SCOURING MECHANISM BEHIND SEAWALL FROM TSUNAMI OVERFLOW AND OPTIMUM CONDITIONS TO REDUCE TSUNAMI ENERGY WITH AN ARTIFICAIL TRENCH

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Some of coastal structures were collapsed owing to the local scouring by overflows after Tohoku tsunami. In order to understand the characteristics of the scouring behind seawalls due to tsunami, experimental studies and numerical simulation were carried out. The sour profiles formed behind a seawall could be classified into two types. The turbulent kinematic energy has effects on the development of the scour hole. The kinematic energy will decrease with an artificial trench behind a seawall. The rate of energy decay depended on the scale of trench not the shape.

Keywords: laboratory experiment; CADMAS-SUF; k-e turbulence modeling

Introducing

Many coastal structures were collapsed or damaged due to the 2011 Tohoku Tsunami, as shown in Fig.1. There are some reasons why coastal structures were damaged One of them is a large scour holes formed behind the seawalls. The scour, which is often occurred at the base of the structures, can severely endanger the stability of these structures. The scour mechanism by overflows from the seawalls due to tsunami is different from bank overflows because the flow due to tsunami has momentum in the flow direction. Therefore the scour mechanism due to tsunami flow has not been clear. Also it was reported through field surveys after tsunami attacks that tsunami energies decrease by channels or trenches behind hydraulic structures and some areas were protected from tsunami attacks (Tanimoto et al.2012)

Figure 1 Collapsed seawalls due to tsunami

The objectives of this study are to understand the scouring mechanism experimentally and propose the optimum profiles of a trench to reduce tsunami energies through a numerical approach.

Experiments

The experiments were performed in a recirculation open channel flume, which is 12m long, 0.4m deep and 0.4m wide. A schematic drawing of the open channel and the experimental set up is shown in Fig.2. A model seawall was installed at a section 4.0m from the inlet. A fixed and a movable bed behind the seawall were made with a horizontal slope of 0 %. The movable bed was made of coarse sand with a medium grain size of 5mm. The velocity distributions were measured using magnetic

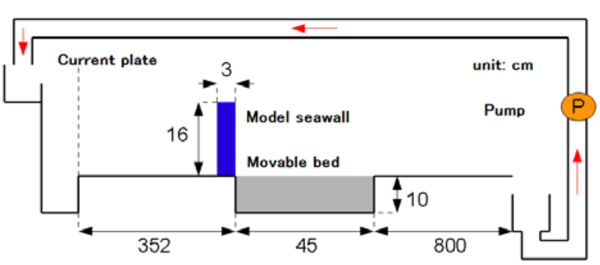

Figure 2 Experimental setup

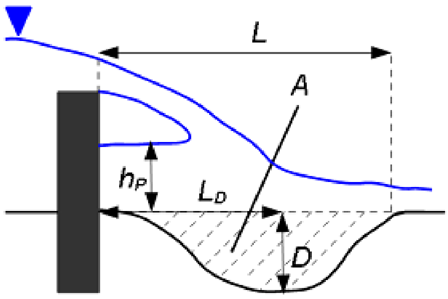

Figure 3 Definition sketch for scour hole

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velocity meters over the fixed bed and the scour holes shape as a function of time was studied with a digital camera image.

The parameters affecting a local scour behind the seawall are shown in Fig.3 In which L is the maximum scouring length, A is the scouring are, hp is the height of pool, D is the maximum scouring depth and L_D is the length from the seawall at the maximum scouring depth. The flow discharge was varied from 0.9 to 2.7 ℓ /s and each test was run for 1 hour, which was sufficient for most of the tests to reach a quasi equilibrium state of scoring. At the beginning the measurement time interval was 10 seconds, being expanded on later.

Experimental results

Figure 4 shows the scouring of the bed and the predominant flow direction during over flowing. The local scour was formed downstream of seawall and the scoured sediments were accumulated as ridge of scour hole.

Figure 4 Scouring downstream of over flow

Figure 5 shows the temporal variation of the parameters in Fig.3. At the beginning the parameter L_D and hp were developed rapidly until 100 seconds, reaching the quasi equilibrium. Values of other parameters, L, D and A are increasing gradually after 100 seconds when the over flow started.

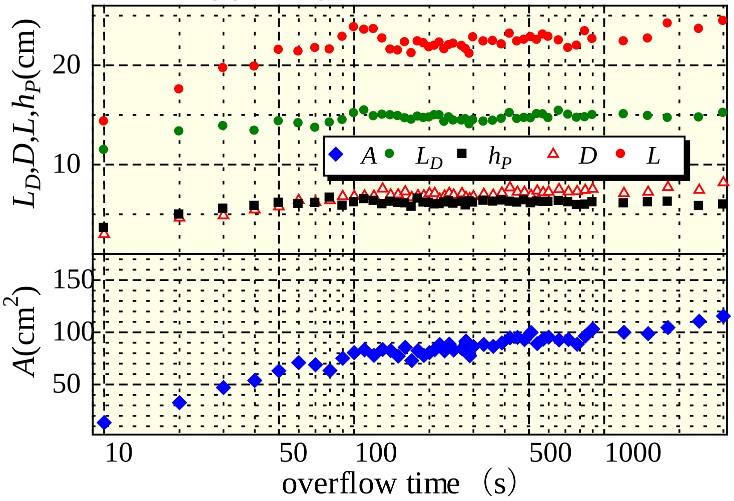

Figure 5 Time variation of scour parameters

Figure 6 shows the scour profiles during and after water-stop. The both scour profiles are the concave shapes, however, they were different each other. With increasing of discharges, a step is formed close to the seawall and the profile shapes for all runs are almost symmetrical about the maximum depth of scour with a slight skewness in the flow direction during overflowing. But the angle of down side slope is approximately corresponding to an angle of repose after water-stop.

Numerical simulations

CADMAS-SURF (<u>SU</u>per <u>R</u>oller <u>F</u>lume for <u>C</u>omputer <u>A</u>ided <u>D</u>esign of <u>Ma</u>ritime <u>S</u>tructure) was applied to simulate the flow over the seawall due to tsunami. CASMAS-SURF (e.g. Coastal

Development Institute of Technology 2001) has been applied to many costal issues and the appropriated results have been obtained. But little attempt has been made

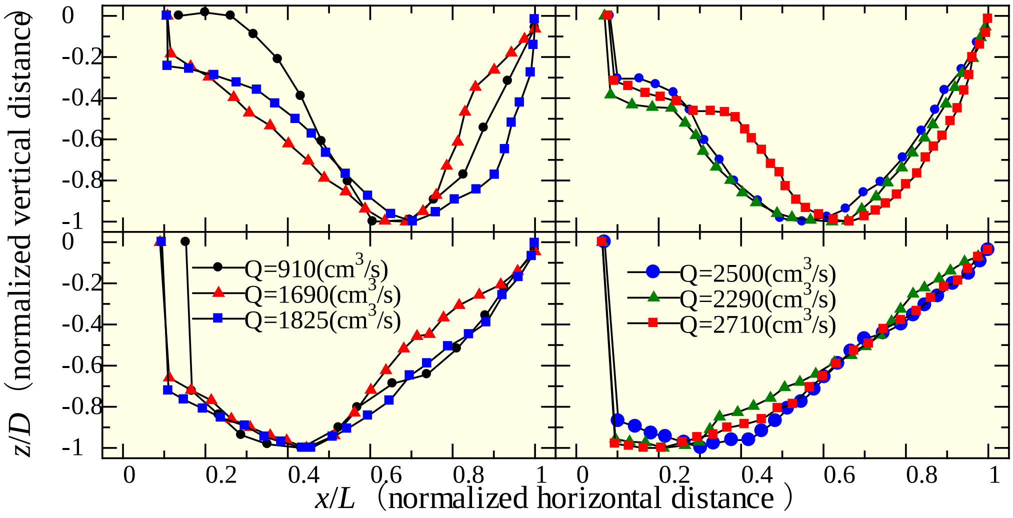

Figure 6 Scour shapes (upper: during over low, lower: after water-stop)

for expanding its application to flows over seawall. CADMAS-SURF is based on the continuity equation, momentum and conservation equation for turbulent kinematic energy k and its dissipation rate ε. In order to handle the free surface of the fluid, the VOF (Volume of Fluid) method was applied. The calculated mesh sizes are changed from 0.5 to 10 cm in the horizontal direction and a constant value of 0.5cm in the vertical direction. The region for calculation is shown in Fig.7. The calculation was carried out under the condition of dam-break flow with changing the initial water level. CADMAS-SURF cannot consider the bed profile changes into the model during calculation, therefore the experimental bed profiles are given as the initial condition. In this calculation, a no-slip condition is applied in the interface between fluid and solid body. It took a couple of hours to obtain the final calculated results.

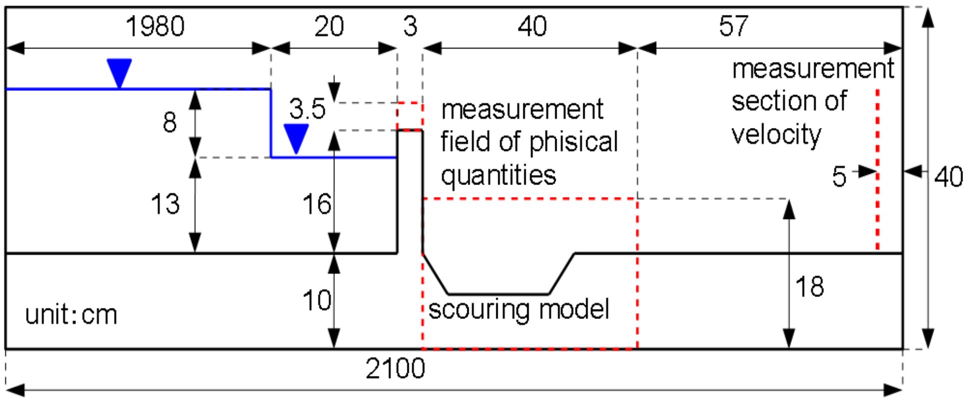

Figure 7 Calculation domain

Simulation results

Figure 8 compares the calculated with the measured results for the velocity vector. The dead water region named “pool” behind the seawall was formed and the agreement for velocity distributions between the calculation and experiment is satisfactory. The attached location of over flow is about 35cm from the seawall.

Figure 9 shows comparison of the calculated velocity with the measured velocity at the same points. The calculated values overestimate the measurement just a near the bed. But it was noticed that the appropriated results on over flows have been obtained.

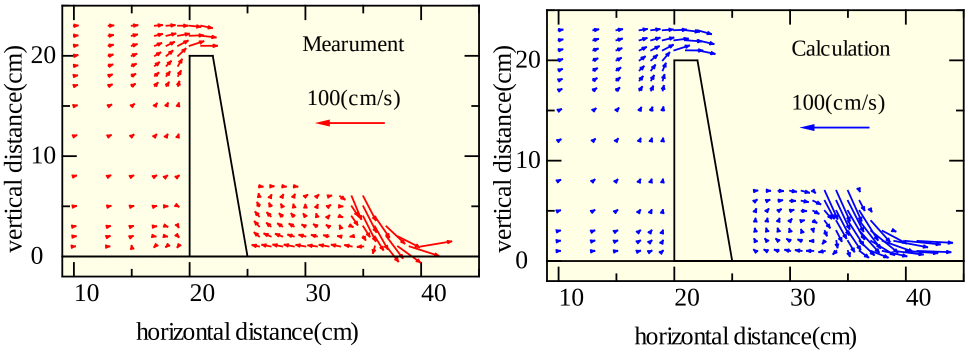

Figure 8 Comparison of velocity vectors

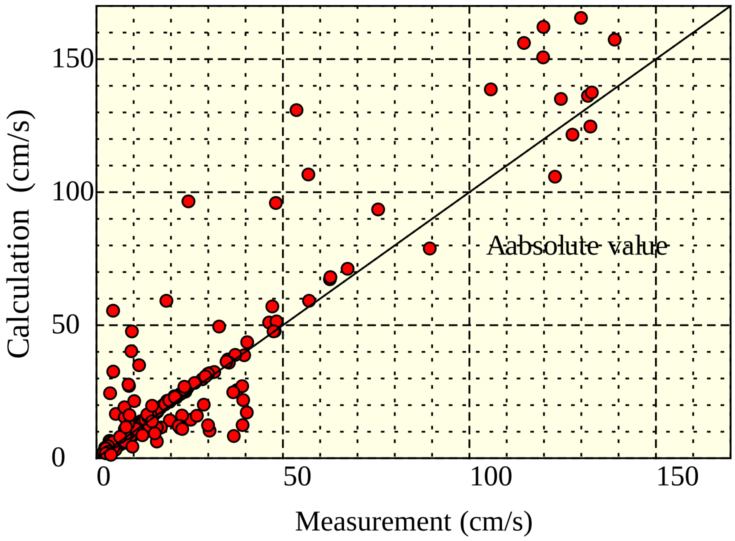

Figure 9 Comparison between calculation and measurement

Figure 10 shows time variations of water depth and averaged velocity over the crown of a seawall. At the beginning the time variations for calculation are remarkable. Because the water surface oscillates by the impact due to dam break flow were happened. But after 10 seconds later, the calculated results become approximately constants, corresponding to experimental ones. Therefore the subsequent results were used ones after 20 seconds.

Figure 11 shows velocity vectors in the scour region at 10 and 60 seconds after overflows. The red line in figures stands for the temporal scour profile. In the initial stage of overflowing, the velocities were so fast, therefore the scour is progressing. After free falling jet reached the water surface in the scour hole, clockwise at the upper side and anti-clockwise flows are formed in the scour hole. Especially anti-clockwise flow can be seen at the down side, corresponding to Fig.4.

Figure 12 shows the turbulent kinematic energy and its dissipation ratio. When the size of scour hole is small, the peak value of the turbulent kinematic energy is seen close to the right side of scour hole. Therefore the scour would expanded toward the down side stream. On the other hand, its dissipation ratio was small there.

With progress in time (t=60 second), the peak value of turbulent kinematic energy decrease and its location moves more down side stream. On the other hand, the location where the ratio of the turbulent kinematic dissipation has peaks move toward the seawall. When the scour hole attains an equilibrium state, the distribution profiles of turbulent kinematic energy and its dissipation ration are very similar and the both of peak value are seen at almost same position.

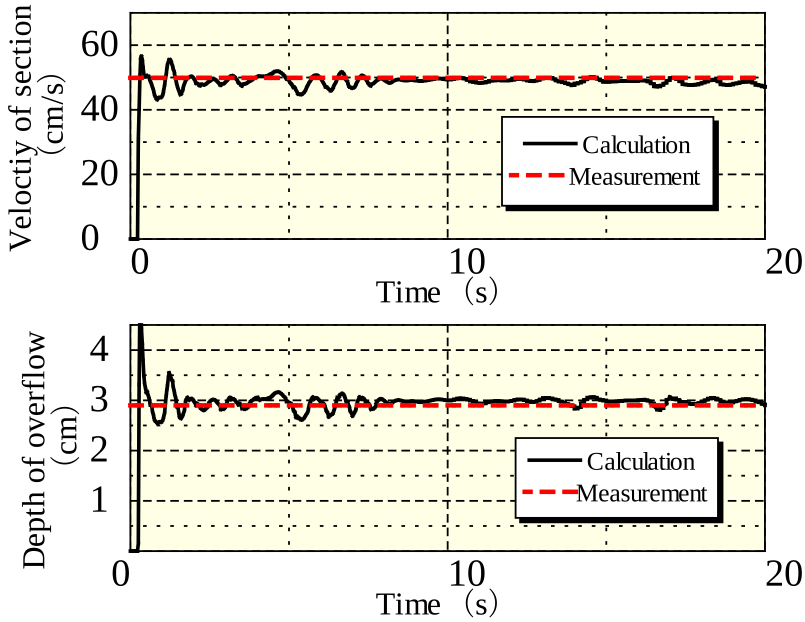

Figure 10 Time variations of velocity and water depth

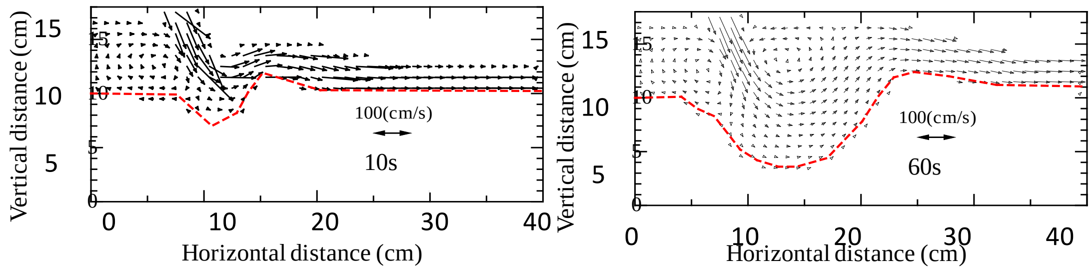

Figure 11 Velocity vectors

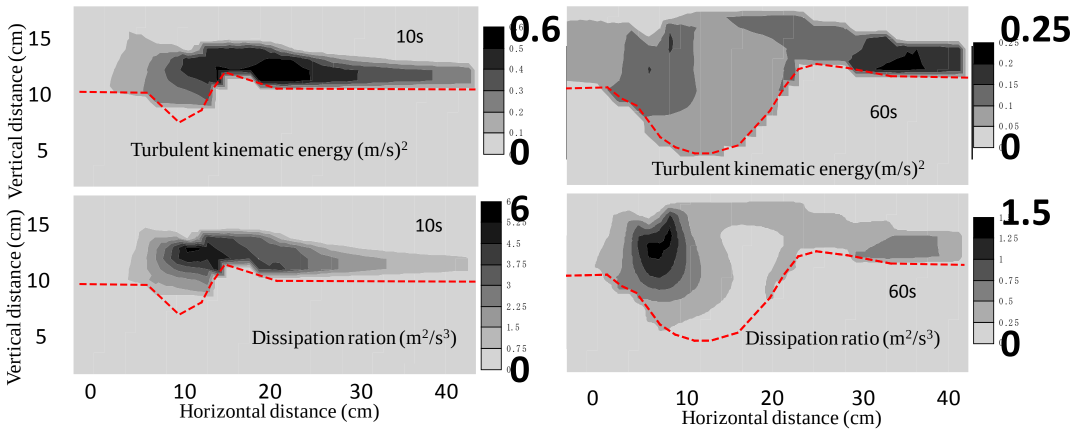

Figure 12 Turbulent kinematic energy and its dissipation ratio

Energy damping by an artificial trench

In order to estimate the amount of tsunami energy changes due to differences of a scour hole area, scour holes of any size were given in numerical simulation as an initial bed profile and the averaged velocities at a reference cross section of down side stream were obtained. Figure 13 shows the relationship between the mean velocities and scour hole areas. With increasing of a scour hole area the mean velocity is decreasing more less 8000 square millimeters.

Figure 14 shows the averaged velocities at a reference cross section of down side stream with the artificial trench in any shape and same size. The artificial trench is two types; rectangle and trapezoid. The trenches can help attenuate average velocities; approximately 60% of velocities without a trench. Also a trapezoid trench is more effective than a rectangle trench about velocity decreasing.

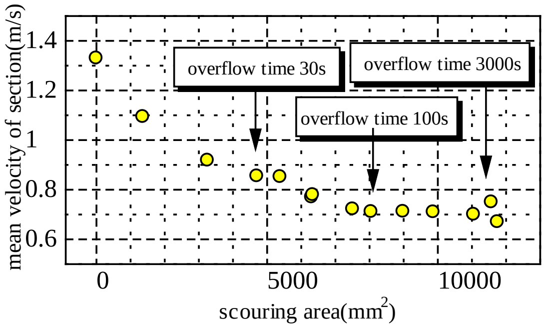

Figure 13 Relationship between mean velocities and scour hole area

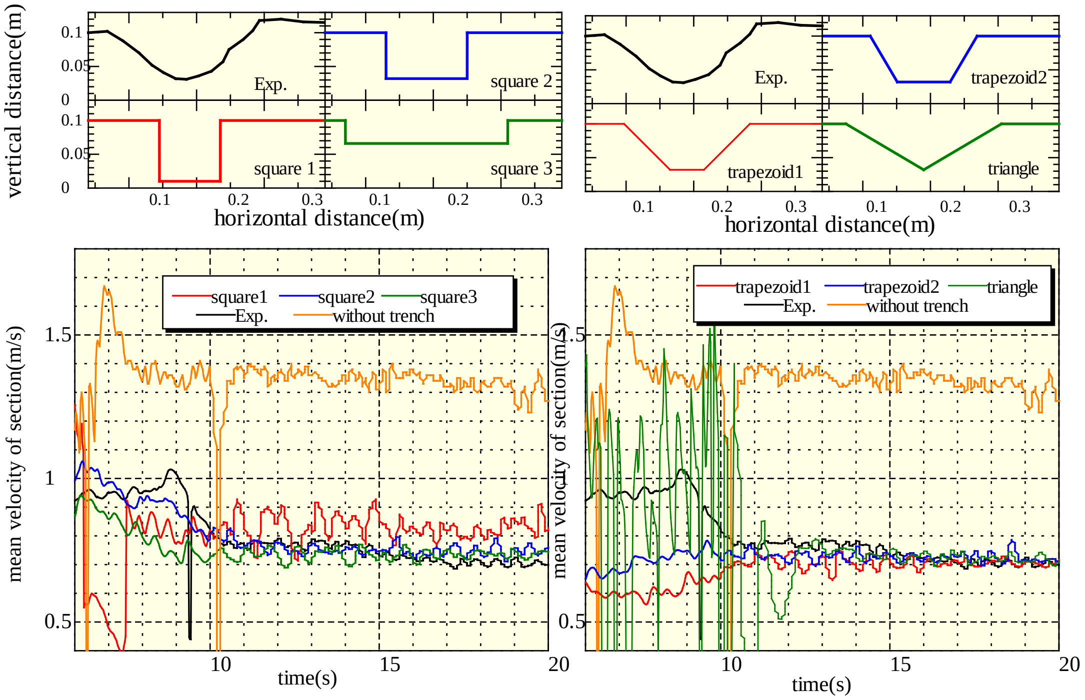

Figure 14 Mean velocity changes due to trench shape

Conclusions

①Scour profiles behind seawall have two kinds during flows, changing after stopping flow.
②A scour hole is rapidly developing immediately from the start of the over flow, growing gradually.
③In the process of development of a scour hole, the turbulent kinematic energy is large .
④The both of the distribution profiles of the turbulent kinematic energy and its dissipation ratio are similar at the equilibrium scour hole.
⑤An artificial trench behind seawall could reduce tsunami energy. A trapezoid trench is more effective for reducing energy than a rectangle trench.

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