Overtopping Breakwater for Wave Energy Conversion at the Port of Naples: Status and Perspectives

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1. INTRODUCTION

Nowadays over 1500 Wave Energy Converter (WECs) are patented worldwide!!

Focusing on the Wave devices, very few WECs are developed in full scale but... none of the patented devices are ready for the commercial phase.

Two main problems for the future commercialization of these innovative devices:

- Very high cost
- Reliability of technologies
1. INTRODUCTION

Move from **standalone device** to **hybrid systems** embedded in other coastal or offshore structures.

The primary function of the “hybrid system” remains the harbour/coastal protection… with the adding values of the energy production.

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**Cost reduction:**
breakwater would be built regardless of the inclusion of a WEC (sharing cost due to integration)

**High reliability:**
performances and global stability as traditional breakwaters

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DISSIPATE WAVE ENERGY → CAPTURE THE WAVE ENERGY → Provide useful energy [electricity]
2. THE OBREC DEVICE

Overtopping Wave Energy Converter (OTD) **embedded** into coastal defense structure

The principal function of this *Innovative breakwater* remains the harbour/coastal protection, with the adding values of the **energy production**.
2. THE OBREC DEVICE

2012: First physical model test campaign (Aalborg University, Denmark)

Traditional breakwater vs OBREC

The integration of the OBREC in the traditional breakwater improves the hydraulic performances:

- **overtopping** at the rear side of the structures is *reduced* due the presence of a triangular parapet at the top of the wall;

- **reflection** coefficients are *similar* (or in some conditions lower) than those measured for the traditional breakwaters due the wave energy absorption into the reservoir.

2. THE OBREC DEVICE

2014: Second physical model test campaign (Aalborg University, Denmark)

- Different shape of the frontal ramp;
- Influence of the ramp extension under the SWL;
- Different dimension of the reservoir width.

A specific set of design formulas are provided with the intent to be of direct use by engineers in preliminary design of full scale devices.

These formulas have been used to design the first OBREC prototype breakwater at Naples Harbour (Italy).

3. FULL-SCALE PROTOTYPE AT THE NAPLES HARBOUR

World’s first Overtopping WEC prototype completely embedded into a breakwater has been installed in 2015 at the Port of Naples.
3. FULL-SCALE PROTOTYPE AT THE NAPLES HARBOUR

3.1 SITE SELECTION

**Ideal site to test the OBREC prototype for this stage of development**
[Low occurrences of extreme storms]
- Reduction of the construction costs
- Safer and less expensive maintenance operations

- **Challenge** = demonstrate the structural reliability and evaluate the overall performances during the storms
- **Aim** = acquire data during the storm events, using the pilot plant as a **large natural laboratory** in which the **field data** are collected and analyzed for future applications in the more energetic and exposed coastal areas.

**Average annual wave power:**
\[ P \approx 2.5 \text{ kW/m} \]
[long periods of calm sea states]

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3. FULL-SCALE PROTOTYPE AT THE NAPLES HARBOUR

3. FULL-SCALE PROTOTYPE AT THE NAPLES HARBOUR

3.2 GEOMETRY

(Real Scale laboratory)
Ramp crest freeboard = 1.7 m

(Natural Waves Laboratory)
Ramp crest freeboard = 1.00 m
The waverider buoy, Directional Wave Spectra Drifting Buoy (DWSDB), uses Global Positioning System (GPS) technology developed by the Lagrangian Drifter Laboratory (LDL) of the Scripps Institution of Oceanography (SIO) in San Diego.

Cheaper than the traditional wave buoy...

..only 12 Kg!
3. FULL-SCALE PROTOTYPE AT THE NAPLES HARBOUR

The wave data are transmitted via the Iridium satellite system and they are accessible in real time on dedicated website.

Comparison between wave parameters measured from the GPS-buoy and an ADCP.

3. FULL-SCALE PROTOTYPE AT THE NAPLES HARBOUR

Wave loading

*Wave pressure* will be measured by *pressure transducers* located on the different parts of the structure.

The **aim** is to collect and analyze *pressure data* during *storm events* in order to:

- **compare** it with the theoretical prediction;
- **validate** the pressure data analyzed in small scale model.

Overtopping in the reservoirs

*Pressure transducers* will be placed on small boxes in the machine room in order to measure the variation of the water depth *d(t)* inside the frontal reservoirs.

\[
\begin{align*}
    d(t) & \Rightarrow H(t) & \Rightarrow q(t)
\end{align*}
\]

- *Water depth in the reservoirs*
- *Hydraulic head*
- *Instantaneous flow rate*
3. **FULL-SCALE PROTOTYPE AT THE NAPLES HARBOUR**

3 semi-Kaplan low head turbines have been placed with a total power of 2.5 Kw

The purpose is to **test different low head turbines** in order to find the optimal technology for overtopping hydro-marine turbines, via a cost-benefit analysis.
• Extend the range of application of the design formulas also for 3D conditions

• Provide useful indications for the **stability analysis** and the **geometrical optimization** of the OBREC integrated into both rubble mound breakwater and **vertical caisson**.


BRIGAID is a 4-year project (2016-2020) under EU Horizon2020 aimed to effectively bridge the gap between innovators and end-users in resilience to floods, droughts and extreme weather.
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