Project Title: SENER Fixed Oscillating Water Column

Project Acronym: SENERFOWC

Project Reference Number: 1040

Infrastructure Accessed UCC_MaREI - Deep Ocean Basin

Infrastructure
Access
Reports

ABOUT MARINET

The MaRINET2 project is the second iteration of the successful EU funded MaRINET Infrastructures Network, both of which are coordinated and managed by Irish research centre MaREI in University College Cork and avail of the Lir National Ocean Test Facilities.

MaRINET2 is a €10.5 million project which includes **39 organisations** representing some of the top offshore renewable energy testing facilities in Europe and globally. The project depends on strong international ties across Europe and draws on the expertise and participation of **13 countries**. Over 80 experts from these distinguished centres across Europe will be descending on Dublin for the launch and kick-off meeting on the 2nd of February.

The original MaRINET project has been described as a *"model of success that demonstrates what the EU can achieve in terms of collaboration and sharing knowledge transnationally".* Máire Geoghegan-Quinn, European Commissioner for Research, Innovation and Science, November 2013

MARINET2 expands on the success of its predecessor with an even greater number and variety of testing facilities across offshore wind, wave, tidal current, electrical and environmental/cross-cutting sectors. The project not only aims to provide greater access to testing infrastructures across Europe, but also is driven to improve the quality of testing internationally through standardisation of testing and staff exchange programmes.

The MaRINET2 project will run in parallel to the MaREI, UCC coordinated EU marinerg-i project which aims to develop a business plan to put this international network of infrastructures on the European Strategy Forum for Research Infrastructures (ESFRI) roadmap.

The project will include at least 5 trans-national access calls where applicants can submit proposals for testing in the online portal. Details of and links to the call submission system are available on the project website www.marinet2.eu

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1 Introduction & Background

1.1 Introduction

SENER has been developing technology for more than 2 years. During this time SENER has requested 3 patents in relation with the technology and has done 3 tank testing campaigns: first of a fixed OWC chamber in Universidad Politecnica de Madrid in order to calibrate the numerical model of the water column (damping), second testing of a fixed and floating device in a flume in Cantabria and third tank testing of the fixed and floating device in the CCOB, also in Cantabria, both with the aim of analyzing the performances of the device, as well as calibrate the numerical model (hydrodynamic coefficients). In summary, the aim of these tests was the proof of concept and the calibration of the "in-house" software that SENER is developing (SENERWave). The results were very good for the fixed device. Now, we need to understand the effects of the bathymetry of the seabed in the performances of the fixed device. Therefore, it was necessary to access a facility where it is possible to change the slope of the seabed, as well as permitting the test of a 1:25 scale device in the basin, in terms of depth and waves.

1.2 Development So Far

1.2.1 Stage Gate Progress

Previously completed: ✓

Planned for this project: ➲

STAGE GATE CRITERIA	Status
Stage 1 – Concept Validation	
• Linear monochromatic waves to validate or calibrate numerical models of the system (25 – 100 waves)	✓
• Finite monochromatic waves to include higher order effects (25 –100 waves)	✓
• Hull(s) sea worthiness in real seas (scaled duration at 3 hours)	✓
• Restricted degrees of freedom (DoF) if required by the early mathematical models	✓
• Provide the empirical hydrodynamic co-efficient associated with the device (for mathematical modelling tuning)	✓
• Investigate physical process governing device response. May not be well defined theoretically or numerically solvable	✓
• Real seaway productivity (scaled duration at 20-30 minutes)	✓
• Initially 2-D (flume) test programme	✓
• Short crested seas need only be run at this early stage if the devices anticipated performance would be significantly affected by them	✓
• Evidence of the device seaworthiness	✓
• Initial indication of the full system load regimes	✓
Stage 2 – Design Validation	
• Accurately simulated PTO characteristics	✓
• Performance in real seaways (long and short crested)	✓
• Survival loading and extreme motion behaviour.	✓
• Active damping control (may be deferred to Stage 3)	✓
• Device design changes and modifications	✓
• Mooring arrangements and effects on motion	✓
• Data for proposed PTO design and bench testing (Stage 3)	✓
• Engineering Design (Prototype), feasibility and costing	✓
• Site Review for Stage 3 and Stage 4 deployments	✓
• Over topping rates	✓

STAGE GATE CRITERIA	Status
Stage 3 – Sub-Systems Validation	
• To investigate physical properties not well scaled & validate performance figures	➲
• To employ a realistic/actual PTO and generating system & develop control strategies	
• To qualify environmental factors (i.e. the device on the environment and vice versa) e.g. marine growth, corrosion, windage and current drag	➲
• To validate electrical supply quality and power electronic requirements.	
• To quantify survival conditions, mooring behaviour and hull seaworthiness	✓
• Manufacturing, deployment, recovery and O&M (component reliability)	
• Project planning and management, including licensing, certification, insurance etc.	
Stage 4 – Solo Device Validation	
• Hull seaworthiness and survival strategies	
• Mooring and cable connection issues, including failure modes	
• PTO performance and reliability	
• Component and assembly longevity	
• Electricity supply quality (absorbed/pneumatic power-converted/electrical power)	
• Application in local wave climate conditions	
• Project management, manufacturing, deployment, recovery, etc	
• Service, maintenance and operational experience [O&M]	
• Accepted EIA	
Stage 5 – Multi-Device Demonstration	
• Economic Feasibility/Profitability	
• Multiple units performance	
• Device array interactions	
• Power supply interaction & quality	
• Environmental impact issues	
• Full technical and economic due diligence	
• Compliance of all operations with existing legal requirements	

1.2.2 Plan For This Access

As discussed in the introduction the objective for these tests was to assess the effects of the bathymetry of the seabed in order to achieve performances validation and numerical model calibration. The effect of bathymetry on nearshore devices is not sufficiently studied. On the other hand, the numerical models for the study of the performances of devices near to the coast do not usually take into account the effects of the seafloor, and therefore, it was necessary to carry out tests in conditions more or less close to the reality for the purpose of (i) validating the calculation tools and (ii) ruling out possible adverse effects that influence the performance of the device and, consequently, the economic models developed.

Therefore, in this test campaign we have carried out tests with regular waves with two different slopes of the seabed to understand well the effects produced, as well as tests with irregular waves with the objective of checking the behaviour under real wave conditions.

2 Outline of Work Carried Out

2.1 Setup

Prior to the test campaign, SENER designed, built and provided to Lir data about the model to be tested and assembly procedures, as well as information about additional tools and handling/lifting requirements. Lir confirmed suitability of the model, availability of the equipment required and feasibility of the testing in the Deep Ocean Basin (DOB).

Model transport, delivery, lifting and handling means:

- Model items were delivered to Lir where a pallet truck was required.
- Model was delivered by SENER at Lir on September 27th, disassembled.
- Items were packaged on October 10th and picked up by SENER on October 13th.
- All items had lifting points (eyebolt/pallet) to be handled using forklift and overhead crane to bring into the basin.
- The DOB overhead crane capacity was 2 Tonnes; the maximum unit weight to be lifted was 200kg.
- 4*2m or 2*4m sling length were required.
- SENER transport had means to put all loads on the floor inside the building available to be handled using the overhead crane.

Model assembly process:

- Model was assembled and anchored to the basin floor using nuts and bolts.
- Model assembly was done by SENER personnel with close support of Lir personnel.
- Lir provided hand tools for the nuts and bolts assembly and a workbench to do simple fixes.
- To attach SENER model to the floor, Lir provided M12 T-bolts, washers and nuts.
- Once described by SENER the attachment locations, Lir personnel installed in the floor the previous bolt assemblies.
- Model bases (3° or 6°) were fixed to the floor using these bolt assemblies. Lir provided additional M12 nuts for it.
- SENER carried gauges and means to level these bases prior installing the model.
- The model was screwed to the 3°-6° bases using fixing means provided by SENER.
- SENER personnel had permission to access movable floor when in the top most position out of the water.
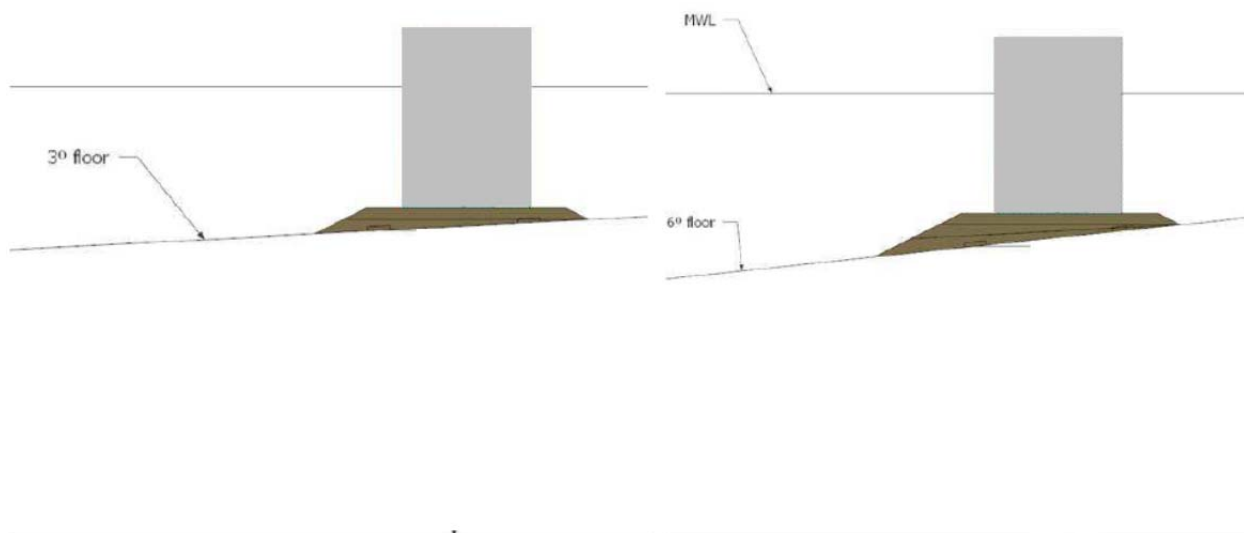- SENER personnel brought and wore safety shoes, gloves and received and followed safety instructions and indications from Lir personnel.
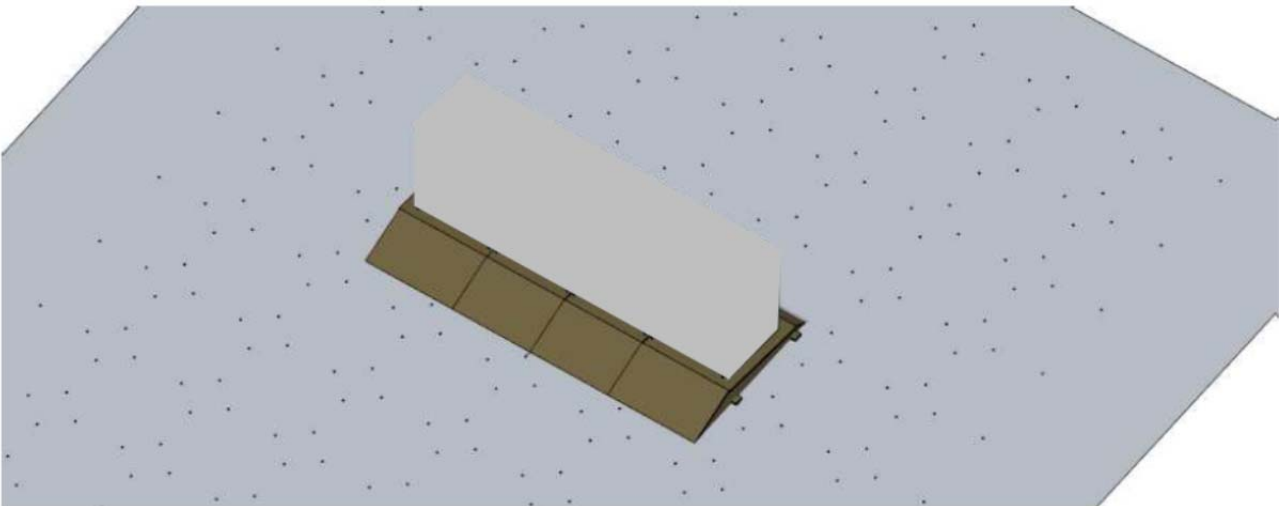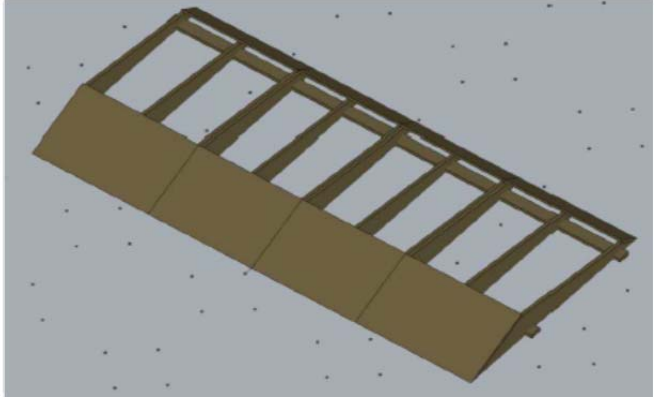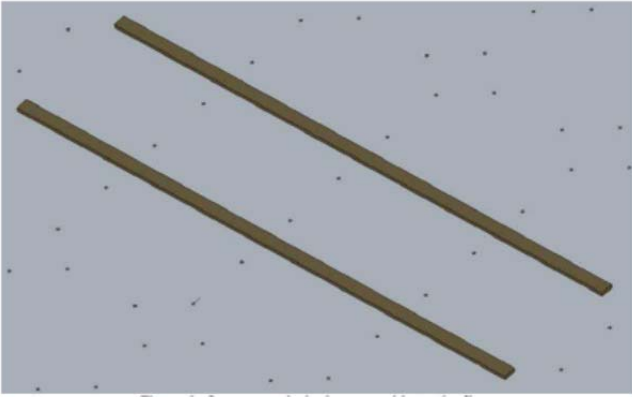

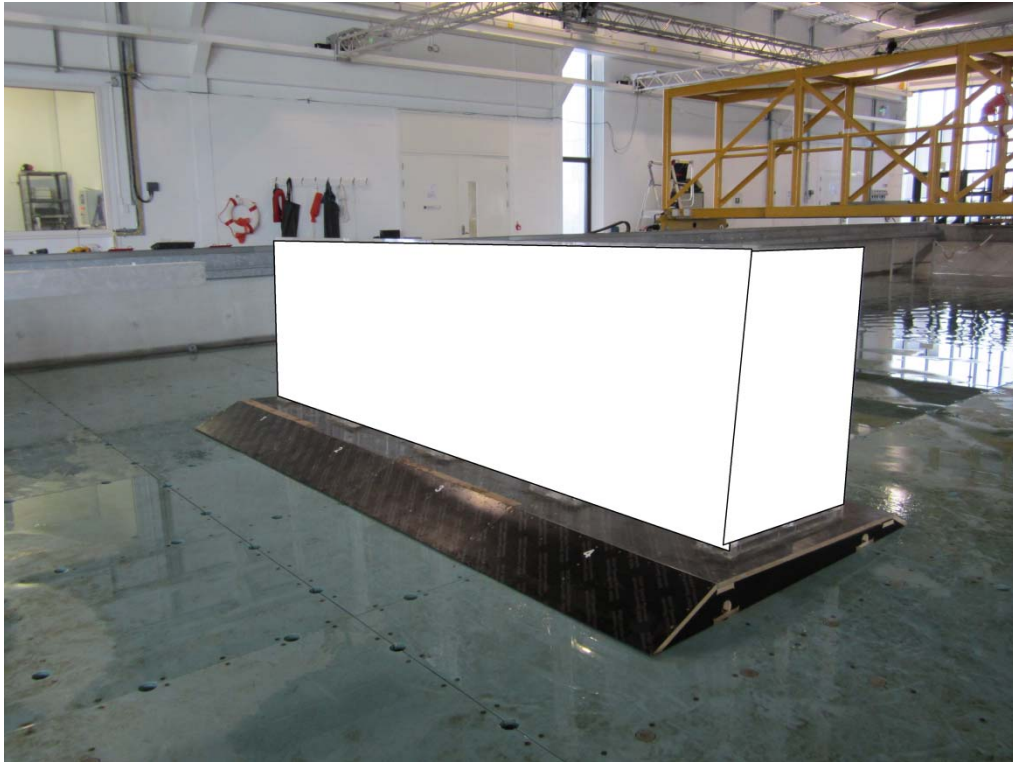**Figure 2.1 LiR Model Arrangements**
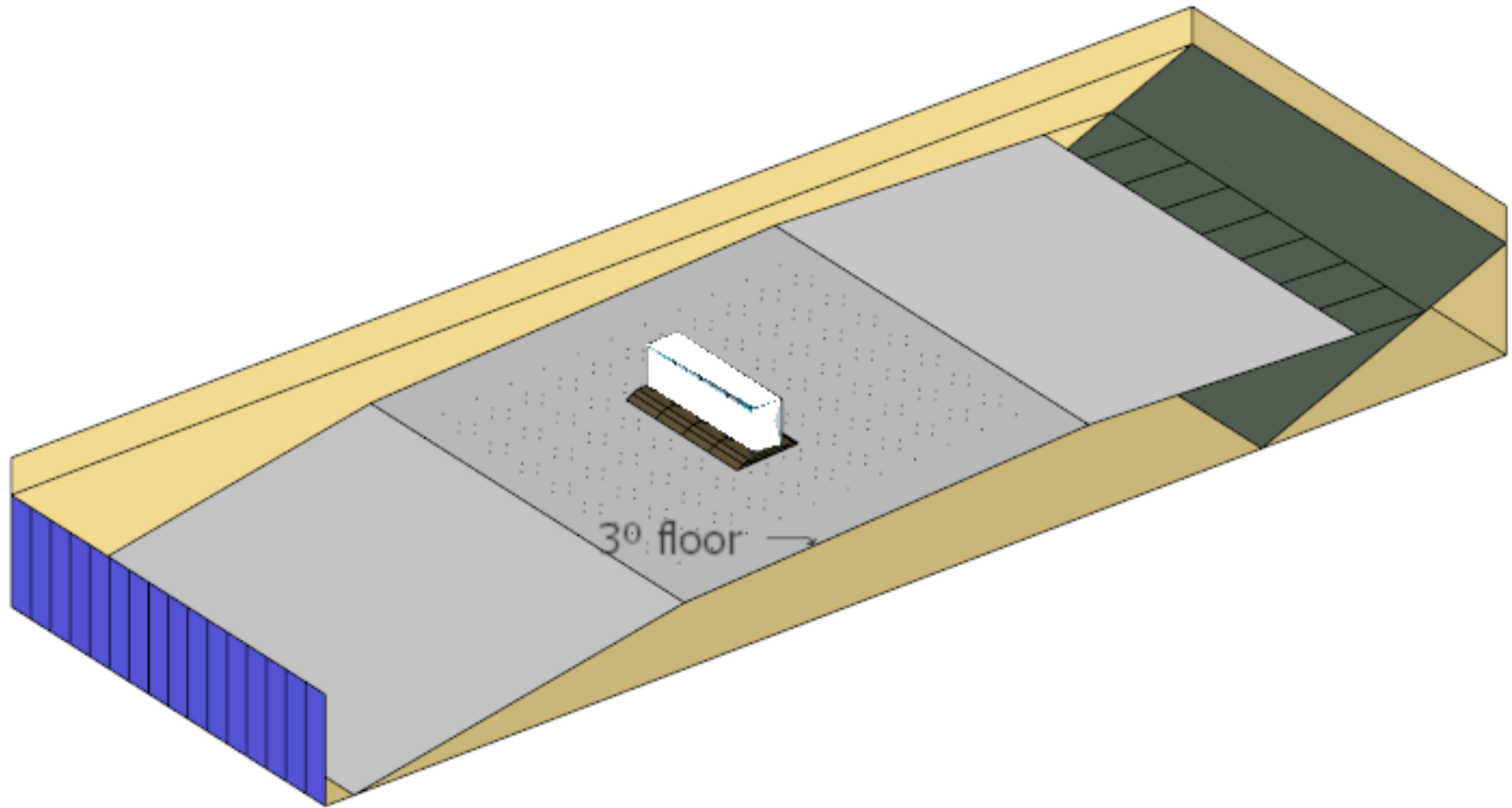
Figure 2.2 LiR Model Assembly

Figure 2.3 LiR Basin with model installed (drawing)

2.2 Tests

2.2.1 Test Plan

An estimated 6.5 days of access was planned to carry out the tests as follow:

- 2 days for test preparation, including sensors setup and calibration and wave calibration for incident wave characteristics (24 regular and 2 irregular)
- 1 day to install model with 3-degree slope.
- 0.5 day testing (24 regular, 6 to 10 minutes per test including 2 minutes of wave generation)
- 1 day to install model with 6-degree slope.
- 0.5 day testing (24 regular, 6 to 10 minutes per test including 2 minutes of wave generation)
- 0.5 day to study irregular waves and repeat some tests if necessary (at least 2 tests, 15-20 minutes per test)
- 1 day to remove the device (SENER responsibility)

Some extra time was included in this schedule in order to cover uncertainties in the model installation time and modification between configurations.

The test conditions have been:

Regular waves at 3 and 6 degrees floor slope				JONSWAP sea states at 6degrees floor slope			
Prototype scale		Tank scale		Prototype scale		Tank scale	
H	T	H	T	Hs	Tp	Hs	Tp
1	6	0.04	1.2	2	7	0.08	1.4
2	6	0.08	1.2	2	9	0.08	1.8
3.5	6	0.14	1.2				
1	7	0.04	1.4				
2	7	0.08	1.4				
3.5	7	0.14	1.4				
1	8	0.04	1.6				
2	8	0.08	1.6				
3.5	8	0.14	1.6				
1	9	0.04	1.8				
2	9	0.08	1.8				
3.5	9	0.14	1.8				
1	10	0.04	2				
2	10	0.08	2				
3.5	10	0.14	2				
1	11	0.04	2.2				
2	11	0.08	2.2				
3.5	11	0.14	2.2				
1	12	0.04	2.4				
2	12	0.08	2.4				
3.5	12	0.14	2.4				
1	14	0.04	2.8				
2	14	0.08	2.8				
3.5	14	0.14	2.8				

Table 2.1 List of Waves carried out

Finally, we required 6 days in order to complete the entire test, dedicating the last day for repeating the wave calibration in order to assess the goodness of the first calibration, because the register showed a lot of noise in the measurement of the wave height.

2.3 Results

The acquisition system included 10 wave probes, 6 were dedicated to measure the incident wave characteristics in front of the device and 4 were placed in the model to measure the movement of the water surface inside the water column. This allowed the comparison between water column oscillation and the incident wave.

Additionally, the pressure on the walls was measured in order to calibrate the numerical models for the design of the structure.
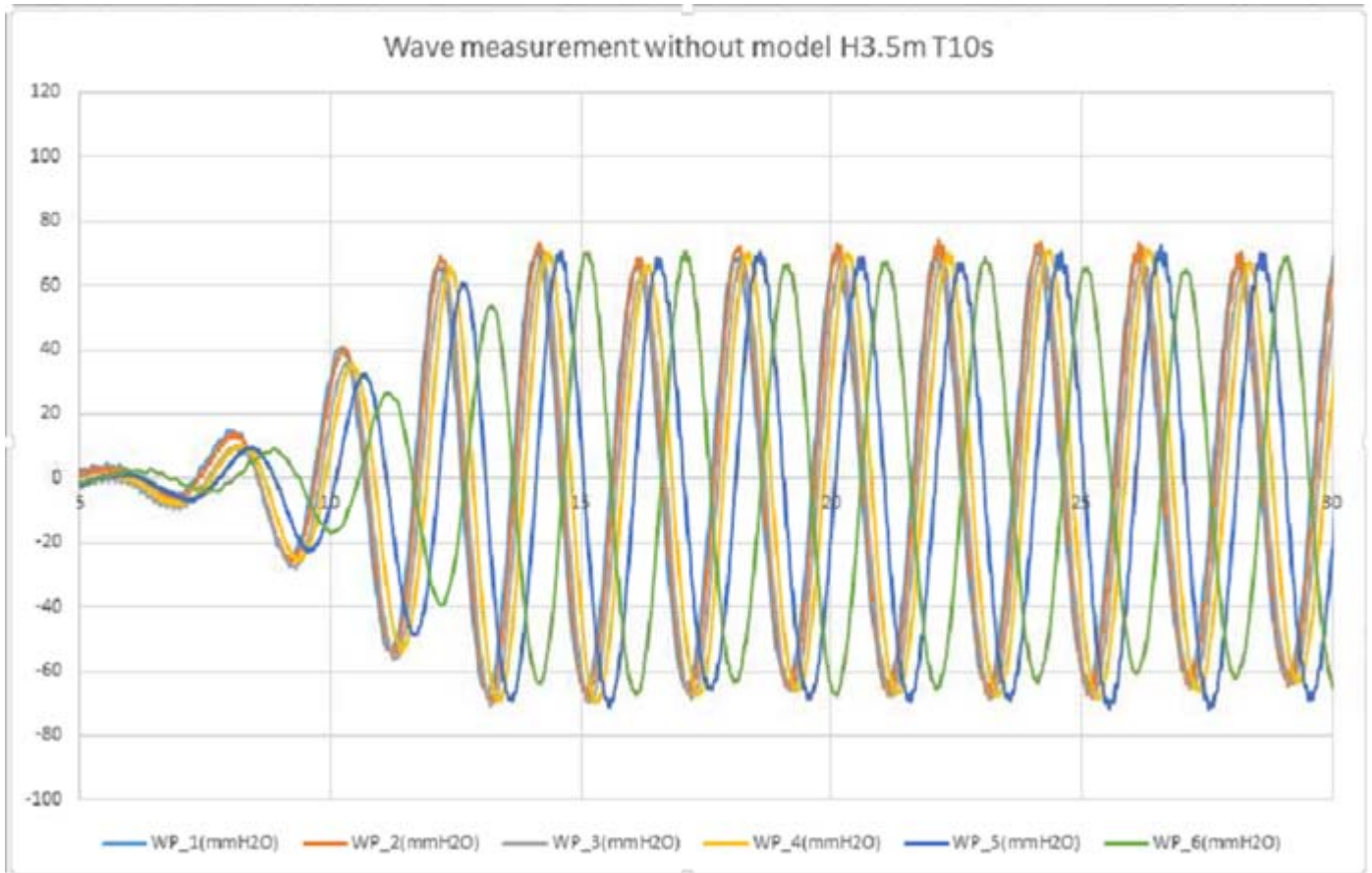
Figure 2.4 Example of the wave height measured without the model.

Figure 2.5 Example of the wave height measured 3º (response inside the water columns).
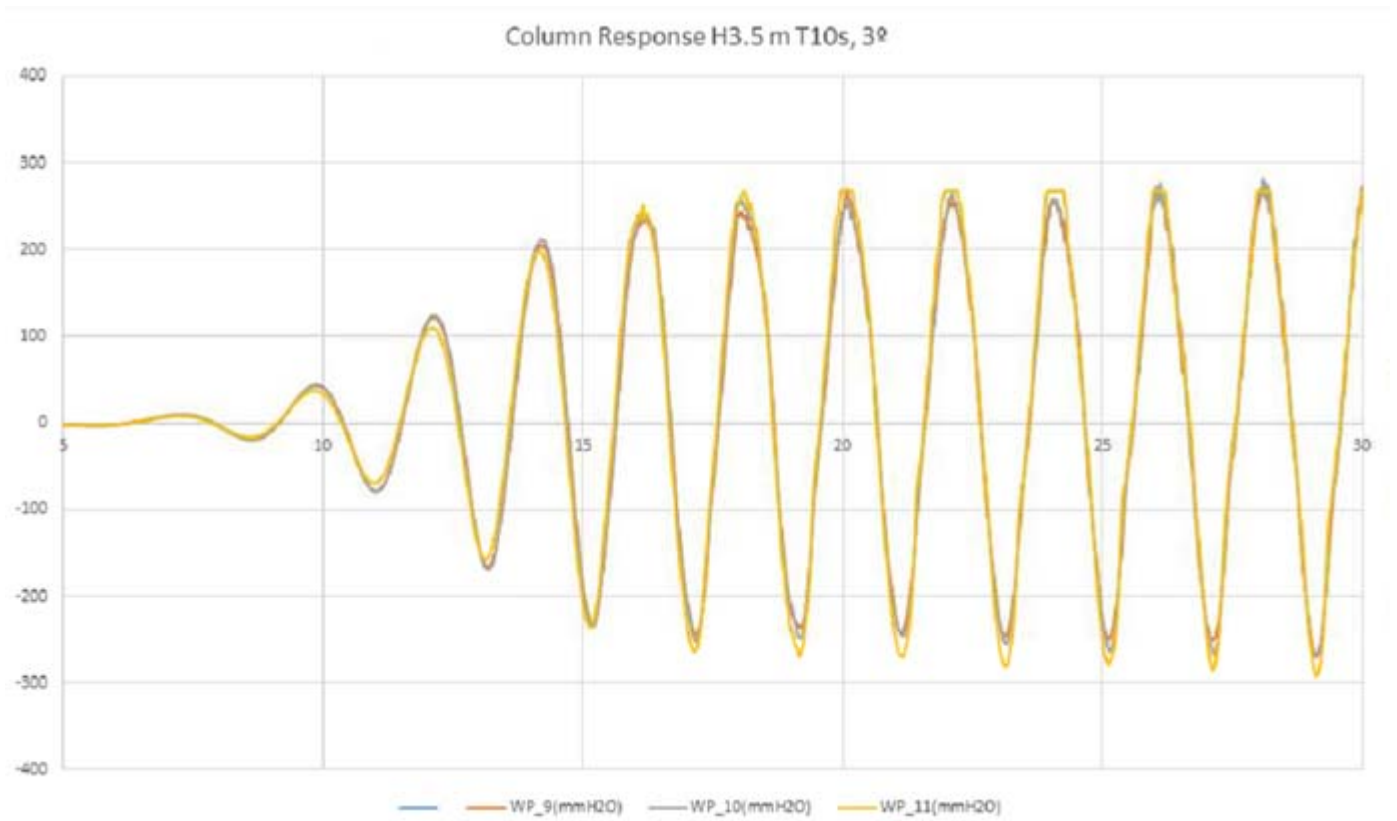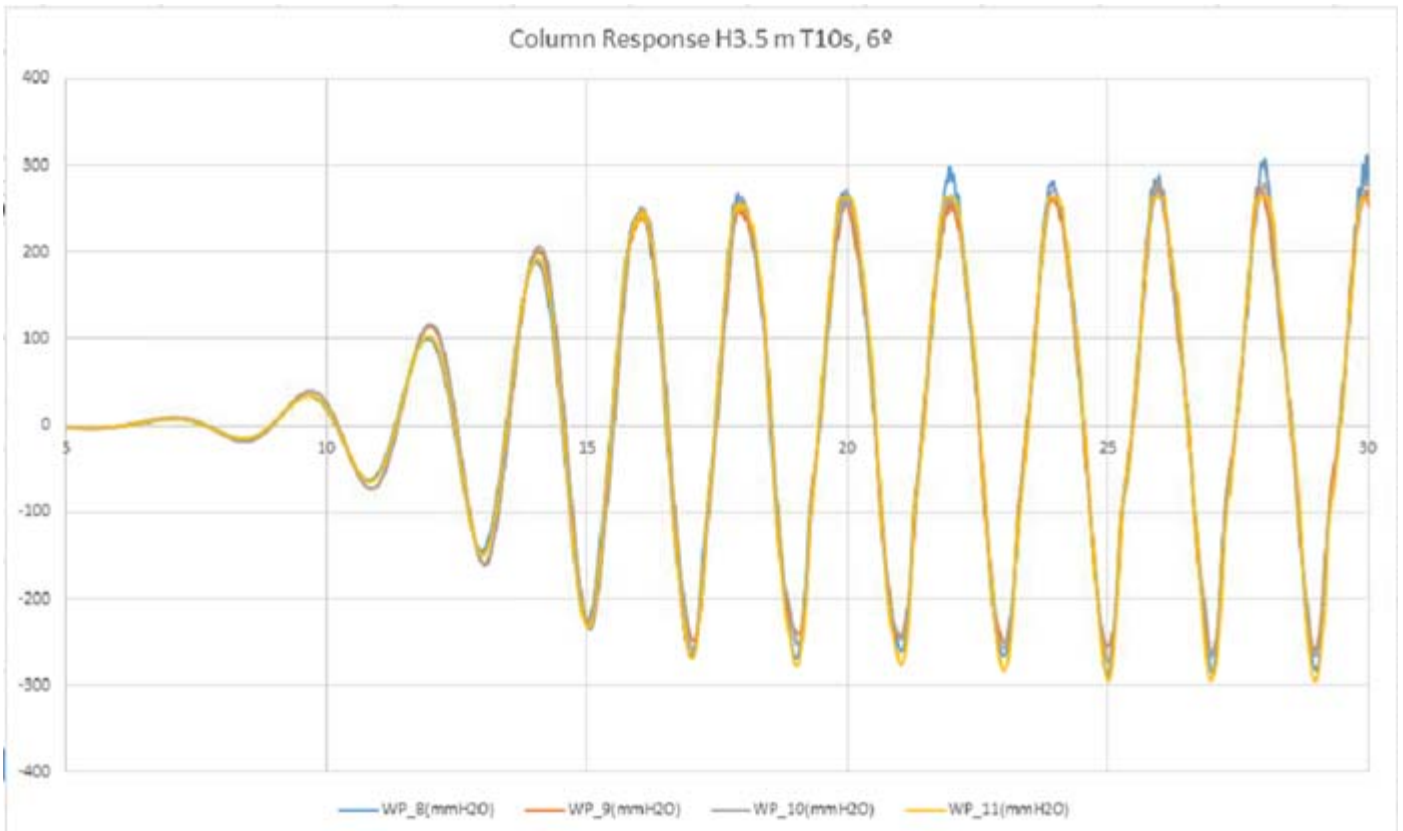
Figure 2.6 Example of the wave height measured 6º (response inside the water columns).
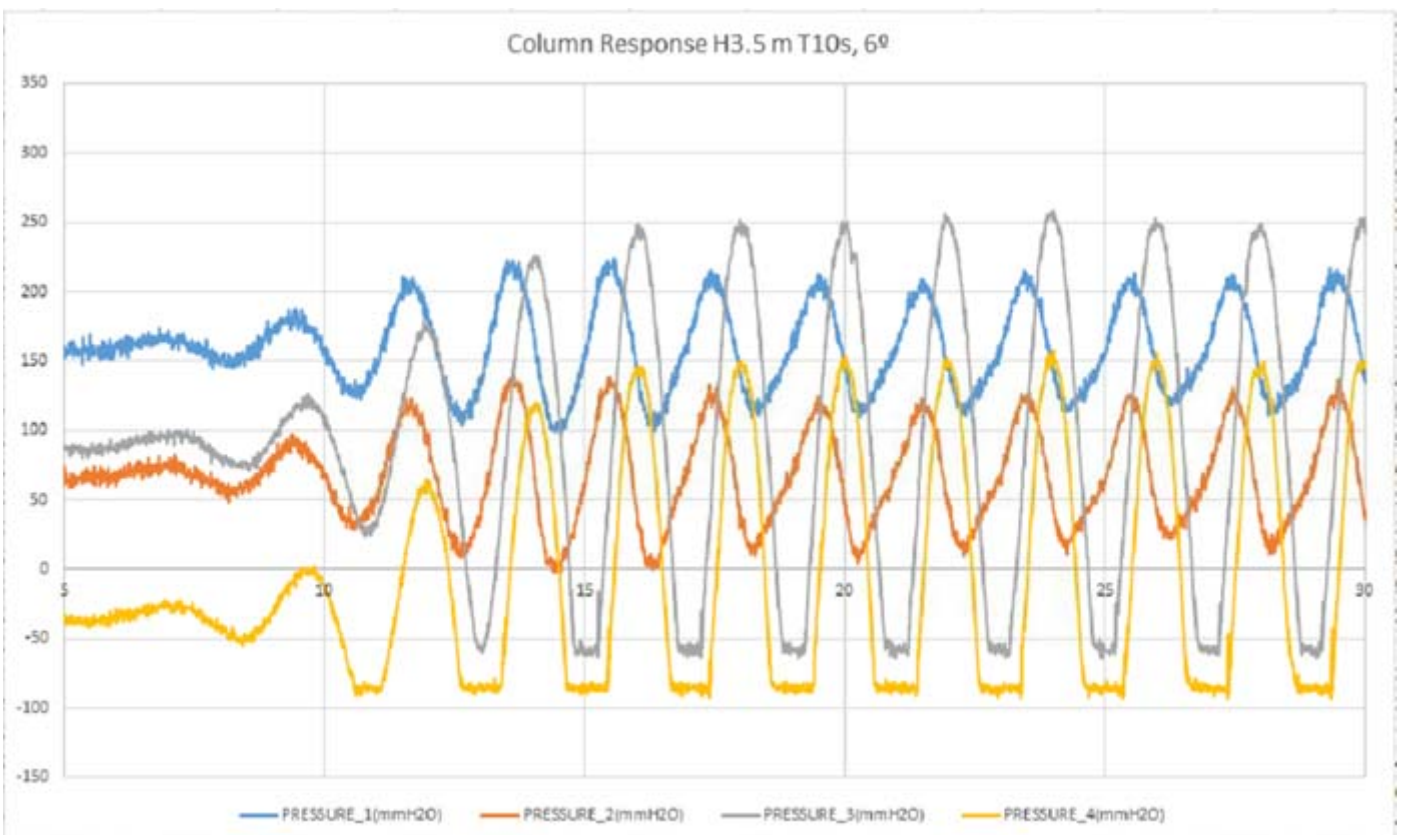

Figure 2.7 Example of the pressure measured.

2.4 Analysis & Conclusions

The objective for these tests was to assess the effects of the bathymetry of the seabed in order to achieve performances validation and numerical model calibration.

After carrying out the tests, analysis was developed. First, it was necessary to filter the "noise" of the measurements in order to know the real movement of the water surface. Two sources of "noise" were identified: electronic "noise" from the data acquisition system, and "noise" produced by the wave probes movement produced by the waves.

In order to compare with the numerical simulations, it was used the Response Amplitude Operator for both slopes, defined as the amplitude of the free surface inside the water columns between the amplitude of the incident wave.

For the amplitude of the free surface registers of each test were analysed, avoiding the first part of the register where the wave was still being generated, and the last part, were reflections from the beach of the basin appeared. This was studied for each wave depending on its period.

It is important to note that in these tests with such a large model scale, the effects of reflection on the structure and on the side walls and the absortive beach of the tank have been very important, so the analysis of the waves on a case-by-case basis has been crucial for the interpretation of the experimental results and for being able to compare them with the numerical ones. Despite the effort made, in some of the cases there is some uncertainty. Even so, the results show a very good correlation between SENERWave and the experiments.

For the amplitude of the incident wave, we needed to do the wave calibration in the tank without any model or slope in order to be able to use "Mansard & Funke" method. Apart from the fact that it cannot be used with slope, an additional problem was that the slope changes the wave generated in the paddles (at the beginning of the basin). Finally we took the decision of determining two RAOs: one assuming the good repeatability of the wave generation in the DOB, and taking as incident wave the one calibrated without model or slope, and second RAO using as incident wave the one measured during the waves' calibration without model but with the respective slope, taking the measurement of the wave probes situated in the position of each water column.
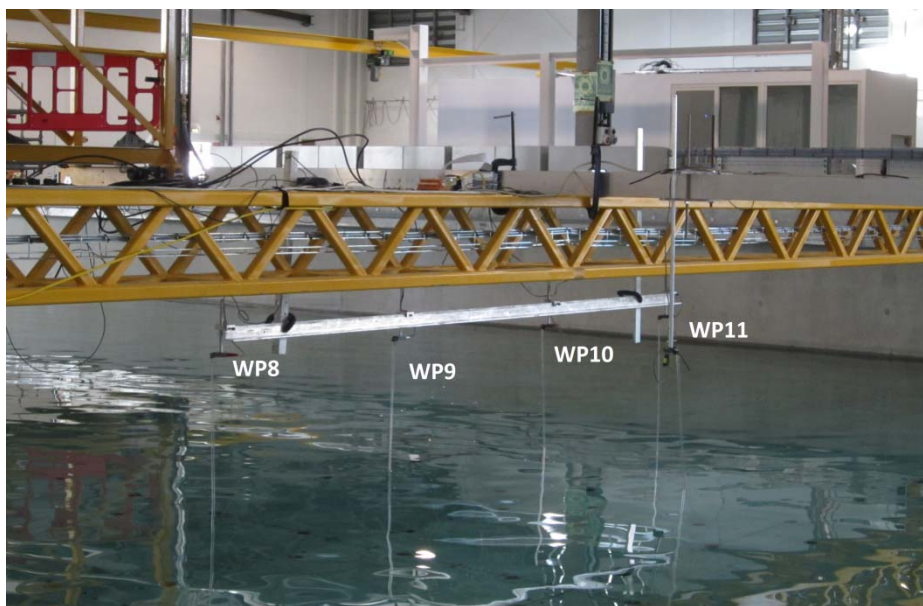
Figure 3.1 Wave Probes at each water column during wave calibration (no model).

After analysing the results, the conclusions are that the slope of the seabed does not affect to the performance of the device. The results are also in line with the numerical simulations carried out so they demonstrate the reliability of SENERWave when analysing the hydrodynamic performance of this and other devices.
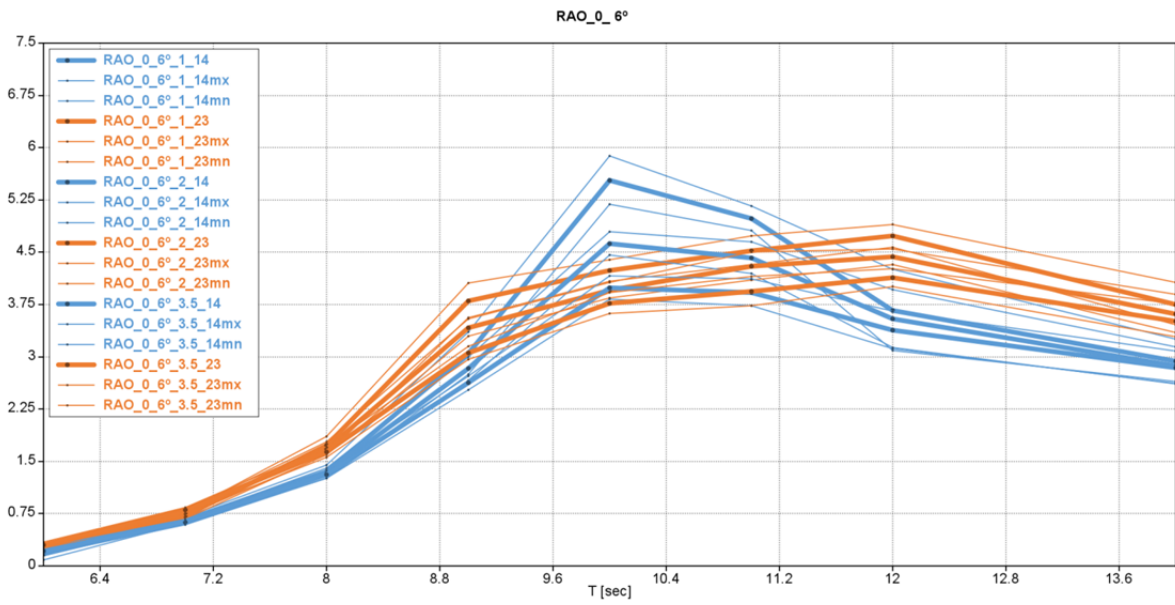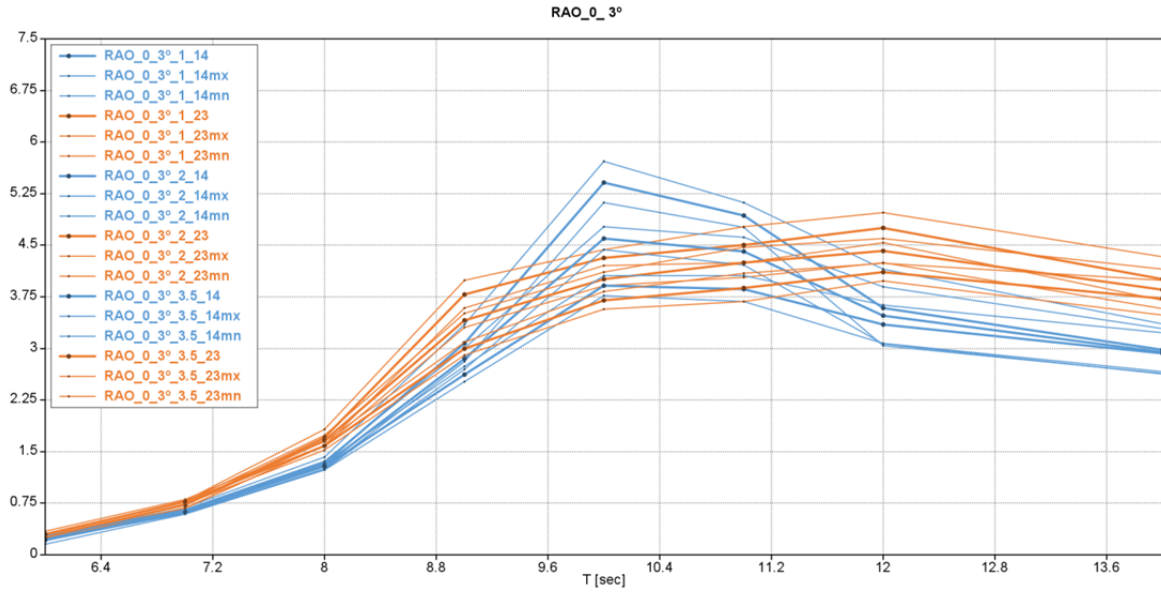
Figure 3.2 RAOs of columns 1&4 and 2&3 for both slopes: mean, max, min.
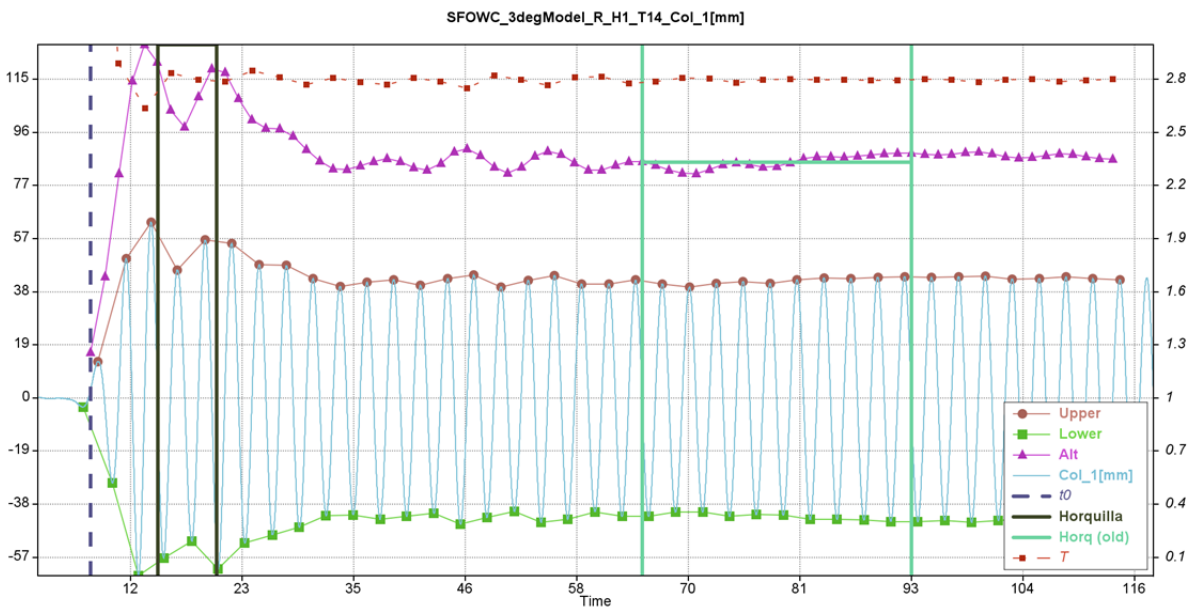
Figure 3.3 Analysis of the register of one of the test after filtering it.

Figure 3.4 Comparison between the experimental results (LiR) and SENERWave (SFM).

3 Main Learning Outcomes

3.1 Progress Made

3.1.1 Progress Made: For This User-Group or Technology

The effects of the bathymetry in coastal structure were quite known, but not the effects in the performances on nearshore and onshore devices such as OWC ones. Also, having a good tool for the structural design is important to assess the difference between the results from the theory and the classical methods (Goda, 1985) for calculating loads on breakwaters.
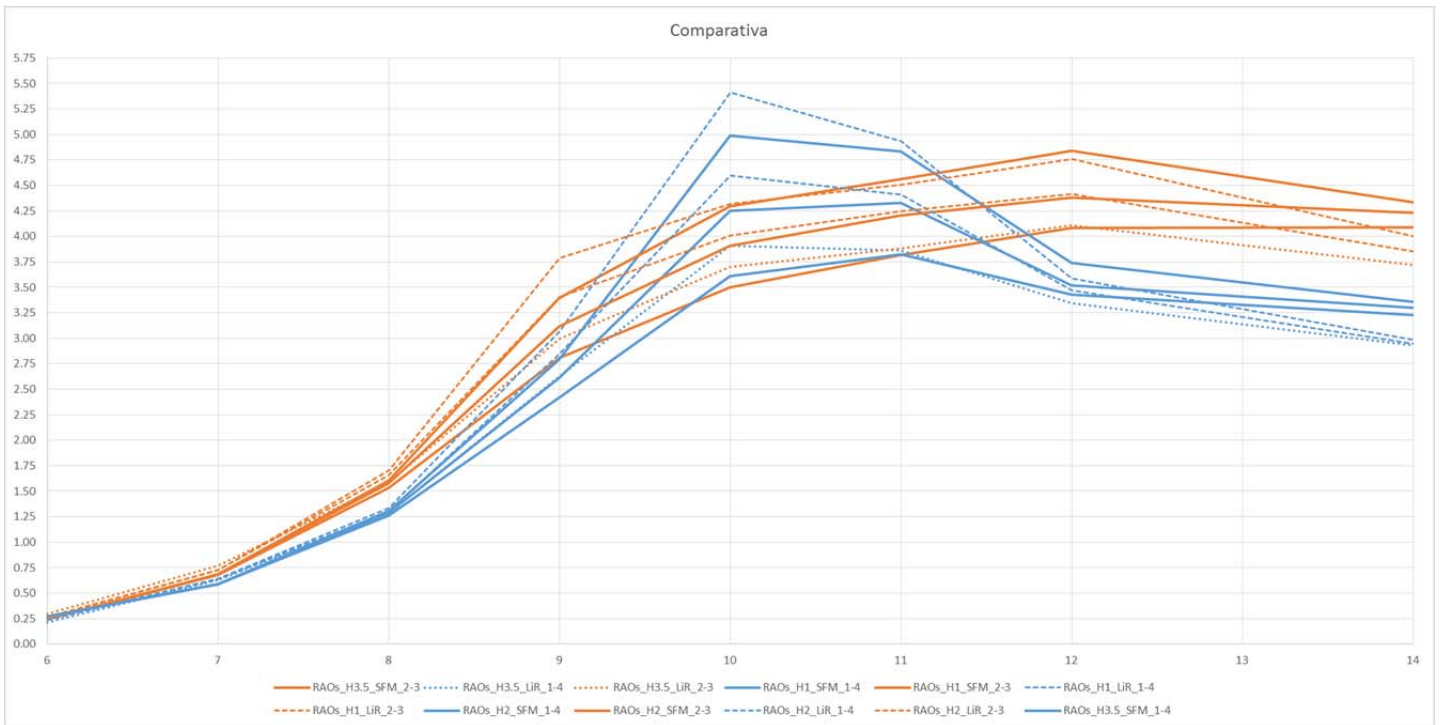
In that sense, main progress for SENER is the completion of the tests to assure that SENERWave is reliable for the hydrodynamic performance estimation of SENER device and others.

3.1.1.1 Next Steps for Research or Staged Development Plan

Next steps should be:

- Design and test a prototype of the PTO (Unidirectional Air Turbine).
- Test again in our test bench the non-return valves.
- Install a full-scale prototype.

3.1.2 Progress Made: For Marine Renewable Energy Industry

Researchers and companies coming to Lir-NOTF facility to test its own devices will benefit from the knowledge acquired by the DOB staff to test nearshore devices with different slopes as this was tested for the first time in the facility, and avoid the problems in the data acquisition system.

Moreover, there was a transmission of information between SENER staff and MaREI researchers that can benefit the Renewable Energy Industry with new and deep studies on this type of technology.

And finally, SENER has progressed with its own simulation tool, SENERWave, adjusting the hydrodynamic coefficients needed to study its nearshore device, but also every fixed and floating device in order to analyse their performances. Added to the fact that SENERWave is able to study the economics of each device, which will

give the idea of the future cost of electricity and will provide conclusions about funding or not a specific technology. Therefore, it can be used for all the Marine Renewable Energy Industry.

3.2 Key Lessons Learned

- Prepare as much as possible the test before going to the test facility:
    - Tools required for the model assembly.
    - Sensors needed.
    - Confirm each part scope of work and limitations.
    - Health Insurances in place.
    - Do the simulations if possible of what you are going to test to make easier the analysis of the results.
- Be careful with the model transportation: protect every part of the model and do not assume that the carrier will respect the cargo.
- Be sure before starting the test that there is not any source of noise that could affect the measurement with the data acquisition system.
- Analyse each test after termination. Do not wait to be at the office, because you cannot repeat anything.

4 Further Information

4.1 Scientific Publications

N/A

4.2 Website & Social Media

http://www.poweroilandgas.sener/wec

5 References

Paper "Assessment of a Spar buoy oscillating-water-column wave energy converter including a fully dynamic model" (EWTEC 2017, Cork).

Poster "Spar-buoy OWC six-DOF hybrid mooring feedback control modelling", (2017 Maynooth University Wave Energy Workshop)

SENERWave presentation at HYWEC workshop celebrated in the Basque Centre of Applied Mathematics.

6 Appendices

6.1 Stage Development Summary Table

The table following offers an overview of the test programmes recommended by IEA-OES for each Technology Readiness Level. This is only offered as a guide and is in no way extensive of the full test programme that should be committed to at each TRL.

TRL 9
•Actual system "flight proven" through successful mission operations

TRL 8
•Actual system completed and "flight qualified" through test and demonstration (ground or space)

TRL 7
•System prototype demonstration in a space environment

TRL 6
•System/subsystem model or prototype demonstration in a relevant environment (ground or space)

TRL 5
•Component and/or breadboard validation in relevant environment

TRL 4
•Component and/or breadboard validation in laboratory environment

TRL 3
•Analytical and experimental critical function and/or characteristic proof-of-concept

TRL 2
•Technology concept and/or application formulated

TRL 1
•Basic principles observed and reported

NASA Technology Readiness Levels[1]

[1] https://www.nasa.gov/directorates/heo/scan/engineering/technology/txt_accordion1.html

NASA TRL Definition Hardware Description Software Description Exit Criteria

TRL	Definition	Hardware Description	Software Description	Exit Criteria
1	Basic principles observed and reported.	Scientific knowledge generated underpinning hardware technology concepts/applications.	Scientific knowledge generated underpinning basic properties of software architecture and mathematical formulation.	Peer reviewed publication of research underlying the proposed concept/application.
2	Technology concept and/or application formulated.	Invention begins, practical application is identified but is speculative, no experimental proof or detailed analysis is available to support the conjecture.	Practical application is identified but is speculative, no experimental proof or detailed analysis is available to support the conjecture. Basic properties of algorithms, representations and concepts defined. Basic principles coded. Experiments performed with synthetic data.	Documented description of the application/concept that addresses feasibility and benefit.
3	Analytical and experimental critical function and/or characteristic proof of concept.	Analytical studies place the technology in an appropriate context and laboratory demonstrations, modelling and simulation validate analytical prediction.	Development of limited functionality to validate critical properties and predictions using non-integrated software components.	Documented analytical/experimental results validating predictions of key parameters.
4	Component and/or breadboard validation in laboratory environment.	A low fidelity system/component breadboard is built and operated to demonstrate basic functionality and critical test environments, and associated performance predictions are defined relative to the final operating environment.	Key, functionally critical, software components are integrated, and functionally validated, to establish interoperability and begin architecture development. Relevant Environments defined and performance in this environment predicted.	Documented test Performance demonstrating agreement with analytical predictions. Documented definition of relevant environment.
5	Component and/or breadboard validation in relevant environment.	A medium fidelity system/component brassboard is built and operated to demonstrate overall performance in a simulated operational environment with realistic support elements that demonstrates overall performance in critical areas. Performance predictions are made for subsequent development phases.	End-to-end software elements implemented and interfaced with existing systems/simulations conforming to target environment. End-to-end software system, tested in relevant environment, meeting predicted performance. Operational environment performance predicted. Prototype implementations developed.	Documented test performance demonstrating agreement with analytical predictions. Documented definition of scaling requirements.
6	System/sub-system model or prototype demonstration in an operational environment.	A high fidelity system/component prototype that adequately addresses all critical scaling issues is built and operated in a relevant environment to demonstrate operations under critical environmental conditions.	Prototype implementations of the software demonstrated on full-scale realistic problems. Partially integrate with existing hardware/software systems. Limited documentation available. Engineering feasibility fully demonstrated.	Documented test performance demonstrating agreement with analytical predictions.
7	System prototype demonstration in an operational environment.	A high fidelity engineering unit that adequately addresses all critical scaling issues is built and operated in a relevant environment to demonstrate performance in the actual operational environment and platform (ground, airborne, or space).	Prototype software exists having all key functionality available for demonstration and test. Well integrated with operational hardware/software systems demonstrating operational feasibility. Most software bugs removed. Limited documentation available.	Documented test Performance demonstrating agreement with analytical predictions.
8	Actual system completed and "flight qualified" through test and demonstration.	The final product in its final configuration is successfully demonstrated through test and analysis for its intended operational environment and platform (ground, airborne, or space).	All software has been thoroughly debugged and fully integrated with all operational hardware and software systems. All user documentation, training documentation, and maintenance documentation completed. All functionality successfully demonstrated in simulated operational scenarios. Verification and Validation (V&V) completed.	Documented test performance verifying analytical predictions.
9	Actual system flight proven through successful mission operations.	The final product is successfully operated in an actual mission.	All software has been thoroughly debugged and fully integrated with all operational hardware/software systems. All documentation has been completed. Sustaining software engineering support is in place. System has been successfully operated in the operational environment.	Documented mission operational results

DEVELOPMENT PROTOCOL	STAGE 1 CONCEPT VALIDATION			STAGE 2 DESIGN VALIDATION	STAGE 3 SYSTEMS VALIDATION		STAGE 4 DEVICE VALIDATION		STAGE 5 ECONOMICS VALIDATION
	TRL 1: Confirmation of Operation	TRL 2: Performance Convergence	TRL 3: Device Optimisation	TRL 4: Sub-Systems Assessment	TRL5: Sub-Assembly Bench Tests	TRL 6: Full System Sea Trials	TRL 7: Solo, Sheltered, Grid Emulator	TRL 8: Solo, Exposed, Grid Connected	TRL 9: Multi-device Array (3-5)
Objectives/ Investigations	Op. Verification Design Variables Physical Process Validate/Calibrate Maths Model Damping Effect Signal Phase	Real Generic Seas Design variables Damping PTO Natural Periods Power Absorption Wave to Devise Response Phase	Hull Geometry Components Configurations Power Take-Off Characteristics Design Eng. (Naval Architects)	Final Design Accurate PTO [Active Control] Mooring system Survival Options Power Production Added mass	PTO Method Options & Control Inst. Power Absorption Electricity Production & Quality	Scale effects of Overall Performance Characteristics Mooring & Anchorage Security Environmental Influences & Factors	Oper & Mains Procedures Electrical Output Quality Grid Supply, Stability & Security PTO Performance at all phases Control Strategy Seaworthiness, Survival & Lifecycle Analysis Device Array Interaction (Stages 1 & 2)		Grid Connection Array Interaction Maintenance Service Schedules Component Life Economics
Output/ Measurement	Vessel Motion Response Amplitude Operators & Stability Pressure / Force, Velocity RAOs with Phase Diagrams Power Conversion Characteristic Time Histories Hull Seaworthiness; Excessive Rotations or Submergence Water Surface Elevation Abeam of Devices			Motion RAOs Phase Diagrams Power v Time Wave Climates @ head, beam, follow	PTO Forces & Power Conversion Control Strategies	Incident Wave Field 6 D of F Body Motion & Phase Seaworthiness of Hull & Mooring [Survival Strategies]	Full On-Board Monitoring Kit for Extended Physical Parameters Power Matrix Supply forecasting	Array Interaction Annual Power Prod. Elec. Power Perfrm. Failure Rates Grid EIA reviews	Service, Maintenance & Production Monitor, Telemetry for Periodic checks & Evaluation
Primary Scale (λ)	λ = 1 : 25 - 100 (∴ λₑ = 1 : 5 - 10)			λ = 1 : 10 - 25	λ = 1 : 2 - 10		λ = 1 : 1 - 2		λ = 1:1, Full size
Facility	2D Flume or 3D Basin			3D Basin	Power Electronics Lab	Benign Site	Sheltered Full Scale Site	Exposed Full Scale Site	Open Location
Duration –inc Analysis	1-3months	1-3months	1 3 months	6 – 12 months	6 – 18 months		12 – 36 months		1 – 5 years
Typical No. Tests	250 - 750	250 - 500	100 - 250	100 - 250	50 - 250		Continuous		Statistical Sample
Budget (€,000)	1 – 5	25-75	25-50	50 - 250	1,000 – 2,500		10,000 – 20,000		2,500 – 7,500
Device	Idealised with Quick Change Options Simulated PTO (0-∞ Damping Range) Std Mooring & Mass Distribution		Distributed Mass Minimal Drag Design Dynamics	Final design (internal view) Mooring Layout	Advanced PTO Simulation Special Materials	Full Fabrication True PTO & Elec Generator	Grid Control Electronics or Emulator Emergency Response Strategies Pre-Production Pre-Commercial		Operational Multi-Device
Excitation / Waves	Monochromatic Linear (10-25Δf) (25-100 waves)	Panchromatic Waves (20min scale) +ve 15 Classical Seaways Spectra Long crested Head Seas		Deployment -Pilot Site Sea Spectra Long, Short Crested Classical Seas Select Mean wave Approach Angle		Extended Test Period to Ensure all Seaways inc.	Full Scatter Diagram for initial Evaluation Continuous Thereafter Time & Frequency Domain Analysis		
Specials	DofF (heave only) 2-Dimentional Solo & Multi Hull	Short Crest Seas Angled Waves As Required	Storm Seas (3hr) Finite Regular As required	Power Take-Off Bench Test PTO & Generator	Device Output Repeatability Survival Forces	Salt Corrosion Marine Growth Permissions	Grid Emulator Quick Release Cable Service Ops	Stakeholder Consult. Health & Safety Issues	Small Array (Up-grade to Generating Station)?
Maths Methods (Computer)	Hydrodynamic, Numerical Frequency Domain to Solve the Model Undamped Linear Equations of Motion		Finite Waves Applied Damping Multi Freq Inputs	Time Domain Response Model & Control Strategy Naval Architects Design Codes for Hull, Mooring & Anchorage System. Economic & Business Plan			Economic Model Electrical Stab. Array Interaction	Grid Simulation Wave forecasting	Array Interaction Market Projection for Devise Sales
EVALUATION [Stage Gates]									
Absorbed Power Converted [kW]									
Weight, [tonnes]									
Manufacturing Cost [€]									
Capture [kW/tonne] or [kW/m^3]	[200-50 m^3]								
Production [c/kW]	< 25 €c / kW			≤ 15 €c / kW			≤ 10 €c / kW		≤ 5 €c / kW

6.2 Any Other Appendices

N/A