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Tsunami Force on A Building With Sea Wall Protection

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Abstract-***The frequency of tsunami in Indonesia is increasing since the past few decades. The increasing of both the frequency of tsunami and the population in coastal area intensify the vulnerability of such area to tsunami disasters. Tsunamis do not only cause a large number of casualties but also damages to infrastructures along the shore. Wall protection is one possible solution to reduce tsunami force. The effectiveness however depends on the ratio between the tsunami height to the wall height and the distance between the wall and the buildings.A 24m long flume of 1.45m width and 1.5m height was utilized for the experiment. Various tsunami wave fronts were generated using a dam break mechanism. The model of buildings was tested both with and without wall protection installed at various distances in front of the buildings.The results indicated that the force reduction of building depends on the ratio between sea wall height and building high. A simplified formula for the calculation of tsunami force on protected building is proposed***

Keyword-***tsunami force, building, sea wall protection***

1. Introduction

The frequency of tsunami in Indonesia is increasing since the past few decades. The increasing of both the frequency of tsunami and the population in coastal area intensify the vulnerability of such area to tsunami disasters. Tsunamis do not only cause a large number of casualties but also damages to infrastructures along the shore. The damage of infrastructures may be due to the characteristics of tsunami (speed and height of the waves), building characteristics (shape, pores, height, and width of the buildings), and the condition of the surrounding area (i.e. existing *sea wall* or strong buildings along the shore which may protect other buildings from tsunami attack). The damaging power of a tsunami is shown by the depicted situation of an area after being swept by tsunami in Figure 1.

Figure 1. Debris resulted from structures that were demolished by tsunami Aceh 2004 (NurYuwono, 2005)

This study is aimed to investigate the force of tsunami on protected buildings. In order to measure the force of tsunami on buildings, several variables that contribute to the force should be identified. Tsunami force is influenced by the characteristics of the tsunami waves, such as the height of the waves and speed of the waves. Other factors are related to the type, the existence of sea walls in front of the buildings. Sea walls in front of the buildings are barriers which affect the hydrodynamic nature of the flow at the shore and hence the force of tsunami on buildings. The height and the relative distance of the barriers to the buildings are also important factors influencing force on protected buildings.

Tsunami force has a huge damaging power. Methods and formulae to design buildings that can survive from tsunami and to protect other buildings from tsunami attack are therefore required.

2. Theoritical Review

The celerity of tsunami wave front may be written as

$$U = k\sqrt{gh} \qquad (1)$$

where h is inundation depth (m), g is gravitational acceleration (9,81m/s^2), and k is surge Froude number.

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Chanson analytically solved the problem of surge waves due to dam break on land, similar to tsunami wave. Chanson found Equation (2) for the speed of surge on dry land.

$$\frac{8}{3}\frac{1}{f}\frac{\left(1-\frac{1}{2}\frac{U}{\sqrt{g d_0}}\right)^3}{\frac{U^2}{g d_0}} = \sqrt{\frac{g}{d_0}}\, t \qquad (2)$$

where f is Darcy-Weisbach factor, g is gravitational acceleration, t is time and d_0 is the depth of the basin.

Hydrodynamic force is caused by tsunami bore which surge at high speed even on land. The drag force which is the combination of lateral force due to pressure from the shift of water mass and friction due to water flowing around a structure. The dragforce can be written as:

$$F_D = \frac{1}{2}\rho_s C_d A U^2 \qquad (3)$$

where C_d is the drag coefficient

The force on a building behind the wall is a function of the distance from the wall to the building, the length of hydraulic drop, height of the surge, and height of the wall. Hence, the force on the building behind the wall can be predicted using Equation (4) and (5).

$$F = \frac{1}{2}\rho_s C_d k_t A U^2 \left(\frac{S}{L_d}\right)^{0,5}$$

for $\frac{S}{L_d} \leq 0,5$ (5)

$$F = 0,35\rho_s C_d k_t A U^2$$

for $0,5 < \frac{S}{L_d} \leq 1$ (6)

where C_d is drag coefficient, k_t is coefficient related to $\frac{h}{h_t}$, h_{at} is water depth on top of the wall, h_t is height of the wall, A is tsunami affected area, S is distance between building and the wall, L_d is hydraulic drop length. k_t value are presented in Figure 2.

Figure 2. Relationship between h/h_t and k_t

3. PhysicalModelSet Up

A physical model for tsunami surge generation was set up in a flume of 24 m length, 1.45 m width, and 1.5 m height. The flume was divided into two parts where the upstream part was used as a basin, and the downstream part was the model of landward shore (Figure 3).

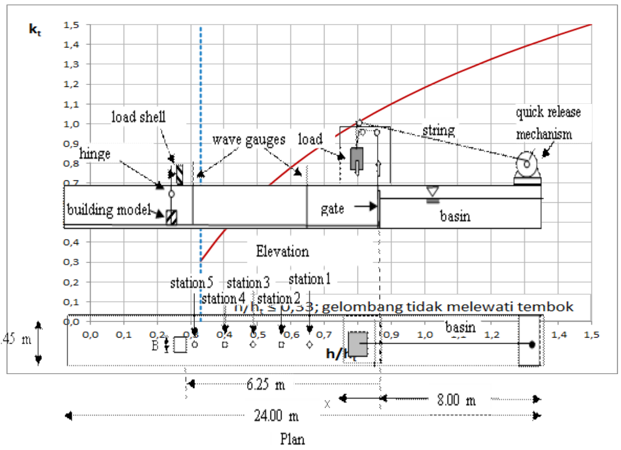

Figure 3. Layout of model

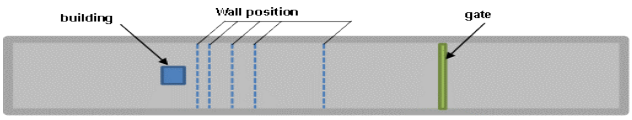

Figure 4. Wall position in the flume

There were two kinds of model, the building model and the barrier model. There were three building models: a solid building sized 20 cm x 20 cm x 20 cm.

Measuring the height and speed of the wave was conducted using six wave probes installed in the wave channel with 1 m interval between each probe. Wave probes were connected to a computer to record the height of the waves at every station. The time taken by the front to move from one probe to the next was measured digitally and the speed can be calculated.

The force of the waves was measured by hanging the building model on a steel cylindrical rod with 1 inch diameter. At the top of the rod, a load cell knocker was installed. If a wave hits the building, the building will move back andthe knocker will press the load cell and the force of the wave on the building can be measured

4. Result of Study

Surge Velocity

Assuming that the front celerity is constant at negligible bottom friction as suggested by Chanson (2006), it can be inferred that the average Froude number decreases with increasing surge height. Based on the observation, the maximum surge height was 15 cm (Figure5)

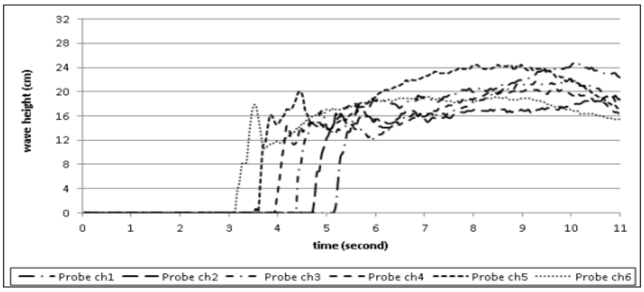

Figure 5. Profile of tsunami front in channel, d_0 = 60 cm

Force on a Building with a Sea Wall Protection

Sea walls built in coastal areas are expected to protect buildings behind them from tsunami waves. The presence of the barrier is expected to reduce the force on the buildings behind them.

The force on buildings behind sea walls at drops was calculated using Equation (5) and is presented in Figure . The height of the walls highly influenced the reduction of the force produced in Figure 6, showing that the smaller the value of h/h_t the bigger the reduction of the force of the waves. In low walls, force reduction was very small. It can be seen from the force for $h/h_t \geq 1{,}5$ in which the reduction of the wave force after the drops ($S/L_d \geq 1$) was around 1,2-4%. The reduction of the wave force by the sea wall at h/h_t = 0,77 was 24%- 35%, at h/h_t = 0,5 was 50%-60%, and at h/h_t = 0,38 was 75%-80%. The closer the buildings to the walls ($S/L_d \leq 0.5$), the bigger is the reduction of the force of tsunami.

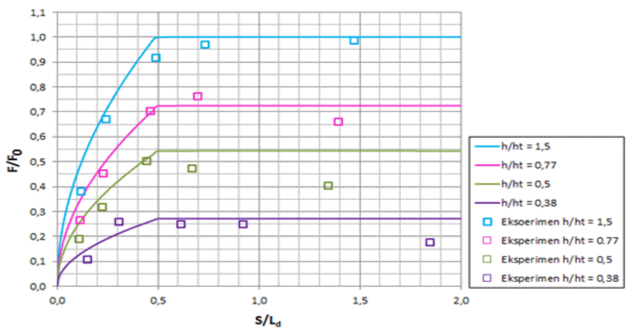

Figure 6. Comparison between the wave force on a building behind a wall in the laboratory and Equation (4).

5. Conclusion

The force of tsunami depends on the height and speed of the tsunami wave front.

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