Pancer village is about 5 m, and the tsunami height was 9.4 m at the seaside part and 7.4 m at the main street in the central part. Thus, the wave inundated the surface with the thickness of 2-4 m. But in Lampoon village, the height of the tsunami was measured as 5.4 m in the residential area, but it also measured the tsunami with a height of 9.1 m at a point on the seaside, about 1 km east of the entrance to the village[2]. **Table 1** beside is shows ratio of human and house damage to total population and number of houses by villages in Lampon and Pancer[2]. From this table, reported that the tsunami height was 5.7-9.4 m in Pancer and around 5.4 m in Lampon. It happened because different of the surface height of the residential area (topography), early hypothesis is because of the unique topographic in front of Lampon village that can decrease height of wave in the residential area. **Fig. 1** beside show digs topography before settlement area in Lampon village.

Table 1 Ratio of human and house damage to total population and number of houses by villages

Village	Killed A	Population B	Mortality A/B	Collapsed C	Houses D	Ratio C/D	Tsunami height (m)
Lampon	40	645	6.20%	112	171	65.50%	5.4
Pancer	121	3081	3.93%	704	996	70.68%	5.7 - 9.4

Source: Tsugi et al, 1995

Fig 1 Dig topography before settlement in Lampon village

3. Analysis and result

The wave simulated by using CADMAS Surf 2D, hydraulic models are used as shown in **Fig. 2** below. The following formula are basic equation in CADMAS Surf 2D simulation, Navier-Stokes equation of wave motion for x and z direction (1), (2), and the volume rate of fluid according to VOF method (3). The governing equations consisted of the continuity equation, the momentum equation, the free surface equation (VOF), and the turbulence model[3]. Wherein t is the time; x , z are the horizontal and vertical coordinates, u , w is the horizontal and vertical velocity components; ρ is the density of fluid; p is the pressure; v is the summation of molecular kinematic viscosity and eddy kinematic viscosity; g is the gravitational acceleration; v_γ is the volume porosity; x_γ , z_γ are the surface porosity components in the x and z projections; S_F , S_u , S_w are wave generation source; D_x , D_z are the coefficient for sponge layer.

Simulation of bore wave propagation in CADMAS-Surf requires time history of wave surface elevation and wave velocity on input boundary. In this study, following analytical formula purposed by Fukui et al (in Wijatmiko) was employed to estimate the fluid velocity

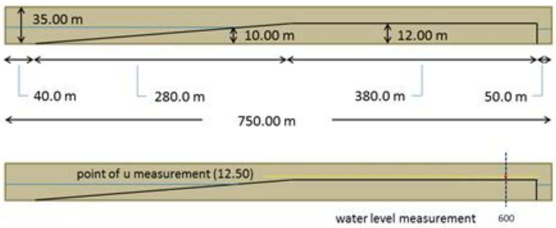

Fig. 2 Hydraulic model of simulation

$$\lambda_v \frac{\partial u}{\partial t} + \frac{\partial \lambda_x uu}{\partial x} + \frac{\partial \lambda_z wu}{\partial z} = -\frac{\gamma_v}{\rho}\frac{\partial p}{\partial x} + \frac{\partial}{\partial x}\left\{\gamma_x v_e\left(2\frac{\partial u}{\partial x}\right)\right\} + \frac{\partial}{\partial z}\left\{\gamma_z v_e\left(\frac{\partial u}{\partial z} + \frac{\partial w}{\partial x}\right)\right\} - D_x u + S_u - R_x \quad (1)$$

$$\lambda_v \frac{\partial w}{\partial t} + \frac{\partial \lambda_x uw}{\partial x} + \frac{\partial \lambda_z ww}{\partial z} = -\frac{\gamma_v}{\rho}\frac{\partial p}{\partial z} + \frac{\partial}{\partial z}\left\{\gamma_z v_e\left(2\frac{\partial w}{\partial z}\right)\right\} + \frac{\partial}{\partial x}\left\{\gamma_x v_e\left(\frac{\partial w}{\partial x} + \frac{\partial u}{\partial z}\right)\right\} - D_z w + S_w - R_z - \gamma_v g \quad (2)$$

$$\gamma_v \frac{\partial F}{\partial t} + \frac{\partial \gamma_x uF}{\partial x} + \frac{\partial \gamma_z wF}{\partial z} = S_F \quad (3)$$

from water surface on input boundary, because the water surface elevation is commonly measured in numerical simulation, experiments and fields by comparison with velocity of fluid. Where U is mean velocity, g is the acceleration of gravity, $H=h+\zeta$ the total depth from datum (**Fig. 3**), ζ the temporal bore height. η is the velocity coefficient which equal to 1.03, and was taken from the ratio of water level and wave height[3].

$$U = \frac{C\zeta}{H} = \zeta\sqrt{\frac{gH(H+h)}{2H(H+\eta\zeta)}} \quad (4)$$

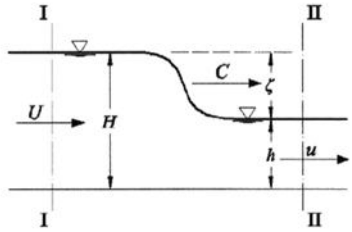

Fig. 3 Bore wave profile

In this study, the two-dimensional simulation is performed to investigate the efficiency of the unique topographic with the same wave propagation parameters; wave lengths, wave heights, period and drafts. The length of hydrodynamic model is 750.00 m, the height is 35.00 m, the wave depth is 10.0 m, the wave height is 6.0 m, the wave period 80.0 second and the wave function is matrix data table to generate bore wave propagation.

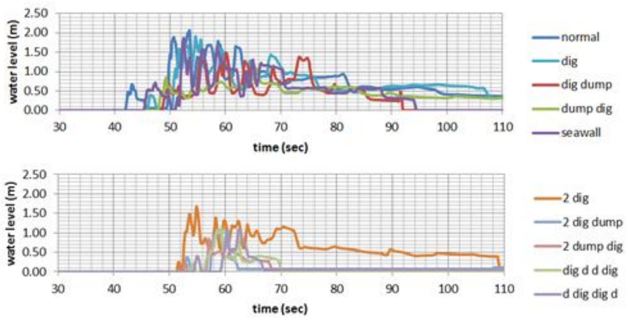

Fig. 4 water height on 600 m

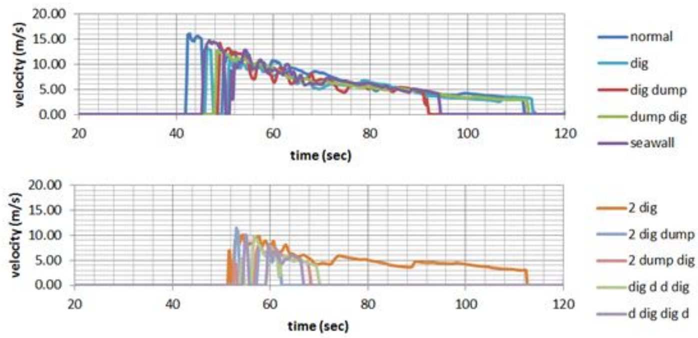

Fig. 5 velocity on 600 m

The profile and wave height of all cases just after transformation on 600 m are shown in **Fig. 4**. Velocities of all cases after transformation on 600 m are shown in **Fig. 5.** At this step (600 m), the wave profile in measured point has different wave height. Slightly smaller wave height is obtained in the case of double dig dump combination with decreased measurement value. This effect is related to the obstacle of the unique topography. Smaller velocity is obtained in the case of dig dump combination, velocity in this step was decreased significantly if compare with sea wall and normal case.

Fig. 6 shows dig dump topographic after hit by wave, several waves back and turbulence in dig area, other wave propagation are over topping of dump area. Phenomena in the 'dump dig dig dump' case are wave propagation reduced in first 'dump dig' topography and partial wave are trapped by second 'dig dump'. The other side, over top of wave thought the 'dig dump' topography only small part of water and decreased significantly if compare with other case. (**Fig. 7**)

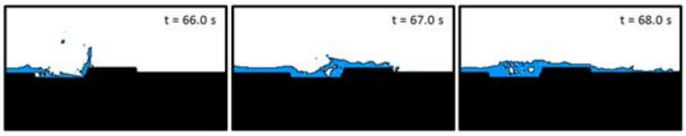

Fig. 6 dig dump topographic hit by wave

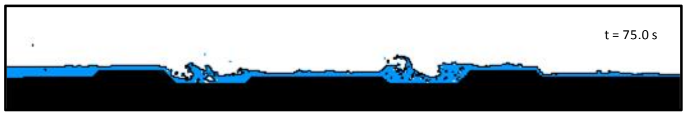

Fig. 7 water trapped by 2nd dig dump topography

The following table shows the comparison between each case from measurement of simulation result. According to this result as shown on **table 2**, wave height and velocity after hit the obstacle in case of 'dump dig dig dump' have significant result if compare with normal case. Wave height was decrease from 2.10 m to 0.40 m (1.70 m) and velocity was decrease from 13.50 m/s to 6.15 m/s (7.35 m/s).

Table 2 comparison of wave height and velocity

No	CASES	water height			velocity		
		325	550	600	325	550	600
1	normal	3.30	2.30	2.10	15.00	14.00	13.50
2	dig	3.30	2.10	1.90	15.00	12.50	11.50
3	dig dump	3.30	1.60	1.30	15.00	10.50	10.00
4	dump dig	3.30	1.55	1.10	15.00	10.00	10.00
5	seawall	3.30	1.80	1.45	15.00	12.00	11.75
6	2 dig	3.30	1.55	1.20	15.00	9.25	8.25
7	2 dig dump	3.30	0.90	0.65	15.00	9.00	8.05
8	2 dump dig	3.30	0.80	0.55	15.00	8.50	8.00
9	dig dump dump dig	3.30	0.75	0.45	15.00	8.25	6.50
10	dump dig dig dump	3.30	0.80	0.40	15.00	8.20	6.15

Conclusions

The result of 2D wave simulation has been found that case of 'dump dig dig dump' more effective to reducing the wave energy. In this case, wave propagation reduced in first 'dump dig' topography and partial wave was trapped by second 'dig dump'. The other side, over top of wave thought the 'dig dump' topography only small part of water and decreased significantly if compare with other case. The case of 'dump dig dig dump' can reduce the wave height up to 0.40 m and wave velocity was decreased up to 6.15 m/s. For further research, it would be better if use a kind of tsunami waves such as bore wave propagation in 3D CADMAS Surf, so that the water height and the wave velocity can be appreciated well by the unique topographic.

Reference

(1) Tsugi et al. *Field Survey of the East Java Earthquake and Tsunami of June 3, 1994*. Pure and Applied Geophysics 144, 3/4, pp. 839-854., 1995

(2) The Study Group for the Development of CADMAS-SURF. CADMAS-SURF User's manual. p 519, 2003.

(3) Wijatmiko, I., Murakami, K, *Numerical Simulation of Tsunami Bore Pressure on Cylindrical Structure*, Annual Journal of Civil Engineering in the Ocean, JSCE, Vol 26., pp. 273-278., 2010.