ADVANCES IN EVALUATING TSUNAMI FORCES ON COASTAL STRUCTURES

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Introduction

At source, tsunami waves have relatively small wave heights (typically 0.5-2m), but very long wavelengths. As these waves approache the shoreline and enter the shallower waters, their wavelength reduces and their wave height increases dramatically. The resulting waves can cause violent impacts on infrastructure and structures, and the long wavelengths lead to extensive inundation inland causing destruction over large areas of coast as seen recently in Japan (2011). Clearly there is a need for a systematic analysis of the physics of tsunami flows in and around buildings and the forces and pressures they produce on structures as a function of time. The first steps towards such a study are presented.This paper presents preliminary observations obtained from sets of unique physical experiments designed to study the impact of tsunami-like waves on coastal structures towards the development of tsunami design/assessment guidance.

The UCL-HR Wallingford Experiments

Through a UCL-HR Wallingford collaboration an innovative method for generating tsunami in the laboratory was developed that uses a pneumatic, rather than a paddle system. Tests carried out using the new tsunami generator demonstrate that it is the only facility worldwide currently able to produce wavelengths long enough to represent tsunami and generate stable trough-led waves (see Rossetto et al. 2011). The maximum wavelength generated to date corresponding to the Mercator recording (2004 tsunami) with wavelength of 23km reproduced at scale 1/50.The original aim of this study was to model accurately the propagation of earthquake-generated tsunami through the surf zone and to the inundation of buildings behind the shoreline. New tsunami runup equations have been produced, following a better understanding of the tsunami evolution onshore (Charvet et al. 2013). A better understanding of the evolution of forces and pressures over time is also arising from the results of a limited number of experiments carried out on structures in the flume using the tsunami generator and a number of small scale tests carried out at UCL (see Figure 1) to better characterise steady flows around rectangular cylinders (Lloyd, 2014 and Qi et al. 2014). In particular, the latter show that for a single configuration and blockage ratio, that once a critical Froude Number is surpassed the flow regime around the square cylinder passes from being sub-critical (where drag forces dominate) to choked (where hydrostatic forces dominate). In recognition of the fact that the majority of numerical models cannot represent buildings explicitly in their simulations, Qi et al (2014) propose a set of equations for describing the forces on the rectangular cylinder from only knowledge of the flow velocity, depth and Froude number in front of the cylinder and the ratio of the cylinder width to that of the flume. When these steady state equations are applied to the unsteady case of the rectangular buildings tested under tsunami,

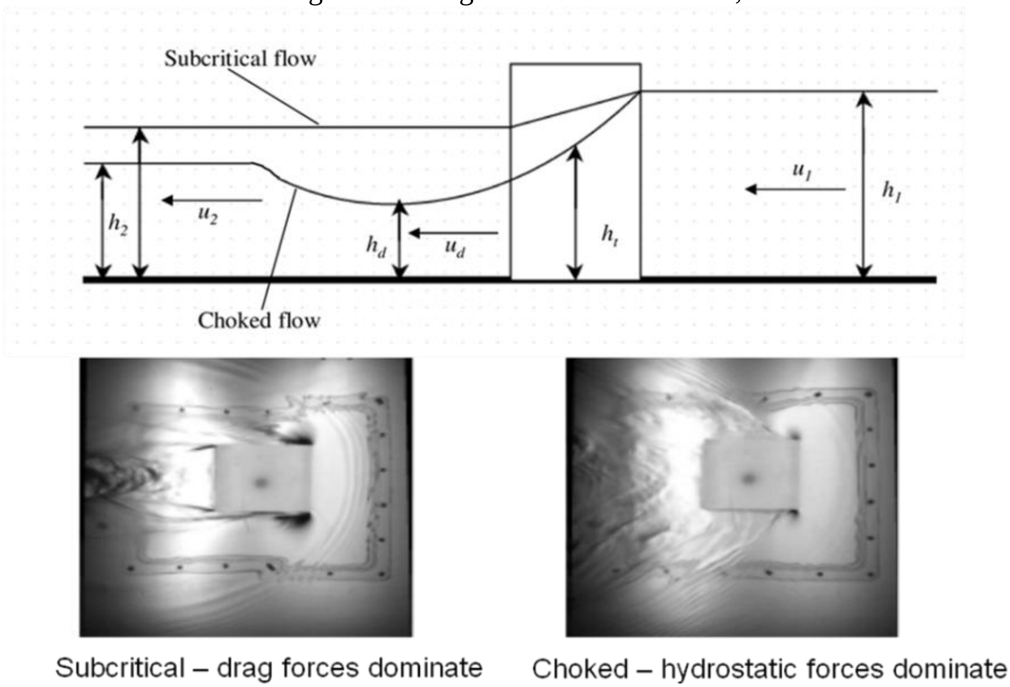

Figure 1. Schematic diagram and photos of the steady flow tests at UCL showing the identified Choked and Subcritical flow regimes (adapted from Lloyd 2014 and Qi et al. 2014).

Figure 2 results; i.e. the measured force time-histories seem to agree well with those predicted by the steady flow equations. These results suggest that a steady flow assumption may be applied to the unsteady case of tsunami onshore flow. However, it is recognised that the UCL-HRW tests for forces on a rectangular body subjected to tsunami onshore flow are few (13 waves repeated 3 times each) and pertain to a single structural configuration.

Conclusions and Next Steps

This paper presents research on tsunami forces that is very much a work in progress. The author was successful in obtaining an ERC Starting Grant called “URBAN WAVES” for the continued experimental and numerical modelling of tsunami flows around buildings but also for the study of tsunami impact on coastal defences. This project sees an improved version of the pneumatic tsunami generator built and placed in a 100m x 1.8m flume located at HR Wallingford.

Using the new facility, three phases of experiments will be carried out during the 5 years of the grant and will be accompanied by extensive numerical analysis.

Acknowledgements

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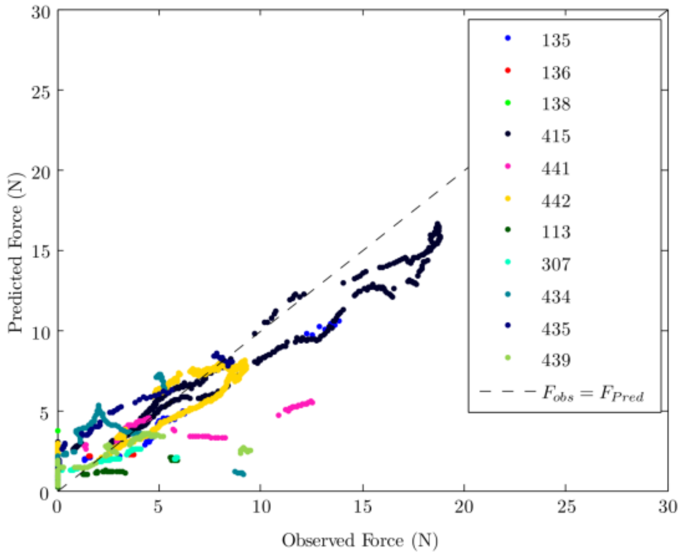

Figure 2. UCL-HRW tests of forces on a rectangular body subjected to 13 different tsunami-like waves: Observed forces versus those predicted by the Qi et al. (2014) equations.

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