Estimation of Tsunami Wave Load Acting on Storage Tank

Susumu Araki, Wataru Kunimatsu, Shinji Nishiyama, Tomohiro Furuse, Shin-ichi Aoki
Department of Civil Engineering, Osaka University
Suita, Osaka, Japan

Yasuo Kotake
Technical Research Institute, Toyo Construction Co., Ltd.
Nishinomiya, Hyogo, Japan

ABSTRACT

Damage to storage tanks in large industrial complexes can lead to a spill of gas or oil. In order to prevent damage to storage tanks, tsunami wave load acting on model cylindrical storage tanks are measured. The measured results show that the buoyancy is predominant in the vertical component of the tsunami wave load. The measured horizontal component of the tsunami wave load is compared with the wave load calculated by equations including a term representing velocity.

KEY WORDS: Tsunami; tank; wave load; inundation depth; velocity; buoyancy.

INTRODUCTION

A massive tsunami struck the northeastern coast of Japan in 2011. The tsunami caused serious damage to large industrial complexes facing the sea. Damage to storage tanks in large industrial complexes can lead to a spill of gas or oil, which is one of the main causes of fires. Fires in large industrial complexes can last long and spread out surrounding areas because a large amount of gas and oil is stored.

A huge tsunami generated at Nankai trough located south of Japan is predicted to strike Japan in the near future. The Nankai trough tsunami will strike large industrial complexes in Japan. Therefore, we need to take countermeasures against tsunami striking in large industrial complexes. In order to prevent damage to storage tanks in large industrial complexes, tsunami wave loads acting on them have to be investigated and estimated. Tsunami wave loads acting on structures on land have been conducted, e.g., Asakura et al. (2002), Arnason et al. (2009), Fire and Disaster Management Agency of Japan (FDMA) (2009), Nouri et al. (2010), Arimitsu et al. (2012) and so on.

In this study, tsunami wave loads acting on model storage tanks were measured in a wave basin experiment. From the measured tsunami wave load, the characteristics and the estimation of the tsunami wave load acting on the tanks were discussed.

HYDRAULIC EXPERIMENT

Experimental Setup

The hydraulic experiment was conducted in a wave basin at Technical Research Institute, Naruo, Toyo Construction Co., Ltd. The wave basin is 30 m long, 19 m wide and 1.5 m deep. Tsunami waves like solitary waves were generated in the wave basin by piston type wave maker which has the maximum stroke of 1.5 m. A model harbor was constructed in the wave basin shown in Figure 1. A model storage site on which model cylindrical storage tanks were placed was located in the model harbor. The blue rectangle in the figure is the storage site, which is 1.8 m long and 2.9 m wide. Yellow slender structures in the figure are breakwaters. In the model storage site, 12 cylindrical storage tanks can be placed in total. The tsunami wave was obliquely incident on the storage site. The model cylindrical storage tanks were made of acrylic plastic and were 15 cm in diameter and 10 cm in height. Figure 2 shows a plan view of the storage site. The cylindrical storage tanks are numbered as shown in the figure. Figure 3 shows a photograph of the model cylindrical storage tanks placed in the model storage site. The storage tanks were surrounded by walls against oil spill on the storage site. The walls were 1.0 cm high. The model scale was assumed to be 1:100.

The water surface elevation was measured offshore (in front of the wave paddle) and at each point where cylindrical storage tanks were placed by capacitance-type wave gauge. The horizontal water particle velocity 1.0 cm above the bed of the storage site was measured at each point of cylindrical storage tanks by electro-magnetic velocity meter installed in the bed. The horizontal and vertical tsunami wave loads acting on the cylindrical storage tanks were measured by three-component force transducer installed in the bed. There was a gap of several millimeters between the cylindrical storage tank and the bed of the storage site in order to measure the tsunami wave load.

Procedure for Measurement

Two kinds of incident wave were generated in the wave basin. The one