COMPARISON OF NUMERICAL MODEL AND PHYSICAL MODEL OF LANDSLIDE GENERATED WAVE

Warniyati[*)]

Abstrak

Pergerakan gelombang yang diakibatkan oleh pergeseran tanah dasar bisa diperkirakan dengan tiga metode yaitu pendekatan analitik, pendekatan numerik serta simulasi model numerik dan model fisik. Model Perambatan gelombang pada kondisi batas bergerak mungkin bisa digunakan untuk meramalkan perambatan gelombang akibat pergerseran tanah tersebut. Simulasi model fisik dilakukan dengan membuat kolam yang pada salah satu ujungnya dibuat ada pergeseran tanah. Model pergeseran tanah dibuat dengan menjatuhkan balok pada salah satu ujung kolam berisi air sehingga terbentuk gelombang tsunami yang merambat ke ujung yang lain. Tinggi gelombang dan waktu perambatan gelombang dalam kolam dari ujung satu ke ujung yang lain diamati dan dicatat. Model numerik dilakukan dengan skema karakteristik dan input menggunakan data model fisik. Model Pergerseran tanah dilakukan secara numerik. Perbandingan antara model numerik dan model fisik cukup memuaskan, perubahan muka air pada sta-1 cukup memuaskan sedangkan pada dua stasiun yang lain terjadi perbedaan yang cukup signifikan. Perbedaan massa pada model numerik adalah sekitar 7% lebih kecil. Waktu perambatan gelombang pada model numerik terlambat 0.2 detik dibandingkan model fisik.

Kata kunci : Kolam, Pergerseran tanah, Gelombang.

I. Introduction

Attempts at predicting water wave motion arising from a landslide may be classified into three approaches i.e. simplified analytical approach, numerical approach, numerical and physical simulation.

The first approach simplifies both the property of the slide material and physical laws governing the appropriate fluid dynamics. The shape and the time history of the landslide are assumed to follow a certain equation whilst the linear wave equation is usually assumed to be valid. The approach is limited either one dimensional or to asymmetric problems.

The second, empirical approach is an inductive method. All variables which contribute to the wave characteristic may be include in the formulation. The variables are arranged to form dimensionless group and coefficients are introduced. These are assessed using statistical techniques to match the physical model data.

The third technique omits some of the simplifications adopted in the previous ones. Application to more complicated problem, where wave attenuation, diffraction and reflection are involved, is therefore possible.

One possible method for simulating the landslide wave is by employed the depth averaged or long wave equation. Landslide generated waves have been studied, using the depth averaged equations, by Koutitas (1977), Chaudhry et. al. (1983), Apostolos Roussias (1986), Gozali and Hunt (1989), in ‘x-t’ space, and by Raney and Butler (1976), and Kaya (1985) in ‘x-y-t’ space (in Triatmadja, 1990)

Hunt (1988) used the linear theory to model landslide generated waves by injecting an instantaneous point source of fluid through the bottom of the channel. His assume that time are large relative to the duration time of the landslide and that distances are large relative to a characteristics horizontal dimension of the volume of water displaced by the slide material.

A mathematical model was developed for the simulation of wave propagation with moving boundaries (warniyati, 1998). In the case of landslide, this model may be can applied and the corection may be calibrated using physical model data.

II. Method

The numerical scheme of long waves in the moving boundaries dealt with the fixed bottom situation. In the case of the landslide, the bottom level is obviously displaced. The volume of the landslide above the original bottom level is equal to the volume of water which is displaced by the landslide when no porosity is taken into account. The energy of the slide (kinetic and potential) are

[*)]. ***Warniaty,*** *Dosen Program Studi Teknik Perkapalan Fakultas Teknik Unpatti*

transformed and redistributed in friction force along the bottom together with the drag force and potential energy of the slide above the original bottom level. The friction force on the bottom does not contribute in generating the wave, since it is transformed to another type of energy namely heat. Only the last two components of landslide energy will then play a role in generating waves. The equality of the volumes of the water being displaces and of the landslide, suggests that the potential energy of the slide after the slide process, with respect to the original bottom level, is equal to the potential energy of the displaced water.

By adding the bottom displacement term □ on the right hand side, the continuity equation for the moving bottom case is determined. The equation read:

$$\eta_P = \bar{\eta} + \varsigma - \left(U\, h_x + V\, h_y + h\, U_y + h\, V_y\right)\Delta t + \left[1 - 2\left(\Delta t/\Delta s\right)^2 \left(C^2 + U^2 + V^2\right)\right]\left(\eta - \bar{\eta}\right) - 4\, h\, U\left((U - \bar{U}) + 4\, h\, V(V - \bar{V})\right)\left(\Delta t/\Delta s\right)^2$$

Where $\zeta = h^t - h^{t+\Delta t}$ is the bottom displacement.

If the bottom disturbance is vertical there is no need for horizontal momentum correction. However a horizontal correction should be applied when the slide is not purely vertical. This is for example suggestion by Triatmadja, Kaya and Butler (1976).

$$U_P = \bar{U} - g\, \eta_x\, \Delta t - \left(U_y\, V - U\, U_x\right)\Delta t + \left[1 - 2\left(\Delta t/\Delta s\right)^2 \left(C^2 + U^2 + V^2\right)\right]\left(U - \bar{U}\right) - 4g\,\left(h - \bar{h}\right)\left(\Delta t/\Delta s\right)^2 - g\, U\, S_{i,j}\, \Delta t + F_{sx}\Delta t$$

$$V_P = \bar{V} - g\, \eta_x\, \Delta t - \left(V_x\, U - V\, V_y\right)\Delta t + \left[1 - 2\left(\Delta t/\Delta s\right)^2 \left(C^2 + U^2 + V^2\right)\right]\left(V - \bar{V}\right) - 4g\left(h - \bar{h}\right)\left(\Delta t/\Delta s\right)^2 - g\, V\, S_{i,j}\, \Delta t + F_{sy}\Delta t$$

where F_{SX} and F_{SY} were the slide force along x and y directions, V_{SY} and V_{SY} were the slide velocity along x and y directions and K_P and K_V were the pressure drag coefficient and viscous drag coefficient respectively.

Kaya (1995) defined:

$$F_{SX} = \frac{K_p}{2h}\left(V_{Sx} - U\right)^2 + \frac{K_V}{2h}\left(V_{SX} - U\right)^2$$

$$F_{SY} = \frac{K_p}{2h}\left(V_{SY} - U\right)^2 + \frac{K_V}{2h}\left(V_{SY} - U\right)^2$$

Butler (1976) defined:

$$F_{SX} = \beta\left(V_{SX} - U\right)\left[\left(V_{Sx} - U\right)^2\left(V_{SY} - V\right)^2\right]^{0.5}$$

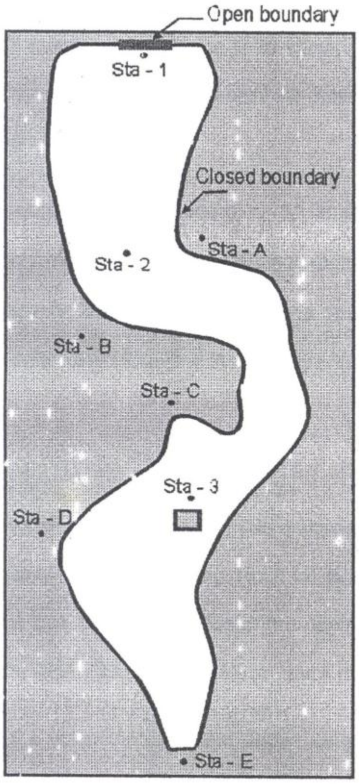
$$F_{SY} = \beta\left(V_{SY} - V\right)\left[\left(V_{SX} - U\right)^2\left(V_{SY} - V\right)^2\right]^{0.5}$$

$$\beta = \frac{1}{2h}\left[\frac{K_p \varsigma}{\Delta S} + K_V\right]$$

In this study vertical disturbance is utilize to generate tsunami wave, however the disturbance is a falling box by which a horizontal velocity exist. A momentum correction may be calibrated using physical model data.

The physical model was a basin in wich a landslidemay be simulated at one end of the basin. The slope of basin was varied to test the performence of the mathematical model. The basin was made of sand and cement mixture to ensure impermeability. The depth of the imaginary lake was than measure and the contour line was made. When at the one end of this imaginary lake a landslide was imposed, tsunami wave resulted. This tsunami wave will creep to other end of the imaginary lake and to all the boundary of variying slope.

The model test was started with filling the basin with water up to maximum water depth that is 0.06 m. This is the zero still water level. The instrument to measure the wave height was than instaled. These instruments include wave probe that are conected with wave recorder. The landslide was generated using vertical moving block. The moving block was droped vertically at one end of the imaginary lake using a lever. Droping the block will create the tsunami wave wich propagated down the lake. Run-up occur at the boundary of the imaginary lake. The run-up was observed in some location according to visual method by marking the wet area due to the wave propagation.The total time wave travel to the end of the basin observed by stopwach. Schematization of imaginary lake with the recording station is presente in Figure 1.



Notations:

: Wet area

: Dry area

Figure 1. Schematization of imaginary lake

The aim of the numerical simulation is to show that the numerical scheme is capable to simulated the water which willmove due to the increasing water level in the imaginary lake. Numerical simulation of wave generated by landslide is conducted using the characteristic scheme. The time step (Δt) used in the numerical modelwas 0.025 second and distand between two calculation nodes (Δs) was 0.03 m.

The physical model data was used for this numerical model input. The landslide is simulated using moving block numerically. The total time of landslide in the open boundaries was 0.5 second. The speed of the slide was actualyvariable, but it may be averaged as 0.1m/s.

III. Results and Discussions

The result of water displacement above still water level at each recording station are presented in figure 2. In the open boundary water fluctuation increase for 0.5 second. The water fluctuationwas graduallydiminished and died out. Mass conservation in the basin was achieved. The increases in water level both due to run-up and submerged blockwas represented by increasing wet area in the basin. At certain time however run-down occured in certain location in the boundary giving less wet area on computation grid.

The result of increasing and decreasing wet grid in the imaginary lake are presented in figure 3. Moving boundary is the consequences of the process of wave run-up and run-down. If the wave run-up to a higher level of dry land, the number of wet grid increases. Conversely, if the wave run-down, the number of wet grid decrease. The maximum total wet grids is 4172 at t = 3.05 s when the wave run-up is maximum. During the firs6 seconds the wet grids increased considerably, because at this time the waves moves in mildly sloping bathymetry. After the wave moves in bathymetry with steep slope, hence the run-up was low. As the time approached is 30 second the fluctuation of wet grid is insignificant, because the water fluctuationin the computational domain has been damped out due to frictioal effect and numerical dissipation. Comparison between the numerical and physical model is conducted to investigate the correlation between the numerical model and the physical model.

Comparison of maximum water displacment above still water level is given in Table 1.

Table 1. Maximum water displacement above still water level

Location	Numerical result (m)	Physical result (m)
Sta-1	0.003	0.034
Sta-2	0.0056	0.012
Sta-3	0.0023	0.0048

Comparison of numerical result with physical at Sta-1 is satisfactory. The other two downstream station a significantdifferent resulting. This could be dou to numerical dissipation, both in the inner grids and along theboundary where treatment to wave ru-up run-down to applied.

As the fluctuation of wet grid is diminished, total numerical increase of mass of water was observed. Total wet area in this condition was 4133, average water elevation (η) is 0.001747m.The distance between two nodes (Δs) is 0.03, hence the total increaseof water is 0.0065 m^3. In the physical model total increase of water volume is 0.007 m^3. In the numerical model total increase water volume is minus about 7% less from that of physical model. This deficit may resulted from some volume which remain in the dry area.

Totaltime of wave traveling along the basin in the physical model is 9.34 s, while in numerical model is 9.2 s. This condition agree with the theory of wave celerity in the shallow water. Depth average in shallow water (h) is 0.004 m, wave celerity is 0.63 m/s. The length of the basin (l) is 6 m, hence the total time wave travel to the end the basin is 9.5 s.

The run-up in the numerical model is about 70% less from the physical model. This deficit may result due to inaccuracy of velocity vector the moving boundary in the numerical model and for example the numerical range of dry to wet condition. A more detail numerical discritization may be needed for greeter accuracy.

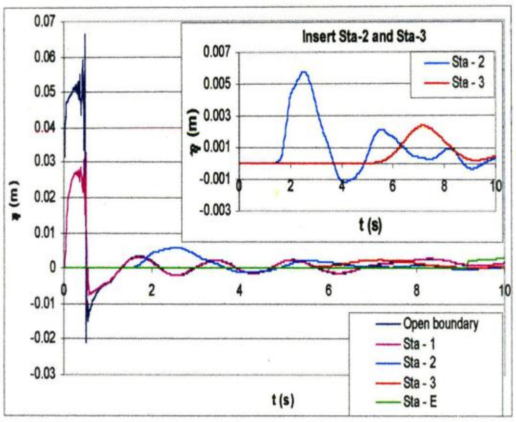


Figure 2. Water displacement above still water level

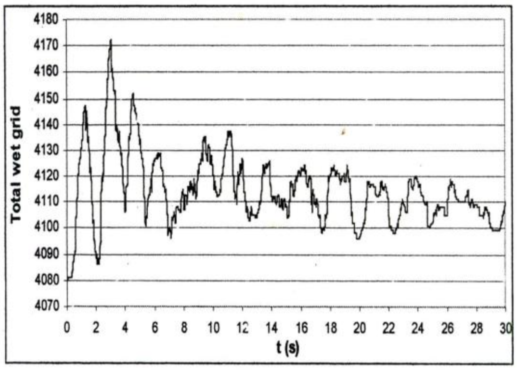


Figure 3. Total Wet grid

IV. Conclusions

Comparison of numerical result with the physical of water displacment at Sta-1 is satisfactory.The other two down stream sations show a significant different from the physical simulation. The masserror in the numerical model is about 7% less. The total time of wave traveling along the basin in the numerical model is 0.2 s less from the physical model. The comparison was satisfactory.

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