DIPARTIMENTO DI INGEGNERIA CIVILE, EDILE E AMBIENTALE - I C E A
DEPARTMENT OF CIVIL, ENVIRONMENTAL AND ARCHITECTURAL ENGINEERING

UNIVERSITÀ DEGLI STUDI DI PADOVA

MARITIME LABORATORY OF PADOVA UNIVERSITY

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Maritime Laboratory of Padova University

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Web page:	www.dicea.unipd.it/servizi/laboratori/laboratorio-marittimo
Responsible of the Lab:	prof. Piero Ruol
Other scientific personnel:	1 senior (prof. Luca Martinelli) and 2 junior Researchers
Other permanent staff:	1 technician, 1 electronic designer, 1 structural designer

The University of Padova was founded in 1222, and is one of the oldest Universities in the World. The hydraulic school was founded in 1842, by Domenico Turazza. In Italy, Padova was the first University to focus on maritime works (1910) and in 1925 a wave basin was already set up. To our knowledge, the only other similar laboratories in Europe were Dresda, Karlsruhe, Pietersburg and Vienna. In 1954 a new wave basin 18 m x 21 m was built (where now the wave flume is located), the first in Italy.
Since then, the Maritime laboratory has been extensively used for prediction of wave transformation inside the ports.

Today, the Maritime laboratory is equipped with the most modern and valuable equipment, suitable to perform laboratory tests both for basic research activities and for applied research studies. The activities are mainly referred to the following topics: random wave transformation in shallow waters; wave transformations induced by marine structures and coastal defence works; stability tests for coastal and harbour structures; wave penetration in harbours; impact assessment evaluation of coastal works along sandy coasts; crosshore and longshore sediment transport; littoral morphodynamics; wave action on structures and mooring systems.
The laboratory comprises two different facilities, a wave flume and a wave basin.
Close to the maritime laboratory, there are several other facilities (e.g. Geotechnical and Hydraulic laboratories of the Department) that can provide backup and exchange of instrumentation.

The staff at Padova University has also worked in many others laboratories in Europe, including the following large scale facilities: LIC in Bari (I), LSF CRF in Wallingford (UK), Deep and Shallow water basin in Aalborg (DK), FZK GWK in Hamburg (D).
Field of expertise (proved by over 100 publications, conference invitations, etc) include wave analysis, data analysis in general, development and calibration of numerical modeling.

Fig. 1. Wave flume (left), wave basin (right)

Wave flume

Dimensions: 35.0 m x 1.0 m (height 1.30 m).
The flume is equipped with a fixed hydraulic wavemaker (with paddle 1.0 m x 1.4 m) with serve-valve and position transducer connected to personal computer, allowing to generate regular and irregular wave attacks of assigned spectral characteristics. Random wave sequences may be repeated.
The wave paddle can oscillate differently and act as a piston (horizontal translation) or can be hinged at the bottom. In most cases the wave generator will be operated in "piston mode", i.e. with horizontal translations.

The flume was completely rebuilt in 2002, changing the old concrete structure with a steel one, made by U-shape steel beams (without any superstructure) at the top of which a couple of rails were placed, allowing for a cart to run on them (on the cart the wave gauges or the automatic bottom profile can be mounted). Both the sides of the flume have been completely made by glass, perfectly placed along the flume to avoid different friction along the two sides. The flume was also equipped with a new pumping system allowing for recirculation from one side of the flume to the other. Actual pump gives limited discharge (50-100 m^3/h). A separate pump was used in some cases, with a discharge in the range 100-300 m^3/h. The flume was equipped with an "active absorption" device in 2005; this upgrade is necessary to avoid that the waves reflected by the structure or by the beach under investigation can affect the wave generation itself. The servo actuator and the paddle piston were replaced in August 2017.

The rear absorbing beach is formed by metallic porous plates with adjustable inclination, and geogrid rolls. An example of measured reflection coefficient is given in Fig. 2.

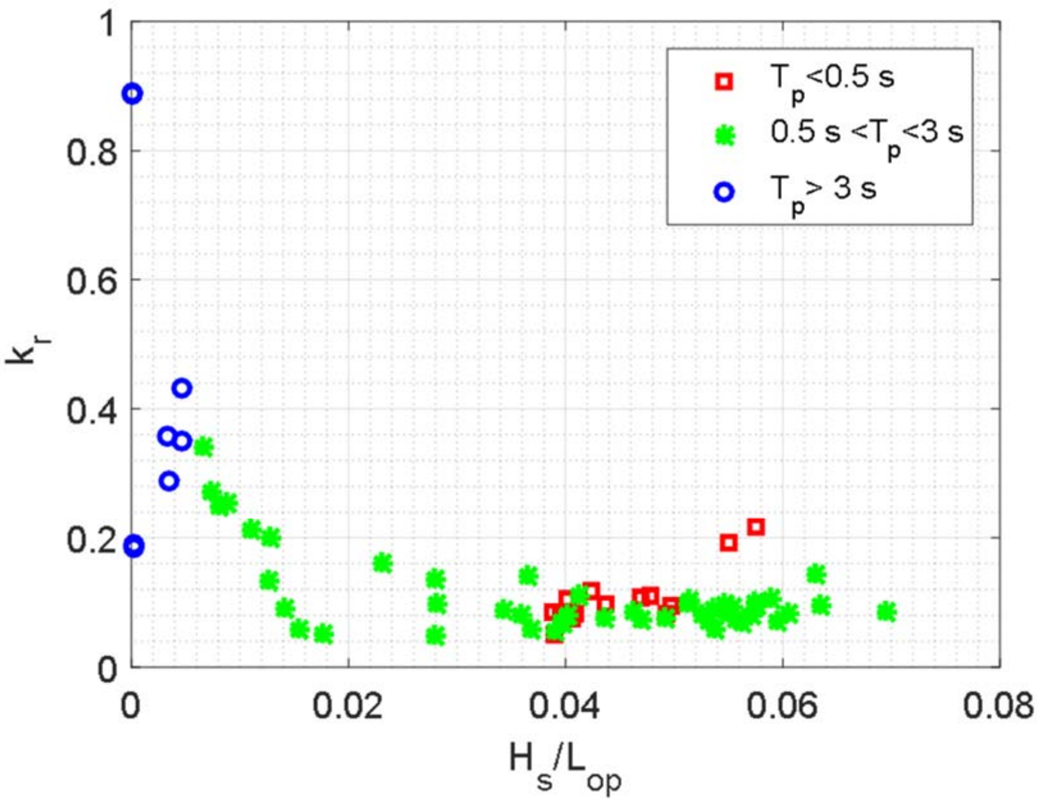


Fig. 2. Reflection coefficient of the rear absorbing beach

Fig. 3. Artificial units (stability)

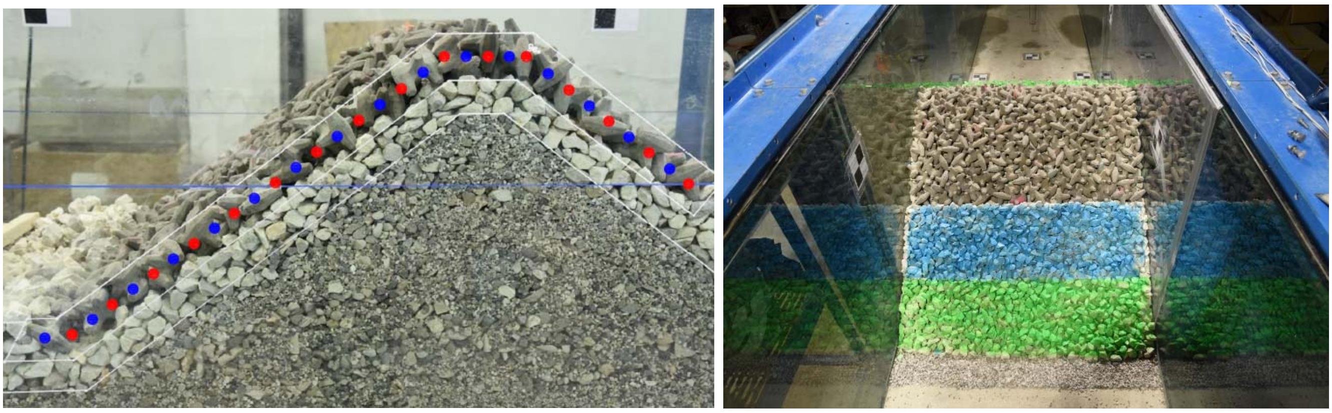


Fig. 4. Artificial units (stability)

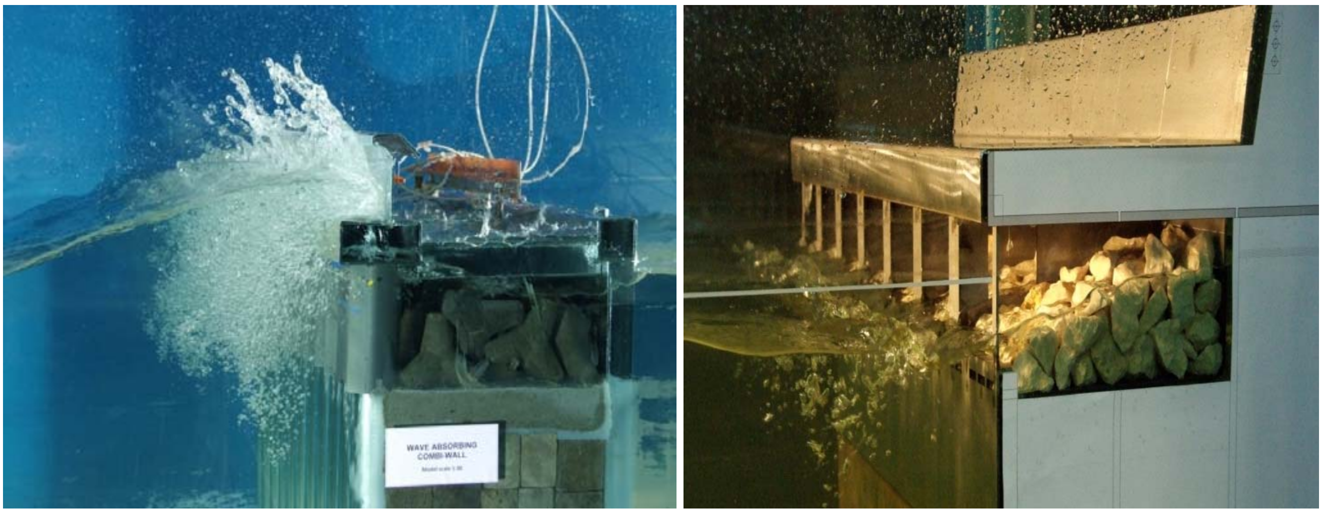


Fig. 5. Vertical wall structures (wave reflection and loads)

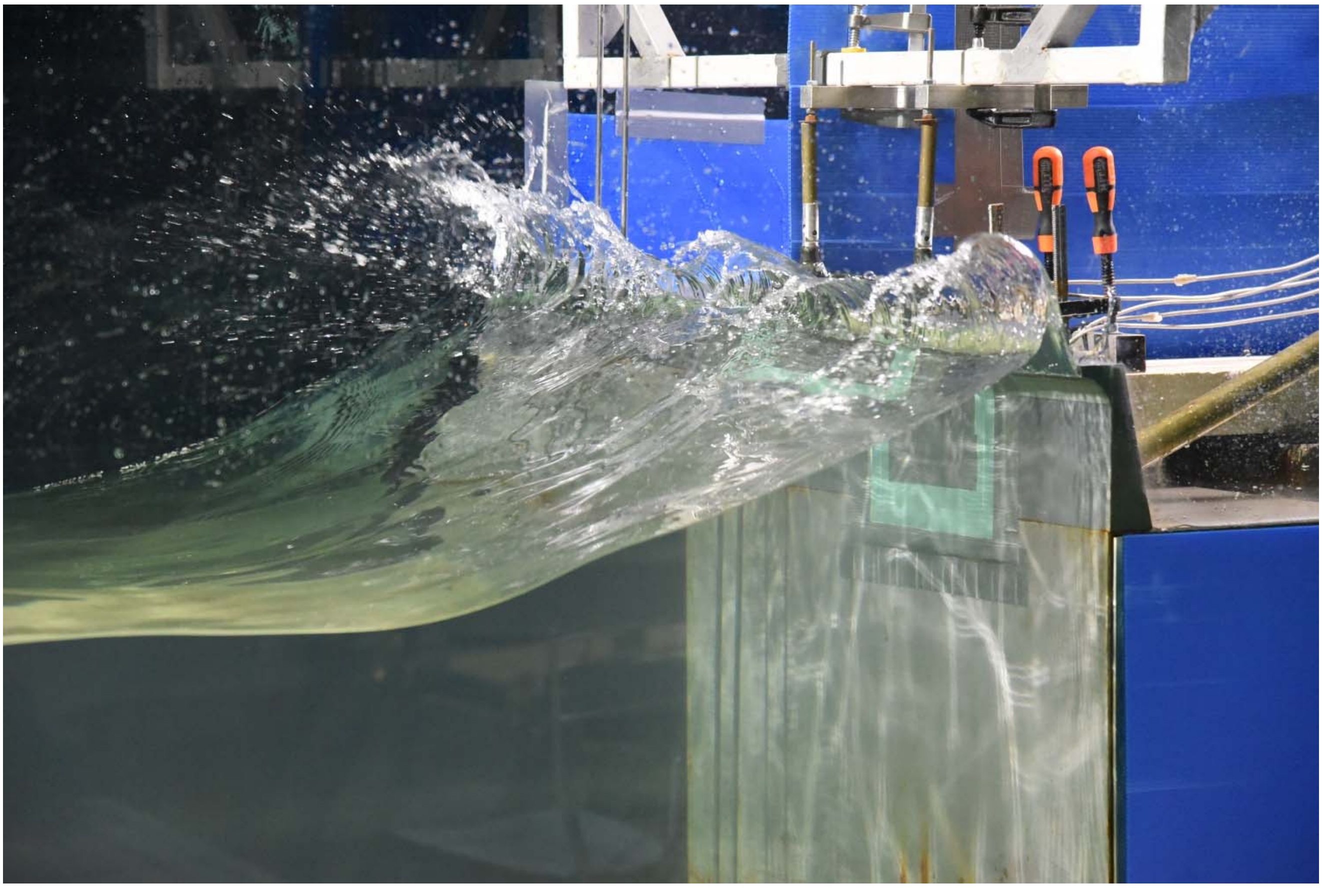


Fig. 6. Vertical wall structures (loads on curved parapet)

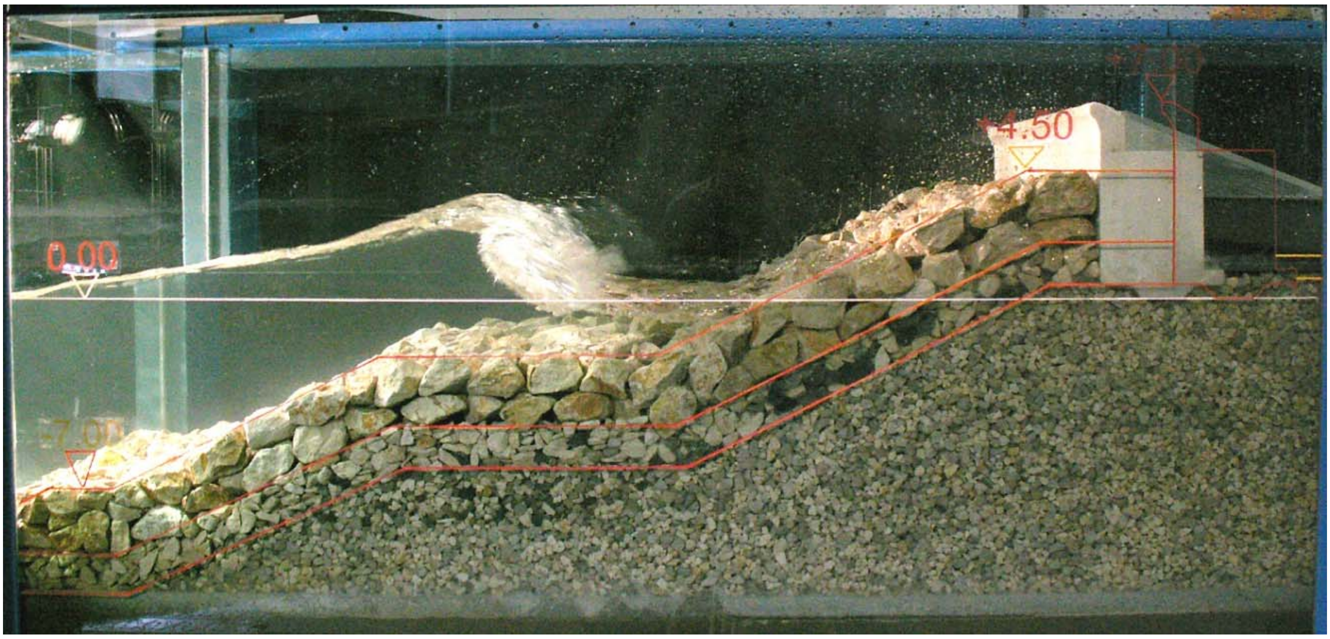


Fig. 7. Natural stones (stability)

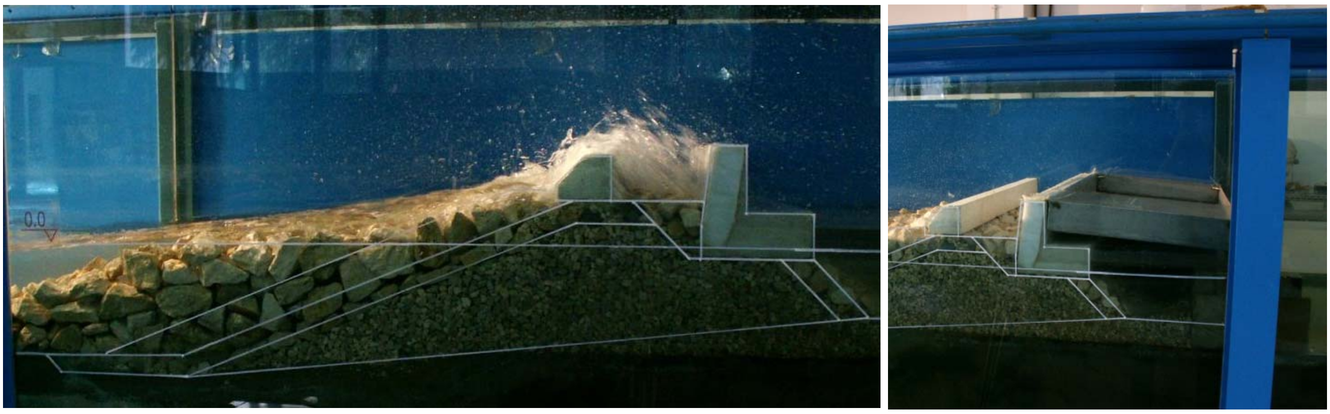


Fig. 8. Overtopping measurements

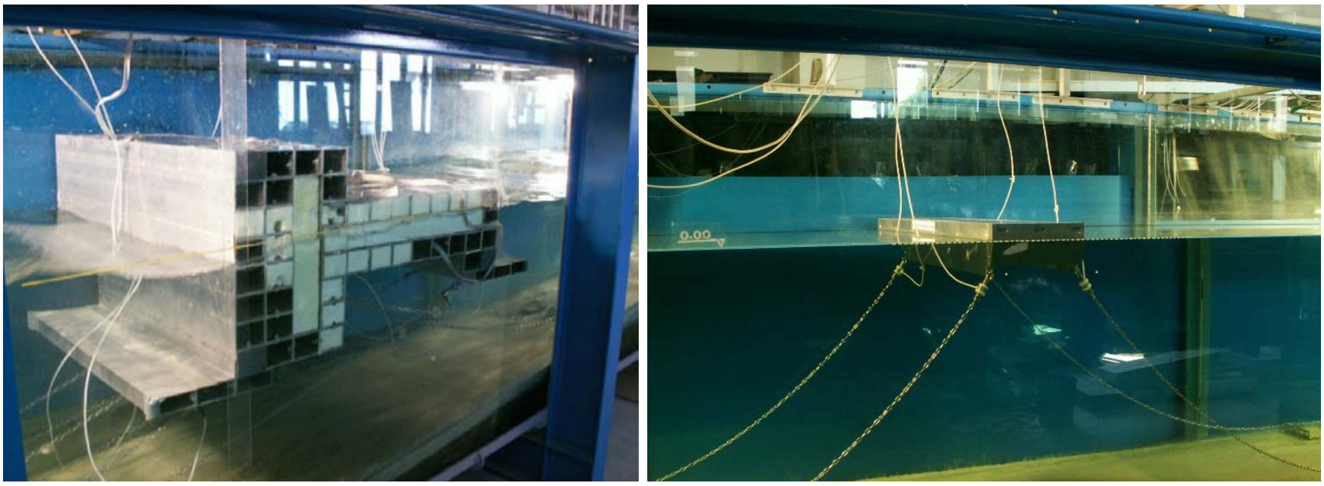


Fig. 9. Floating breakwaters (wave reflection, wave transmission and loads)

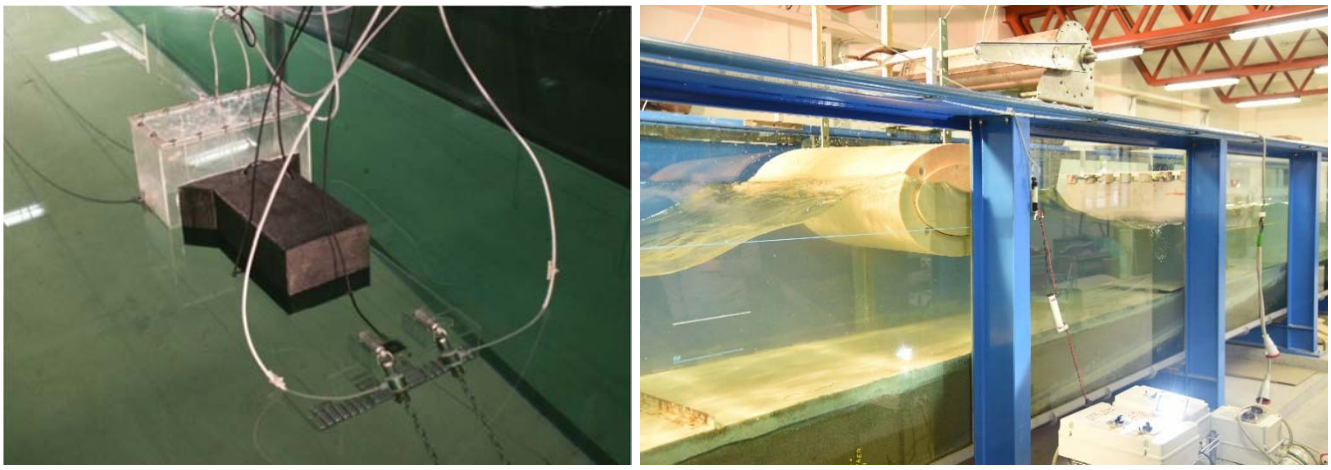


Fig. 10. Wave energy converters

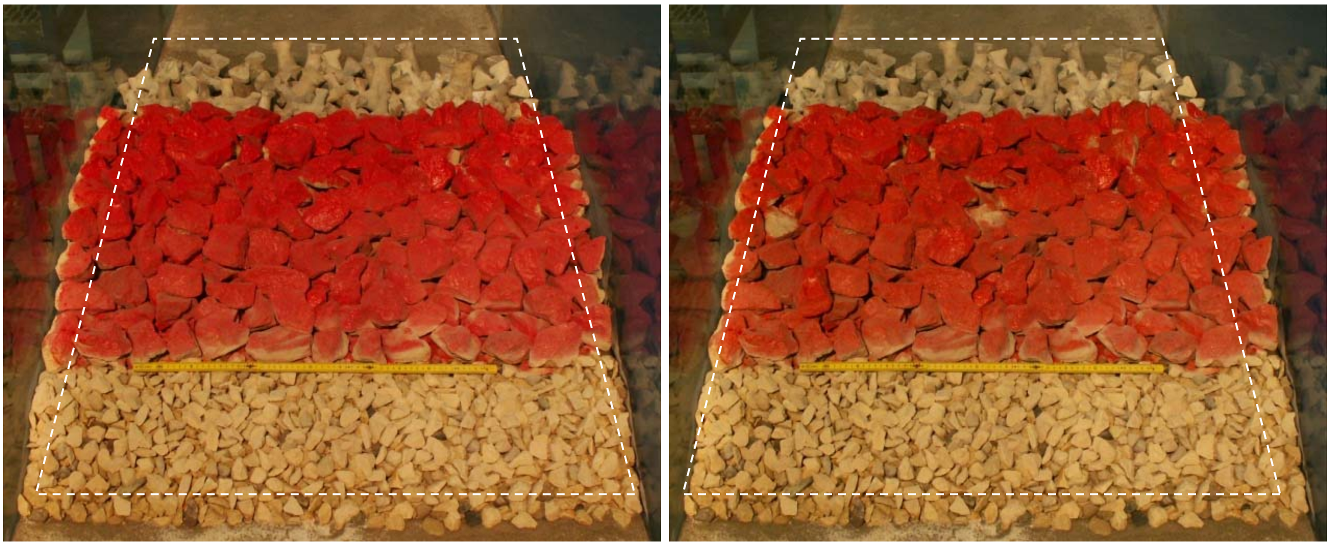


Fig. 11. Overlay photographic technique (pictures before and after)

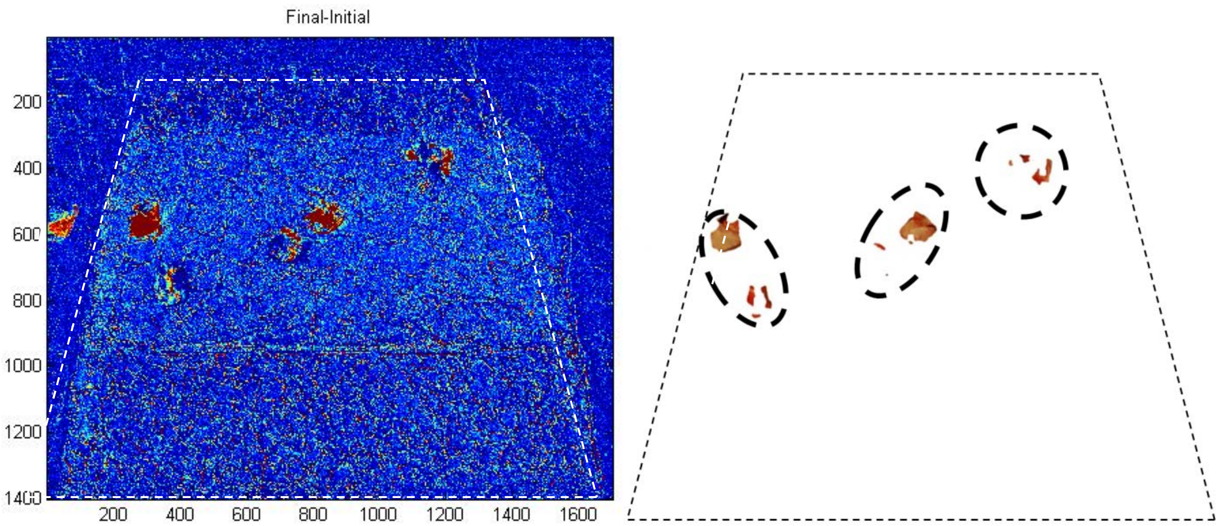


Fig. 12. Overlay photographic technique (results)

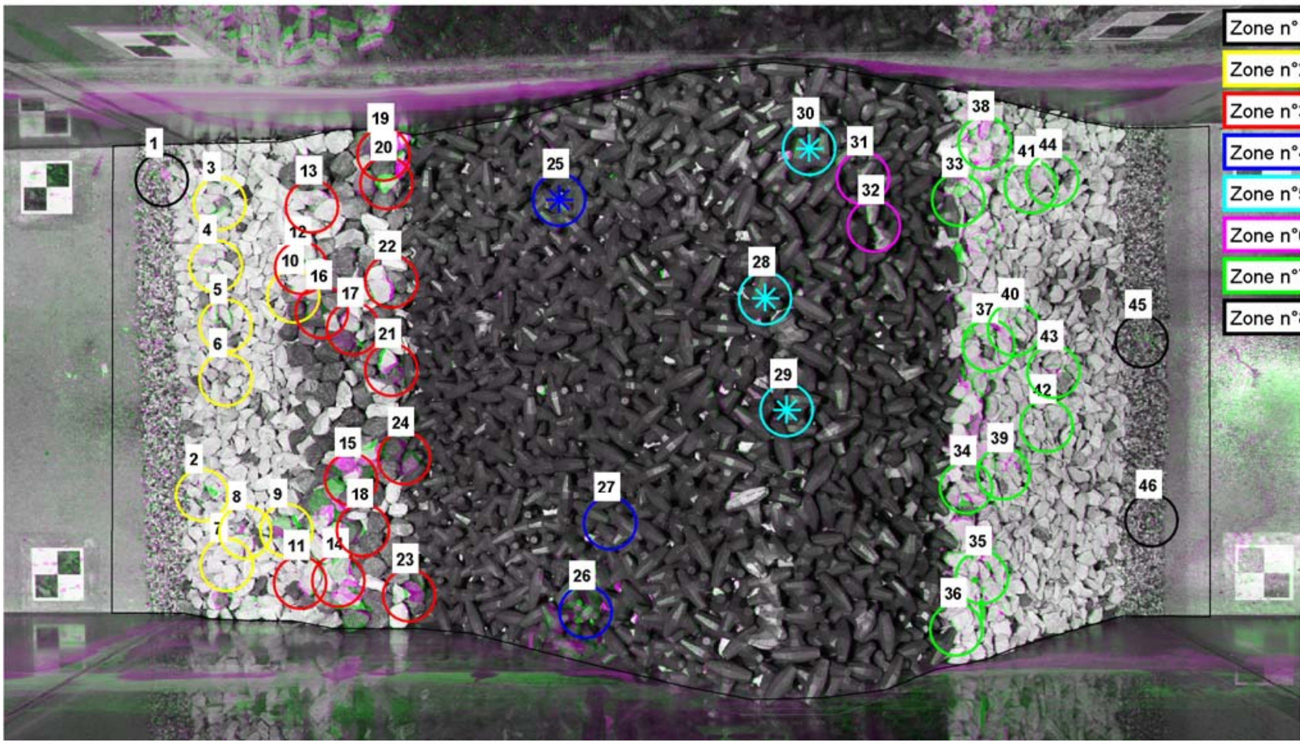


Fig. 13. Rocking and displacement obtained by the photographic overlay technique

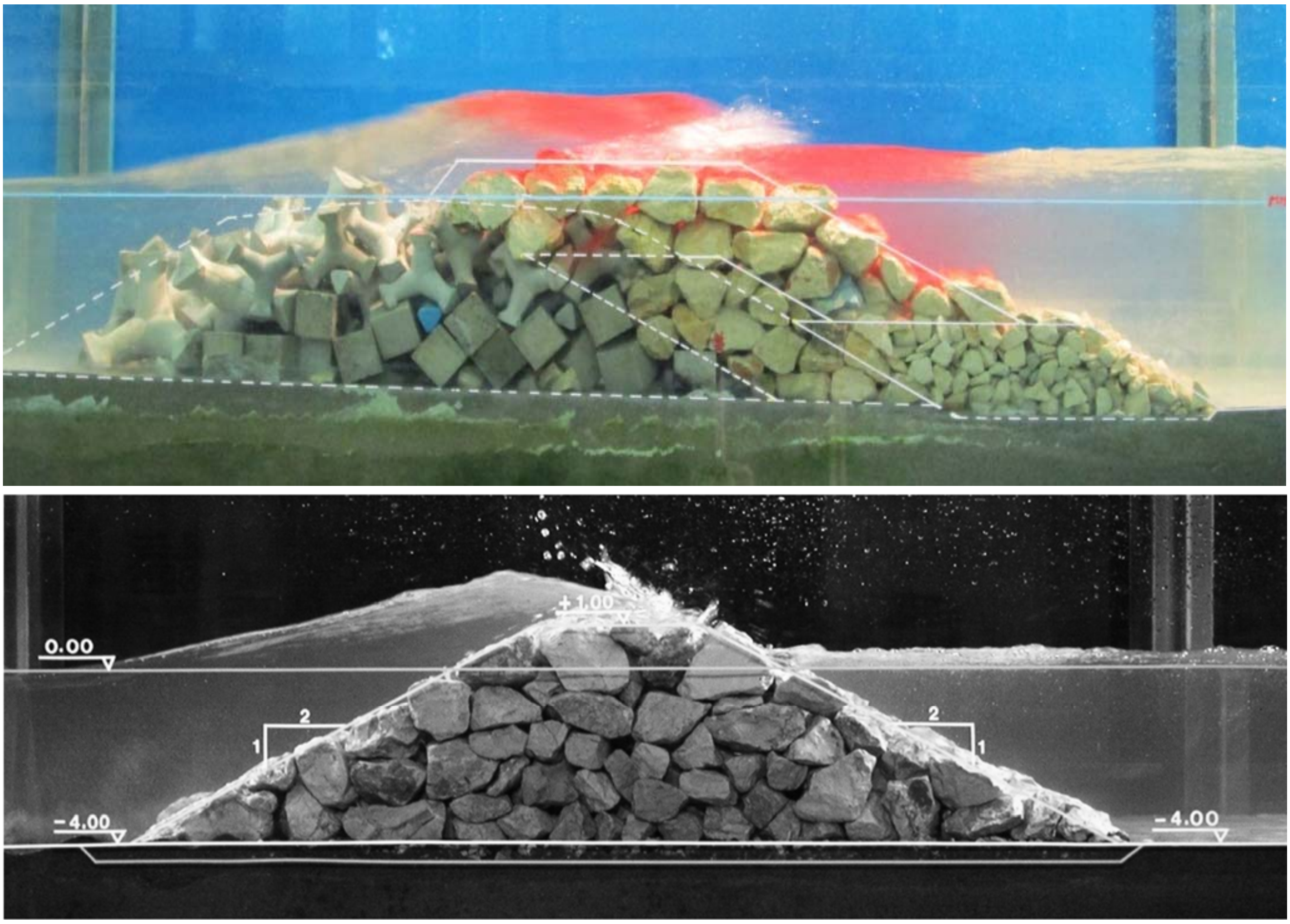


Fig. 14. Low crested structures

Fig. 15. Coastal protection structure

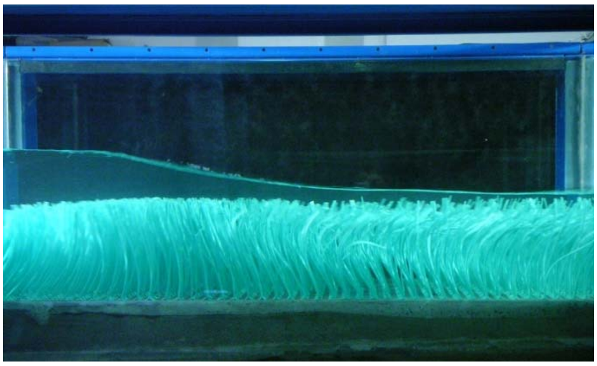


Fig. 16. Wave attenuation

Fig. 17. Investigation of damage during construction phase

Wave basin

Dimensions: 20.6 m x 17.8 m (height 0.80 m).
It is equipped with a movable hydraulic wave paddle, 0.85 m high and 8.0 m long (extendible to 10.0 m) with serve-valve and position transducer connected to personal computer, allowing to generate regular and irregular wave attacks of assigned spectral characteristics as well as solitary waves (with set- down compensation). The wave paddle can oscillate horizontally, and act as a piston. It may be moved, for generation of oblique waves.

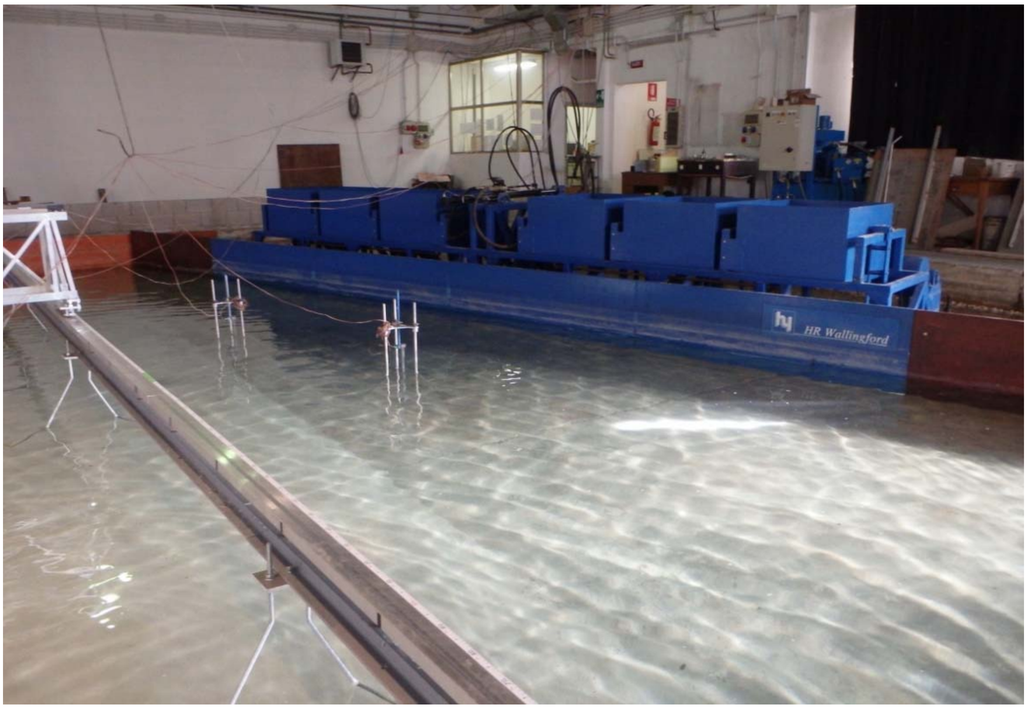


Fig. 18. Wavemaker

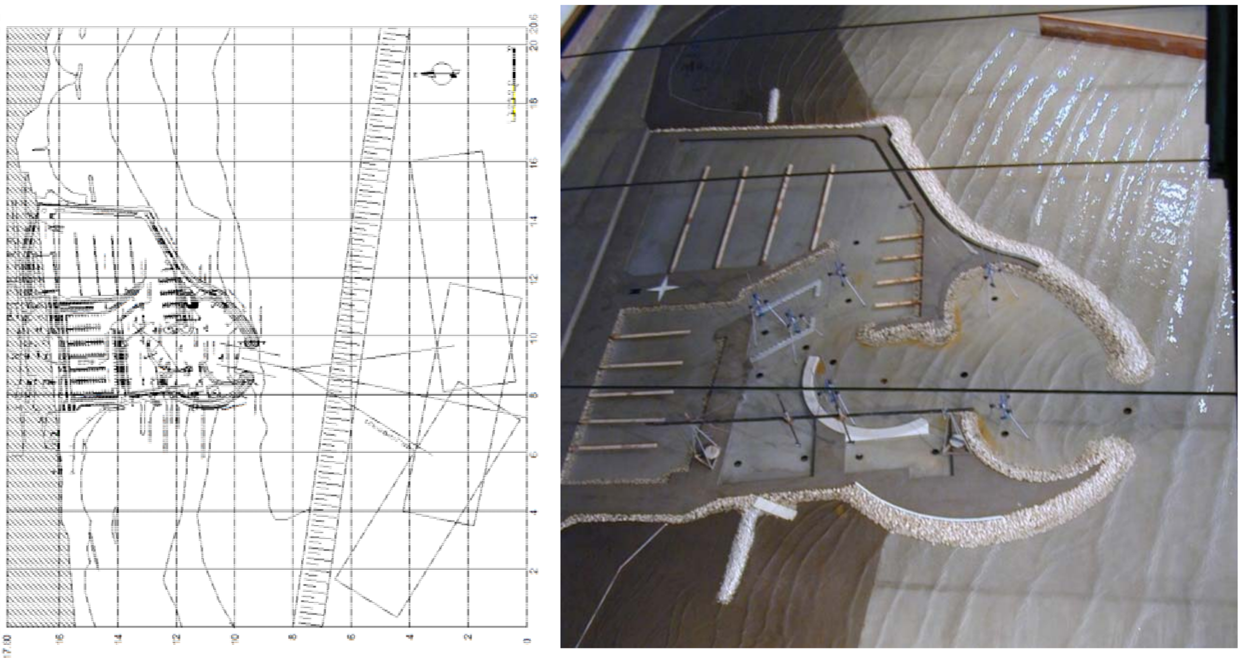


Fig. 19. From the design (left) to the model (right)

Fig. 20. From the model (left) to the construction (right)

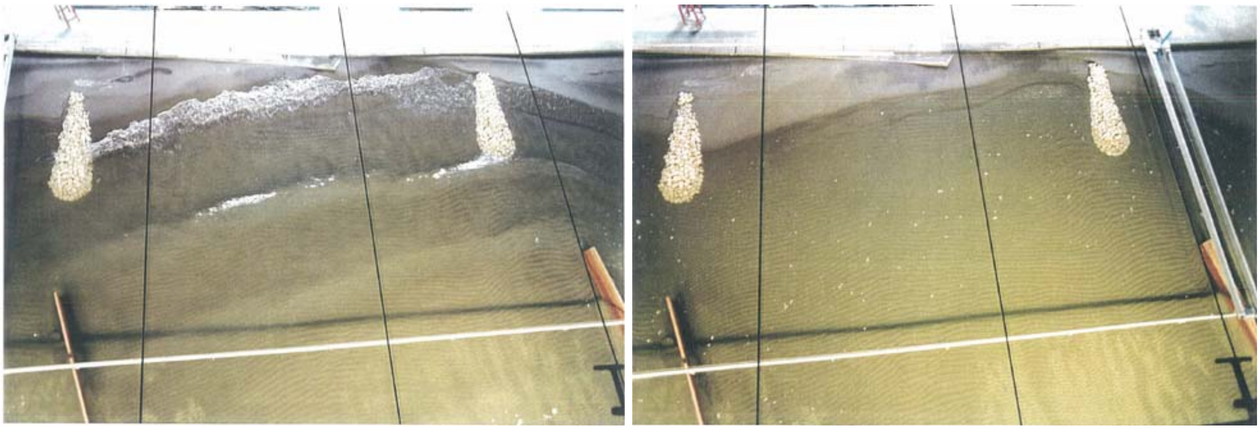


Fig. 21. Movable bed model: protected nourishment

Fig. 22. Movable bed model: plain nourishments

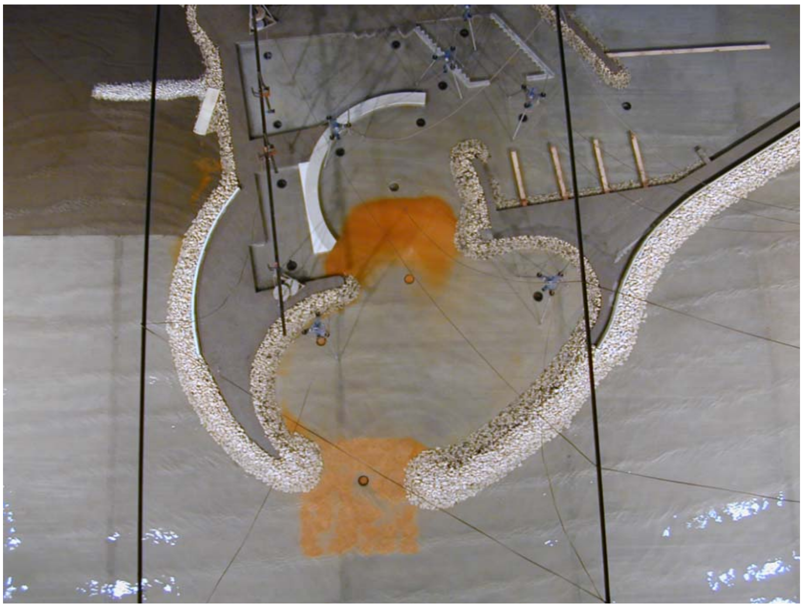


Fig. 23. Harbour siltation analysis

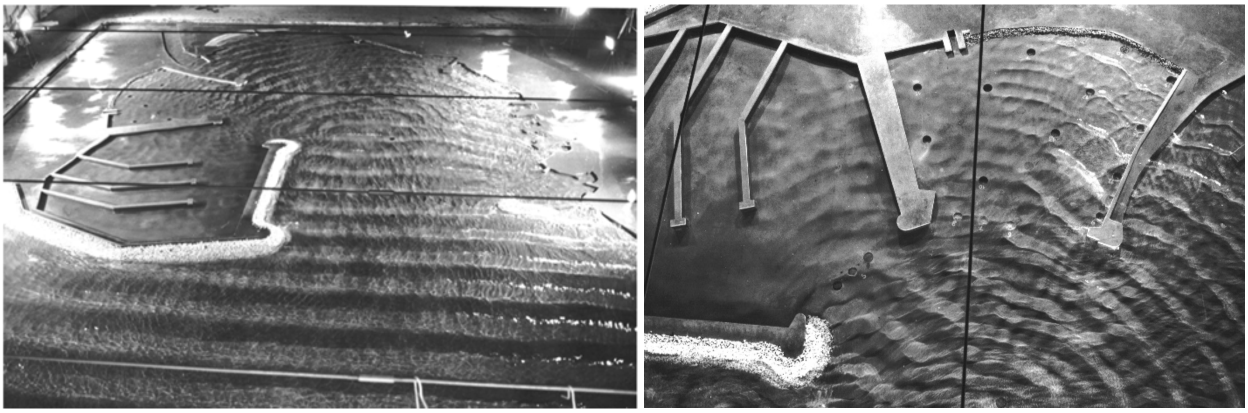
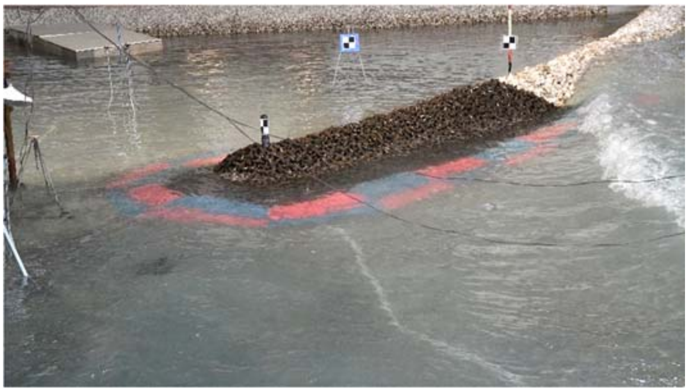
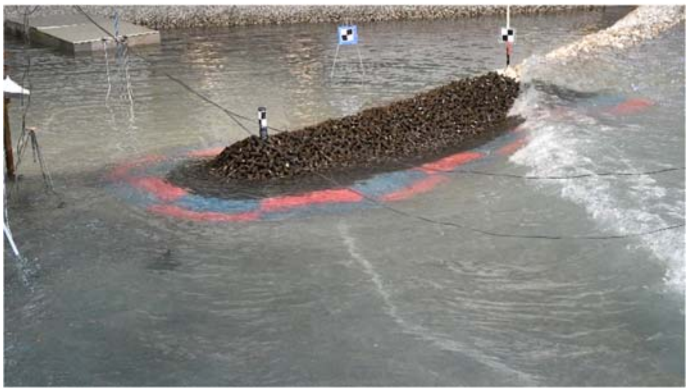


Fig. 24. Fixed bed model (with regular waves)

Fig. 25. Roundhead stability 3D test



Frame 1/8



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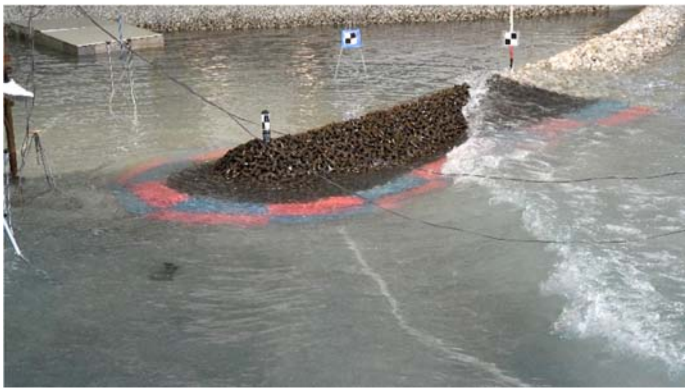
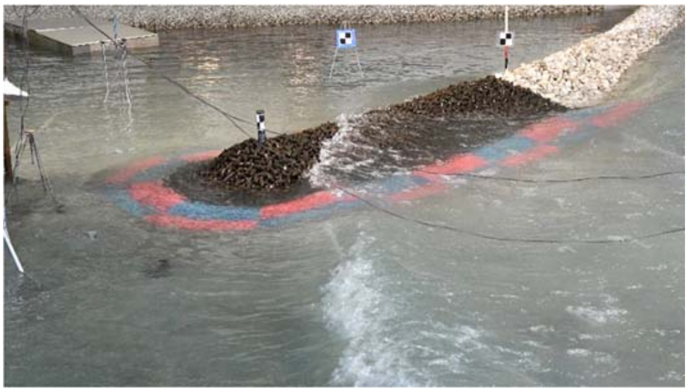


Frame 3/8

Frame 4/8



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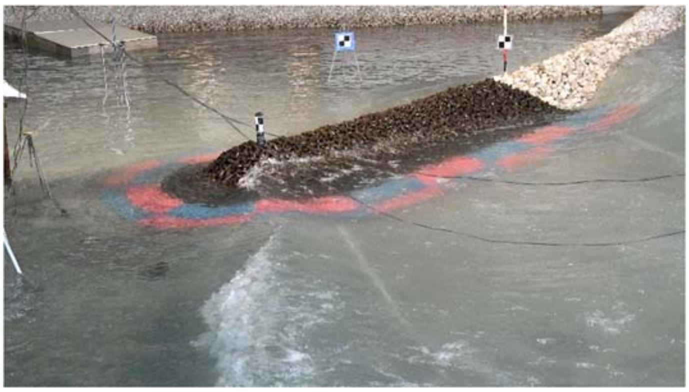
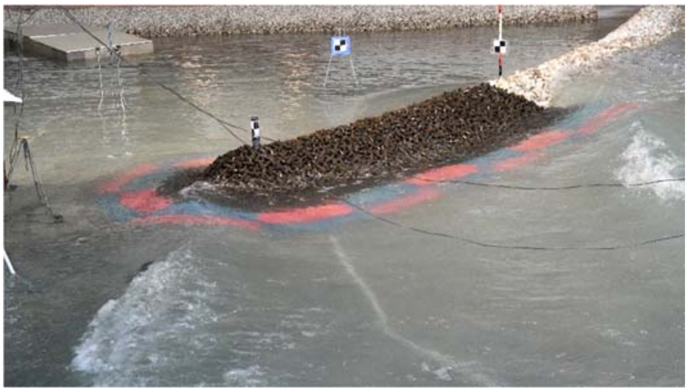
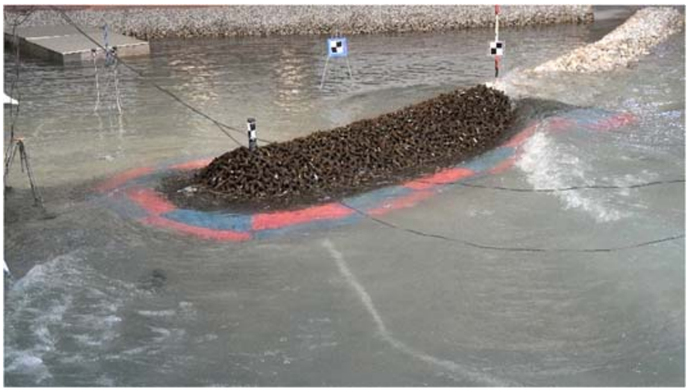


Frame 6/8



Frame 7/8



Frame 8/8

Fig. 26. Wave structure interaction

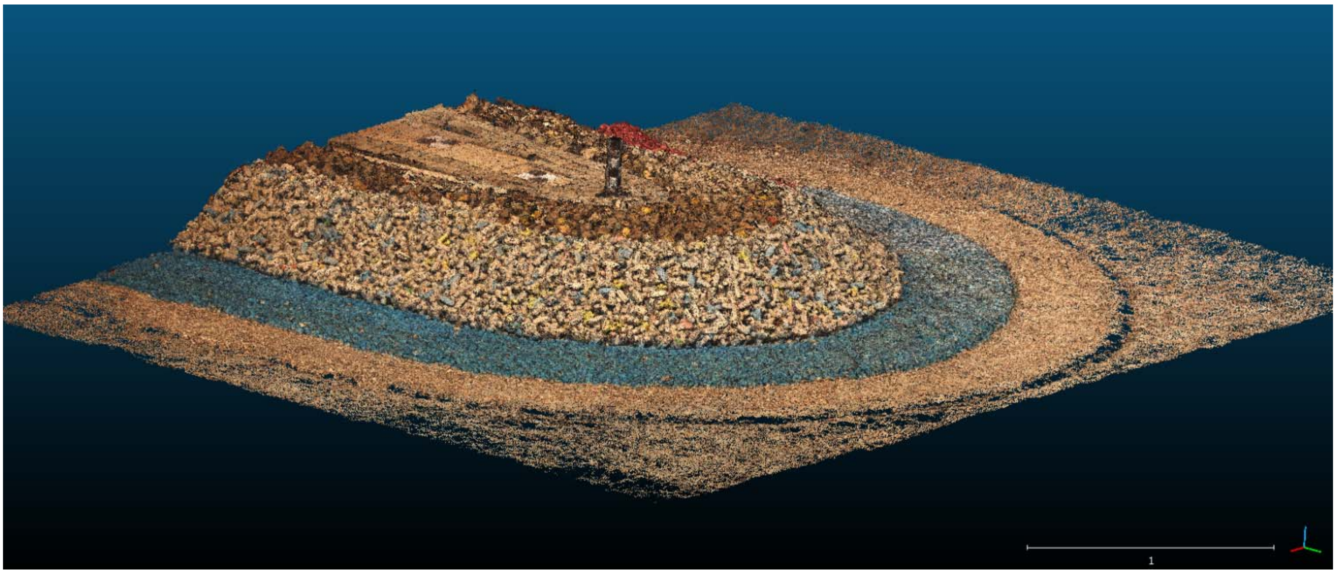


Fig. 27. 3D digital elevation model for stability analysis

Fig. 28. 3D digital elevation model for stability analysis

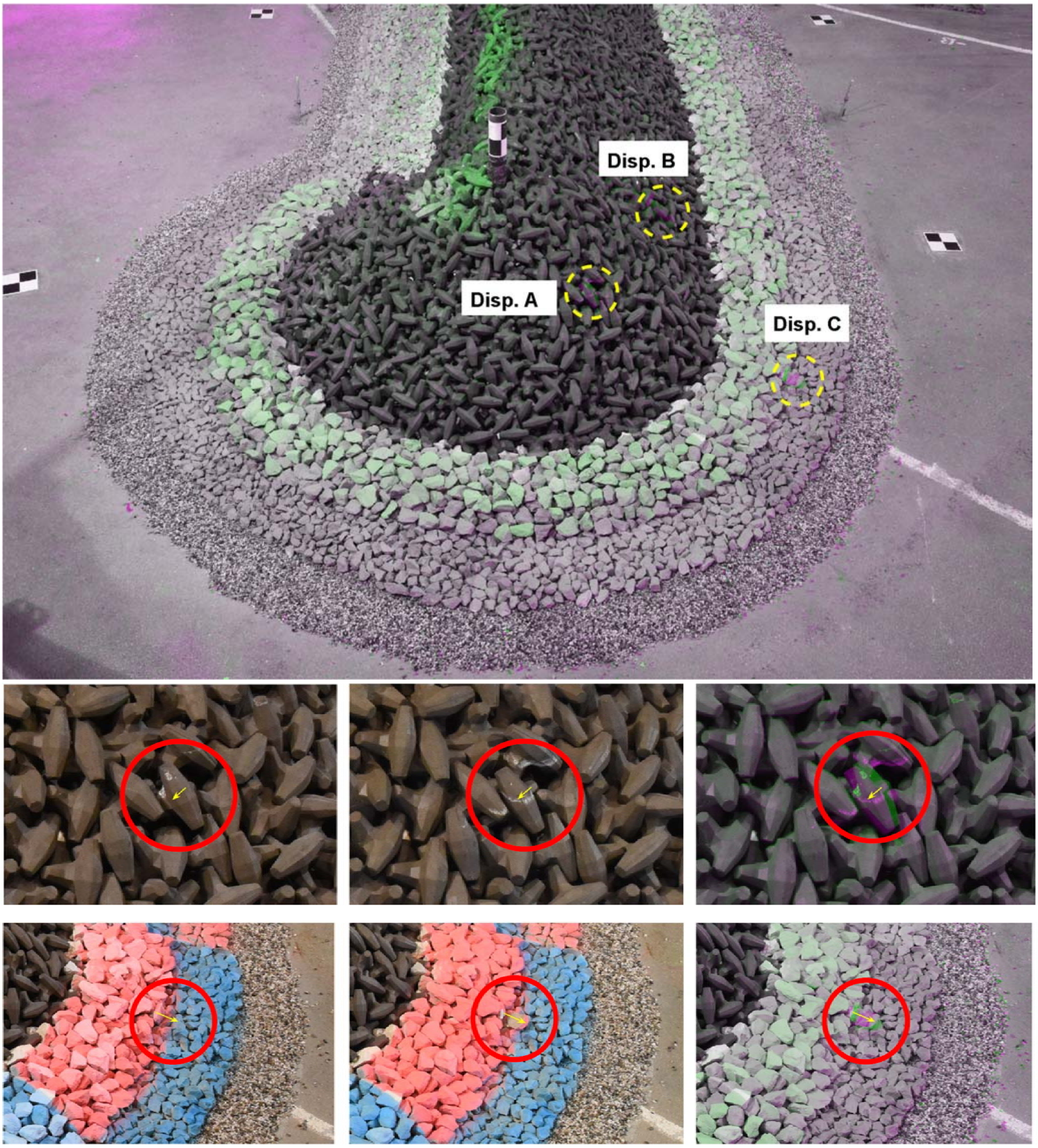


Fig. 29. Results of photographic overlay technique

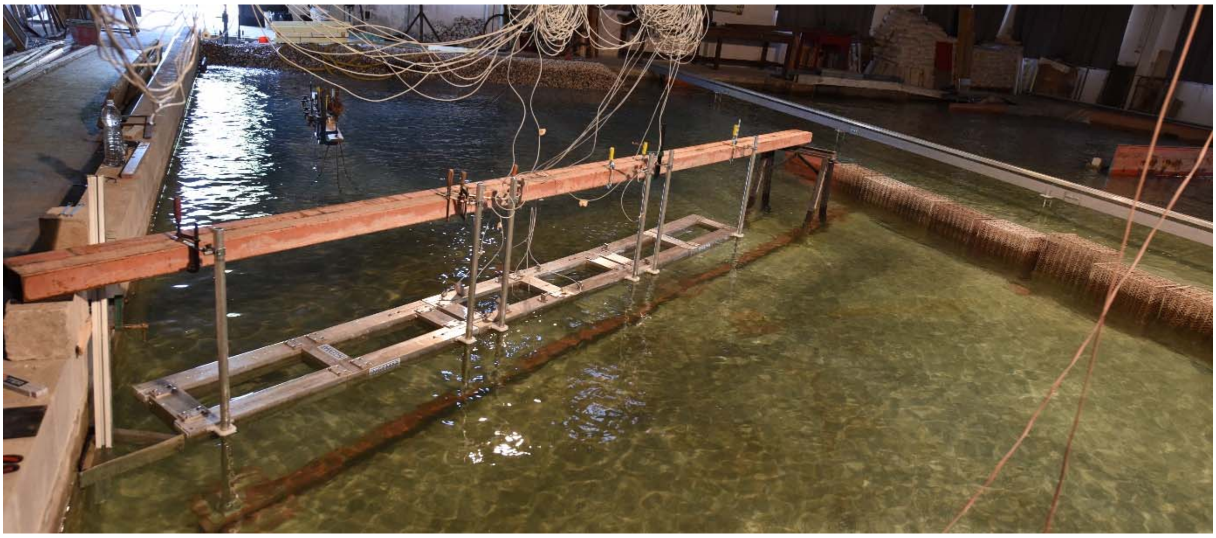


Fig. 30. Floating structures (evaluation of loads)

Wave generation

The Wallingford Wave Generation Software is used to operate the wave makers both in the basin and in the flume, capable of reproducing regular and irregular waves.
Irregular waves are typically generated according to a JONSWAP spectrum using a white noise filter with random phase and amplitude, with a cycle of 20 minutes. The software can generate other standard or custom defined spectra.
A self-made software has been developed to generate waves correct at second order for research testing. A hardware wave absorption system is present, installed at the wave flume.

Instruments

The measuring devices in use in the maritime laboratory are shortly summarized hereafter:

- wave gauges (several resistive gauges of different length),
- strain gauges (of different shape, weight and design load),
- electronic water discharge measuring instruments,
- pressure transducers,
- displacement meters,
- automatic bottom profilers (laser and touch-sensitive probes),
- a current flow meter (micropropeller),
- an air flow meter,
- digital camera and video recording equipment interfaced with a photographic overlay technique,
- laser level and laser measuring device,
- logging system can sample up to 50kHz,
- the flume and basin are also equipped with suitable software for wave generation and data acquisition from all instruments, and for the analyses of the results with the most updated methods,
- energy backup system of 20 minutes,
- workstation for numerical simulations equipped with Tesla K80 GPU card.

Control rooms are equipped with wired and wi-fi internet and intranet connections.

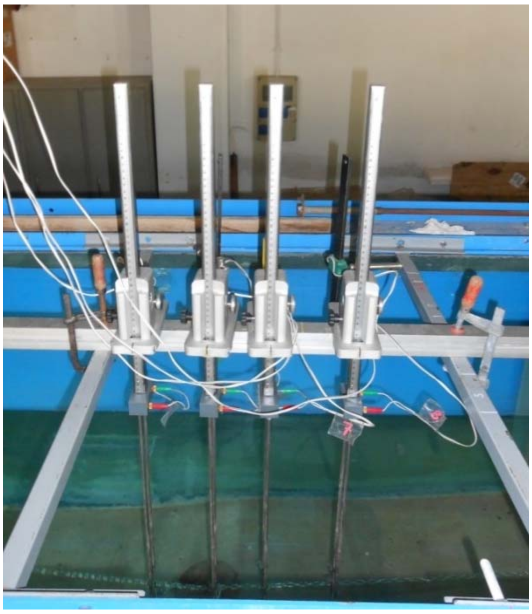


Fig. 31. Resistive wave gauges: large (left) and small (right)

Fig. 32. 2D bed profiling system

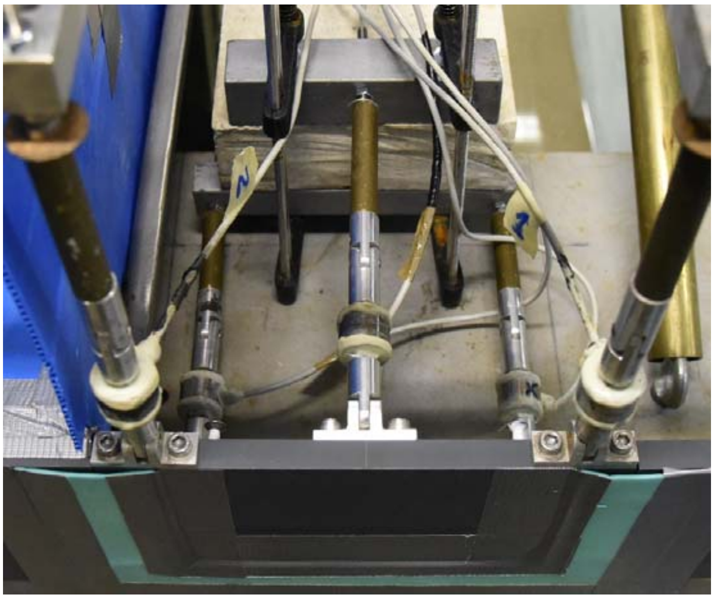


Fig. 33. Strain gauges

Principal research activities, since 2010

Studio su modello fisico sul potere di riflessione della banchina del porto di Tremestieri (ME) **2D physical model tests on the reflection phenomenon induced by the quaywall of Tremestieri harbour**	CO.ED.MAR	2010
Esecuzione di prove sperimentali su un modello di wec (wave energy converter) in canale ad onde dotato di sistema di ricircolo delle correnti. **2D physical model tests on a WEC (wave energy converter) under wave and current actions**	DISTART (Univ. Bologna)	2010
Studio su modello fisico del dispositivo di conversione dell'energia ondosa denominato "Seabreath" **2D physical model tests on the efficiency of a WEC (wave energy converter) called "SEABREATH"**	SEABREATH (Merighigroup)	2011
Studio su modello fisico 2D sulla trasmissione e stabilità del nuovo sistema antierosione con barriera sommersa **2D physical model tests on the transmission and stability of a new type of submerged coastal protection barrier**	EDIL IMPIANTI	2011
Studio su modello fisico sul potere di riflessione del lato interno del Prolungamento Antemurale Colombo del Porto di Civitavecchia (RM) **2D physical model tests on the reflection phenomenon induced by the quaywall of Civitavecchia harbour**	COEDMAR	2012
Studio su modello fisico sul comportamento di alcuni dispositivi frangionde galleggianti del tipo a pi-greca (Pile restrained, FCA 20x4, 100 tons and 20x6, 120tons) **2D physical model tests on the behavior of some P-type floating breakwater (Pile restrained, FCA 20x4, 100 tons and 20x6, 120 tons)**	INGEMAR	2012
Studio su modello fisico bi-dimensionale sul comportamento delle due opere esterne (molo di sopraflutto) del Porto turistico di Capo d'Orlando (ME) **2D physical model tests on the behavior of 2 different rubble- mound breakwaters of Capo D'Orlando harbour**	Ing. Giuseppe Franco (RC)	2012
Studio su modello fisico bi-dimensionale del comportamento delle opere esterne dell'approdo in San Bartolomeo al Mare (IM) **2D physical model tests on the behavior of rubble- mound breakwater of Capo San Bartolomeo al Mare harbour**	Comune di SBM	2012
Indagine sperimentale su una barriera frangionde costituita da elementi monoblocco galleggianti in cls armato denominati "BW 500" **2D physical model tests on the behavior of a concrete floating breakwater called BW 500**	Sistema WALCON (FE)	2013

Studio su modello fisico sulla interazione onda-struttura in riferimento al nuovo molo del terminal Petroli di Aliaga, Turchia **Wave flume experimental investigation on the wave-structure interaction for the new jetty of the Refinery Marine Terminal, Aliaga, Turkey**	Piacentini Costruzioni (MO)	2013
Contratto di Ricerca per la modellazione numerica di sistemi di ancoraggio di dispositivi per la conversione di energia ondosa **Research activity concerning the numerical modelling of WEC (Wave Energy Converters) under different mooring systems**	Dip. DICAM, Università di Bologna	2013
Studio su modello fisico bidimensionale del comportamento di un mega-frangionde galleggiante in ferrocemento **2D physical model tests on the behavior of a very large floating breakwater in ferrocement**	Porti Galleggianti (CA)	2014
Indagine sperimentale nel canale ad onde sull'interazione fra onde ed una nuova banchina assorbente **2D physical model tests on the behavior of a new absorbing-type quaywall under wave attacks**	Piacentini Costruzioni (MO)	2014
Coordinamento del progetto di ricerca "Gestione Integrata della Zona Costiera. Progetto per lo studio e il monitoraggio della linea di costa per la definizione degli interventi di difesa dei litorali dall'erosione nella Regione Veneto" **Integrated Coastal Zone Management for the Veneto Region**	Regione Veneto	2014
Studio su modello fisico bidimensionale del progetto Mamaia Sud in Romania **2D physical model tests for the Mamaia Sud project in Romania**	PORR Bau GmbH	2014
Studio su modello fisico bidimensionale di un nuovo convertitore di energia chiamato SloWED **2D physical model tests on the behavior of WEC (Wave energy converter) called SloWED**	SloWED	2015
Studio su modello fisico bidimensionale del comportamento di un frangiflutti galleggiante (FCA 12x6, 150 tons) **2D physical model tests on the behavior of a floating breakwater (FCA 12x6, 150 tons)**	INGEMAR Srl	2015
Progetto ENI: "Sand Engine" – Studio su modello fisico tridimensionale in condizioni di fondale mobile **3D physical model tests on the behavior of a large beach nourishment Sand Engine" – 3D model tests in movable bed conditions**	D'Appolonia S.p.A.	2015
Studio su modello fisico della riflessione indotta dalla costruenda banchina interna nella darsena Nord del porto di Piombino **2D physical model tests on the reflection phenomenon induced by the new Northern quaywall in Piombino harbor**	NUOVA CO.ED.MAR.	2015
Progetto di ricerca sul ripascimento artificiale tramite pennelli in sabbia (3D tests) **Research project on beach nourishment: Sand groins 3D movable bed tests**	Univ. Padova	2016

Indagine sperimentale 2D e 3D su una barriera frangionde a moduli con composizione variabile, denominata FCA-CMV **2D and 3D experimental analyses on wave transmission and loads on interconnections between modules of a new floating breakwater**	INGEMAR Srl	2016
Studio su modello fisico della stabilità del piede del molo di Lido di Venezia-ACCROPODE™ **3D roundhead stability tests for Venice Lido jetty with ACCROPODE™**	Thetis SpA	2016
Studio su un modello fisico 2D delle sollecitazioni applicate al muro paraonde dell'Antemurale Cristoforo Colombo nel porto di Civitavecchia (Roma) **2D physical model tests on the wave load applied on the recurved parapet wall of the vertical breakwater in Civitavecchia (Rome)**	Pietro Cidonio SpA	2016
Studio parametrico su un modello fisico 2D delle sollecitazioni applicate a un muro paraonde ricurvo **Experimental investigation on the effect of the parapet shape on the wave load applied to a vertical breakwater**	Univ. Padova	2016
Indagine sperimentale 2D e 3D del comportamento della diga in CoreLoc per il porto di Mirbat (Oman) **Experimental investigation in wave flume (2D) and in wave basin (3D) on the behaviour of the breakwater of the fishery Harbour at Mirbat (Sultanate of Oman)**	Sering International LLC	2017
Indagine sperimentale 2D del comportamento della diga in CoreLoc per il porto di Lima (Oman) **Experimental investigation in wave flume (2D) on the behaviour of the breakwater of the fishery Harbour at Lima (Sultanate of Oman)**	Sering International LLC	2017

Recent publications in international journals based on laboratory results

Comola F., Andersen T.L., Martinelli L., Burcharth H.F., Ruol P. (2014): Damage pattern and damage progression on breakwater roundheads under multidirectional waves. Coastal Engineering 2014, 83(1) 24-35.

Mendoza E., Silva R., Zanuttigh B., Angelelli E., Andersen T.L., Martinelli L., Nørgaard J., Ruol P. (2014): Beach response to wave energy converter farms acting as coastal defence. Coastal Engineering 2014, 87(5), 97-111.

Martinelli L, Pezzutto P. and Ruol P., (2013): Experimentally based model to size the geometry of a new OWC device, with reference to the Mediterranean Sea wave climate, Energies 2013, 6(9), 4696-4720.

Ruol P., Martinelli L, Pezzutto P. (2013): Formula to Predict Transmission For Π-Type Floating Breakwaters (2013), Journal of Waterway, Port, Coastal, and Ocean Engineering 2013, 139(1) -8

Martinelli L., Ruol P., Zanuttigh B. (2008): Wave basin experiments on floating breakwaters with different layouts, Applied Ocean Research, 30(3), July 2008, 199-207.