Effect of sea-dykes on tsunami run-up

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TAIWAN.

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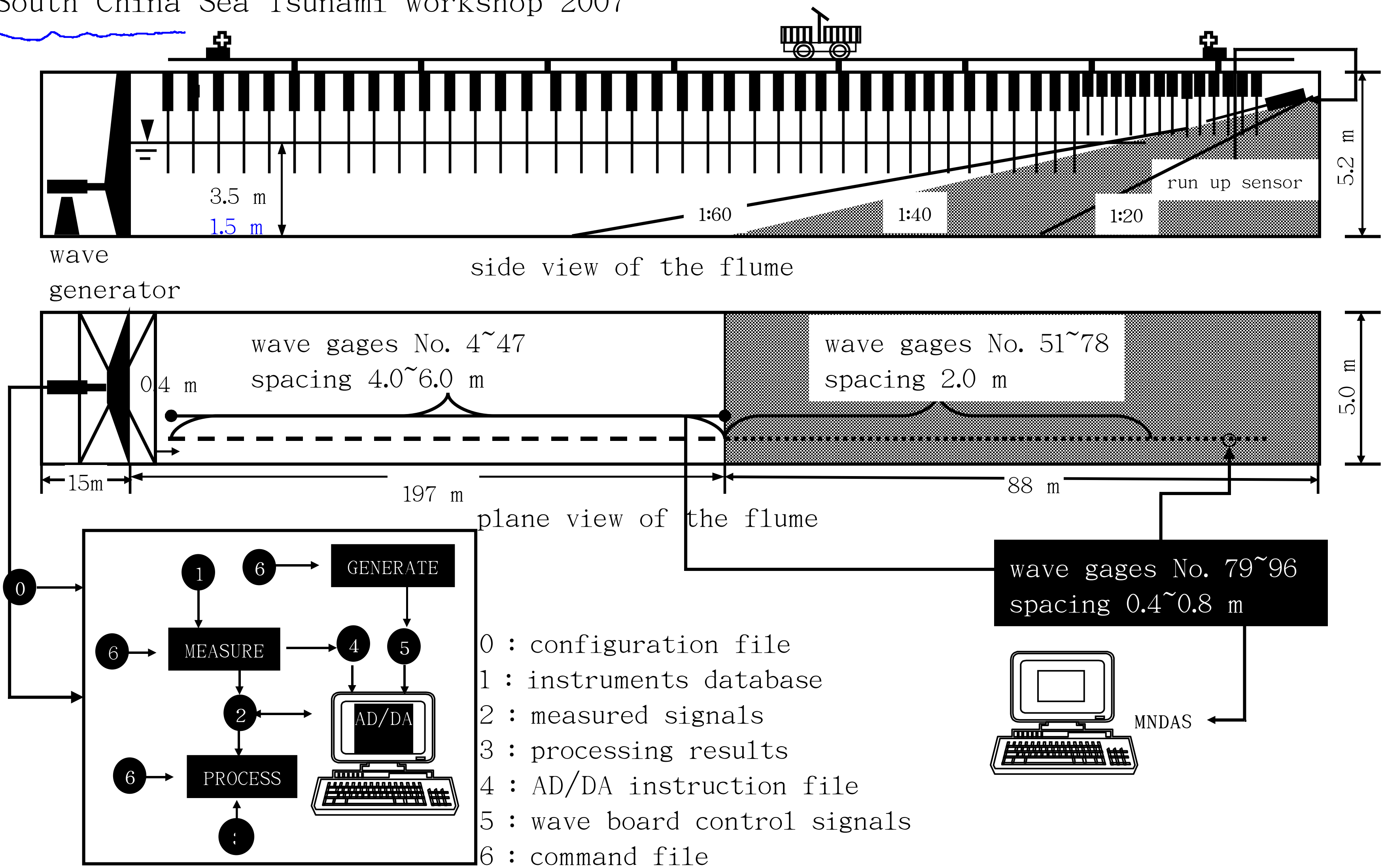
Outline

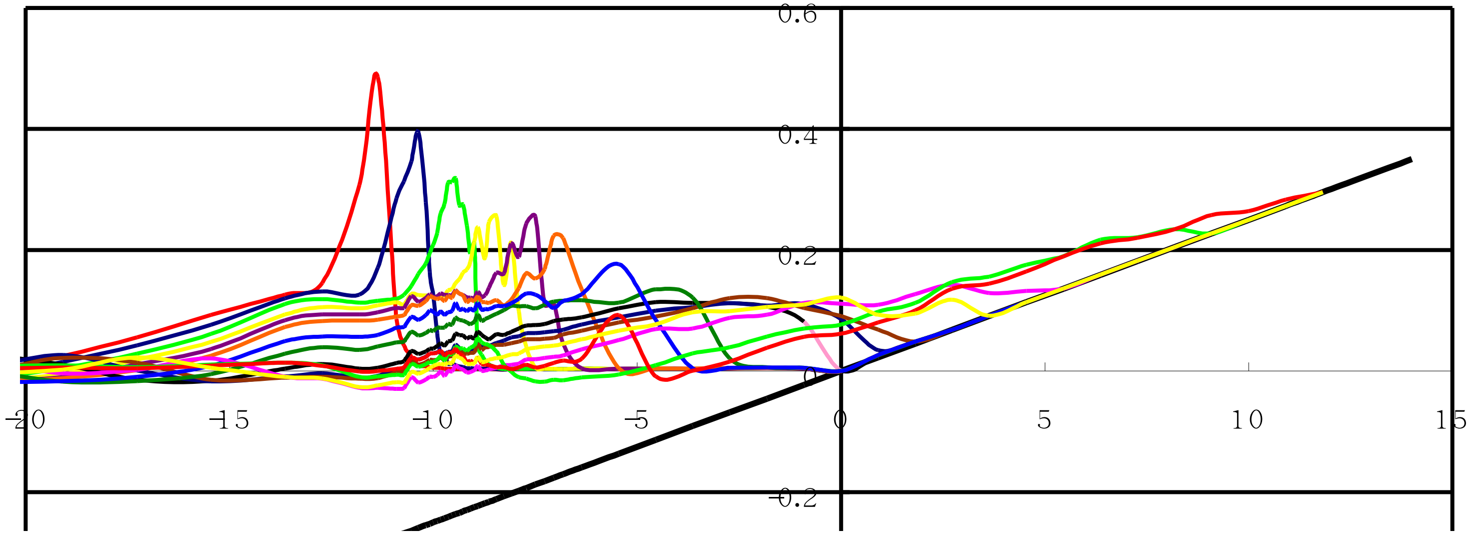
- Introduction
  - tsunami research in THL after the 2004 Indian Ocean tsunami
  - The motivation and the objectives of present study
- Preliminary results
- Ongoing experiments
- Future works



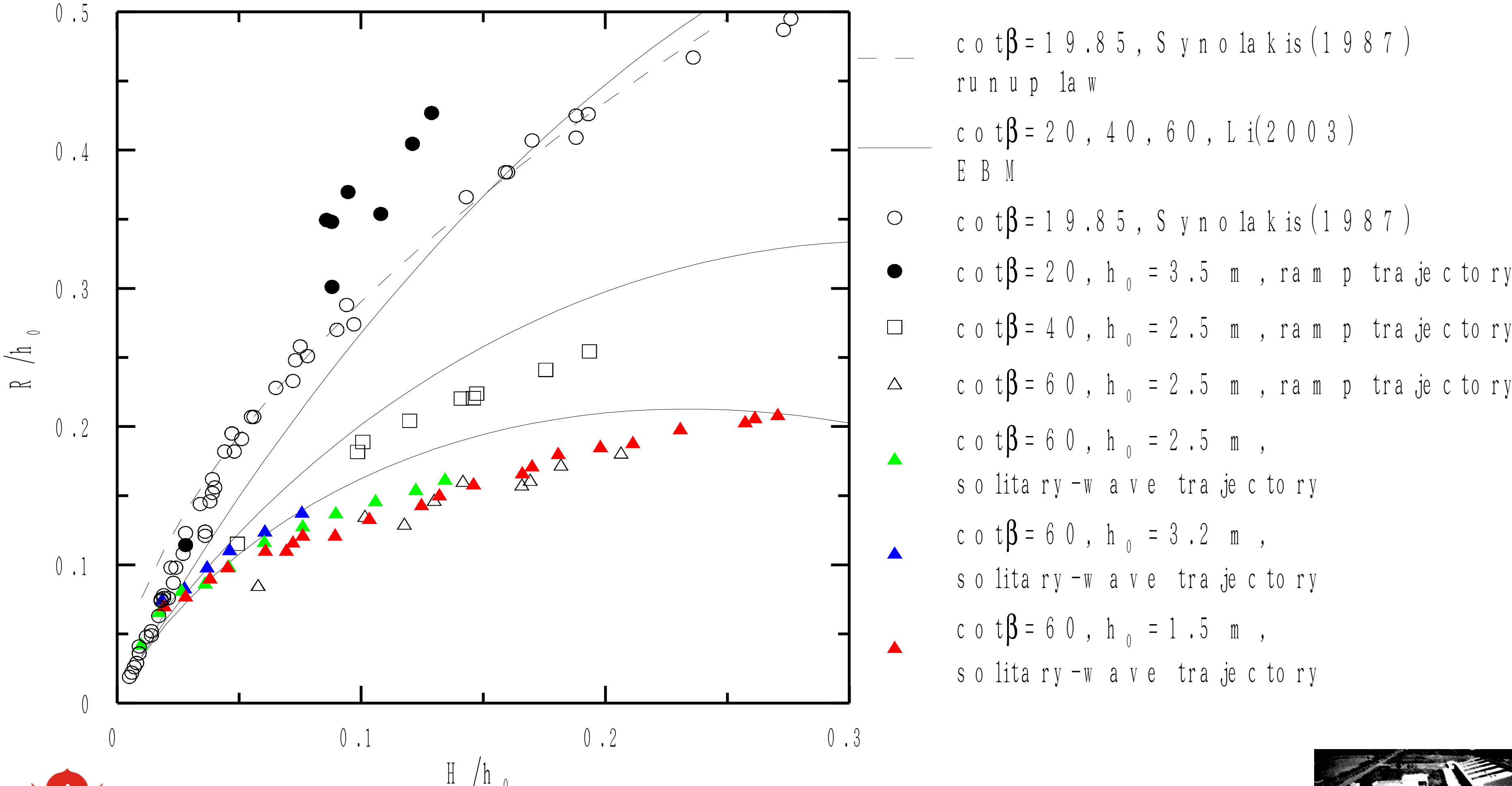
Experimental set-up


90

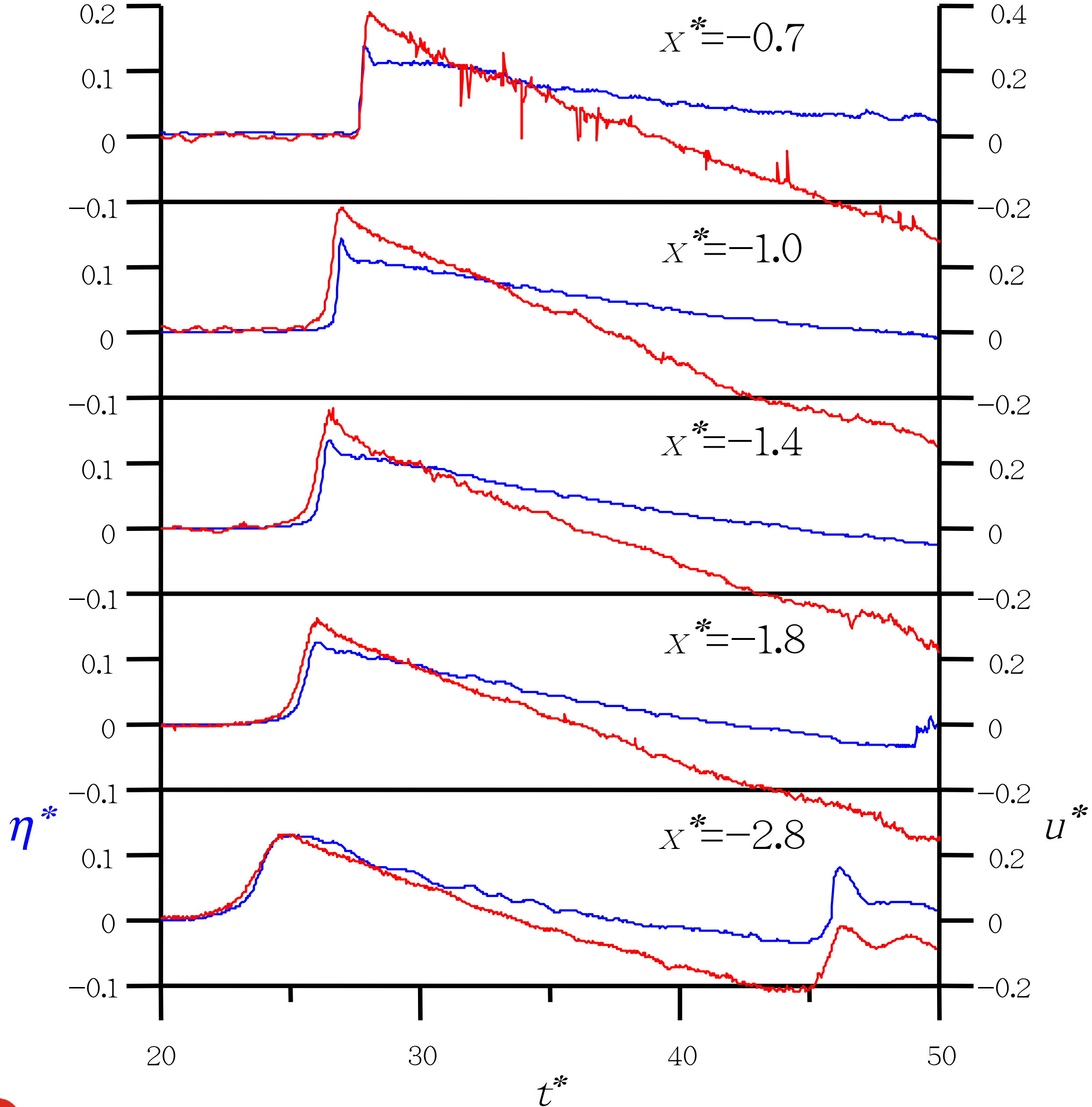
Surface wave profiles after breaking



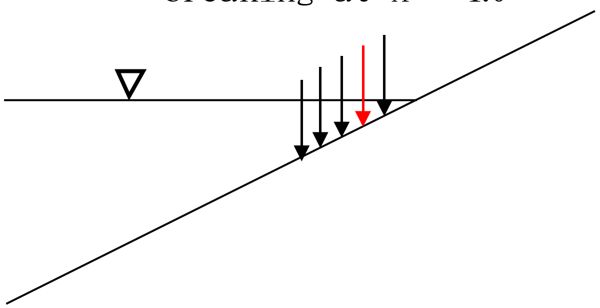
R/h_0 vs. H/h_0



0.5
0.4
0.3
0.2
0.1
0
R/h0
0
0.1
0.2
0.3
H/h0
cotβ=19.85, Synolakis(1987) runup law
cotβ=20, 40, 60, Li(2003) EBM
cotβ=19.85, Synolakis(1987)
cotβ=20, h0=3.5 m, ramp trajectory
cotβ=40, h0=2.5 m, ramp trajectory
cotβ=60, h0=2.5 m, ramp trajectory
cotβ=60, h0=2.5 m, solitary-wave trajectory
cotβ=60, h0=3.2 m, solitary-wave trajectory
cotβ=60, h0=1.5 m, solitary-wave trajectory

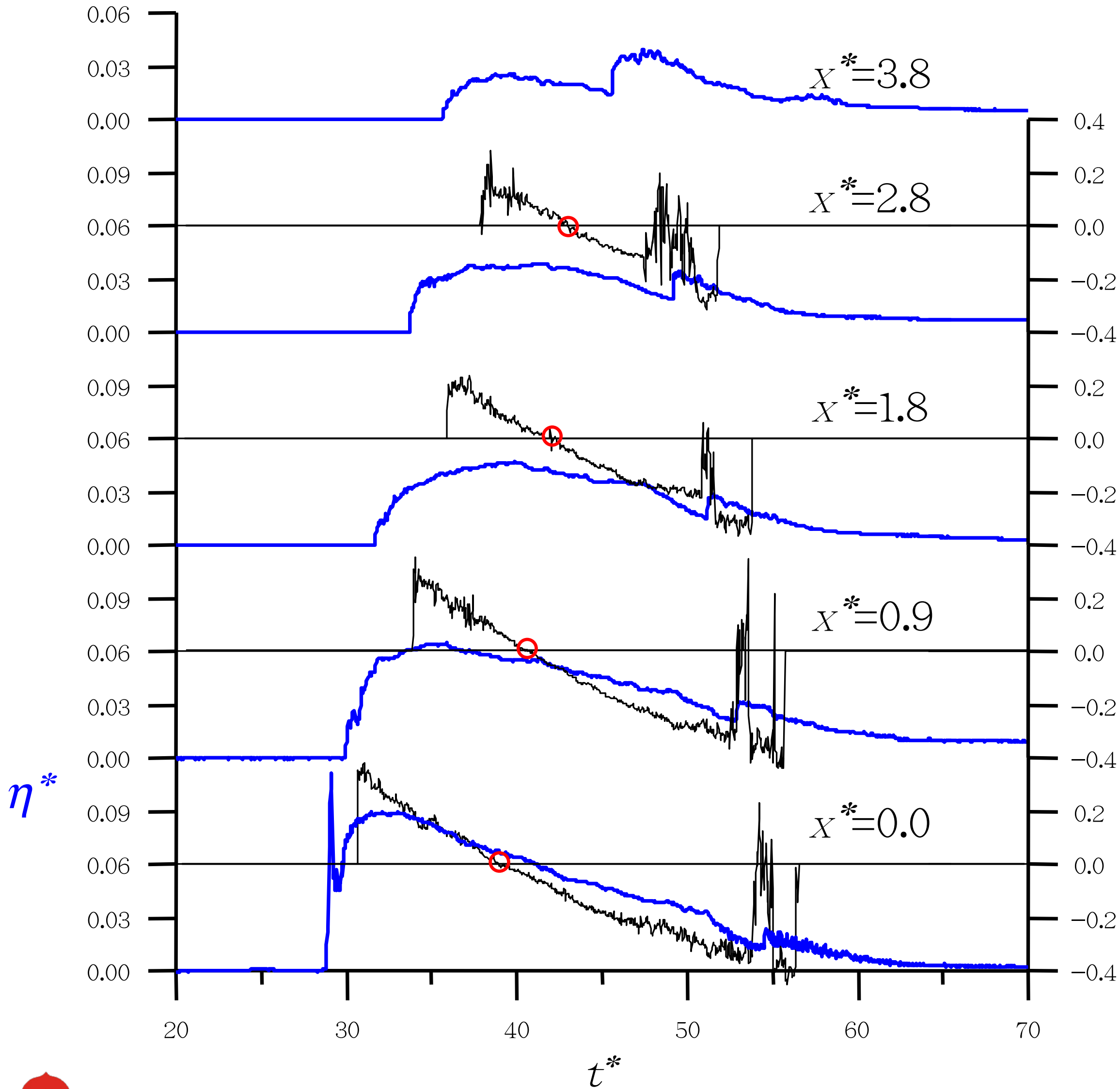


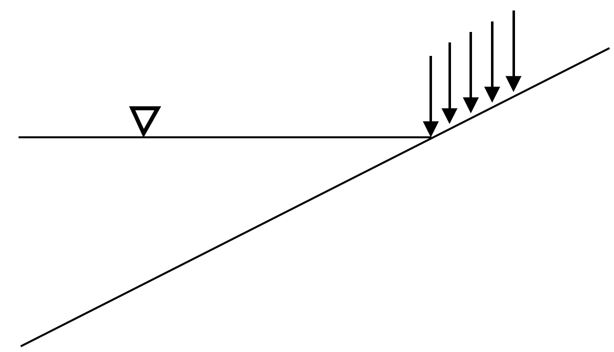
η^* and u^*
($\cot\beta$=20, H/h=0.12)

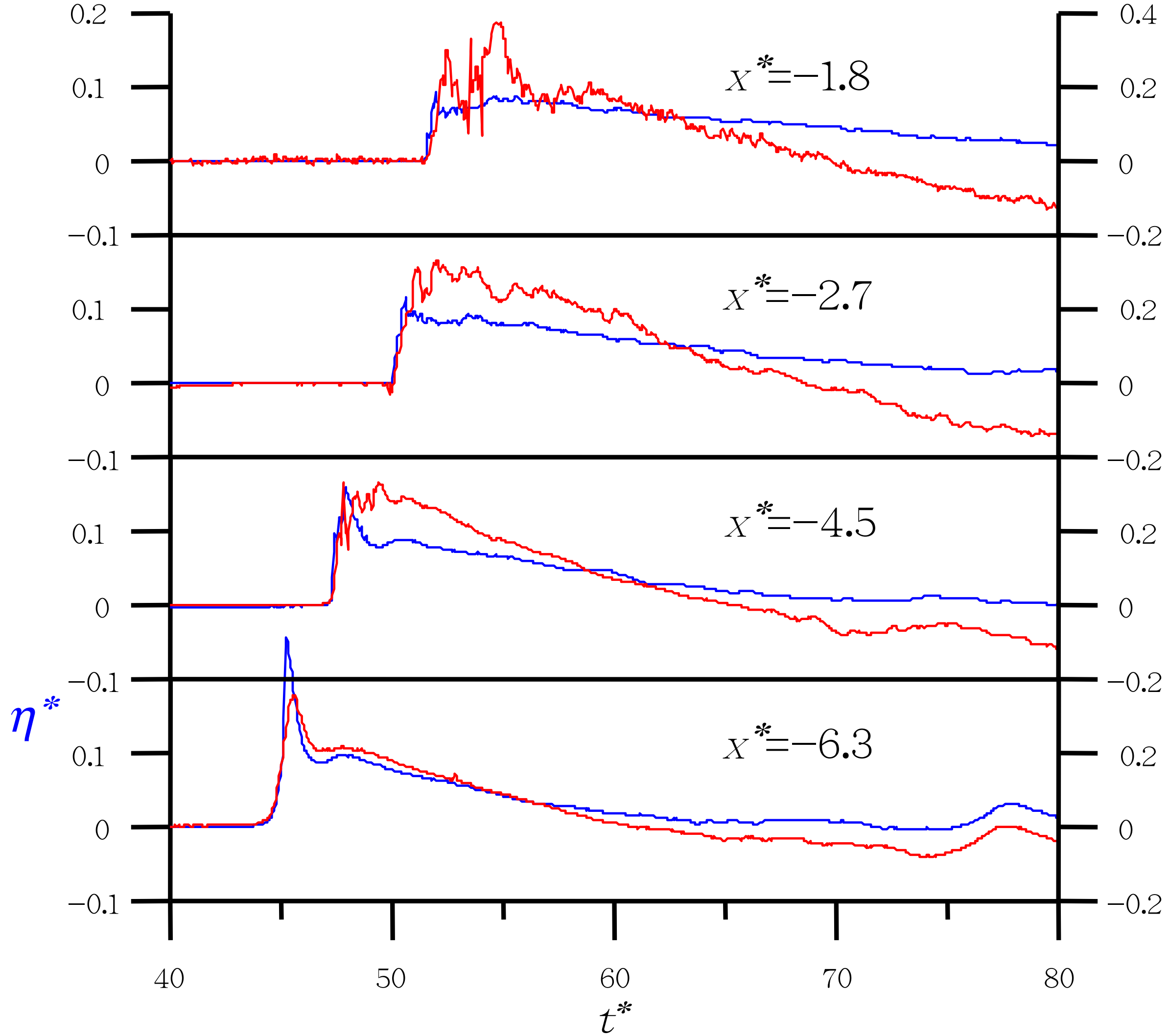


η^* and u^* above shoreline

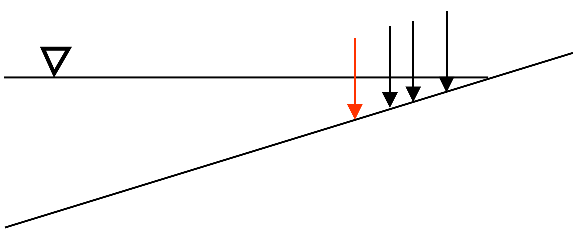
($\cot\beta=20$, $H/h=0.12$)

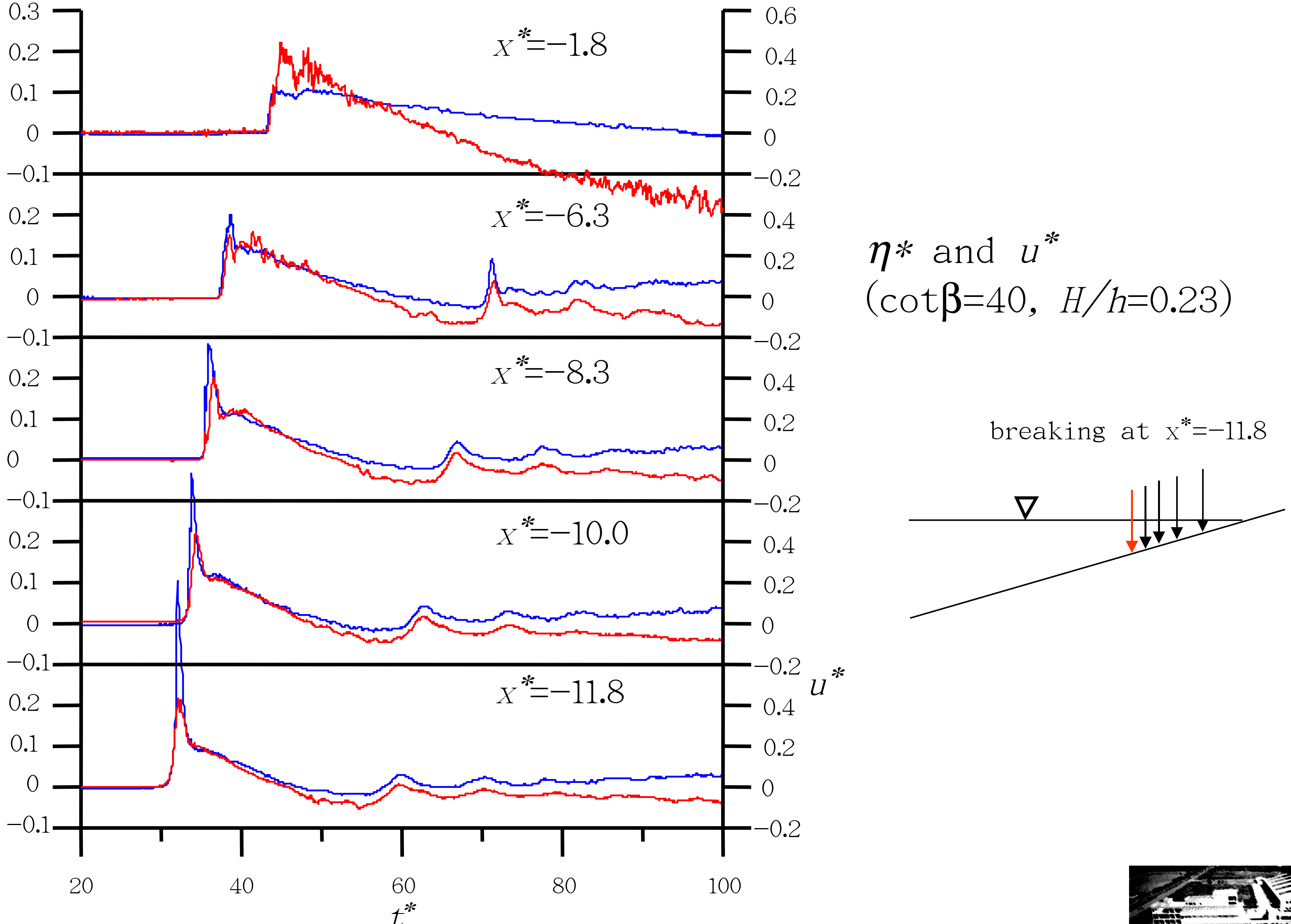


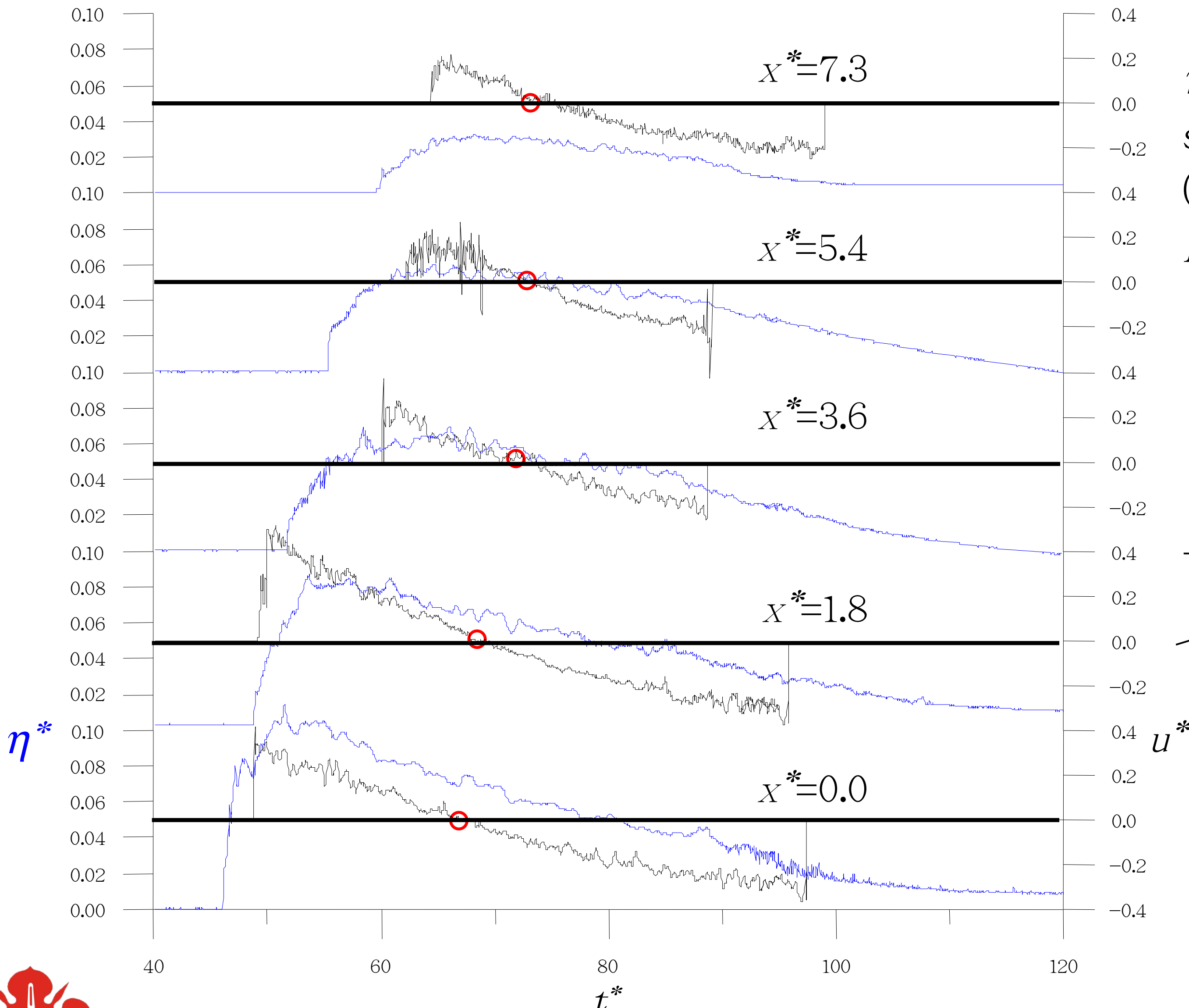




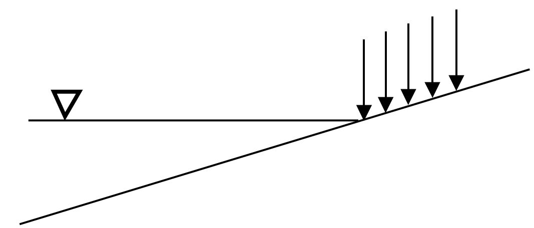
η^* and u^*
(cotβ=40, H/h=0.12)




0.3
0.2
0.1
0
−0.1
0.6
0.4
0.2
0
−0.2
x*=−1.8
x*=−6.3
x*=−8.3
x*=−10.0
x*=−11.8
η*
u*
20
40
60
80
100
t*
η* and u*
(cotβ=40, H/h=0.23)
breaking at x*=−11.8

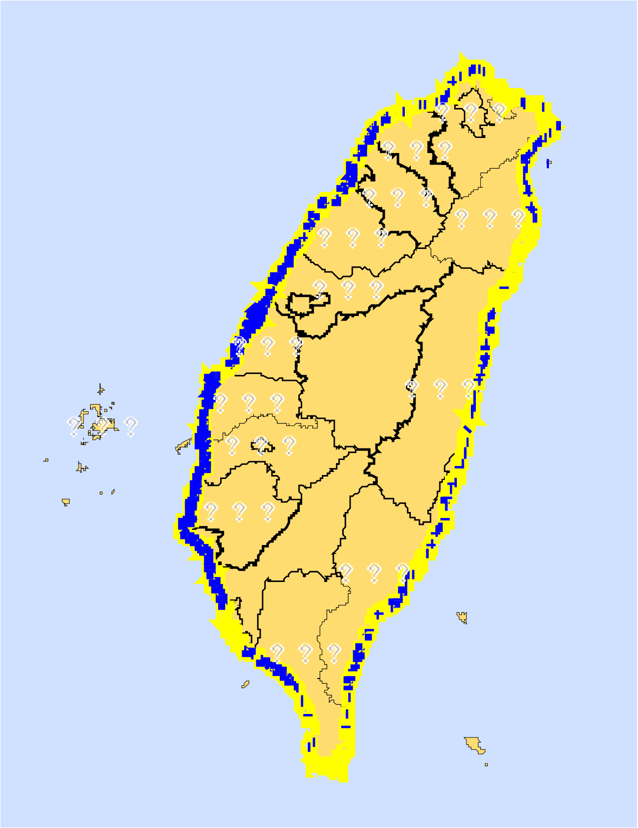


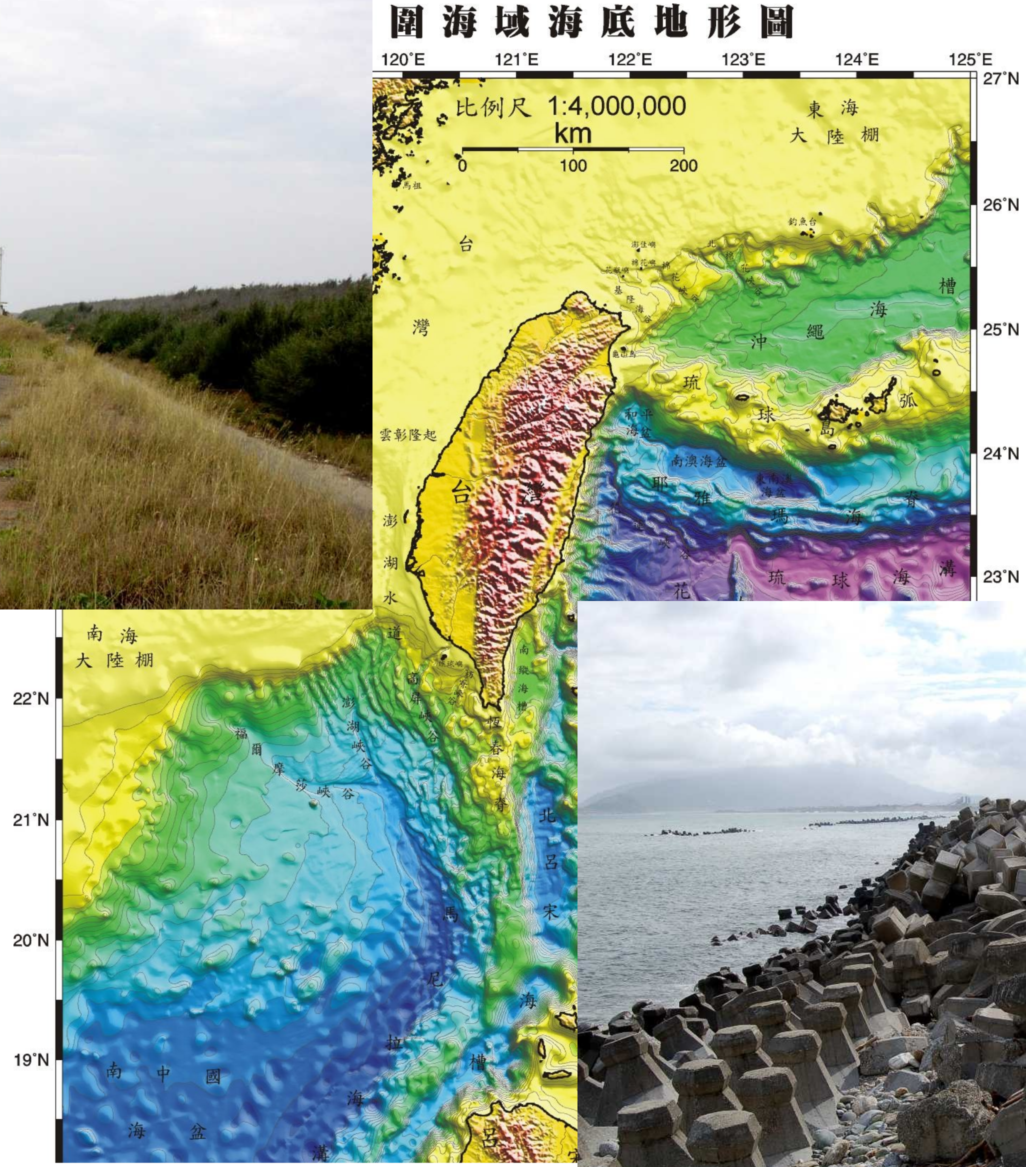
η^* and u^* above shoreline ($\cot\beta=40$, $H/h=0.23$)



About 1/3 coastline is protected

- coast length 1,141 km with 369.8 km protected by sea-dykes or revetments
- design wave conditions:
  - West coast
    - —$H_{1/3}$:4–6 m, $T_{1/3}$:8–10 s
  - East coast
    - —$H_{1/3}$:10–14 m, $T_{1/3}$:10–16 s
- crown levels of sea dykes or revetments
  - West coast
    - —E.L. +4~ +6 m
  - East coast
    - —E.L. +8~+10 m





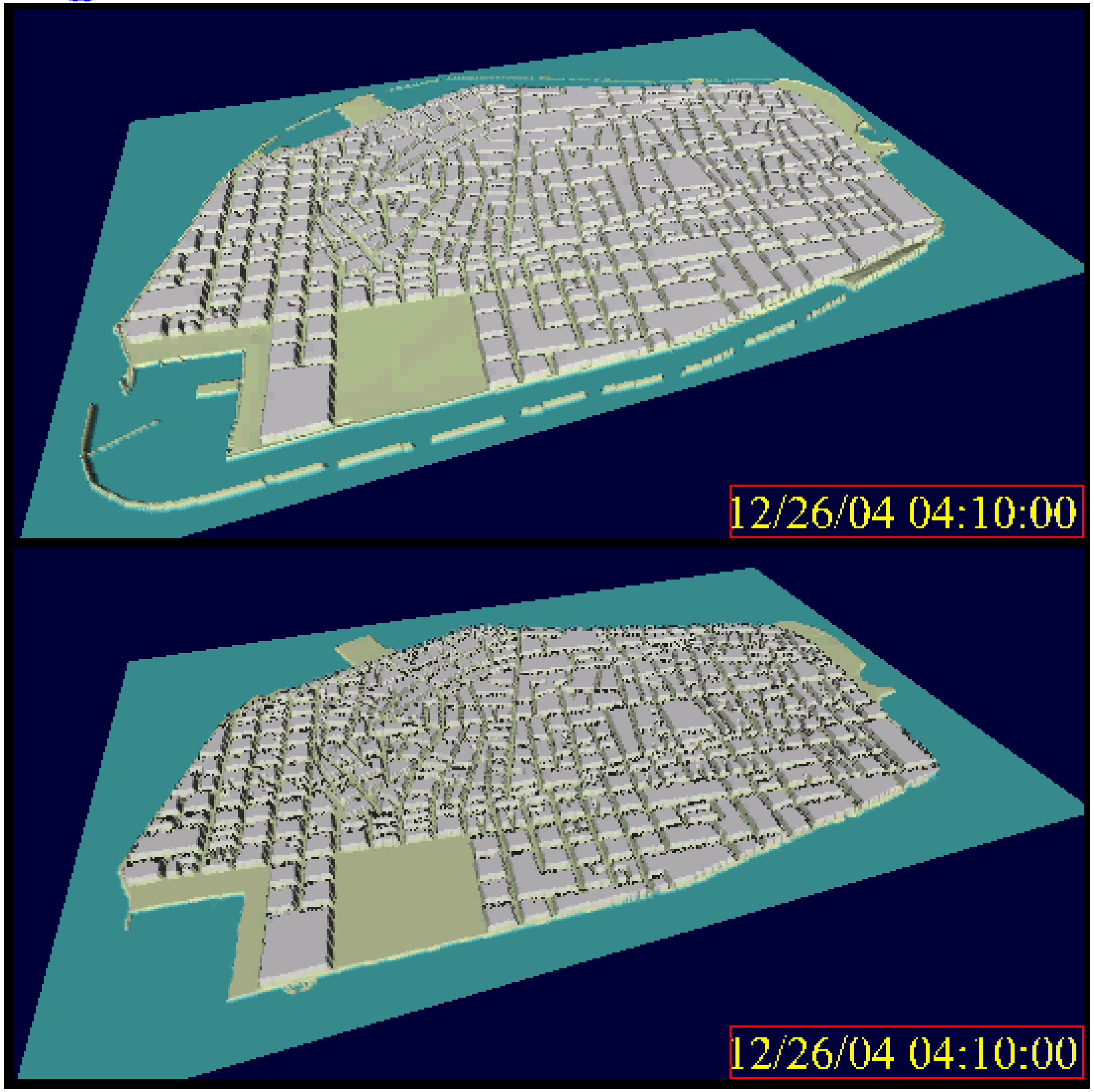
A typical coastal landscape of Taiwan

Seafloor bathymetry source: NCOR, TAIWAN

A report about the role of sea-dykes (revetments) in the 2004 tsunami attack

- ……….. However, on Male Island, which is the national capital of the Republic of Maldives, revetments and other structures have been constructed around the island…………………. The island was relatively unaffected by the Sumatra tsunami because these revetments helped protect the island from inundation.

National Institute for Land and Infrastructure Management, Ministry of Land, Infrastructure and Transport, Japan



State of tsunami wave run-up with and without revetment

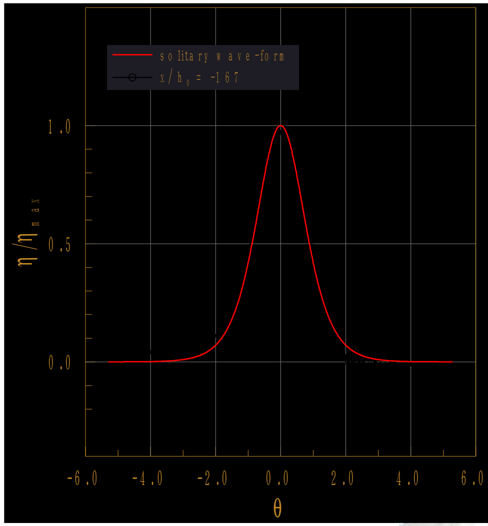
National Institute for Land and Infrastructure Management, Ministry of Land, Infrastructure and Transport, Japan

The objectives

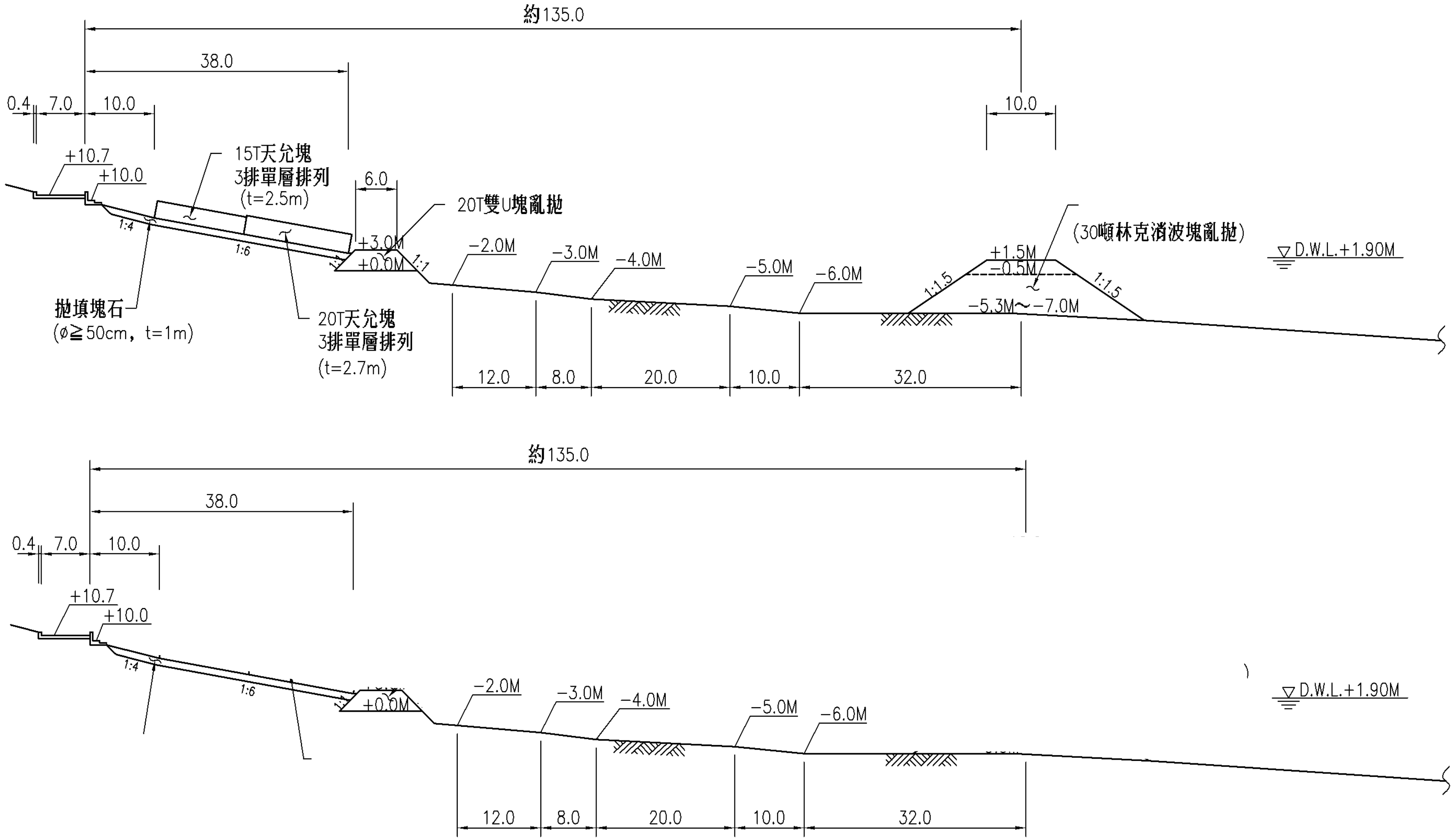
- Tsunami run-up and overflow when there are sea-dykes (revetments) protecting the coast
- Hydrodynamics around the sea dykes (revetments) and the overflow field in a tsunami attack

Preliminary results

by taking advantage of consulting projects that originally aimed to investigate the stability of sea-dykes under storm wave conditions

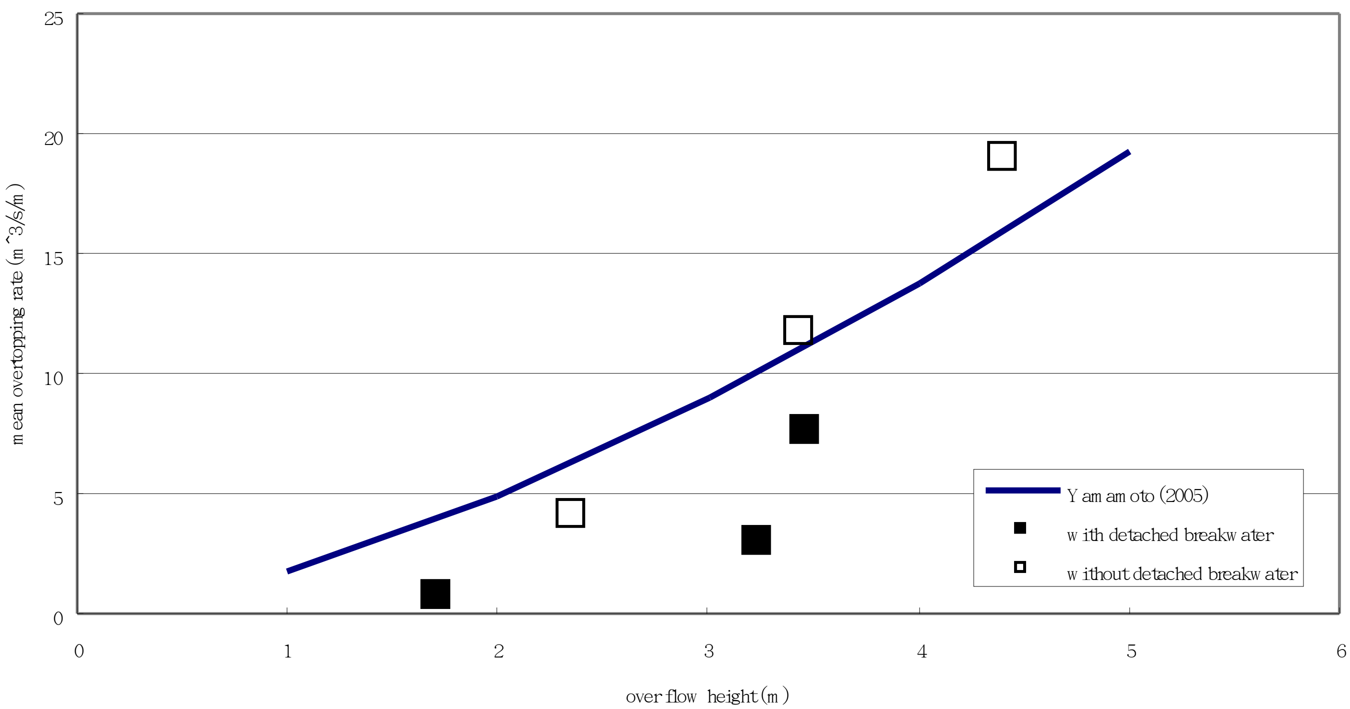


- The flume
  - 200 m×2 m×2 m
- The wave maker
  - Servo-electrical piston type
  - Stroke: 1.0 m
  - Max. 0.4 m solitary wave height under 1.0 m water depth

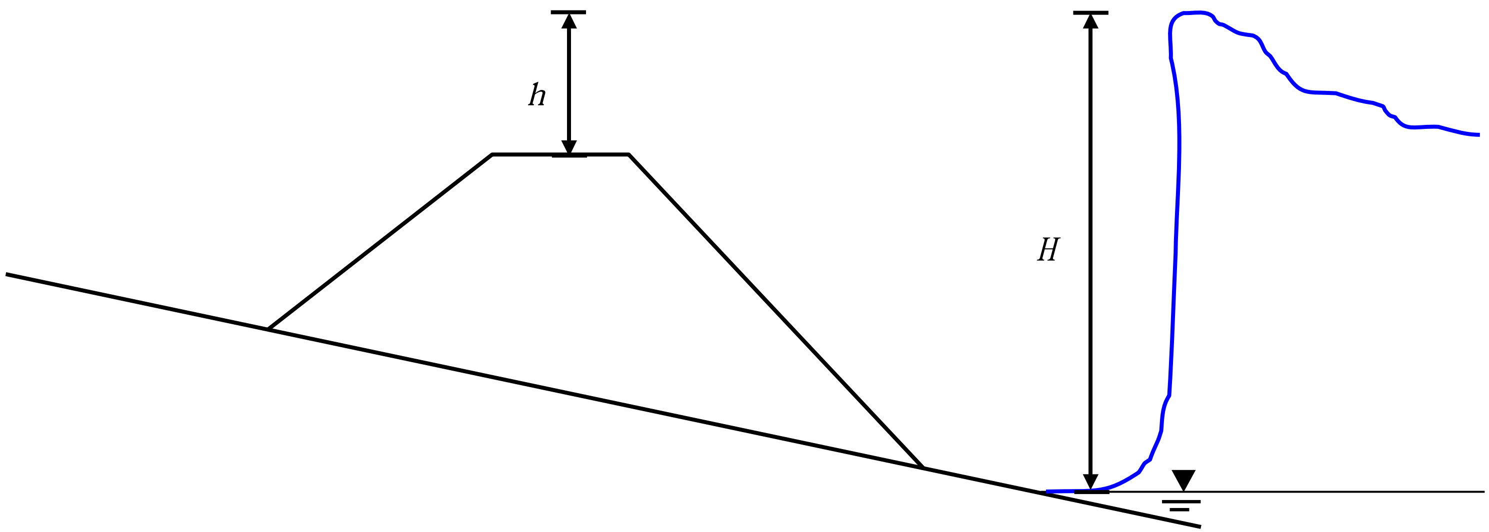


A typical sea-dyke profile of the east coast

The mean overflow rate



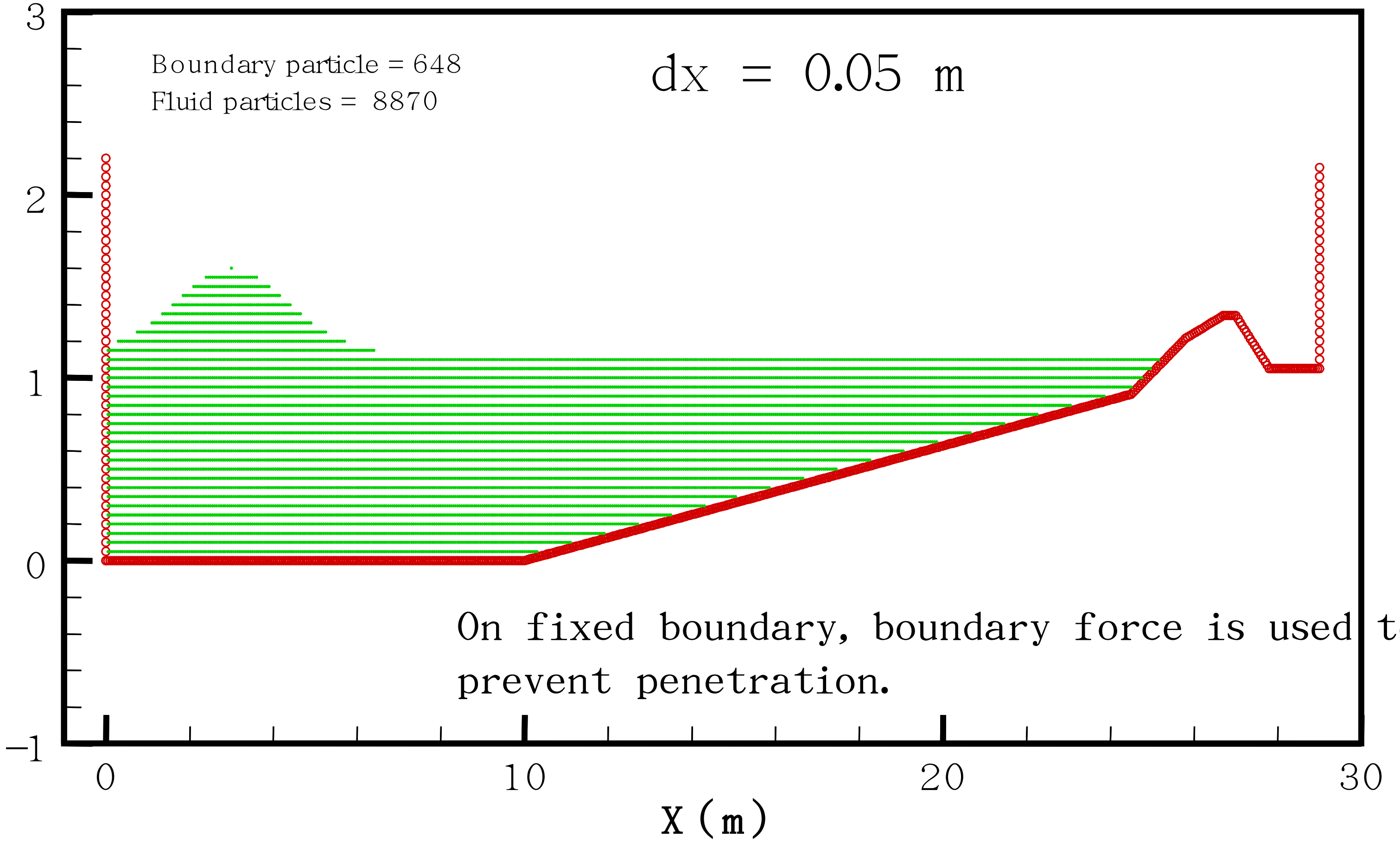
The mean overflow rate



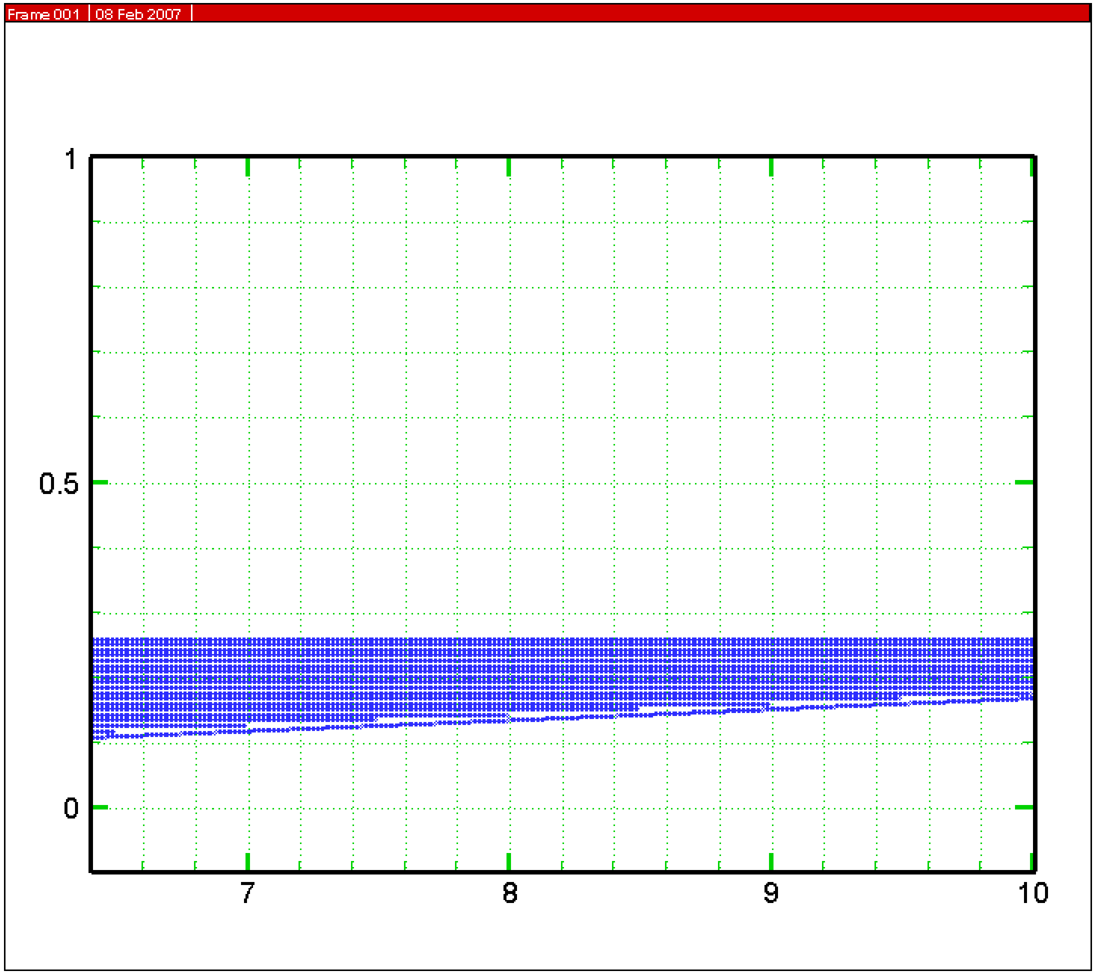
$$q = 0.55 \times \sqrt{gh} \times h \quad (m^3/m/s)$$

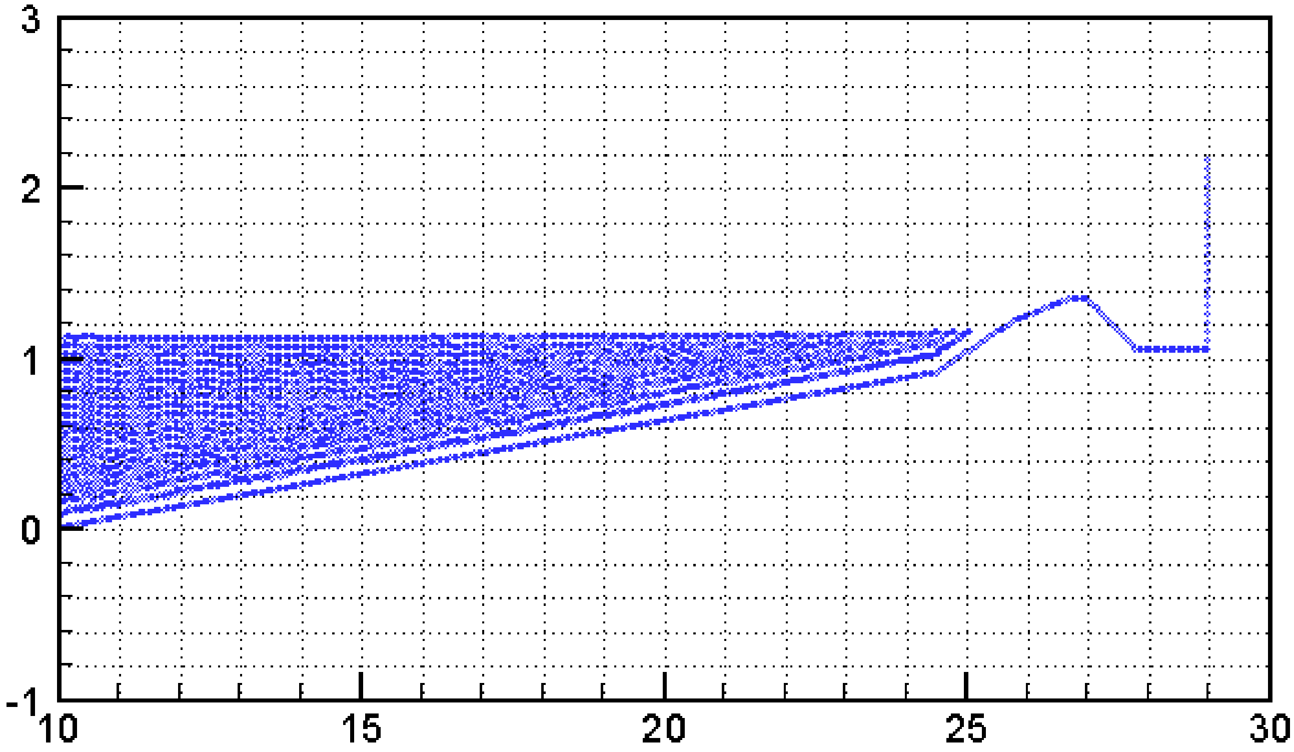
- Where *h* is the overflow height
  - by Takanashi and Yamamoto (2005)

Computation domain



On fixed boundary, boundary force is used to prevent penetration.


Frame 001 | 08 Feb 2007 |
1
0.5
0
7
8
9
10


3
2
1
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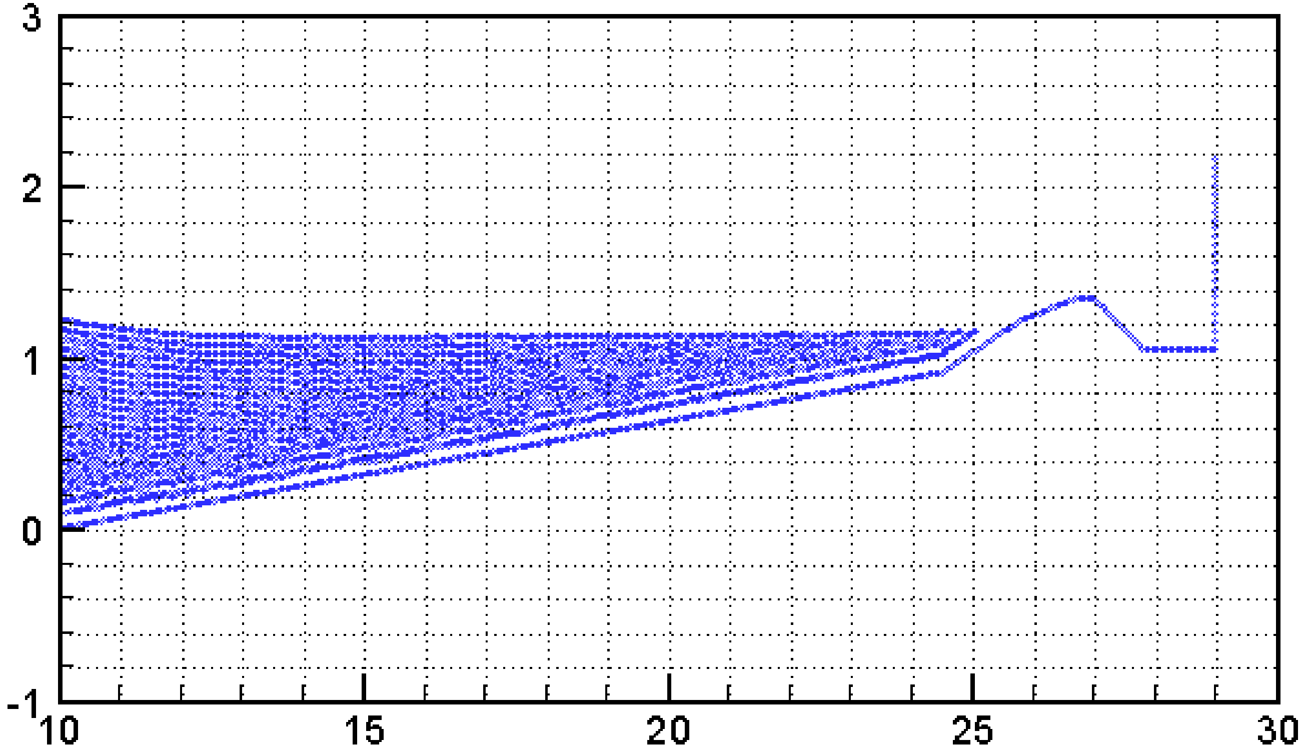
-1
10
15
20
25
30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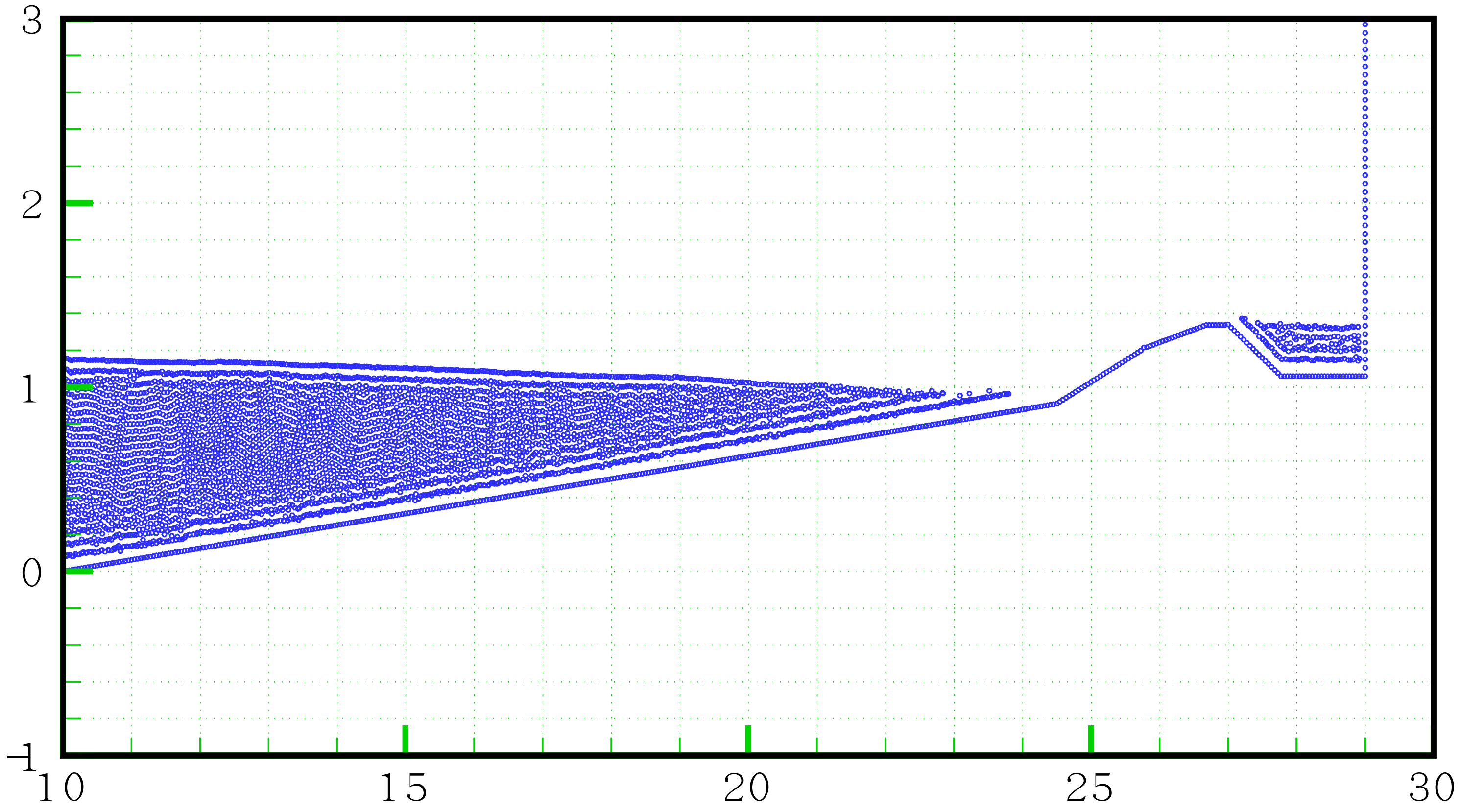
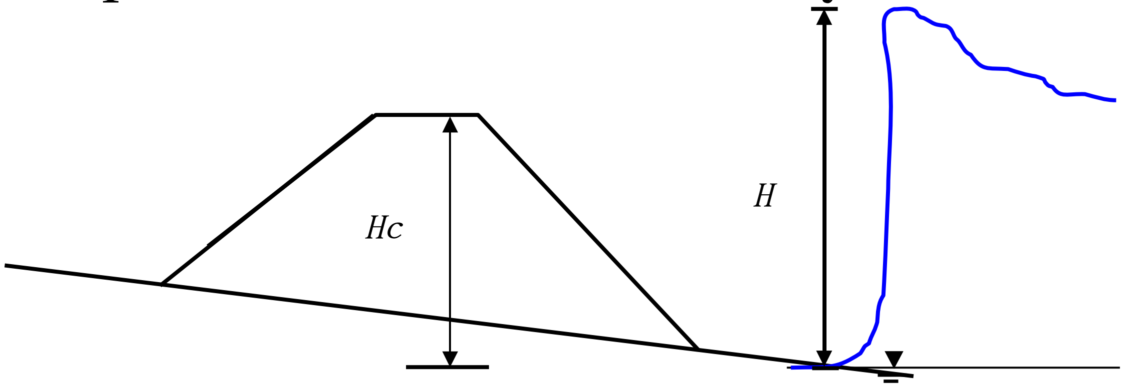

3
2
1
0
-1
10
15
20
25
30

Ongoing experiments

Considerations in test program

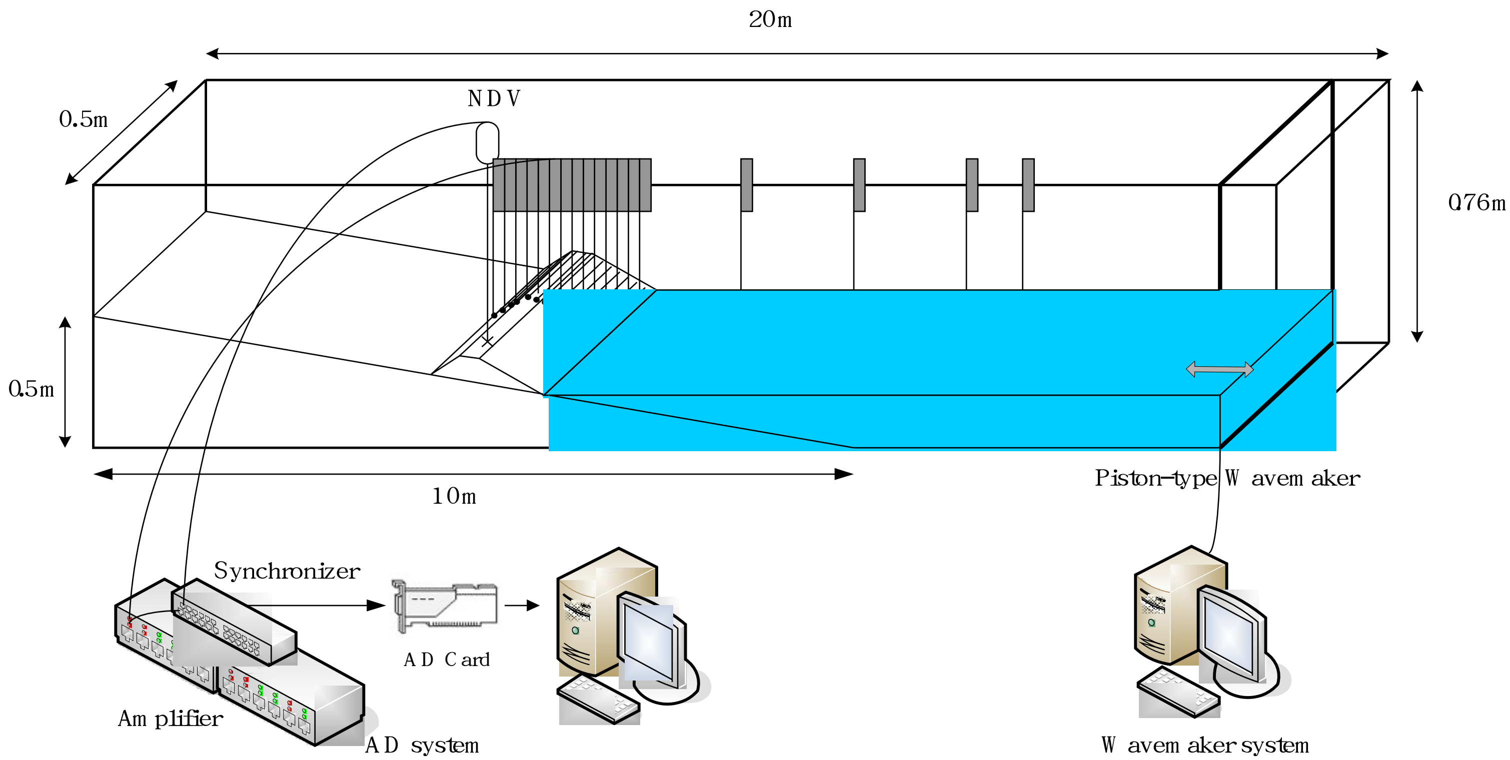
- tsunami heights
  - the tsunami heights (*H*) are the same order to the sea-dyke height above the sea level (*Hc*)
- The sea-dyke
  - front and rear slopes
- The slope behind the sea-dyke



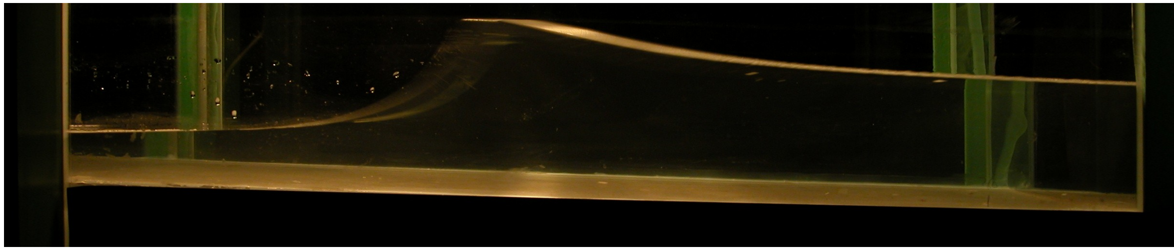
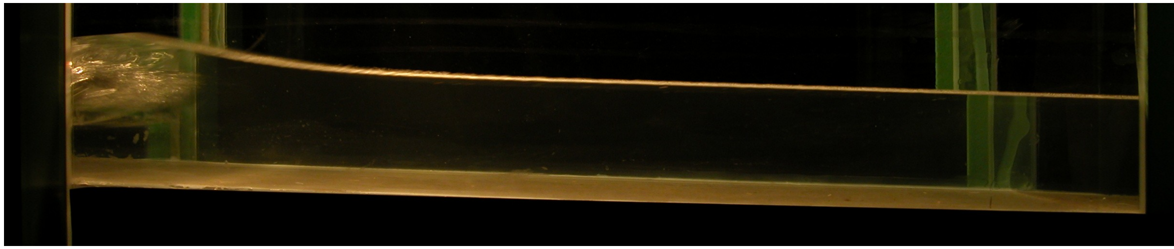
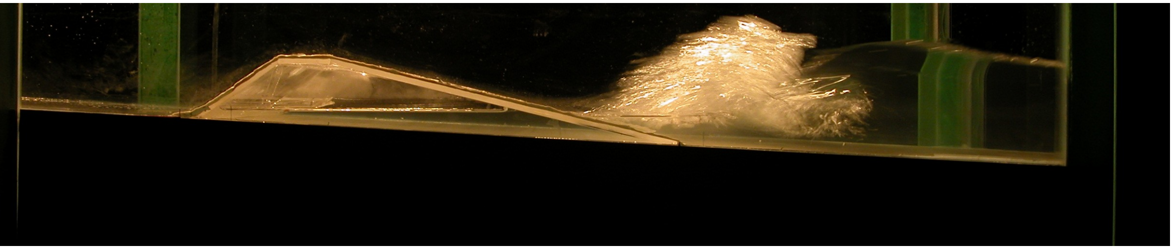
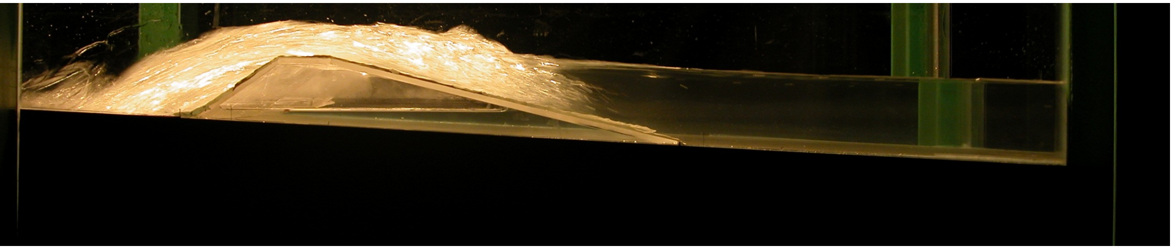
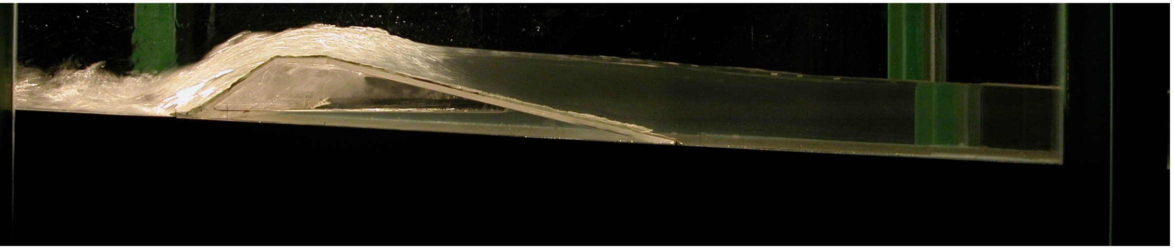
Disaster cases of coastal structures by tsunamis (Yamamoto et. al.,2006)

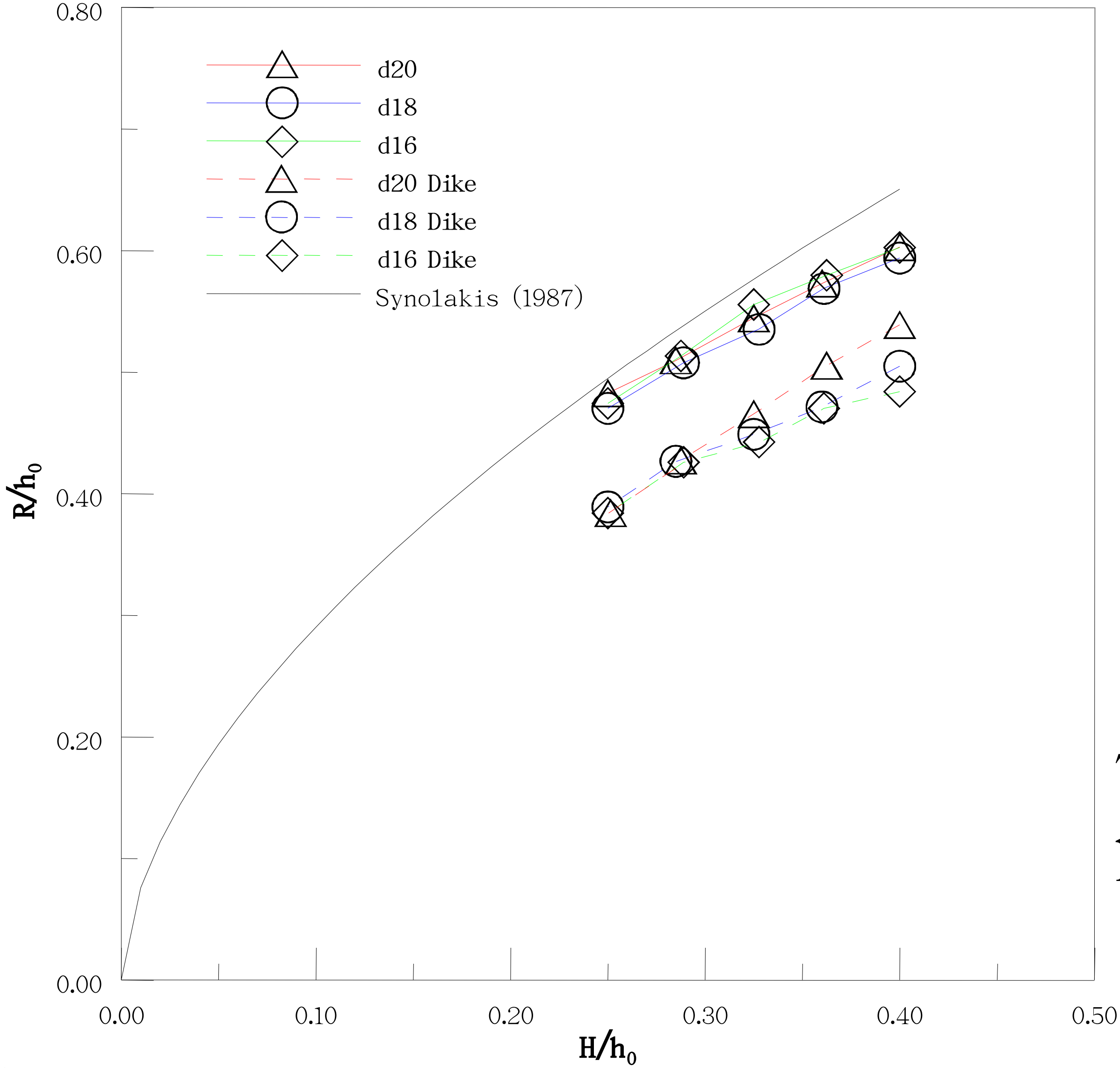
Date of disaster	Coastal name	Structure type	Damage level	Type of destructive force	Crown height (m)	Tsunami height (m)	Mean overflow rate ($m^3/m/s$)
Hokkaido Prefecture (1993 July 12)	Hirahama, Taisei-cho	Revetment (crown covered with concrete)	Complete destruction	By incident tsunami pressure	6.00	8.0	4.87
	Umikurimae, Okushiri-cho	Self-supported dike	Complete destruction	By incident tsunami pressure	5.30	8.7	10.79
	Monai, Okushiri-cho	Self-supported revetment	Complete destruction	By incident tsunami pressure	6.50	21.0	95.07
	Aonae, Okushiri-cho	Self-supported revetment	Complete destruction	By tsunami pressure from back coast	4.50	12.4	38.23

Date of disaster	Coastal name	Structure type	Damage level	Type of destructive force	Crown height (m)	Tsunami height (m)	Mean overflow rate ($m^3/m/s$)
Akita Prefecture facing the Nihon sea (1983 May 26)	Kodomari fishery harbor	Block-type revetment (crown not covered)	Complete destruction	By return flow	4.00	5.3	2.55
	Todoroki fishery harbor	Self-supported revetment	Partial destruction	By return flow	3.70	4.0	0.28
	Iwadate fishery harbor	Self-supported revetment	Partial destruction	By incident tsunami pressure	4.65	7.0	6.12
	Iwadate fishery harbor	Self-supported revetment	Partial destruction	By incident tsunami pressure	5.65	8.8	9.81
	Minehama	Self-supported revetment	Partial destruction	By incident tsunami pressure	5.30	6.9	3.52
	Kotohama	Reinforced concrete revetment (the crown was covered)	Complete destruction	Destruction of front face and outflow of	5.25	8.5	10.09

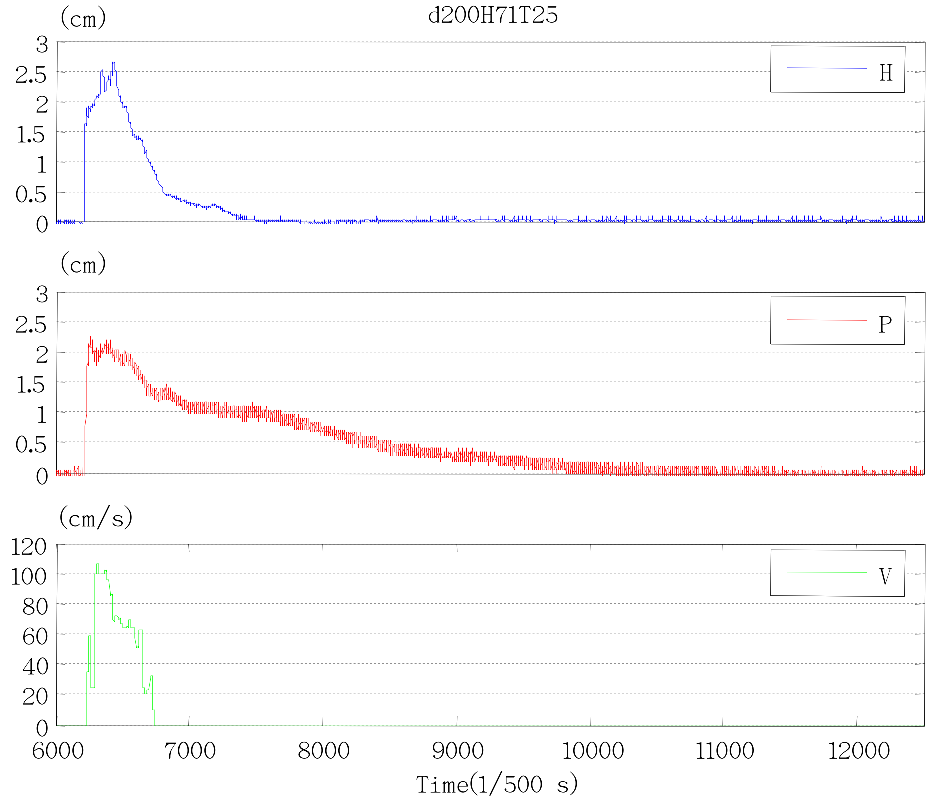


- A solitary wave propagate on an inclined beach & a sea-dyke
  - The run-up heights, mean overflow rate
  - The pressure distribution on the structure
  - The flow field

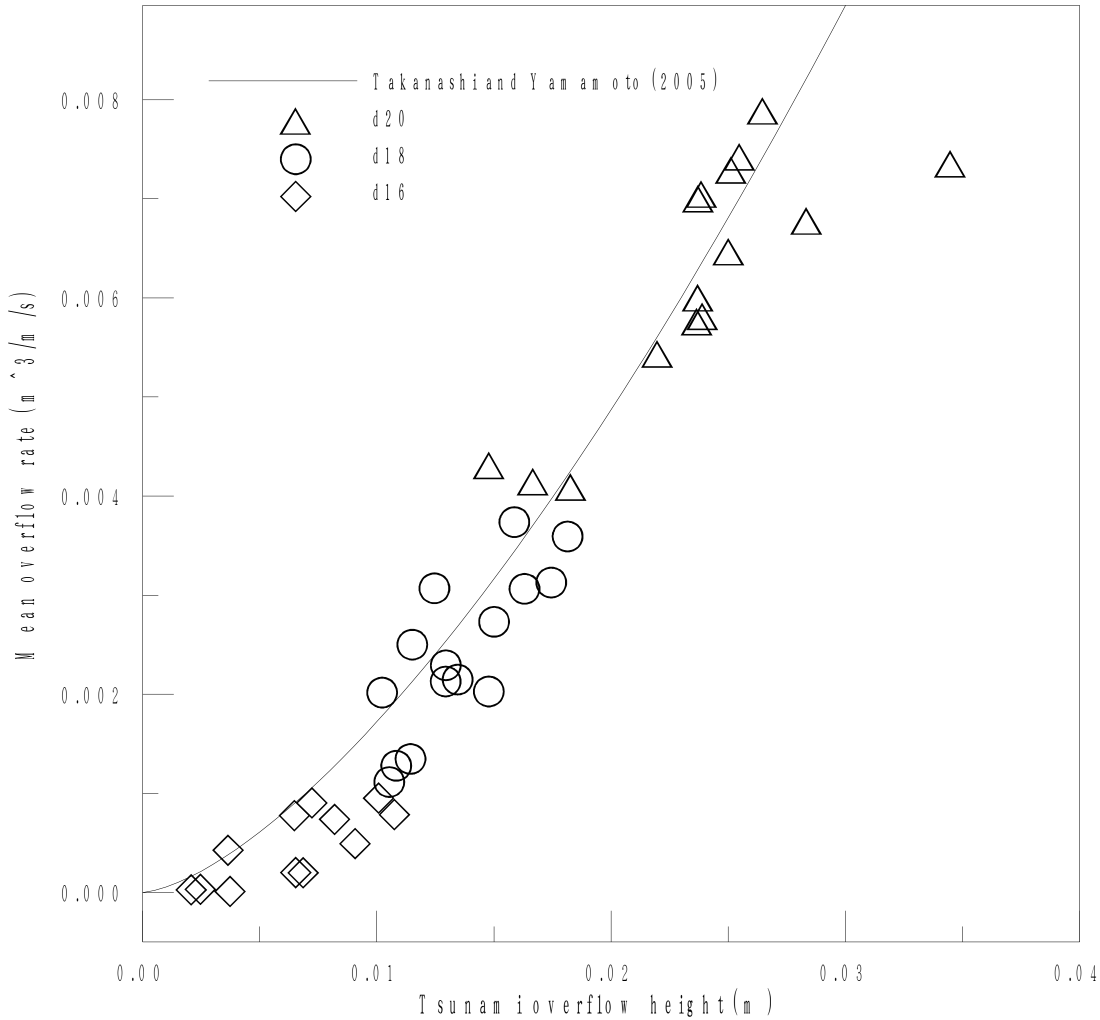








The run-up heights



Time series of the overflow depth, pressure and velocity on top of the sea-dyke



The overflow

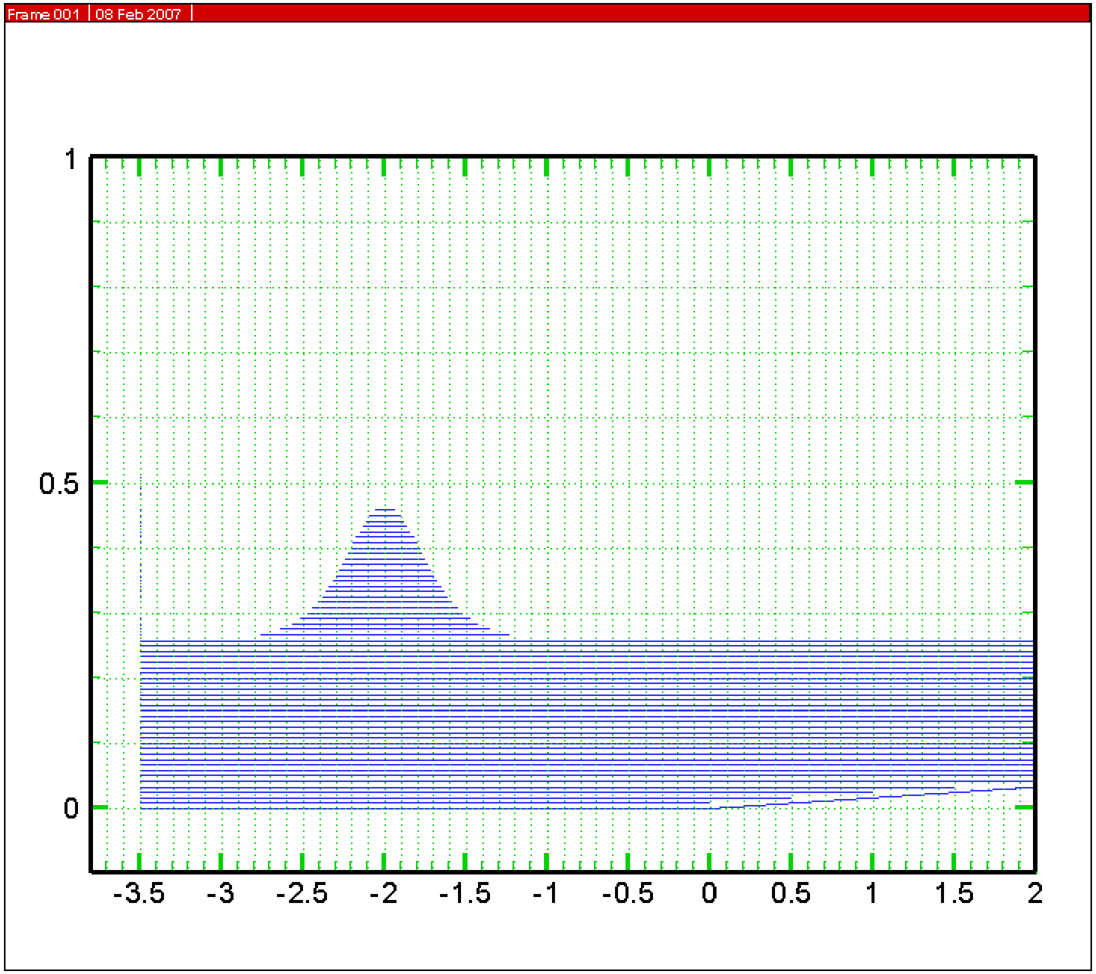
Future works

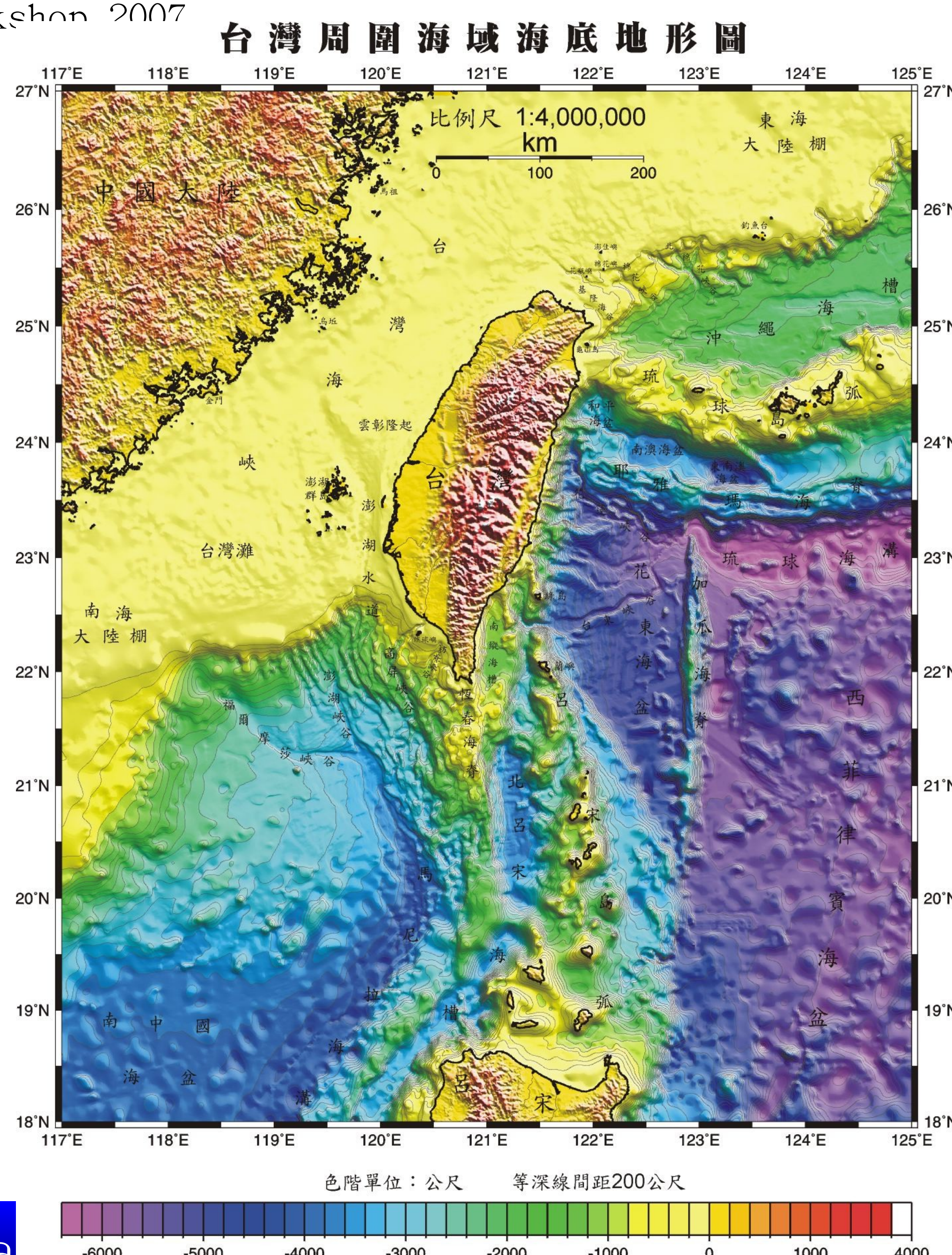
- To use the super tank for larger scale tests on

Thank you !

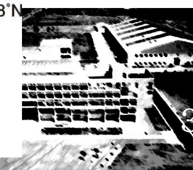
Tainan Hydraulics Lab. (THL)

http://www.thl.ncku.edu.tw


Frame 001 | 08 Feb 2007 |
1
0.5
0
-3.5
-3
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2

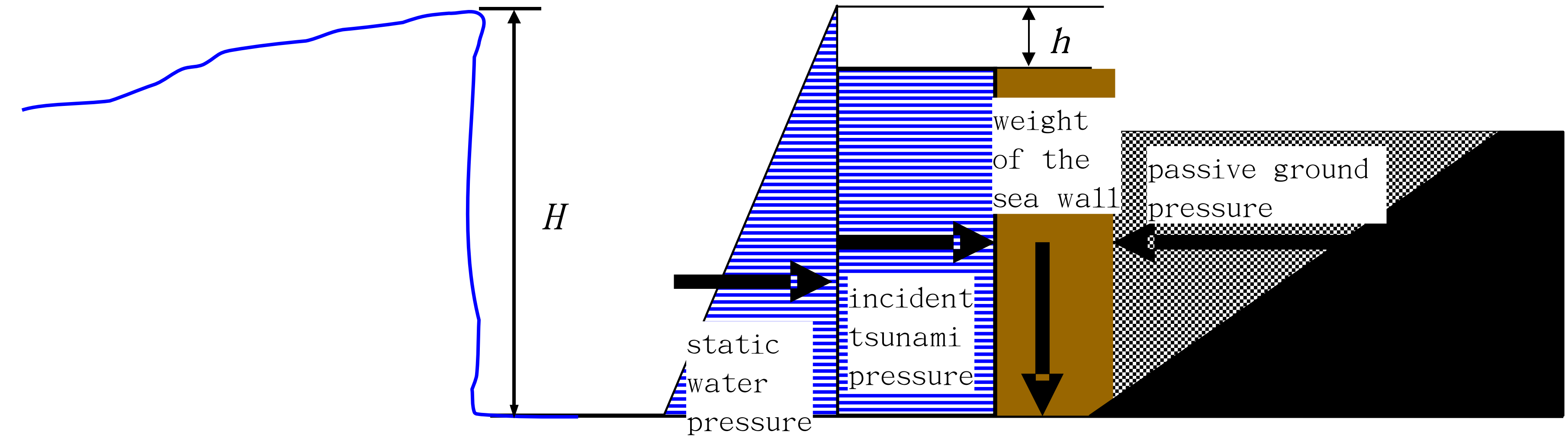


Seafloor bathymetry around TAIWAN
(source: NCOR, TAIWAN)



The worries

- Can it happen here ?
- How bad can it be if it can happen here ?
- How about the defense capability of the existing coastal defense works ?

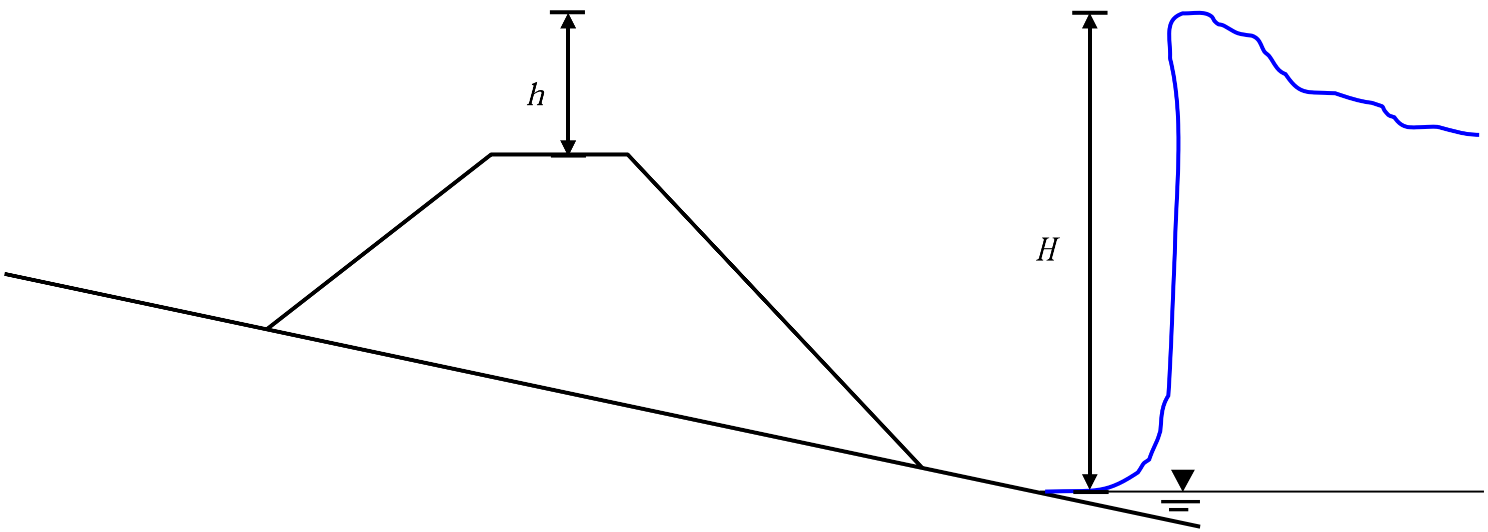


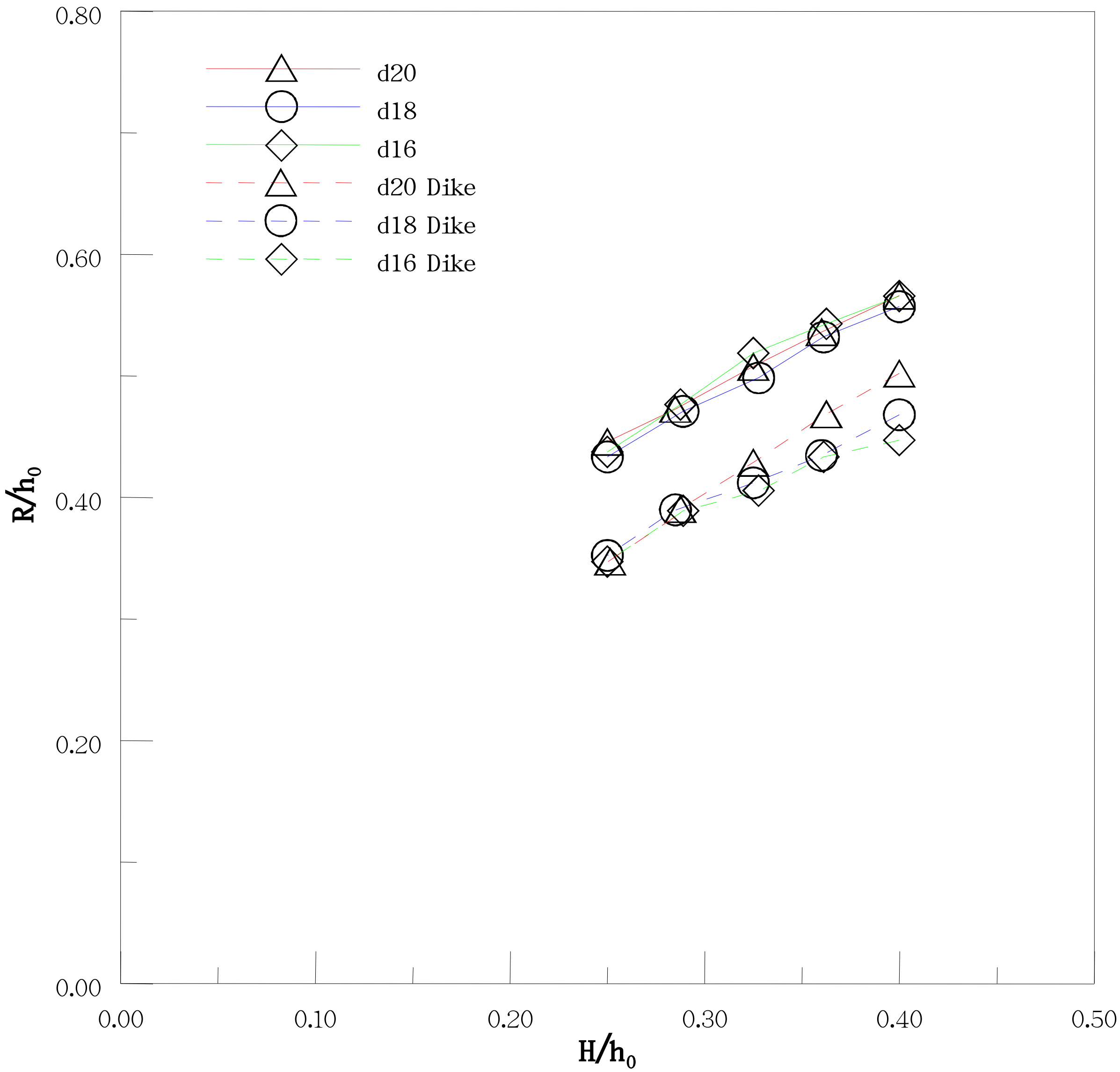
$$q = 0.55 \times \sqrt{gh} \times h \quad (m^3/m/s)$$

- Where *h* is the overflow height
  - by Takanashi and Yamamoto (2005)

$$u = 1.1\sqrt{gH}$$

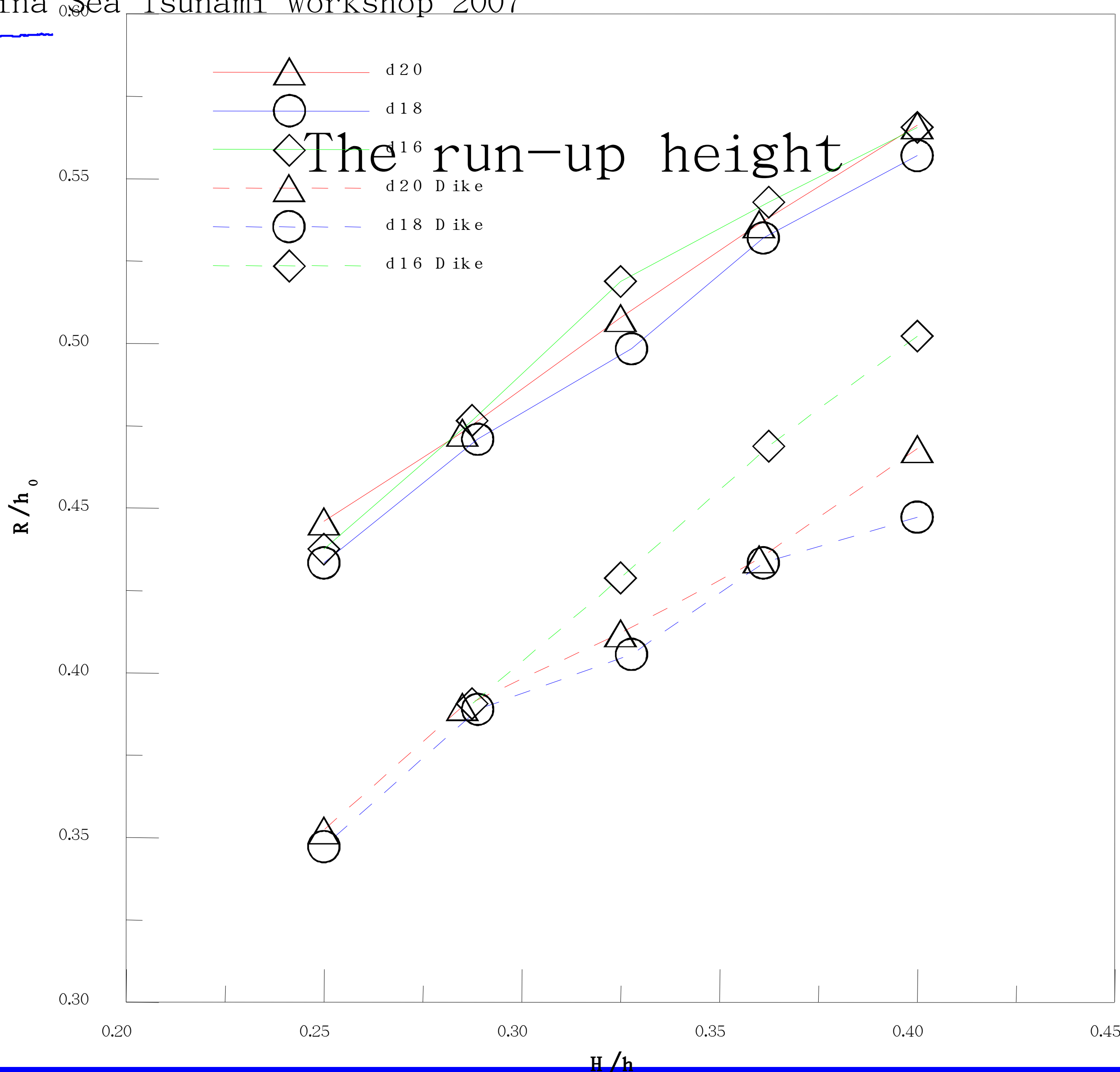
- Where *H* is the tsunami height
  - by Iizuka and Matsutomi (2000)

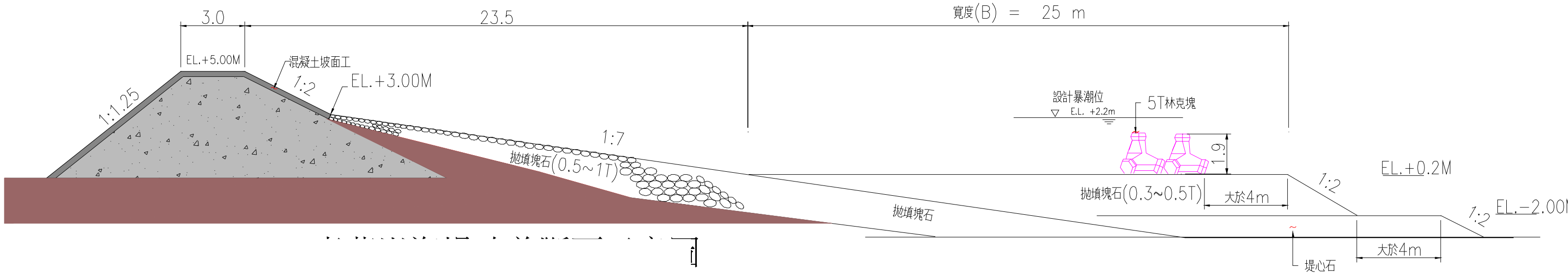

h
H

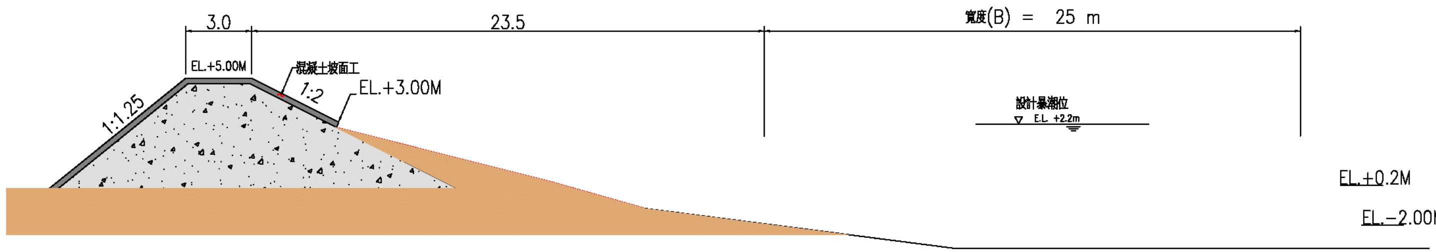


0.80
0.60
0.40
0.20
0.00
R/h0
0.00
0.10
0.20
0.30
0.40
0.50
H/h0
d20
d18
d16
d20 Dike
d18 Dike
d16 Dike

The run-up height







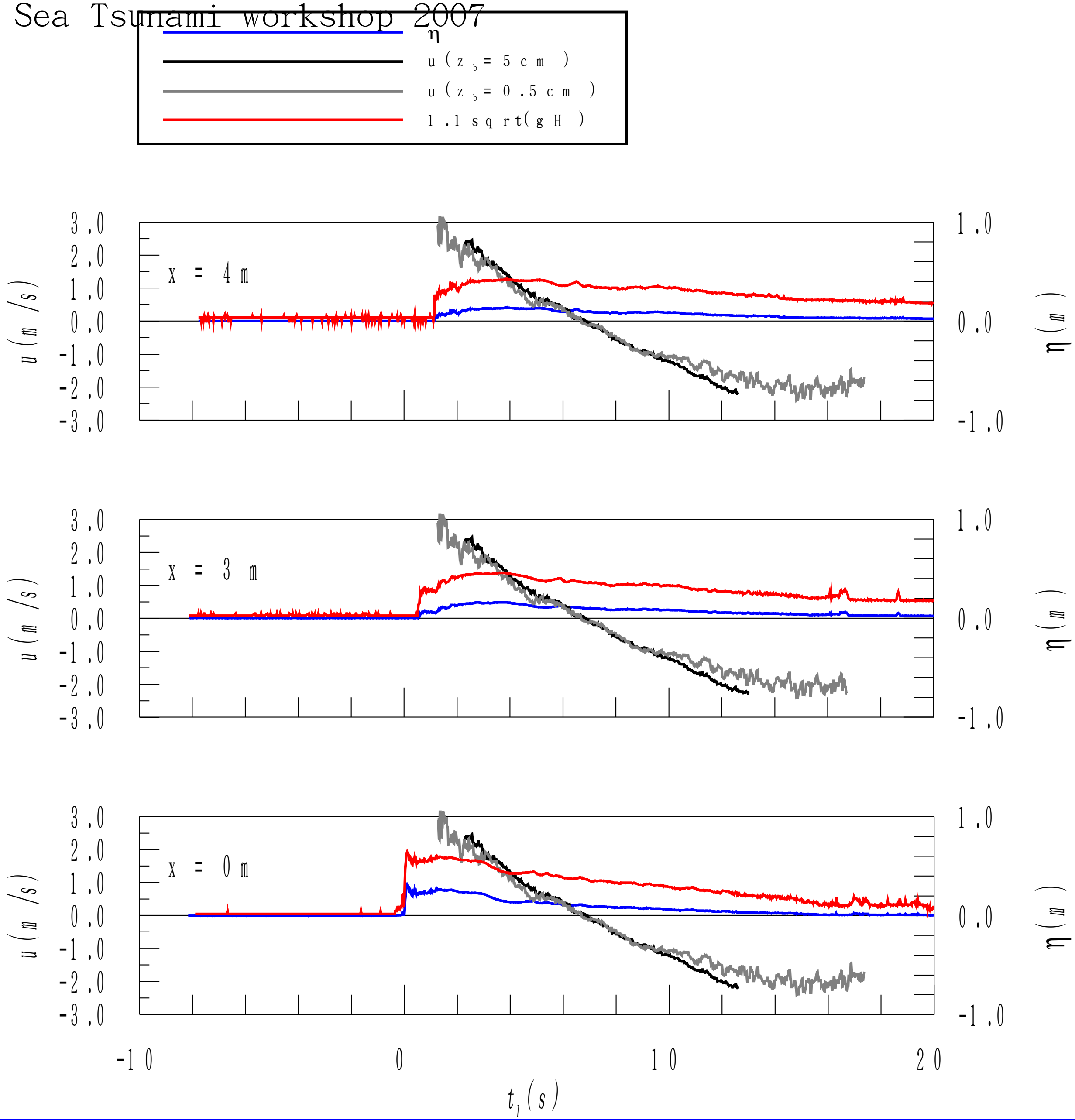
A typical sea-dyke profile of the west coast

Design Wave condition VS. solitary waves

sea level: E.L. +2.2 m
crown level: E.L. +5.0 m

- Design wave
  - $H_{1/3}$=6.0 m, $T_{1/3}$=12.0 s
  - overflow:
    - —0.045 $m^3/s/m$
  - tolerance:
    - —0.050 $m^3/s/m$

- Solitary wave
  - H_0=6.0 m
  - overflow:
    - —0.987 (2.041) $m^3/s/m$
  - H_0=4.8 m
    - —0.673 (1.237) $m^3/s/m$
  - H_0=3.6 m
    - —0.203 (0.827) $m^3/s/m$
  - H_0=2.4 m
    - —0.173 (0.607) $m^3/s/m$
  - H_0=1.2 m
    - —0.162 (0.297) m³/s/


η
u (z_b = 5 cm)
u (z_b = 0.5 cm)
1.1 sqrt(gH)
x = 4 m
x = 3 m
x = 0 m
u (m/s)
η (m)
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
1.0
0.0
-1.0
-10
0
10
20
t_1 (s)