

SCOUR AROUND VERTICAL WALL BREAKWATERS UNDER RANDOM AND SOLITARY WAVES

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INTRODUCTION

In this study, flow and scour processes around the head of a vertical wall breakwater under random and solitary waves are investigated by physical model experiments. The flow and scour around the head of a vertical wall breakwater has been studied extensively by Sumer and Fredsøe (1997) for regular waves and by Sogut et al. (2022) for solitary waves. Present study extend the first study incorporating random waves and the latter study with higher values of the Keulegan-Carpenter number (KC). Sogut et al. (2022) investigated scour around sharp-edged vertical structures under solitary waves for the Keulegan-Carpenter number range of $(1.87 < KC_s < 6.28)$. This study covers both sharp-edged and round vertical wall head structures for KC_s number range for solitary waves with $O(20)$. In the first stage of physical model tests, the time series of the random wave conditions to be considered in the tests are determined and hard-bottom undisturbed velocity measurements are performed at the location of the structure. In the second stage, the lee-wake vortices are investigated visually, injecting dissolvable dye into the water. At this stage, possible blockage effect by the structure in the wave flume is also investigated through transversal velocity measurements starting from the tip of the structure to the flume wall, to ensure the scour processes are not agitated due to the converging flow effect in the flume. At the third stage, the morphological changes and their time scales around the head of a vertical wall breakwater are investigated.

EXPERIMENTAL SETUP

The experiments are performed in a 1.5 m wide inner flume divided with glass walls of a random wave flume of 28.9 m in length (with a useful length of 20.6 m), 6 m in width and 1 m in depth in Middle East Technical University (METU), Department of Civil Engineering, Coastal and Ocean Engineering Laboratory. Breakwater models are placed into 10 m long sand pit filled up with $d_{50}=0.21$ mm with $d_{84}/d_{16} = 0.58$. (Figure 1). Two different head types are used, which are acrylic made sharp-edged head and round head. The width of the structures is $B=0.06$ m. The flume width is 1.5 m. The length of the structure is selected as 0.54 m (9B), leaving a 0.96 m (16B) opening at the structure location (distance between the structure head and flume wall in transversal direction), wider than the width given in the experiments of Sumer and Fredsøe (1997) to minimize the possible blockage effects (Figure 2). The water depth over the sand pit is kept constant as 0.4 m for random and regular waves, and taken as 0.2, 0.3 and 0.4 m for solitary waves.

The wave approach is perpendicular for all cases. For regular waves, the tested KC range ($KC=U_m T/B$, where U is maximum orbital velocity, T is wave period and B is width of the structure) range is $1.4 < KC < 5.2$. For random

waves, the tested KC number range ($KC_p=U_s T_p/B$, where U_s is significant value of maximum orbital velocity and T_p is peak wave period) is $2.0 < KC_p < 14.8$. For solitary waves, three different water depths ($h/B = 3.33, 5.0, 6.67$, where h is the water depth and B is the structure width) and three different wave heights (H) with $H/B = 0.5 \sim 2.0$ are considered. The tested KC range is $22.4 < KC_s < 29.6$ ($KC_s=U_m T/B$, U_m is the maximum particle velocity, T is the pseudo-period of solitary waves computed using Huang and Yuan, 2010). A total of 21 tests were performed for the round head structure and 17 tests were performed for the sharp-edged structure.

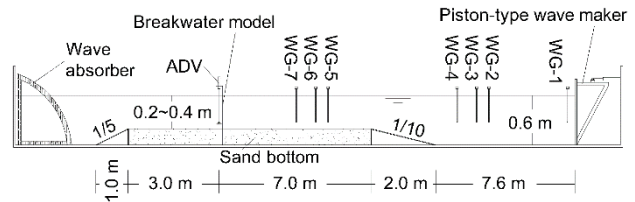


Figure 1 - Location of the gauges and the structure (not to scale).

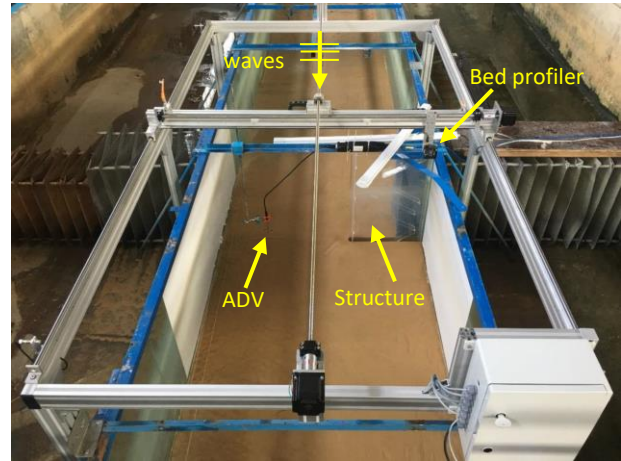


Figure 2 - General view of experimental setup from lee-side.

The lee-wake vortices are observed via an action camera mounted at the lee-side of the structure aimed at a gridded bottom around the structure (Figure 3). Instantaneous scour depths adjacent to the head of breakwater are observed from inside of the structure via a mini camera (Figure 4). Scour hole and the bed level changes around the structure are measured with a bottom profiler equipped with Banner® brand LTF24IC2LDQ model laser sensor before and after each test. Flow velocities are measured by Nortek® Vectrino+ Acoustic Doppler Velocimeter (ADV) with a 200 Hz sampling frequency, mounted 10B distance from breakwater head and 0.05 m above sand bottom. A

priori each test, the sand bottom is levelled to a horizontal plane, compacted by hand with a flat board, and then watered to aid compaction.

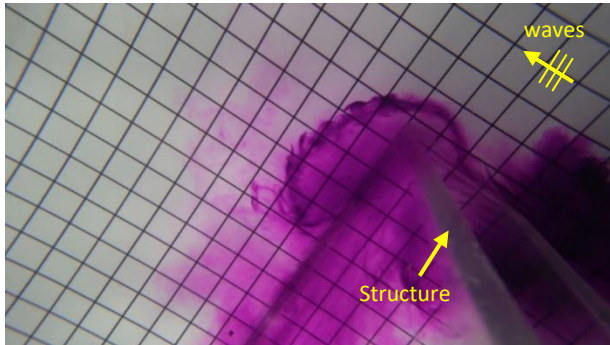


Figure 3 - Flow visualization of lee-wake vortices for sharp-edged structure (grid by 2cm x 2cm).

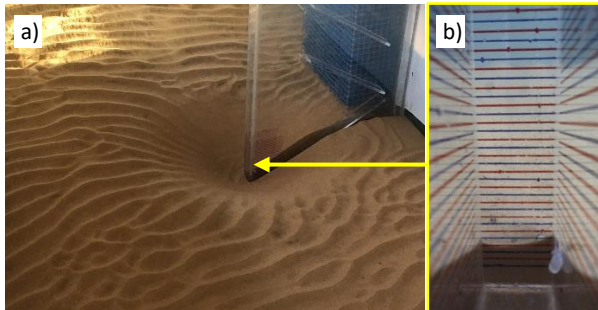


Figure 4 - a) Scoured hole around the structure, b) view of scour hole from inside of the structure via mini-camera.

RESULTS AND CONCLUSIONS

In the experiments, the transversal velocity measurements show that the blockage effect vanishes after 10B transversal distance from the tip of the structure head. The longitudinal and transversal dimensions of the lee-wake vortices under regular waves are observed in agreement with the observations of Sumer and Fredsøe (1997). No significant differences were observed between structure types.

The equilibrium scour depths (S/B), however, are found to be larger than the observations of the latter study by O(5) for both regular waves and random waves (Figure 5). It was observed that scour depths are from 20% to 25% higher for the sharp-edged structures than the round head structures under random waves. Also, the time scale of the scour in random waves is observed to be larger than regular waves with an O(100) for similar KC numbers, referring to a much slower progress of scour under random waves. Furthermore, KC number computed for the random waves using the significant value of the maximum orbital velocity (U_s) is found to represent the sediment transport character around the structure better than the root-mean-square value (U_{rms}).

Test results for sharp-crested head structures under solitary waves are given in Figure 6 together with the test results of Sogut et al. (2022). Scour depths are observed to increase by 15% on average in case of sharp-edged structure tests. For the same solitary wave height, as the water depth increases the particle velocities are

decreased, thus the KC_s values and accordingly the scour depths are decreased.

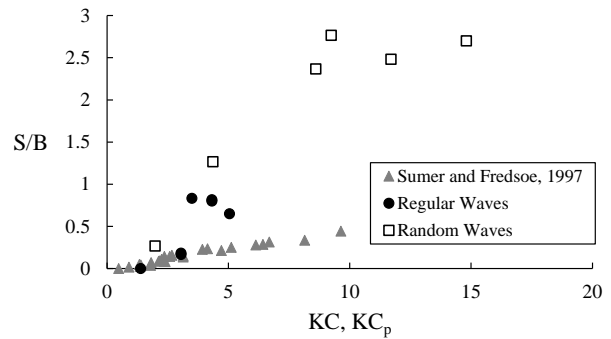


Figure 5 - Equilibrium scour depths around round head structure (KC for regular waves, KC_p for random waves).

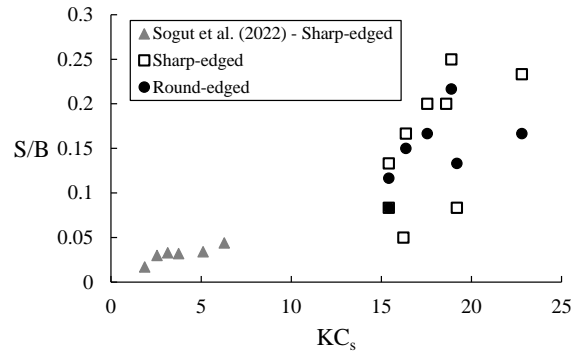


Figure 6 - Equilibrium scour depths for solitary waves.

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