Application of SEC-HY21 Model on Tsunami Simulations

Min-Ching Chiou*, Chin-Pin Ko*, Chiang-An Hsu**, Chen-Shan Kung***

* Sinotech Engineering Services, LTD., Taipei, TAIWAN, China
** Civil, Hydraulic Engineering and Railway Transportation Research Center, Sinotech Engineering Consultants Inc., Taipei, TAIWAN, China
*** Sinotech Engineering Consultants, LTD., Taipei, TAIWAN, China

ABSTRACT

SEC-HY21 is an integrated software package developed by Sinotech Engineering Group for two-dimensional depth-averaged hydraulic simulations. In this study, the application of SEC-HY21 on tsunami simulation is introduced firstly with a focus on its verification and validation. The developed numerical tsunami model is tested by a series of benchmark problems suggested by the National Oceanic and Atmospheric Administration (NOAA) of the United States. Secondly, potential tsunami triggered by fault movements and underwater earthquakes in the vicinity of Taiwan and their impact on the island’s nuclear power plants are analyzed. The results show that SEC-HY21 is capable to effectively simulate the phenomena of tsunami, including tsunami generation, propagation, run-up and inundation.

KEY WORDS: SEC-HY21; tsunami simulation; fault movement; run-up; inundation.

INTRODUCTION

The 2004 Indian Ocean earthquake, which occurred on December 26 with a magnitude of 9.0, caused a series of devastating tsunamis that struck the coasts bordering the Indian Ocean. More than 230,000 people in fourteen countries lost their lives and the maximum run-up height along the inundating coastal areas was up to 30 meters high. After the disaster, many countries began to recognize the destructive power of tsunami and launched into developing early warning systems. Taiwan, an island located on the Pacific Ring of Fire, is particularly susceptible to tsunami attacks. Earthquakes occur often and tsunamis have been recorded in history. Therefore, development of effective tsunami simulations and the implementation of an early warning system are of high priority.

On March 11, 2011, a 9.0-magnitude earthquake off the northeastern coast of Japan triggered tsunami waves of up to 30 meters high, which washed up the coastal regions of Fukushima, Iwate and Ibaraki prefectures. Besides the massive loss of life, environmental devastation and infrastructural damage, the tsunami also impaired the Fukushima nuclear power plant, leading to plant failures and subsequently releases of contaminated, radioactive material into the environment. Since there are four nuclear power plants situated along the coast of Taiwan, the public is highly concerned with the safety of the plants in the face of a tsunami strike. Following the Japanese tsunami, Taiwan Power Company contracted Sinotech Engineering Consultants to conduct tsunami simulations and safety assessments of the nuclear power plants in Taiwan.

The tsunami simulations are comprised of three stages: (1) tsunami generation, (2) far-field propagation, and (3) near shore run-up and inundation. Tsunami can be triggered by submarine earthquake, underwater landslide, immersed volcano eruption or a large meteorite impacting the ocean. Earthquakes caused most tsunamis. Typically, the Okada (1985) method is used to derive the initial waveform caused by fault dislocation. Next, the numerical models solving two-dimensional shallow-water wave equations are applied to simulate the tsunami propagation, run-up and inundation.

Sinotech Engineering Group has devoted itself to the development of SEC-HY21, the first commercial software for general-purpose two-dimensional surface-water modeling in Taiwan. SEC-HY21 is a numerical model based on the nonlinear wave equations similar to other international tsunami models, such as MOST, TUNAMIN2, COMCOT, and MIKE21. However, the numerical method used by SEC-HY21 is improved. Users are able to build unstructured triangular meshes for numerical models, so that the actual configuration of basal topography and constructions can be fully reflected. Furthermore, the mesh resolution can be adjusted easily so that high-resolution meshes can be built in the areas of tsunami run-up and inundation.

Model verification is the most important step before simulations. NOAA has collected the standards and procedures for tsunami model verification (Synolakis, et al., 2007). It is suggested that the tsunami model should be tested and verified by comparing with analytical solutions, hydraulic experiment results and field measurement data. In this study, some of the benchmark problems conducted by SEC-HY21 will be presented to prove that SEC-HY21 is capable to simulate tsunami. Lastly, its practical application on evaluation tsunami readiness of the nuclear power plants in Taiwan is demonstrated.

FUNCTIONS OF SEC-HY21