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Verification of the Functional Efficiency of Submerged Breakwater by Field Measurements

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Company: **Van Oord Dredging and Marine Contractors B.V.**

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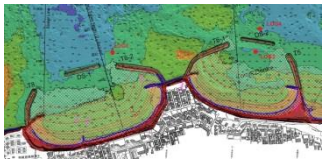

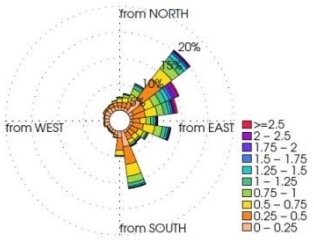

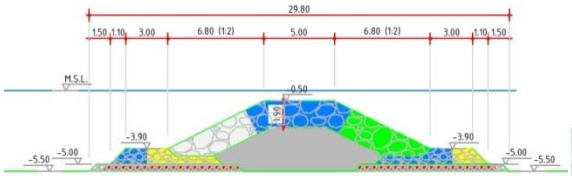

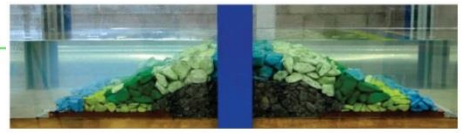

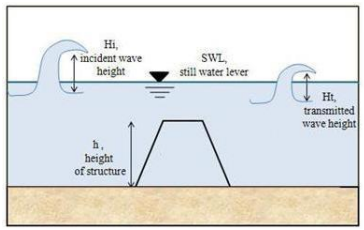

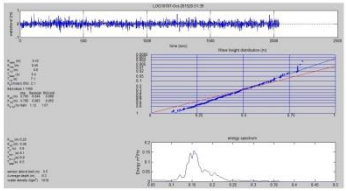

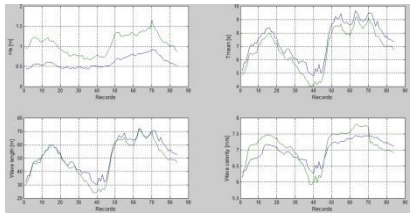

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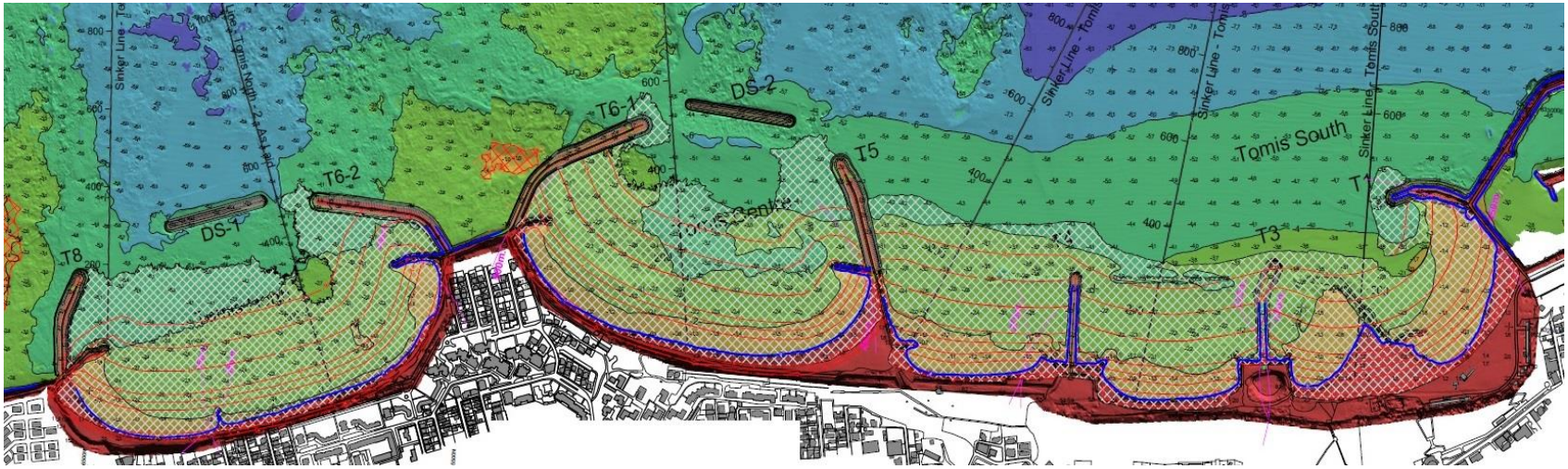
Project details

- **Project** — Protection and Rehabilitation of the Southern Part of the Romanian Black Sea Coast
- **Client** — Romanian National Waters Administration (ANAR-ABADL)
- **Contractor** — Van Oord – SCT Joint-Venture
- **Consultant** — Romair Consulting S.R.L.



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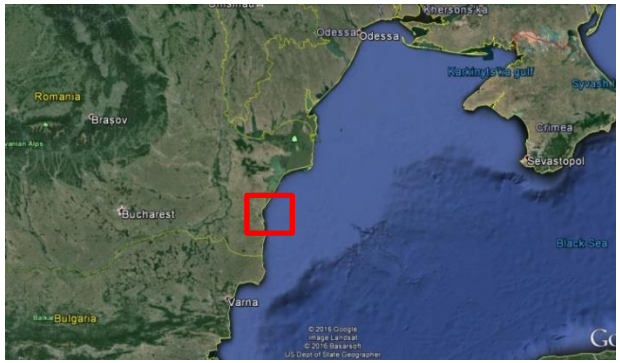
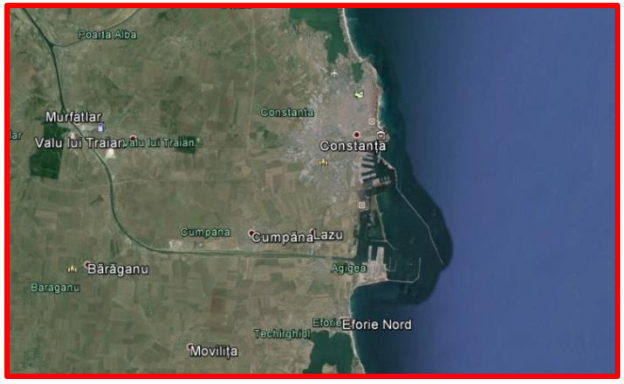
Project location

- Constanta city, South-Eastern part of Romania





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Measurements scope

- Scope – investigate the change in wave parameters due to the breakwater
- Estimate the transmission **coefficient Ct**
- Comparison of the 2D physical model with the real performance on the field
- Gaining confidence in reliable long-term beach protection predictions

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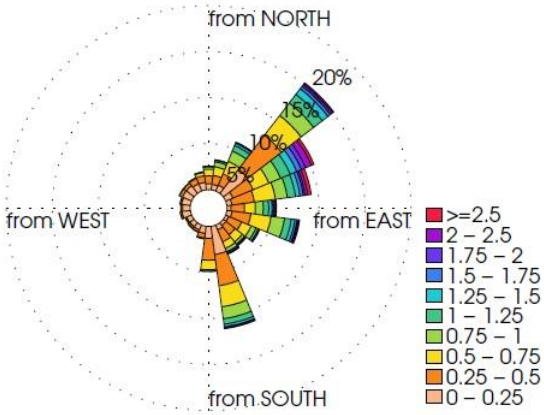
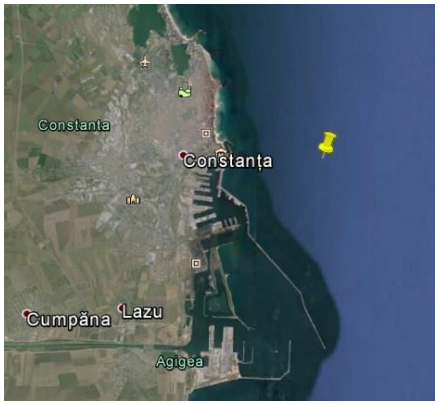
Design wave conditions

Annual wave rose for a nearshore point at 25.1 m water depth:





Inshore Independent Extreme Wave Conditions at 5m water depth

Wave conditions coincident with water level of +1.5mMSL (per 30° offshore direction sector)																				
RP (yrs)	0-30°			30-60°			60-90°			90-120°			120-150°			150-180°			180-210°		
	H_{m0} (m)	T_p (s)	MWD (°N)	H_{m0} (m)	T_p (s)	MWD (°N)	H_{m0} (m)	T_p (s)	MWD (°N)	H_{m0} (m)	T_p (s)	MWD (°N)	H_{m0} (m)	T_p (s)	MWD (°N)	H_{m0} (m)	T_p (s)	MWD (°N)	H_{m0} (m)	T_p (s)	MWD (°N)
1	1.3	6.6	62	2.2	7.7	76	2.3	7.6	85	1.9	7.4	96	1.3	6.9	110	1.1	6.9	120	1.0	7.3	125
5	1.9	7.4	67	2.8	8.6	81	2.9	8.8	89	2.9	8.6	98	2.2	8.1	108	1.9	8.1	118	1.6	8.7	122
10	2.0	7.6	68	2.9	8.8	82	3.0	9.0	90	3.0	8.9	98	2.4	8.3	108	2.0	8.4	117	1.7	8.9	122
20	2.1	7.8	69	3.0	8.9	83	3.0	9.1	91	3.0	9.1	99	2.6	8.6	108	2.2	8.6	117	1.8	9.1	122
50	2.3	9.0	70	3.0	9.1	84	3.1	9.3	92	3.1	9.3	99	2.8	8.8	108	2.4	8.8	116	1.9	9.3	121
100	2.4	8.2	71	3.0	9.2	84	3.1	9.5	92	3.1	9.5	99	2.9	9.0	108	2.5	8.9	116	1.9	9.3	121
200	2.5	8.4	72	3.1	9.3	85	3.1	9.6	93	3.1	9.6	99	2.9	9.2	108	2.6	9.1	116	2.0	9.4	121

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Location overview

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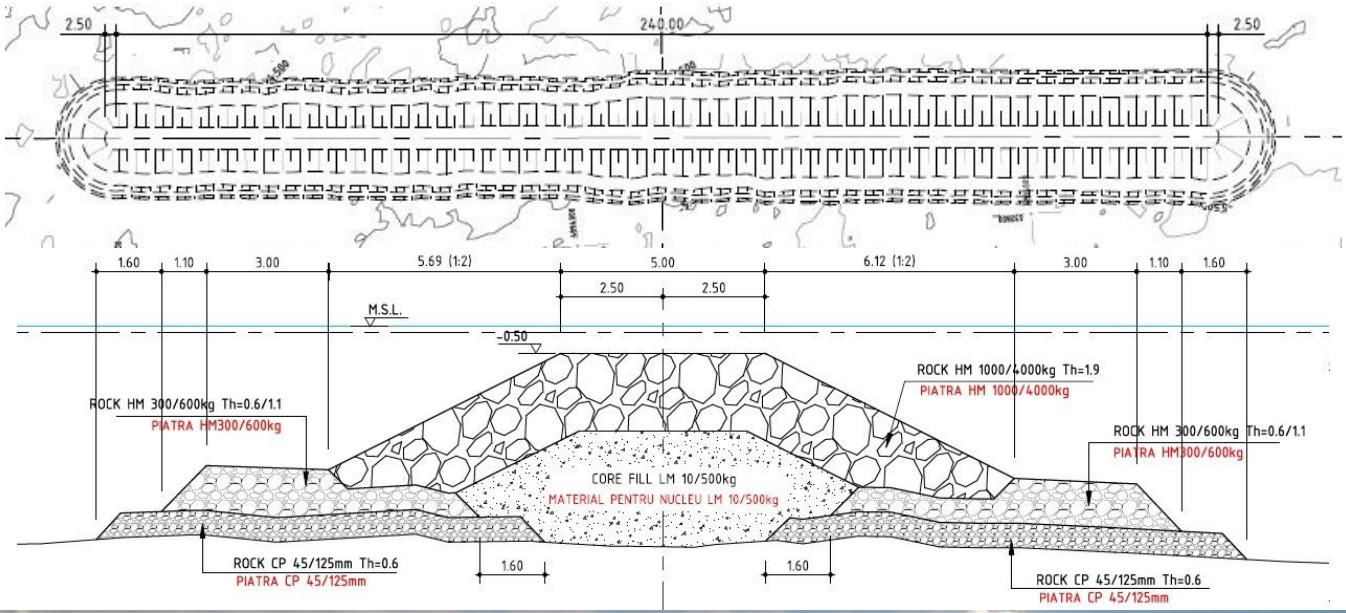
Breakwaters design



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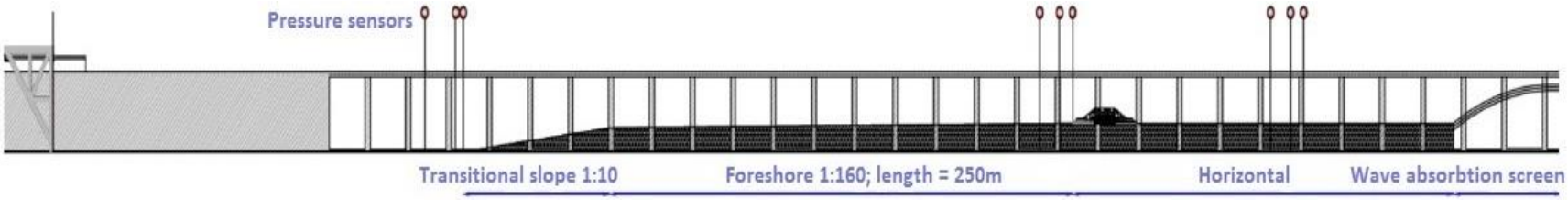
Modeling set-up

Deltares
Enabling Delta Life

- 2D physical tests performed at Deltares in the Netherlands

Physical model test facilities at Deltares (wave flume 1 x 1.2 x 55m)



Schematic test set-up

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2D simulations and results

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Enabling Delta Life

Calibrated wave conditions submerged breakwater

Calibrated Conditions	RP	MSL	Deep			Toe		
			H_s	T_{pm}	$T_{m-1,0}$	H_s	T_{pm}	$T_{m-1,0}$
	[1/yrs]	[m+MN75]	[m]	[s]	[s]	[m]	[s]	[s]
Condition 101 (HW)	not defined	0.6	1.2	6.2	5.7	1.2	6.3	6.0
Condition 102 (HW)	1	0.6	2.3	8.8	8.1	2.3	8.9	8.8
Condition 103 (HW)	10	0.7	2.7	10.9	10.0	2.7	11.1	10.1
Condition 104 (SLS) HW	100	0.8	3.6	12.7	11.4	2.9	12.6	10.0
Condition 105 (SLS) LW	100 + DLWL	0.3	3.3	11.8	10.8	2.7	11.8	9.9
Condition 106 (ULS) LW	100 + extreme DLWL	0.0	3.5	11.9	10.8	2.7	11.9	9.9
Condition 107 (ULS) HW	100+20%	0.8	4.3	12.6	11.5	3.0	12.8	11.6

- 7 simulations
- Second order wave generation
- JONSWAP spectrum
- 6 hours of simulations for each test
- Transmission coefficients: 0.57 – 0.69

2D physical test results

Crest Width 5m	Wave Parameters						
	Deep		Toe		Transmitted		C_t
Test	H_{m0}	T_p	H_{m0}	T_p	H_{m0}	T_p	-
T601	1.2	6.2	1.1	6.3	0.8	6.3	0.69
T602	2.3	8.8	2.3	8.9	1.4	9.1	0.61
T603	2.7	10.9	2.6	11.1	1.7	11.3	0.65
T604	3.6	12.6	2.9	12.7	2.0	13.2	0.69
T607	4.3	12.7	3.0	12.7	2.0	13.2	0.69
T605	3.3	11.9	2.7	12.0	1.6	12.1	0.61
T606	3.5	11.8	2.6	12.1	1.5	12.1	0.57

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Modeling set-up

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Pressure sensors

- Watertight cylinders with microchips and memory card
- Variable sampling frequency – 4.5 Hz used
- Records the underwater pressure parameter
- General settings:

  - 30 min of recordings and 90 minutes break

  - one set of data every two hours: wave spectrum, Hs, etc.

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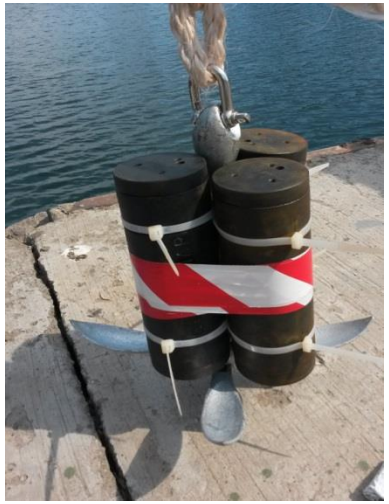
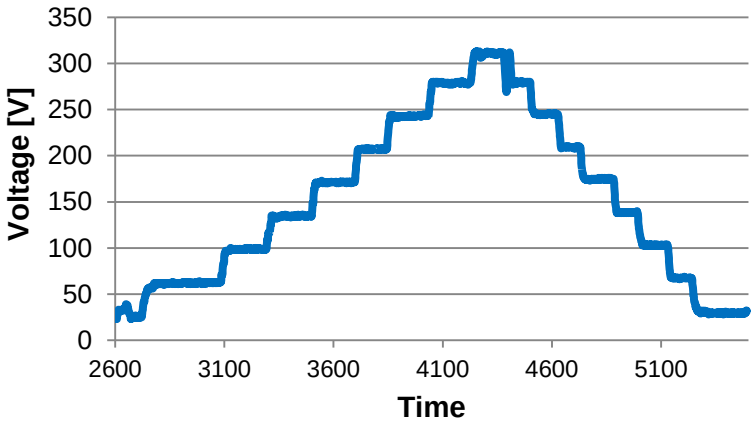
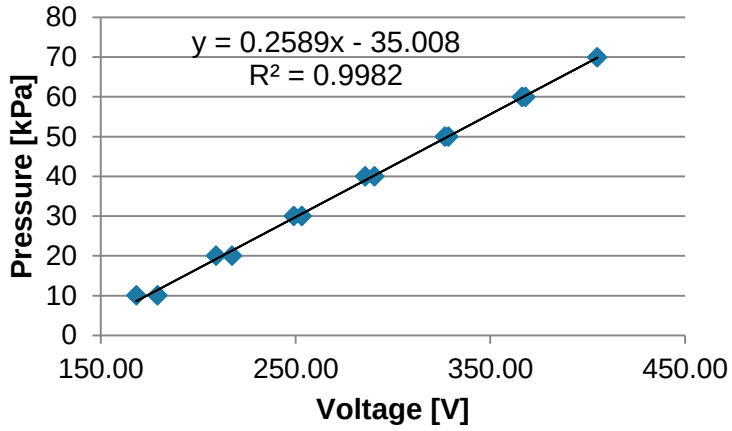
Calibration procedure

- The devices are lowered into the water gradually to known water depths
- Coefficients A and B are calculated to match the known hydrostatic pressure at certain depth
- **p = A · X + B [Pa]**







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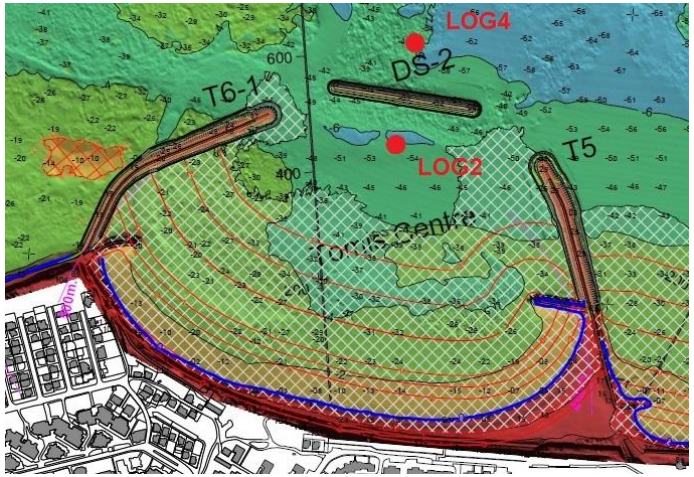
Device installation procedure

- Devices set in the office
- Transported with a work boat
- Attached to a concrete anchor
- Signaled with a buoy
- GPS position saved
- Retrieved after the storm has passed



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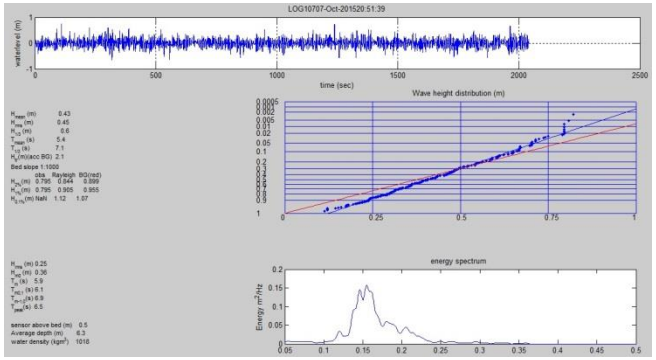
Output

Scrip developed by TU Delft

Raw data → Matlab → Results and Plots

$D,248
$D,249
$D,249
$D,249
$D,248
$D,248
$D,247
$D,247
……

→ MATLAB →



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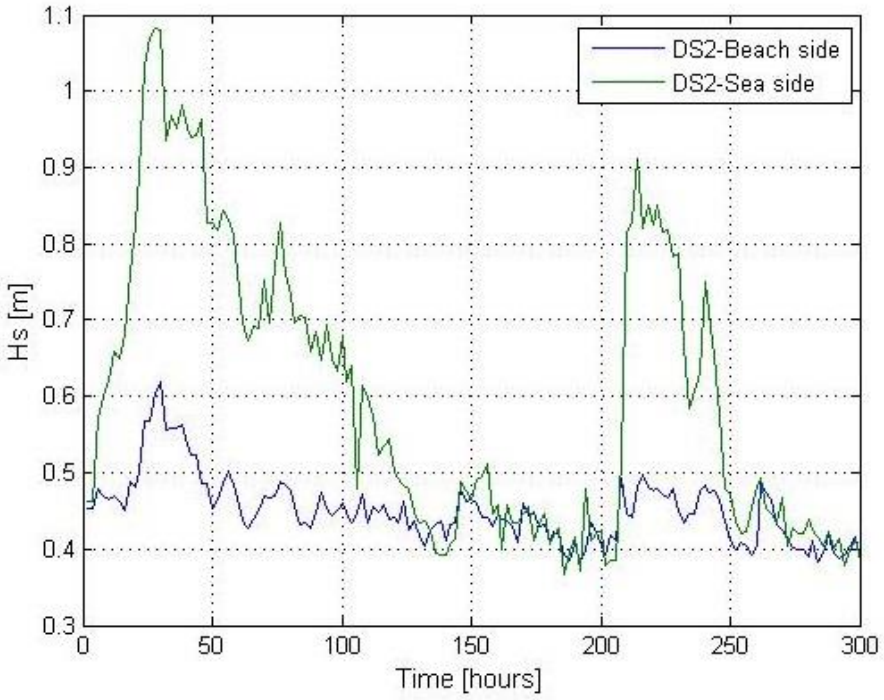
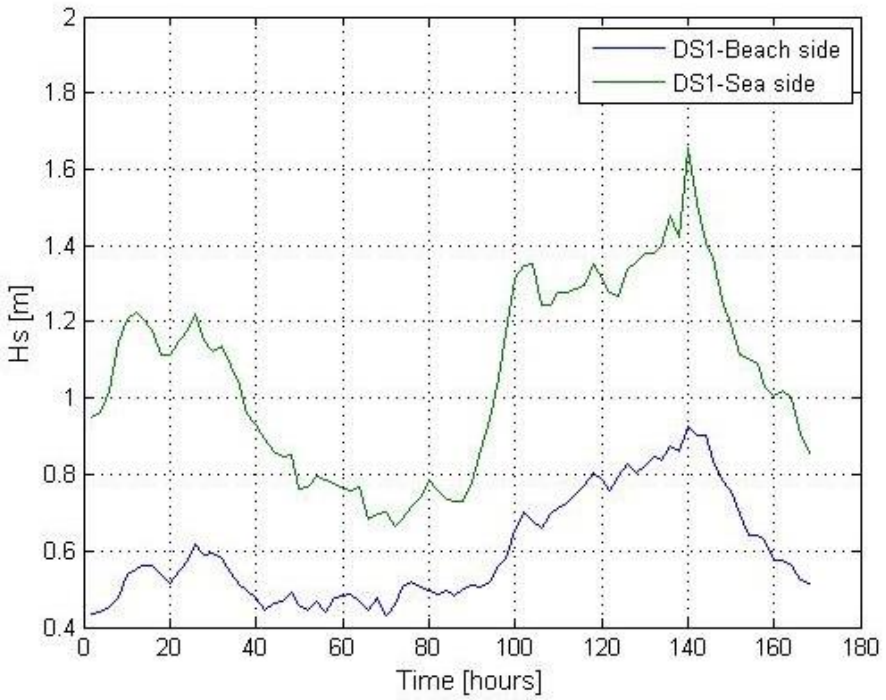
Wave transmission

- One set of measurements for each of the 2 breakwaters

Breakwater DS2



Breakwater DS1



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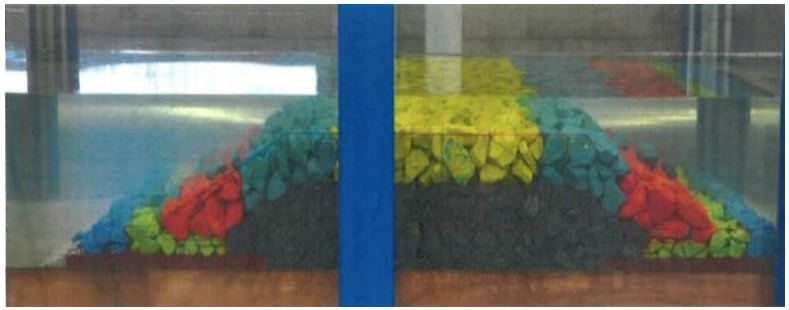
Comparison with the 2D physical model

2D Physical Model:



Field test:

Hs [m]	Ct [-]
1.2	0.69
2.3	0.61
2.7	0.65
3.6	0.69
4.3	0.69
3.3	0.61

Hs [m]	Ct [-]	
	DS1	**DS2**
0.8	0.61	0.59
1	0.53	0.56
1.2	0.53	-
1.4	0.58	-
1.6	0.58	-

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- 2D flume testes 30% more conservative than field tests
- Ct take approximately the same values for the same conditions
- Efficiency of the breakwaters proved to be higher than expected
- More test with higher Hs need to be performed to confirm the results
- Pressure sensors – cheap, simple and reliable devices which provide consistent results

Thank you for your attention!

Questions?