Using New Technology in Disaster Risk Reduction: Particle Method Analysis

New technology: Particle methods

Particle methods are numerical analysis methods that simulate the behavior of continuous masses by modeling all substances—including fluids—as continuous masses of particles. We at NEWJEC have engaged in joint research with Professor Hitoshi Gotoh of the Kyoto University Graduate School to use particle methods in various examinations of phenomena associated with severe deformation that cannot be simulated using general particle methods (e.g. the finite element method). We are also leveraging our know-how of particle methods to develop an evacuation simulation model for analyzing crowd evacuation behavior with individual people as constituent elements.

Case example 1: Tsunami causes breakwater damage

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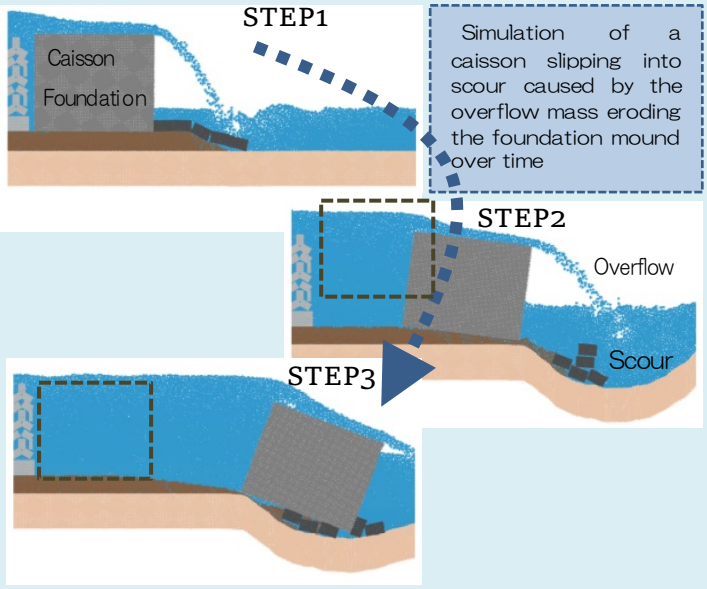
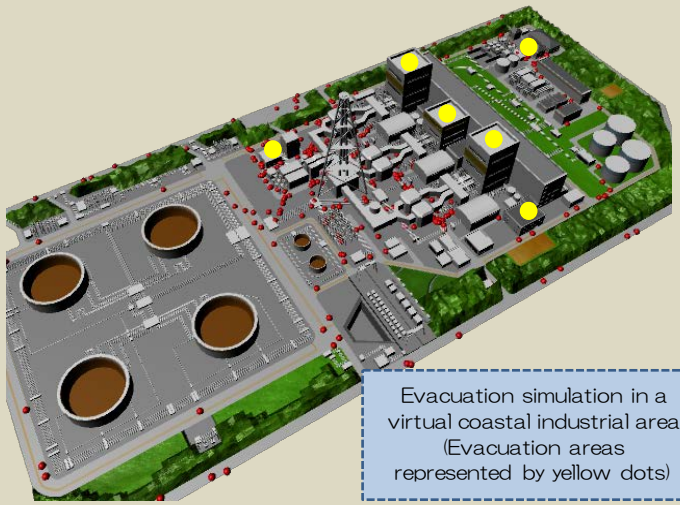


Simulation of a caisson slipping into scour caused by the overflow mass eroding the foundation mound over time

Case example 2: Evacuation simulation

Rapid, smooth evacuation is the key to survival for people living and working in coastal areas when tsunami are approaching. Therefore, it is important to ensure proper evacuation routes and stairways as well as evacuation areas. Unfortunately, evacuation drills and other efforts taken during normal times rarely replicate the urgency with which people must evacuate during disasters.

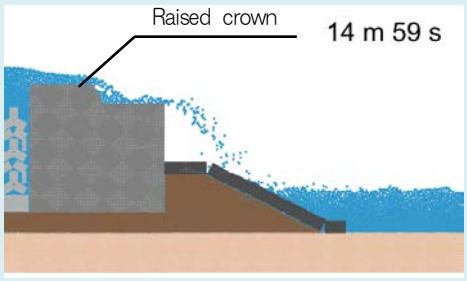


Evacuation simulation in a virtual coastal industrial area (Evacuation areas represented by yellow dots)

Accordingly, evacuation simulations that realistically depict how crowd evacuation behavior unfolds in a virtual environment are an effective means of replicating the urgency. This method goes beyond setting out appropriate evacuation routes and areas, and it should help residents learn to visualize what to do when a tsunami approaches.

Demonstration of the effects of countermeasures (e.g. breakwater widening)

Using riprap or the like behind breakwaters to effectively widen them demonstrably limits caisson slippage and scour caused by overflow mass.



Ascertaining the time required for evacuation

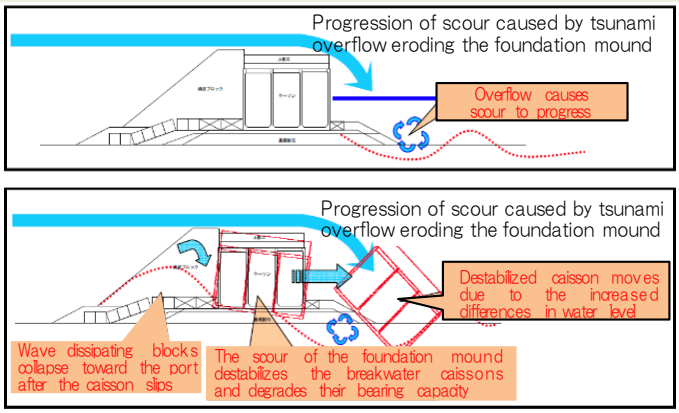
Those from which it takes the most time to reach evacuation areas.

Particle method-based tsunami-resistance analysis for breakwaters (simulating damage, demonstrating the effects of countermeasures)

Introduction

The damage to a breakwater north of the Hattaro district of Hachinohe Port is a typical example of the damage caused by the tsunami triggered by the 2011 Tohoku Earthquake. Although the breakwater caissons withstood the tsunami wave force, they slipped down into scour that occurred when overflow from the tsunami eroded the foundation mound. This type of damage was not envisioned, and it is difficult to confirm the safety of the caissons with only a conventional stability comparison.

We at NEWJEC are developing technology (with Professor Hitoshi Gotoh of the Department of Civil and Earth Resources Engineering of the Kyoto University Graduate School of Engineering) in which the use of particle methods makes it possible to simulate damage to breakwater caissons and demonstrate the effects of countermeasures.



Source: Materials from the Third Advisory Panel for Tsunami and Earthquake Countermeasure Technology for Ports and Harbors in Tohoku

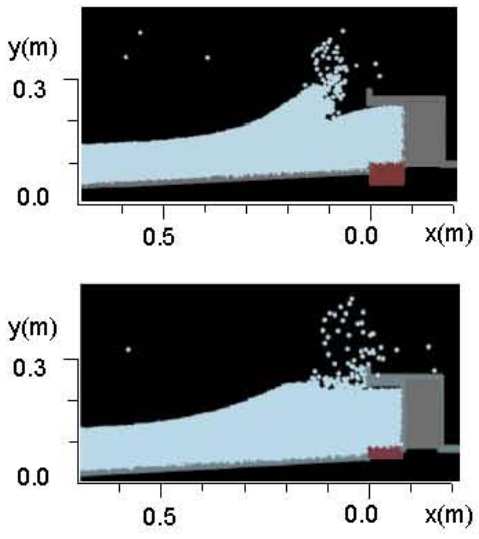
Damage to a breakwater north of the Hattaro district of Hachinohe Port

Example of damage to a breakwater (reconnaissance survey of Miyako/Kuji)

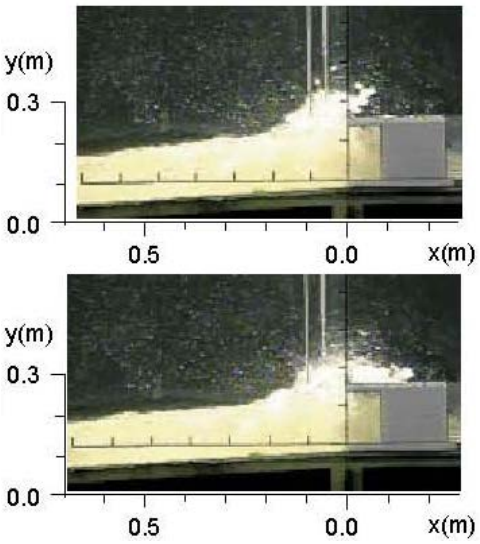
■ Characteristics of particle method-based analysis

- Enables visualization of splitting and merging of waves caused by waves breaking and complex motion phenomena of sand and structures.
- Enables determination of physical quantities (e.g. wave pressure, overflow volume, structure movement) required for design conditions.
- With no computational grid as in the case of finite difference and finite element methods, enables the processing of phenomena involving severe deformation.

【Simulation results】



【Hydraulic model experiment results】



We ran a simulation to see what happens when a wave breaks and flows over an embankment with one open end facing the wave and a protrusion on the top.
Compared to the hydraulic model experiment, the simulation produced better reproductions of the phenomena and yielded precise overflow amount calculation results compared to experimental values.