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Characteristics of Tsunami Waves and Forces by Hybrid Tsunami Generator

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Introduction

From the 2011 Tohoku Earthquake Tsunami, several unexpected large and very long inundations occurred and caused some casualties and extensive damage to infrastructure on coastal areas along the Iwate and Miyagi Prefectures (Mase et al, 2013 and Mori et al, 2011). These inundations shaped new wave type which suddenly became a phenomena in current tsunami research. Tsunami wave type accordingly can no longer characterized as either solitary wave, N-shape, or long sinusoidal wave only as previous research stated.

In order to investigate and improve the understanding of this phenomena, the Disaster Prevention Research Institute (DPRI) has built a tsunami generator, called the Hybrid Tsunami Open Flume in Ujigawa (HyTOFU). HyTOFU is the latest wave generator that has the capability to generate a tsunami wave by using either a mechanical wave generator (piston paddle), water jet pump, head storage tank or combination of the above mechanisms.

This research study focuses to elaborate HyTOFU capabilities with main purpose to obtain tsunami fragility functions as assessment tool for tsunami mitigation based on Tohoku tsunami event.

Methodologies

Experiments of tsunami waves and forces have been run on HyTOFU; the flume's dimensions are 44 m long, 4 m wide and 2 m deep, with a design water depth of 80 cm (Fig.1). To generate a tsunami wave, physical experiments have been conducted using both individual and combination of three wave generation mechanisms. The first mechanism of wave generation is the mechanical wave generator. This generator has a maximum stroke of piston paddle of 2.5 m and can produce a maximum wave height up to 1 m. In this experiment, the wave height target was between 10 and 50 cm. The second mechanism of wave generation uses the head storage tank. To generate the wave, a volume of water is dropped from a storage tank into the flume by opening its instant gate. In this mechanism, there are 4 parameters to be controlled: 1) volume of tank (up to 4 m^3); 2) height of tank (0 – 100 cm); 3) height of open gate (up to 80 cm) and 4) speed of opening gate. The last mechanism of wave generation is to generate constant and periodic flow by using a pump. The pump has a 70 kw maximum power, while the maximum discharge is 0.83 m^3/s. The constant flow comes out from two outlet-sized 2 m x 0.2 m under the mechanical generator. Constant flow experiments are conducted using water discharges of 0.1, 0.2, 0.3 and 0.35 m^3/s.

In addition, to obtain information about fluid behavior and forces on simple structures, velocity and wave pressure are measured using single and multiple boxes. Pressure sensors and Acoustic Doppler Velocimeters (ADVs) are also used to measure pressure and velocity profiles. Pressure measurements are taken on an acrylic box with 9 sensors on the front side, 6 on the lateral side, and 5 on the back side (Fig 2). Sensors are mounted on boxes by using double-sided tape and clay. Pressure measurements were then obtained to generate waves by multiple combinations of mechanical and pumping tsunami generation mechanisms.

Results and discussion

Result of experiments show that using the mechanical wave generator produces good agreement between input of targeted wave height and output of actual wave height (Fig. 3). For waves generated by the pumping mechanism, the amount of water discharge influences the output of wave

height. If the water discharge increases, wave height also increases linearly. The head storage tank experiment also shows good agreement between the output wave height and the input tank volume. There are no significant difference of wave height when the tank height or opening gate height are changed. However, the output wave height is slightly influenced by the input of opening gate speed.

Pressure profiles show good agreement with wave height conditions. If wave height increased, the pressure likewise increased. In the front, lateral and back sides of the box, each sensor gave different results depending on water flow around the box.

In near future, higher complexity experiments will be conducted on a 1/200 scale model of Onagawa city during the Tohoku Earthquake Tsunami to investigate local fluid behavior, velocity and pressure along the street.

References

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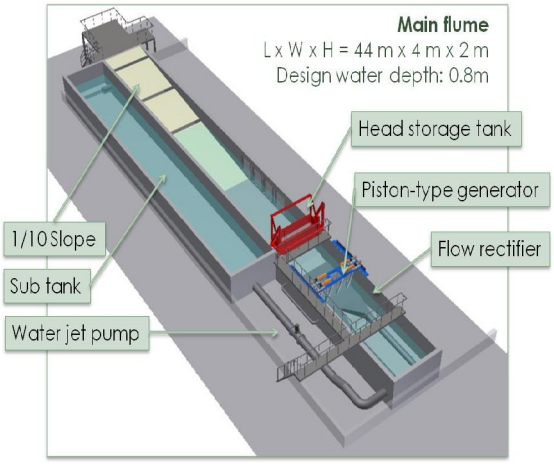

Figure 1. Hybrid Tsunami Open Flume in Ujigawa (HyTOFU)

Figure 2. Acrylic box with pressure sensor

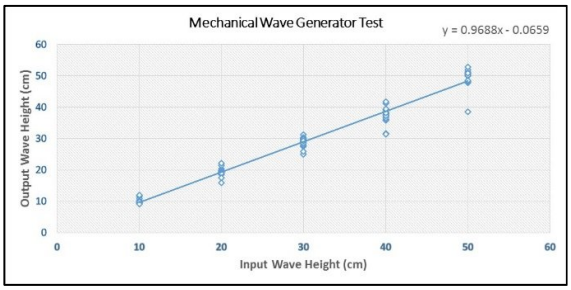

Figure 3. Correlation between input wave height and output actual wave height by mechanical wave generator.