Effects of Sloshing of Water in Receiving Water Tank on Water Distribution System during Earthquake

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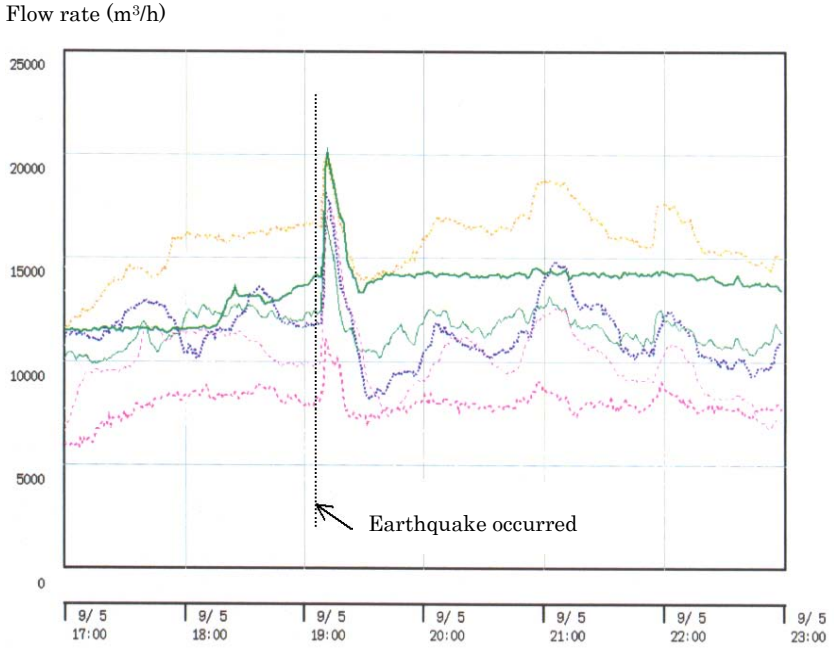
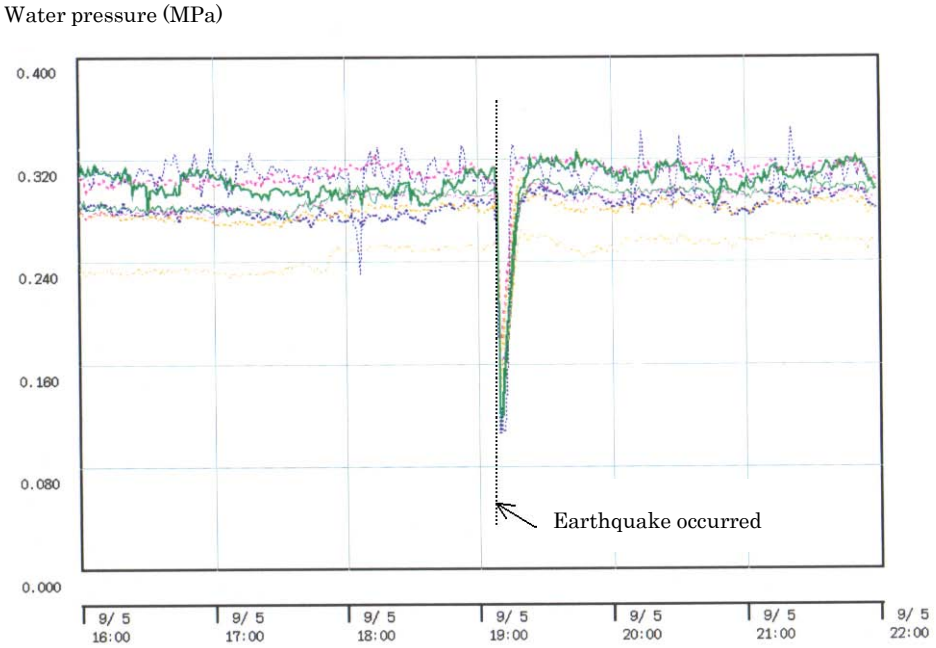
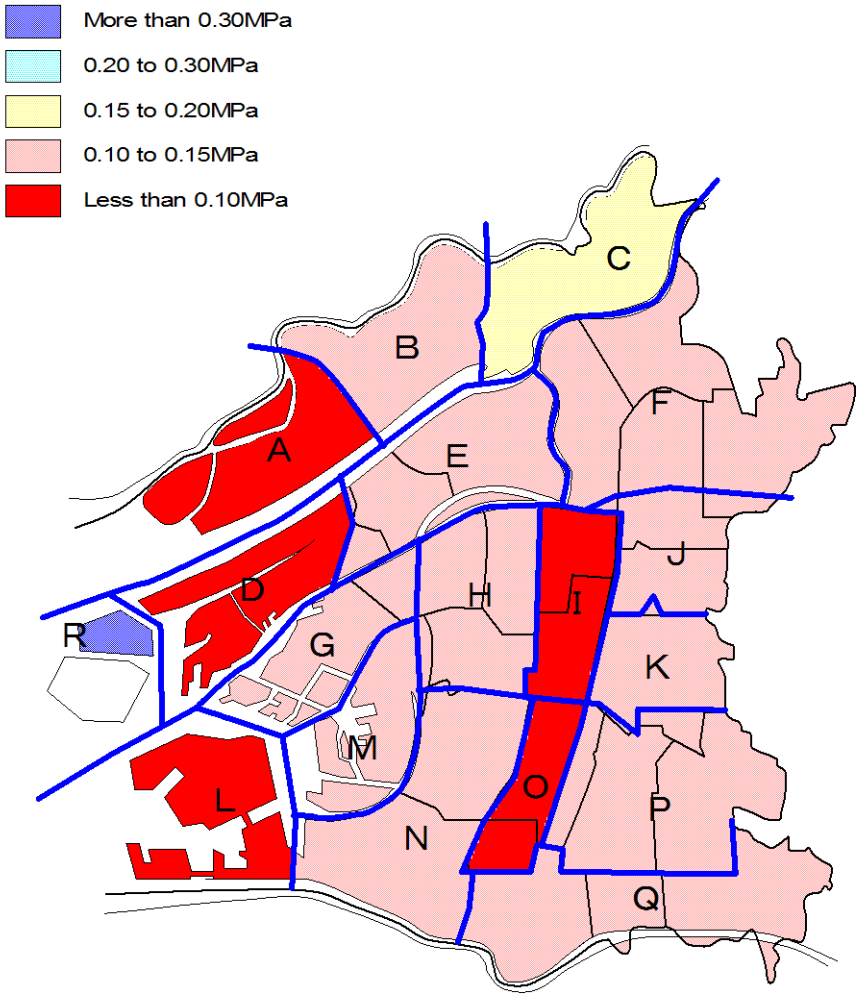
Flow rate and water pressure at water distribution plants during the 2004 Kii-hanto oki earthquake





Distribution of water pressure

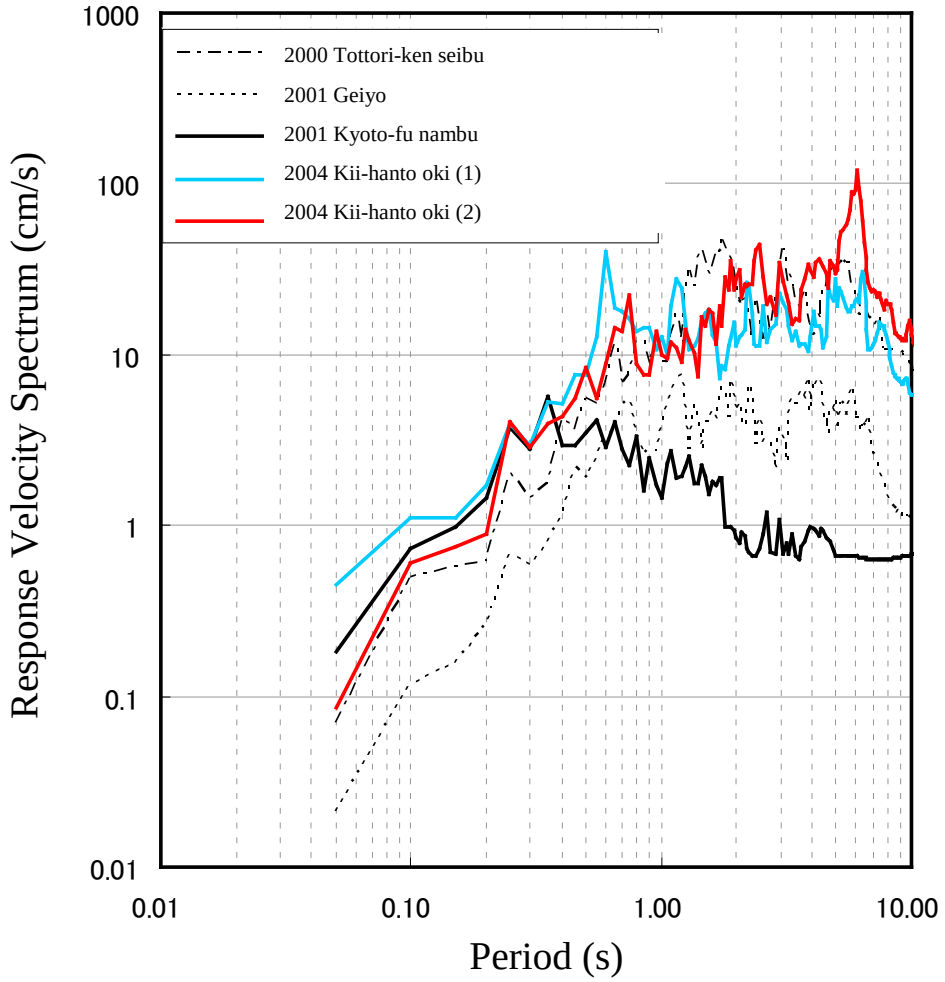


Unusual phenomena at OWWB

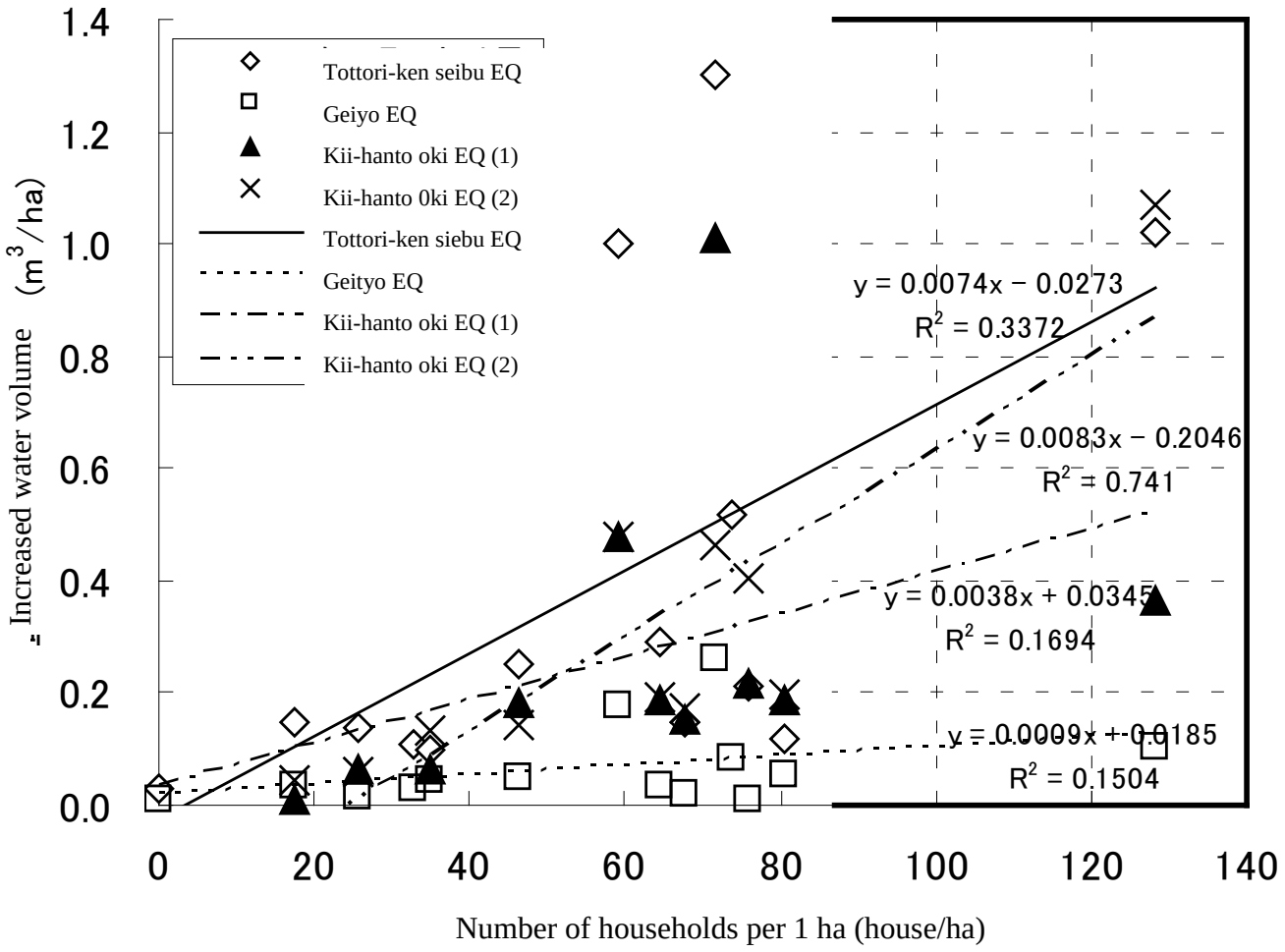
Name of earthquake	Date	Time	Magunitude	SI in Osaka	Occurrence
Tottori-ken seibu	2000.10.6	13:30	7.3	4	Yes
Geiyo	2001.3.24	15:28	6.7	2	Yes
Kyoto-fu Nambu	2001.8.25	22:21	5.3	3	No
Kii-hanto oki (1)	2004.9.5	19:07	6.9	4	Yes
Kii-hanto oki (2)	2004.9.5	23:57	7.4	4	Yes

* SI: JMA Seismic Intensity

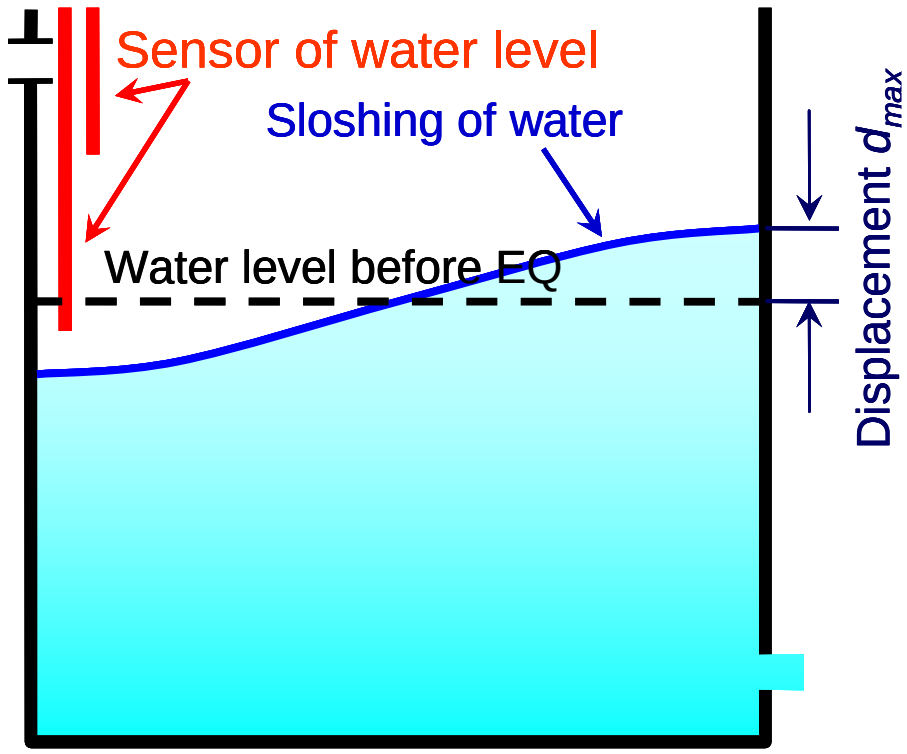
Response velocity spectra



Increased water volume vs. number of households



Mechanism of draw of water



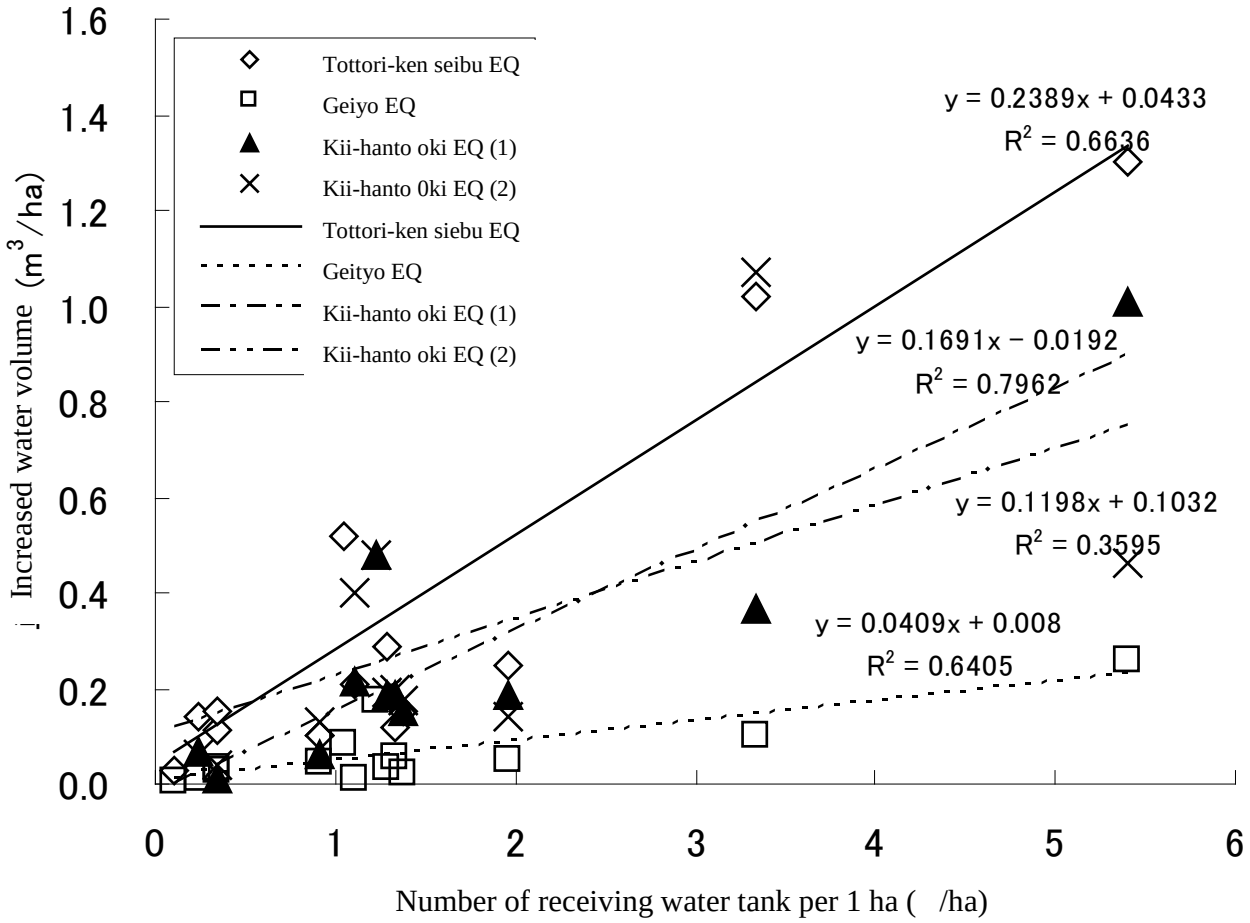
EQ Occurs

Sloshing of water in receiving water tank

Sensor detects water level becomes low

Draw of water

Increased water volume vs. number of receiving water tank



Predominant period of water in receiving water tank

$$Ts = \frac{2\pi}{1.58\sqrt{\frac{g}{l}}\tanh\left(1.58\frac{h}{l}\right)}$$

where,

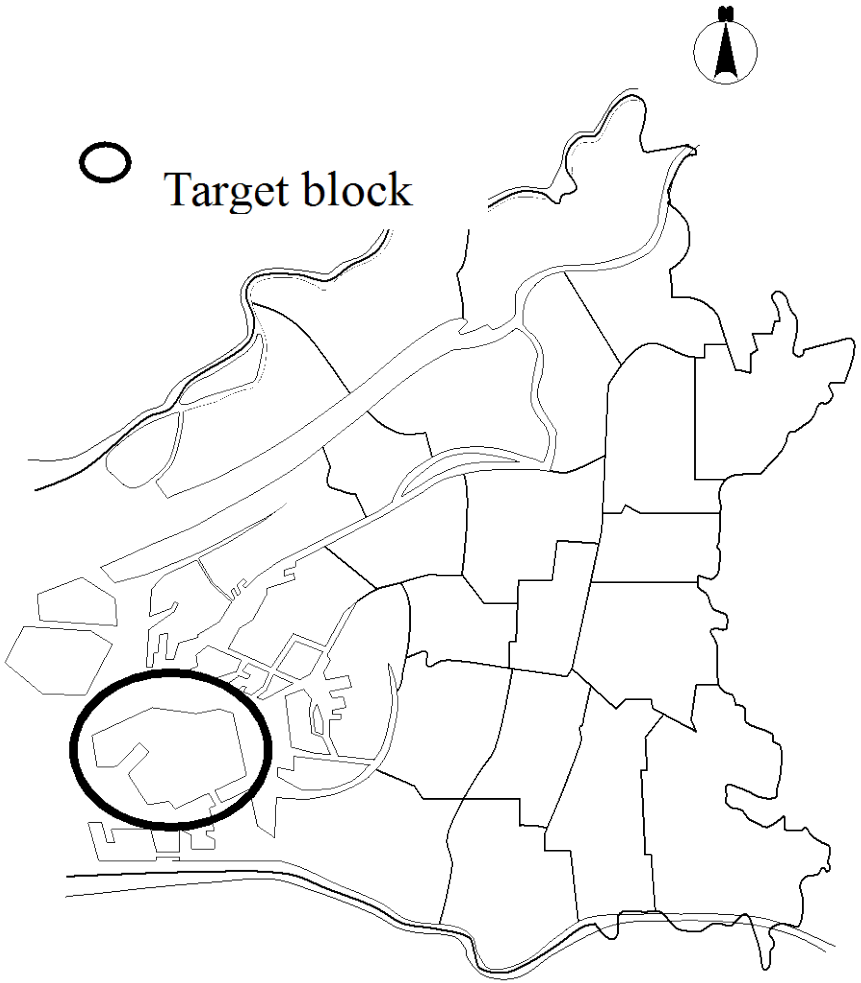
Ts : Predominant period of sloshing (s)

g : Acceleration of gravity (m/s^2)

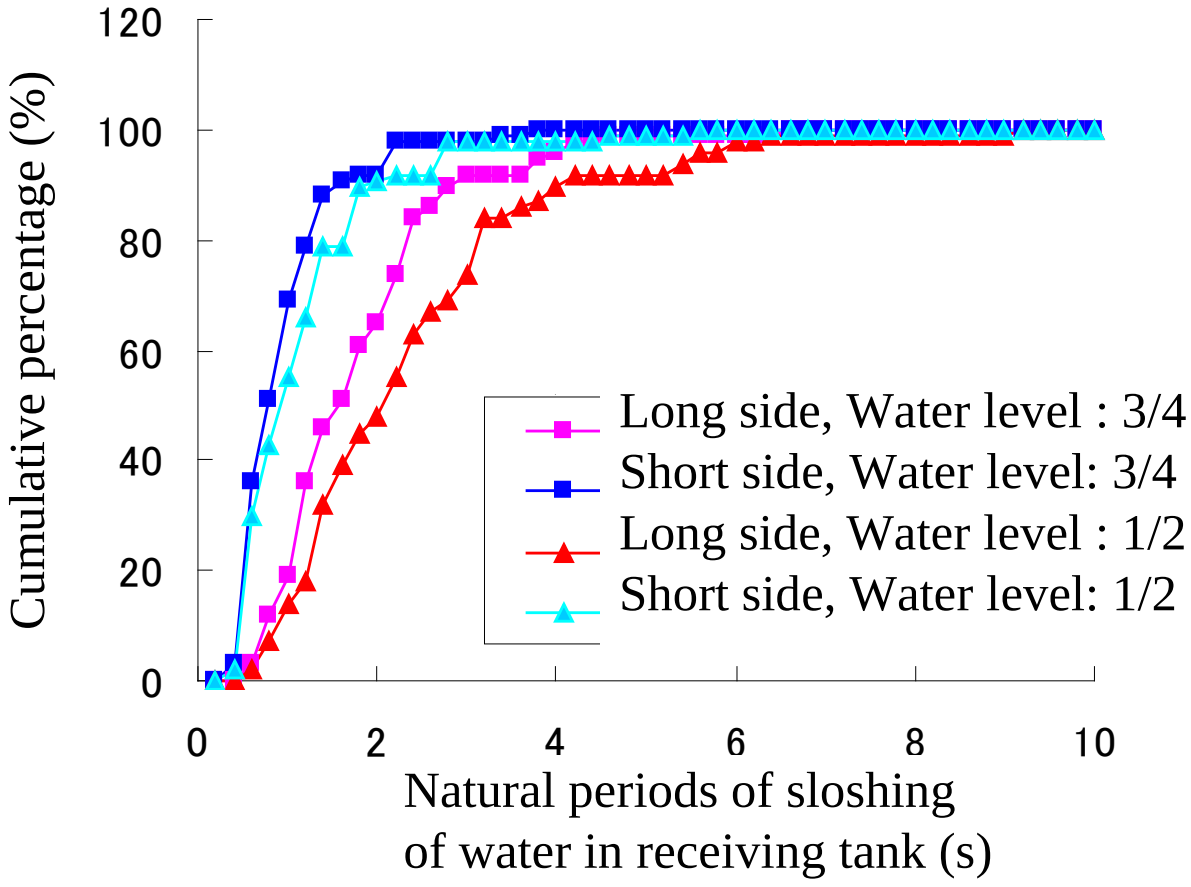
h : Depth of water (m)

l : 1/2 of length of basement (m)

Location of target block



Predominant period of water in receiving water tank

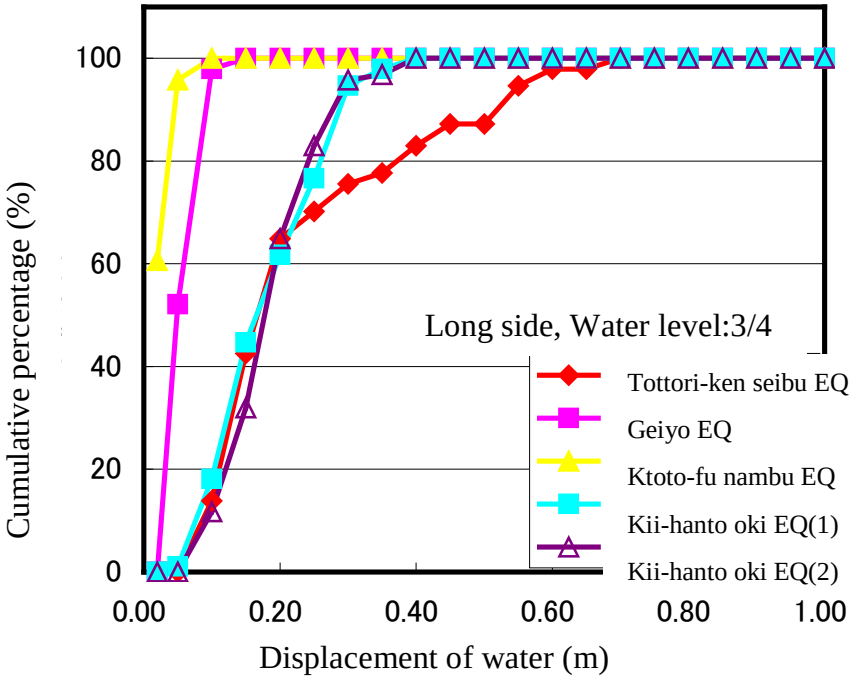


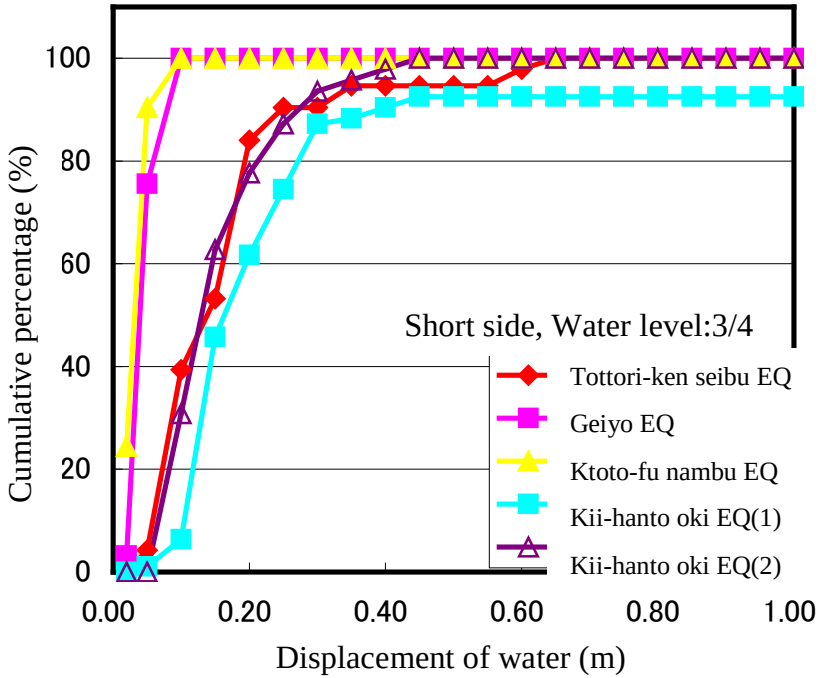
Maximum displacement of water caused by sloshing

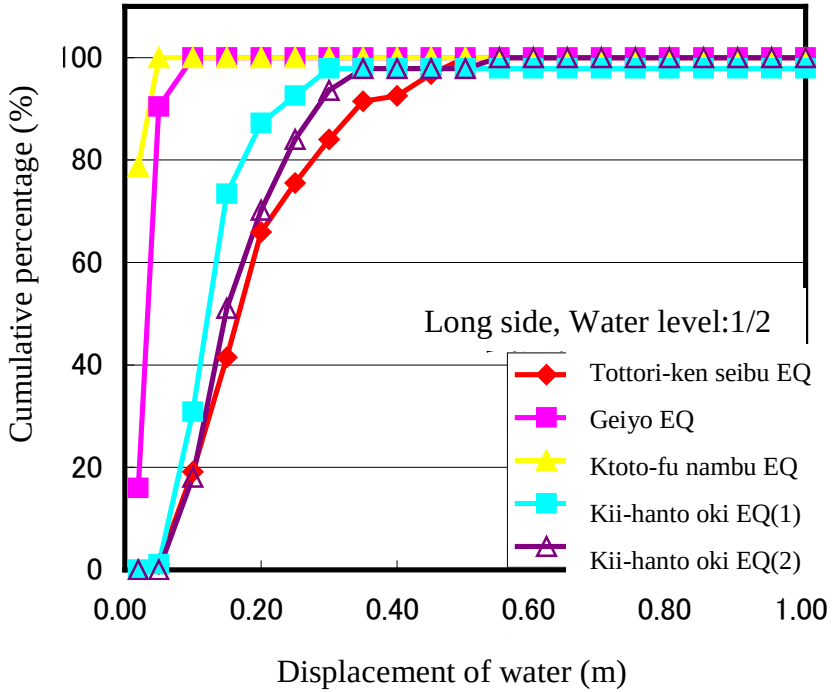
$$d_{\max} = \frac{0.527 l \coth\left(1.58 \frac{h}{l}\right)}{\frac{g}{\omega_h^2 l} - 1}$$

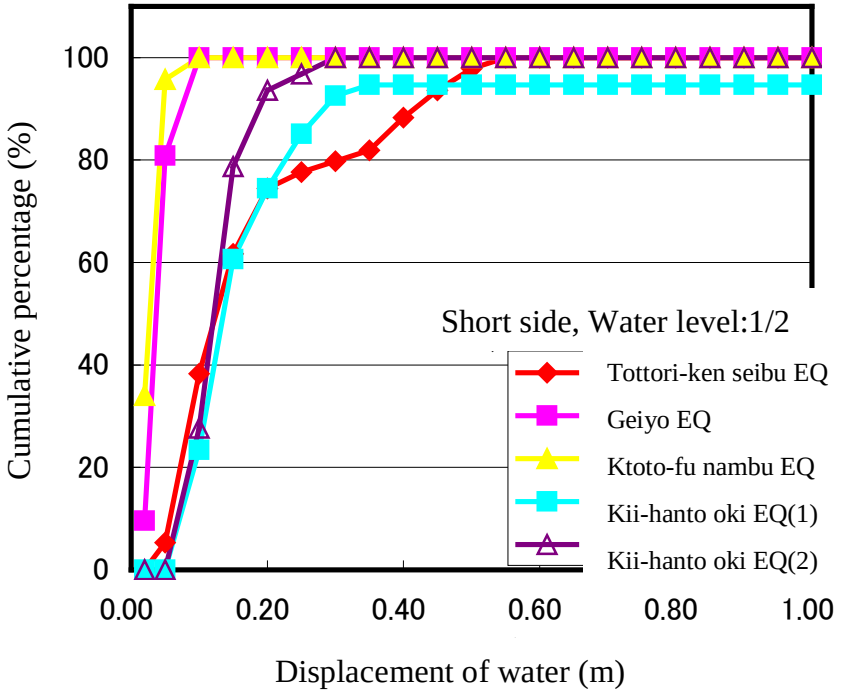
$$\omega_h = 1.58 \frac{S_v}{l} \tanh\left(1.58 \frac{h}{l}\right)$$

g : Acceleration of gravity (m/s^2)
h : Depth of water (m)
l : 1/2 of length of basement (m)
S_v: Response velocity spectrum of predominant period of sloshing (m/s)
ω_h :Predominant circular frequency

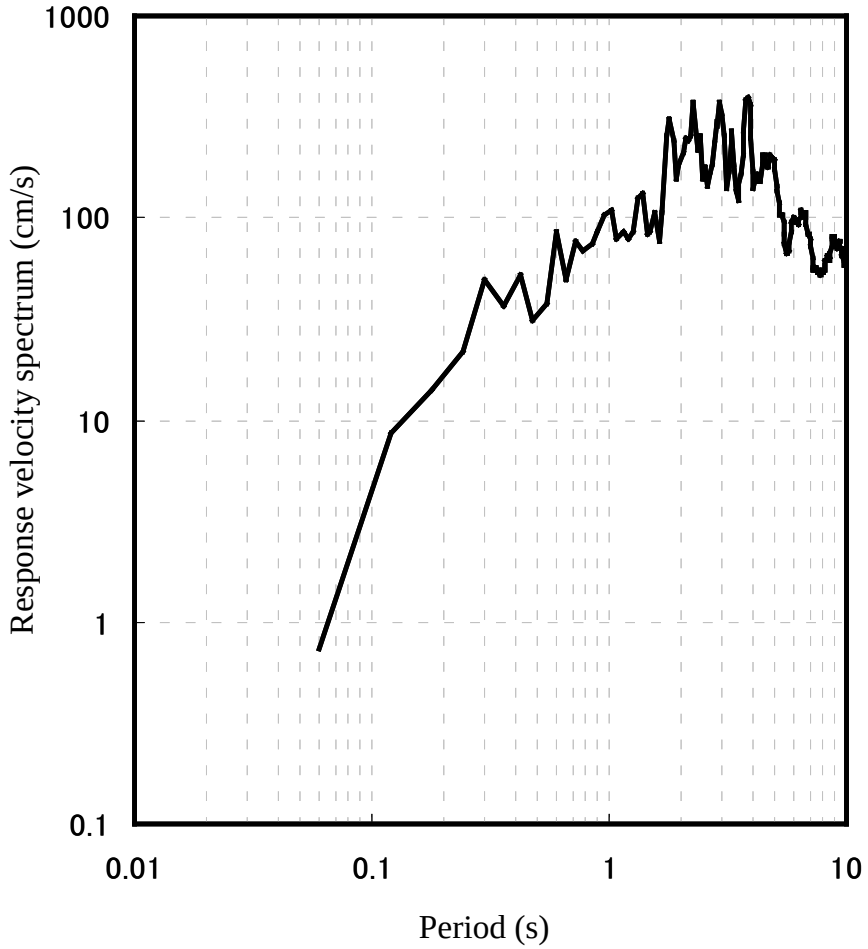

Long side, Water level:3/4
Cumulative percentage (%)
Displacement of water (m)
Tottori-ken seibu EQ
Geiyo EQ
Ktoto-fu nambu EQ
Kii-hanto oki EQ(1)
Kii-hanto oki EQ(2)


Short side, Water level:3/4
Cumulative percentage (%)
Displacement of water (m)
Tottori-ken seibu EQ
Geiyo EQ
Ktoto-fu nambu EQ
Kii-hanto oki EQ(1)
Kii-hanto oki EQ(2)

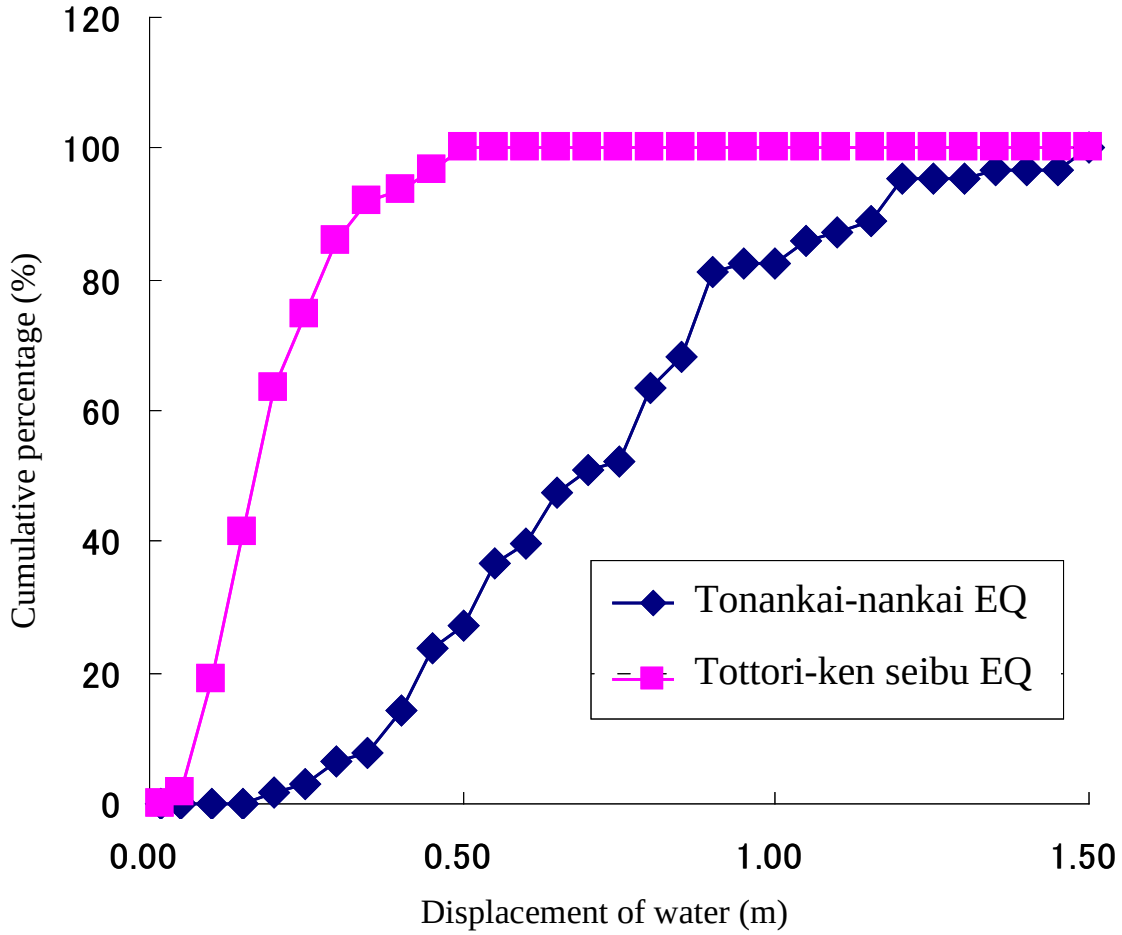

Long side, Water level:1/2
Cumulative percentage (%)
Displacement of water (m)
Tottori-ken seibu EQ
Geiyo EQ
Ktoto-fu nambu EQ
Kii-hanto oki EQ(1)
Kii-hanto oki EQ(2)


Short side, Water level:1/2
Cumulative percentage (%)
Displacement of water (m)
Tottori-ken seibu EQ
Geiyo EQ
Ktoto-fu nambu EQ
Kii-hanto oki EQ(1)
Kii-hanto oki EQ(2)

Response velocity spectrum of Tonankai-nankai EQ.



Maximum displacement of water in receiving water tank



Concluding remarks(1)

- A long period ground motion affects the unusual phenomena of the water distribution system.
- If sloshing of water in receiving water tank is occurred by an earthquake, draw of water to receiving water tank from pipeline starts by error of sensor of water level in the receiving water tank.
- Sloshing of water in receiving water tank, therefore, may be one of the causes of unusual phenomena.

Concluding remarks(2)

- The maximum displacement of water caused by sloshing was estimated by using a scenario earthquake waveform of Tonankai-nankai earthquake. The maximum displacement of water was more than 0.5m for more than 60% of all water tanks in this example.

- These phenomena induced by sloshing may affect life of citizen severely after the earthquake.

Thank you for your kind attention.