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論 文 要 旨

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専　攻	Urban Innovation	コース	Urban Innovation
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論文題目	SPH simulations on failure of a breakwater mound due to tsunami scour under experimental conditions		
和訳または英訳	実験で観察された津波越流時の防波堤マウンドの洗掘挙動に関する SPH シミュレーション		

Failure of breakwater during tsunami causes extensive damages to the human lives and properties. Therefore it is very important to investigate the failure mechanisms of breakwater due to tsunami. Many studies were conducted to investigate the failure mechanisms of a breakwater but a few concentrated extensively on scour of landside mound. The study has attempted to investigate the failure mechanism of breakwater focusing on the deformation behavior of mound due to scour with experimentally as well as numerically. Moreover, it has proposed some counter measures and the changes of deformation behavior of the mound due to introduction of the countermeasures were also observed.

For experimental investigation, the study has prepared a model of Kamaishi breakwater with a scale of 1/200 of the prototype. Overtopping water falling to the landside mound combined with seepage flow was prepared in the experiment to reproduce the natural tsunami attack in caisson type breakwater system. To investigate scour mechanisms step by step the study had conducted experiments with several cases for observing the seepage flow effect only, overtopping water without seepage flow and finally combination of seepage and overtopping effects. The study has found that scour due to overtopping water in the mound increased when seepage flow was combined together. The experimental study has found that existence of hydraulic gradients between seaside and landside of the breakwater is a key parameter to accelerate the scour depth. It has also found that mound showed simultaneous scour and collapse behavior during the process of scouring. Therefore, countermeasures were designed with an ability to reduce the hydraulic gradients and also to control the collapse of mound. It was found that maximum hydraulic gradient was reduced from 0.44 to 0.30 with the introduction of the countermeasures. Collapse of mound was found to be controlled due to physical reinforcement effect. Moreover, it was found that countermeasure had changed the transportation characteristics of the scoured soils. As a result the scour depth and width were found to be significantly reduced when countermeasures were installed in the experiment.

The study has also attempted to simulate numerically the deformation behaviors of mound due to scour. For numerical simulation it has developed a smoothed particle hydrodynamic (SPH) code with capability of simulating water and soil together. Water was developed as a Newtonian fluid with viscosity and soil was developed as an elastic plastic material with Drucker-Prager failure criteria. The study has conducted simulation of couette flow, shear cavity flow, dam break flow to prove the accuracy of the developed SPH code for fluids. Moreover, simple shear test for soils, granular flow and bearing capacity test for soils were conducted to validate the SPH code for soils.

Additionally, flow through the porous soil was simulated to verify the coupling of water and soil. It was found that SPH codes for fluids, soils and coupling were successful in simulating such benchmark cases.

Deformation behavior of mound due to scour observed in the experiment was associated with water fall impact, particle detachment, scour and collapse, transporting and resettling of the scoured soils. The developed SPH code has used a simplified scour model based on seepage force to take into account the high impact force due to fall of overtopping water as well as the seepage flow from the seaside. Moreover, the study has considered the critical strength of soil in the scour model that is a determinant to initiate scour process in grain level. The study has simulated the deformation behavior of mound during scour with and without considering seepage flow from seaside. The study has found that developed SPH code for scour was qualitatively successful in simulating the deformation behavior of mound as observed in the experiment.

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