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EXPERIMENTAL STUDY ON TSUNAMI FORCES ACTING ON VERTICAL SEAWALLS UNDER OVERFLOW

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Contents

OBJECTS

Tsunami disaster mitigation

Protection => 2011 => Reduction

Great East Japan Earthquake

The viewpoint of failsafe

Tsunami overflows the sea walls

How to estimate the overflow tsunami forces

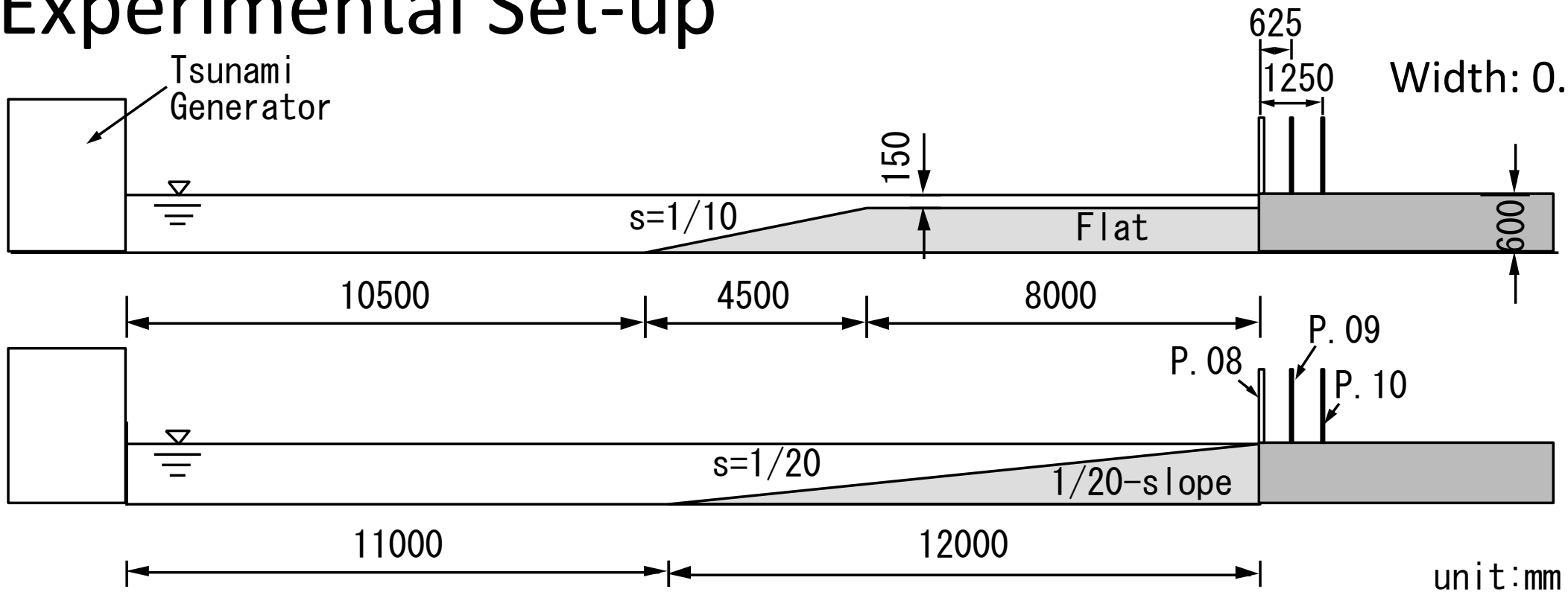
Non-overflow tsunami force => Overestimation?(Optimal design)

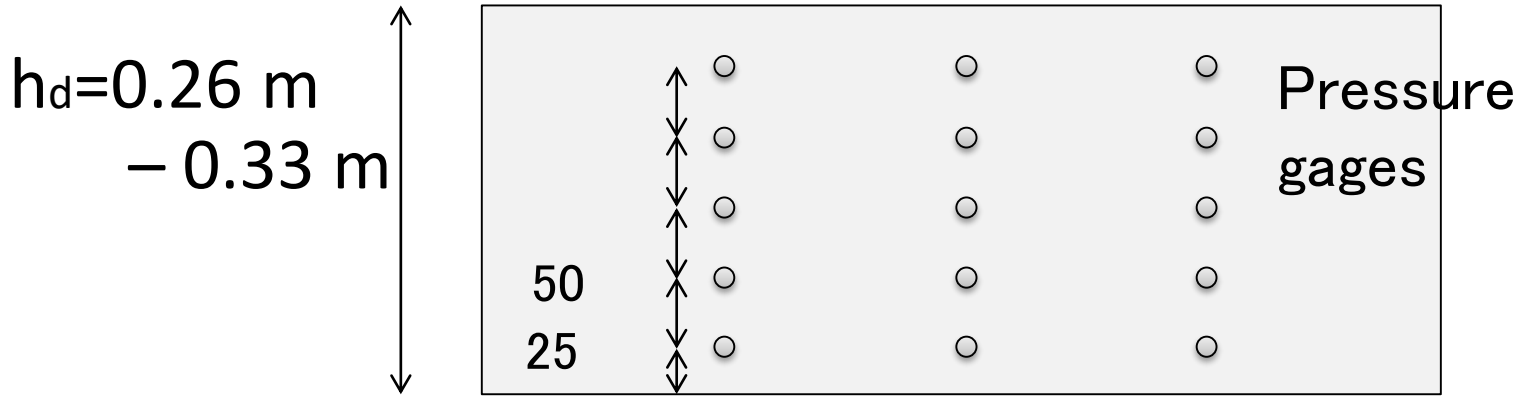
Estimation method of the overflowing tsunami force

comparing with the no-overflow condition

HYDRAULIC EXPERIMENTS

Experimental Set-up

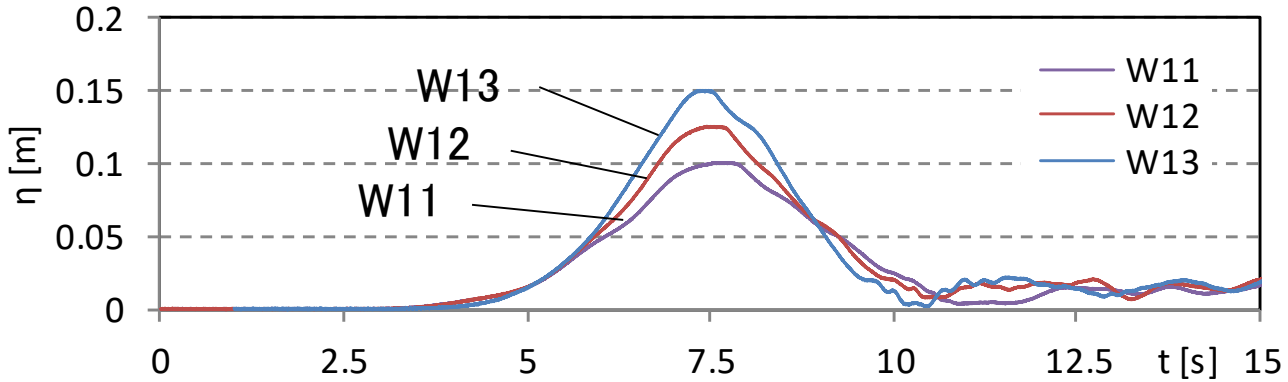




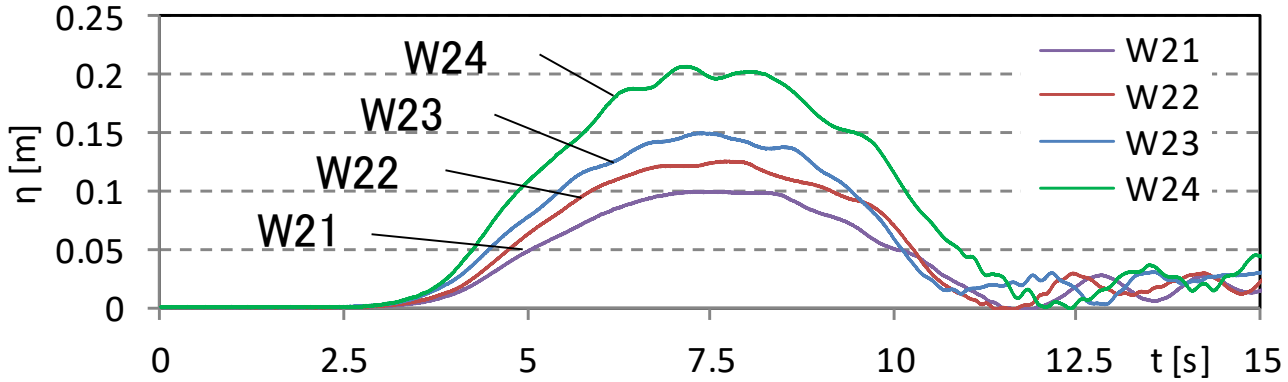
HYDRAULIC EXPERIMENTS

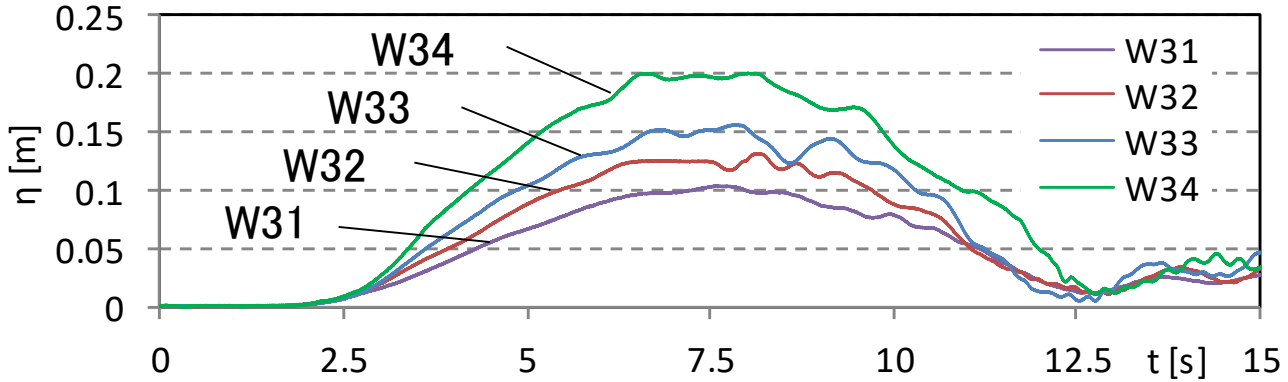
Incident Tsunami Waves

Tsunami profiles at 15 m distance from the coast line



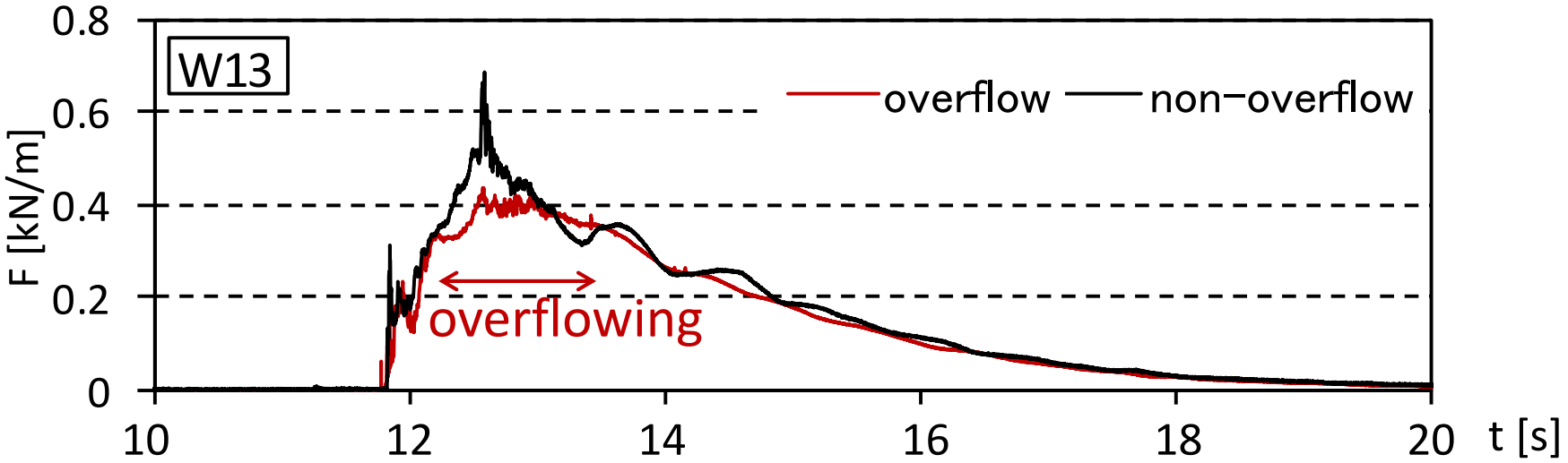
3 kinds of tsunami periods
4 kinds of tsunami height

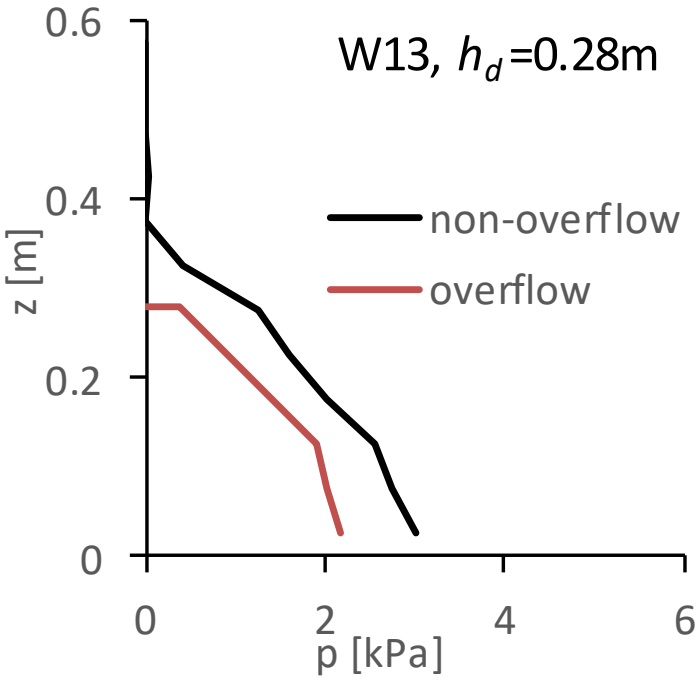




HYDRAULIC EXPERIMENTS

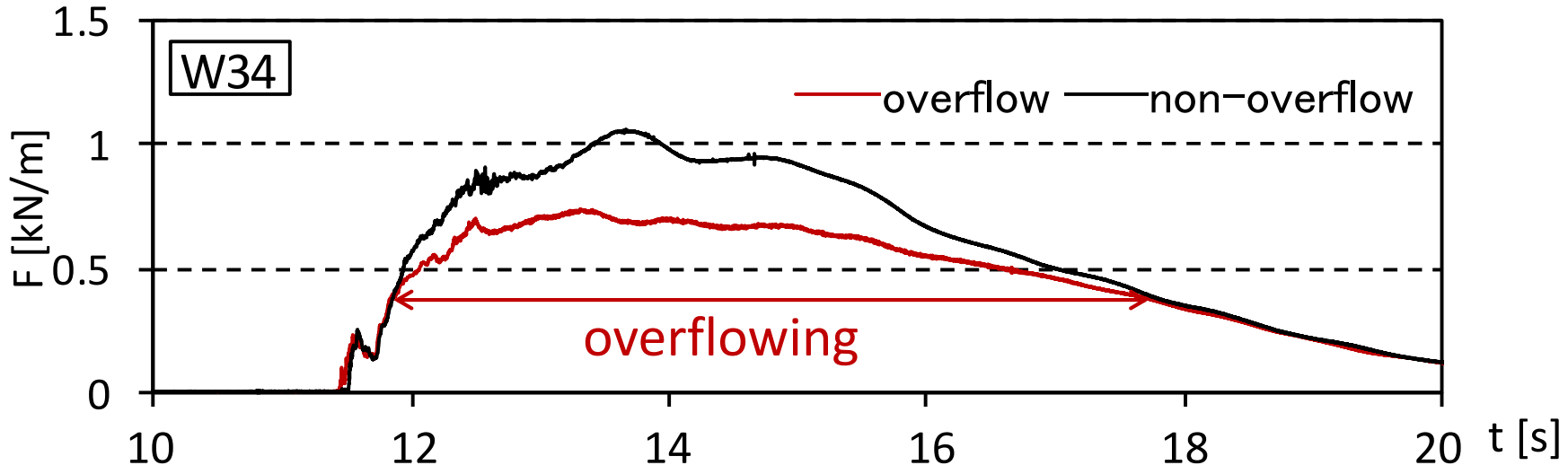
Experimental results



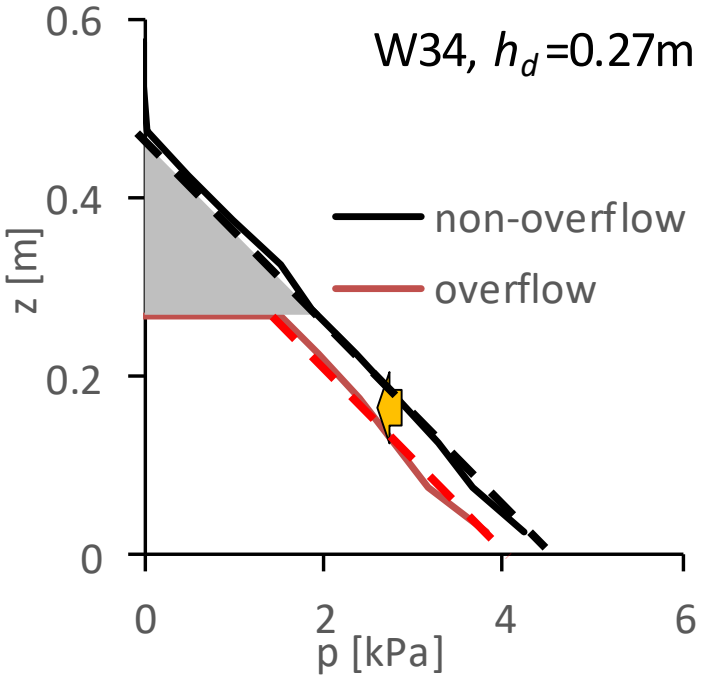


HYDRAULIC EXPERIMENTS

Experimental results

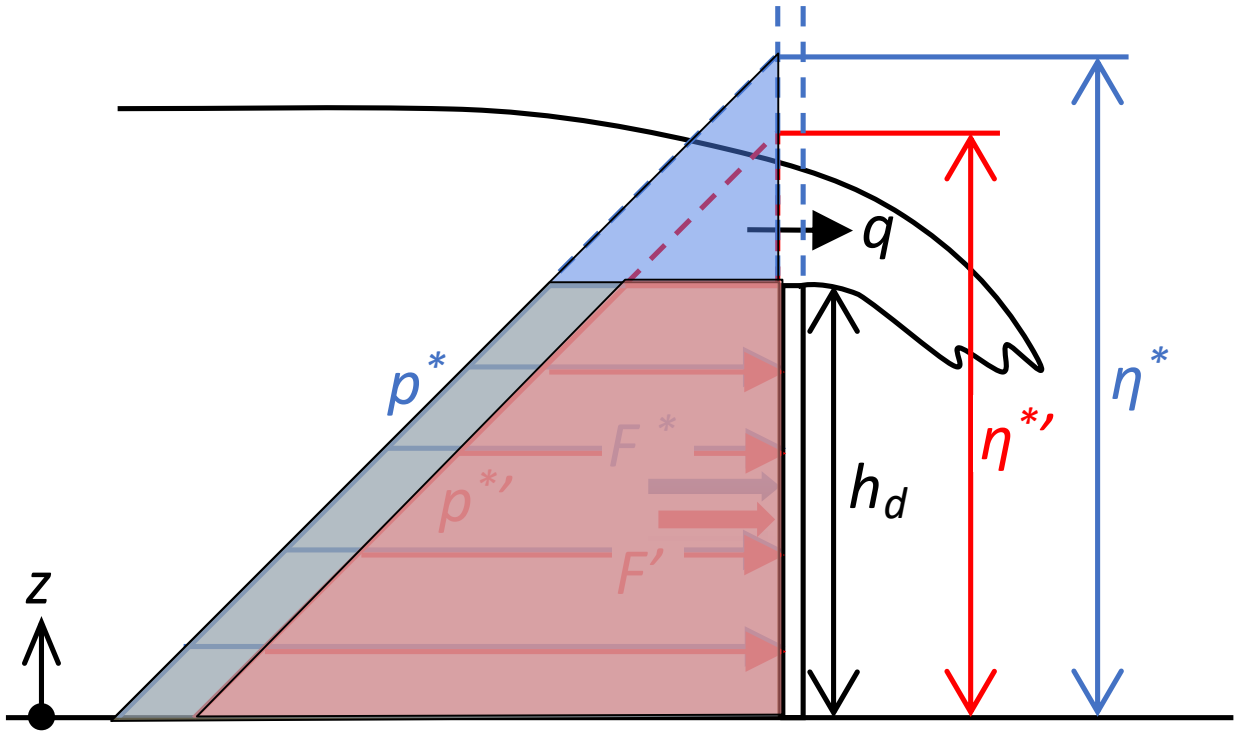


- Hydrostatic pressure profile
- The top pressure vanishes
- The overall pressure decreases



HYDRAULIC EXPERIMENTS

Analytical Model of overflowing tsunami pressure



$$F = \int_0^{\eta^*} p^* dz$$

Non-overflow tsunami force

$$F^* = \int_0^{h_d} p^* dz$$

Partial tsunami force

$$F' = \int_0^{h_d} p^{*\prime} dz$$

Overflow tsunami force

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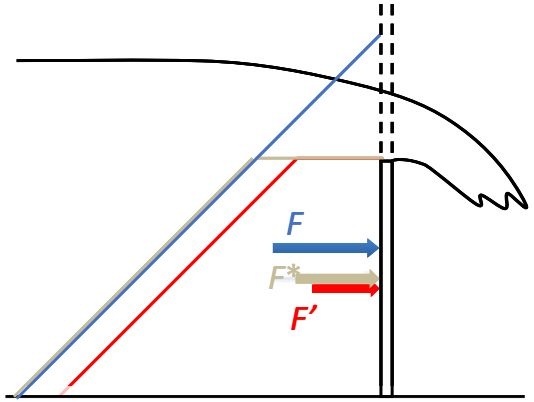
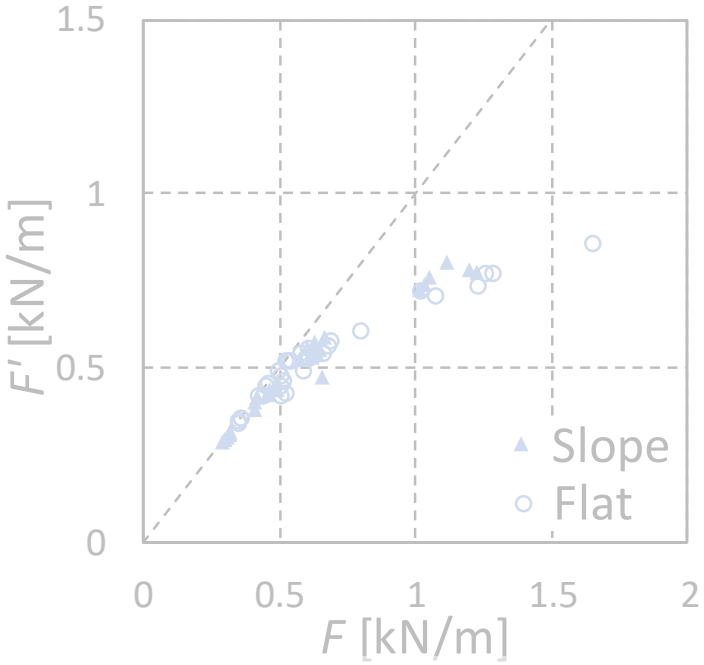
HYDRAULIC EXPERIMENTS

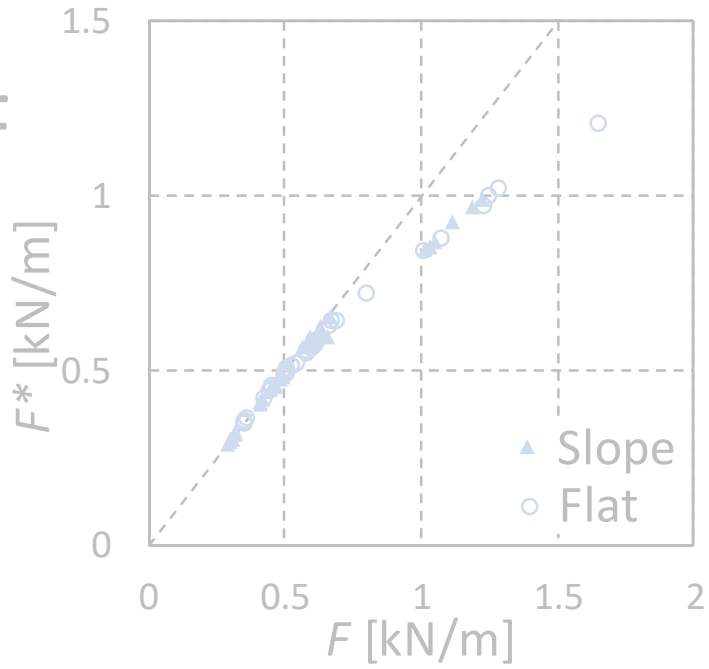
Comparisons of tsunami forces



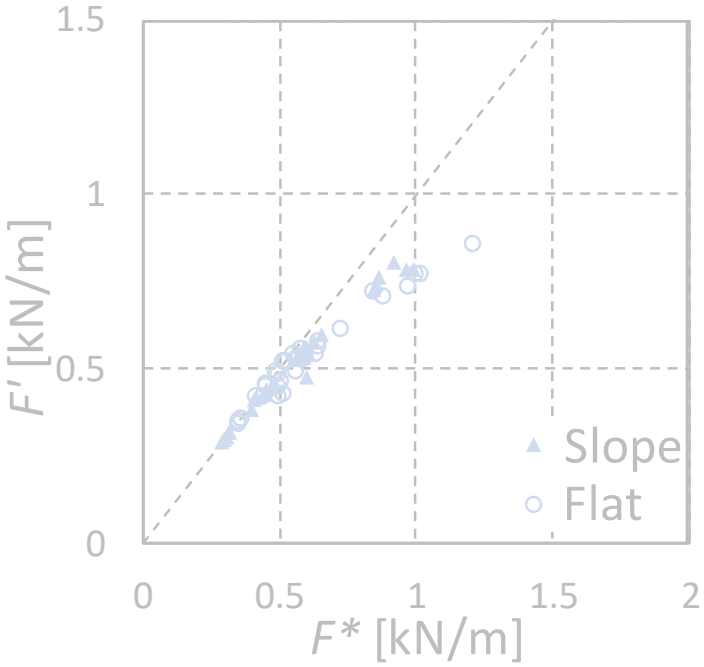
Non-overflow F vs. Overflow F'



Non-overflow F vs. Partial F*



Partial F* vs. Overflow F'

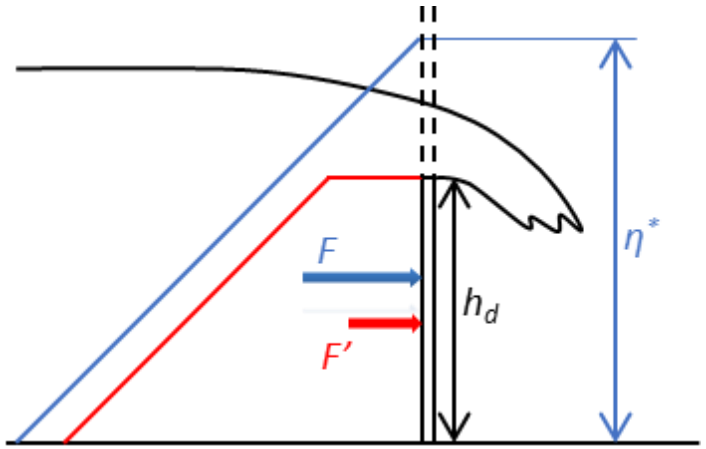


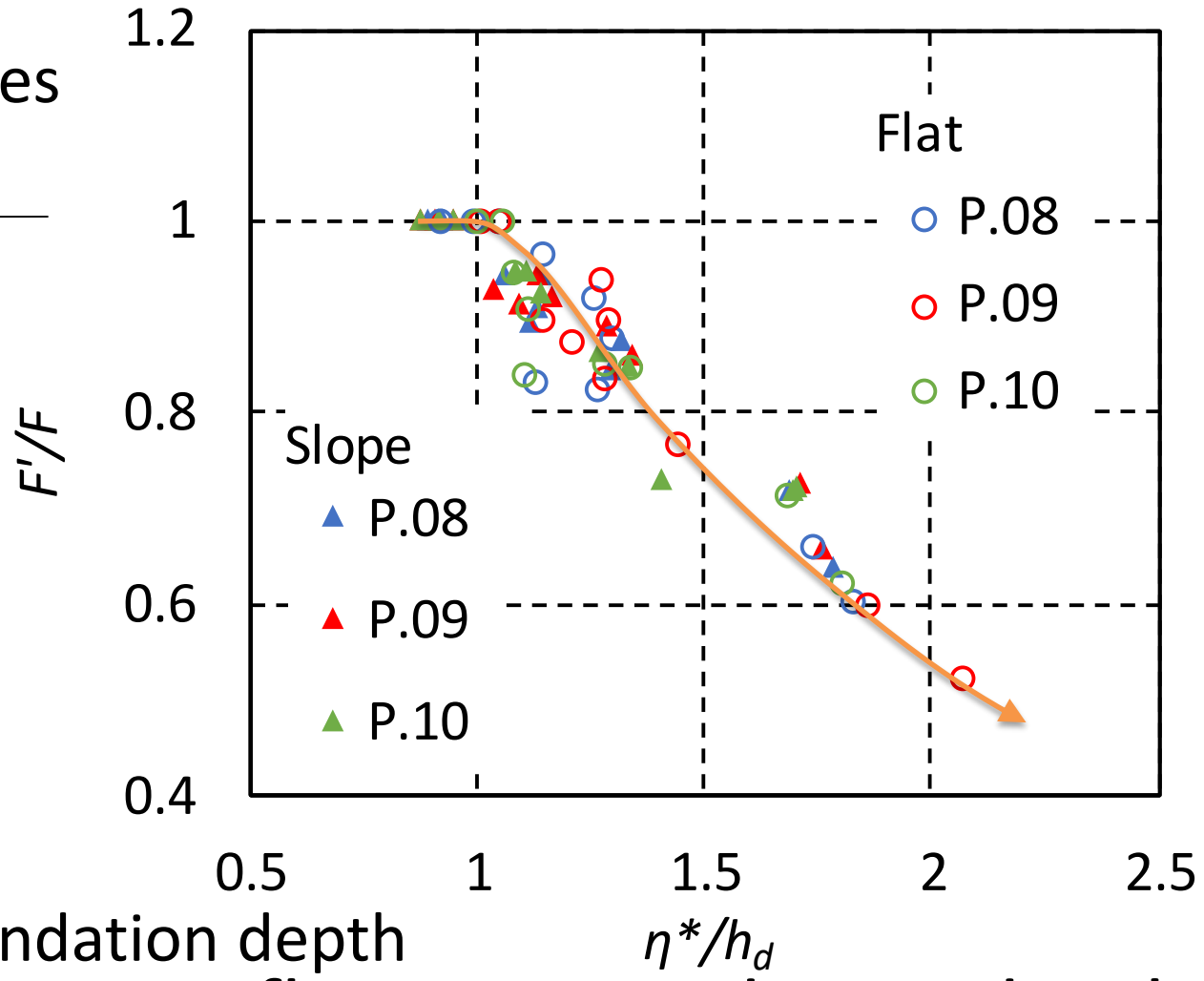
HYDRAULIC EXPERIMENTS

Tsunami forces reduction

Tsunami force reduction rates

$$\frac{\text{Overflow } F'}{\text{Non-overflow } F}$$





Relative inundation depth

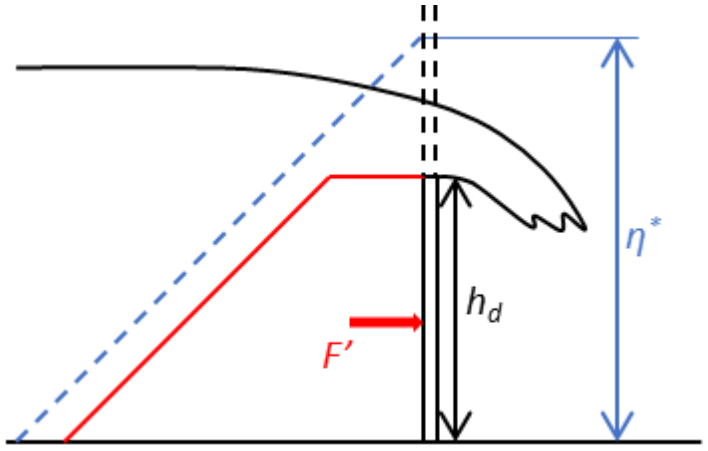
$$\frac{\text{non-overflowing inundation depth } \eta^*}{\text{wall height } h_d}$$

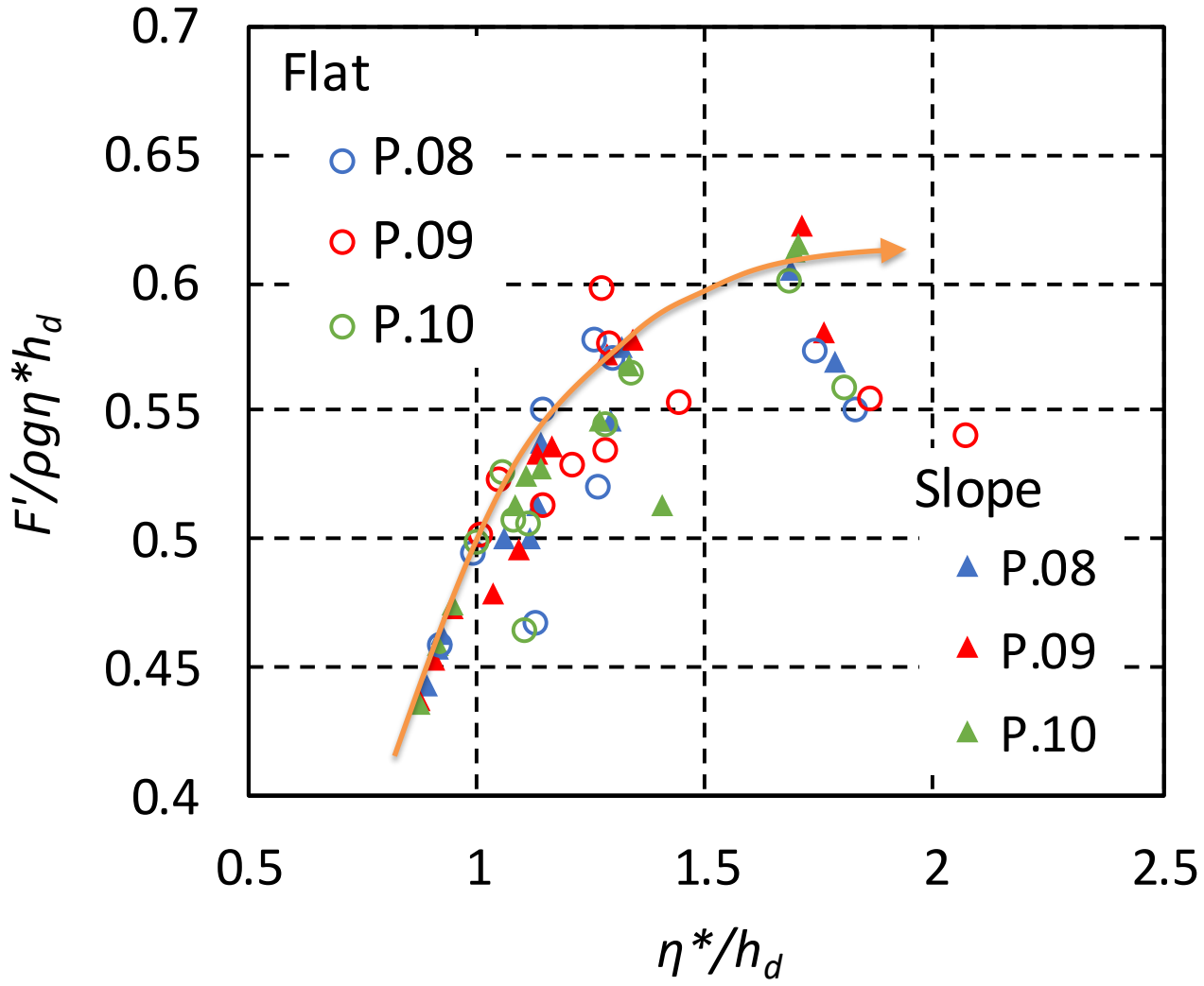
HYDRAULIC EXPERIMENTS

Dimensionless tsunami forces

Dimensionless tsunami forces

$$\frac{\text{Overflow } F'}{\rho g\, \eta^*\, h_d}$$





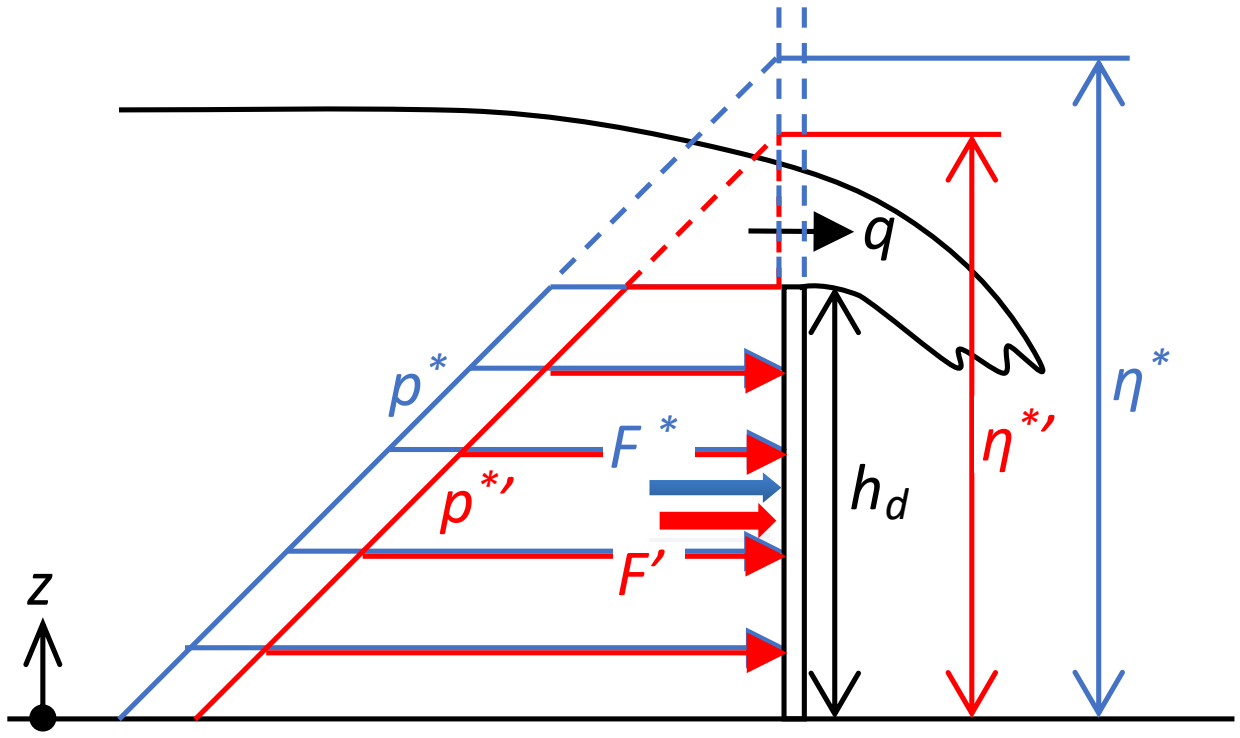
Relative inundation depth

ESTIMATION MODEL

$$F = \frac{1}{2}\rho g \eta^{*2} \qquad F^{*} = \frac{1}{2}\rho g h_d \left(2\eta^{*} - h_d\right) \qquad F' = \frac{1}{2}\rho g h_d \left(2\eta^{*\prime} - h_d\right)$$

Momentum conservation

$$\frac{1}{2}\rho g \eta^{*2} = \frac{1}{2}\rho g \eta^{*\prime 2} + \rho \frac{q^2}{\eta^{*\prime} - h_d}$$



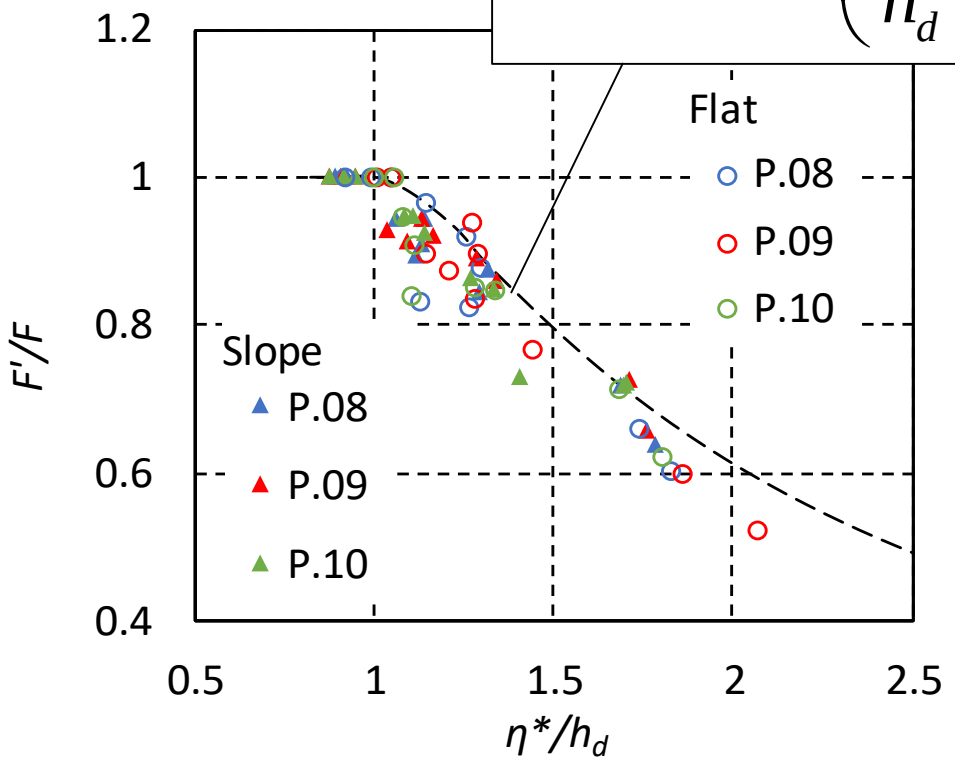
Overflow discharge

$$q = C\left(\eta^{*\prime} - h_d\right)^{3/2}$$

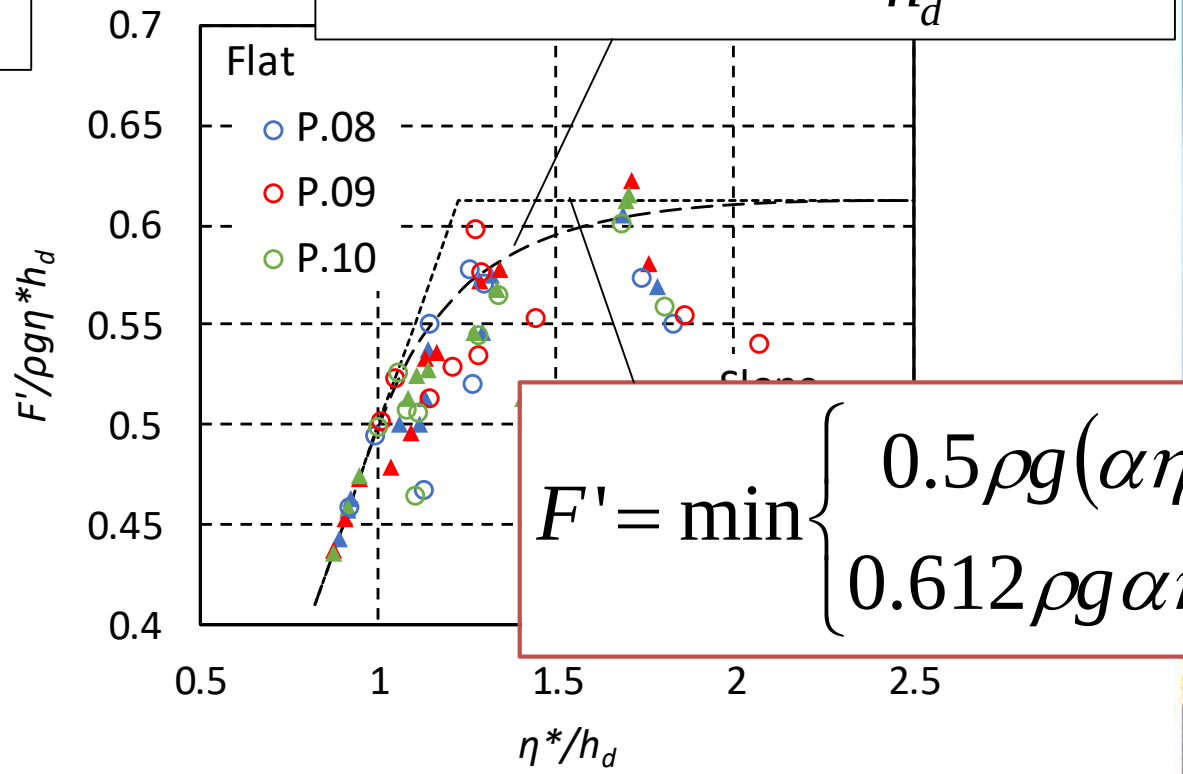
C : discharge coefficient=$\sqrt{g}$

ESTIMATION MODEL

$$\frac{F'}{F} = \frac{1+2\sqrt{3\left(\frac{\eta^*}{h_d}\right)^2}-2}{3\left(\frac{\eta^*}{h_d}\right)^2}$$



$$\frac{F'}{\rho g \eta^* h_d} = \frac{1+2\sqrt{3\left(\frac{\eta^*}{h_d}\right)^2}-2}{3\frac{\eta^*}{h_d}}$$



$$F' = \min\begin{cases} 0.5\rho g(\alpha\eta_0)^2 \\ 0.612\rho g\alpha\eta_0 h_d \end{cases}$$

CONCLUSIONS

The physical model tests were conducted and a theoretical model was proposed for the tsunami-induced force acting on seawalls under overflow condition.

- ✓ The tsunami force reduction due to the overflow is caused by the decreases of effective area and hydraulic pressure.

- ✓ The tsunami force reduction rate can be safely estimated by the proposed model.

ESTIMATION MODEL

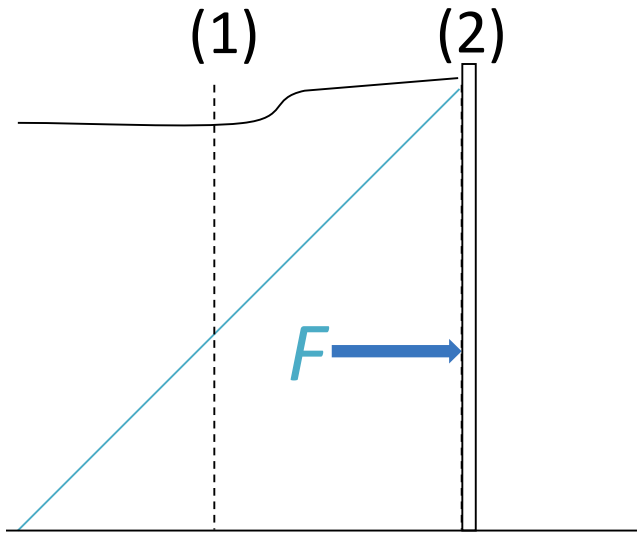
Momentum conservation

Non-overflow

$$M_{in}^{(1)} + M_{out}^{(1)} = \frac{1}{2}\rho g \eta^{*2}$$

Overflow

$$M_{in}^{(2)} + M_{out}^{(2)} = \frac{1}{2}\rho g \eta^{*'2} + \rho \frac{q^2}{\eta^{*'} - h_d}$$



$$M_{in}^{(1)} = M_{in}^{(2)} \qquad M_{out}^{(1)} > M_{out}^{(2)}$$

$$\frac{1}{2}\rho g \eta^{*2} > \frac{1}{2}\rho g \eta^{*'2} + \rho \frac{q^2}{\eta^{*'} - h_d}$$