Stability Estimation Method for Armor Units For Breakwaters with Parapets Against Tsunami Overflow

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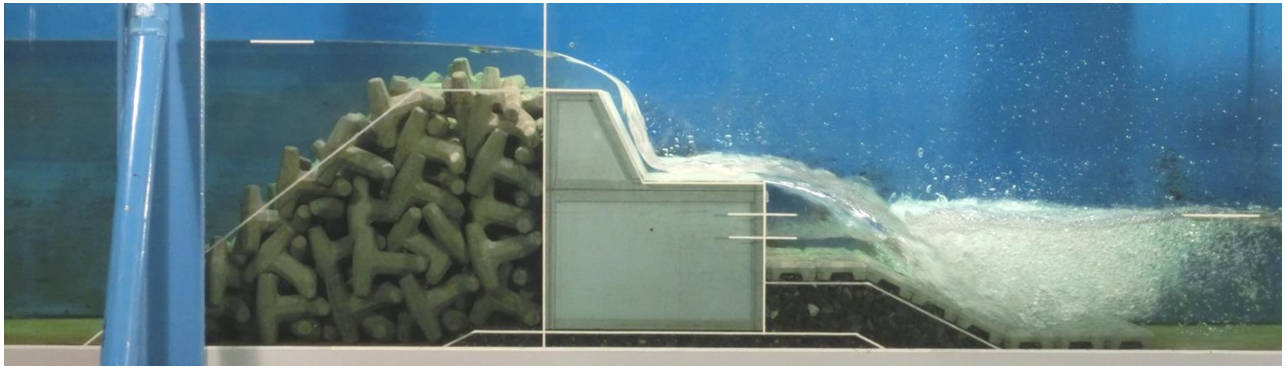

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Outline

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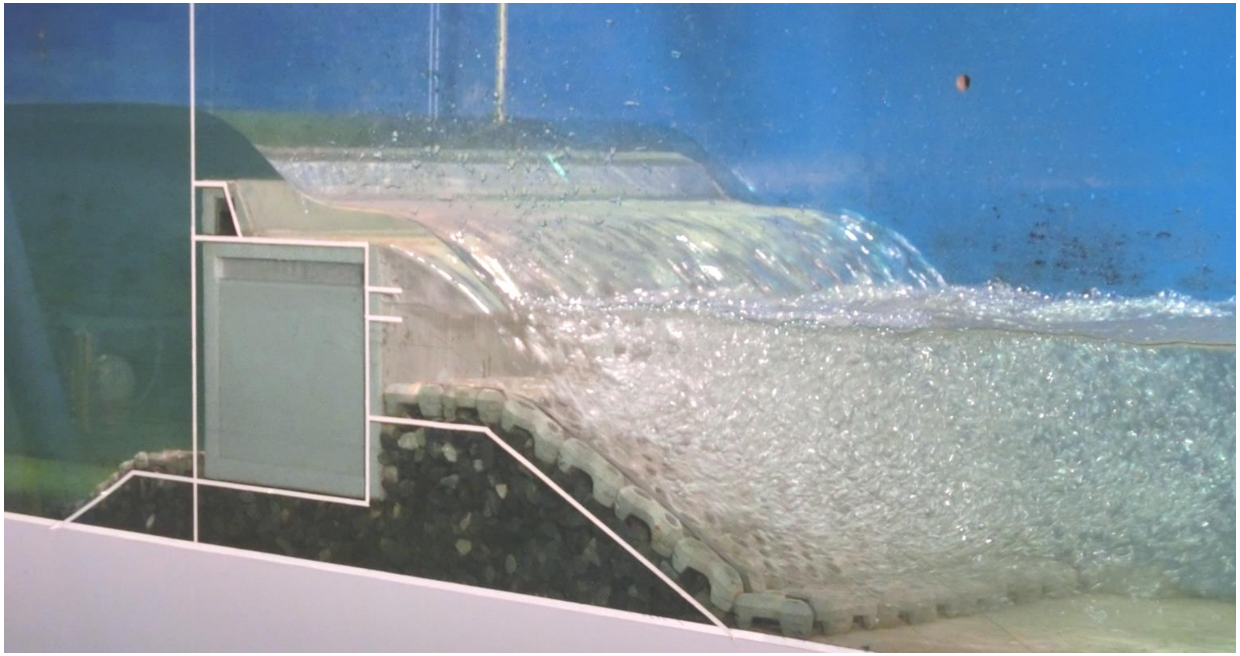
- Conclusions

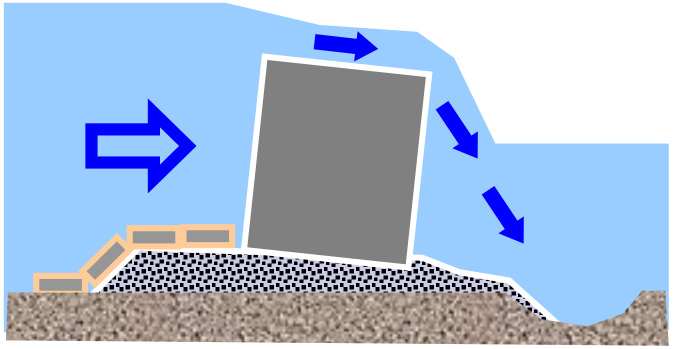


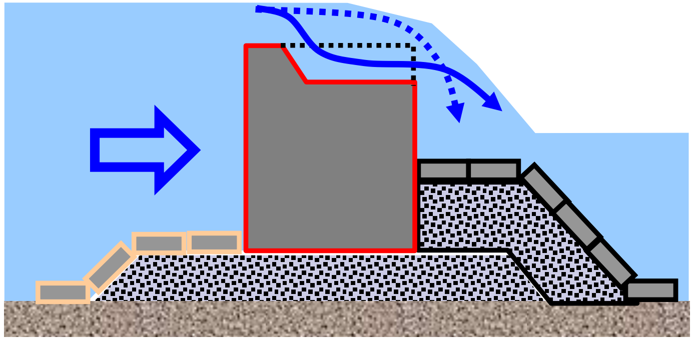
Introduction

- **Scouring of rear side rubble mound is one of the failure mechanism of breakwaters during 2011 Great East Japan Tsunami.**

- **Reinforcement of rear side using additional rubble stones and armor units is an effective countermeasure.**

- **Installing a parapet on the caisson is also effective because the parapet redirects the overtopped water flow in the horizontal direction.**



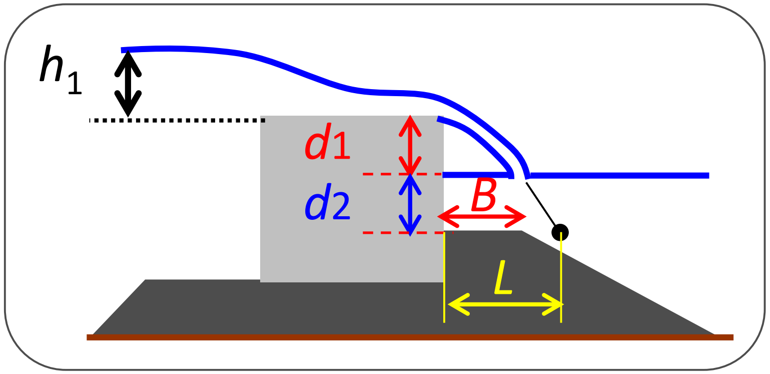


Motivation

- **The objective of this study is to establish a practical method to estimate the required mass of armor units against tsunami overflow.**

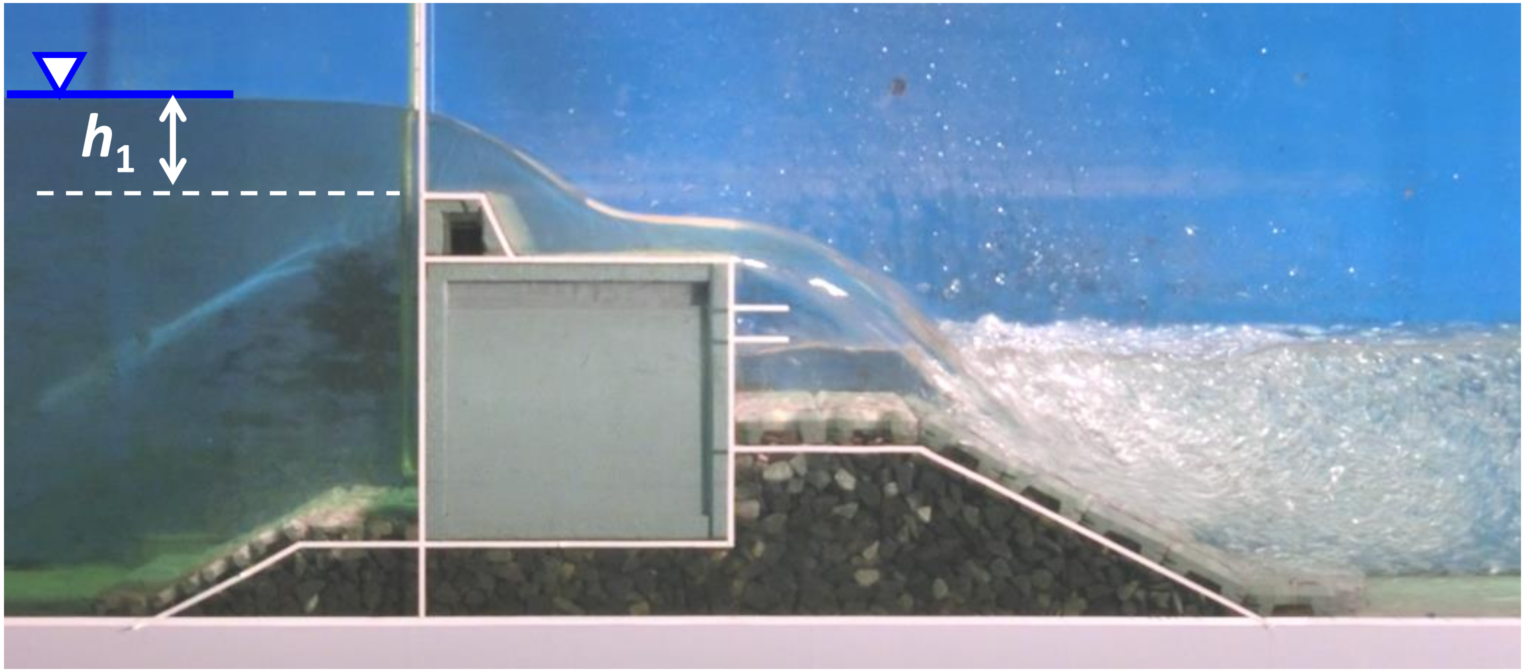
- **Previously, we proposed a simple stability estimation method based on the overflow depth (Mitsui et al. 2014).**

- **However, the applicable range of the method is limited to the rectangular caisson.**



- **In this study, we propose a new method that can be applied to a caisson with parapet.**

Hydraulic model experiments



- Model scale is 1/50.
- Steady overflow is generated by a pump.
- Stability limit of the armor units are investigated by gradually increasing the overflow depth h_1.
- Wide range of test conditions by changing:
  - Dimensions of the breakwater
  - Presence or absence of a parapet
  - Shape and mass of the armor units

Example of test results

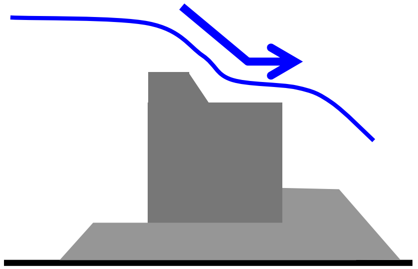
Rectangular caisson

Damaged at h_1 = 9 cm

Caisson with parapet

Damaged at h_1 = 7 cm

The effect of parapet changes complicatedly depending on the height and width of parapet, overflow depth, etc.



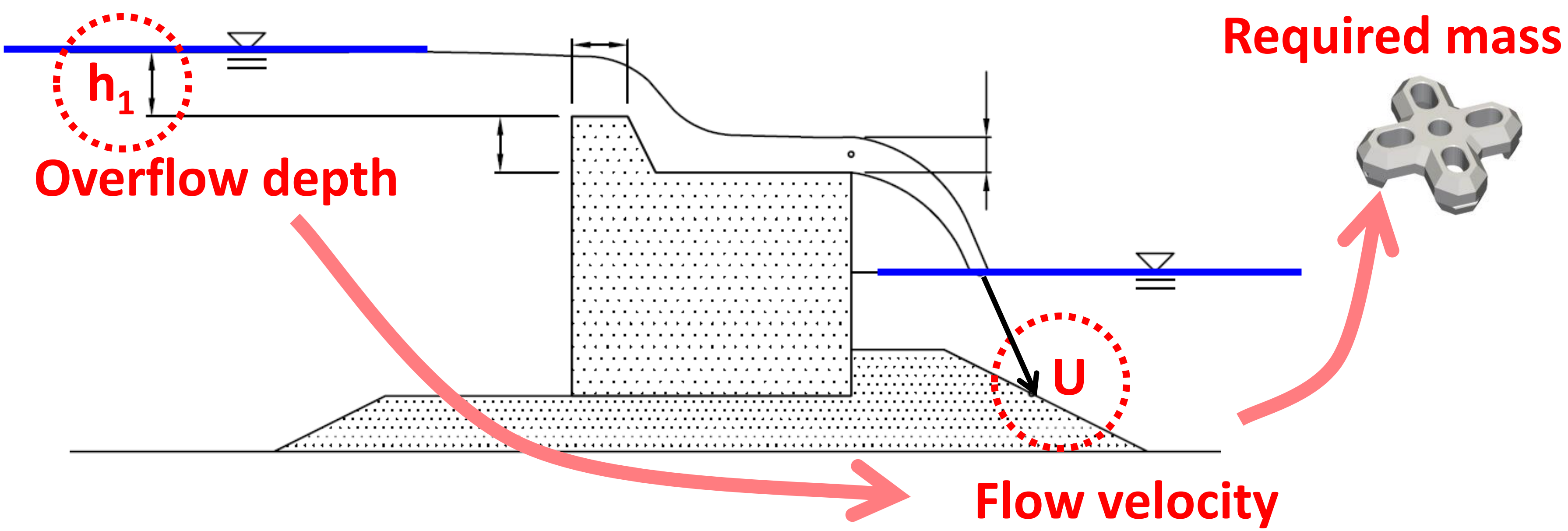
Flow velocity and impingement position changes due to a parapet

New stability estimation method

The method is divided into two successive parts:

(1) Calculate impinging flow velocity onto the mound
(Mitsui et al. 2017)

(2) Calculate required mass of armor units using the impinging flow velocity



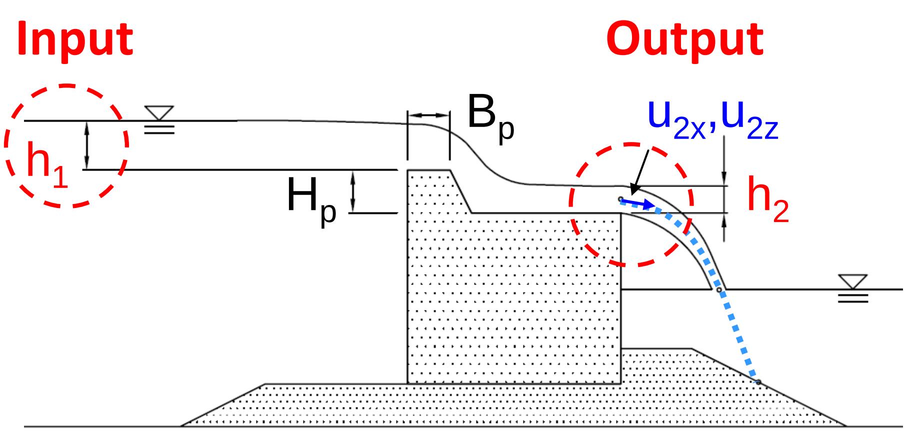
(1-1) Flow velocity and water depth at the rear end of the caisson

Input

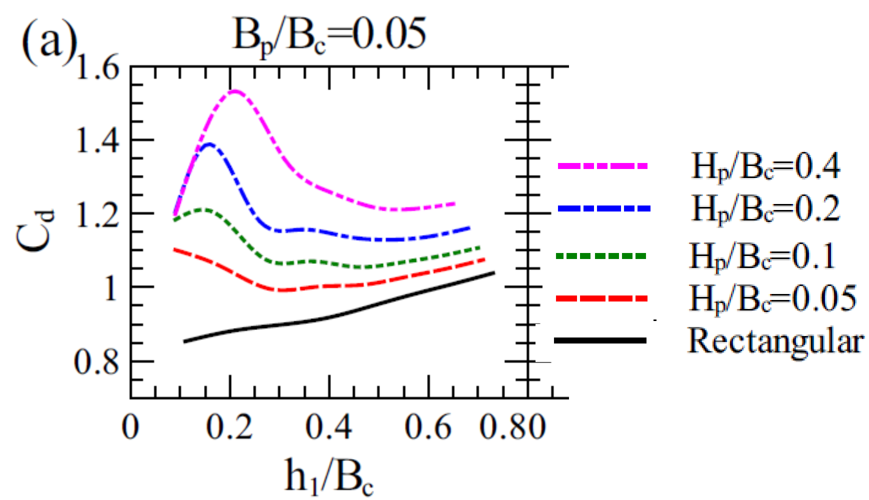
- h_1 (overflow depth)
- Dimensions of the caisson (H_p, B_p, etc.)

Output

- h_2 (water depth)
- u_{2x}, u_{2z} (flow velocity)



Calculation diagrams based on comprehensive numerical simulation

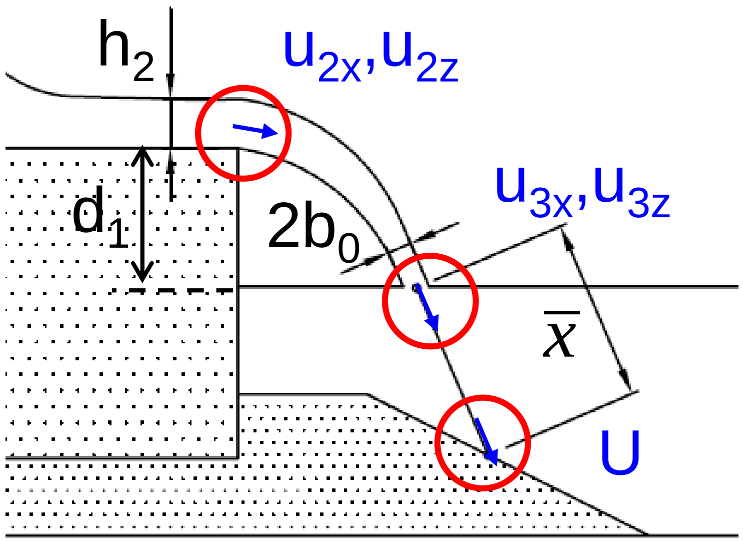


(1-2) Impinging flow velocity onto the mound

- **Calculate u_{3x} and u_{3z} from the free fall assumption**

$$u_{3x} = u_{2x}$$

$$u_{3z} = -\sqrt{u_{2z}^2 + 2g\left(d_1 + h_2/2\right)}$$



- **Calculate U using two-dimensional free jet theory** (Rajaratnam, 1976)

$$U = \min\left(u_3, u_3 \frac{C_1}{\sqrt{\bar{x}/b_0}}\right)$$

U : Flow velocity impinging to the mound

C_1 : Experimental constant (= 3.0 in this study)

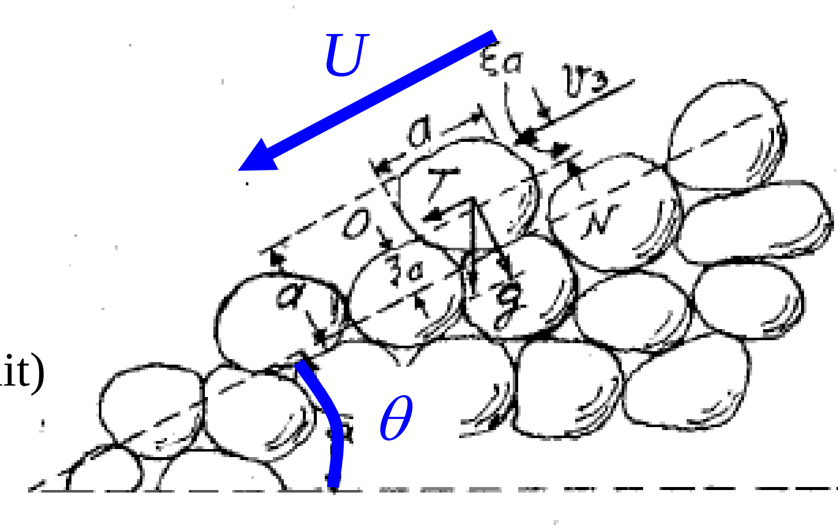
b_0 : Half of the thickness of water jet at the water surface

$\bar{x}$: Diffusion distance under the water surface

Calculation of required mass of armor units

◆ **Formula by Isbash (1932)**

$$M = \frac{\pi \rho_r U^6}{48 g^3 Y^6 \left(S_r - 1\right)^3 \cos^3 \theta}$$

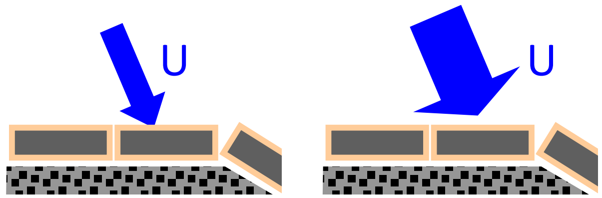


M : Required mass of stone (or armor unit)
ρ_r : Mass density of stone
S_r : Specific gravity of stone
U : Flow velocity near the stone
θ : Angle of structure slope with the horizontal
Y : Isbash number (stability number)

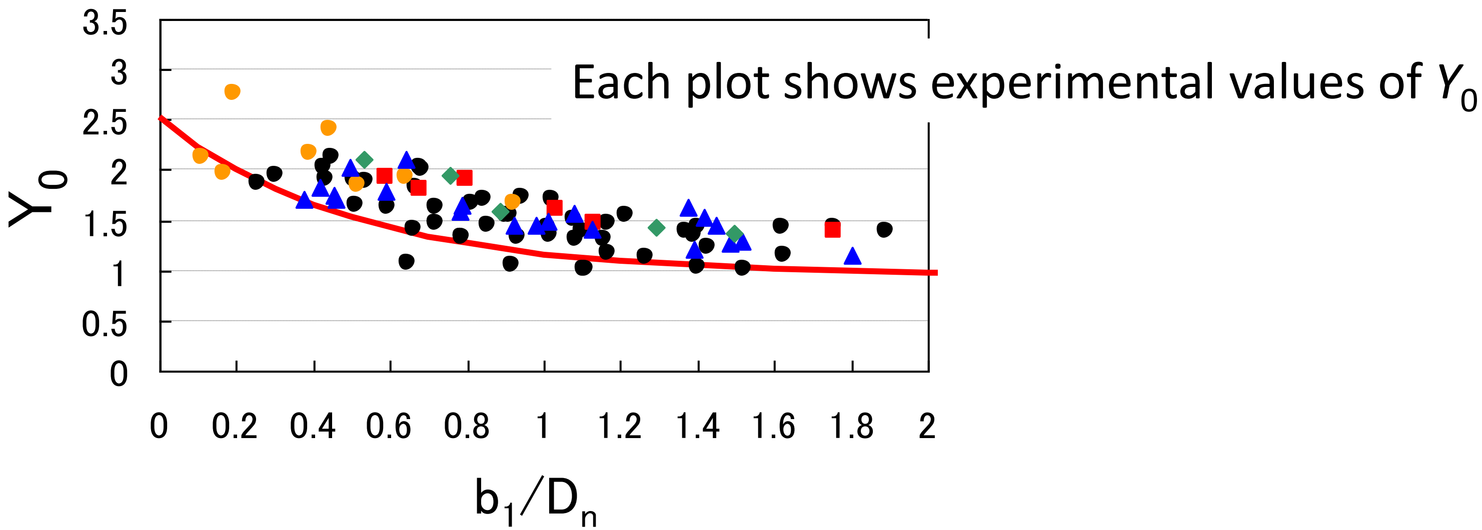
- **Relationship between the flow velocity *U* and the required mass of the stone *M***
- **Derived from the balance of moments acting on a stone on the slope**

1. Influence of the thickness of the water jet

◆ **Even though the flow velocity is the same, the fluid force acting on the armor unit increases as the thickness of the water jet increases.**



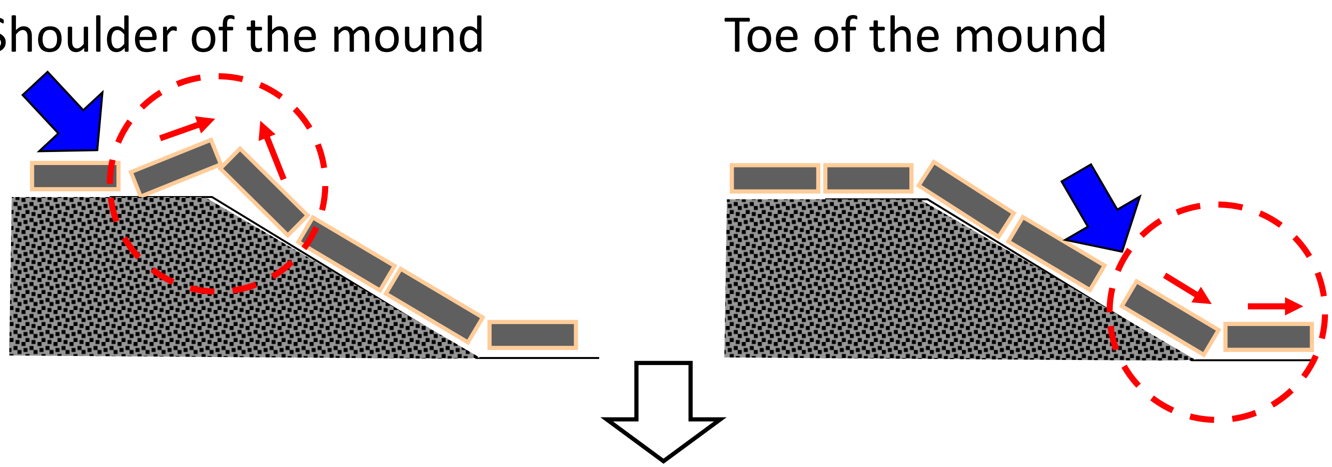
◆ **Isbash number Y_0 is expressed as a function of the ratio of the thickness of the water jet b_1 to the length of the armor unit D_n.**



2. Influence of the impingement position

- **Armor units at the shoulder of the mound or at the toe of the mound have low resistance to external forces because the back support is weak in these parts.**

<u>Structural weak points</u>



- **Isbash number is reduced when the water jet impinges onto these weak points.**

$$Y = C_R Y_0$$

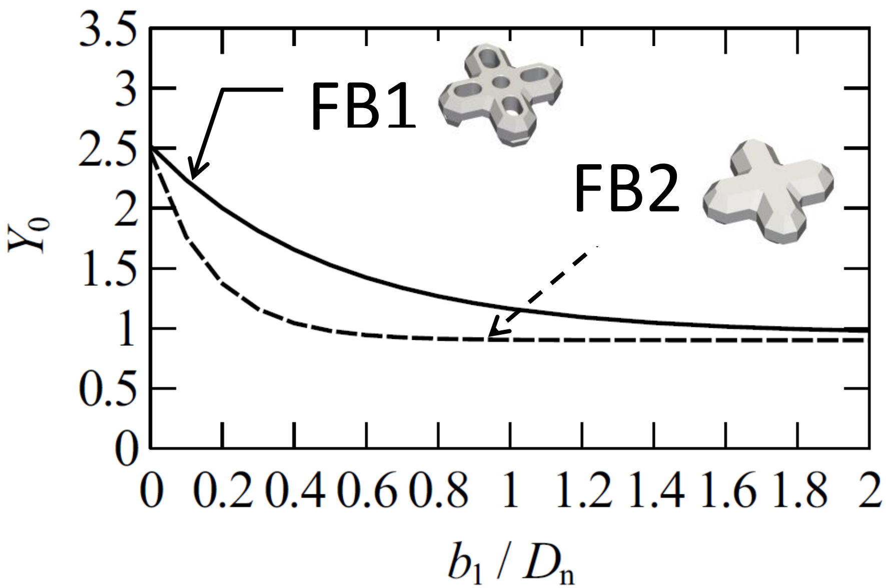
C_R : Stability reduction coefficient

Determination of the Isbash number for each armor units

◆ **Isbash number for each armor unit is determined based on the experimental results.**

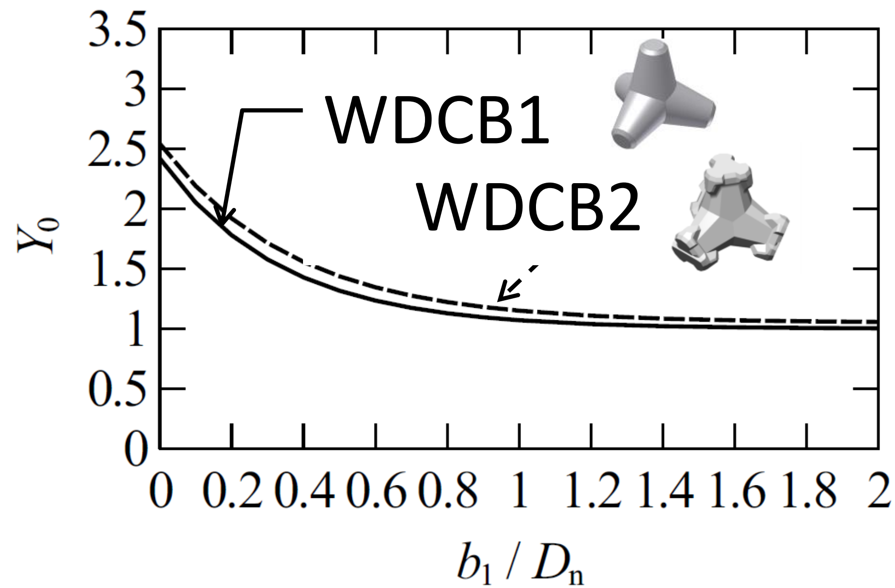
Flat type armor block

(one-layer)



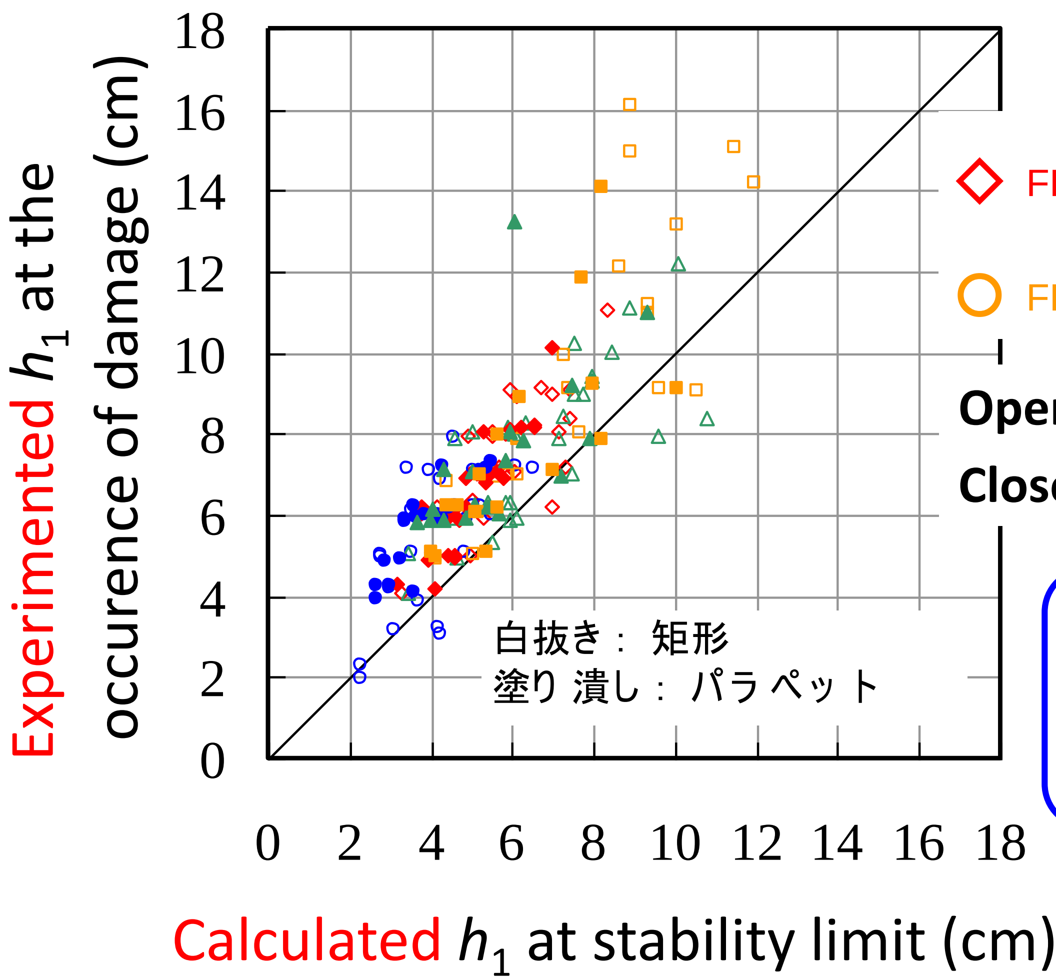
Wave-dissipating concrete block

(two-layer)



Validation of the method

◆ **The overflow depths at the stability limit calculated by the method were compared with the experimental results.**



Open plots : Rectangular caisson

Closed plots : Caisson with parapet

Good agreement regardless of the presence or absence of parapet

Conclusions

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A new stability estimation method for armor units against tsunami overflow is proposed that can be applied to caissons with a parapet.

- **A direct grasp of the influence of the parapet on the armor stability is enabled.**
- **Required mass of armor units is easily calculated (numerical computation is not required).**
- **Influence of the impingement position of the water jet and influence of the thickness of the jet are considered.**

Thank you for your attention !