Study on Tsunami Soliton Fission and Its Breaking on Continental Shelf

Background

On May 26 in 1983, the big earthquake (M7.7) occurred in Japan Sea, and generated a huge tsunami, that is the 1983 Nihonkai-Chubu earthquake tsunami. Then the remarkable characteristic of tsunami phenomenon was observed on the gentle seabed slope in the shallow water along coast. That is “tsunami soliton fission”, which is short waves split around tsunami crest. It is caused by the effect of wave nonlinearity and dispersion. If soliton fission occurred, new leading wave height increases remarkably, and breaks. So tsunami force which is affected by soliton fission and wave-breaking is more powerful than before. It is important to investigate characteristics on breaking of tsunami soliton fission.

Objectives

To reveal mechanism of tsunami shoaling and wave-breaking criterion of split wave by tsunami soliton fission. And new numerical model for tsunami shoaling and wave-breaking with tsunami soliton fission is proposed.

Principal Results

1. Undistorted experiment for investigation of tsunami shoaling and wave-breaking

(1) Undistorted experiment carried out for tsunami shoaling on a continental shelf in the LARGE WAVE FLUME, which is 205m long. Three models of the continental shelf were set up, which have 100m lengths, and 1/100, 1/150, and 1/200 slope respectively (figure 1). Input wave profile is sinusoidal wave shape only with one wavelength. Ranges of wave amplitude and period are respectively from 0.005m to 0.09m and from 20sec to 120sec. Figure 2 shows an example of time histories of water elevation, which describes tsunami shoaling, soliton fission, and its wave-breaking.

(2) Water surface elevations were measured across the flume, and ten or eleven wave gages were thickly installed around the point of wave-breaking (figure 3). We proposed new methods for calculating wave velocity and wave-breaking criterion based on time histories of water elevation, and applied to the experiment. As a result; at the point of wave-breaking, maximum ratio of surface water particle horizontal velocity to wave velocity is from 0.5 to 1.2 (figure 4). These values of parameters for breaker limit are larger than those by the former study.

2. Modification of wave-breaking model in numerical simulation

(1) Former numerical model tended to yield smaller wave-breaking height than the experimental result because criterion of wave-breaking was smaller value (figure 5(a)). Additionally split waves broke earlier than experiment result when a large descent wave led before adjacent soliton fission (figure 5(a)).

(2) To overcome this problem, wave-breaking model was modified as follows; a) a new parameter for detection of appearance of soliton fission b) modification of diffusion coefficient c) increase in criterion for wave-breaking. New wave-breaking model estimated wave-breaking height accurately, in which error ranges of 80% of all cases are less than 10% for position and height at wave-breaking.

The new wave-breaking model contributes to accuracy improvement for evaluation of wave force and sand transport by tsunami.

The present study results from the activity of Tsunami Evaluation Subcommittee (Chair person: Dr. Shuto) of Nuclear Civil Engineering Committee in JSCE (Japan Society of Civil Engineers), which is supported by Japanese electric power companies.

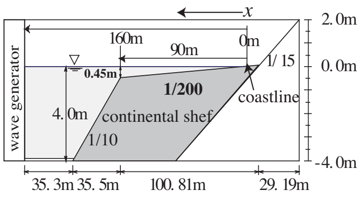
Future Developments

Next target is evaluation of wave force and sand transport by tsunami to evaluate tsunami disaster on land.

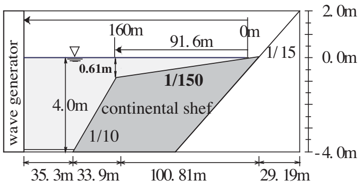
Main Researcher: Masafumi Matsuyama, M.E.,
Research Engineer, Fluid Dynamics Sector, Civil Engineering Research Laboratory

Reference

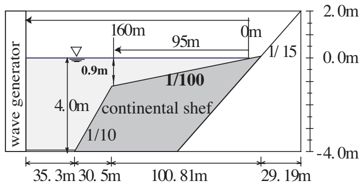
M. Matsuyama, et.al., 2006, “Study on tsunami soliton fission and its breaking on continental shelf”, CRIEPI Report N05045 (in Japanese)



(a) slope1/200



(b) slope 1/150



(c) slope 1/100

Fig.1 Three kinds of continental shelf models in the wave flume

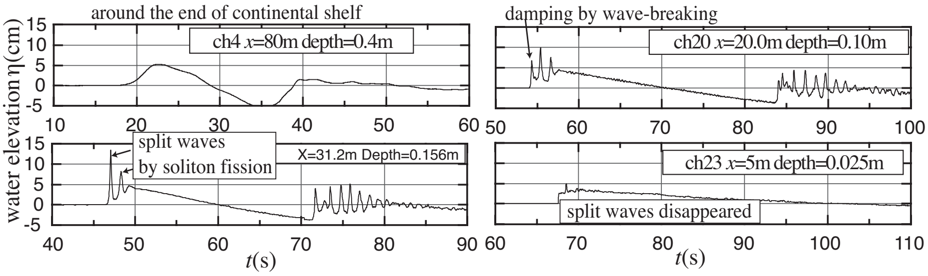


Fig.2 Time histories of water elevation (amplitude 0.03m, period 20s, slope1/200)

$$\gamma = \frac{u_S}{c} = \frac{\eta}{D} - \frac{h}{3Dc^2}\left\{D\frac{\partial^2\eta}{\partial t^2} - 2\left(\frac{\partial\eta}{\partial t}\right)^2\right\}$$

$D = h + \eta$　η : water elevation
h : still water depth　c : wave velocity
u_S : horiaontal wave particle velocity on surface

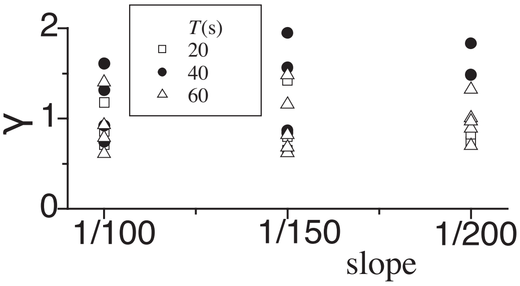


Fig.4 γ at wave-breaking point (Upper equation estimated γ from time histories of water elevation)

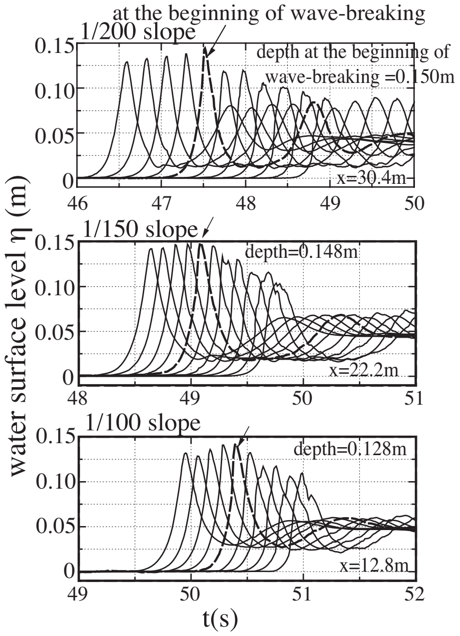


Fig.3 Time histories of first split wave around wave-breaking point

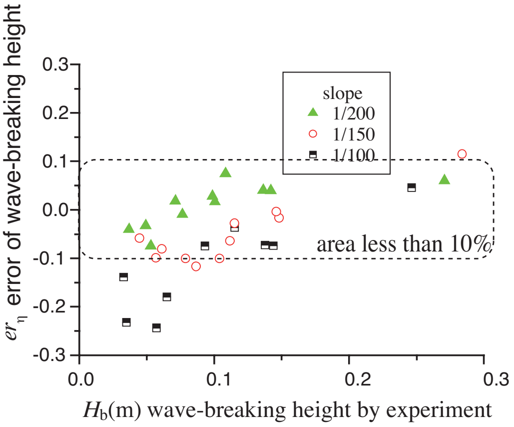


Fig.5 Error distribution of wave-breaking height by numerical results

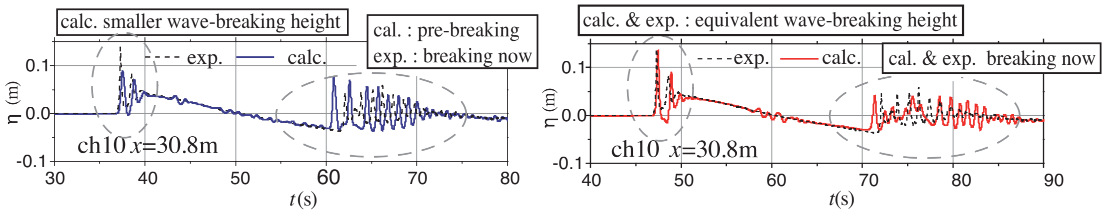


Fig.6 Comparison of time histories of water elevations between former and new model