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TSUNAMI PING-PONG: GENERATING THE WHOLE TSUNAMI EVENT

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1 INTRODUCTION

Considerable progress has been made over the past two decades in modelling representative tsunami waves in the laboratory. Developments such as the pneumatic tsunami simulator, TS, (Chandler et al, 2021), large wave paddles (Schimmels et al, 2016) and pump driven systems (Goseberg et al, 2013) have allowed full incident tsunami time series to be reproduced at large enough scales to provide reliable physical modelling data. These developments have enabled new insights into the time-varying influence of tsunami waves on run-up (McGovern et al, 2018), buildings (Foster et al, 2017), coastal structures (McGovern et al, 2022) and in particular the scour of sediments around these structures (McGovern et al, 2019). These advances are changing the way engineers and others design and plan for tsunami. However we are still only modelling 'half the story'.

In all existing published studies, the experiments simulated the effect of a single incident wave. We have so far ignored two significant elements of real tsunami events. Firstly, the rundown or return flow and secondly, the effect of multiple waves within a wave train. Both these aspects are difficult to model physically, particularly as the return flow and subsequent waves require a representative topography downstream of a test section. In most facilities there is not enough flume left to create this overland topography. In addition, changing this bathymetry to represent different scenarios such as a coastal plain or a small foreshore and an inland cliff, requires significant modelling effort and cost.

To solve these challenges we propose the use of two TSs facing each other with the test section in between. This concept is shown in Figure 1. This extended abstract presents data from initial trials of the dual TS system conducted at HR Wallingford in 2023 during a three-day test window as part of the MAKEWAVES collaboration. The importance of simulating the return flow from a tsunami is demonstrated through its influence on scour around a rectangular building.

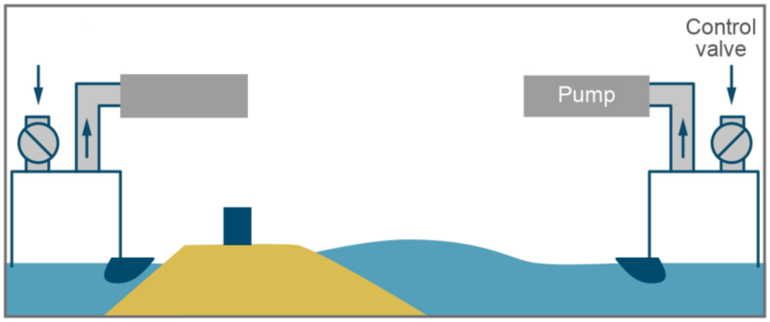

Figure 1. Dual Tsunami Simulator concept

2 EXPERIMENTAL SETUP

The proof-of-concept experiments were performed in a 100m long, 1.8m wide flume with a similar experimental setup to that described in McGovern et al (2018) and Foster et al (2017). For both the MAKEWAVES and these tests a 1:30 slope was constructed from the flume floor to a horizontal test section 1.0m above the flume floor. The test section had a narrow concrete section followed by a 0.3m deep sediment pit filled with fine sand ($d_{50} \approx 0.2$mm). A rectangular building 0.4m wide by 0.2m long was placed in the centre of the test section and extended 0.3m above and below the initial bed level.

Around this building eight ‘scour gauges’ (standard resistance wave gauges calibrated to detect changes in burial depth) were placed, see insert in Figure 2. These recorded the scour evolution around the structure providing a record of the scour depth during the incident and return flows. Video and post test photogrammetry were employed to validate the scour gauge recordings. Three crest-led (CL) waves were tested (periods of 45s, 80s & 160s) in combination with two air valve opening rates to determine the release of water from the second TS, which created the return flow. Due to the limitations of the control system, each TS was controlled separately and the setup did not allow a valve time series to be used to control the return flow.

3 RESULTS AND PRELIMINARY CONCLUSIONS

The scour gauge time series from around the rectangular building are shown in Figure 2 together with the free-surface elevation (*FSE*) at the still water line (*SWL*). These provide a strong justification for the need to include and investigate the return flow. The FSE trace shows the incident wave arriving, then being absorbed by the second TS before it is released. A pause was left between the incident and return flow. This would not be expected in prototype but was done to clearly demonstrate the control of the return flow. The wave conditions and Keulegan-Carpenter (*KC)* values for these tests are comparable to McGovern et al (2019) and others. The maximum scour depth recorded compares well with those reported in McGovern et al (2019) for similar conditions (0.07 to 0.08m maximum scour depth compared with SG_01 in this study). The scour depth at the end of the test is different however due to the influence of the return flow which backfills the incident wave scour hole by an additional 0.02 to 0.015m compared to McGovern et al (2019). The scour at the downstream side of the building is even more significantly affected by the return flow (SG_03 and 05). Further analysis of the initial data is expected to provide initial insights into the influence of the return flow on scour. The results so far demonstrate the dual TS concept is capable of modelling tsunami return flow and the importance of the return flow. A full experimental programme is being planned to explore these themes further.

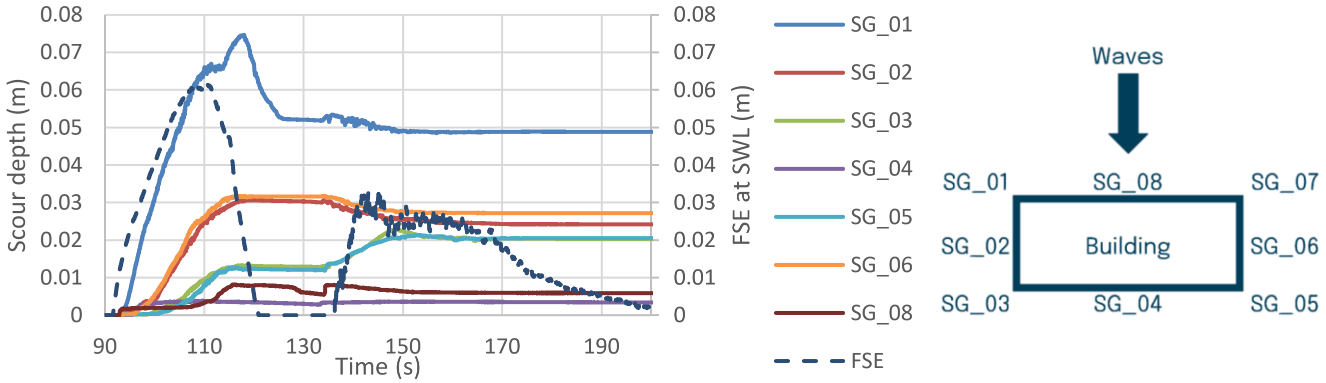

Figure 2. Scour and FSE time series for CL45 wave with return flow release rate 1.5°/s, insert right showing arrangement of scour gauges (SG) around building (note SG_07 was not operational during testing)

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