Model Study of Tsunami Wave Loading on Bridges

Indrasenan Thusyanthan & Elena Martinez
Engineering Department, University of Cambridge
Cambridge, United Kingdom

ABSTRACT

This paper presents the initial results of a series of model tests carried out, as part of an ongoing research project in Cambridge, to understand the maximum impact pressure of a tsunami wave on coastal bridges. The paper also contains a review of literature relevant to this project. A simple pier and deck bridge design was tested at 1:25 scale, using miniature pressure sensors to monitor the impact loads. The effects of foundation depth, pier height, pier width and bridge deck height on the impact pressures have been investigated.

KEY WORDS: tsunami wave, coastal bridges, modelling, wave impact pressure.

INTRODUCTION

Boxing-day 2004 tsunami was a natural disaster that claimed more than 220 000 lives and destroyed infrastructure along the coasts of many counties in the pacific, Indonesia and Sri Lanka being the worst hit. The total economic cost of catastrophe is estimated to be more than 10 billion euros. According to the Red Cross, more than 2.3 million were affected by the disaster. In light of this disaster, early waning system has been put in place for any future tsunamis in the pacific. While early warning systems can be used for evacuating people and saving lives, better designs for coastal structures are required if we are to improve their chances of survival in an event of a tsunami and reduce the economic and financial loss. Bridges are one of the important infrastructures that need to be protected in an event of tsunami. This research aims to better understand the tsunami wave impact loading on bridges.

This paper presents model scale study of tsunami wave loading on bridge structures. Experiments were performed in a 4.5 m length wave tank using model bridge structures (1:25 scale). The tsunami wave was created in the wave tank by releasing a heavy weight (~100 kg) into the water at the deep end of the tank. The sudden displacement of water in the deep end of the tank created a single wave and the wave propagated to the shore where the model bridge was placed. A high speed (1000 frames/s) video camera was used to capture the tsunami wave as it impacts the structure. The sea bed was instrumented with miniature pore pressure transducers for measuring the excess pore pressures during the passage of tsunami wave, and the model bridge was instrumented with miniature stress transducers to measure the wave loading. A series of experiments were carried out to understand maximum impact wave loading on different bridge configurations.

LITERATURE REVIEW

There is a wide range of literature on the subject of wave loading, with most papers focusing on the effects of individual or continuous waves on vertical walls.

The U.S. Army coastal engineering research centre produces technical notes to aid in the design of walls on the shore. There are two relevant notes (U.S. Army Corps of Engineers, 1990 and 1991), with a distinction made between walls shoreward of the still-water line and those seaward of it.

For walls shoreward of the still-water line, the wave force, F, per unit length of the wall is given by equation (1).

$$F \approx 4.5 \gamma h^2 \qquad (1)$$

where γ is the specific weight of water, and h is the surge height at the wall.

For walls seaward of the still-water line, the wave force per unit length can be divided into the hydrostatic (R_d) and dynamic components(R_h) as shown below.

$$R_d = \frac{\gamma d_b h_c}{2} \qquad (2)$$

$$R_h = \frac{\gamma (d_s + h_c)^2}{2} \qquad (3)$$