ICCE 2018
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The State of the Art and Science of Coastal Engineering

An Experimental Study Of Hydrodynamics Of OWC Device Embodying In Caisson Breakwater

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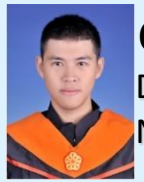

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- EXPERIMENTS SET-UP & SIMULATION
- RESULTS AND DISCUSSTION
- CONCLUSIONS

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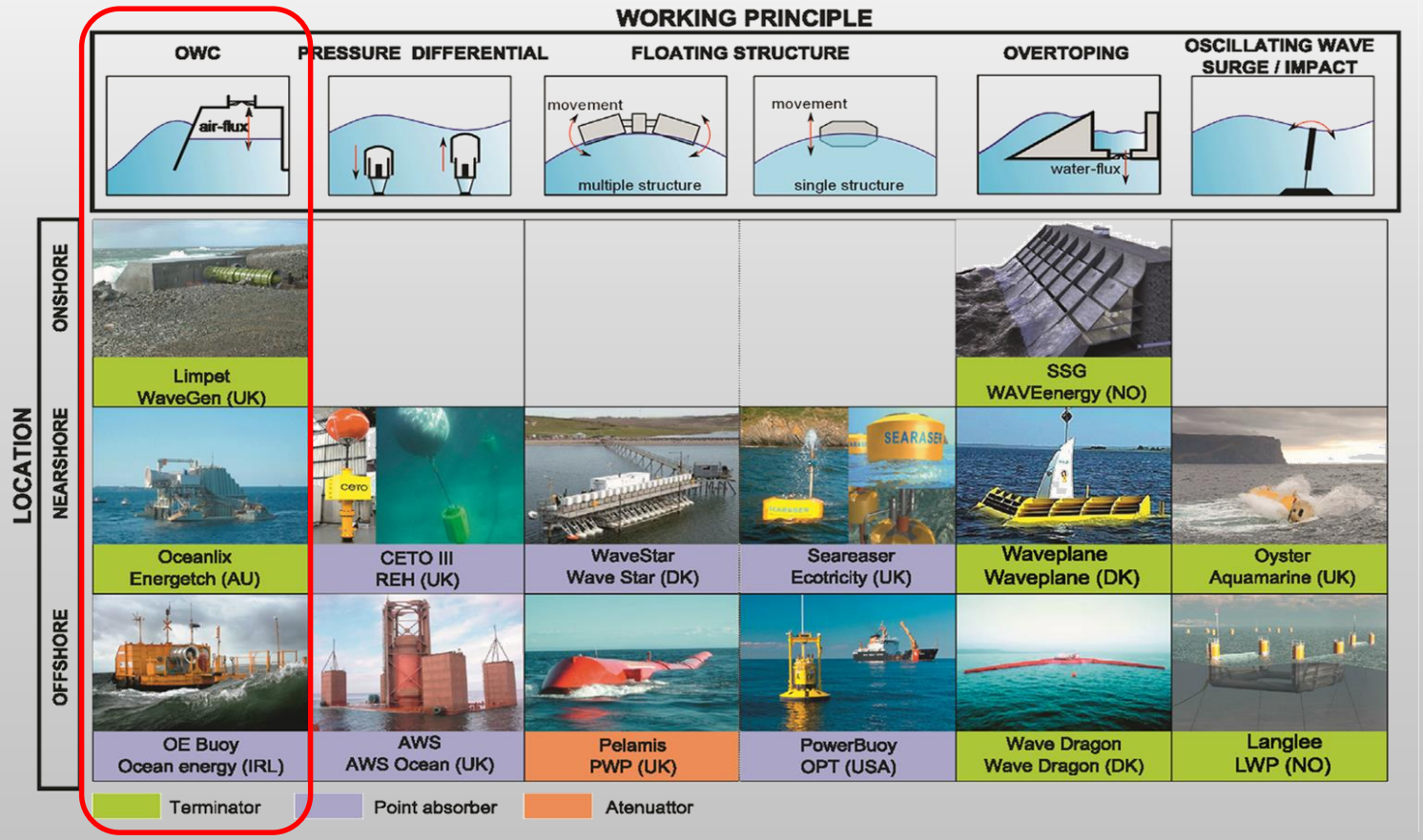

Compilation of several different classifications of WECs (Lopez, 2013)

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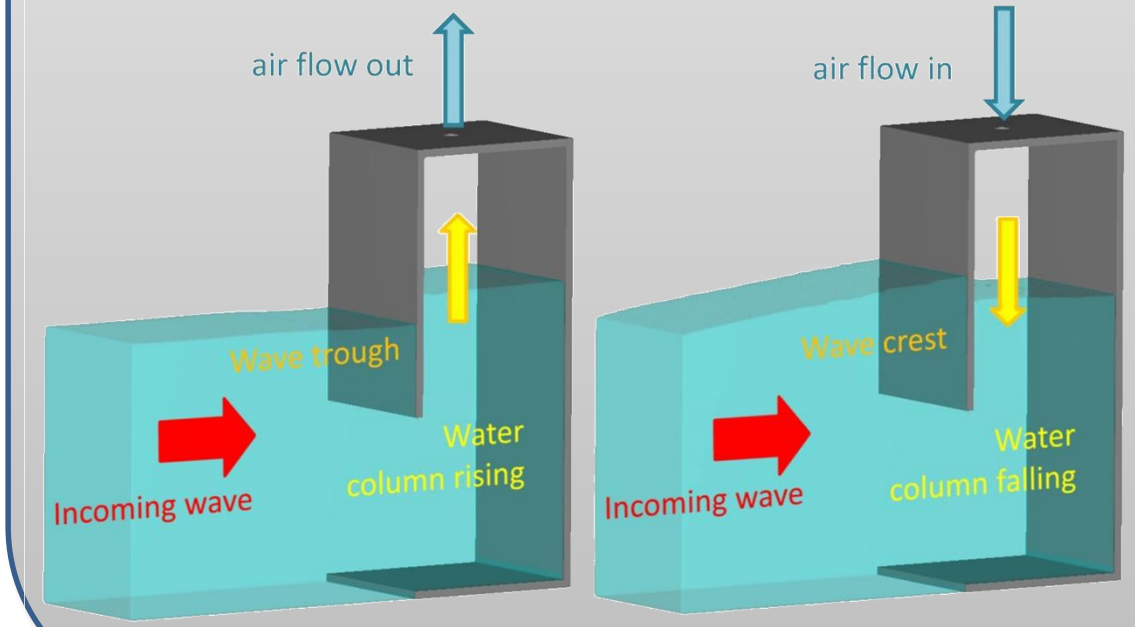
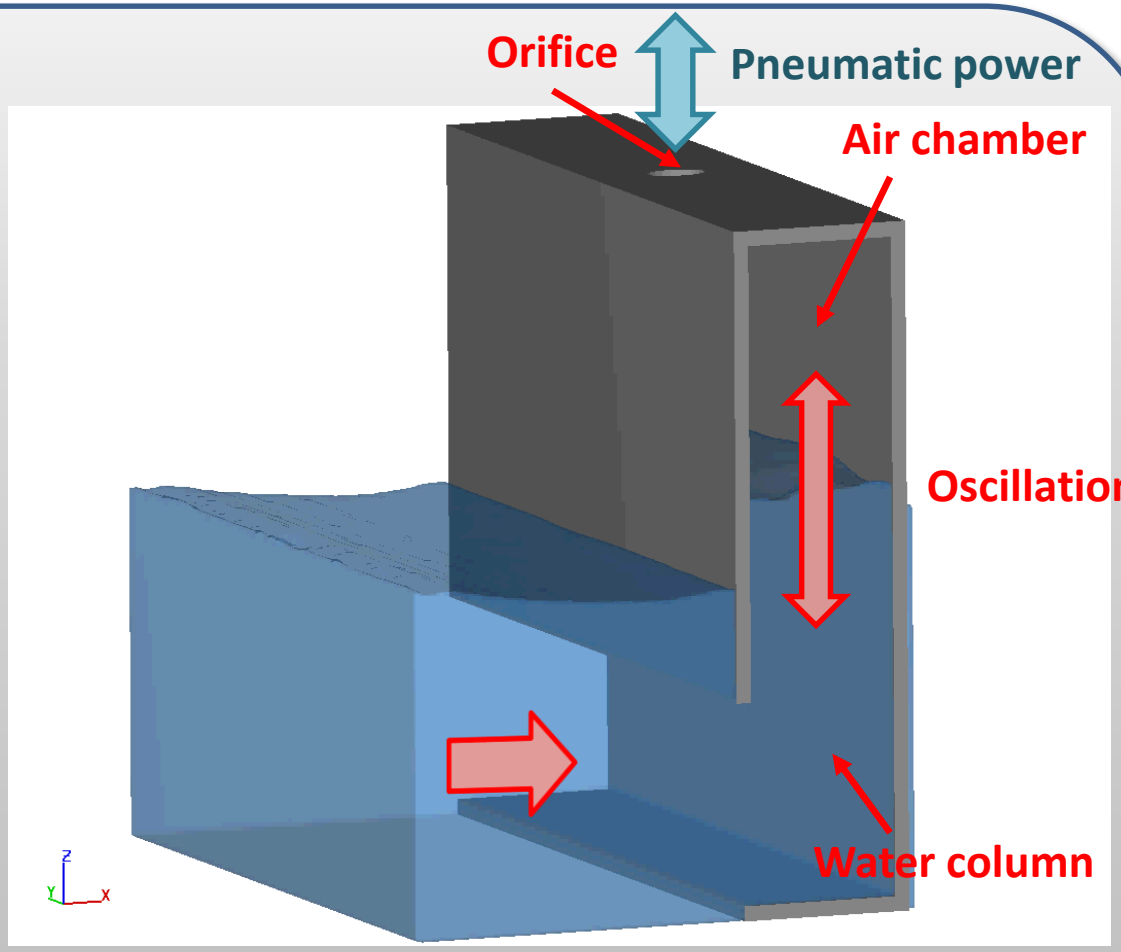
Oscillating Water Column type wave energy converter





Literature review:

National Chung Hsing University

Theoretical:

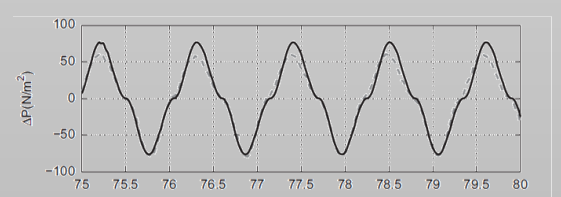
C. C. Mei (1976), Evans (1979, 1982), Evans and Porter (1995), Weber and Thomas (2000), Boccotti et al. (2006, 2007), Martin-Rivas et al. (2008, 2009), Lovas 2010 et al. (2010)

CFD & numerical:

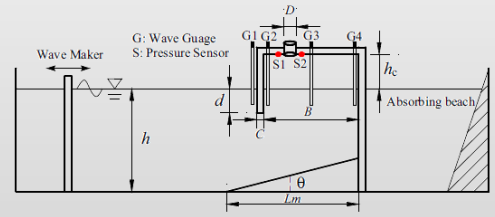
Liu et al. (2008), El Marhani et al. (2008), Zhang et al. (2012), Iturrioz et al. (2014), López et al. (2014), Ning et al. (2015, 2017), Iturrioz et al. (2015), Simonetti et al. (2014, 2015), Torres et al. (2015), Elhanafi et al. (2017), Kuo et al. (2017), Crespo et al. (2017)

Experimental:

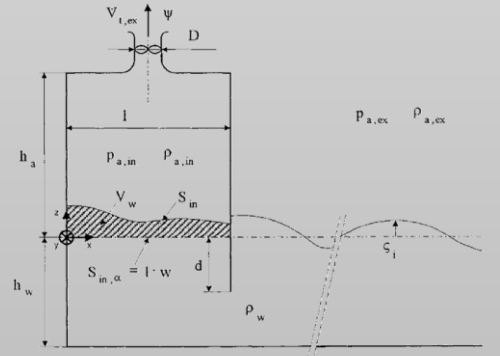
Sarmento et al. (1985, 1992), Tseng et al. (2000), Boccotti et al. (2007), Morris-Thomas et al. (2007), Vicinanza et al. (2012), He et al. (2013), López et al. (2015), Viviano et al. (2016),



Iturrioz et al. (2014)



Ning et al. (2016)



Weber and Thomas (2000)

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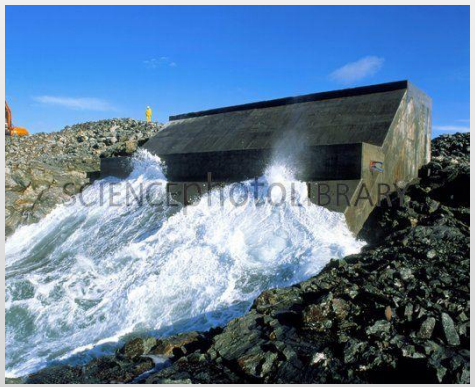
Oscillating water column wave energy converter

Company	Technology	Country base
Dresser-Rand	HydroAir	USA
Ecole Centrale de Nantes	SEAREV	France
Energias de Portugal	Foz do Douro breakwater	Portugal
Fobox AS	FO3	Norway
Grays Harbor Ocean	Titan Platform	USA
Energy Company HydroGen	HydroGen 10	France
Instituto Superior Tecnico	Pico OWC	Portugal
Leancon Wave Energy	Multi Absorbing Wave	Denmark
New Energy Solutions LLC	Energy Convertor (MAWEC)	USA
	Power System (OCPS)	
	Oscillating Cascade	
Oceanlinx	GreenWAVE / BlueWAVE	Australia
ORECon	MRC 1000	UK
RWE nPower renewables	OWC	Germany
Renewable Energy	Wave Water	USA
Ocean Energy Ltd	Ocean Energy Buoy	
Pumps	Pump (WWP)	
SeWave Ltd	OWC	Faroe Islands
Straum AS	OWC	Norway
Union Electrica Fenosa of Spain	OWC	Spain of Spain
Voith Hydro Wavegen	Limpet	UK



Limpet. UK

Pico OWC. Portugal

Oceanlinx. Australia

INTRODUCTION:

Mutriku harbor, Basque Country, Spain.

Civitavecchia, Italy (Arena et al., 2012).

Advantages of breakwater-integrated OWC:

- Budget could be saved.
- Easier operations.
- More simple maintenance.
- Without submarine cable.
- Less risk of damages.

- Falcão and Henriques (2016)

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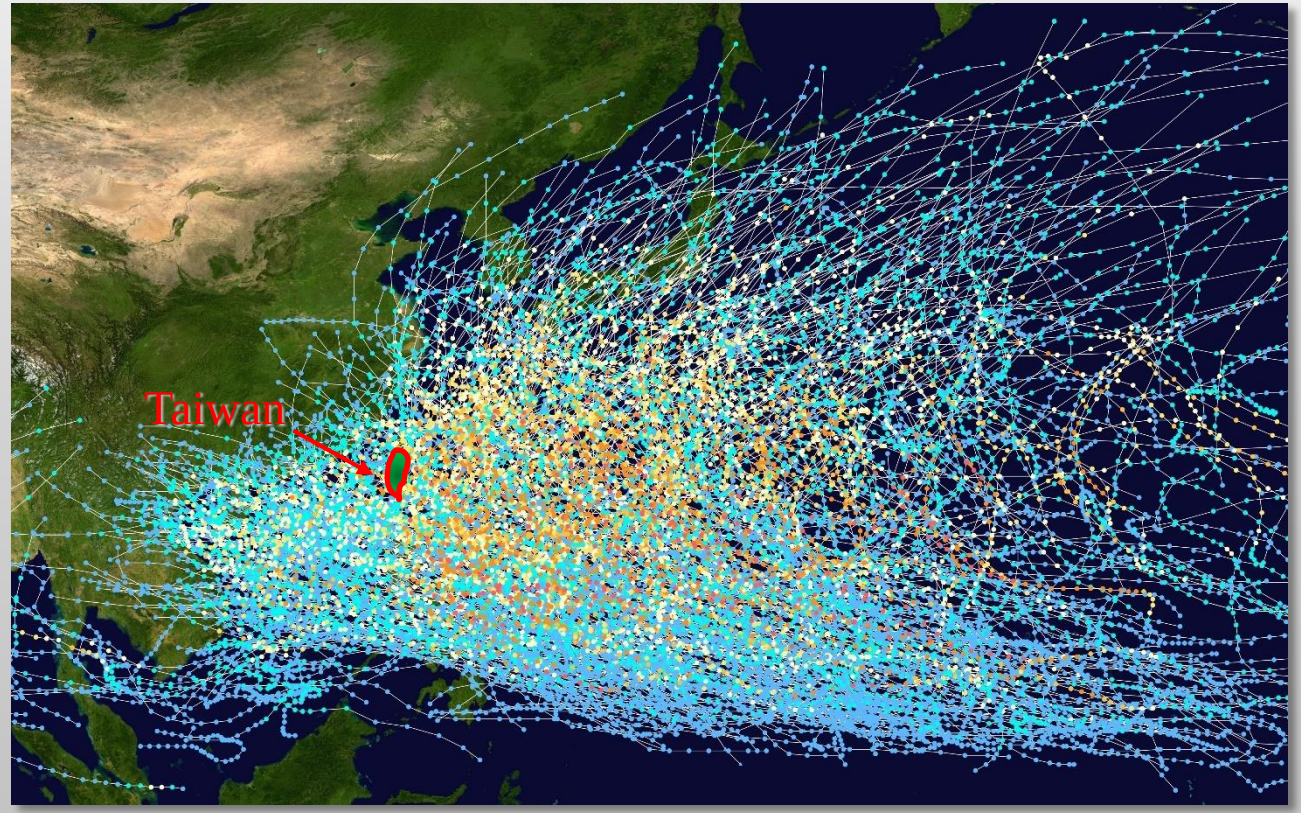
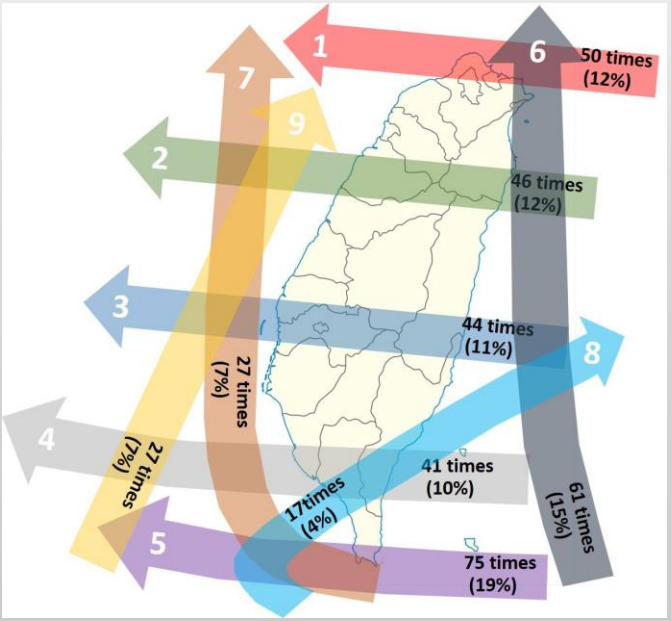
Situation of Taiwan:



Tracks of all tropical cyclones in the northern-western Pacific Ocean 1980-2005
Data by Wikimedia user : Nilfanion



4 to 5 typhoons per years on average

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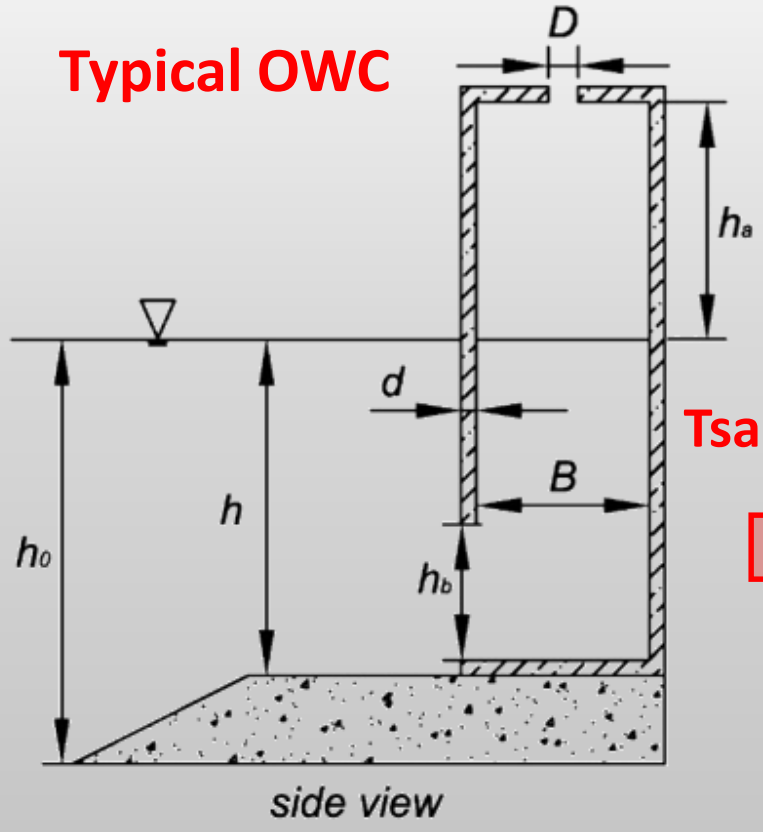
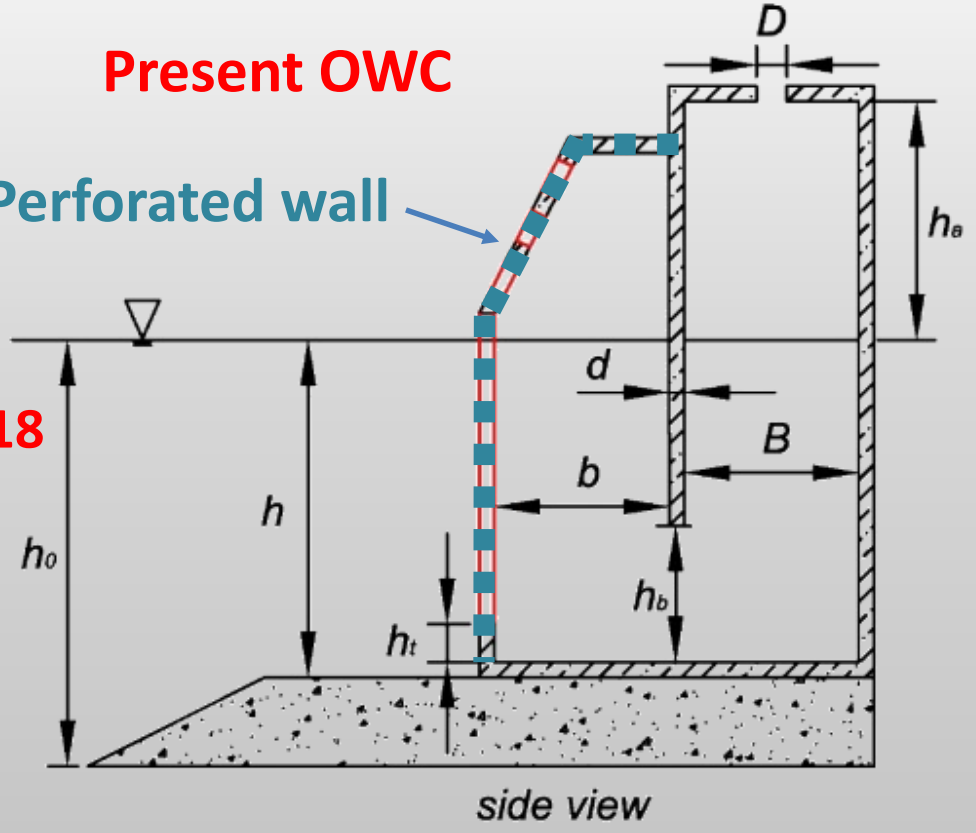
Typical OWC



Tsai et al. 2018

Present OWC



Present OWC devices:

- **Reduce the wave force** acting on the structure during storm time.
- **Promote the efficiency of the power** extraction in regular duration.

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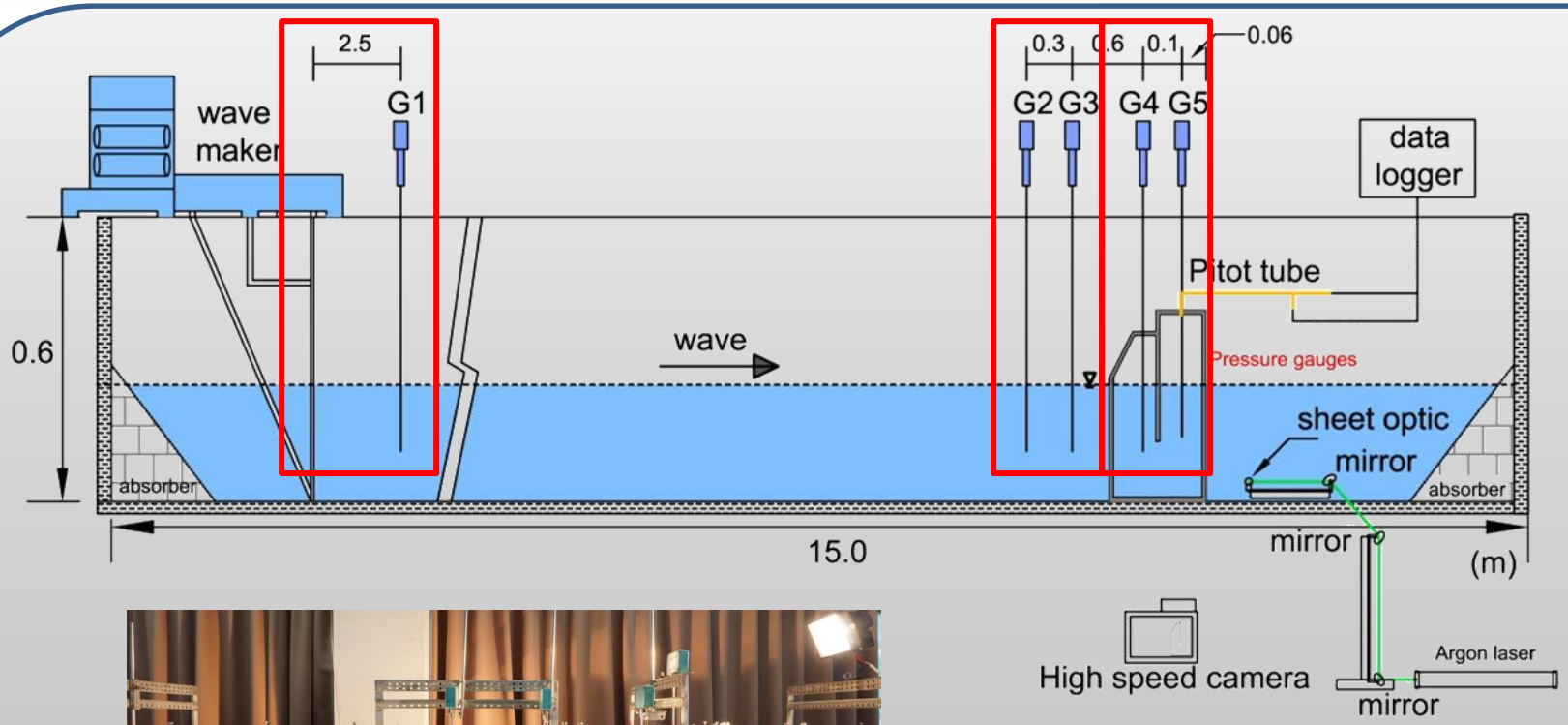
EXPERIMENTS SET-UP:



H_i	0.04 m
T	0.65 to 1.3 s
d	0.24 m
B/L	0.06 to 0.18

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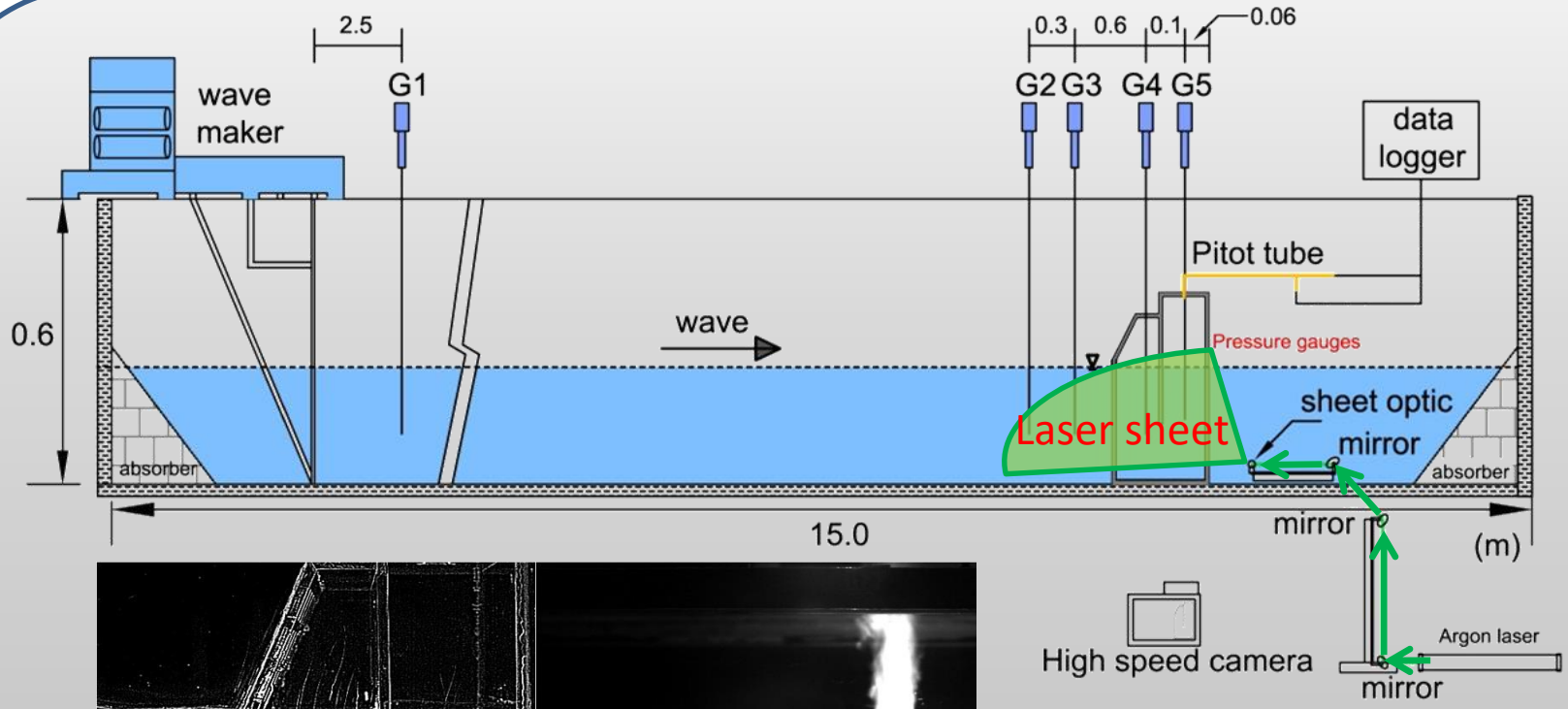
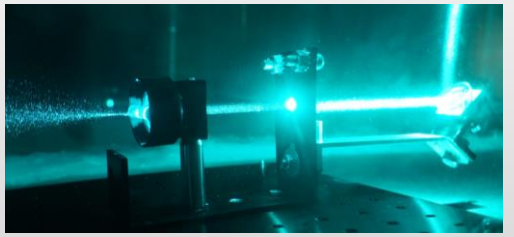
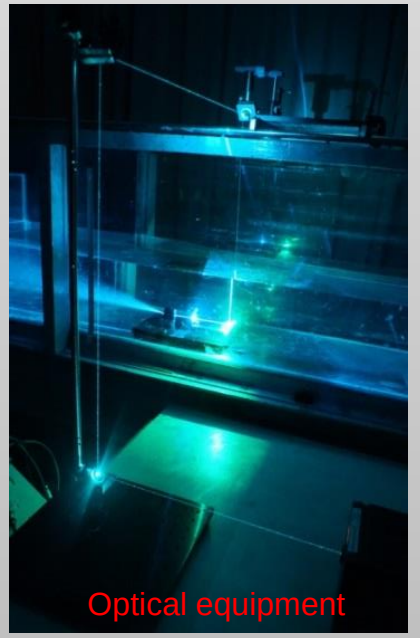
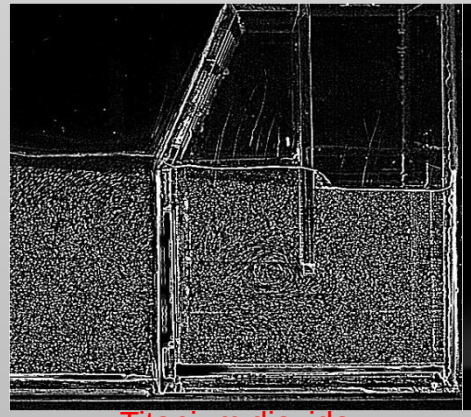




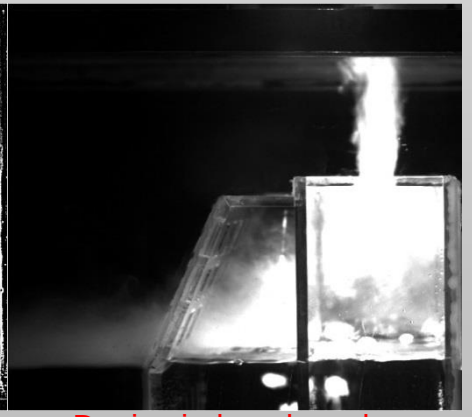
Sheet optic mirror



Optical equipment



Titanium dioxide



Dry ice induced smoke

Resolution : 800x600

Sample Rate : 60(fps)

NUMERICAL SIMULATION:

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Simulated by 3D CFD model

- Two-fluids model
- FAVOR technique
- VOF method
- RNG turbulent model

Three-dimensional mass continuity equation and the momentum equation

$$V_F \frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x_i}(\rho u_i A_i) = 0,$$ -mass continuity equation

$$\frac{\partial \rho u_i}{\partial t} + \frac{1}{V_F}\frac{\partial (\rho u_i u_j A_j)}{\partial x_j} = -\frac{\partial p}{\partial x_i} + \rho g_i + \frac{1}{V_F}\frac{\partial}{\partial x_j} A_j \left[\mu \left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i} \right) - \rho \langle u'_i u'_j \rangle \right]$$ - momentum equation

$$V_F \frac{\partial (\rho I)}{\partial t} + \frac{\partial}{\partial x_i}(\rho I u_i A_i) = -p \frac{\partial u_i A_i}{\partial x_i},$$ -internal energy equation

NUMERICAL SIMULATION:

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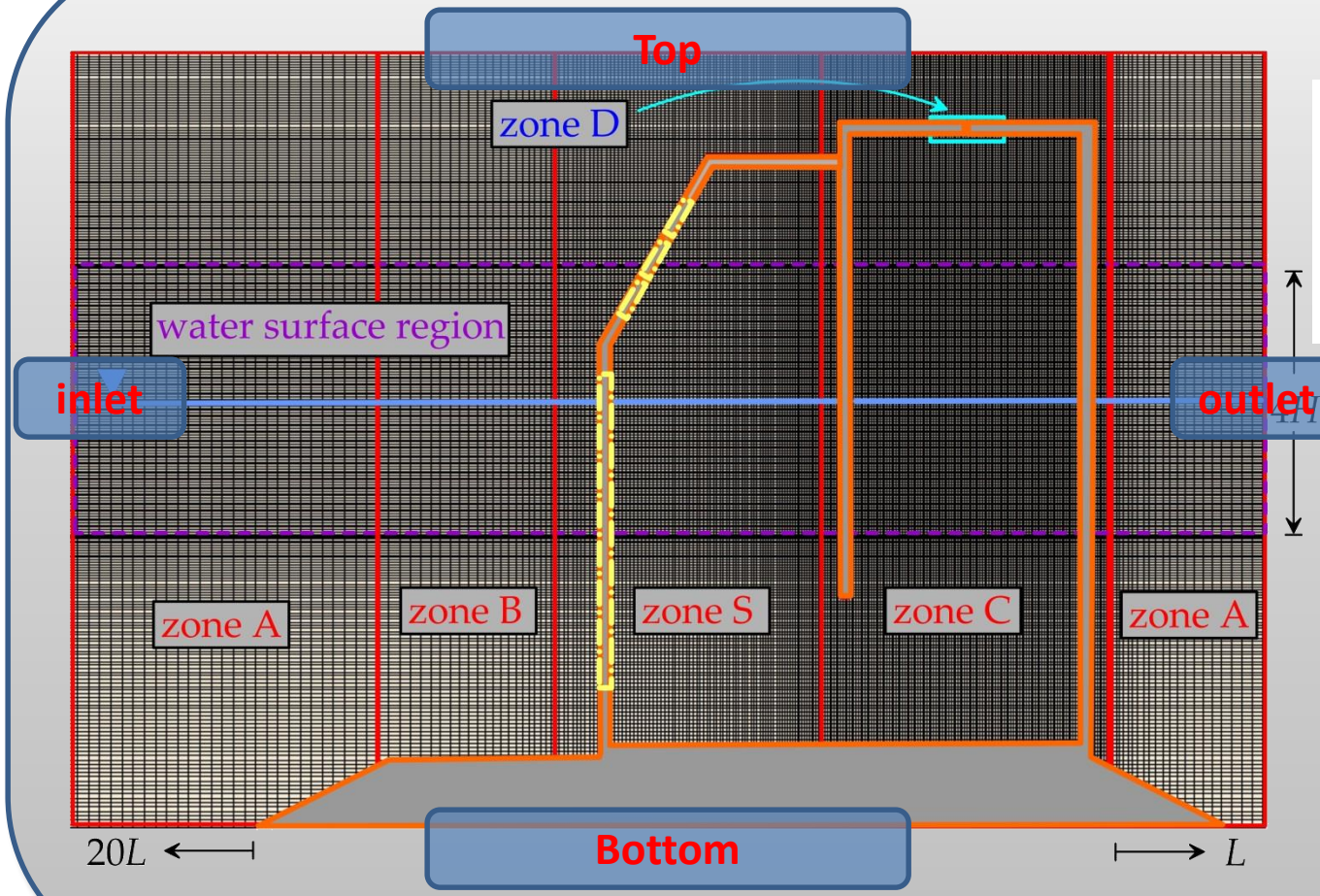

	ΔX	ΔY	ΔZ	ΔZ (Water Surface Region)
zone A	L/56~L/186	W/10	H/22	H/44
zone B	L/112~L/372	W/20	H/44	H/88
zone C	L/112~L/372	W/20	H/66	H/132
zone D	D/10~D/18	D/10~D/18	d/5	-
zone S	L/168~L/558	W/20	H/66	H/132

L: wavelength; *H*: incident wave height; *W*: chamber width; *D*: orifice diameter; *d*: wall thickness.

- Nonlinear wave boundary (Inlet)
- Wall boundary (bottom)
- Continuative boundary (outlet)
- Pneumatic continuative boundary (top)

- NO-slip condition on all solid surface

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RESULTS AND DISCUSSIONS :

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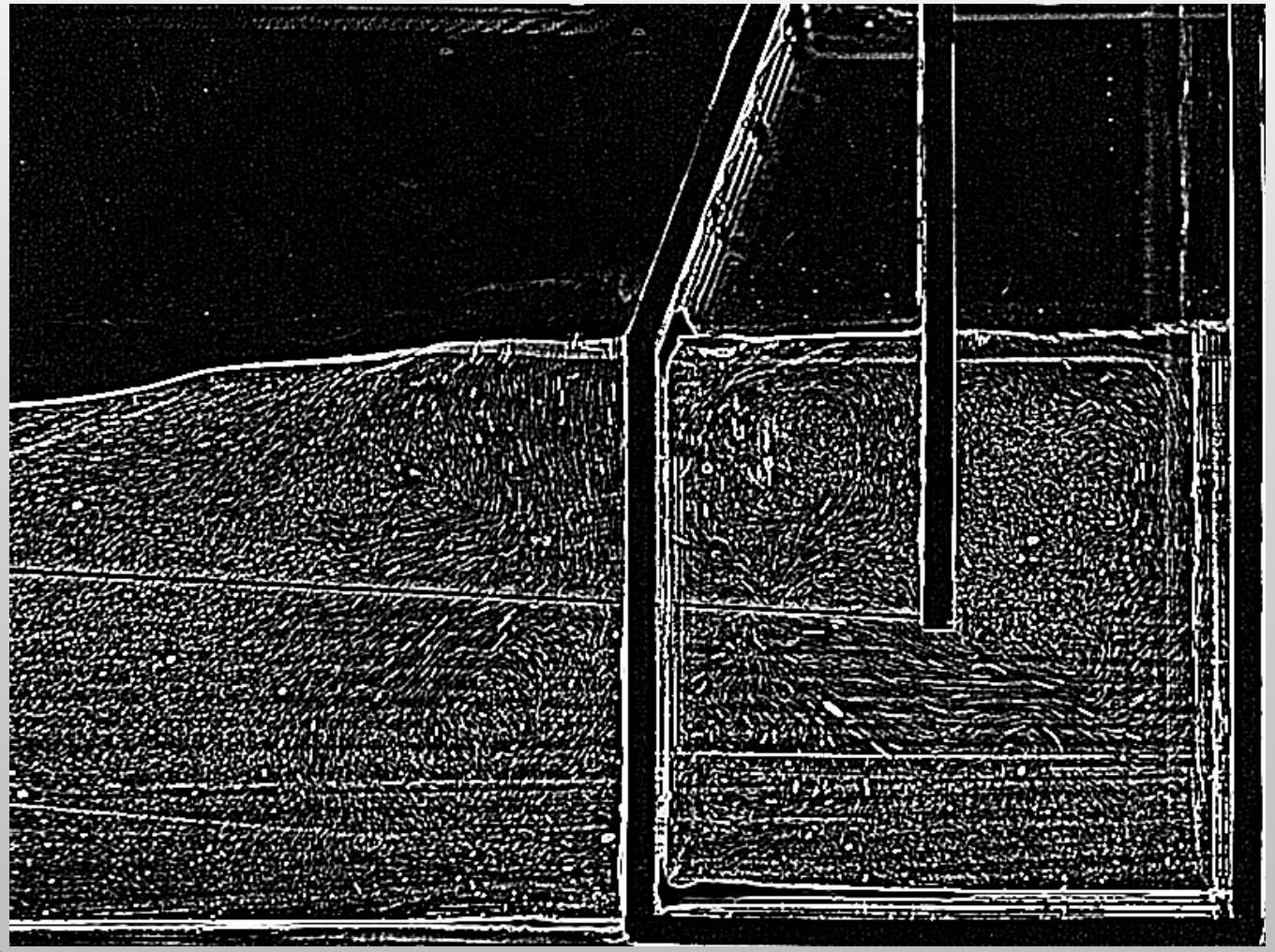

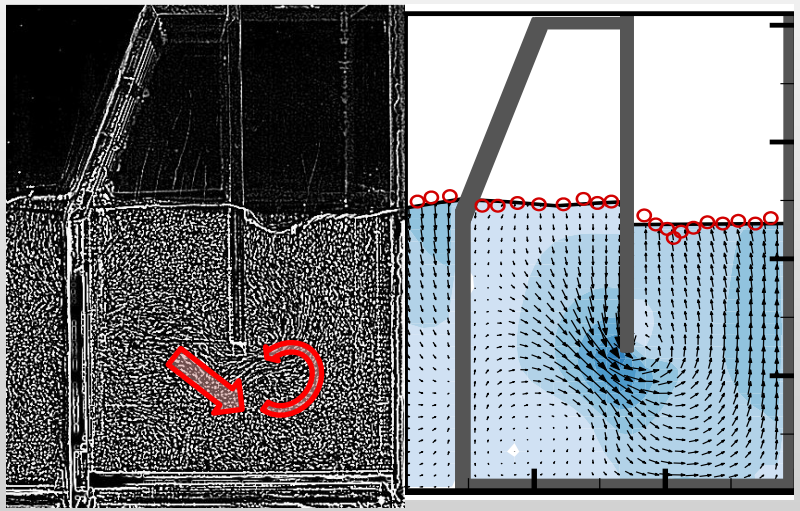

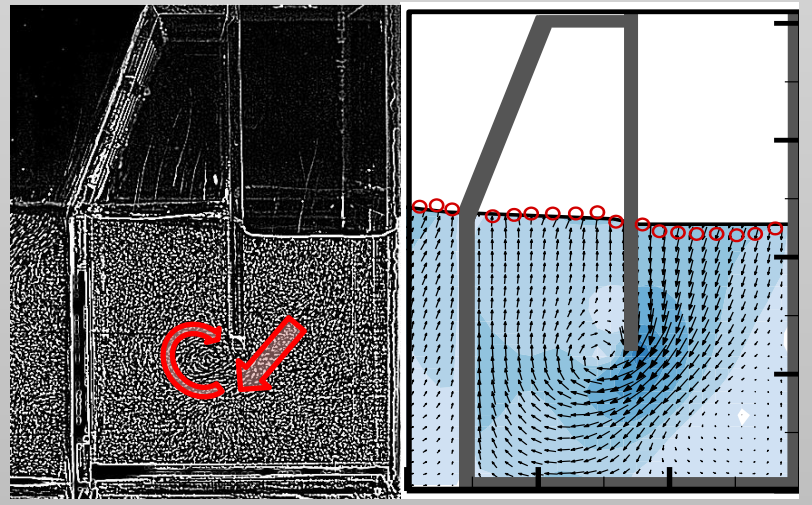

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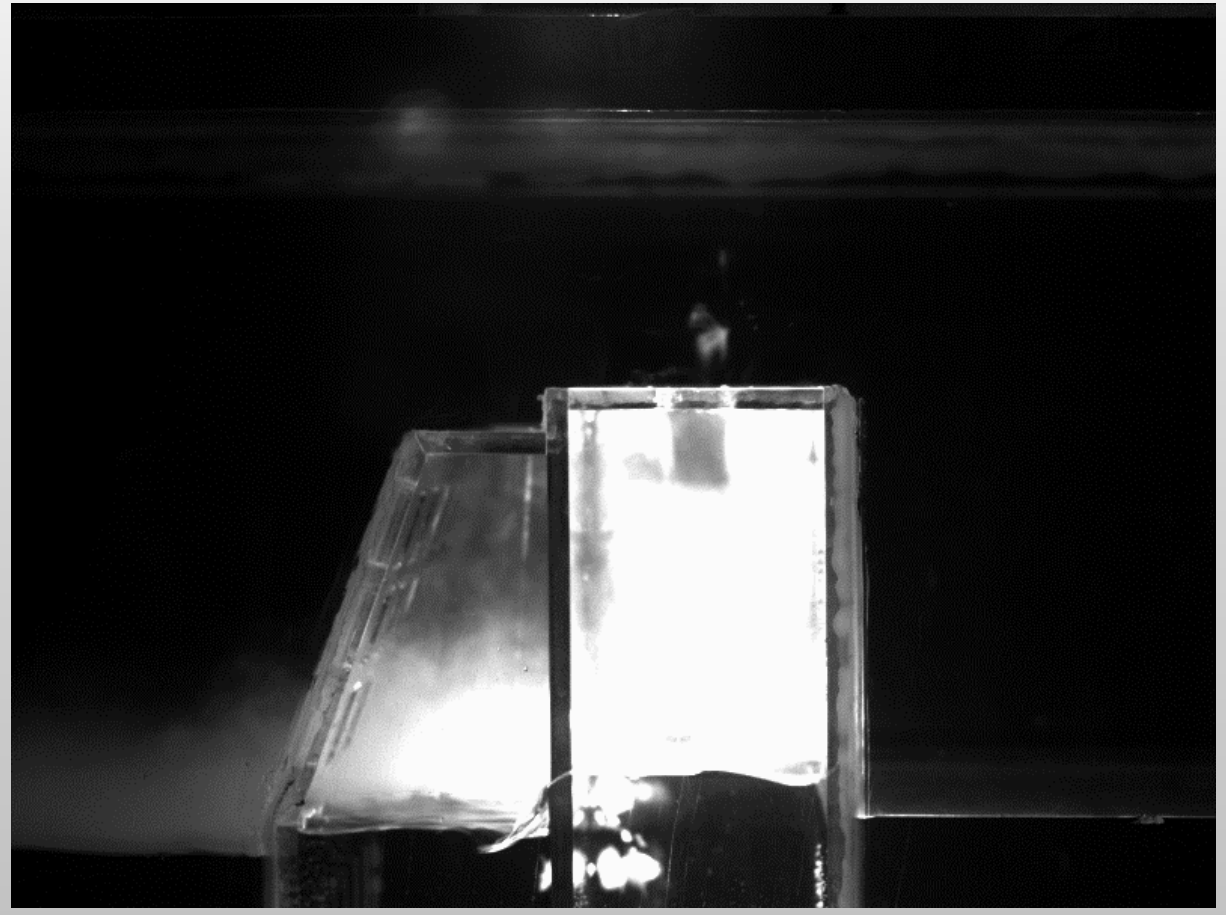

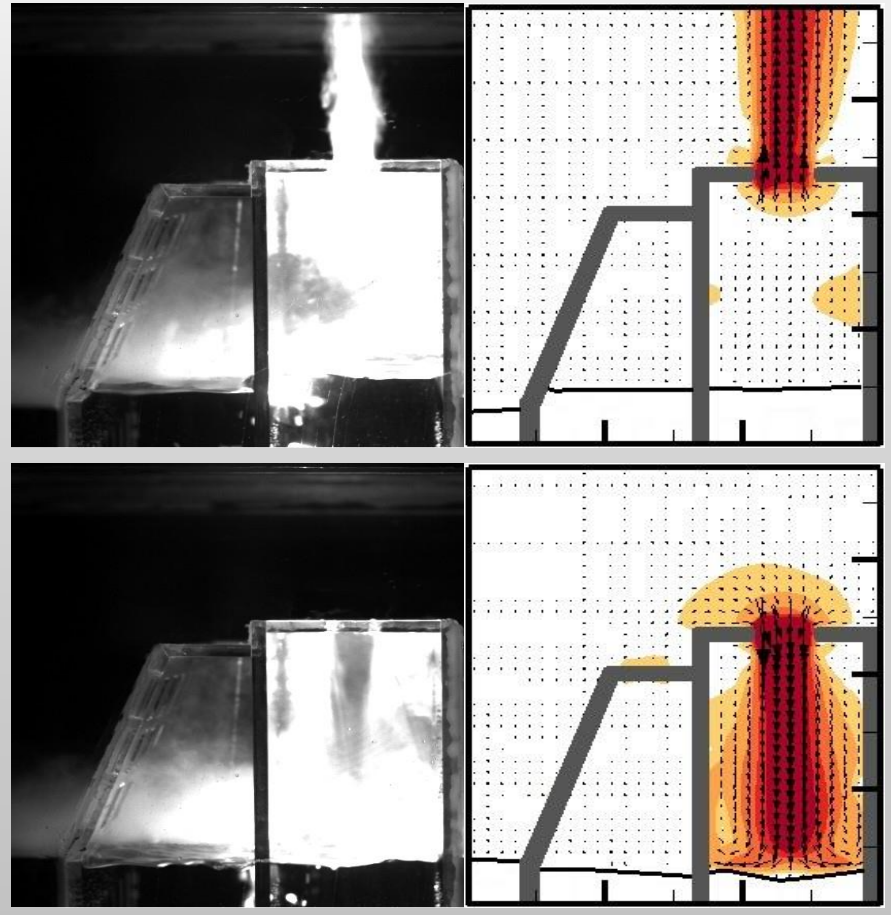

Dry ice induced smoke

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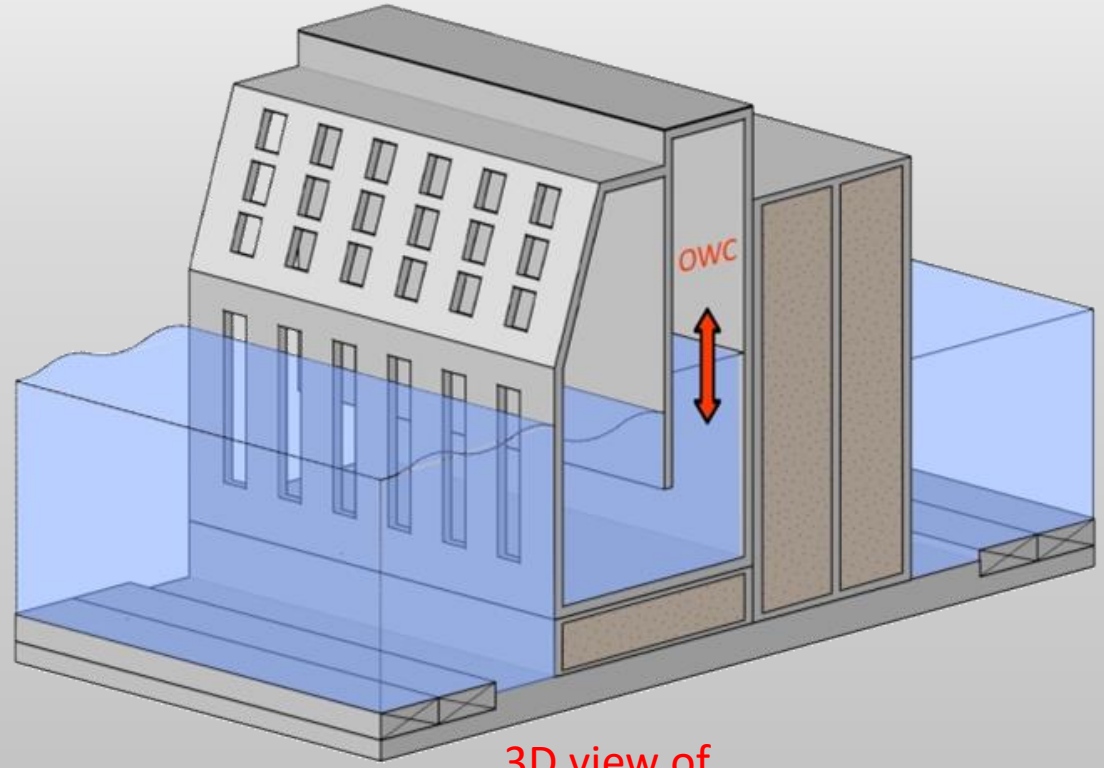
Full scale modelling

H	2.2 m
T	6.0 to 10.0 s
h	18.0 m
h_0	26m

Taichung harbor, Taiwan



3D view of
the breakwater integrated OWC device

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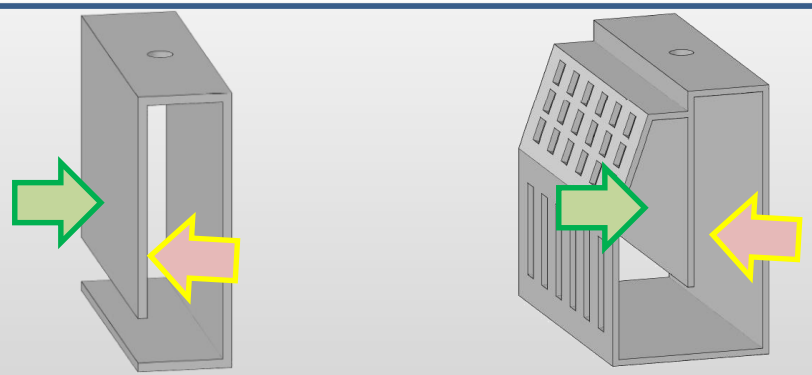
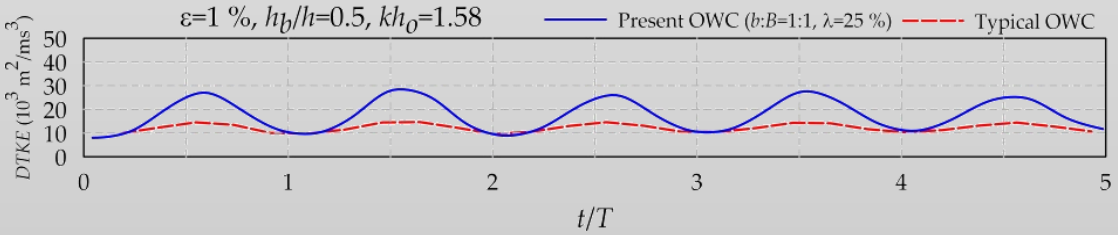
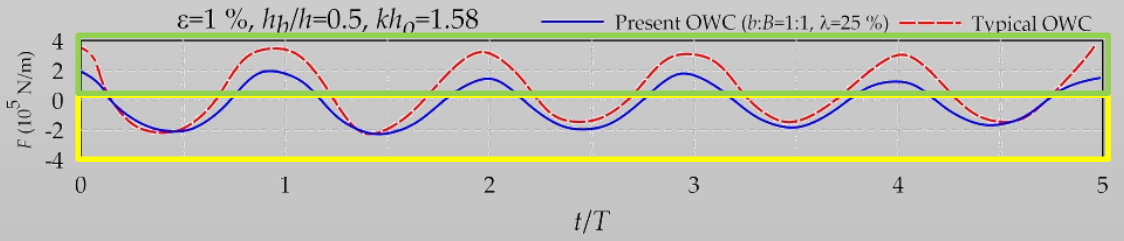
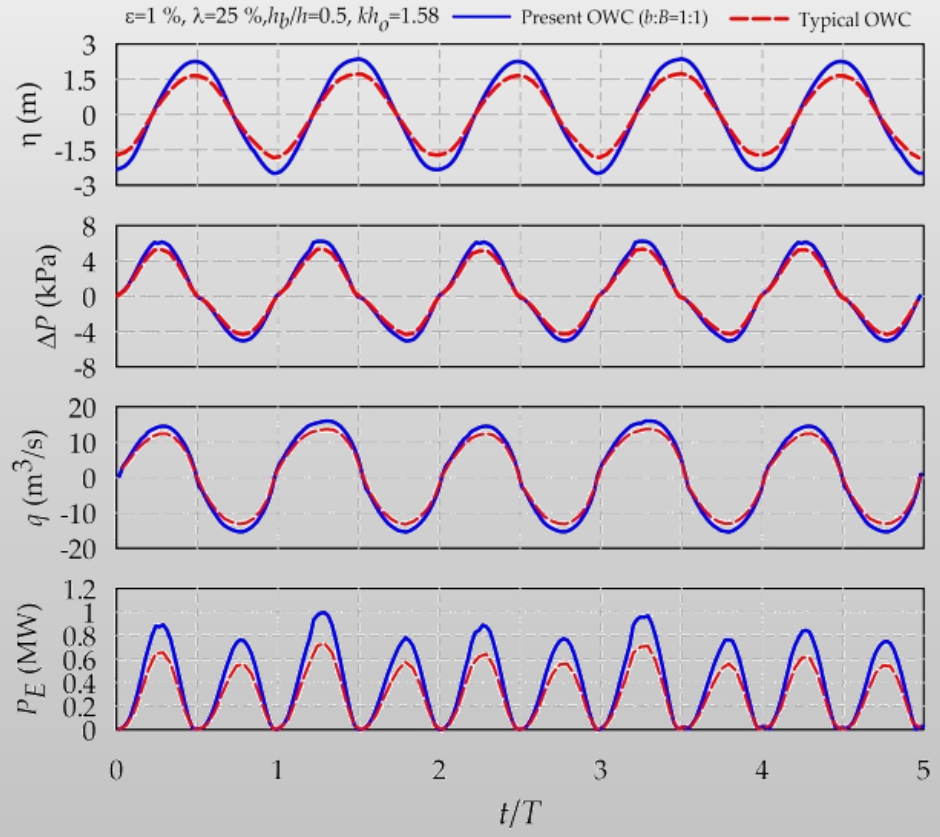




Comparison of the variation of DTKE of the present and typical OWC devices.



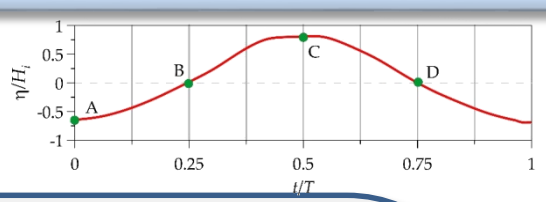
Comparison of the horizontal force acting on draught of the present and typical OWC devices.

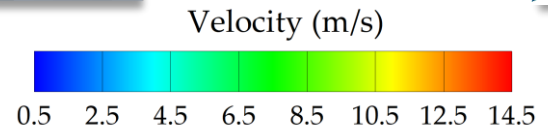


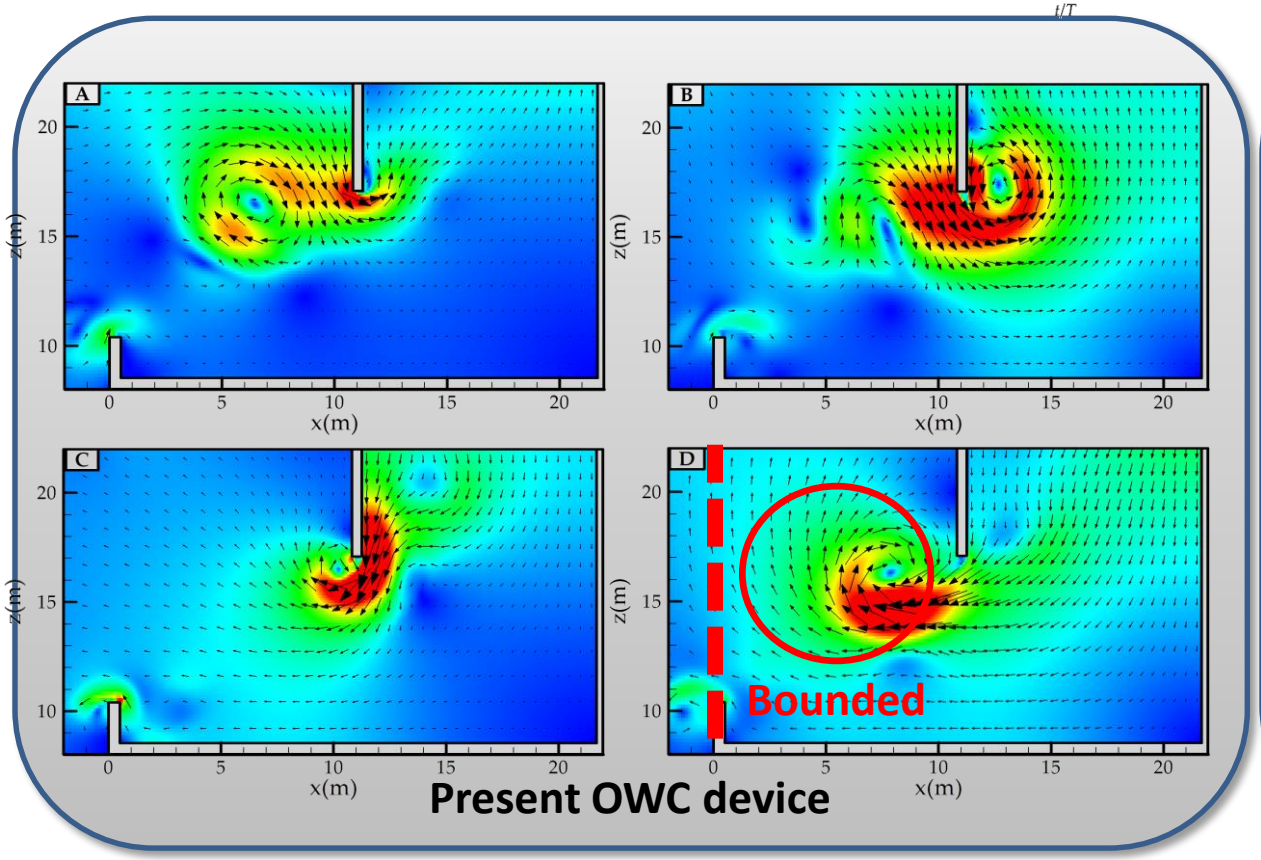
Comparison between present and typical OWC device.
η, ΔP, q, PE



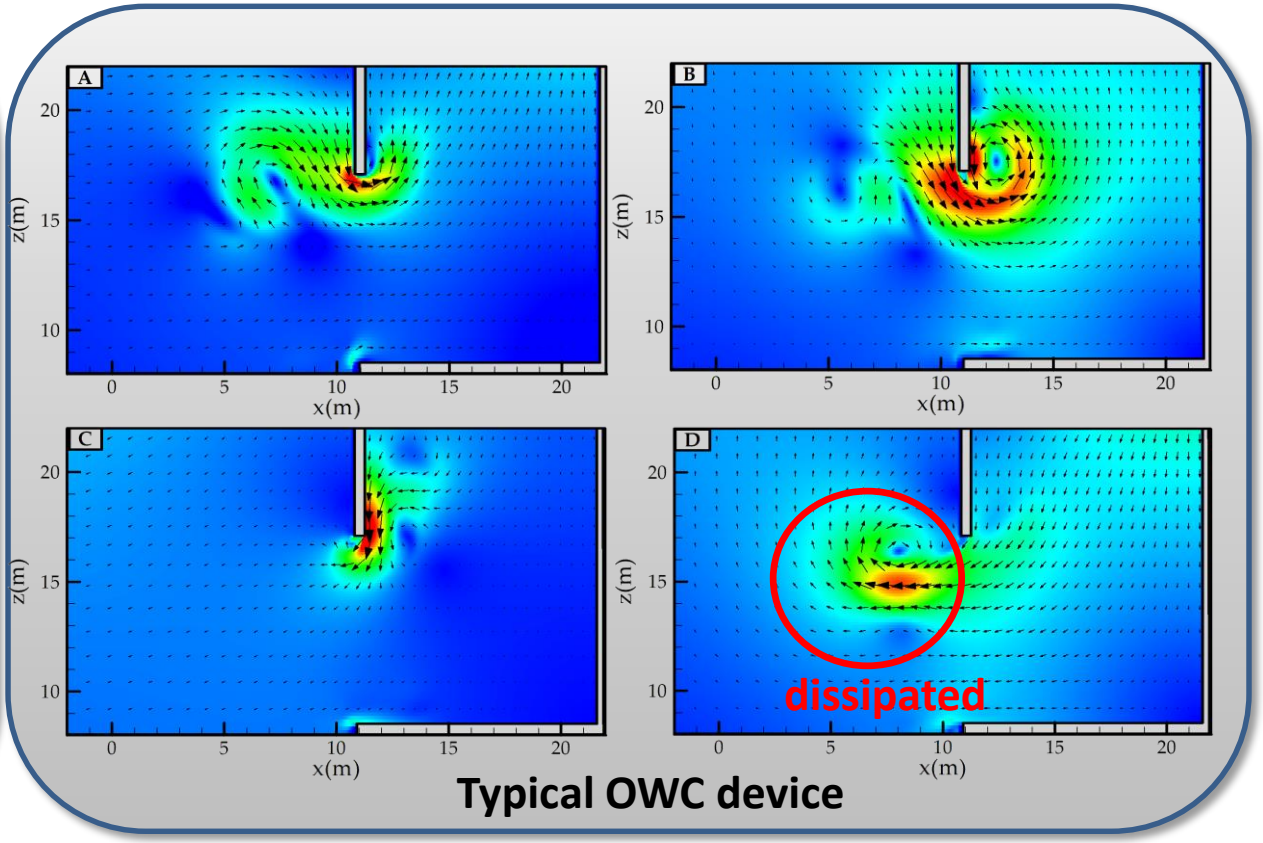

RESULTS AND DISCUSSTION :







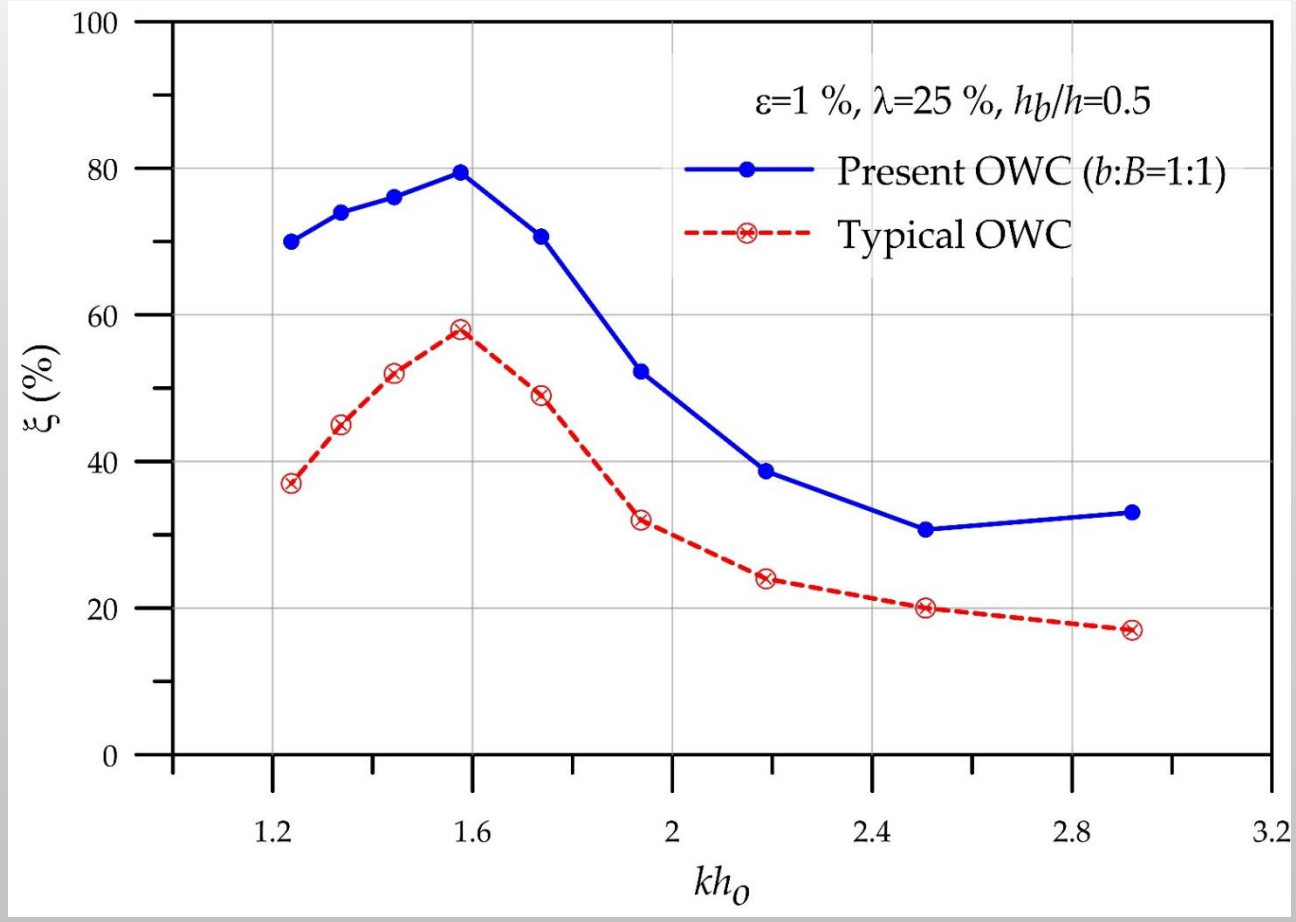
Present OWC device



Typical OWC device

Comparisons of flow characteristics

RESULTS AND DISCUSSION :



Efficiency Comparison between present and typical OWC devices by versus Kh0.

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CONCLUSIONS:

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This study carried out the experiments to investigate the hydrodynamic and air flow characteristics of OWC devices. Here are some conclusions…

•The addition of perforated wall could bounded the water and form an U-type pattern flow, this flow would enhance the oscillation of the water column.

•The airflow induced by water column was investigated both in the visualization experiments and numerical model. The cone type airflow was found significantly in this study.

•The perforated wall do reduce the wave force impact on the front wall.

Based on the above: the present OWC device can not only promote the efficiency of the power extraction, but also can reduce the wave force acting on the structure.

Thank You

For Your Attention