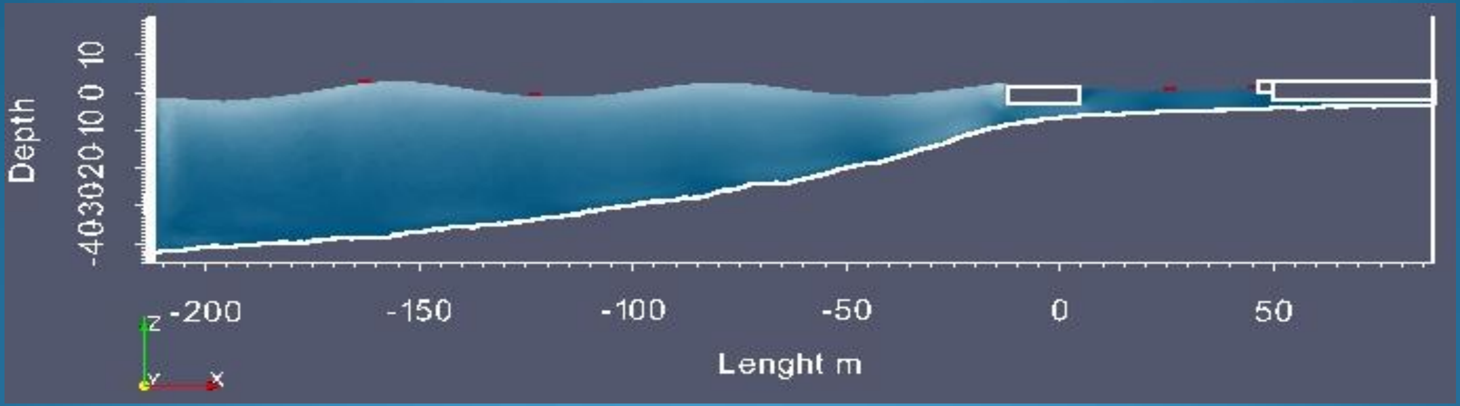
Performance Optimization of a Floating Breakwater Model Using SPH Method, with a Practical Application



Directed By : PhD G. Rodríguez
PhD A. Crespo

Alejandro Rueda Duran

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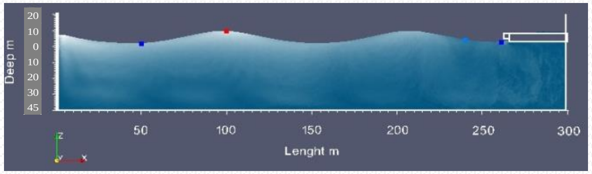
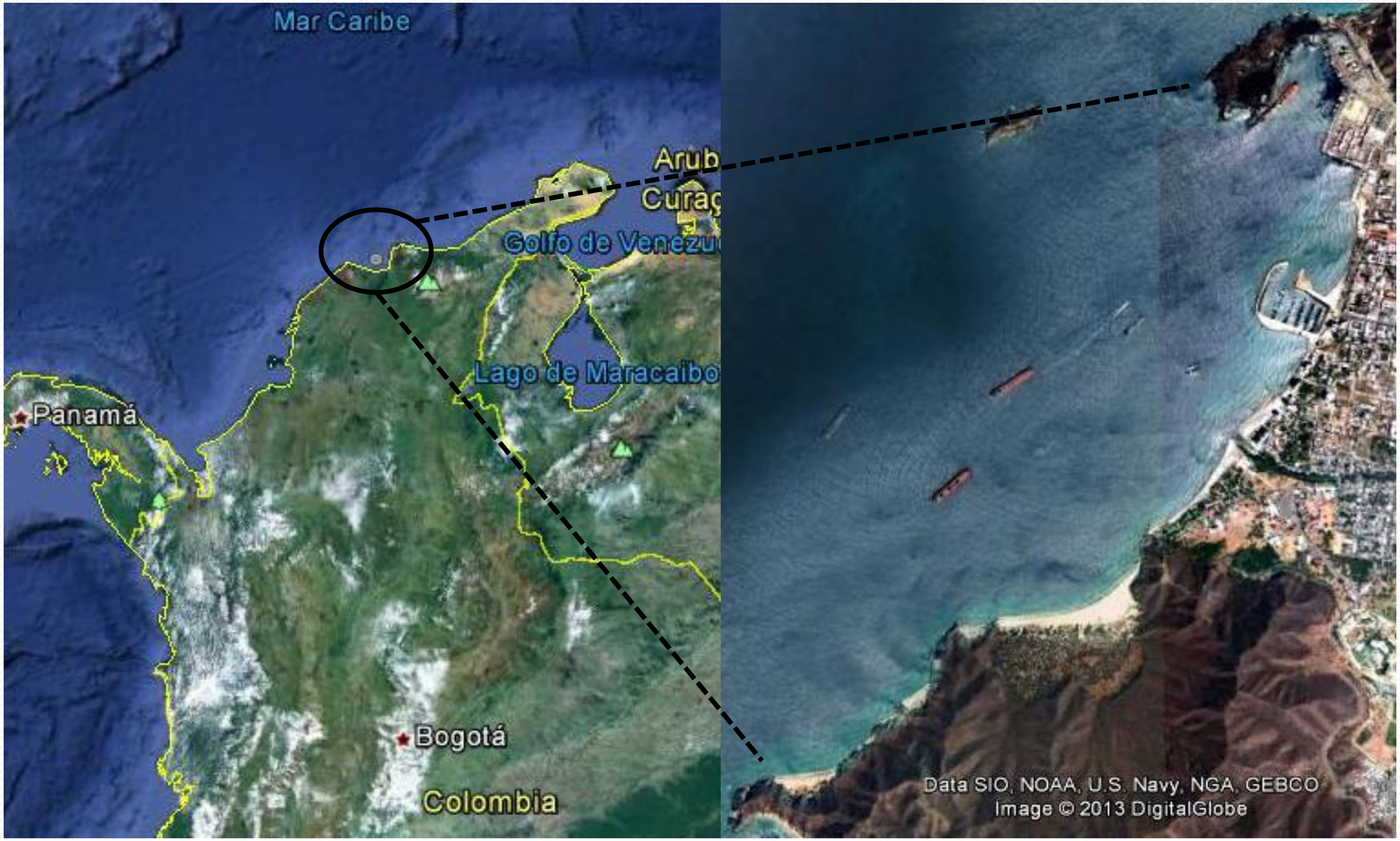


1. Problem Study Description

a. Survey Area



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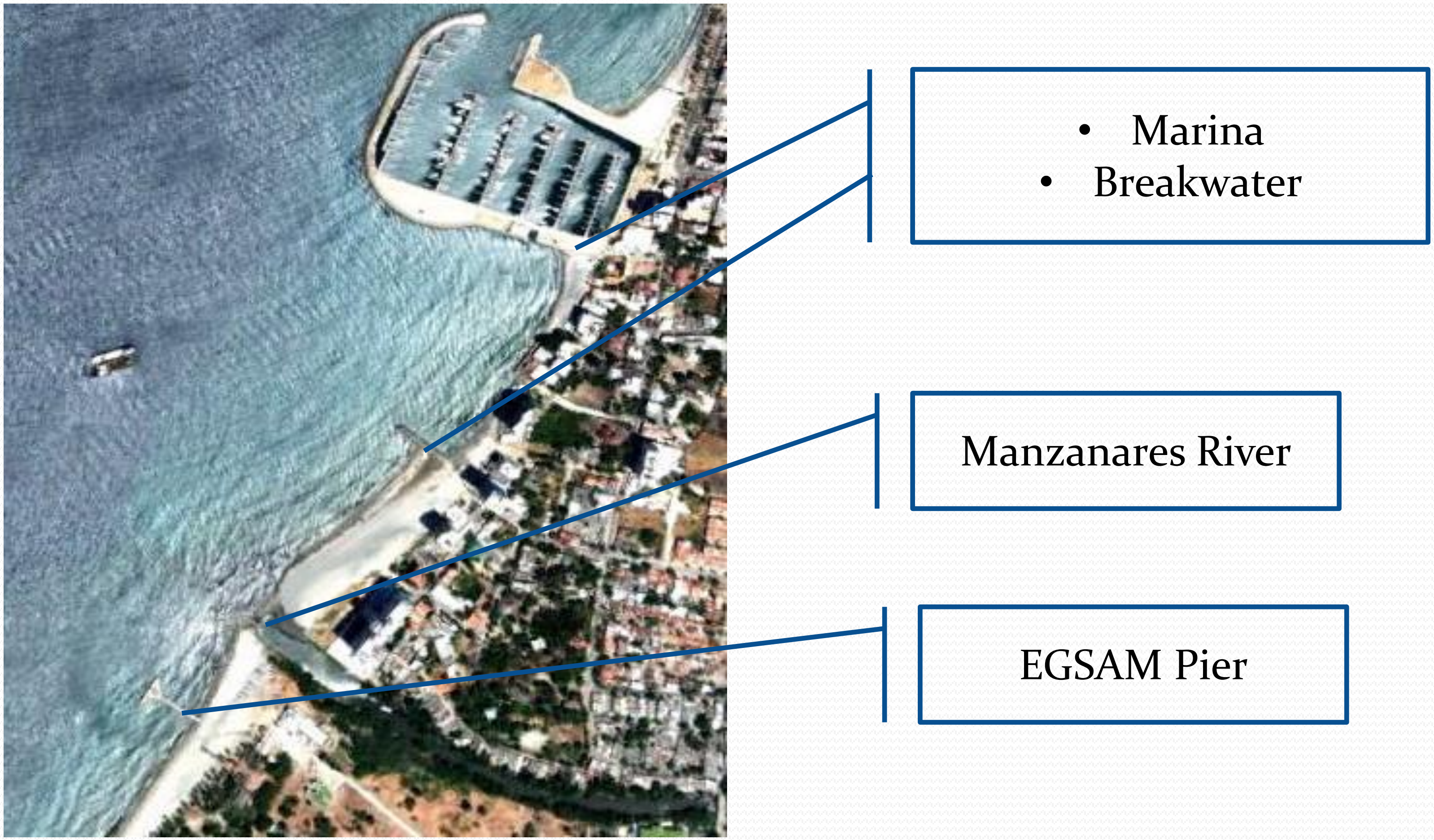


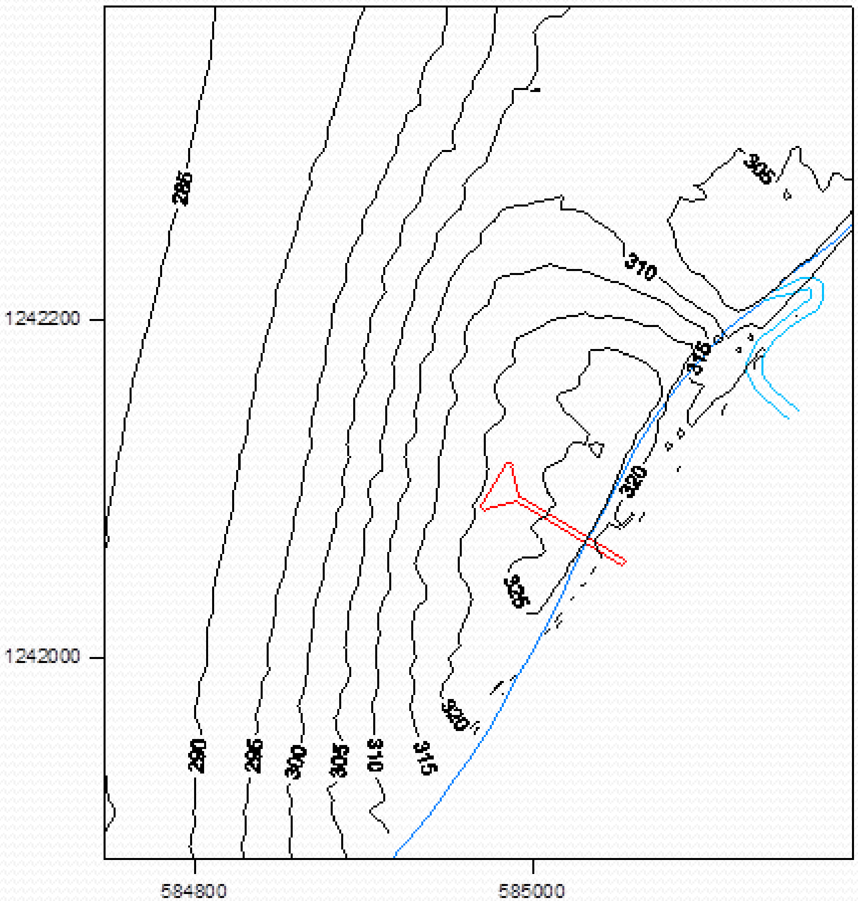
1. Problem Study Description

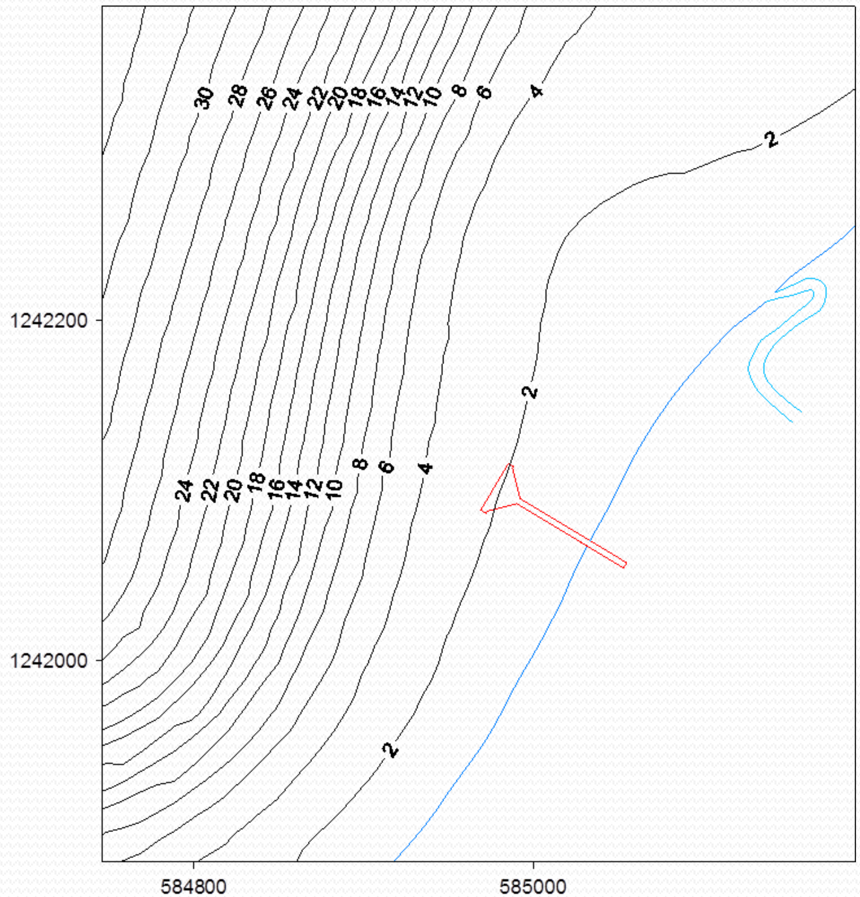
a. Survey Area

Images from: Google Earth

1. Problem Study Description

a. Survey Area

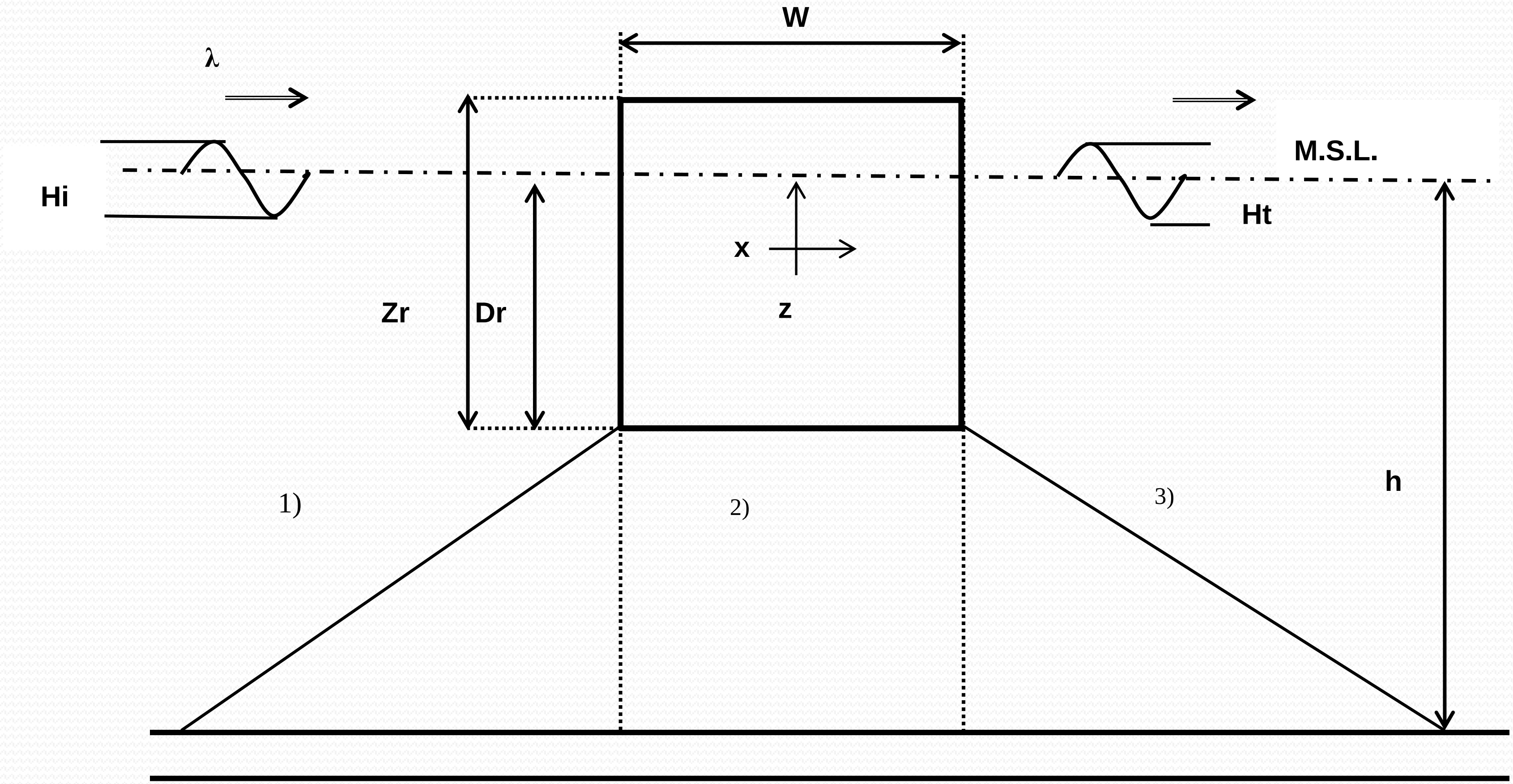




Images from: Sergei Lonin

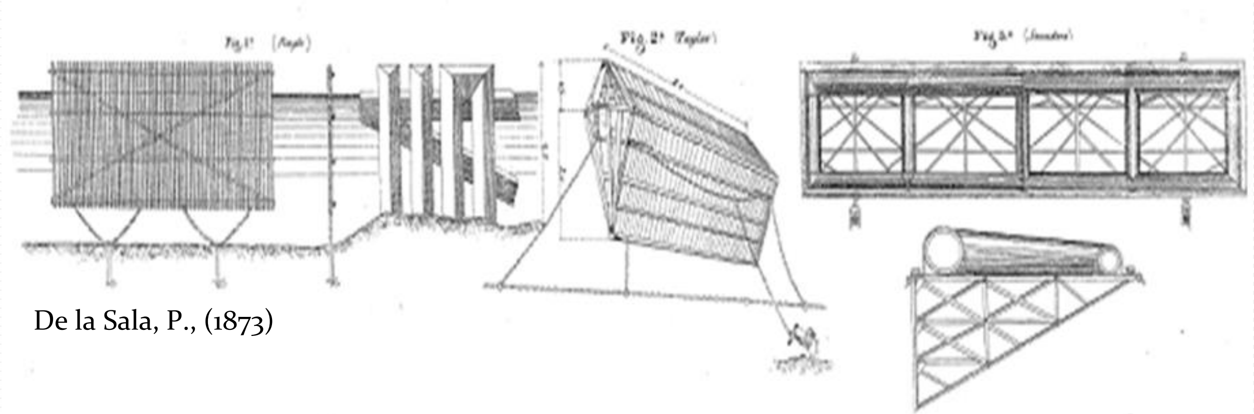
1. Problem Study Description

b. Floating Breakwaters Overview



1. Problem Study Description

b. Floating Breakwaters Overview

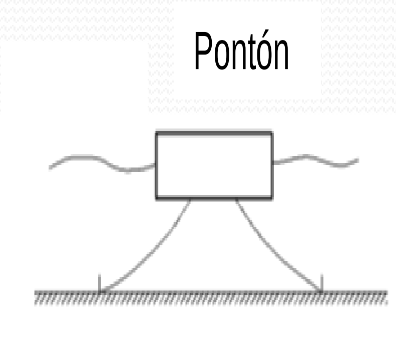


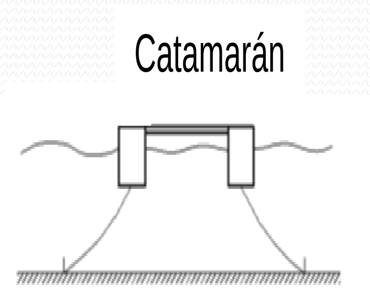
De la Sala, P., (1873)

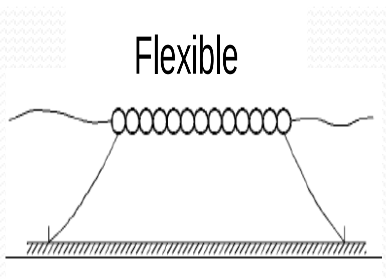
U.S. Navy Civil Engineering Laboratory

1. Problem Study Description

b. Floating Breakwaters Overview





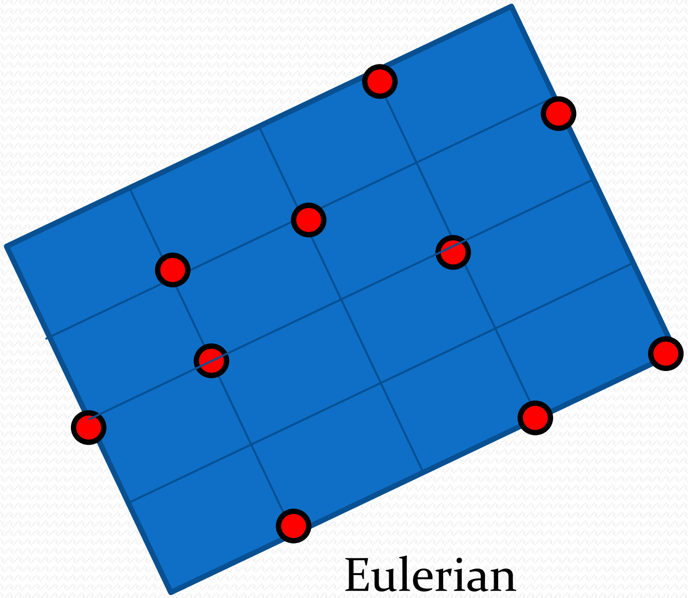


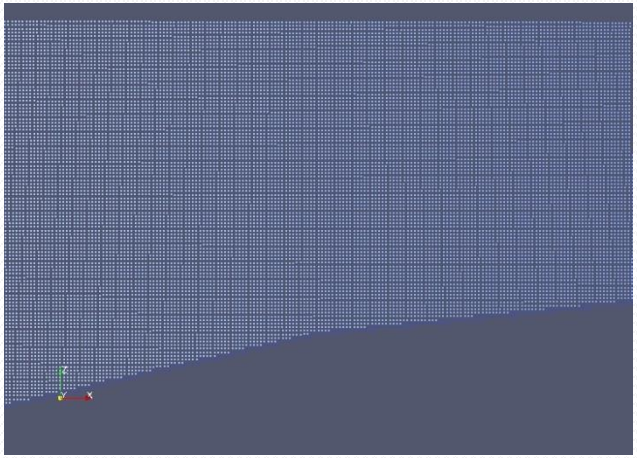
2. Smoothed Particle Hydrodynamics - SPH

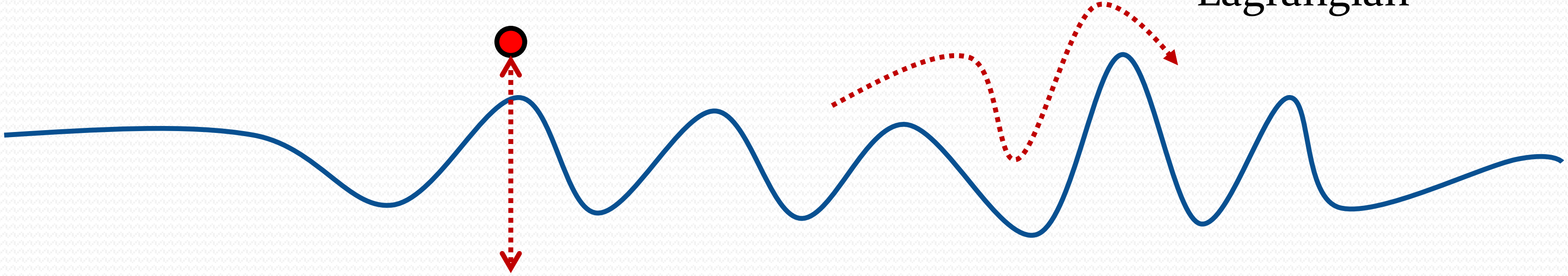
- Astrophysics and Cosmology, Gingold and Monaghan (1977) and Lucy (1977)
- SPHysics (2007) y DualSPHysics (2010)
  - University of Vigo (Spain),
  - University of Manchester (UK) and
  - The Johns Hopkins University (U.S.A.)
- Free Code www.dual.sphysics.org
  - Fortran95
  - C++

2. Smoothed Particle Hydrodynamics - SPH

- Lagrangian Method







2. Smoothed Particle Hydrodynamics - SPH

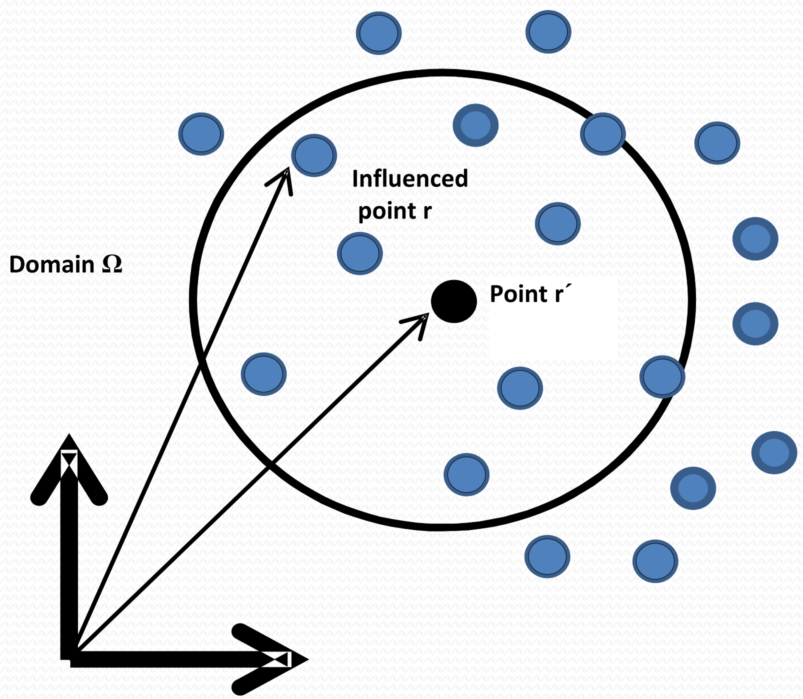
- Reality is reproduced(fluid) y (objects): Particles
  - Properties (e.g., mass, ρ, vel., position and P)
  - To represent the passing from a continuous medium (fluid) to a discrete (particles), SPH uses the kernel function

$$A(\mathbf{r}) = \int_{\Omega} A(\mathbf{r}')W(\mathbf{r} - \mathbf{r}', h)d\mathbf{r}' \qquad (1)$$

$$W_{ab} = W(r_a - r_b, h) \qquad (2)$$

- Where ***r*** is the particle position; *W* is the weighting function or kernel; *h* is the weighting function smoothing length controls the domain Ω

2. Smoothed Particle Hydrodynamics - SPH



1. Controls the interaction of each particle
2. Reduced computational cost - estimate only where fluid
3. It is slower to having to propagate "many" particles

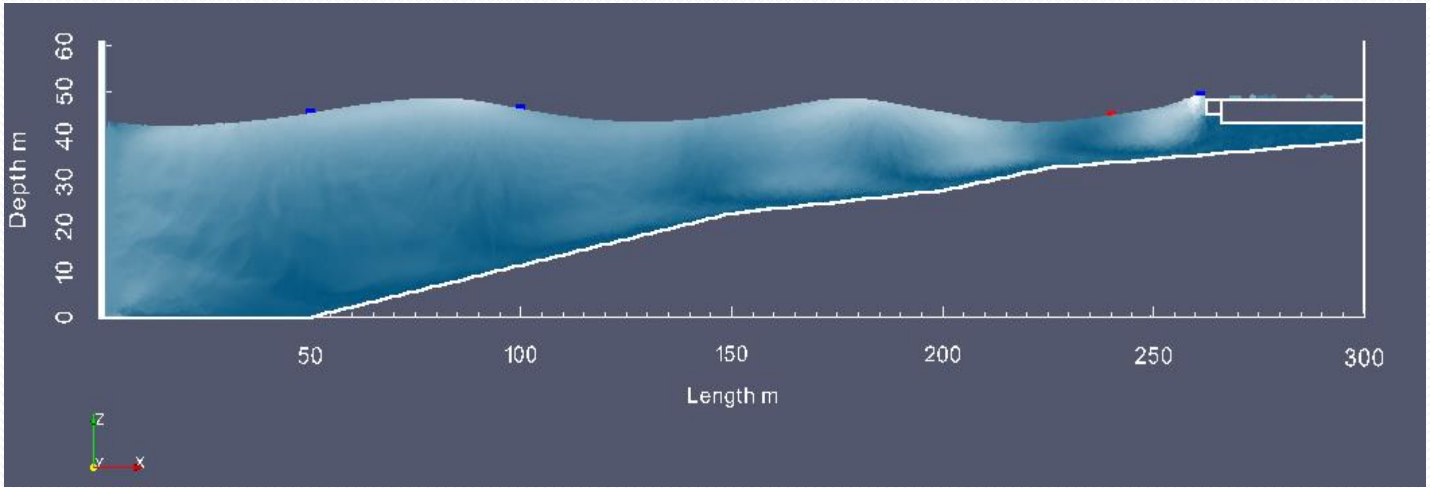
2. Smoothed Particle Hydrodynamics - SPH

- Momentum Equation. Monaghan (1992)
  - $\frac{d\mathbf{v_a}}{dt} = -\sum_b m_b \left(\frac{P_a}{\rho_a^2} + \frac{P_b}{\rho_b^2}\right) \boldsymbol{\nabla}_a W_{ab} + \mathbf{g}$ (3)
- Artificial Viscosity. Monaghan (1992)
  - $\frac{d\mathbf{v_a}}{dt} = -\sum_b m_b \left(\frac{P_a}{\rho_a^2} + \frac{P_b}{\rho_b^2}\right) \boldsymbol{\nabla}_a W_{ab} + \mathbf{g}$ (4)
- *Continuity Equation*
  - $\frac{d\rho_a}{dt} = \sum_b m_b \mathbf{v}_{ab} \boldsymbol{\nabla}_a W_{ab}$ (5)

1. Methodology

a. Box Model Design

The following dimensions were used in the box model design:



- Separation between particles: 0.25m.
- 121,812 particles were used in 2D and 7,264,747 in 3D.
- A bathymetry designed to strokes

3. Methodology

b. FB Study Case Design

- To validate the model we used the structure proposed by Bruce (1985) for Friday Bay (Washington).
- For FB design a methodology was employed by the authors using a relationship :
  - Wide (w)
  - Height (Z_R)
  - Draft (D_r)
  - Depth (h)
  - Wave length(λ)
  - Period (T)

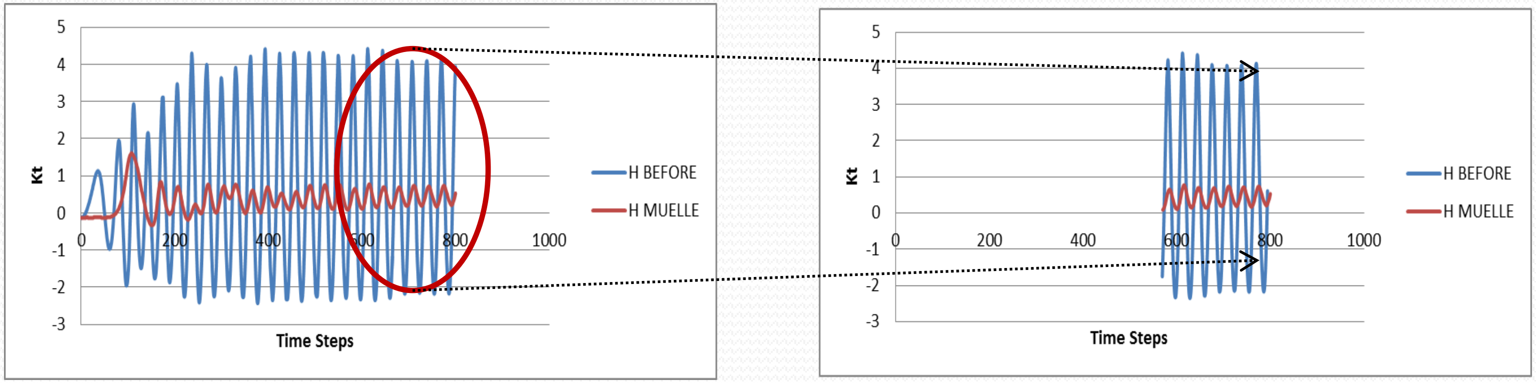
3. Methodology

a. FB Study Case Design

References	Thesis Code	Place	Height FB /Draft Zr/Dr	Wide / Draft W/Dr	Wave Height/ Depth H/h	Depth/ Wave Lenght h/λ	Wide/ Wave Lenght W/λ	Draft / Depth Dr/h	Wave Height/ Wave Lenght Hi/λ	Dimentional Depth 2πh/λ
Brebner (1968)	Case 1	Physical Model	2,221844	7,5647092	0,200	0,345	0,383	0,147	0,069	2,167
Bruce (1985)	Case 2	Olympia Harbor (Washington)	1,5714286	6	0,156	0,196	0,165	0,140	0,031	1,231
Torum (1987)	Case 3	Physical Model	1,4285714	4,6869141	0,123	0,223	0,091	0,088	0,027	1,401
Manuel (1995)	Case 4	Physical Model	1,3333333	2	0,032	0,620	0,248	0,200	0,020	3,895
Murali (1997)	Case 5	Physical Model	1,4347826	2,826087	0,200	0,108	0,141	0,460	0,022	0,680
Sannasiraj (1998)	Case 6	Physical and Numerical Model	4	4	0,019	0,510	0,087	0,043	0,010	3,203
Allyn (2004)	Case 7	Physical Model	1,2352941	2,2941176	0,076	0,326	0,127	0,170	0,025	2,046
Fouster (2007)	Case 8	Numerical Model	1,25	2,25	0,123	0,396	0,178	0,200	0,049	2,488
Martinelli (2008)	Case 9	Physical Model	2,3333333	6,6666667	0,170	0,246	0,105	0,064	0,042	1,545
Elchahal (2009)	Case 10	Numerical Model	1,1315789	0,6644737	0,050	0,401	0,101	0,380	0,020	2,518
Wang (2010)	Case 11	Numerical Model	1,1111111	1,6	0,150	0,168	0,135	0,450	0,025	0,731
Yoon (2011)	Case 12	Physical and Numerical Model	2,6666667	6,6666667	0,086	0,116	0,106	0,136	0,010	0,731
He (2012)	Case 13	Physical Model	2,259887	8,7570621	0,044	0,225	0,388	0,197	0,010	1,414
Loukogeorgaki (2012)	Case 14	Numerical Model	1,8181818	4,5454545	0,037	0,158	0,250	0,347	0,006	0,995

- FB has a position which is fixed in space and infinitely long in longshore direction
- Ideal, weakly compressible and irrotational flow are assumed
- Wave propagation perpendicular to the beach
- Model was validated running 160s , T= 8,7, and 6s and X_R=50, 75, 100 and 150m

3. Methodology



- To validate the model 90 cases were executed in 2D and the behavior of 630 waves were observed.
- To select the proposed structure for Santa Marta 75 cases were executed and 525 waves evaluated .
- All simulations were executed using GPU (Graphics Processing Units) with support from the Environmental Physics Laboratory of the University of Vigo.

3. Methodology

a. FB Study Case Design

- If the Box model behavior is like closed box.... Resonance????
- Phenomenon that describes the process .....Seiches!!!!!

"Long period oscillations that occur in closed or semi-closed basins, which to generate resonant wave height increases inside"

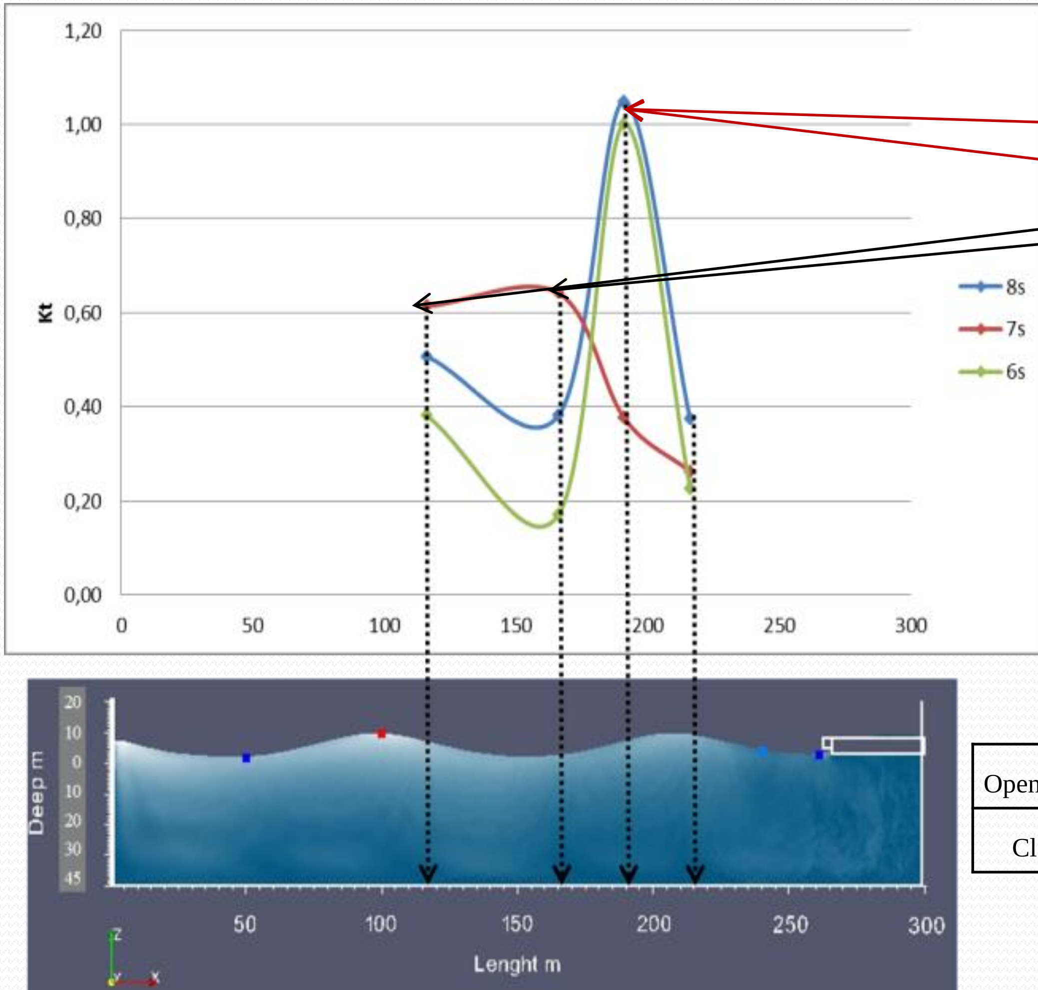
- *Merian (1828)*

$$T_n = \frac{2L}{n\sqrt{gh}} \qquad (6)$$

- where T_n is the natural period of oscillation, L is the length of the domain, n the number of node.
- relationship proposed by Sorensen (1993) wavelength λ and the domain length L to determined a critical ratio.

4. Results and Discussion

a. Box Model Validation

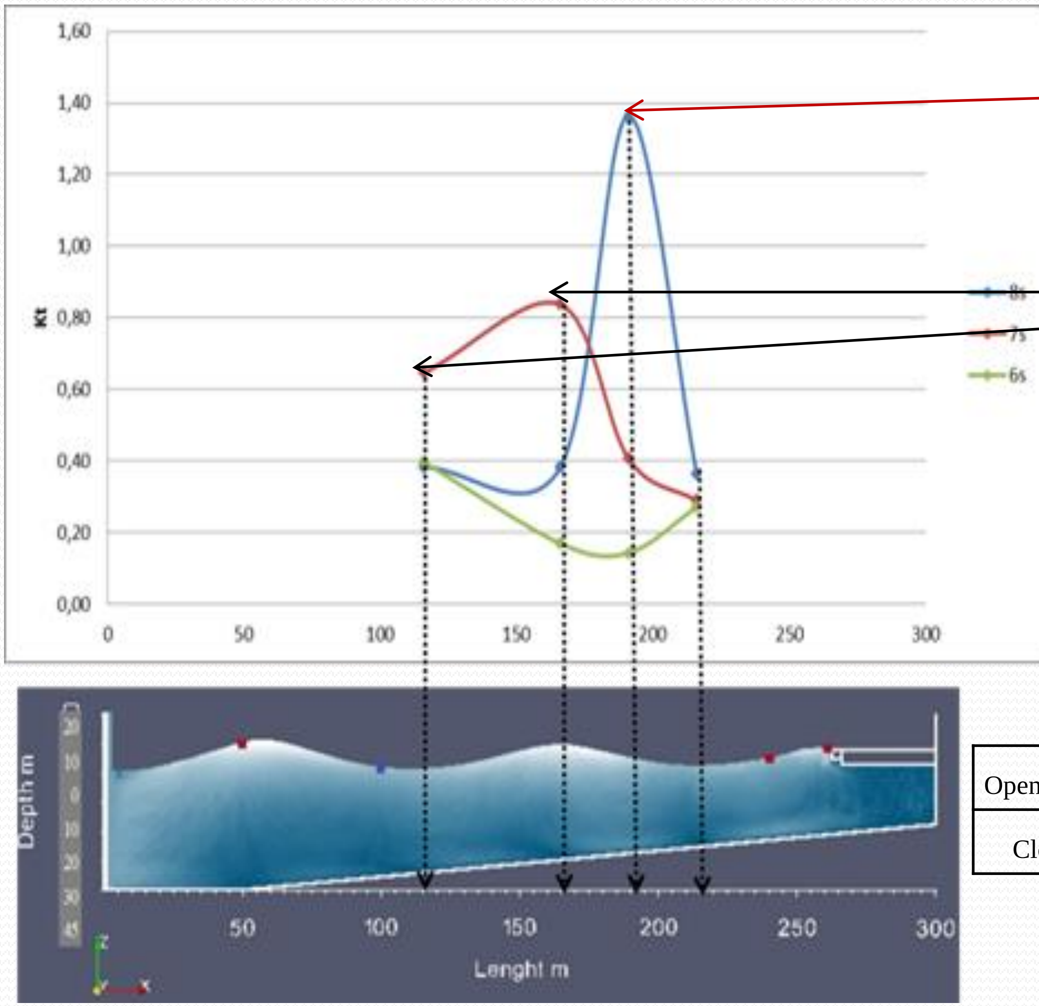


FB Depth			λ/L			
h	45	λ	50	75	100	150
	8	99,576	1,9915	1,33	1	0,66
T	7	76,457	1,5291	1,02	0,76	0,51
	6	56,205	1,1241	0,75	0,56	0,37

Open-ended Basin Critical Periods	0,25	0,75	1,25	1,75	2,25
Closed Basin Critical Periods	0,5	1	1,5	2	2,5

4. Results and Discussion

a. Box Model Validation

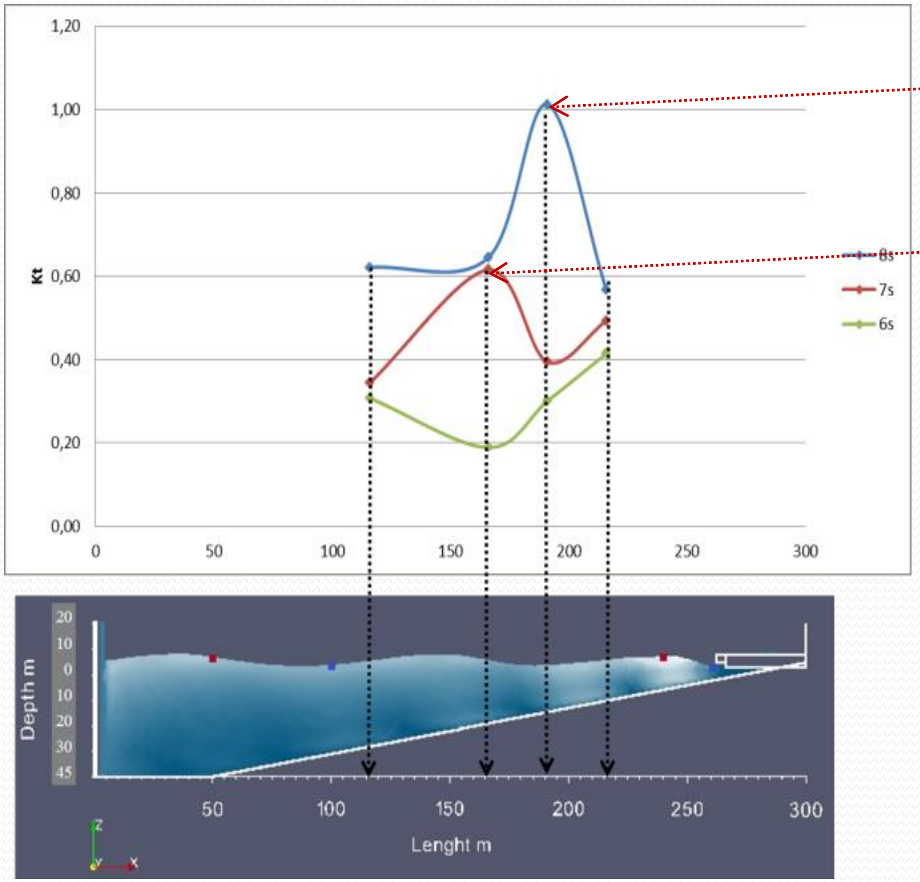


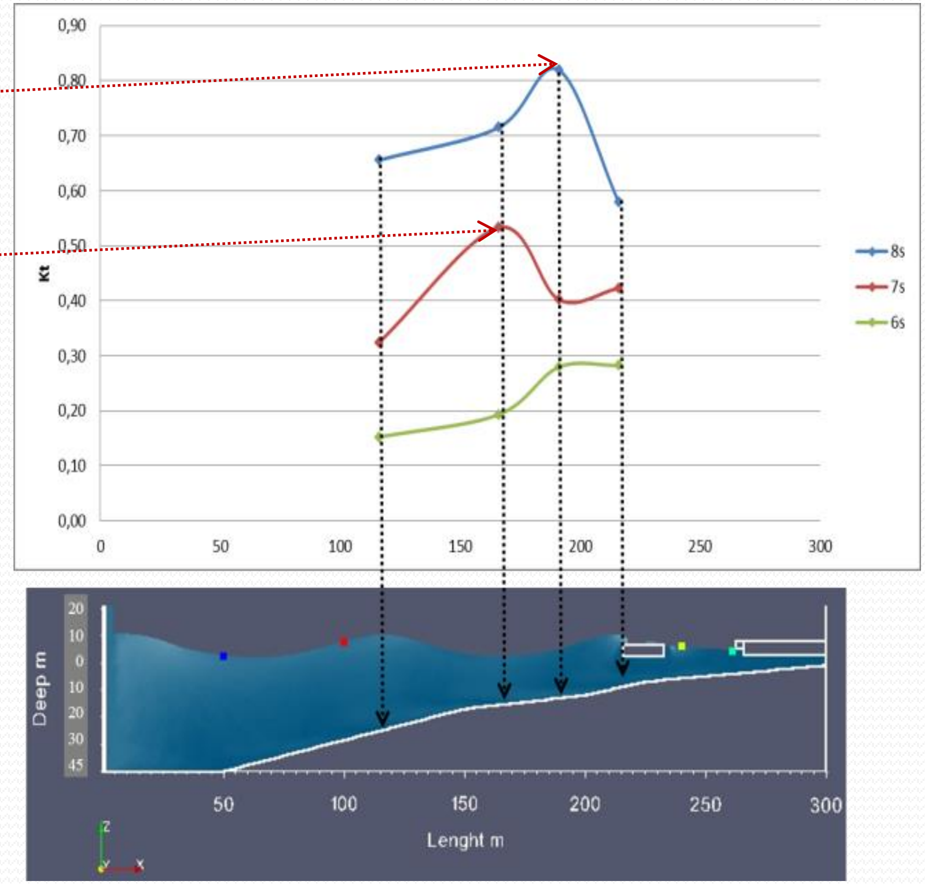
FB Depth		λ	λ/L	FB Depth		λ	λ/L
h	28		50	h	30		75
T	8	97,012	1,9402	T	8	97,653	1,302
	7	75,738	1,5148		7	75,952	1,0127
	6	56,1	1,122		6	56,139	0,7485
FB Depth		**λ**	**λ/L**	**FB Depth**		**λ**	**λ/L**
h	32		100	h	37		150
T	8	98,153	0,9815	T	8	98,976	0,6598
	7	76,106	0,7611		7	76,329	0,5089
	6	56,163	0,5616		6	56,193	0,3746

Open-ended Basin Critical Periods	0,25	0,75	1,25	1,75	2,25
Closed Basin Critical Periods	0,5	1	1,5	2	2,5

4. Results and Discussion

a. Box Model Validation

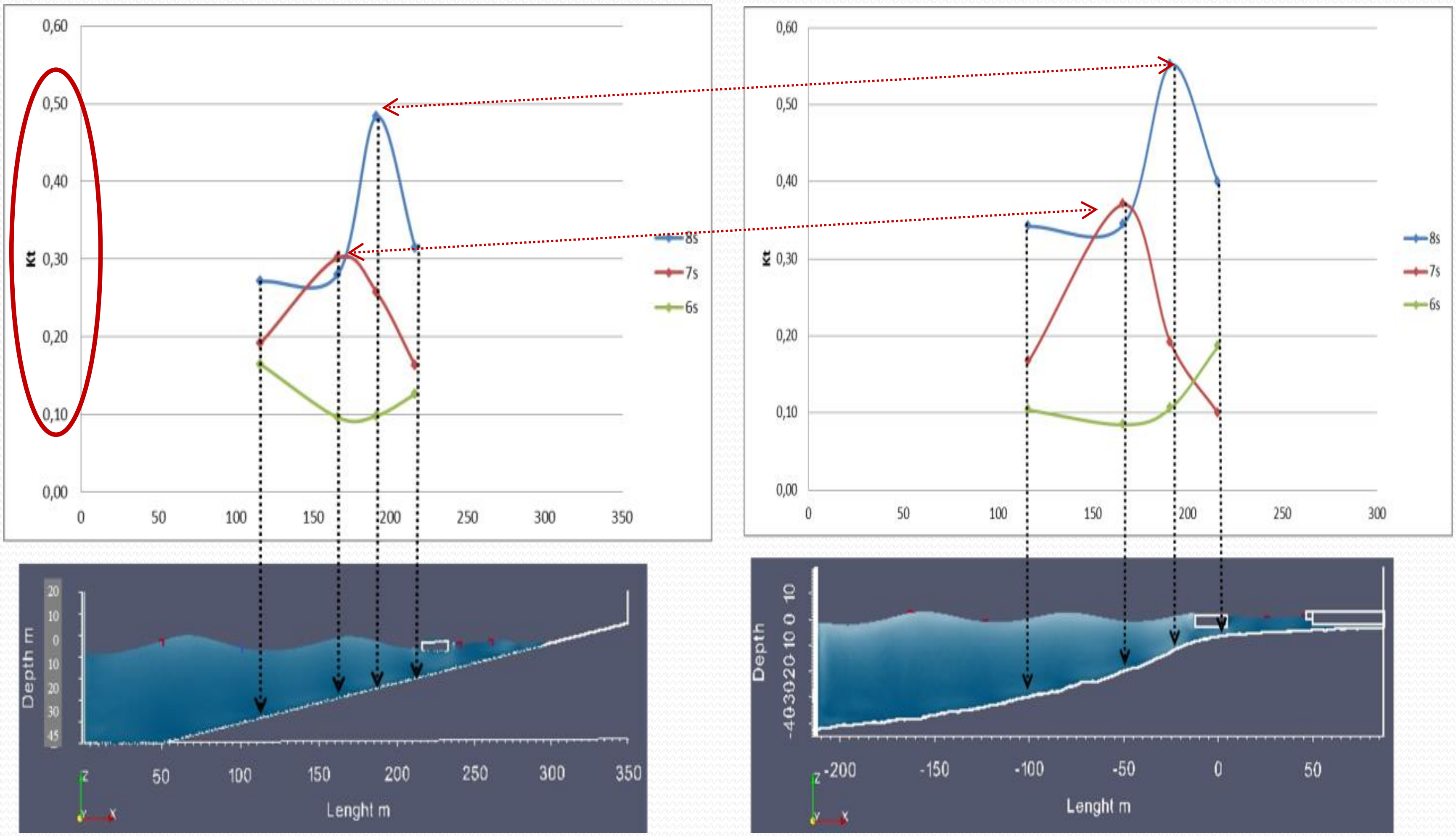




- If in all cases there + / - resonance ..... We had fictitious results???

4. Results and Discussion

a. Box Model Validation



4. Results and Discussion

a. Box Model Validation

- Reflection and resonance are presented in 2D
- There is good correlation between the best condition simulated and the case study
- The box model behaves as closed and semi-closed basin depending on the distance between the FB and Pier
- Overall ….. 2D model validation!!!!!!!

4. Results and Discussion

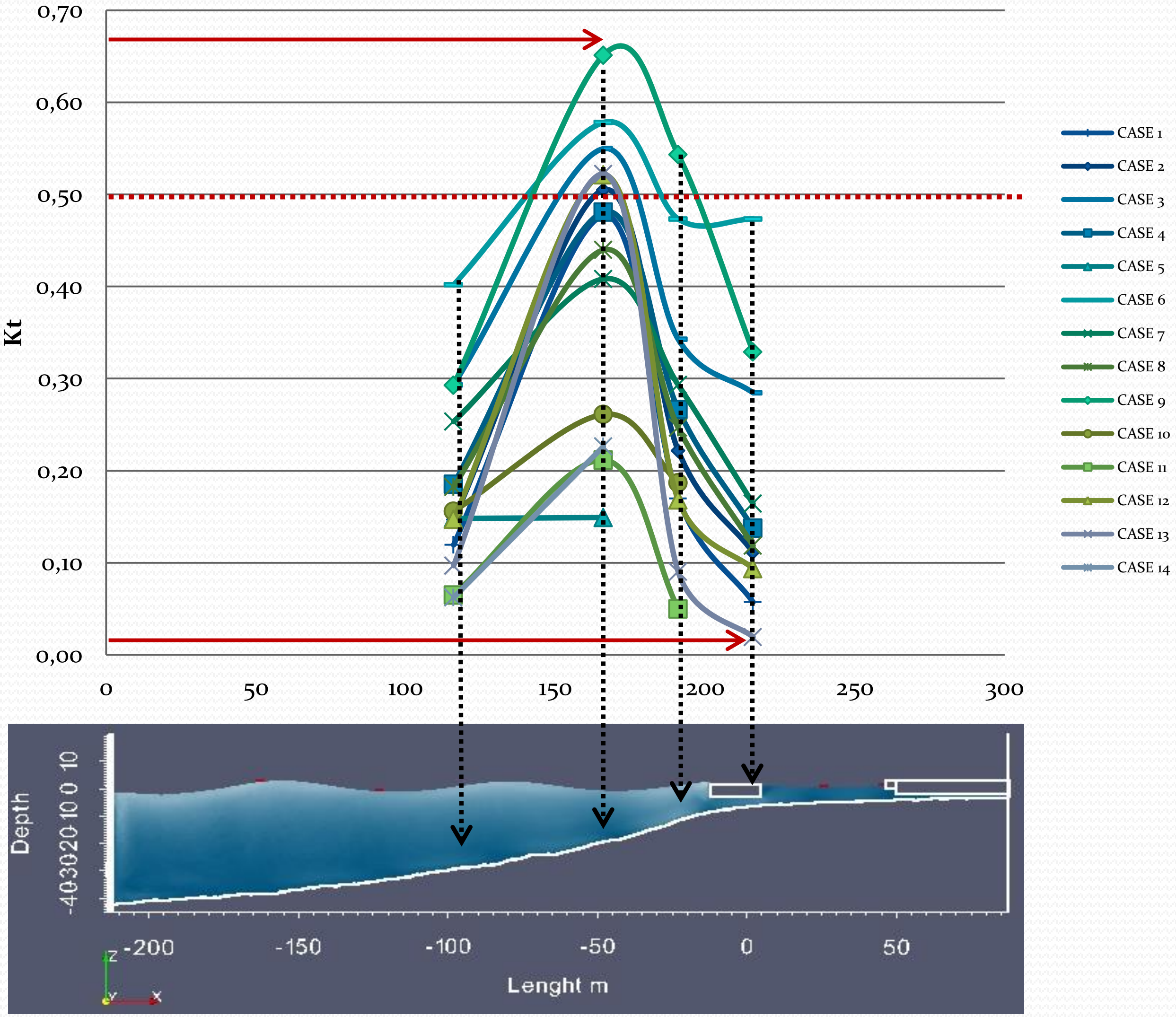
b. Santa Marta Case

- FB Reconstructions:

PARAMER/CASE	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Z_R	6,55	4,4	2,5	5,33	13,2	3,4	4,2	5	2,97	8,6	10	7,27	8,88	12,63
X_R	22	16,8	8,2	8	26	3,4	7,8	9	8,51	5,05	14,4	18,18	34,4	31,57
Dr	2,93	2,8	1,75	4	9,2	0,85	3,4	4	1,27	7,6	9	2,72	3,93	6,94
ERROR	(+/-) 0,25	(+/-) 0,25	(+/-) 0,25	(+/-) 0,25	(+/-) 0,25	(+/-) 0,25	(+/-) 0,25	(+/-) 0,25	(+/-) 0,25	(+/-) 0,25	(+/-) 0,25	(+/-) 0,25	(+/-) 0,25	(+/-) 0,25
Area FB m2	**144,1**	**73,92**	**20,5**	**42,64**	**343,2**	**11,56**	**32,76**	**45**	**25,27**	**43,43**	**144**	**132,2**	**305,5**	**398,7**

4. Results and Discussion

b. Santa Marta Case



4. Results and Discussion

b. Santa Marta Case

Set 1	FB Vol.	Kt	Overall
1	0,60	0,40	1,00
11	0,8	0,8	1,60
12	1,00	0,4	1,40
13	0,40	1,00	1,40
14	0,2	0,60	0,80

Set 2	FB Vol.	Kt	Overall
2	0,33	1,00	1,33
4	0,83	0,66	1,49
5	0,16	0,5	0,66
7	1,00	0,33	1,33
8	0,50	0,83	1,33
10	0,66	0,33	0,99

Set 3	FB Vol.	Kt	Overall
3	0,66	1,00	1,66
6	1,00	0,33	1,33
9	0,33	0,66	0,99

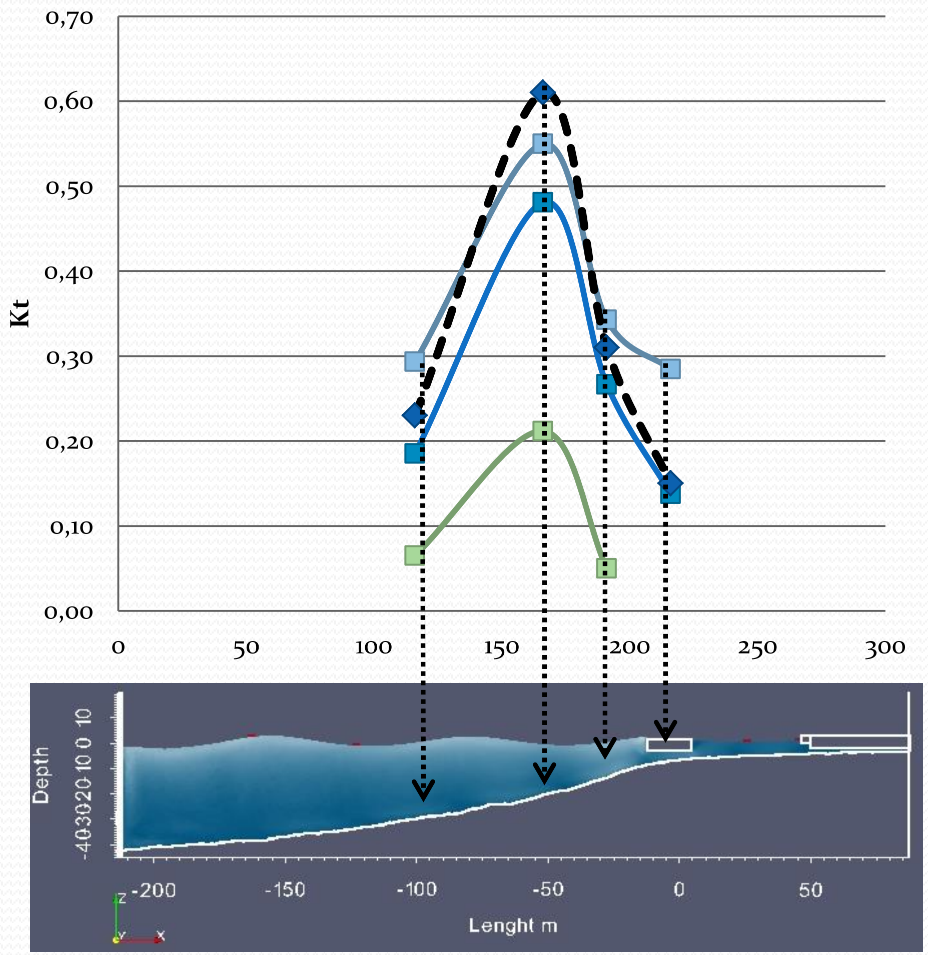
- Santa Marta Case 15:
  - ZR= 6.5m
  - XR= 6.0m
  - DR= 4.0m

Area: 39m^2

Volume 3D: 1560m^3

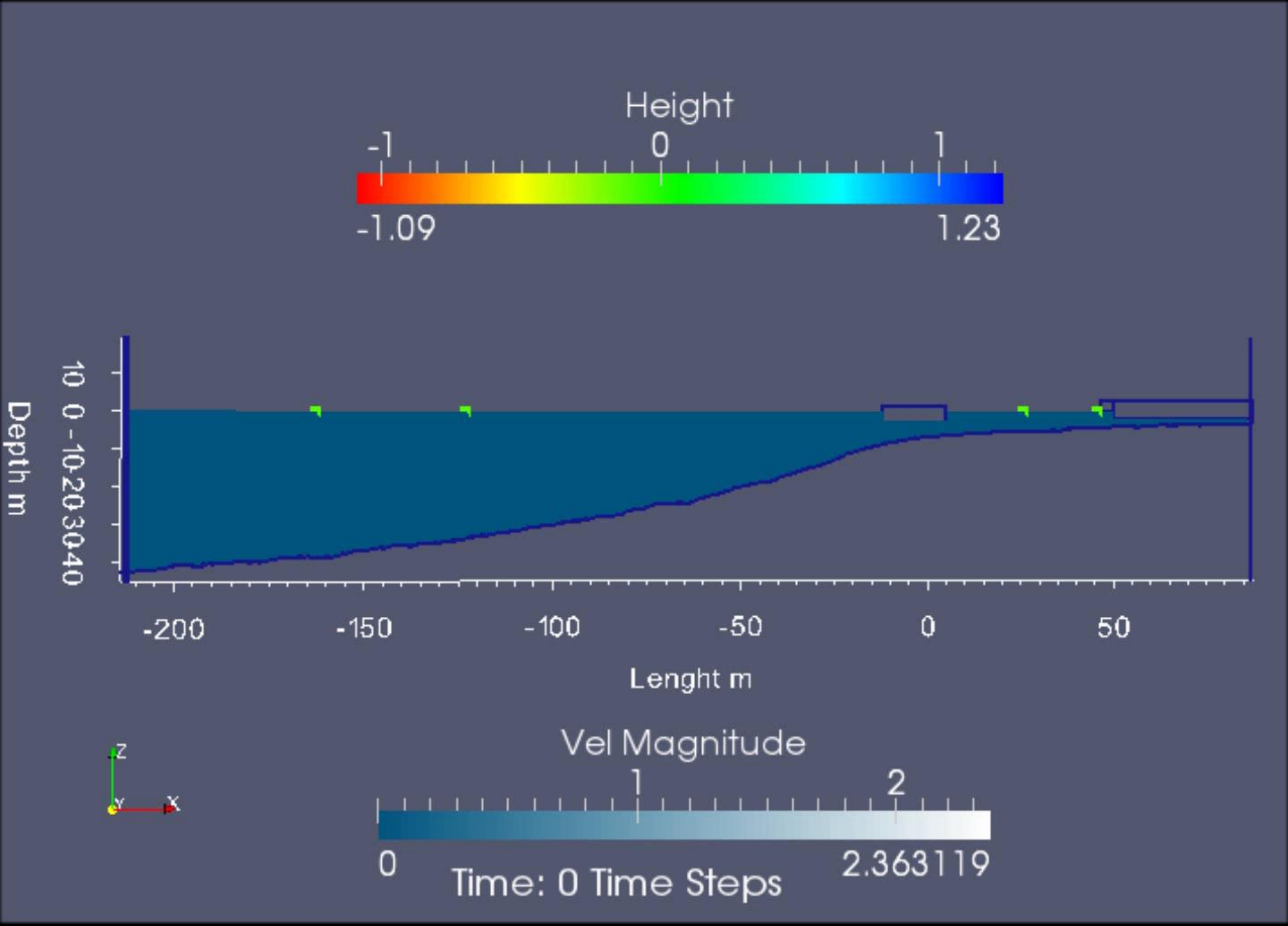
4. Results and Discussion

b. Santa Marta Case



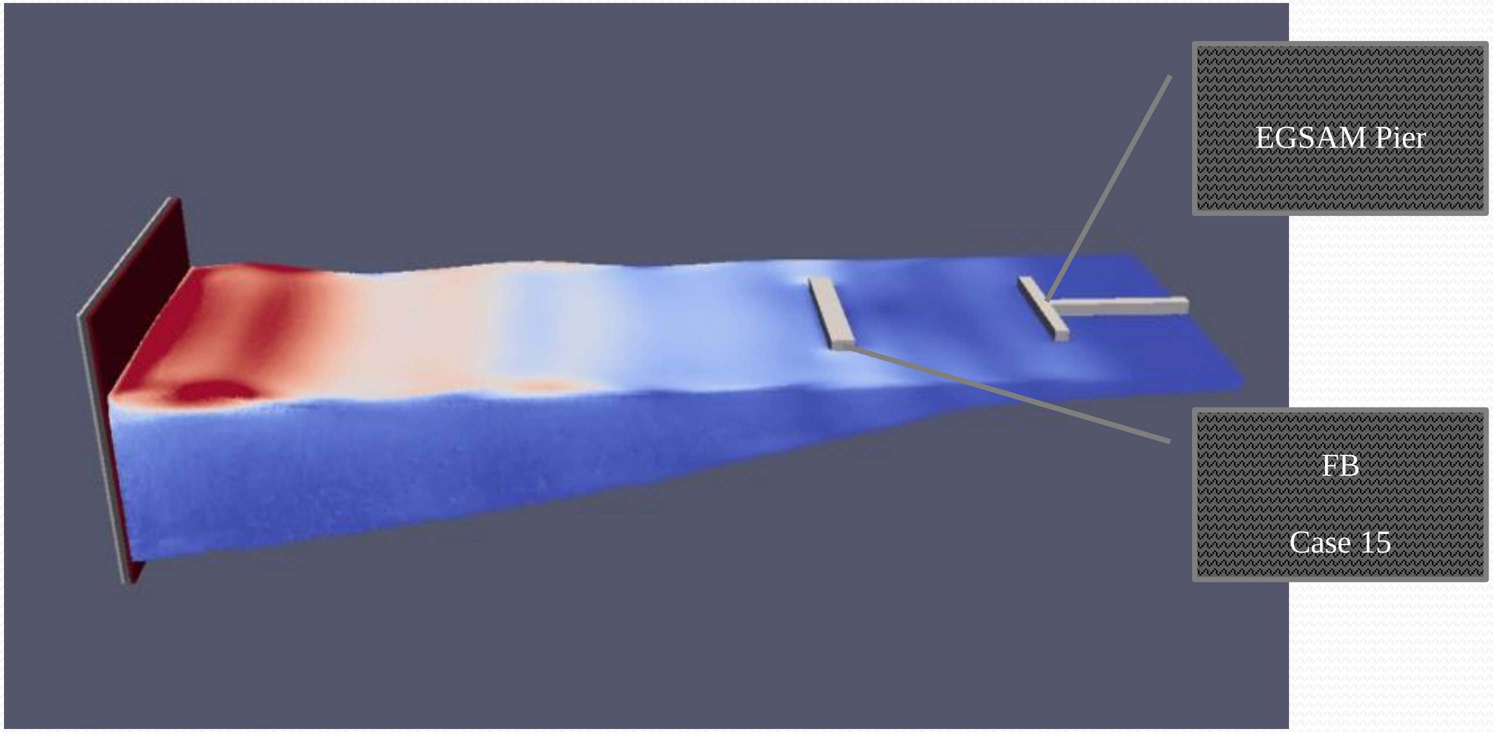
Case	Area m^2
3	20.5
4	42.6
11	144
15	39

- Despite having an area substantially smaller maintains adequate efficiency ranges.
- Now.....3D Simulations.


Height
-1
0
1
-1.09
1.23
10 0 -10-20 30 40
Depth m
-200
-150
-100
-50
0
50
Lenght m
Vel Magnitude
1
2
0
2.363119
Time: 0 Time Steps

4. Results and Discussion

b. Santa Marta 3D Case

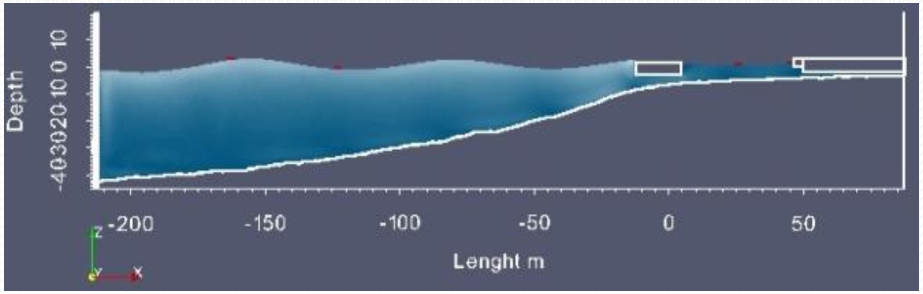


- Diffraction effects on the sides of the FB
- Reflection effect throughout the pier and the FB/Domain
- Energy dissipation by shoaling effect in the back zone to the pier
- Wave set was stabilized at 50 time steps vs. the 350 requiring in 2D

4. Results and Discussion

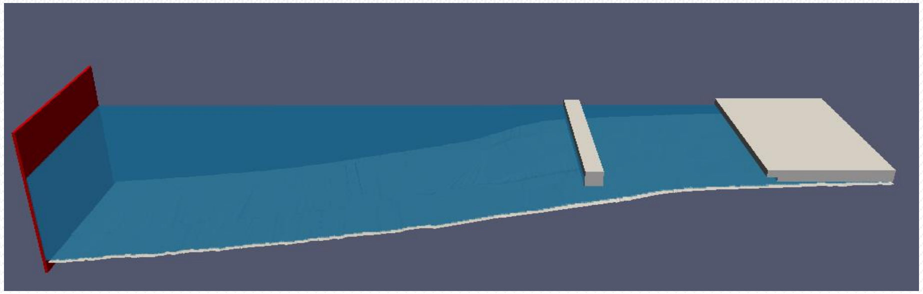
b. Santa Marta 3D Case

1°)



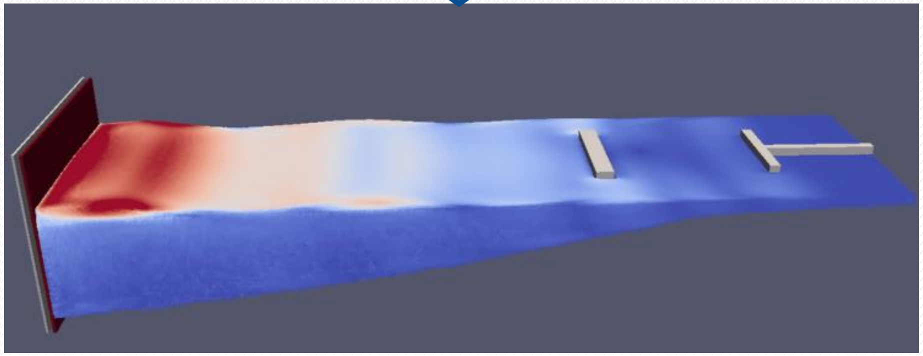
PROMISING RESULTS!
2D with resonance
2D without diffraction

2°)



EXTENSION TO 3D CASE
3D with resonance
3D without diffraction

3°)

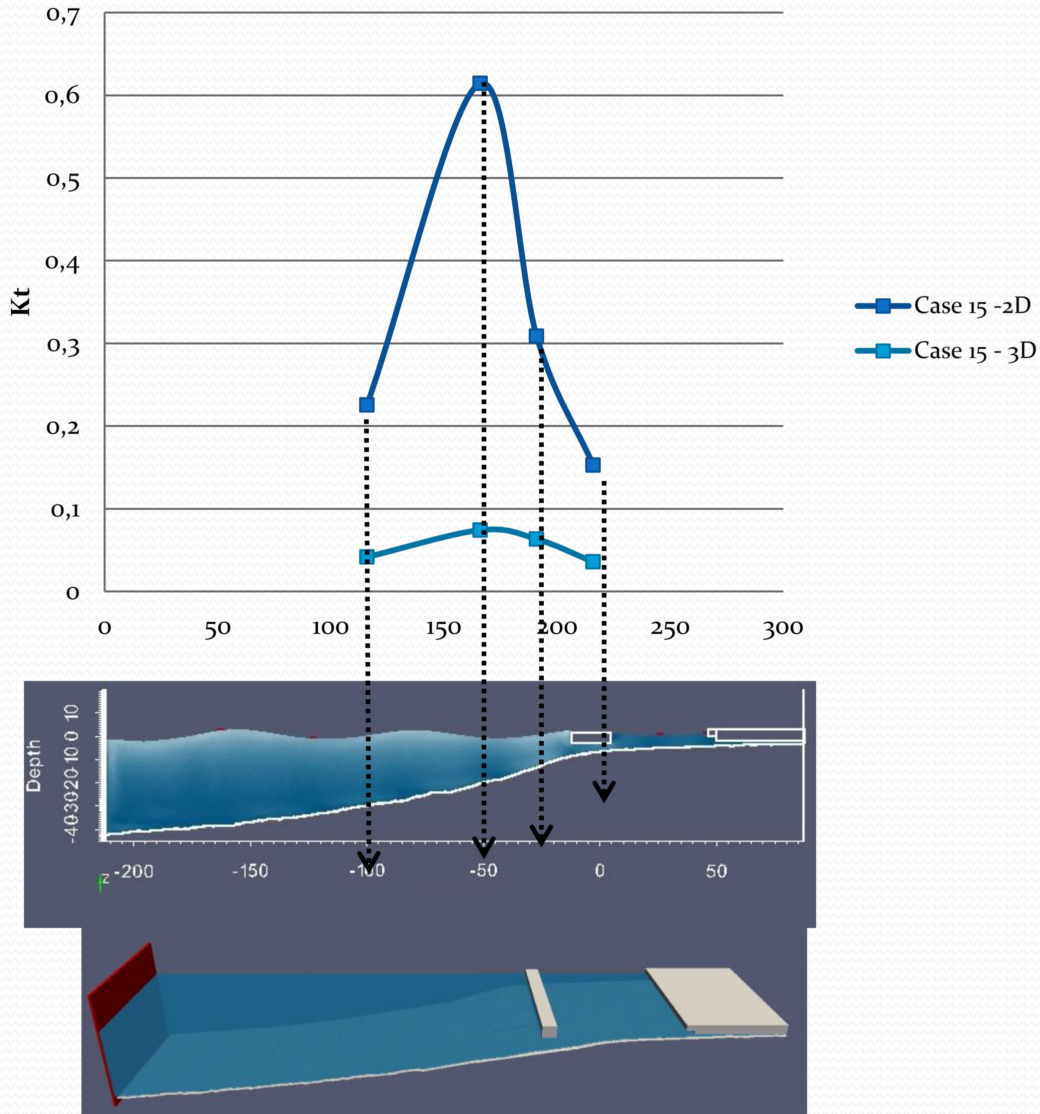


REALISTIC 3D CASE
3D without resonance (beach)
3D with diffraction

We must remove the effect of lateral walls

4. Results and Discussion

b. Santa Marta 2D vs. 3D Case

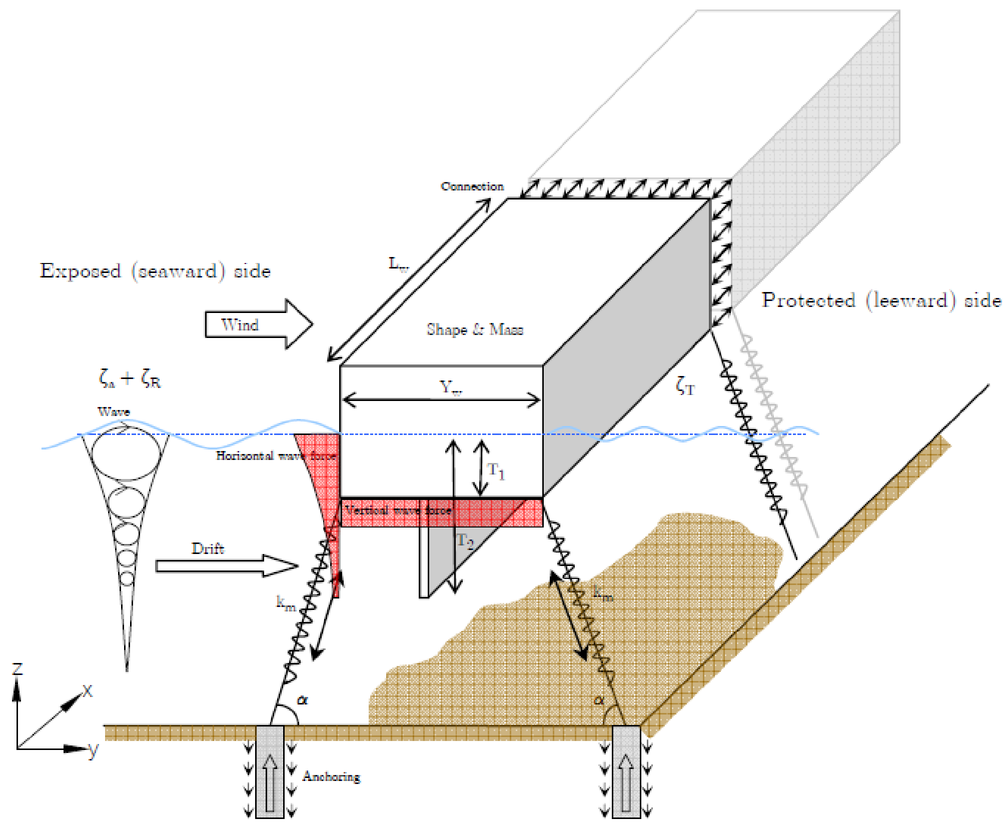


5. Conclusiones

- The FB efficiency, evaluated under real conditions, let's see use in open water areas, under the influence of waves with periods up to 7s.
- The SPH method is adequate to simulate with accuracy the interaction between waves and structure under the effect of an irregular bathymetry.
- Although in reality the conditions of reflection domain boundaries (3D) and resonance (2D) present in the model does not exist, the values remain high precision value.
- The proposed structure for the EGSAM pier has significant advantages and accuracy of data, which must be evaluated in a wave channel, as part of the design process.
- We show that a structure with an area of $39m^2$, or with a volume of 1560 m^3as those studied in this work, can protect a medium port works with a lower degree of environmental impact

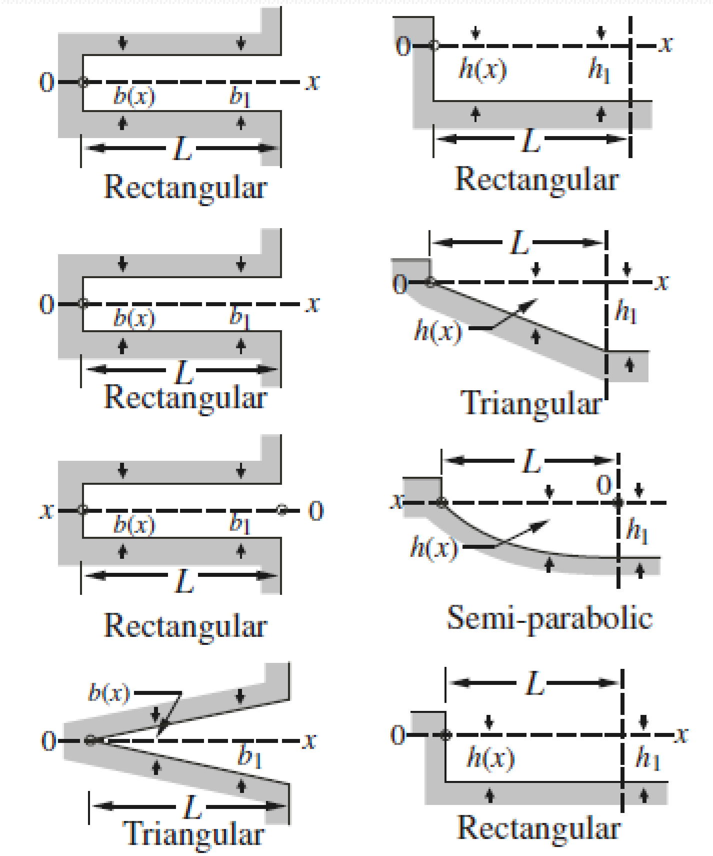
6. SPH Future Research

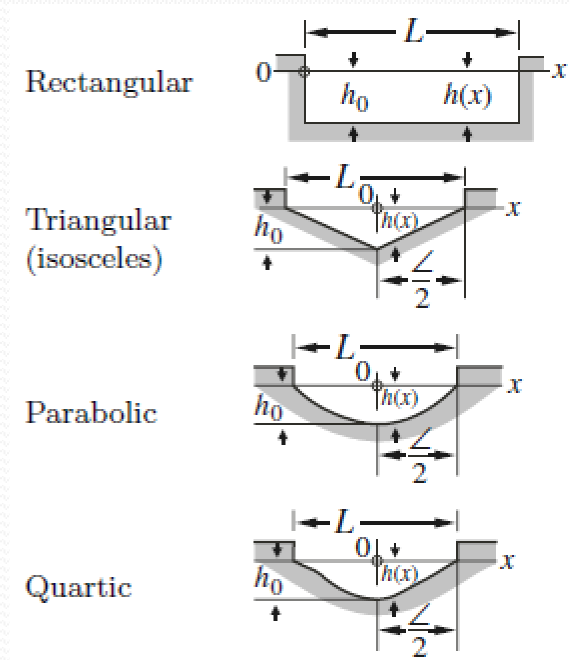
- Floating Breakwaters with free movement



6. SPH Future Research

- Resonance





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- Questions….

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