Experimental study of tsunami wave load acting on storage tank in coastal area

Graduate School of Engineering , Osaka University	○**Wataru Kunimatsu**
Graduate School of Engineering , Osaka University	Shinji Nishiyama
Graduate School of Engineering , Osaka University	Tomohiro Furuse
Graduate School of Engineering , Osaka University	Shin-ichi Aoki
Graduate School of Engineering , Osaka University	Susumu Araki
Naruo Technical Research Institute, Toyo Construction Co	Yasuo Kotake

Outline

1. Introduction
2. Experimental set-up
3. Experimental results
   3.1 The horizontal component of the tsunami wave load
   3.2 The vertical component of the tsunami wave load
   3.3 Comparison without and with the surrounding tanks
   3.4 Characteristic of impulsive force on a tank
4. Conclusion

1.Introduction

Introduction

Energy resource like petroleum or highly pressurized gas are stored in cylindrical tanks or spherical tanks

Industrial parks near coastal area

◆The characteristics of the damage in Tohoku earthquake

✓ mainly storage tanks were damaged
✓ the damage to their parks was spread all over the parks by the tsunami

Introduction

◆For the Nankai trough earthquake

Damage to industrial parks will lead to damage to the hinterland

So, we need to

estimate the tsunami wave load acting on storage tanks accurately

take countermeasures against tsunami striking

But research on industrial parks at coastal area hasn't been done enough

So we have to investigate these matters

not only fundamentally but also practically

Introduction

◆ Point at issue of estimating forces

it is difficult to

estimate tsunami wave load acting on a storage tank

from a tsunami height in front of harbors

◆ Purpose

we investigate

- **The fluid motion** in a harbor using a wave basin

in which cross-shore and longshore fluid motion is generated

- **The applicability of conventional formula**

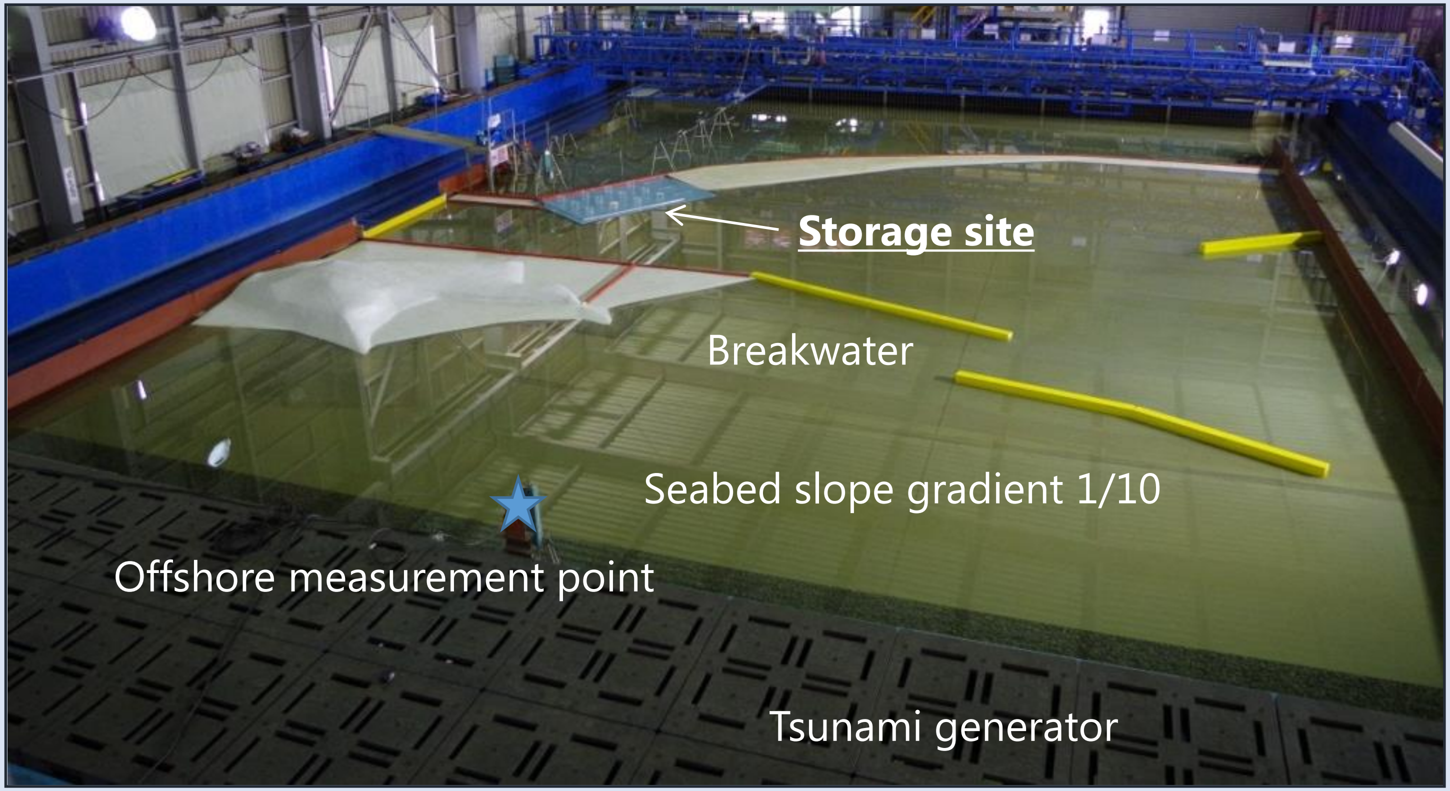
to estimating tsunami wave load acting on a storage tank

2.Experimental set-up

Experimental set-up

☐ Wave basin

Model scale is 1/100



Toyo Construction Co.,LTD. Naruo Technical Research Institute
Wave basin with the tsunami generator（30m×19m）

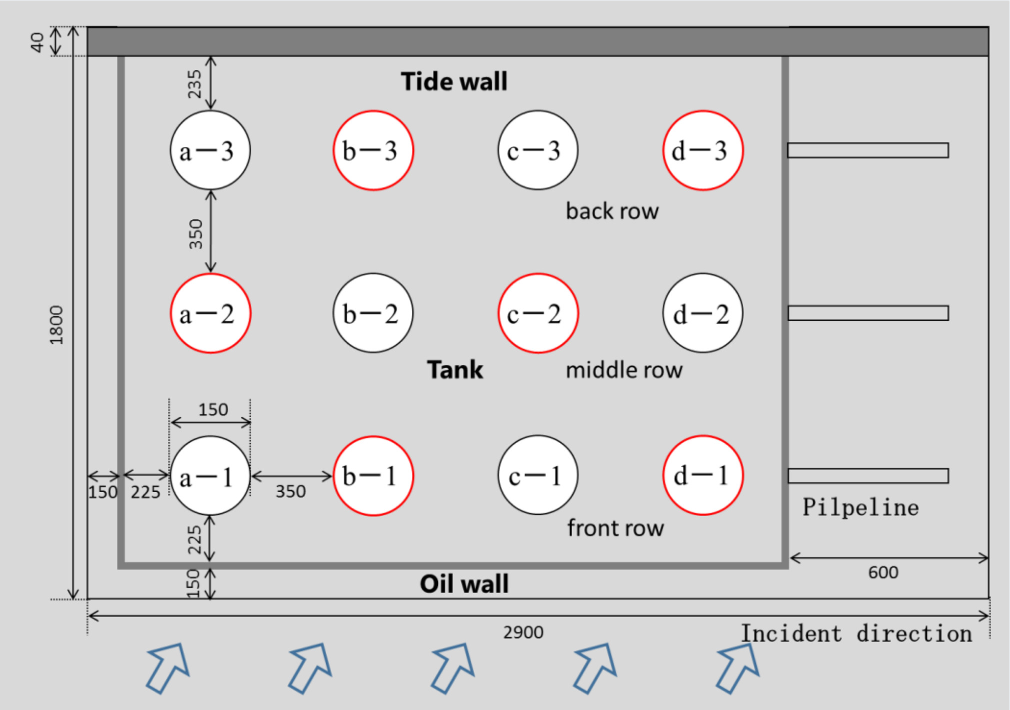
Experimental set-up

- The storage site

○ : Measurement point of tsunami wave load

<u>The circular cylinder</u>

diameter 15cm/height 10cm



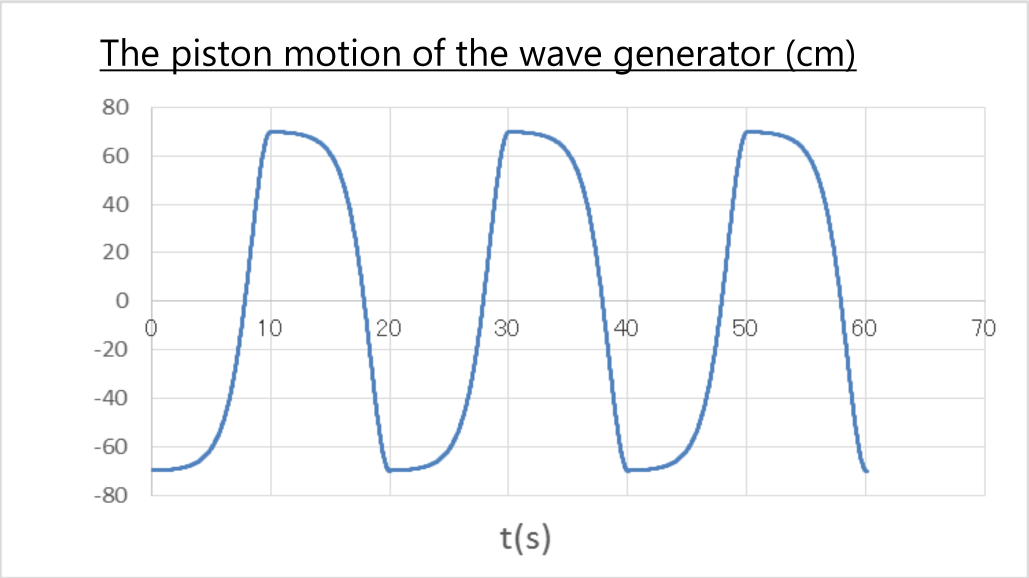
<u>Without the surrounding tanks</u>

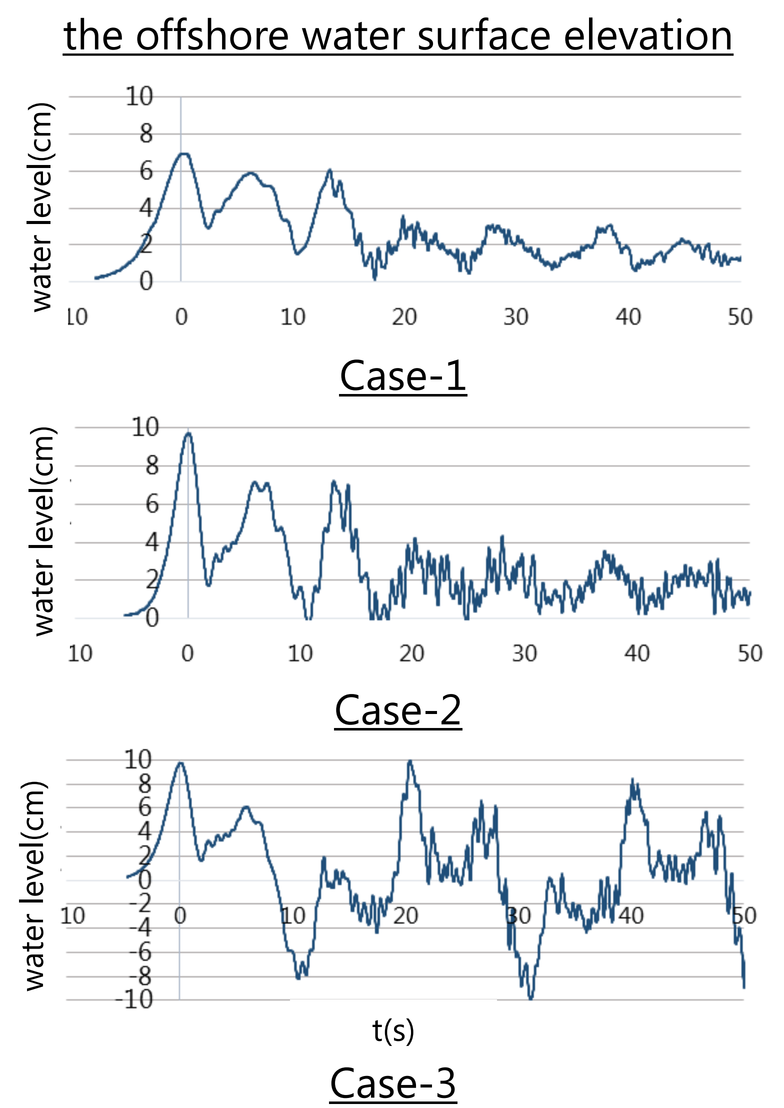
<u>With the surrounding tanks</u>

Experimental set-up

☐ The tsunami wave generation

	Maximum water surface elevation at the offshore point	Wave generator stroke
Case-1	6.9cm	140cm/15s
Case-2	9.7cm	140cm/10s
Case-3	repeating Case-2 three times	





Experimental set-up

◆ Experimental procedure

We measured

① inundation depth and velocity at all points

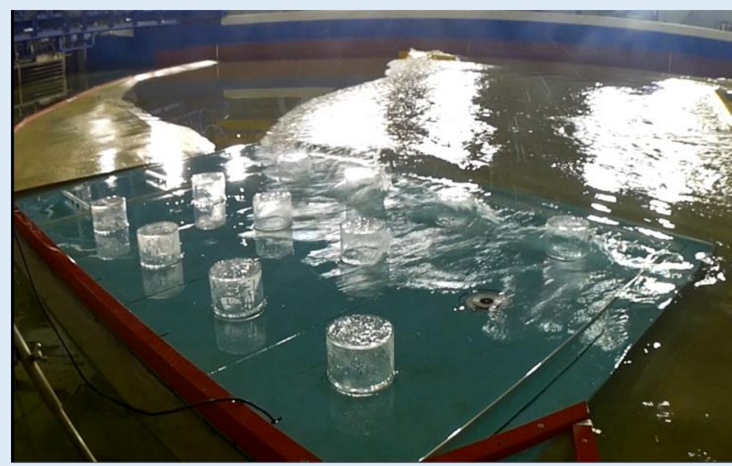
without any tank or oil wall which surrounds the storage site

② inundation depth, velocity and tsunami wave load acting on a tank at each of 8 red points without surrounding tanks

③ inundation depth, velocity and tsunami wave load at each of the 8 red points with surrounding tanks

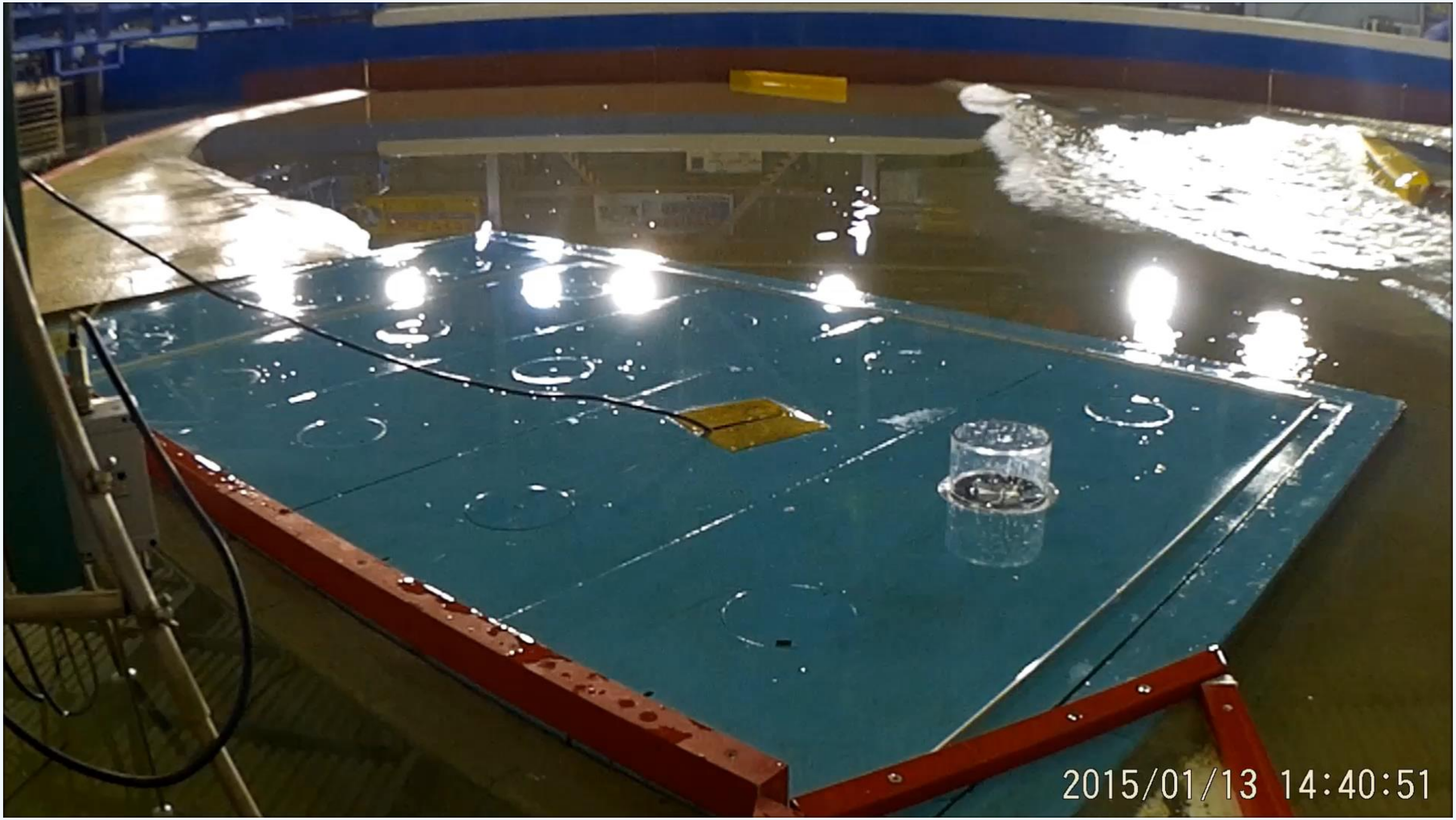
we didn’t measure

inundation depth, velocity and tsunami wave load at the same time



3.Experimental results

The movie of this experiment

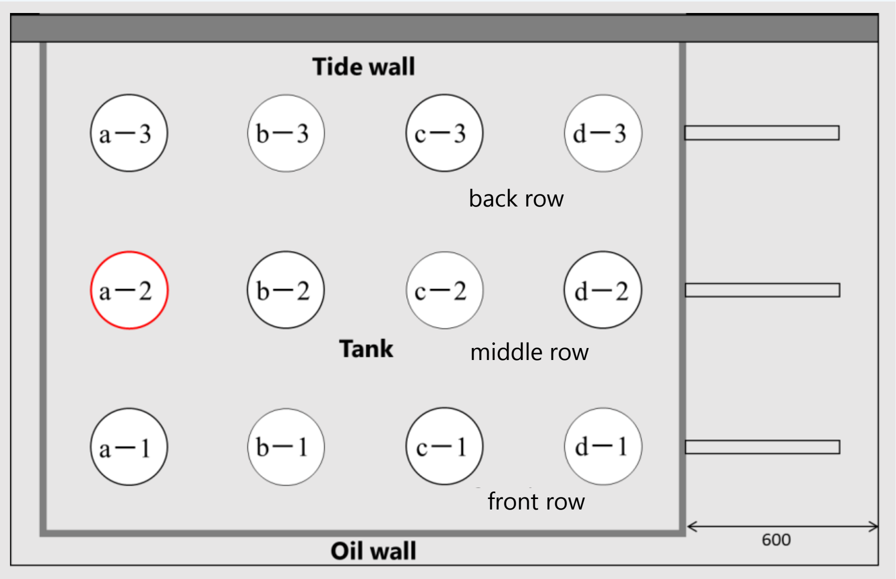


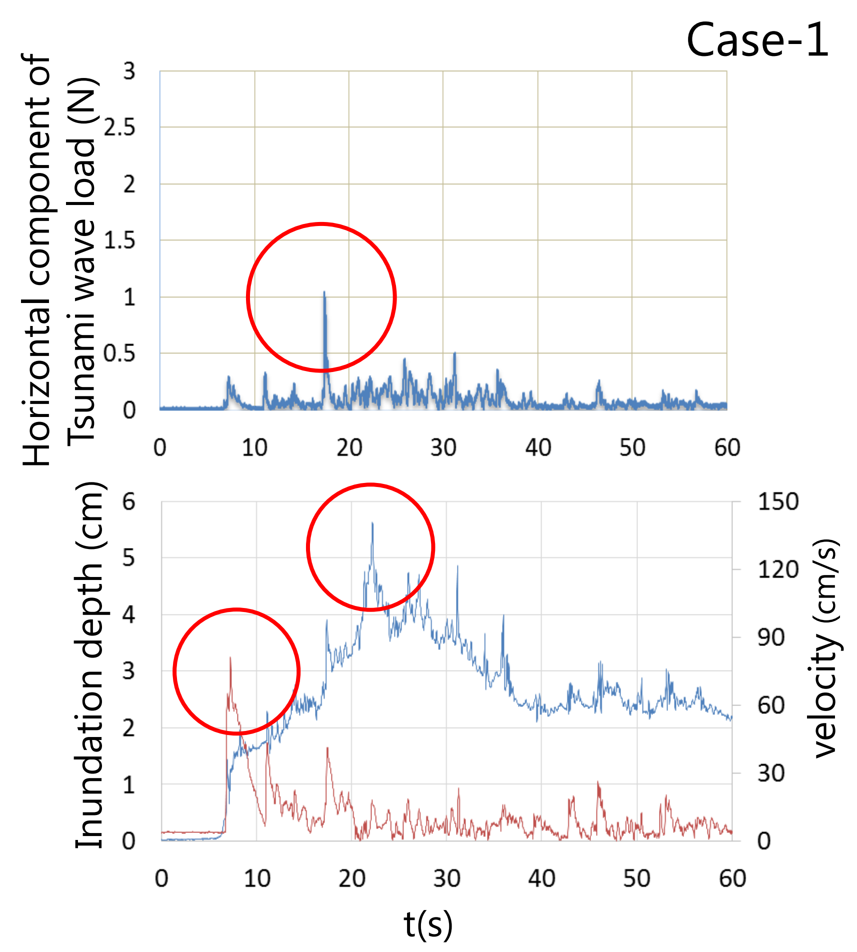
The movie of this experiment

the horizontal component of the tsunami wave load

- the difference among the three cases

  Case-1 at point a-2



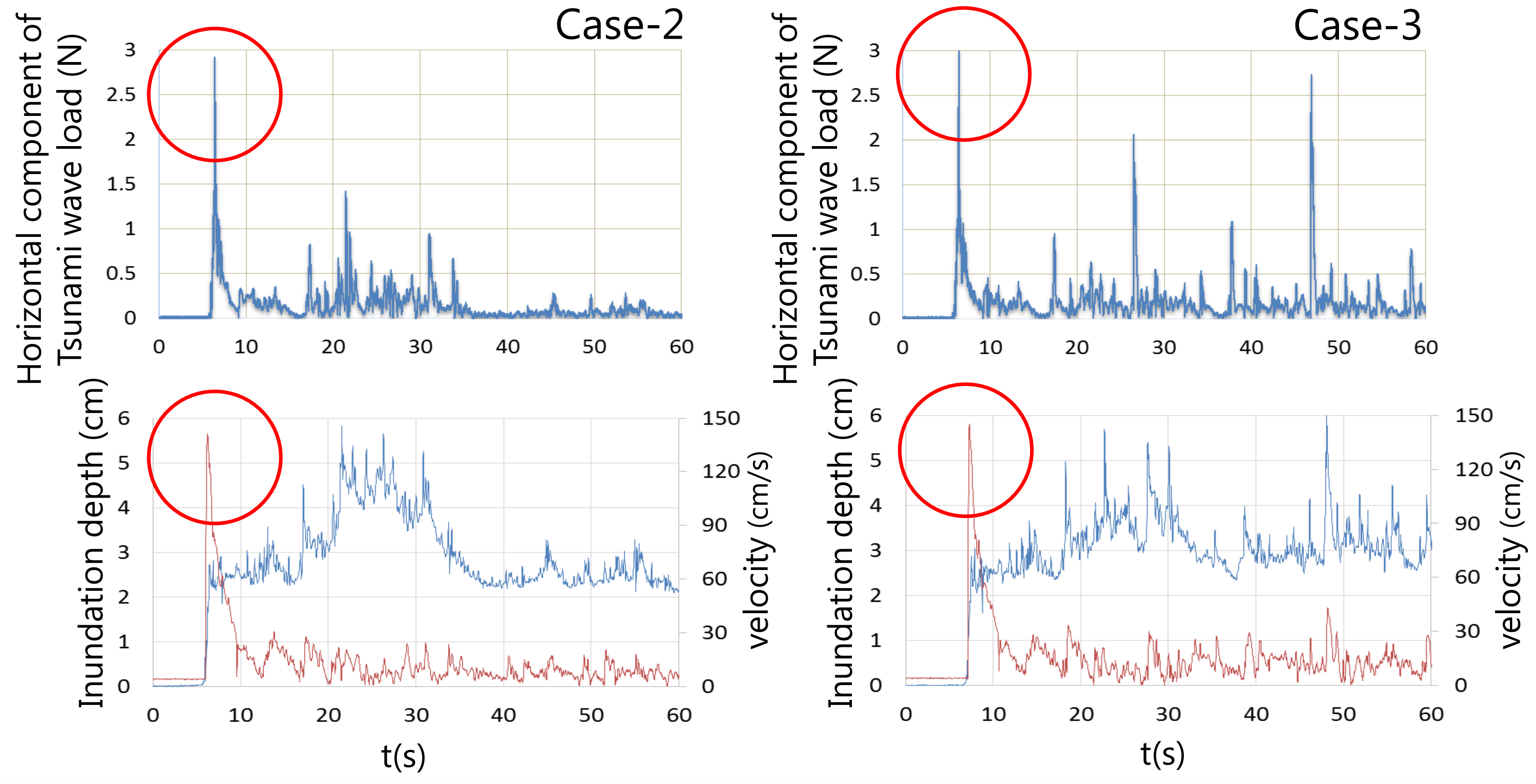


When reflected waves from surrounding terrain and oil walls acted on the tank the tsunami wave load reached the maximum

the horizontal component of the tsunami wave load

◆ the difference among the three cases

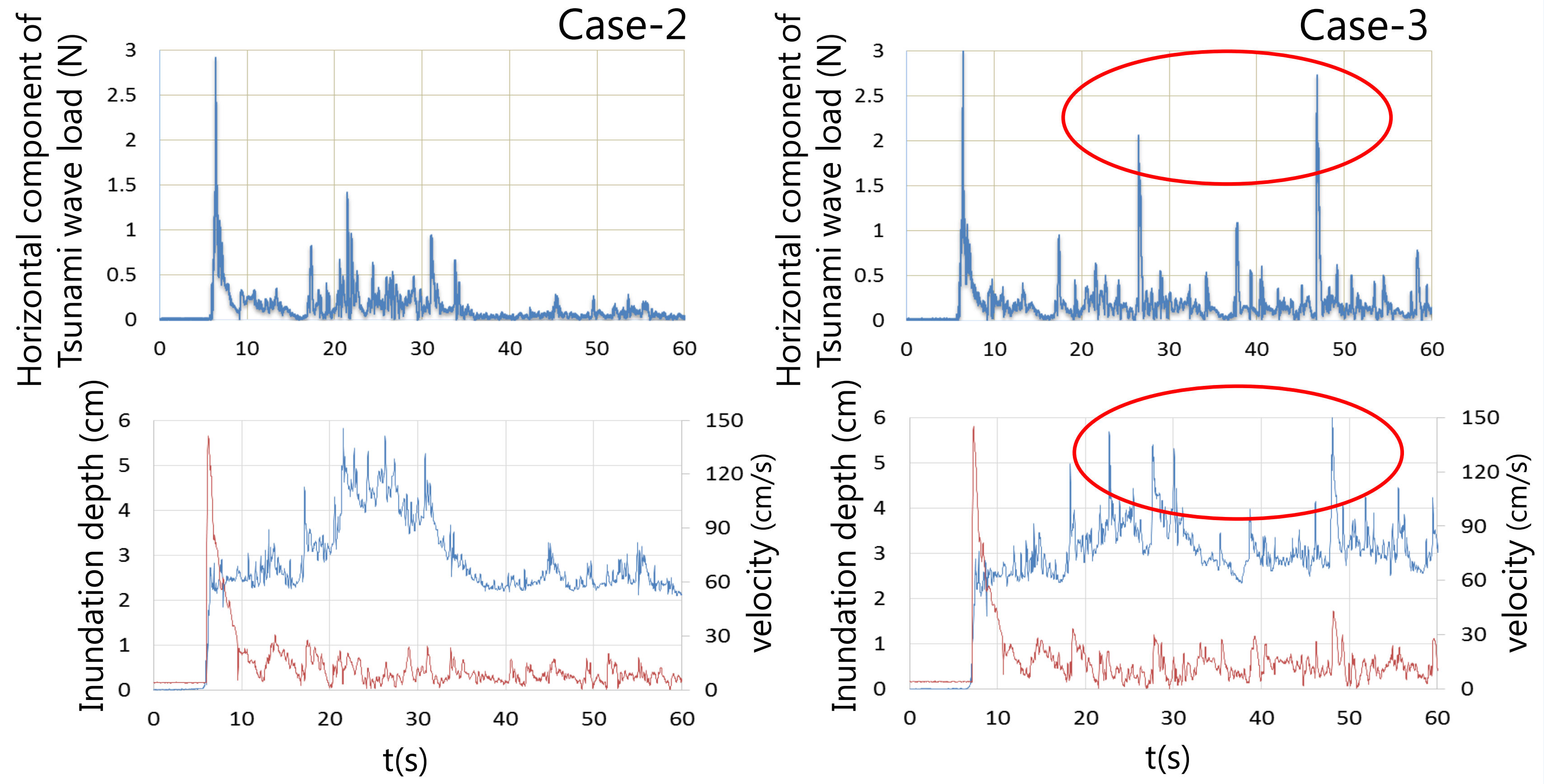
Case-2/3 at point a-2



In both cases, when tsunami acted a tank, the tsunami wave load reached the maximum

the horizontal component of the tsunami wave load

◆ the difference among the three cases
<u>Case-2/3 at point a-2</u>



In case3, after a tank started to be inundated, the tsunami wave load reached relatively large peaks and they correspond to the increase in the inundation depth

the vertical component of the tsunami wave load

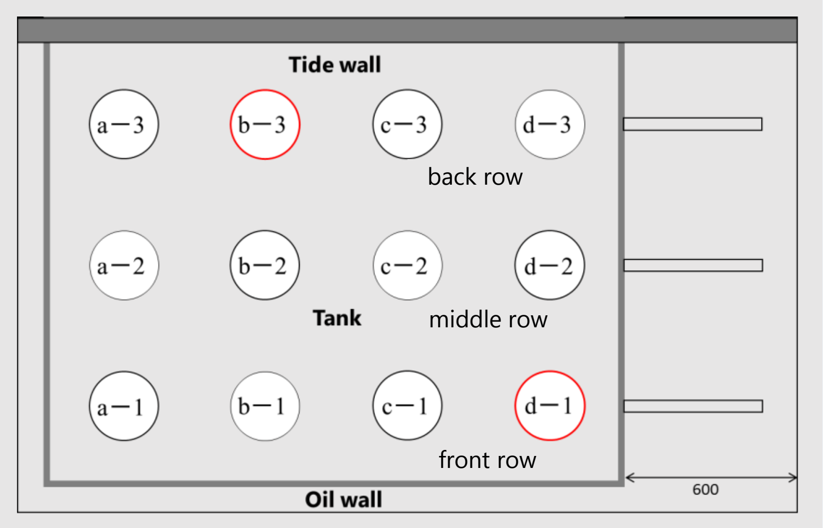
◆Comparison between

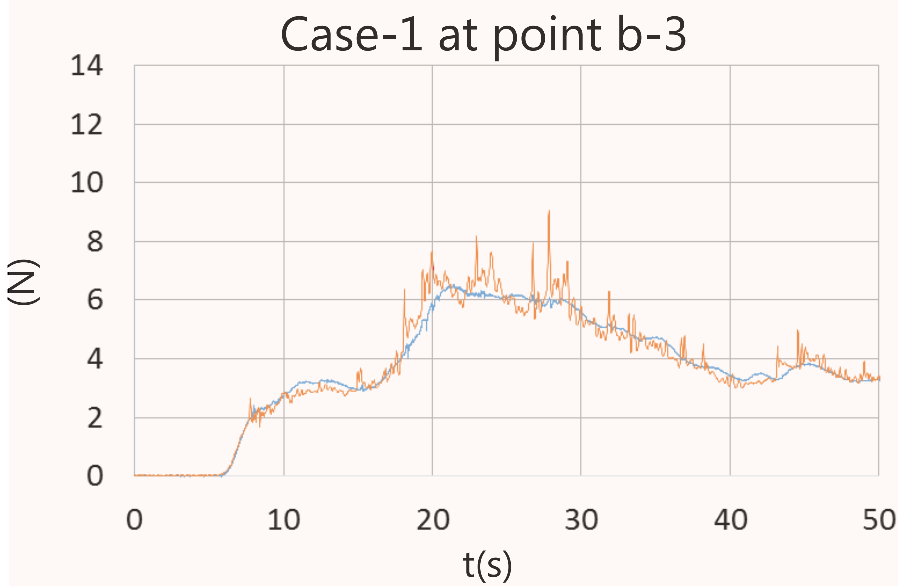
the measured tsunami wave load

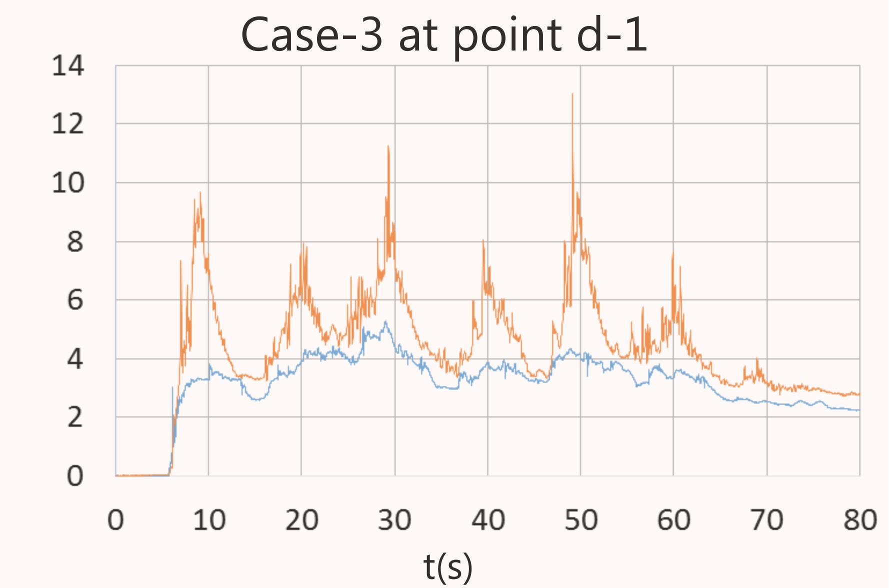
and

the buoyancy calculated by

assuming the hydrostatics condition







the vertical component of the tsunami wave load

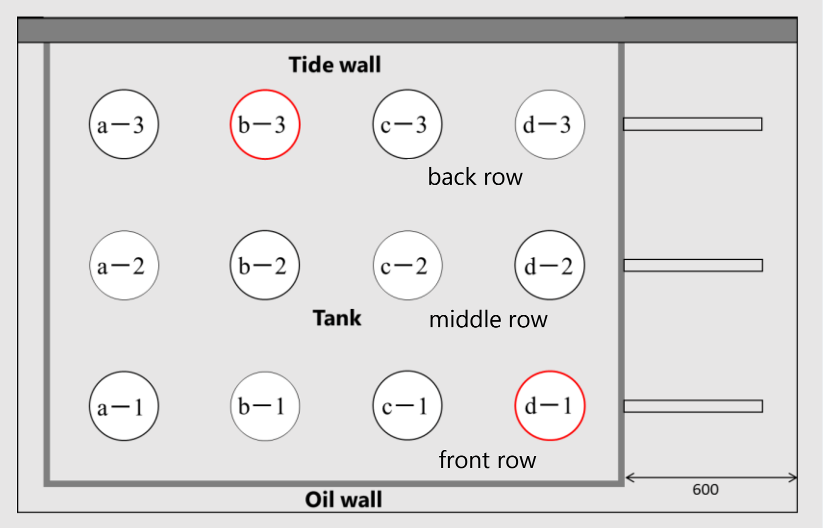
◆Comparison between

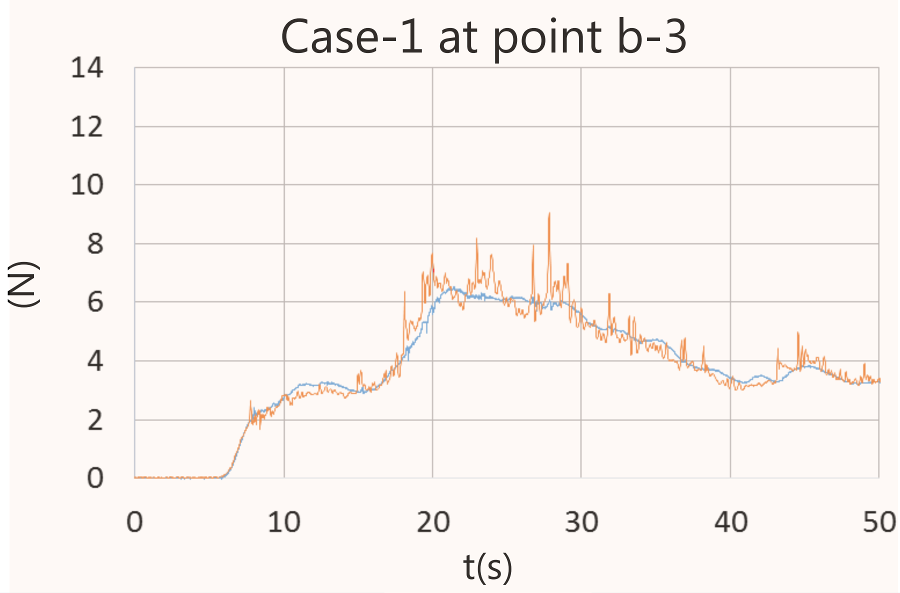
at point b-3

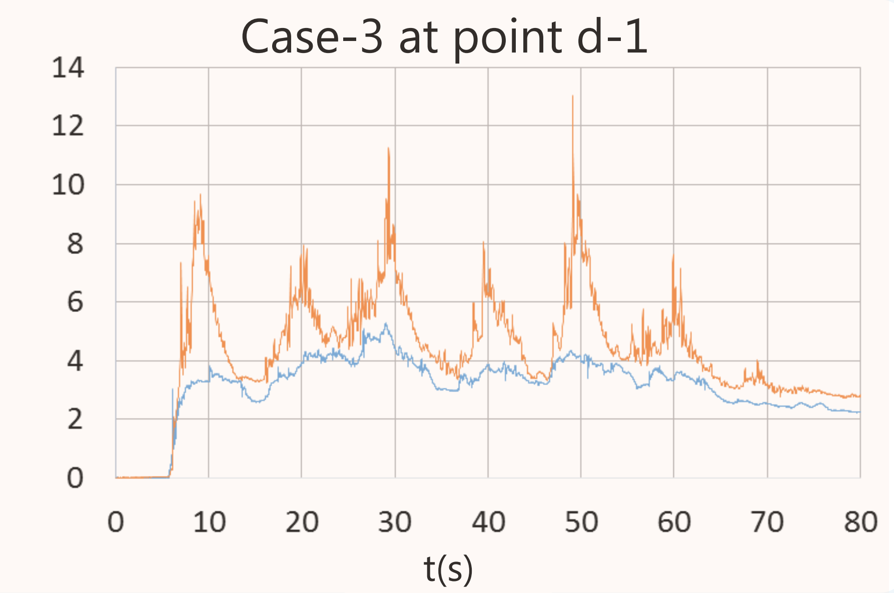
The calculated buoyancy

is in good agreement with

the measured tsunami wave load







the vertical component of the tsunami wave load

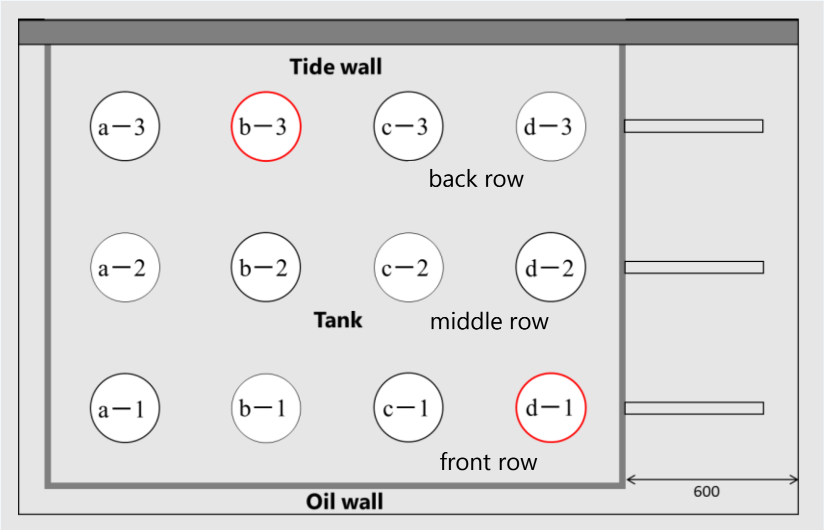
◆Comparison between

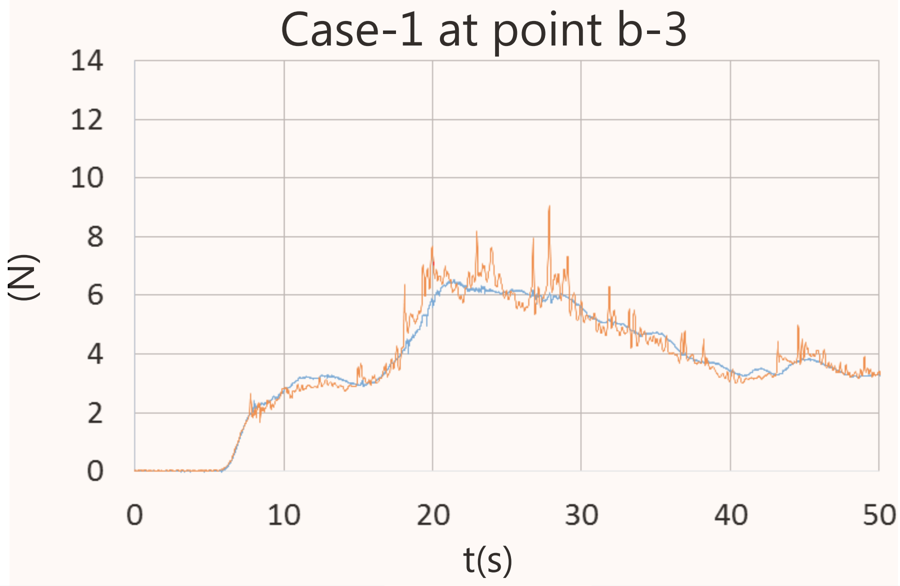
at point d-1

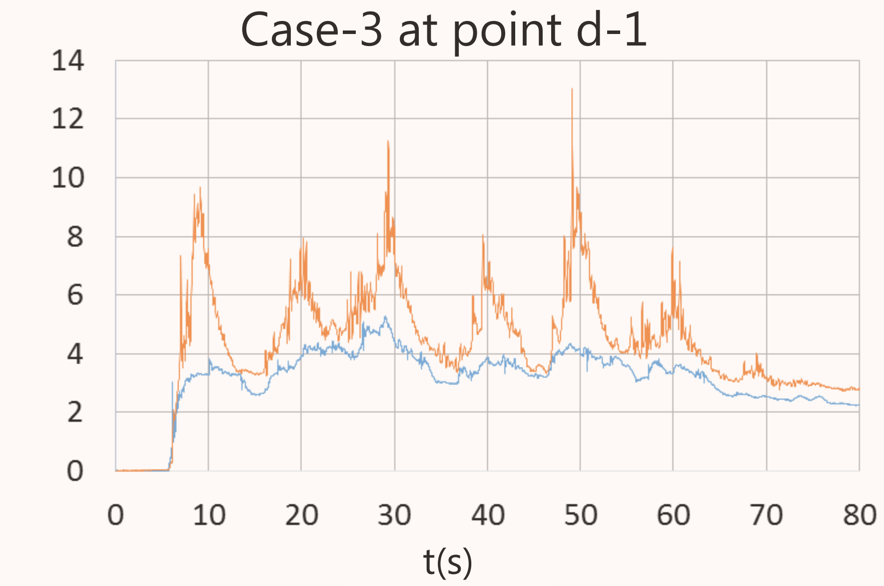
The calculated buoyancy

overestimated

the measured tsunami wave load



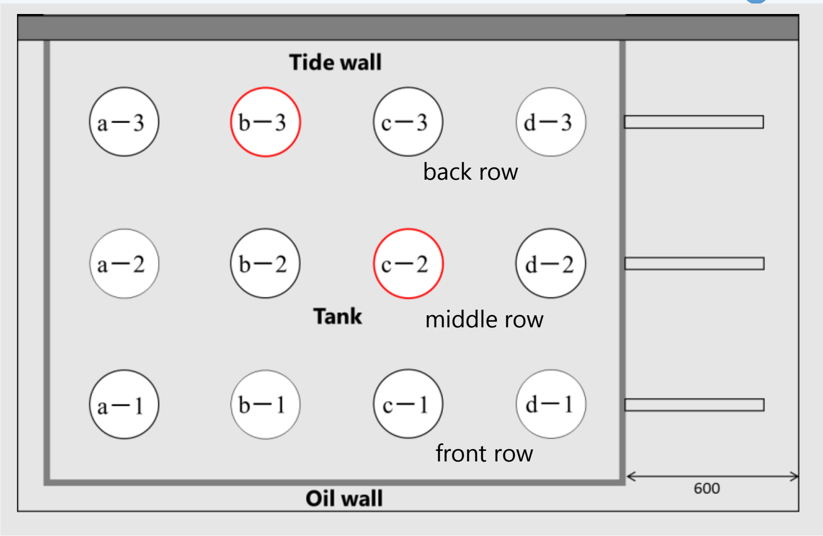




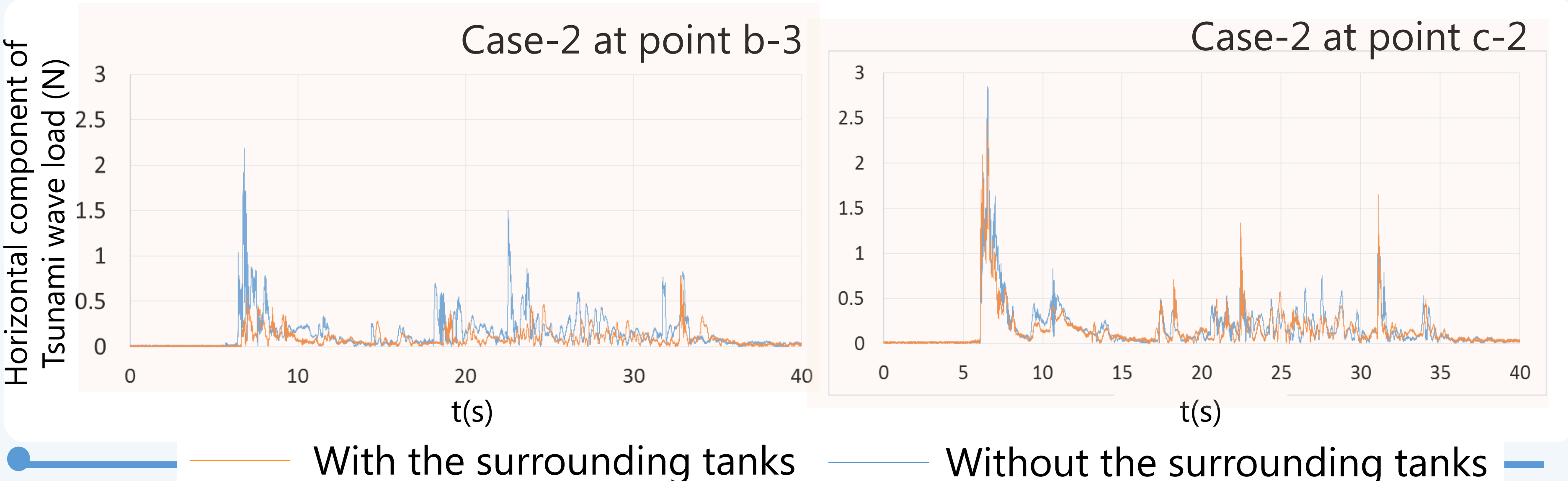
Comparison without and with the surrounding tanks

◆the horizontal component

at point b-3
the tsunami wave load acting on
a tank with the surrounding tanks
by the incident wave is less than
that without the surrounding tanks



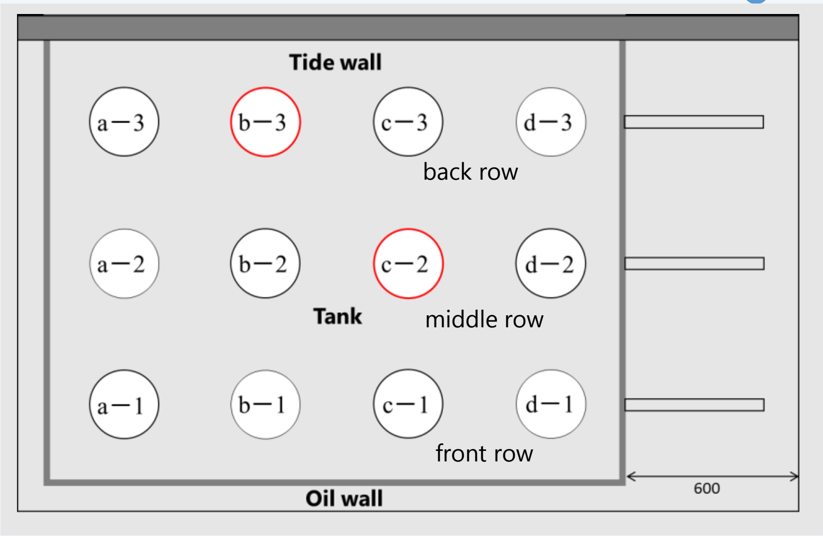
the sheltering effect of tanks in the front and the middle row

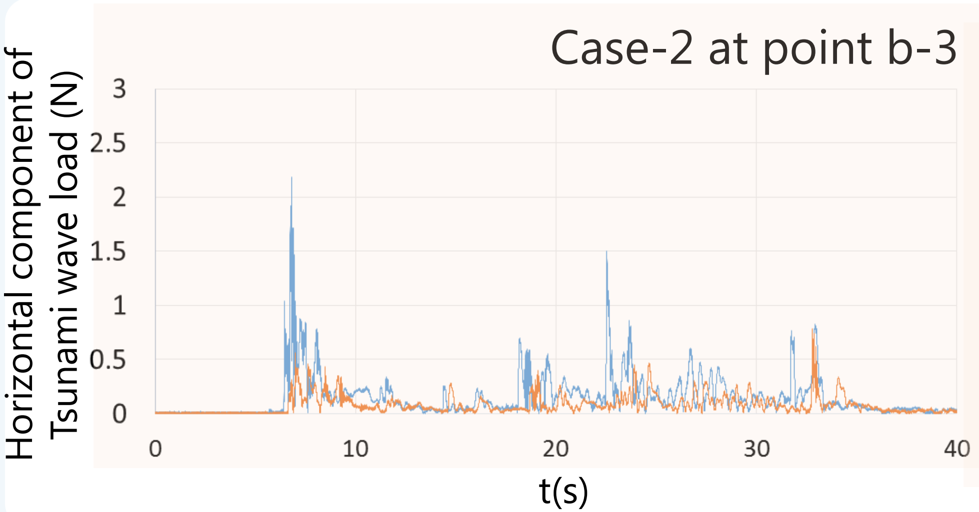


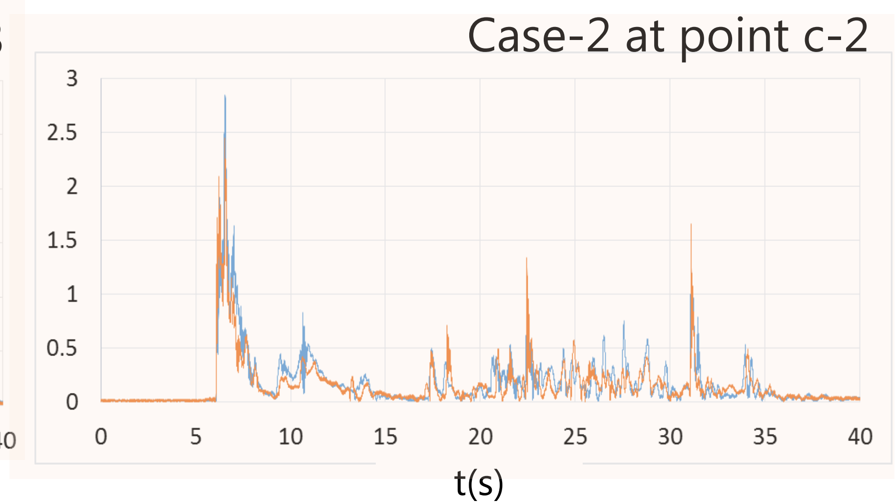
Comparison without and with the surrounding tanks

◆the horizontal component

In the back row
the change with the surrounding tanks
is different from
the change without the surrounding tanks







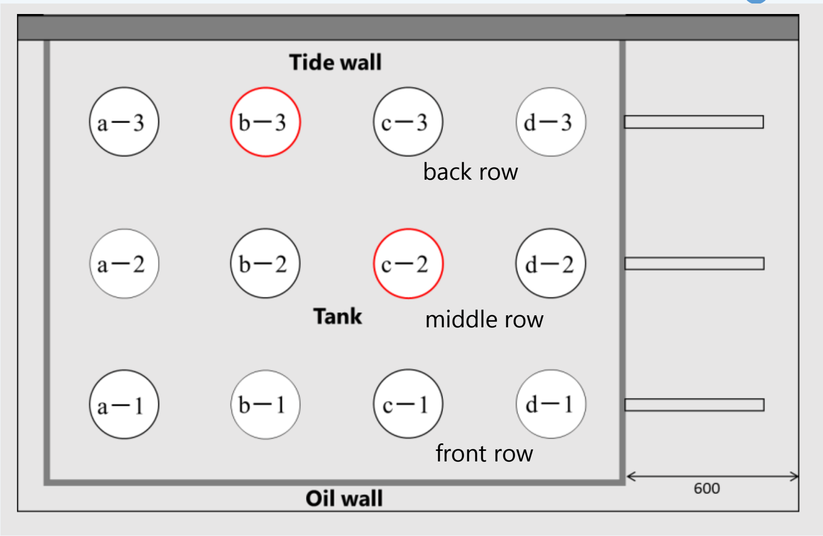
With the surrounding tanks Without the surrounding tanks

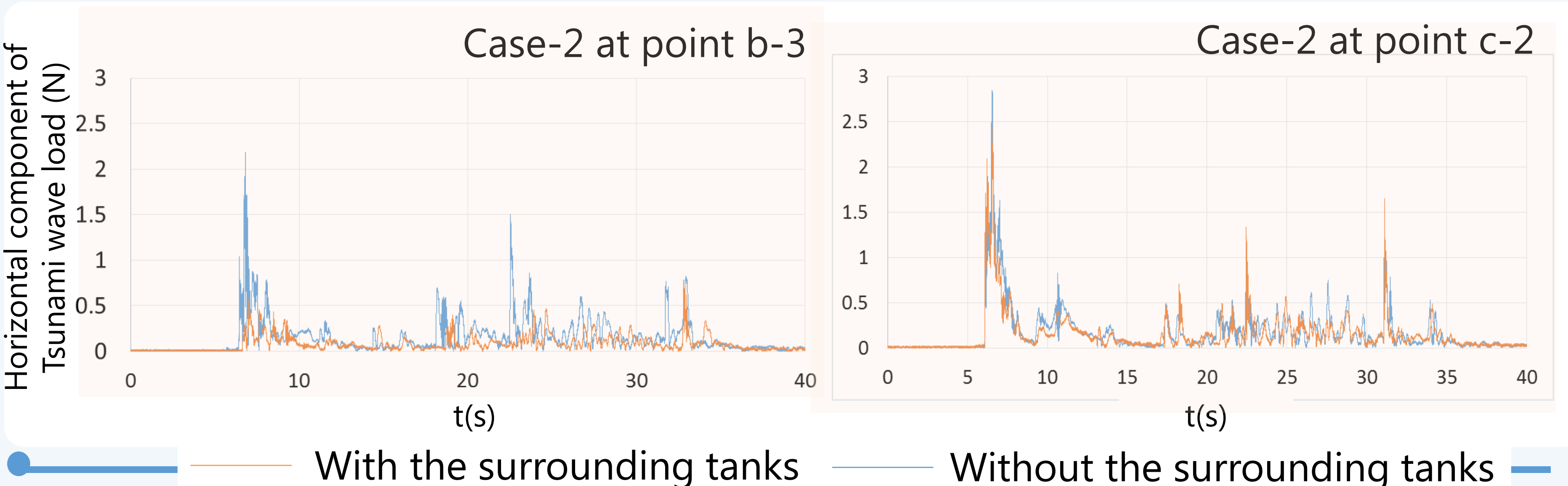
Comparison without and with the surrounding tanks

◆the horizontal component

at point c-2

Possibility of increasing the tsunami wave load because of the presence of the surrounding tanks

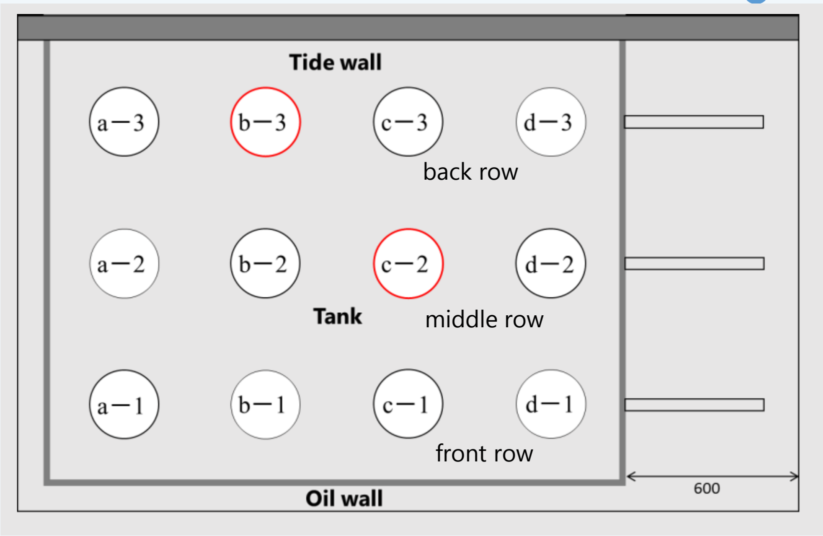


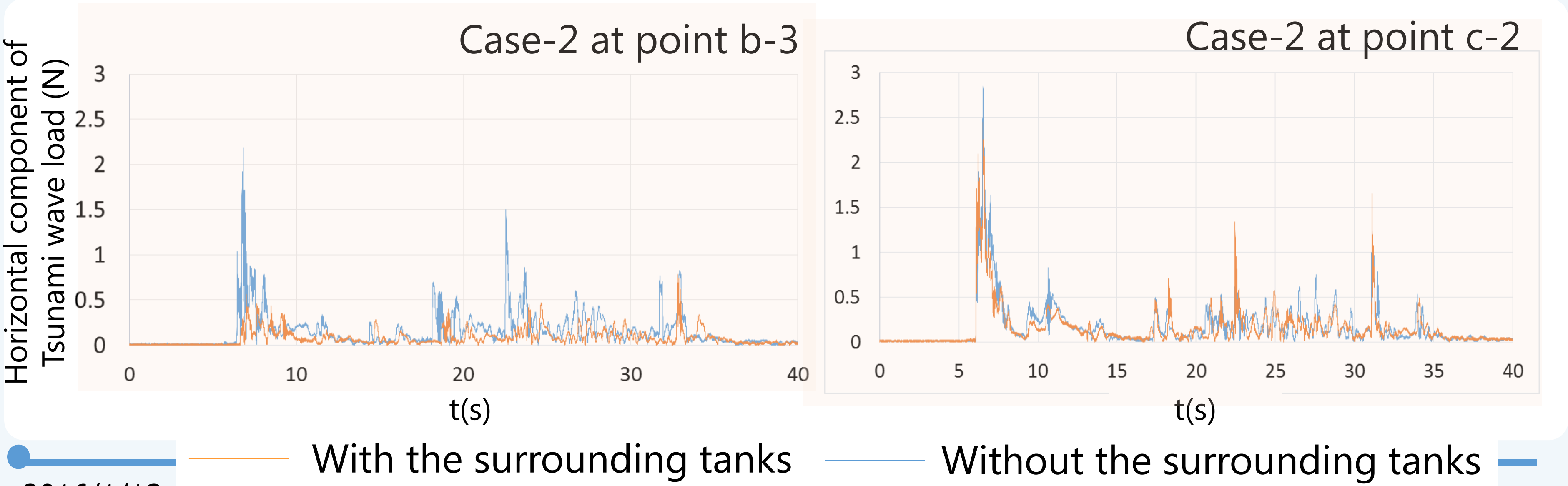


Comparison without and with the surrounding tanks

◆the horizontal component

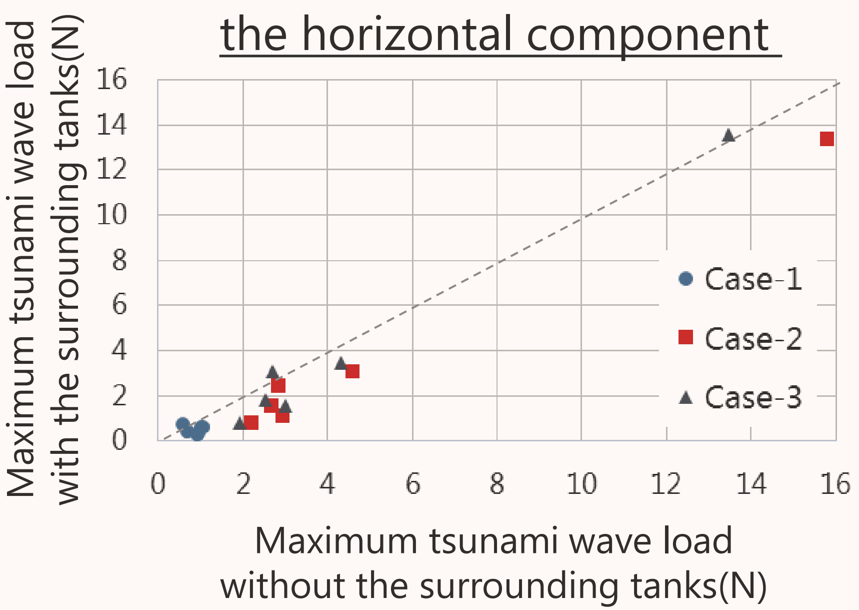
in the middle row
the change with the surrounding tanks
is similar to
the change without surrounding tanks

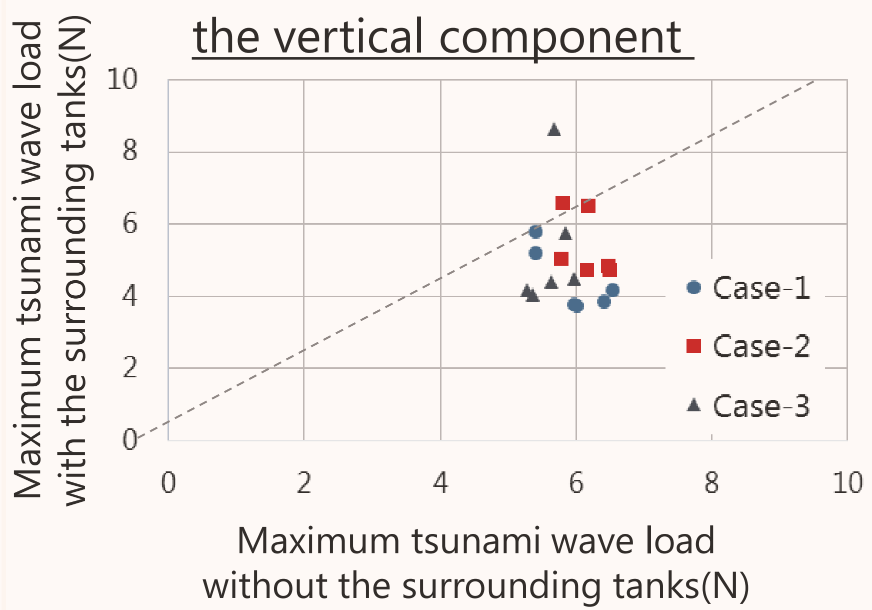




Comparison without and with the surrounding tanks

◆the maximum the tsunami wave load on a tank





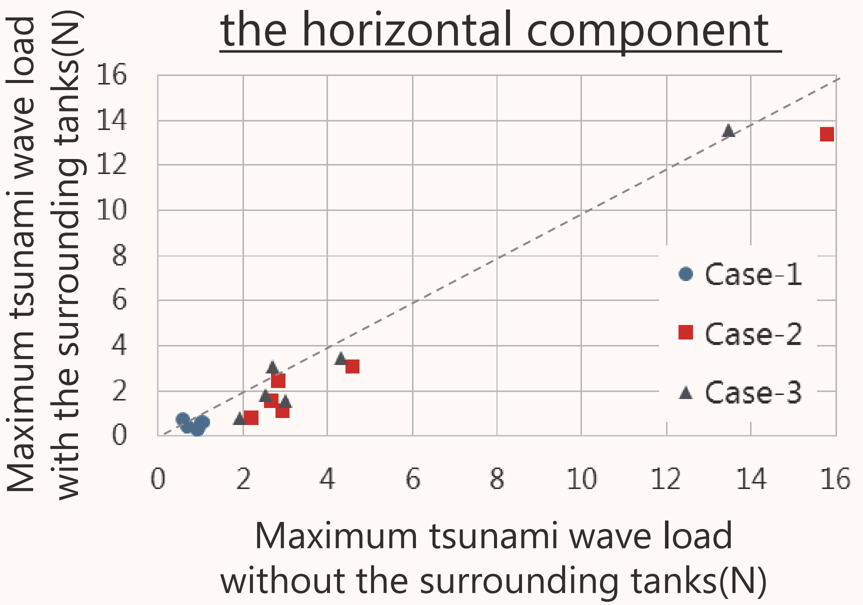
Regarding the maximum horizontal component

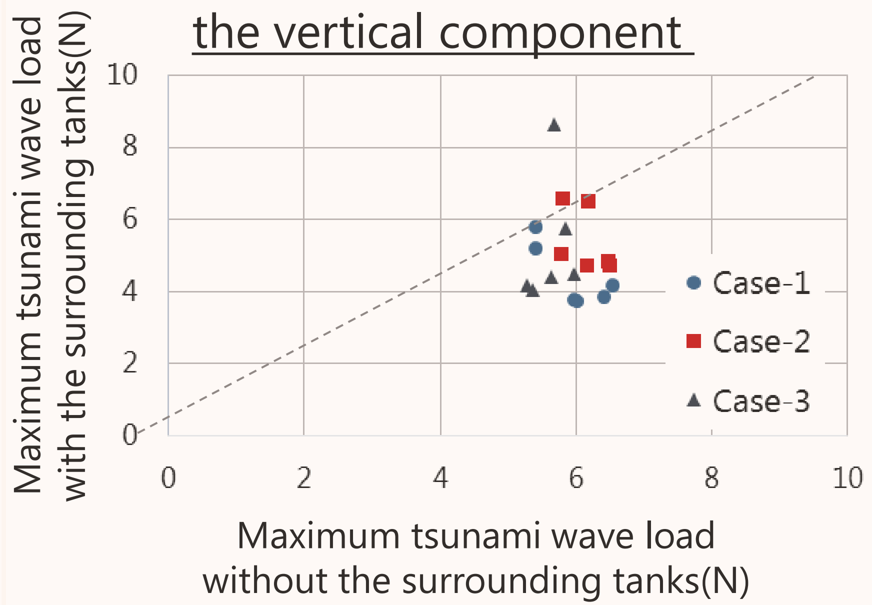
the tsunami wave load on a tank without the surrounding tanks tsunami wave load

was mostly larger than that with the surrounding tanks ases

Comparison without and with the surrounding tanks

◆the maximum the tsunami wave load on a tank





Regarding the vertical component

we didn't see any clear difference between the maximum vertical tsunami wave load on a tank with and without the surrounding tanks among three cases

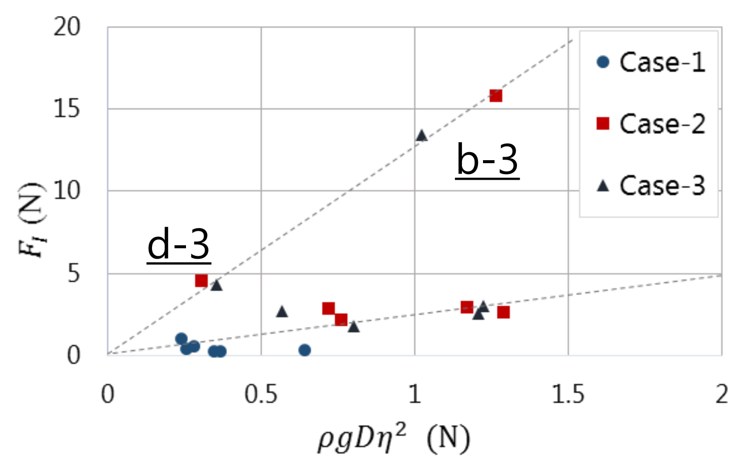
Characteristic of impulsive force

◆the applicability of conventional formulae

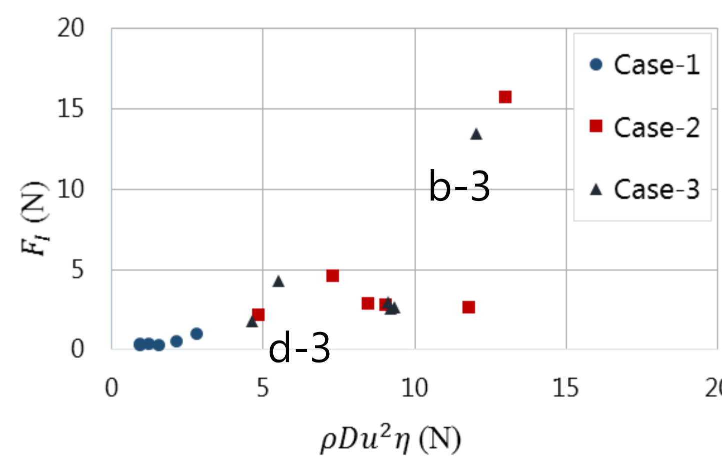
Asakura fomula	$F_I \propto \rho g D \eta^2$
Equation based on slamming into water	$F_I \propto \rho D c^2 \eta \approx \rho D u^2 \eta$

ρ: water density
g: gravitaional acceleration
D: diameter
u: velocity
η: inundation depth

we can see
the difference between the proportion relativity
in the front low and in the middle and the back low



Asakura fomula



Equation based on slamming into water

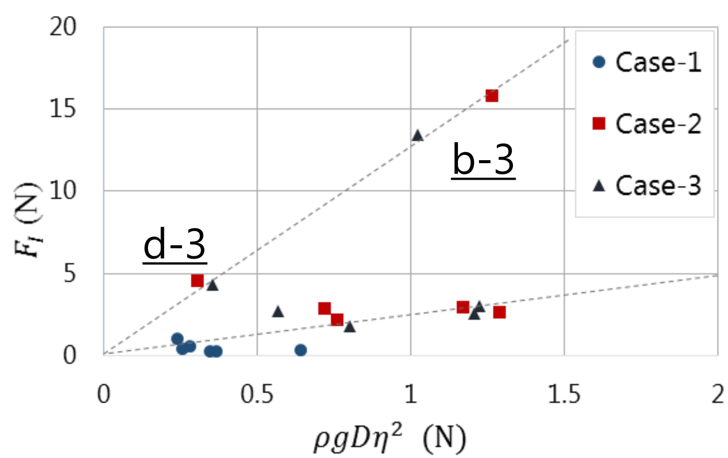
Characteristic of impulsive force

◆the applicability of conventional formulae

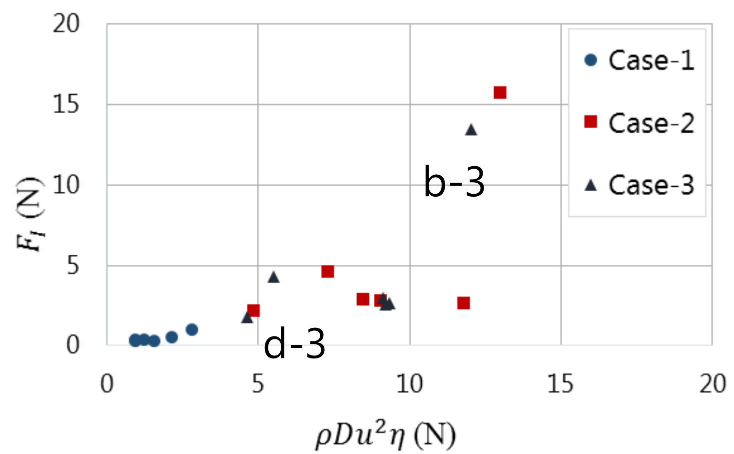
Asakura fomula	$F_I \propto \rho g D \eta^2$
Equation based on slamming into water	$F_I \propto \rho D c^2 \eta \approx \rho D u^2 \eta$

We have not obtained a clear relation so far
So, we need the further discussion

ρ: water density
g: gravitaional acceleration
D: diameter
u: velocity
η: inundation depth



Asakura fomula



Equation based on slamming into water

4.Conclusion

Conclusion

- The vertical component of the tsunami load on a tank was well estimated by the buoyancy calculated form the water surface elevation when the wave surface elevation was small.
- From the comparison between the tsunami wave load with and without the surrounding tanks, the maximum horizontal component of tsunami wave load with the surrounding tanks was smaller than that without the surrounding tanks. In addition, the possibility of increasing of the tsunami wave load was found because of the presence of the surrounding tanks.
- For impulsive force we can use Asakura formula, but we should change the wave force coefficient according to the distance from the seawall.