Development of disaster damage prediction system for flotsam mixed tsunami and tsunami damage mitigation using offshore Mega-floating Structures

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Abstract

The behavior of flotsam mixed tsunami is investigated by a new type of integrated super computation using ALE method (Arbitrary Lagrangian-Eulerian Method) and SPH method (Smoothed Particle Hydrodynamics Method). The fully hydrodynamic governing equations without shallow-water theory were used to calculate tsunami characteristics of water flow with flotsam and debris. Our ALE model predicted the effect of fluid-solid coupled interaction in a limited region, and the model predictions were favorably compared with the scale modeling analysis. This study, our first attempt to simulate the degree of damage caused by the flotsam mixed tsunami, can help optimize the strength of seashore buildings and structures against future tsunami threats. This study also can help estimate structural damage that can be caused by large-scale natural disasters like hurricanes, storms and tornados, and help to develop effective mitigation tools and systems.

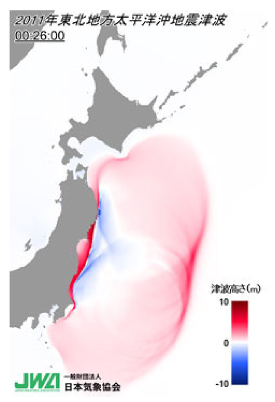
Background

A recent numerical study of tsunami simulation conducted by oceanic scientists predicted damage in a relatively large, approximately several 100km square area [1-3]. Their model used some assumptions including the shallow-water theory [4-7].

Although conventional simulation techniques success for predicting tsunami height and inundation area, because of the use of a shallow-water approximation (*vertical velocity profile is assumed uniform*), with respect to the impact force exerted on the object structure cannot be accurately predicted.
Especially for predicting damage of land and buildings in relatively small area, such as an industrial plant, it is not possible to apply for conventional situation procedure.

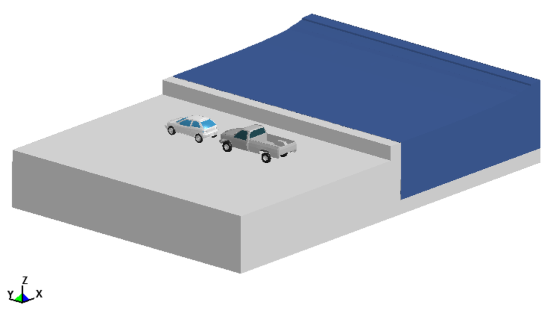
Objectives

We are focusing on a relatively limited region to be analyzed, such as power plants and industrial plants, taking into account the interaction of the structure and the tsunami, fracture behavior and structural deformation.
We are also developing a simultaneous simulation method for the flotsam mixed tsunami behavior of its interface causing deformation when in collision with structures.
In addition, the scale modeling analysis for flotsam mixed tsunami is conducted and compared with numerical results.



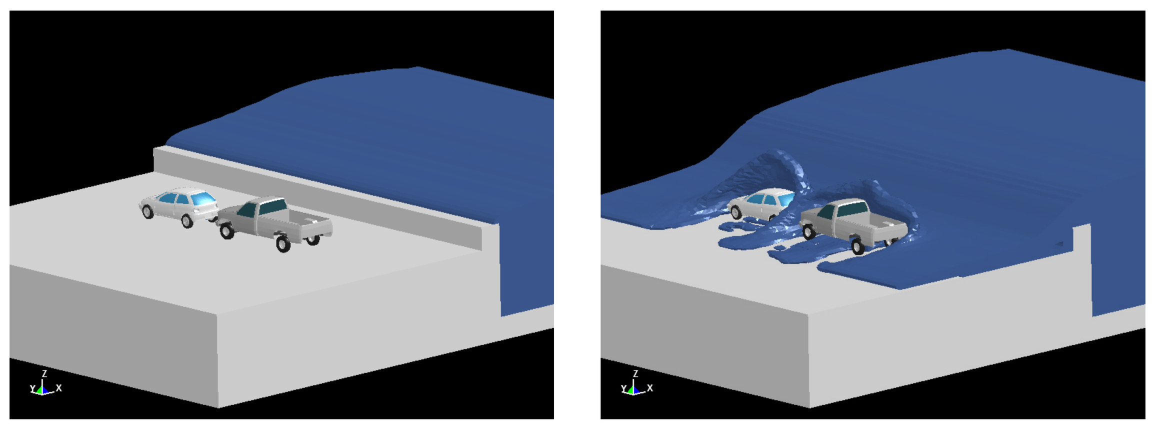
Wide region

Conducted by JWA (Japan Weather Association)



Narrow region (Precise approach)

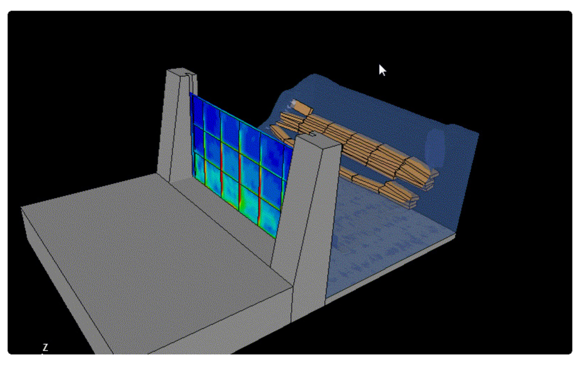
2. Computational result of the flotsam mixed tsunami behavior



The hydrodynamic impact behavior of the tsunami on the vehicles is reasonable simulated by the drifting behavior of the vehicles. It was found that the vehicles were covered by tsunami and were washed by the tsunami's inertia.

The vehicle is covered with tsunami and is washed with tsunami's inertia

The lumber mixed tsunami's hydrodynamic impact behavior to the water gate.



Computational geometry for tsunami struck to water gate

Specifications

- Tsunami: **Euler** element（260288 elements）
- Water gate：**Lagrange** element（22728 elements）(Concrete section：Rigid body, Water gate：Elastic-plastic body）
- Flotsam: **Lagrange** elements（Rigid body, Specific weight: 0.9, Total mass 1.1 ton）（1260 el elments）
- Flow velocity of tsunami: 3.0 m/s
- Size of water gate: width: 5.0m, height: 2.5m

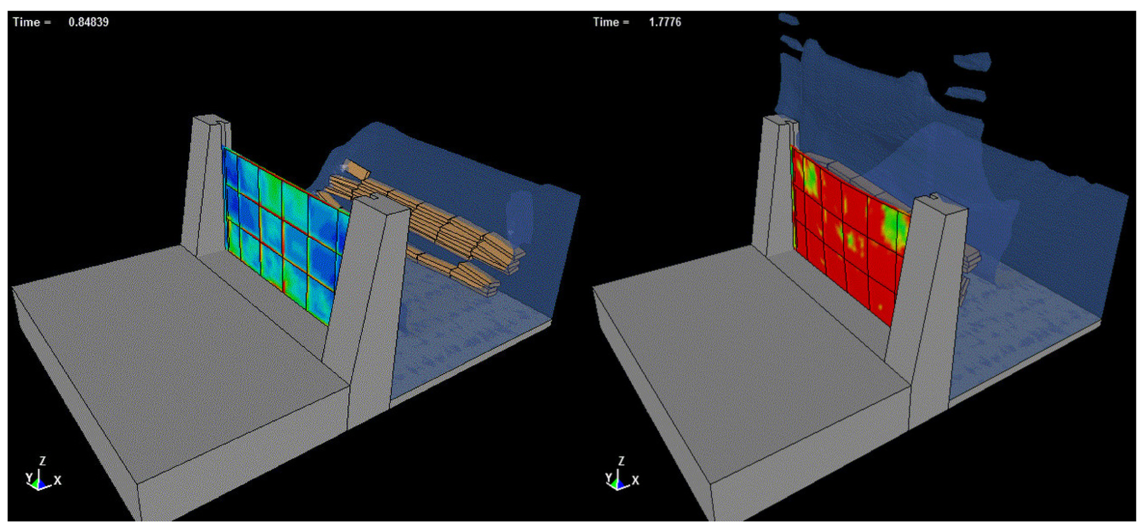
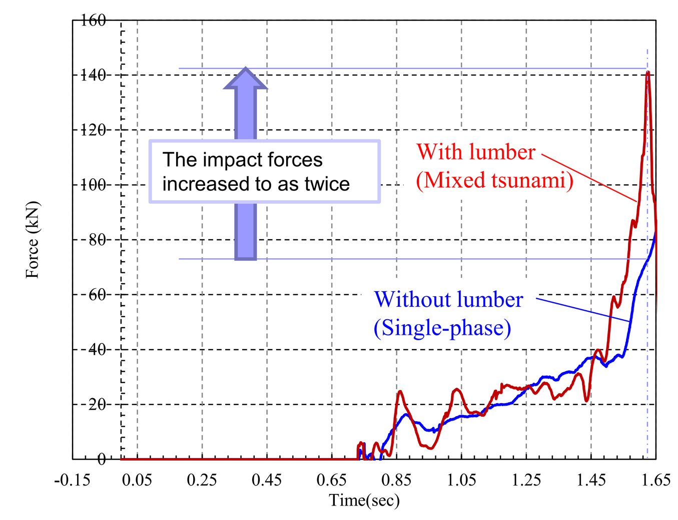


Fig. 4. Lumber mixed tsunami's hydrodynamic impact behavior on the water gate.

The lumber mixed tsunami's hydrodynamic impact behavior to the water gate.

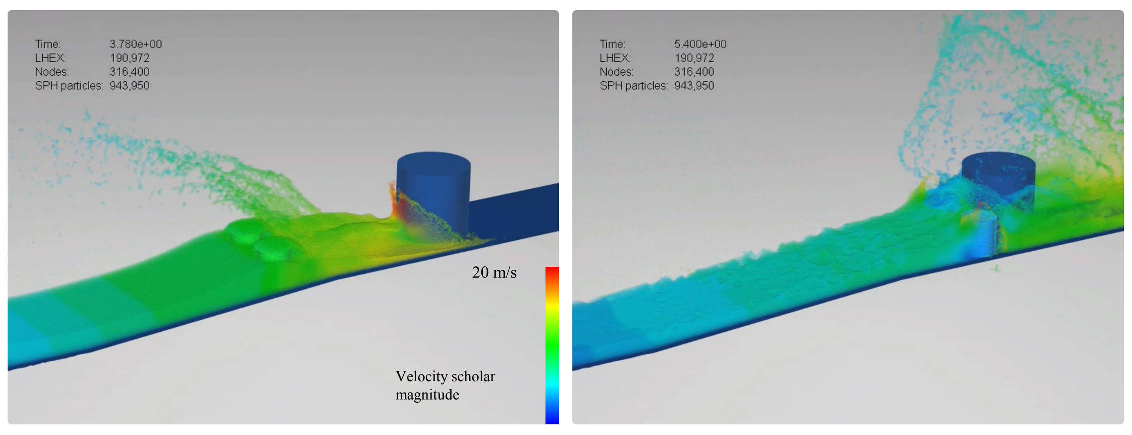


Impact force of lumber mixed with a tsunami was two times greater than that of single phase tsunami (without flotsam case)

Effect of flotsam (lumber) in the tsunami on the impact force to the water gate

Computational result of the flotsam mixed tsunami behavior by **SPH method (Smoothed Particle Hydrodynamics Method).** *Two small tanks are rolled up and are impacting to the large tank.*

Simulation result

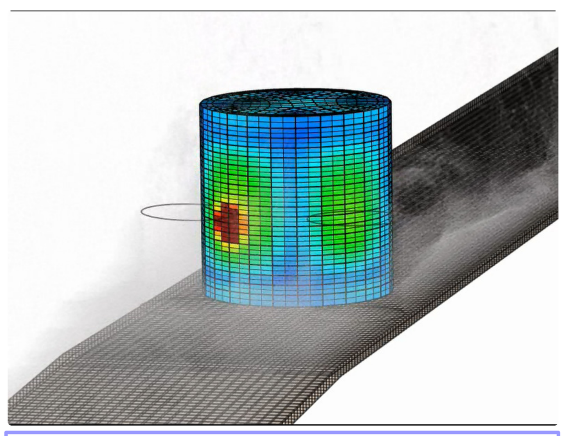


(a) Small tank mixed tsunami flow characteristics and its impact behavior on a land structure

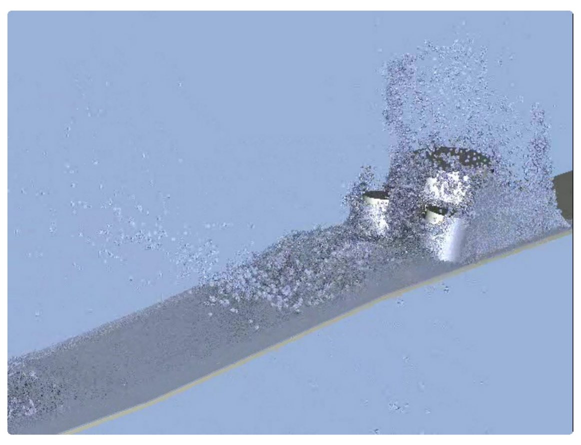
The flow characteristics and behavior of its interface deformation and collision with the land structures were clearly simulated.

Computational result of the flotsam mixed tsunami behavior by **SPH method (Smoothed Particle Hydrodynamics Method).** *Two small tanks are rolled up and are impacting to the large tank.*

Impact stress profile of the land structure with flotsam mixed tsunami impingement; an elastic-plastic body assumption was applied for the land structure



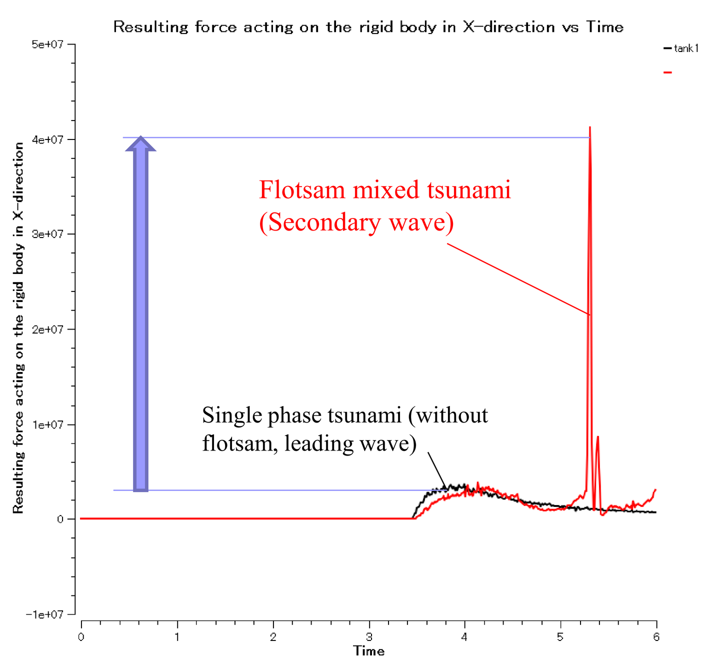
When the flotsam impinges:
Maximum impact stress: 100 MPa
Corresponding maximum plastic strain: 0.0015
is numerically obtained.



Flotsam mixed tsunami (Secondary wave, Pov-RAY rendering)

When the two small tanks impinge the larger tank land structure the maximum impact stress was 100MPa, and a corresponding maximum plastic strain of 0.0015 was numerically obtained.

Computational result of the flotsam mixed tsunami behavior by **SPH method (Smoothed Particle Hydrodynamics Method).** *Two small tanks are rolled up and are impacting to the large tank.*



Impact force of tank to land structure

Single phase tsunami (without flotsam, leading wave):
Maximum 3.5 MN

Flotsam mixed tsunami (Secondary wave)
Maximum: 42 MN

The impact force magnitude of flotsam (small tank) mixed tsunami was **over 10 times** than that of single phase (without flotsam case) tsunami.

Effect of flotsam mixing with tsunami on the impact force with a land structure

Conclusion

1. Two different supercomputing approaches, including the ALE method (Arbitrary Lagrangian-Eulerian Method) and SPH method (Smoothed Particle Hydrodynamics Method), were used to investigate flow characteristics of a flotsam mixed tsunami.
2. The flotsam mixed tsunami behavior associated with interface deformation and collision with land structures was reasonably reproduced by the supercomputing methods.
3. The impact stress profile of land structures with flotsam mixed tsunami impingement was computationally predicted. As a result, it was shown that the impact force of a flotsam mixed tsunami would be over 10 times greater than that of single phase tsunami (without flotsam case). It was also found that the scale effects of mixture density and density differences between flotsam and seawater is the dominant factor for tsunami impact force and damage prediction.