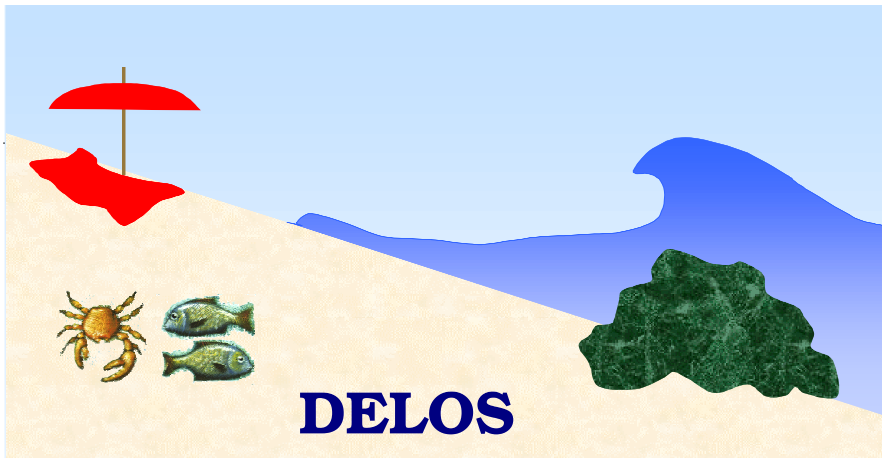
EU Fifth Framework Programme 1998-2002
Energy, Environment and Sustainable Development

Environmental Design of Low Crested Coastal Defence Structures



Deliverable 32

Wave channel experiment
Final Form

Contract n°EVK3-CT-2000-00041

D32. Wave channel experiments final form

Environmental design of low crested coastal defence structures. (DELOS)

EU Fifth Framework Programme 1998-2002. Energy, Environment and Sustainable Development

1. Introduction and objectives.

The laboratory experiments described here are part of the research carried out for the European Project DELOS "Environmental **De**sign of **Lo**w Crested Coastal Defence **S**tructures". These experiments are part of workpackage 2.4 of Research Task 2, dedicated to the hydrodynamics, morphodynamics and structural design of these structures.

The objective of these experiments is to provide calibration data for numerical and empirical models of flow (wp 2.1), morphodynamics (wp 2.2), functionality and stability (wp 2.3) and some insight on scale effects. Output from these tests as flow velocity and drag forces will also be used for Research Task 3, dedicated to ecology impact.

The laboratory tests have been carried out on the laboratories of the University of Cantabria (UCA) and on the Polytechnic University of Catalonia (UPC). Three partners, UCA, University of Bolonia (UB) and University of Roma 3 (UR3) collaborated with researches and equipment in the tests at the University of Cantabria. Test at UPC where carried out by personnel and equipment of UPC.

This document describes the set-up and the tests results. The first part, dedicated to UCA tests has already been described in deliverable D10: Wave channel experiments preliminary form and it is included here to create a comprehensive document on DELOS wave channel experiments. The second part is dedicated to UPC tests.

2. UCA wave flume experiments.

2.1 Experimental set–up.

Experiments were carried out in the wave and current flume of the Coastal Laboratory of the University of Cantabria, during the months of June, July and August 2001.

2.1.1. Wave flume description.

The wave and current flume is 24 m long, 0.60 m wide and 0.80 m high. The piston–type wavemaker has two attached free surface wave gauges integrated in an Active Wave Absorption System (AWACS ®) that allows the absorption of reflected waves from the model. The wavemaker and the rear absorbing beach occupy 4 m at one of the ends of the flume; another 4 m are occupied by a false bottom that can be partially or totally removed to set off a current in the flume. The reversible pumping system has two pumps with a combined maximum discharge of 150 l/s. The remaining 16 m of the flume are available for the testing of models. Bottom and side walls of the testing area are made of glass, allowing the use of LDA or PIV velocity measurements.

2.1.2. Low crested structure model.

Two rubble mounds, low crested structures with 0.25 m and 1.00 m crest width, were tested. Crest elevation from the bottom (0.25 m), front and back slope angles (1V / 2H) and rubble characteristics were maintained constant for both structures. The models had a two-layer armour of selected gravel and a gravel core. Armour and core characteristics are shown in Table 1.

	W_{15} g	W_{50} G	W_{85} g	Porosity -	Density Kg/m^3
Armour	119	153	206	0.53	2647
Core	3.14	4.31	5.60	0.49	2607

Table 1. Characteristics of the gravels used for the models

The low crested structure model was built over a 3.8-m long stainless steel horizontal false bottom, 0.10 m over the glass bottom of the flume, figure 1. In the frontal foot of the rubble, a Plexiglas ramp with 1V / 20 H slope connected the false bottom with the bottom of the flume. In the rear end, another 8-m 1V / 20H Plexiglas ramp simulated the rear beach. Between the horizontal and the inclined false bottom, one rectangular aperture, 0.08 m wide, allowed the water to flow below the beach to the return piping system. When the waves piled-off water behind the breakwater, the head drove the returning flow through the piping system to the false bottom in front of the wavemaker, closing the circuit.

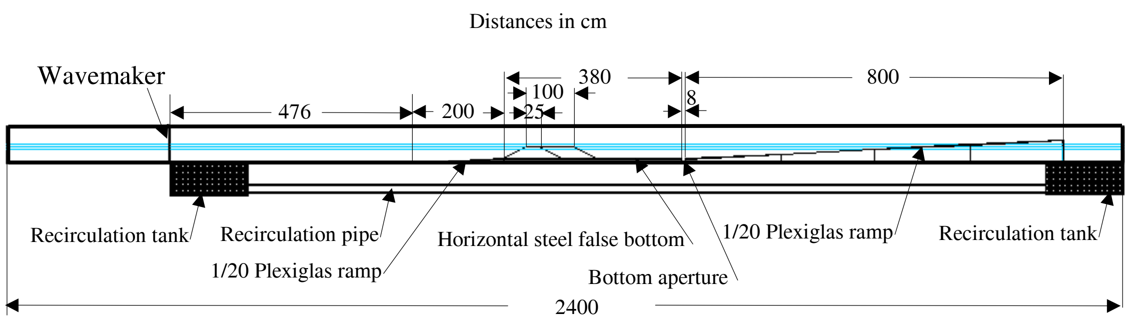


Figure 1. Experimental set-up

2.1.3. Instrumentation.

The following instruments and gauges were installed in the flume:

15 resistive free surface gauges to assess free surface evolution and run-up on the beach.
3 pressure gauges inside the structure rouble.
1 3-D Acoustic Doppler Velocimeter (ADV).
8 Acoustic Doppler Profilers (ADP) 1 Mhz
7 ADP 4 Mhz

12 Laser Doppler Velocimeter measurement points
1 Digital video camera

The coordinate origin, see figure 2, was chosen at the intersection of the frontal ramp with the bottom of the flume. This origin was located 476 cm from the wavemaker and 200 cm before the outer edge of the LCS front slope. Positive X axis direction was opposite the wavemaker. The positive Z coordinate was upwards from the bottom of the flume.

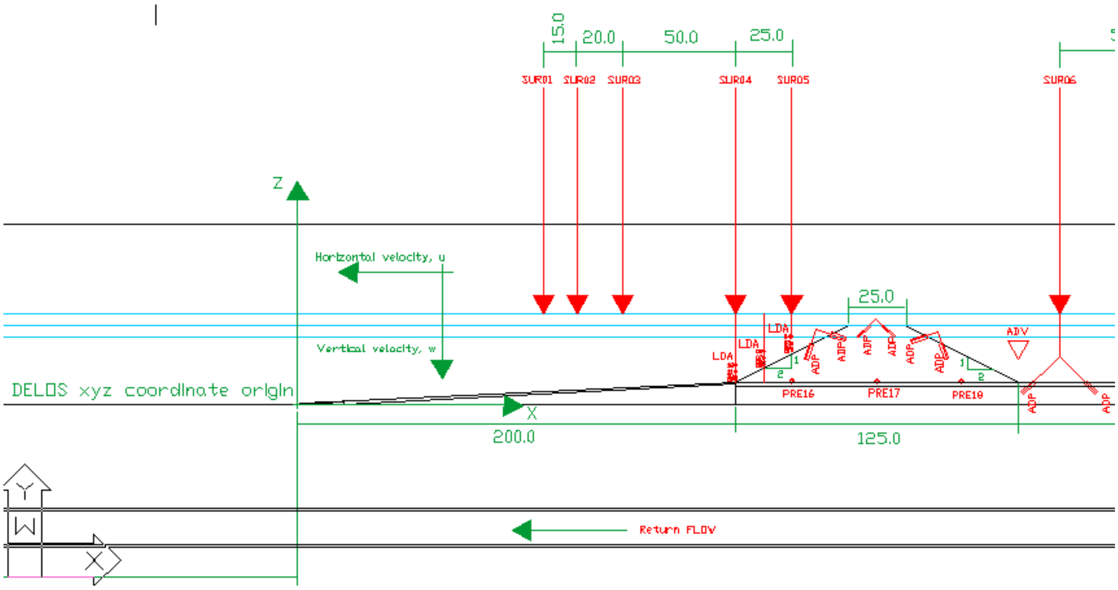


Figure 2. Coordinate system, instruments and measurement points in front of the LCS

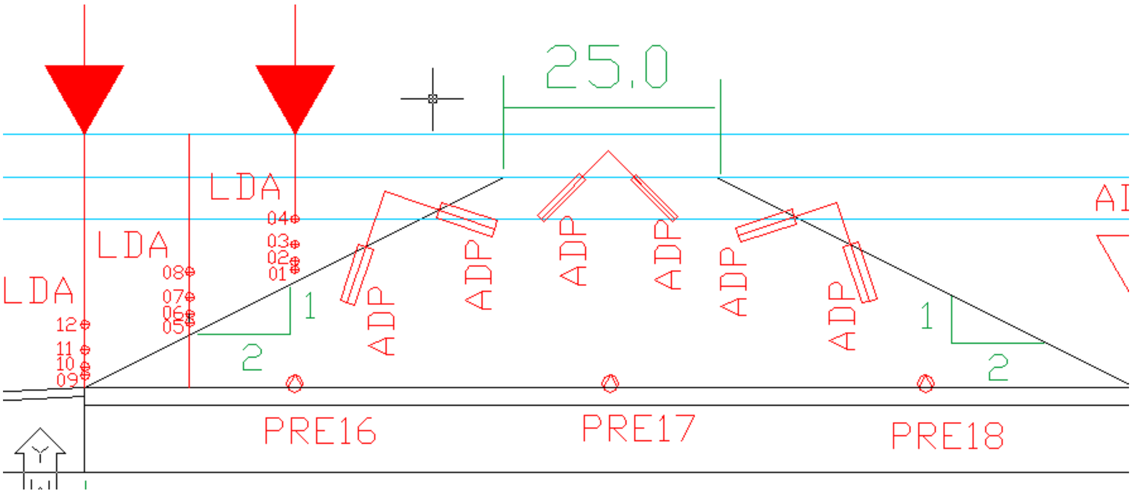


Figure 3. Close–up of the instruments over and on the LCS.

Three (3) free surface gauges were installed in the slope in front of the LCS to separate incident and reflected waves, figure 2. Another two free surface gauges were located over the front slope of the structure at the same X locations of two of the LDA measurement profiles. Six free surface gauges measured transmitted waves in the flat bottom behind the LCS, figure 4. Two of these free surface gauges were located in the intersection of the beams of the two pairs of 1-MHz LDP installed in this area. Three more free surface gauges were installed in the beach slope, one of them over the intersection of the beams of the pair of 4-MHz ADP installed there, figure 5. Finally, the last free surface gauge was laid over the swash zone to measure run up, figure 5.

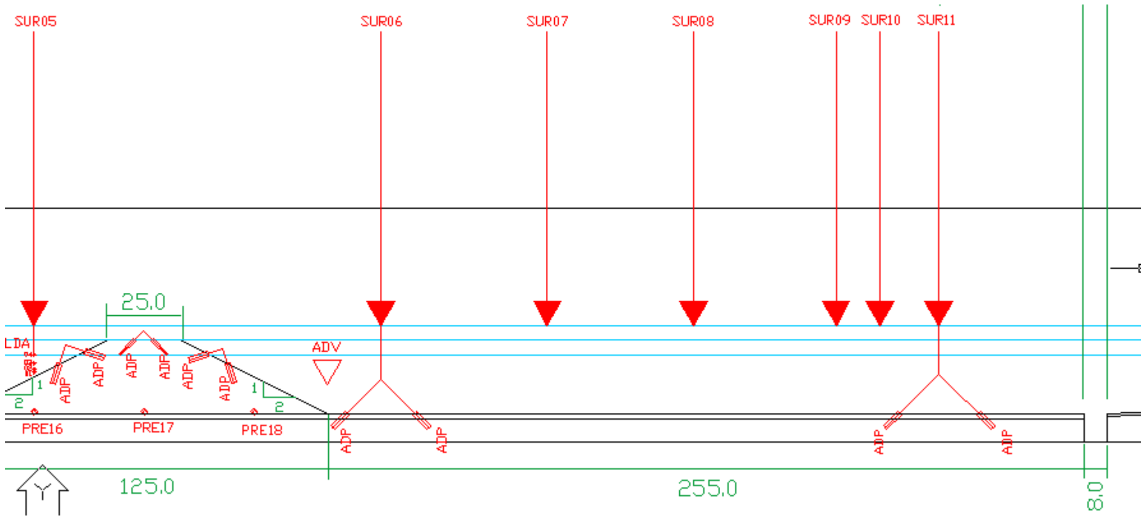


Figure 4. Instruments on the flat bottom behind the LCS.

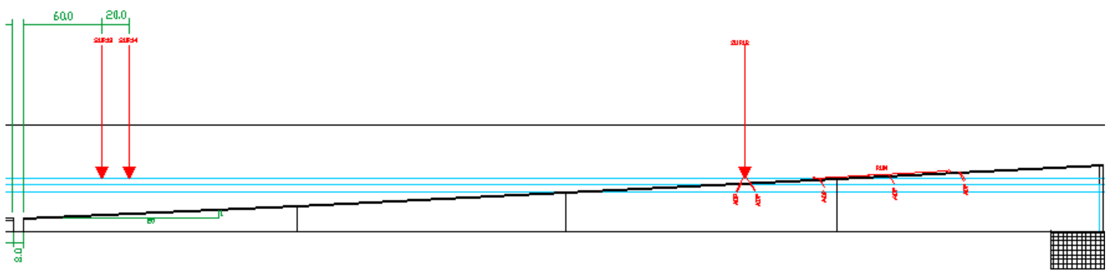


Figure 5. Instruments over the beach slope.

The pressure gauges, see figure 3, were installed over the bottom, inside the LCS structure core, to measure the wave transmission inside the porous rubble. These sensors were attached to the steel frame built inside the LCS for that purpose.

The ADV, figure 4 and photo 1, was located in the lee side of the LCS to measure the complex flow behind the structure.

Six ADPs were installed in pairs on the structure, attached to a steel frame, see figure 3 and photo 2. As installed, the head of these sensors were just protruding from the rubble surface, photo 3, allowing the measurement of flow velocity in the direction of the beam in points 2 to 3 mm apart. As the pair of beams converge, the two convergent beams allowed the measurement of U, W velocities in the areas where the two beams meet. Another four ADP (two pairs) were installed on the false horizontal bottom in the transmission area behind the LCS, photos 4 and 5. Another pair of ADPs were on the beach ramp before the swash zone and finally, three more individual ADPs measured velocities in the swash zone, photo 6.

Photo 1. ADV measuring behind the LCS back slope.

LDA measurements of U, W velocities were taken at 12 points in the front slope of the LCS, see figure 3 and photo 7.

A digital video camera, photo 8, was used to record the free surface over the LCS. To help the calibration of the pictures, a 1-cm square grid, was attached to the flume glass.

Photo 2. ADPs attached to the steel frame before laying the core and armour stones.

Photo 3. ADPs just protruding from the surface of the LCS armour.

Photo 4. ADPs attached to the steel false bottom to be installed horizontally in the transmission zone. Photograph from below the plate

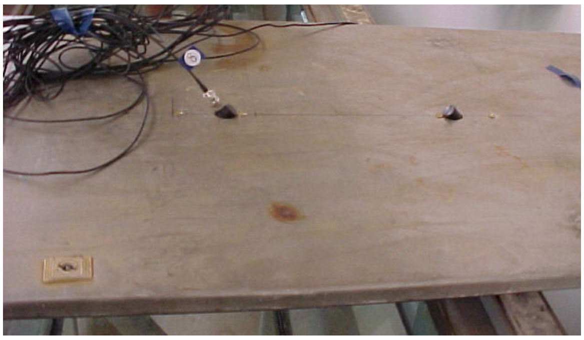


Photo 5. ADPs attached to the steel false bottom to be installed horizontally in the transmission zone. Photograph from above the plate.

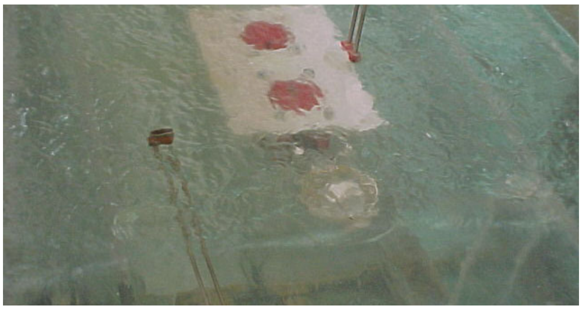


Photo 6. Pair of ADPs attached to the Plexiglas false bottom on the beach. The run-up gauge is also shown.

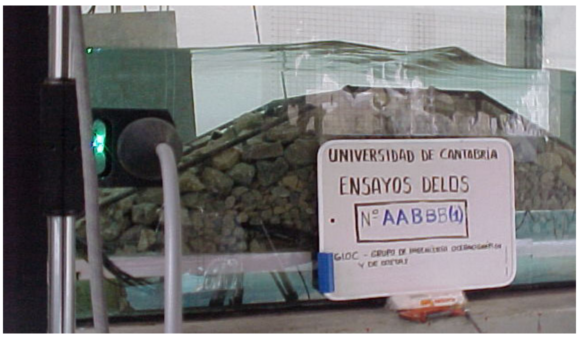


Photo 7. LDA measuring in the front slope of the LCS. The square grid for the video camera is also shown attached to the flume glass.

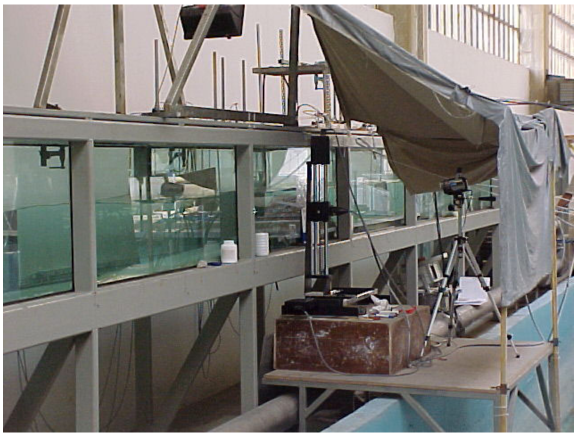


Photo 8. LDA traversing system and video camera.

Finally, an acoustic probe was used to measure the return flow due to the set-up behind the structure. This flow was measured on the pipe of the current system installed in the flume.

A similar instrumentation was prepared for the 1.0-m crest width. In this case, two free surface gauges were placed over the structure at the same location as the ADPs, photo 9.

Photo 9. Free surface gauges over the structure for the 1.0-m crest width.

2.2. Wave tests.

Two different models (crest width 0.25 and 1.00 m) were tested for three different water depths, or three freeboards (-0.05, 0, and 0.05 m). The total number of different wave conditions was 54 for regular waves and 54 for irregular waves. Target wave conditions are indicated in table 2.

The ADP signal processor allowed only the processing of a limited number of signals from the ADP probes. Depending on the water depth and model type, several repetitions of the same wave signal were necessary in order to obtain information from all of the ADP probes. From the original 108 tests, 374 tests (see the complete test table in DELOS.XLS) were necessary to cover all of the ADP points.

Type	Regular	Irregular
H – Hs (m)	0.05, 0.10, 0.15	0.04, 0.07, 0.10
T - Tp (s)	1.6, 2.4, 3.2	1.6, 2.4, 3.2
L (m)	2.53 to 6.17	
H/L	0.00810 to 0.0593	
F/H	-1.00 to 1.00	
B/L	0.0405 to 0.395	
H/h	0.125 to 0.500	
h/L	0.0486 to 0.158	

Table 2. Target parameters for generated waves.

Due to the fact that laser measurements are taken only in one point at a time, for regular waves the laser sensor measured consecutively several wave periods in all 12 points, without stopping the wave generation. In this case, all of the LDA measurement points belong to the same test. As the ADP measurements forced the repetition of the tests, in these repetitions there were laser measurements in one single point or no measurements at all. For irregular waves, one long LDA record was taken in only one point for each wave test. Each time the same wave conditions were repeated (to allow other ADP points to be taken) another LDA measurement was taken in a different point. Depending on the number of ADP repetitions, between 1 and 6 LDA points were taken for irregular tests.

2.3. Data management.

There were four computers controlling the data acquisition process: ADP, ADV, LDA and Control (Wave gauges, pressure gauges and wave generation). Data files were primarily stored in the controlling computers in binary form, so quite a lot of post-processing was necessary to give the data set a manageable form. The stages of the post-processing were: data conversion, synchronization and data storage.

2.3.1. Data conversion and synchronization.

Data from ADV, ADPs and LDA were stored in binary form in their respective computers. First these files were decompressed and transformed to ASCII format. A phase cross-correlation method was used to synchronize signals repeated in several computers.

2.3.2. Data storage

Due to the great amount of data, a lot of work has been expended on the format of data storage. Diagram on figure 6 summarizes the stages of the data base creation.

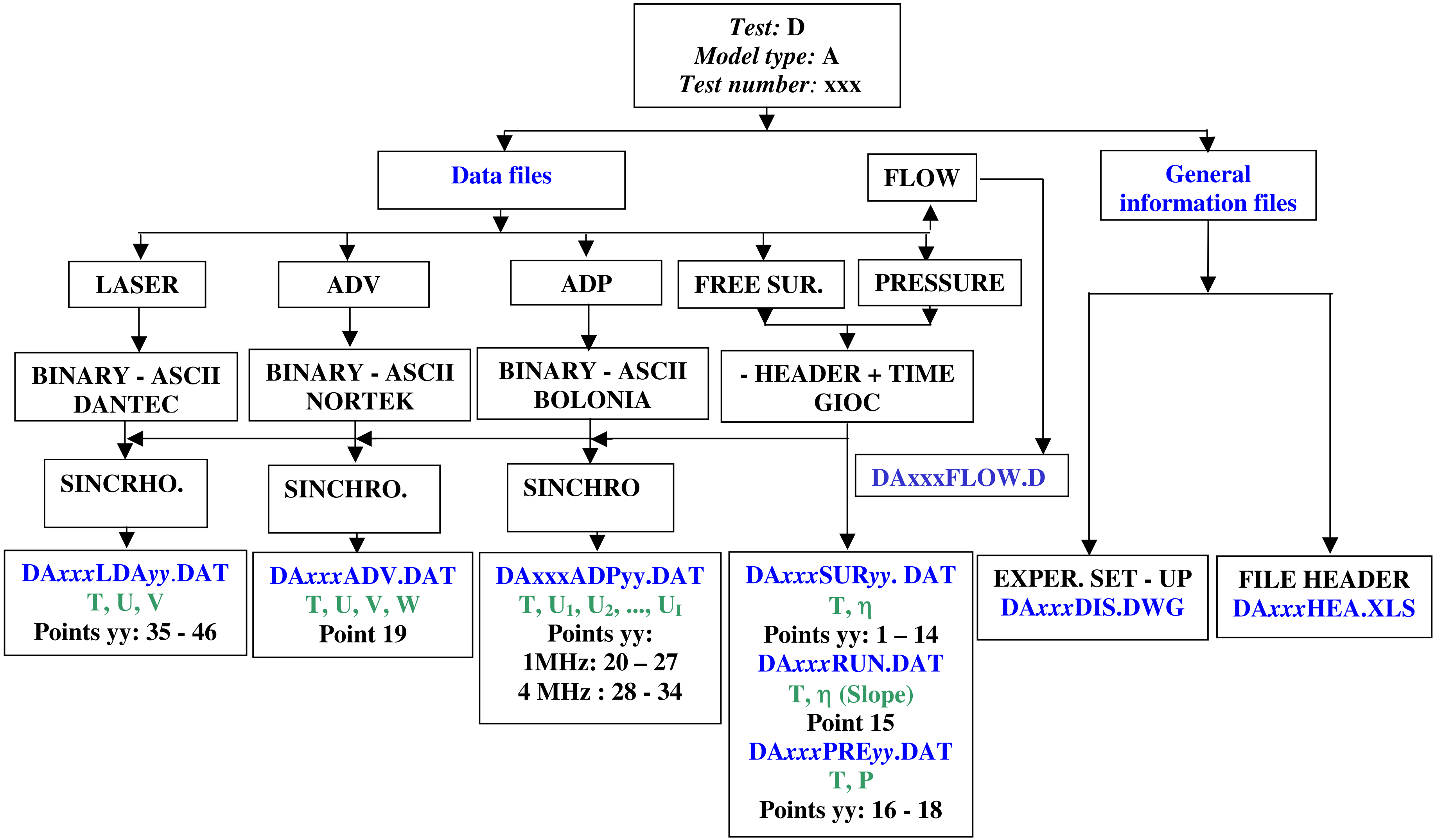


Figure 6. Diagram of data processing

Each test is defined by a set of wave conditions and a given sensor set-up. Each test produces two general information files and several data files. All the files corresponding to the same test have the same key name composed of 5 ASCII digits. The first digit is always "D" from DELOS. The second digit is "A" for the tests with the model with 0.25 crest width and "B" for the model with 1.00 m crest width. The next three digits correspond to the test number.

The type of file is identified with another three or four digits:

LDA: Data from LDA sensor
ADV: Data from ADV sensor
ADP: Data from ADP sensor
SUR: Data from free surface sensor
PRE: Data from pressure sensor
RUN: Data from run-up sensor
FLOW: Data from the return flow sensor
DIS: Drawing with the set-up of the test
HEA: Header file with general information about the test

Finally, data files of one type taken with different sensors (or with the same sensor in a different position as in LDA measurements) are identified by two digits that indicate the measurement point. All data files are ".DAT" (ASCII files). The drawing file is Autocad (.DWG) and the header file is Excel (.XLS). As an example, the file DA016LDA42.DAT, means LDA U, W data taken at point 42 in the DELOS test 16, with a model with 0.25 m of crest width. Information about the position of point 42 in this test can be obtained from the header file or from the drawing file.

In the next sections, a short explanation of each file type will be carried out.

List of data files from one test.

All files from one test are compressed in a ZIP file. Figure 7 shows a part of the list of files corresponding to the test DA016.

Name	Modified	Size	Ratio	Packed	Path
DA016ADP28.dat	18/12/01 19...	1.952.885	87%	252.155	
DA016ADP29.dat	18/12/01 19...	1.957.241	87%	252.262	
DA016ADV.dat	18/12/01 19...	1.142.883	77%	262.511	
DA016DIS.dwg	28/12/01 14...	47.988	64%	17.097	
Da016flow.dat	10/01/02 19...	340	66%	114	
DA016HEA.xls	09/01/02 13...	23.552	79%	4.910	
DA016LDA35.dat	18/12/01 19...	78.068	76%	18.362	
DA016LDA36.dat	18/12/01 19...	95.275	79%	20.236	
DA016LDA37.dat	18/12/01 19...	454.863	81%	87.273	
DA016LDA38.dat	18/12/01 19...	378.563	81%	73.108	

Figure 7. Partial list of files for test DA016.

Drawing file.

As indicated, this file contains the experimental set–up for this test. This file is a .DWG Autocad file. Figure 8 shows the file DA016DIS.DWG. This file helps the user identify the location of sensors and model lay–out.

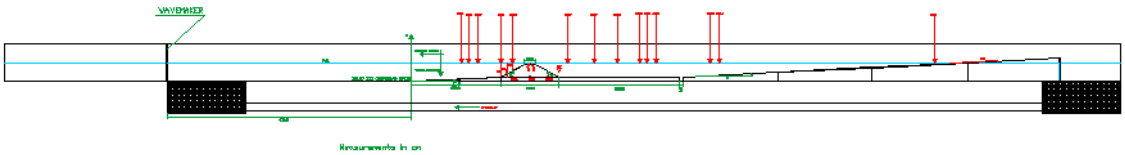


Figure 8. File DA016DIS.DWG

Header file.

This file is an EXCEL file that contains all of the information necessary to help interpretation of data files. The spreadsheet is divided into 8 sheets: General, Target waves, Free surface, Pressure, Velocity ADV, Velocity ADP, Velocity LDA and Return flow.

The General sheet, figure 9, contains general information about the test: laboratory, test facility, test type, date and hour of test, crest width of model and a line for notes. These notes include any further information about the quality of the data, the closure of the return flow, or any other special characteristic of the test to be taken into account.

	A	B	C	D	E	F	G	H
1	**Laboratory**	University of Cantabria						
2	**Test facility**	Wave and current flume						
3	**Test type**	DELOS flow						
4	**Date**	16/07/01						
5	**Hour**	13:06						
6	**Crest width (cm)**	25						
7								
8	**Notes**	See the AutoCAD drawing for details of coordinate orientation, velocity direction and general layout configuration.						
9								

General / Target waves / Free surface / Pressure / Velocity ADV / Velocity ADP / Velocity LDA /

Figure 9. Header file. General information sheet of file DA016HEA.XLS

The Target Waves sheet contains information about characteristics of target waves: Type of waves (Regular nonlinear or irregular), target wave height, target period, spectral type (monochromatic or irregular with TMA spectrum) spectral parameter γ, water depth at wavemaker, duration of time series, absorption of reflected waves (AWACS) and number of measurement points in the corresponding test. Figure 10 shows an example of the Target Waves sheet for file DA016HEA.XLS.

The Free Surface sheet, figure 11, gives the user valuable information about the set-up of free surface gauges: point of measurement, type of measurement (free surface), corresponding appendage of the file name (SUR01), measurement units (cm) and distance of the sensor to the coordinate origin. As the run-up sensor is of the same type, it is included in this sheet.

The Pressure, ADV, and LDA sheets are similar to the previous, see figures 12, 13 and 14 but indicate also the Z coordinate of the measurement point.

	A	B
1	**Type of waves**	Regular non linear
2	**Target wave height (cm)**	5
3	**Target period (s)**	2,4
4	**Spectral type**	Monochromatic
5	**Spectral parameter γ**	N/A
6	**Water depth at wavemaker (cm)**	40
7	**Duration of time series (s)**	1000
8	**AWACS**	Yes
9	**Measurement points**	34

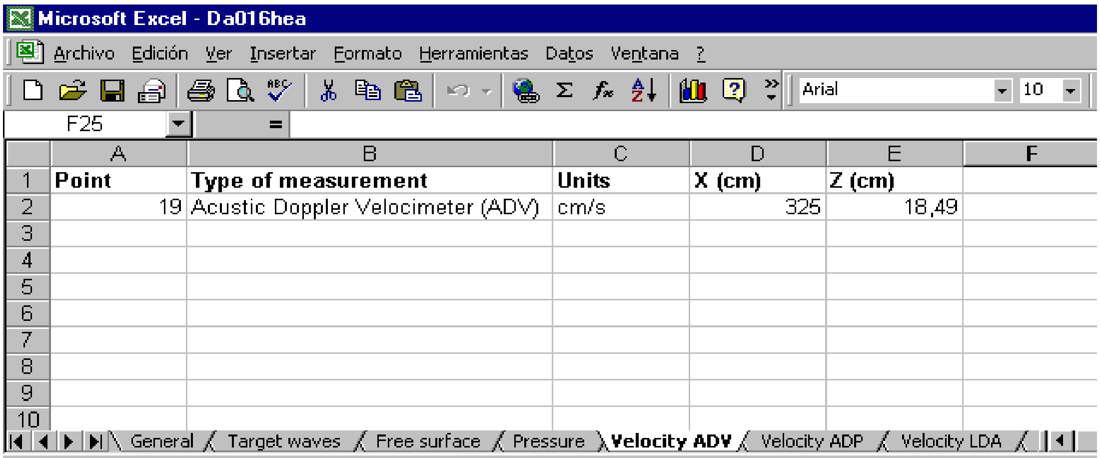
Figure 10. Target Waves sheet for file DA016HEA.XLS

	A	B	C	D
1	**Point**	**Type of measurement**	**Units**	**X (cm)**
2	1	Displacement of free surface relative to SWL (SUR01)	cm	115
3	2	Displacement of free surface relative to SWL (SUR02)	cm	130
4	3	Displacement of free surface relative to SWL (SUR03)	cm	150
5	4	Displacement of free surface relative to SWL (SUR04)	cm	200
6	5	Displacement of free surface relative to SWL (SUR05)	cm	225
7	6	Displacement of free surface relative to SWL (SUR06)	cm	343,3
8	7	Displacement of free surface relative to SWL (SUR07)	cm	400
9	8	Displacement of free surface relative to SWL (SUR08)	cm	450
10	9	Displacement of free surface relative to SWL (SUR09)	cm	468,5
11	10	Displacement of free surface relative to SWL (SUR10)	cm	513,5
12	11	Displacement of free surface relative to SWL (SUR11)	cm	533,5
13	12	Displacement of free surface relative to SWL (SUR12)	cm	1140
14	13	Displacement of free surface relative to SWL (SUR13)	cm	648
15	14	Displacement of free surface relative to SWL (SUR14)	cm	668
16	15	Free surface displacement on the beach relative to SWL (RUN)	cm	1188

Figure 11. Free Surface sheet for file DA016HEA.XLS

	A	B	C	D	E
1	Point	Type of measurement	Units	X (cm)	Z (cm)
2	16	Relative pressure (PRE16)	cm water column	225	10
3	17	Relative pressure (PRE17)	cm water column	262,5	10
4	18	Relative pressure (PRE18)	cm water column	300	10

Figure 12. Pressure sheet for file DA016HEA.XLS

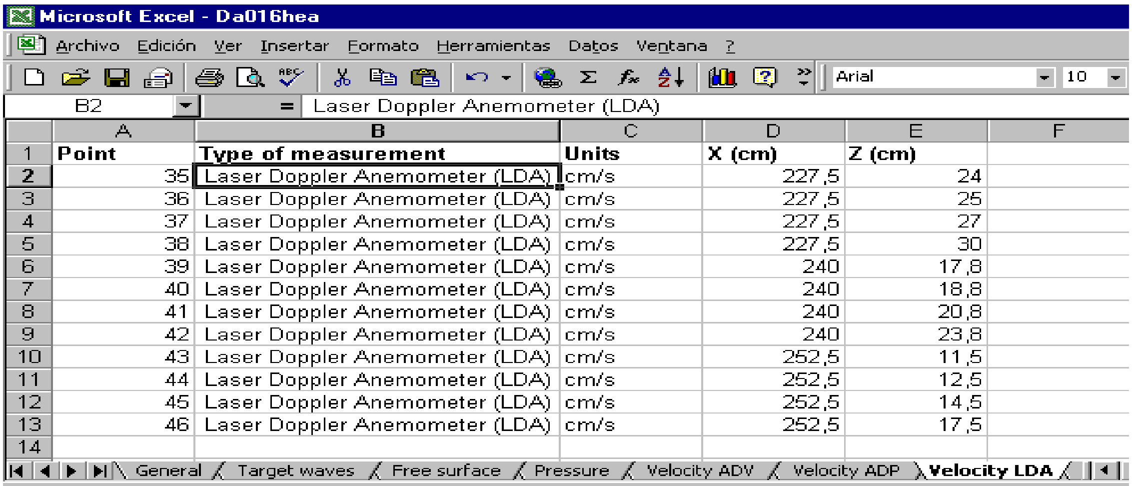


Microsoft Excel - Da016hea

Point	Type of measurement	Units	X (cm)	Z (cm)
19	Acustic Doppler Velocimeter (ADV)	cm/s	325	18,49

General / Target waves / Free surface / Pressure / Velocity ADV / Velocity ADP / Velocity LDA

Figure 13. ADV sheet for file DA016HEA.XLS



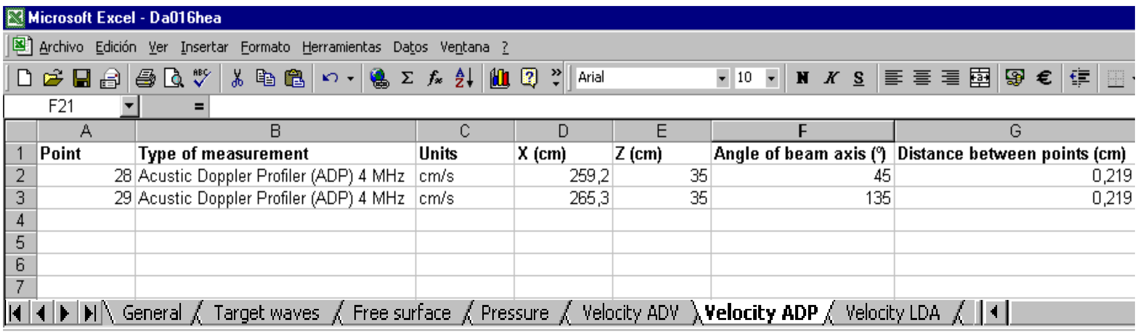
Microsoft Excel - Da016hea

B2 = Laser Doppler Anemometer (LDA)

Point	Type of measurement	Units	X (cm)	Z (cm)
35	Laser Doppler Anemometer (LDA)	cm/s	227,5	24
36	Laser Doppler Anemometer (LDA)	cm/s	227,5	25
37	Laser Doppler Anemometer (LDA)	cm/s	227,5	27
38	Laser Doppler Anemometer (LDA)	cm/s	227,5	30
39	Laser Doppler Anemometer (LDA)	cm/s	240	17,8
40	Laser Doppler Anemometer (LDA)	cm/s	240	18,8
41	Laser Doppler Anemometer (LDA)	cm/s	240	20,8
42	Laser Doppler Anemometer (LDA)	cm/s	240	23,8
43	Laser Doppler Anemometer (LDA)	cm/s	252,5	11,5
44	Laser Doppler Anemometer (LDA)	cm/s	252,5	12,5
45	Laser Doppler Anemometer (LDA)	cm/s	252,5	14,5
46	Laser Doppler Anemometer (LDA)	cm/s	252,5	17,5

General / Target waves / Free surface / Pressure / Velocity ADV / Velocity ADP / Velocity LDA

Figure 14. LDA sheet for file DA016HEA.XLS



Microsoft Excel - Da016hea

Point	Type of measurement	Units	X (cm)	Z (cm)	Angle of beam axis (º)	Distance between points (cm)
28	Acustic Doppler Profiler (ADP) 4 MHz	cm/s	259,2	35	45	0,219
29	Acustic Doppler Profiler (ADP) 4 MHz	cm/s	265,3	35	135	0,219

General / Target waves / Free surface / Pressure / Velocity ADV / Velocity ADP / Velocity LDA

Figure 15. ADP sheet for file DA016HEA.XLS

The ADP sheet, figure 15, also contains the information about the angle of beam axis of the sensor and the distance between points. The coordinates given correspond to the head of the sensor, so the coordinates of each profile should be calculated from the information given in this sheet.

Finally, the return FLOW sheet contains information about the units of the measurements.

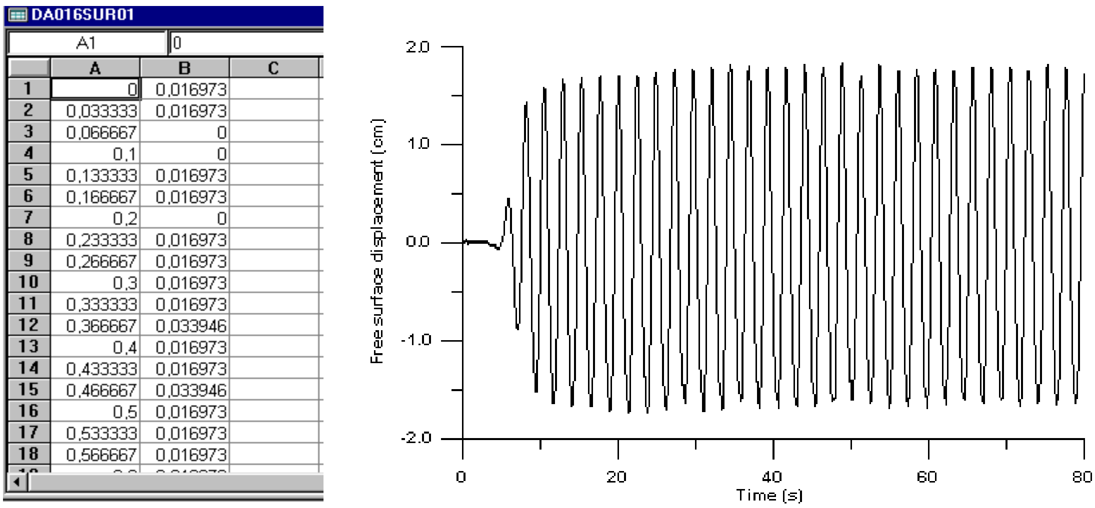
Note that only the measurement points included in the whole spreadsheet are available, if a particular sheet is empty, it means that no data is available for that measurement device.

Measured data files

Data files are ASCII files ".DAT" composed of a time column and one or several columns of data, depending on the sensor type. The name of the data files depends on the sensor type. The origin of time for all files corresponds to the initiation of wavemaker movement.

Free surface files.

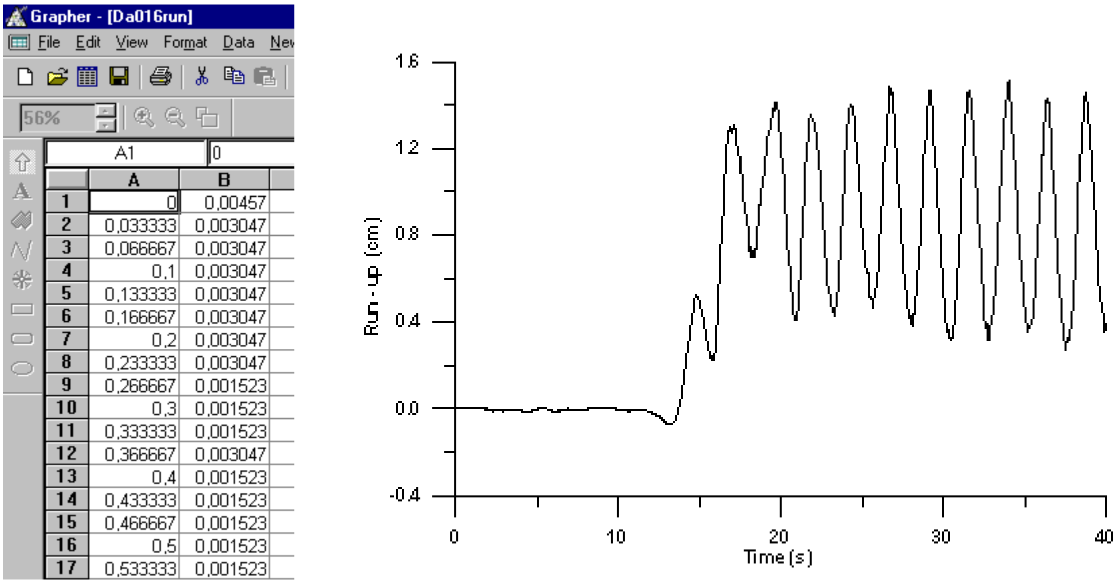
These files are composed of two columns: time and displacement of the free surface over the Still Water Level (SWL). Figure 16 shows a print and a time plot of a part of the file DA016SUR01.DAT, that is the free surface data corresponding to point 1 in test 16.


DA016SUR01

A1 0

	A	B	C
1	0	0,016973	
2	0,033333	0,016973	
3	0,066667	0	
4	0,1	0	
5	0,133333	0,016973	
6	0,166667	0,016973	
7	0,2	0	
8	0,233333	0,016973	
9	0,266667	0,016973	
10	0,3	0,016973	
11	0,333333	0,016973	
12	0,366667	0,033946	
13	0,4	0,016973	
14	0,433333	0,016973	
15	0,466667	0,033946	
16	0,5	0,016973	
17	0,533333	0,016973	
18	0,566667	0,016973	

Figure 16. Data file and plot of file DA016SUR01.DAT



	A	B
1	0	0,00457
2	0,033333	0,003047
3	0,066667	0,003047
4	0,1	0,003047
5	0,133333	0,003047
6	0,166667	0,003047
7	0,2	0,003047
8	0,233333	0,003047
9	0,266667	0,001523
10	0,3	0,001523
11	0,333333	0,001523
12	0,366667	0,003047
13	0,4	0,001523
14	0,433333	0,001523
15	0,466667	0,001523
16	0,5	0,001523
17	0,533333	0,001523

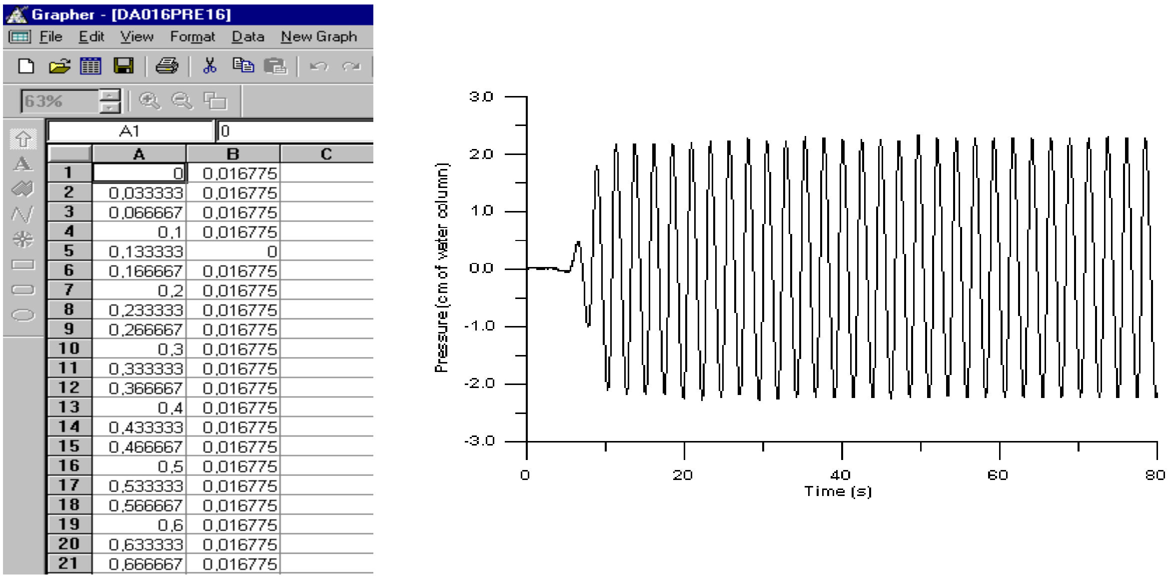
Figure 17. Data and plot of file DA016RUN.DAT

Run-up files.

These files have the same format as the free surface files. They have two columns, the second column corresponding to the measured run–up, i.e. the vertical distance between the SWL and the maximum instantaneous elevation of the water over the beach. Figure 17 shows the run–up for the file DA016RUN.DAT

Pressure files.

These files have the same format as free surface and run-up files. The second column represents the measured pressure. Figure 18 shows the data and time plot of a part of the file DA016PRE16.DAT, corresponding to the measured pressure in point 16 of test 16.



	A	B	C
1	0	0,016775	
2	0,033333	0,016775	
3	0,066667	0,016775	
4	0,1	0,016775	
5	0,133333	0	
6	0,166667	0,016775	
7	0,2	0,016775	
8	0,233333	0,016775	
9	0,266667	0,016775	
10	0,3	0,016775	
11	0,333333	0,016775	
12	0,366667	0,016775	
13	0,4	0,016775	
14	0,433333	0,016775	
15	0,466667	0,016775	
16	0,5	0,016775	
17	0,533333	0,016775	
18	0,566667	0,016775	
19	0,6	0,016775	
20	0,633333	0,016775	
21	0,666667	0,016775	

Figure 18. Data and plot of file DA016PRE16.DAT

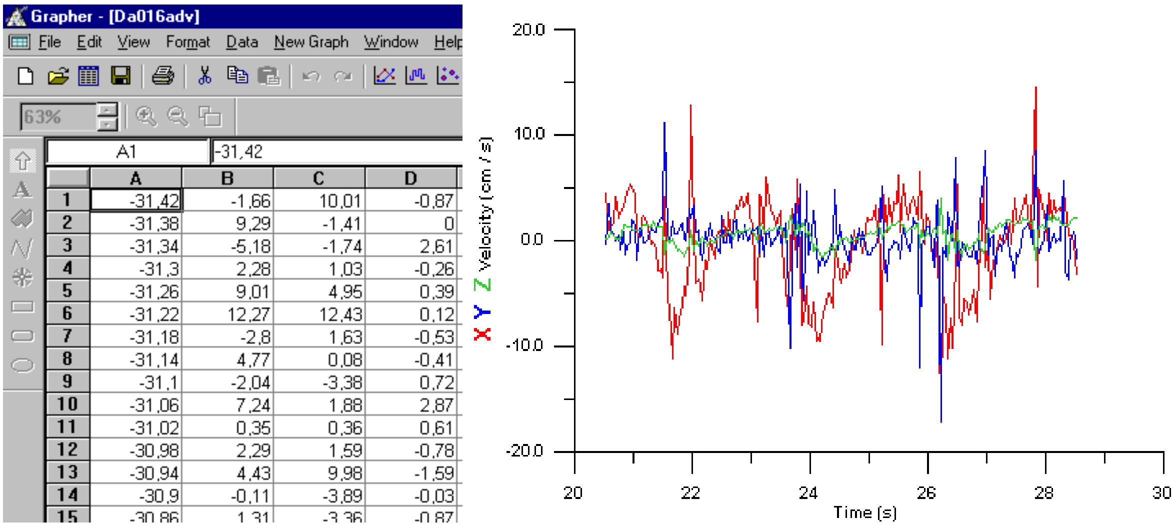


Figure 18. Data and plot of file DA016ADV.DAT

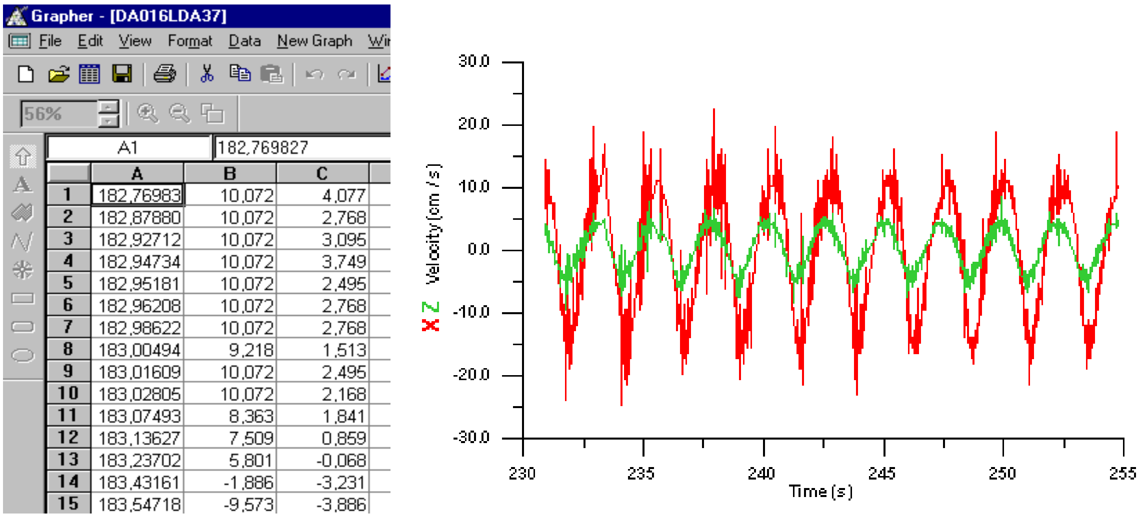
ADV files.

ADV data files have four columns: columns B, C and D correspond respectively to the measured U, V and W velocities. It is important to stress that the convention for the positive direction for velocities is indicated in the drawing file, i.e. the positive U is towards the wavemaker and the positive W is towards the bottom. The positive V follows the screwdriver rule. Figure 19 shows the data and a plot of the file DA016ADV.DAT

The quality of ADV files depends a lot on the seeding particles present in the flow. LDA seeding is not compatible with ADV or ADP seeding. As LDA measurements are more precise, LDA seeding was fed into the wave flume, worsening the quality of ADV measurements.

LDA files.

LDA data files have three columns: the second and third columns correspond respectively to the measured U and W velocities. Again, the convention for the positive direction for velocities is indicated in the drawing file, i.e. the positive U is towards the wavemaker and the positive W is towards the bottom. Figure 19 shows the data and a plot of the file DA016LDA37.DAT that correspond to the LDA data taken at point 37 for test 16.



Grapher - [DA016LDA37]

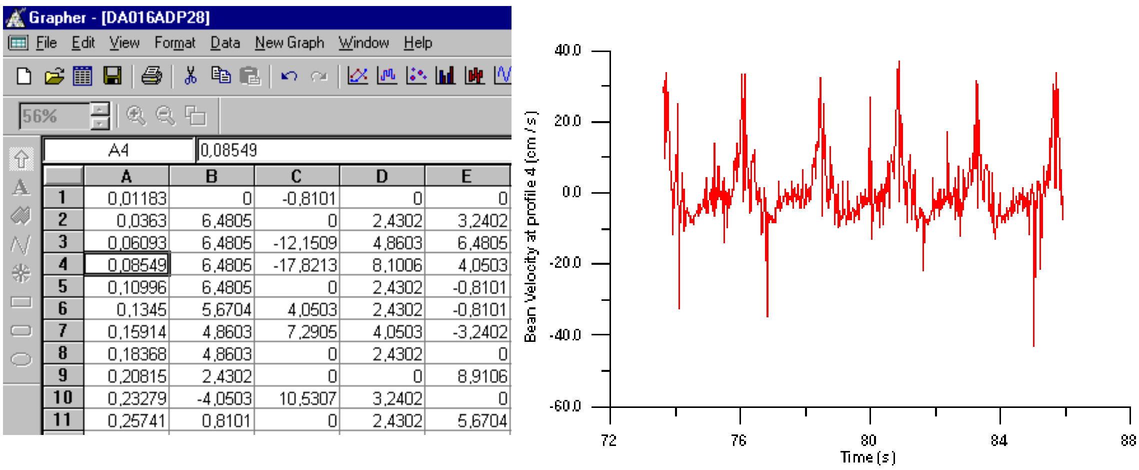
A1 182,769827

	A	B	C
1	182,76983	10,072	4,077
2	182,87880	10,072	2,768
3	182,92712	10,072	3,095
4	182,94734	10,072	3,749
5	182,95181	10,072	2,495
6	182,96208	10,072	2,768
7	182,98622	10,072	2,768
8	183,00494	9,218	1,513
9	183,01609	10,072	2,495
10	183,02805	10,072	2,168
11	183,07493	8,363	1,841
12	183,13627	7,509	0,859
13	183,23702	5,801	-0,068
14	183,43161	-1,886	-3,231
15	183,54718	-9,573	-3,886

Figure 19. Data and plot of file DA016LDA37.DAT

ADP files.

ADP data files have a variable number of columns: the first column corresponds to the time to the origin of wave generation and the successive columns are the measured velocity data in the direction of the acoustic beam corresponding to each profile. The separation between profile points is indicated in the ADP sheet of the corresponding header file. The positive direction of velocity is ???. Figure 19 shows the data and a plot of the file DA016ADP28.DAT that correspond to the ADP data taken at point 28 for test 16.



Grapher - [DA016ADP28]

A4 0,08549

	A	B	C	D	E
1	0,01183	0	-0,8101	0	0
2	0,0363	6,4805	0	2,4302	3,2402
3	0,06093	6,4805	-12,1509	4,8603	6,4805
4	0,08549	6,4805	-17,8213	8,1006	4,0503
5	0,10996	6,4805	0	2,4302	-0,8101
6	0,1345	5,6704	4,0503	2,4302	-0,8101
7	0,15914	4,8603	7,2905	4,0503	-3,2402
8	0,18368	4,8603	0	2,4302	0
9	0,20815	2,4302	0	0	8,9106
10	0,23279	-4,0503	10,5307	3,2402	0
11	0,25741	0,8101	0	2,4302	5,6704

Figure 19. Data and plot of file DA016ADP28.DAT

Flow files.

Return Flow files have two columns, the second column indicating the time-averaged discharge measured in the pipe that connects the rear end of the flume with the bottom near the wavemaker. With this pipe open, the water piled up by the transmitted waves behind the LCS is discharged by gravity at the wavemaker proximity. Figure 21 shows the data and a plot of discharges for file DA016FLOW.DAT. From this figure it can be seen how the flow increases until some equilibrium is reached.

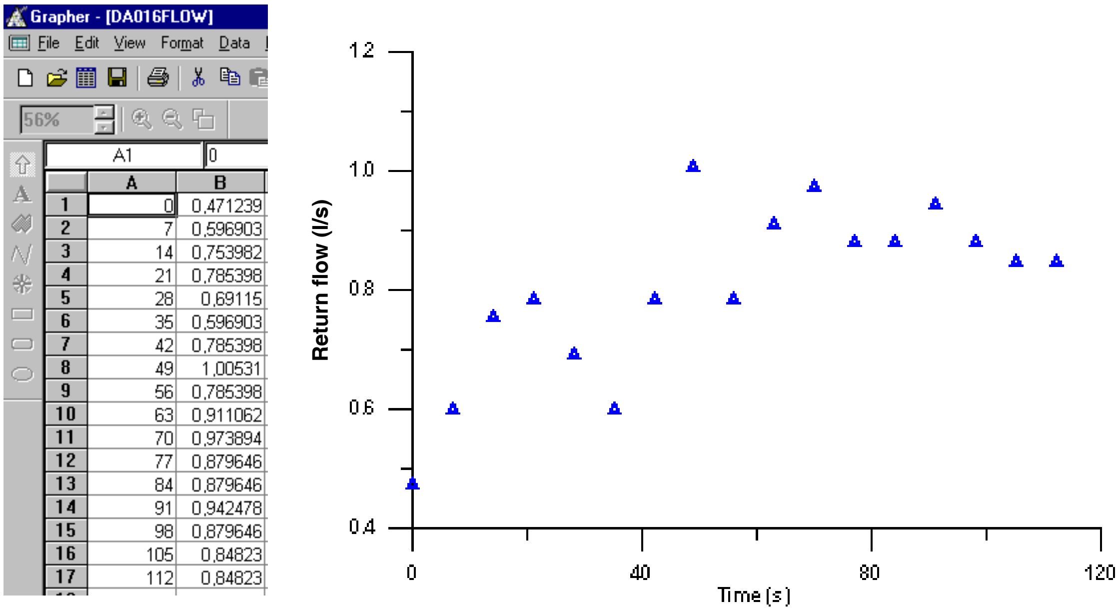


Figure 21. Data and plot of file DA016FLOW.DAT

General information table.

The file DELOSUCA.XLS is an EXCEL table containing all the general information relative to each of the tests. The purpose of this table is to help the user to allocate the required test. The information provided on DELOSUCA.XLS is summarized in table 3.

Column	Information provided
1	Test number
2	Test date
3	Test hour
4	LCS crest width
5	Key name for the test (only for control purposes)
6	Duration of wave generation in seconds
7	Type of waves generated
8	Target wave height
9	Target wave period
10	Type of wave spectrum
11	Peak enhancement parameter γ of spectrum
12	Water depth at wavemaker
13	Total number of measurement points
14	Number of free surface and run–up measurement points
15	Number of pressure measurement points
16	Number of ADV measurement points
17	Number of ADP measurement points
18	Number of LDA measurement points
19	Indicates if return flow was measured: 0 = no return flow measured
20	Indicates if video was taken

Table 3. Information provided in file DELOSUCA.XLS

3. UPC laboratory experiments

3.1. Introduction.

This report describes the tests carried out in the CIEM flume (Maritime Engineering Laboratory (LIM), Polytechnic University of Catalonia (UPC), Barcelona, Spain) during December 2001 and January 2002.

3.2. Infrastructure.

The CIEM flume is 100 meters long 3 meters width and 5 meters depth in front of the wedge paddle (fig. 22). During the tests the bottom was rigid, with a horizontal profile in front of structure section tested (fig. 23). Behind the low crested structure was build a parabolic dissipative beach with homogeneous natural stone (0.5 Kg), to avoid multireflection effects behind the structure.

3.2.1. Physical Model.

It was designed according the next characteristics:

- Representative to a real situation with a land construction method. It means an enough width core and crest elevation respect de mean water level to truck material transport.
- Rouble mound slope representative to stone low crested breakwaters and different to previous test carried out in the CIEM flume.

- The test was focused to hydrodynamic phenomena. The stability analysis was avoided (a metallic net was used to cover and stabilise the structure (figure 24)

Figure 22. Wedge paddle

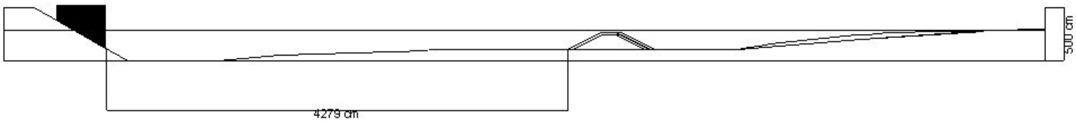


Figure 23. General sketch

Figure 24. Cover layer and metallic net detail.

Material

Te core (figure 25) was constructed with limestone of 20/40 mm size and 2.65 ton/m^3 specific weight. This material was covered with two layers of the same natural stones, with the next weight distribution:

$$W_{50} = 3.36\ Kg$$
$$D_{n50} = 10.82\ cm$$
$$W_{85} / W_{15} = 2.05$$
$$D_{85} / D_{15} = 1.27$$

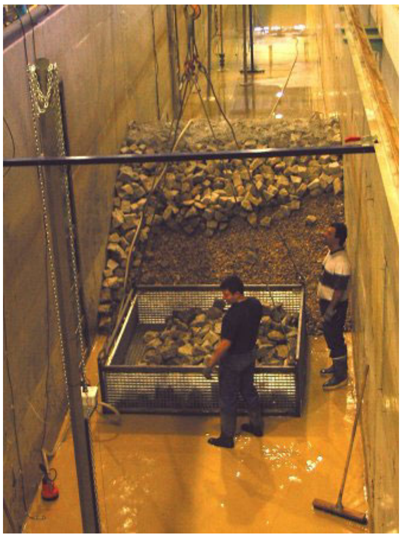


Figure 25. Construction process detail

Sections

Two different LCS symmetric sections were tested with 1H:2V slopes, modifying the crest width. The figure 26 and the table 4 show details of both sections.

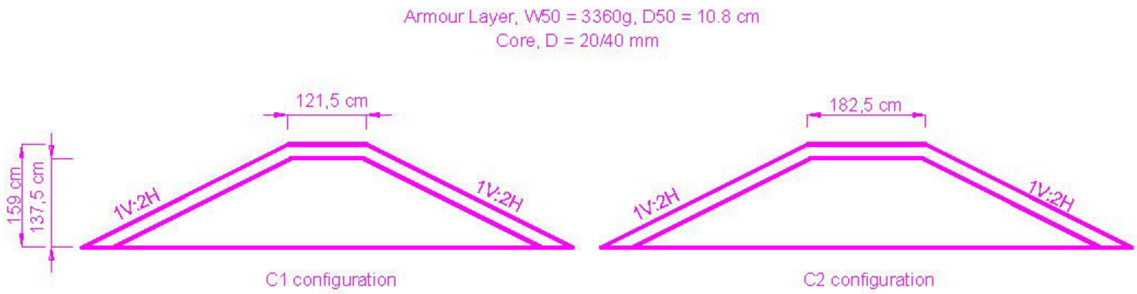


Figure 26. Tested LCS sections.

Crest width	1.21 m and 1.82 m
Crest height	1.59 m
Front and back slope	1V:2H
Freeboards	0.07,0.27 and -0.13 m
Armour stone size	Dn50=0.108 m
Core stone size	20/40 mm
Armour layer thickness	2Dn50

Table 4. Cross section details

3.2.2. Instrumentation

During the test height resistive wave gauges were used, figure 27. Three always in front of the paddle to control the wave absorption system. The other wave gauges were collocated in front (3) and behind (2) the structure.

Figure 27. Wave gauges.

Height pressure sensors, figure 28, were mounted across the flume in front of the LCS along a distance bigger than the generated wavelength.

Figure 28. Pressure sensor

One electromagnetic current meter, figure 29, was collocated in the same cross flume section that the wave gauge number 3 (WG3) to separate incident and reflected waves using the Hughes method (1993).

Figure 29. 2D Electromagnetic current meter.

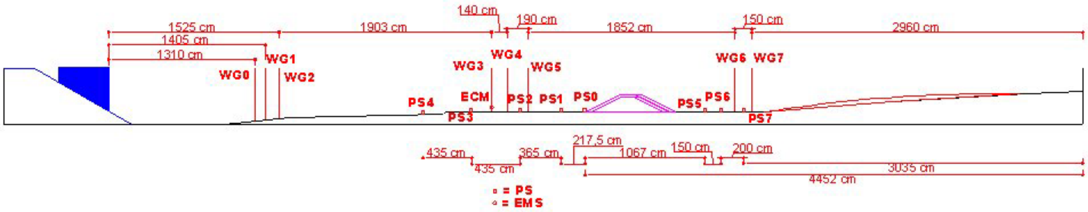


Figure 30. Instrumentation set-up.

The next tables and figure 30 show the different positions of instruments for different freeboards used. The origin coordinate X is in the opposite side to wedge paddle. The origin coordinate Y is in the right paddle lateral wall. The Z origin is in the steel water level (positive up).

Device Code	X (cm)	Y (cm)	Z (cm)	Instrument alignment
WG0	7360	129	-233.0	-----
WG1	7315	129	-223.0	-----
WG2	7195	129	-210.0	-----
WG3	5292	129	-152.0	EMS0
WG4	5152	129	-152.0	-----
WG5	4962	91	-152.0	-----
WG6	3110	129	-152.0	-----
WG7	2960	91	-152.0	-----
EMS0	2655	58	-112.0	WG3
PS0	4452	15	-152.0	-----
PS1	4669.5	15	-152.0	-----
PS2	5034.5	15	-152.0	-----
PS3	5469.5	15	-152.0	-----
PS4	5904.5	15	-169.5	-----
PS5	3385	15	-152.0	-----
PS6	3235	15	-152.0	-----
PS7	3035	15	-152.0	-----

Table 5. Table F1_XYZ. Instrumental coordinate position.

Device Code	X (cm)	Y (cm)	Z (cm)	Instrument alignment
WG0	7360	129	-213.0	-----
WG1	7315	129	-203.0	-----
WG2	7195	129	-190.0	-----
WG3	5292	129	-132.0	EMS0
WG4	5152	129	-132.0	-----
WG5	4962	91	-132.0	-----
WG6	3110	129	-132.0	-----
WG7	2960	91	-132.0	-----
EMS0	2655	58	-92.0	WG3
ATM/N0	4452	15	-132.0	-----
ATM/N1	4669.5	15	-132.0	-----
ATM/N2	5034.5	15	-132.0	-----
ATM/N3	5469.5	15	-132.0	-----
ATM/N4	5904.5	15	-149.5	-----
ATM/N5	3385	15	-132.0	-----
ATM/N6	3235	15	-132.0	-----
ATM/N7	3035	15	-132.0	-----

Table 6. Table F2_XYZ. Instrumental coordinate position.

Device Code	X (cm)	Y (cm)	Z (cm)	Instrument alignment
WG0	7360	129	-253.0	-----
WG1	7315	129	-243.0	-----
WG2	7195	129	-230.0	-----
WG3	5292	129	-172.0	EMS0
WG4	5152	129	-172.0	-----
WG5	4962	91	-172.0	-----
WG6	3110	129	-172.0	-----
WG7	2960	91	-172.0	-----
EMS0	2655	58	-132.0	WG3
ATM/N0	4452	15	-172.0	-----
ATM/N1	4669.5	15	-172.0	-----
ATM/N2	5034.5	15	-172.0	-----
ATM/N3	5469.5	15	-172.0	-----
ATM/N4	5904.5	15	-189.5	-----
ATM/N5	3385	15	-172.0	-----
ATM/N6	3235	15	-172.0	-----
ATM/N7	3035	15	-172.0	-----

Table 7. Table F3_XYZ. Instrumental coordinate position.

3.2.3. Wave conditions.

Different irregular test conditions with JONSWAP spectra and peak factor γ=3.3 were selected according to mean wave real conditions in the Catalan Coast (West Mediterranean Sea). Table 7 shows target values for generated waves.

	Hs (m)	Tp (s)
I1	0.30	2.500
I2	0.50	3.090
I3	0.40	3.090
I4	0.30	3.090
I5	0.40	3.580

Table 7. Irregular Waves.

Regular waves were added to tests, with root mean square wave height equivalent to those of random waves and period equal to the Tz period of the irregular waves (see Table 8).

	H (m)	T (s)
R1	0.30	2.180
R2	0.21	2.180
R3	0.40	2.680
R4	0.28	2.680
R5	0.40	3.110
R6	0.28	3.110

Table 8. Regular Waves.

All waves were generated with three different water level conditions in front of the paddle, figure 9. It means, of course, three different low crested structure freeboards.

Water Depth paddle (cm)	Water Depth LCS toe (cm)	Freeboard (cm)	
262	152	7	Emerged (F1)
242	132	27	Emerged (F2)
282	172	-13	Submerged (F3)

Table 9. Water depth in front of the paddle, in front of LCS and freeboards.

The next table (Table 10) shows the file names created and the corresponding conditions tested.

Test	LCS Configuration	Freeboard (m)	h (m) paddle	h (m) LCS toe	Waves	H (m) (1)	T (s) (2)	Lop (m)	H/h	H/Lop	F/Lop	F/H	Position Table
Emerged													
R1F1C1	C1	0.07	2.62	1.5	regular	0.30	2.18	7.42	0.20	0.040	0.0094	0.23	F1_XYZ
R2F1C1	C1	0.07	2.62	1.5	regular	0.21	2.18	7.42	0.14	0.028	0.0094	0.33	F1_XYZ
R3F1C1	C1	0.07	2.62	1.5	regular	0.40	2.68	11.21	0.27	0.036	0.0062	0.18	F1_XYZ
R4F1C1	C1	0.07	2.62	1.5	regular	0.28	2.68	11.21	0.19	0.025	0.0062	0.25	F1_XYZ
R5F1C1	C1	0.07	2.62	1.5	regular	0.40	3.11	15.10	0.27	0.026	0.0046	0.18	F1_XYZ
R6F1C1	C1	0.07	2.62	1.5	regular	0.28	3.11	15.10	0.19	0.019	0.0046	0.25	F1_XYZ
I1F1C1	C1	0.07	2.62	1.5	JONSWAP 3.3	0.30	2.5	9.76	0.20	0.031	0.0072	0.23	F1_XYZ
I2F1C1	C1	0.07	2.62	1.5	JONSWAP 3.3	0.50	3.09	14.91	0.33	0.034	0.0047	0.14	F1_XYZ
I3F1C1	C1	0.07	2.62	1.5	JONSWAP 3.3	0.40	3.09	14.91	0.27	0.027	0.0047	0.18	F1_XYZ
I4F1C1	C1	0.07	2.62	1.5	JONSWAP 3.3	0.30	3.09	14.91	0.20	0.020	0.0047	0.23	F1_XYZ
I5F1C1	C1	0.07	2.62	1.5	JONSWAP 3.3	0.40	3.58	20.01	0.27	0.020	0.0035	0.18	F1_XYZ
Emerged													
R1F2C1	C1	0.27	2.42	1.3	regular	0.30	2.18	7.42	0.23	0.040	0.0364	0.90	F2_XYZ
R2F2C1	C1	0.27	2.42	1.3	regular	0.21	2.18	7.42	0.16	0.028	0.0364	1.29	F2_XYZ
R3F2C1	C1	0.27	2.42	1.3	regular	0.40	2.68	11.21	0.31	0.036	0.0241	0.68	F2_XYZ
R4F2C1	C1	0.27	2.42	1.3	regular	0.28	2.68	11.21	0.22	0.025	0.0241	0.96	F2_XYZ
R5F2C1	C1	0.27	2.42	1.3	regular	0.40	3.11	15.10	0.31	0.026	0.0179	0.68	F2_XYZ
R6F2C1	C1	0.27	2.42	1.3	regular	0.28	3.11	15.10	0.22	0.019	0.0179	0.96	F2_XYZ
I1F2C1	C1	0.27	2.42	1.3	JONSWAP 3.3	0.30	2.5	9.76	0.23	0.031	0.0277	0.90	F2_XYZ
I2F2C1	C1	0.27	2.42	1.3	JONSWAP 3.3	0.50	3.09	14.91	0.38	0.034	0.0181	0.54	F2_XYZ
I3F2C1	C1	0.27	2.42	1.3	JONSWAP 3.3	0.40	3.09	14.91	0.31	0.027	0.0181	0.68	F2_XYZ
I4F2C1	C1	0.27	2.42	1.3	JONSWAP 3.3	0.30	3.09	14.91	0.23	0.020	0.0181	0.90	F2_XYZ
I5F2C1	C1	0.27	2.42	1.3	JONSWAP 3.3	0.40	3.58	20.01	0.31	0.020	0.0135	0.68	F2_XYZ
Submerged													
R1F3C1	C1	-0.13	2.82	1.7	regular	0.30	2.18	7.42	0.18	0.040	-0.0175	-0.43	F3_XYZ
R2F3C1	C1	-0.13	2.82	1.7	regular	0.21	2.18	7.42	0.12	0.028	-0.0175	-0.62	F3_XYZ
R3F3C1	C1	-0.13	2.82	1.7	regular	0.40	2.68	11.21	0.24	0.036	-0.0116	-0.33	F3_XYZ
R4F3C1	C1	-0.13	2.82	1.7	regular	0.28	2.68	11.21	0.16	0.025	-0.0116	-0.46	F3_XYZ
R5F3C1	C1	-0.13	2.82	1.7	regular	0.40	3.11	15.10	0.24	0.026	-0.0086	-0.33	F3_XYZ
R6F3C1	C1	-0.13	2.82	1.7	regular	0.28	3.11	15.10	0.16	0.019	-0.0086	-0.46	F3_XYZ
I1F3C1	C1	-0.13	2.82	1.7	JONSWAP 3.3	0.30	2.5	9.76	0.18	0.031	-0.0133	-0.43	F3_XYZ
I2F3C1	C1	-0.13	2.82	1.7	JONSWAP 3.3	0.50	3.09	14.91	0.29	0.034	-0.0087	-0.26	F3_XYZ
I3F3C1	C1	-0.13	2.82	1.7	JONSWAP 3.3	0.40	3.09	14.91	0.24	0.027	-0.0087	-0.33	F3_XYZ
I4F3C1	C1	-0.13	2.82	1.7	JONSWAP 3.3	0.30	3.09	14.91	0.18	0.020	-0.0087	-0.43	F3_XYZ
I5F3C1	C1	-0.13	2.82	1.7	JONSWAP 3.3	0.40	3.58	20.01	0.24	0.020	-0.0065	-0.33	F3_XYZ
Submerged													
R1F3C2	C2	-0.13	2.82	1.7	regular	0.30	2.18	7.42	0.18	0.040	-0.0175	-0.43	F3_XYZ
R2F3C2	C2	-0.13	2.82	1.7	regular	0.21	2.18	7.42	0.12	0.028	-0.0175	-0.62	F3_XYZ
R3F3C2	C2	-0.13	2.82	1.7	regular	0.40	2.68	11.21	0.24	0.036	-0.0116	-0.33	F3_XYZ
R4F3C2	C2	-0.13	2.82	1.7	regular	0.28	2.68	11.21	0.16	0.025	-0.0116	-0.46	F3_XYZ
R5F3C2	C2	-0.13	2.82	1.7	regular	0.40	3.11	15.10	0.24	0.026	-0.0086	-0.33	F3_XYZ
R6F3C2	C2	-0.13	2.82	1.7	regular	0.28	3.11	15.10	0.16	0.019	-0.0086	-0.46	F3_XYZ
I1F3C2	C2	-0.13	2.82	1.7	JONSWAP 3.3	0.30	2.5	9.76	0.18	0.031	-0.0133	-0.43	F3_XYZ
I2F3C2	C2	-0.13	2.82	1.7	JONSWAP 3.3	0.50	3.09	14.91	0.29	0.034	-0.0087	-0.26	F3_XYZ
I3F3C2	C2	-0.13	2.82	1.7	JONSWAP 3.3	0.40	3.09	14.91	0.24	0.027	-0.0087	-0.33	F3_XYZ
I4F3C2	C2	-0.13	2.82	1.7	JONSWAP 3.3	0.30	3.09	14.91	0.18	0.020	-0.0087	-0.43	F3_XYZ
I5F3C2	C2	-0.13	2.82	1.7	JONSWAP 3.3	0.40	3.58	20.01	0.24	0.020	-0.0065	-0.33	F3_XYZ
Emerged													
R1F1C2	C2	0.07	2.62	1.5	regular	0.30	2.18	7.42	0.20	0.040	0.0094	0.23	F1_XYZ
R2F1C2	C2	0.07	2.62	1.5	regular	0.21	2.18	7.42	0.14	0.028	0.0094	0.33	F1_XYZ
R3F1C2	C2	0.07	2.62	1.5	regular	0.30	2.68	11.21	0.20	0.027	0.0062	0.23	F1_XYZ
R4F1C2	C2	0.07	2.62	1.5	regular	0.21	2.68	11.21	0.14	0.019	0.0062	0.33	F1_XYZ
R5F1C2	C2	0.07	2.62	1.5	regular	0.40	3.11	15.10	0.27	0.026	0.0046	0.18	F1_XYZ
R6F1C2	C2	0.07	2.62	1.5	regular	0.30	3.11	15.10	0.20	0.020	0.0046	0.23	F1_XYZ
I1F1C2	C2	0.07	2.62	1.5	JONSWAP 3.3	0.30	2.5	9.76	0.20	0.031	0.0072	0.23	F1_XYZ
I2F1C2	C2	0.07	2.62	1.5	JONSWAP 3.3	0.40	3.09	14.91	0.27	0.027	0.0047	0.18	F1_XYZ
I3F1C2	C2	0.07	2.62	1.5	JONSWAP 3.3	0.30	3.09	14.91	0.20	0.020	0.0047	0.23	F1_XYZ
I4F1C2	C2	0.07	2.62	1.5	JONSWAP 3.3	0.40	3.58	20.01	0.27	0.020	0.0035	0.18	F1_XYZ
I5F1C2	C2	0.07	2.62	1.5	JONSWAP 3.3	0.40	3.58	20.01	0.27	0.020	0.0035	0.18	F1_XYZ
Emerged													
R1F2C2	C2	0.27	2.42	1.3	regular	0.30	2.18	7.42	0.23	0.040	0.0364	0.90	F2_XYZ
R2F2C2	C2	0.27	2.42	1.3	regular	0.21	2.18	7.42	0.16	0.028	0.0364	1.29	F2_XYZ
R3F2C2	C2	0.27	2.42	1.3	regular	0.30	2.68	11.21	0.23	0.027	0.0241	0.90	F2_XYZ
R4F2C2	C2	0.27	2.42	1.3	regular	0.21	2.68	11.21	0.16	0.019	0.0241	1.29	F2_XYZ
R5F2C2	C2	0.27	2.42	1.3	regular	0.40	3.11	15.10	0.31	0.026	0.0179	0.68	F2_XYZ
R6F2C2	C2	0.27	2.42	1.3	regular	0.30	3.11	15.10	0.23	0.020	0.0179	0.90	F2_XYZ
I1F2C2	C2	0.27	2.42	1.3	JONSWAP 3.3	0.30	2.5	9.76	0.23	0.031	0.0277	0.90	F2_XYZ
I2F2C2	C2	0.27	2.42	1.3	JONSWAP 3.3	0.40	3.09	14.91	0.31	0.027	0.0181	0.68	F2_XYZ
I3F2C2	C2	0.27	2.42	1.3	JONSWAP 3.3	0.30	3.09	14.91	0.23	0.020	0.0181	0.90	F2_XYZ
I4F2C2	C2	0.27	2.42	1.3	JONSWAP 3.3	0.40	3.58	20.01	0.31	0.020	0.0135	0.68	F2_XYZ
I5F2C2	C2	0.27	2.42	1.3	JONSWAP 3.3	0.40	3.58	20.01	0.31	0.020	0.0135	0.68	F2_XYZ

(1) & (2) there are significant wave and peak period for random waves to generate

Tests not finalized or executed because of to surpass the limit cylinder stroke

Table 10. Nomenclature and wave conditions.

3.2.4. Data acquisition and Wave Generation.

The random waves were generated with the white noise method from shift registers. The acquisition time at 20 Hz sample frequency includes: the initial ramp, the waves (> 1000 waves) to generate the specified spectra, the final ramp and 300 seconds added to control the water level fluctuation behind the LCS.

The regular waves were generated from a sinusoidal signal and the registered signals were sampled at 20 Hz also. The total acquisition time, also includes: initial ramp, an enough number of waves (about 300 waves), the final ramp and 300 seconds added.

3.2.5. Data tests.

To obtain the data tests write to next contact person and e-mail address:

LIM/UPC Laboratori d'Enginyeria Marítima
Director: A.Sánchez-Arcilla
mailto:info.lim@upc.es

3.3. Preliminary Data Analysis.

The use of a programme developed in the laboratory that applies the Hughes spectral method (1993) using the surface elevation and horizontal velocity measured in the wave gauge number 3 (WG3) position allow to present a preliminary analysis of incident and transmitted waves. The results obtained are showed in table 11.

	INC. WAVES			REF. WAVES		TRANS. WAVES									
TEST	H,i (m)	T,i (s)	Lop,i(m)	H,r (m)	T,r (s)	H,t (m)	T,t (s)	F (m)	B (m)	KT	KR	H,i / Lop,i	F / H,i	F/ Lop,i	B / Lopi
I1F1C1	0.267	2.56	10.232	0.053	2.23	0.057	2.56	0.07	1.215	0.21	0.20	0.026	0.262	0.007	0.119
I2F1C1	0.366	3.20	15.988	0.081	25.60	0.131	3.20	0.07	1.215	0.36	0.22	0.023	0.191	0.004	0.076
I3F1C1	0.323	3.20	15.988	0.071	25.60	0.099	3.20	0.07	1.215	0.31	0.22	0.020	0.217	0.004	0.076
I4F1C1	0.251	3.20	15.988	0.051	3.01	0.066	3.20	0.07	1.215	0.26	0.20	0.016	0.279	0.004	0.076
I5F1C1	0.290	3.41	18.155	0.061	3.66	0.122	3.41	0.07	1.215	0.42	0.21	0.016	0.241	0.004	0.067
I1F2C1	0.263	2.56	10.232	0.058	2.23	0.008	25.60	0.27	1.215	0.03	0.22	0.026	1.027	0.026	0.119
I2F2C1	0.338	3.20	15.988	0.089	25.60	0.029	3.21	0.27	1.215	0.09	0.26	0.021	0.799	0.017	0.076
I3F2C1	0.319	3.20	15.988	0.078	25.60	0.027	3.41	0.27	1.215	0.08	0.24	0.020	0.846	0.017	0.076
I4F2C1	0.233	3.01	14.146	0.056	3.01	0.012	3.41	0.27	1.215	0.05	0.24	0.016	1.159	0.019	0.086
I1F3C1	0.276	2.56	10.232	0.049	2.23	0.149	2.56	-0.13	1.215	0.54	0.18	0.027	-0.471	-0.013	0.119
I2F3C1	0.394	3.20	15.988	0.088	25.60	0.210	13.20	-0.13	1.215	0.53	0.22	0.025	-0.330	-0.008	0.076
I3F3C1	0.331	3.20	15.988	0.068	25.60	0.183	3.20	-0.13	1.215	0.55	0.21	0.021	-0.393	-0.008	0.076
I4F3C1	0.263	3.20	15.988	0.053	25.60	0.152	3.20	-0.13	1.215	0.58	0.20	0.016	-0.494	-0.008	0.076
I5F3C1	0.296	3.41	18.155	0.050	25.60	0.190	3.41	-0.13	1.215	0.64	0.17	0.016	-0.439	-0.007	0.067
I1F1C2	0.258	2.56	10.232	0.060	2.23	0.044	2.56	0.07	1.825	0.17	0.23	0.025	0.271	0.007	0.178
I2F1C2	0.370	3.20	15.988	0.096	25.60	0.120	3.20	0.07	1.825	0.32	0.26	0.023	0.189	0.004	0.114
I3F1C2	0.311	3.20	15.988	0.082	25.60	0.086	3.20	0.07	1.825	0.27	0.26	0.019	0.225	0.004	0.114
I4F1C2	0.249	3.20	15.988	0.065	3.01	0.054	3.20	0.07	1.825	0.22	0.26	0.016	0.281	0.004	0.114
I5F1C2	0.251	3.41	18.155	0.058	25.60	0.106	3.41	0.07	1.825	0.42	0.23	0.014	0.279	0.004	0.101
I1F2C2	0.258	2.56	10.232	0.071	2.23	0.007	25.60	0.27	1.825	0.03	0.28	0.025	1.047	0.026	0.178
I3F2C2	0.307	3.20	15.988	0.087	3.66	0.018	38.40	0.27	1.825	0.06	0.28	0.019	0.879	0.017	0.114
I4F2C2	0.245	3.20	15.988	0.057	3.01	0.009	25.60	0.27	1.825	0.04	0.23	0.015	1.102	0.017	0.114
I1F3C2	0.274	2.56	10.232	0.055	2.23	0.132	2.56	-0.13	1.825	0.48	0.20	0.027	-0.474	-0.013	0.178
I2F3C2	0.377	3.20	15.988	0.092	25.60	0.187	3.20	-0.13	1.825	0.49	0.24	0.024	-0.345	-0.008	0.114
I3F3C2	0.327	3.20	15.988	0.076	25.60	0.164	3.20	-0.13	1.825	0.50	0.23	0.020	-0.398	-0.008	0.114
I4F3C2	0.257	3.20	15.988	0.058	25.60	0.135	3.20	-0.13	1.825	0.53	0.23	0.016	-0.506	-0.008	0.114
I5F3C2	0.257	3.41	18.155	0.050	25.60	0.173	3.54	-0.13	1.825	0.67	0.19	0.014	-0.506	-0.007	0.101
R1F1C1	0.488	2.13	7.084	0.133	2.13	0.083	2.23	0.07	1.215	0.17	0.27	0.069	0.143	0.010	0.172
R2F1C1	0.351	2.13	7.084	0.087	2.13	0.041	2.13	0.07	1.215	0.12	0.25	0.050	0.199	0.010	0.172
R3F1C1	0.497	2.69	11.298	0.080	2.69	0.110	2.70	0.07	1.215	0.22	0.16	0.044	0.141	0.006	0.108
R4F1C1	0.357	2.69	11.298	0.049	2.69	0.063	2.70	0.07	1.215	0.18	0.14	0.032	0.196	0.006	0.108
R5F1C1	0.399	3.01	14.146	0.059	3.01	0.103	3.20	0.07	1.215	0.26	0.15	0.028	0.175	0.005	0.086
R6F1C1	0.293	3.01	14.146	0.047	3.01	0.059	3.20	0.07	1.215	0.20	0.16	0.021	0.239	0.005	0.086
R1F2C1	0.428	2.13	7.084	0.111	2.13	0.003	2.13	0.27	1.215	0.01	0.26	0.060	0.631	0.038	0.172
R2F2C1	0.333	2.13	7.084	0.095	2.13	0.001	2.18	0.27	1.215	0.00	0.29	0.047	0.811	0.038	0.172
R3F2C1	0.538	2.69	11.298	0.150	0.90	0.028	2.70	0.27	1.215	0.05	0.28	0.048	0.502	0.024	0.108
R4F2C1	0.371	2.69	11.298	0.066	2.69	0.004	2.70	0.27	1.215	0.01	0.18	0.033	0.728	0.024	0.108
R5F2C1	0.397	3.01	14.146	0.078	1.55	0.012	3.20	0.27	1.215	0.03	0.20	0.028	0.680	0.019	0.086
R6F2C1	0.286	3.01	14.146	0.060	3.01	0.005	3.01	0.27	1.215	0.02	0.21	0.020	0.944	0.019	0.086
R1F3C1	0.509	2.13	7.084	0.106	2.13	0.147	2.13	-0.13	1.215	0.29	0.21	0.072	-0.255	-0.018	0.172
R2F3C1	0.365	2.13	7.084	0.081	2.13	0.108	2.13	-0.13	1.215	0.29	0.22	0.052	-0.356	-0.018	0.172
R3F3C1	0.479	2.69	11.298	0.067	2.69	0.146	2.70	-0.13	1.215	0.30	0.14	0.042	-0.271	-0.012	0.108
R4F3C1	0.342	2.69	11.298	0.036	2.69	0.121	2.70	-0.13	1.215	0.35	0.11	0.030	-0.380	-0.012	0.108
R5F3C1	0.429	3.01	14.146	0.057	3.01	0.157	3.20	-0.13	1.215	0.37	0.13	0.030	-0.303	-0.009	0.086
R6F3C1	0.316	3.01	14.146	0.048	3.01	0.119	3.01	-0.13	1.215	0.38	0.15	0.022	-0.411	-0.009	0.086
R1F1C2	0.489	2.13	7.084	0.159	2.13	0.069	2.23	0.07	1.825	0.14	0.33	0.069	0.143	0.010	0.258
R2F1C2	0.356	2.13	7.084	0.111	2.13	0.035	2.13	0.07	1.825	0.10	0.31	0.050	0.197	0.010	0.258
R3F1C2	0.497	2.69	11.298	0.110	2.69	0.097	2.70	0.07	1.825	0.19	0.22	0.044	0.141	0.006	0.162
R4F1C2	0.355	2.69	11.298	0.067	2.69	0.047	2.70	0.07	1.825	0.13	0.19	0.031	0.197	0.006	0.162
R5F1C2	0.402	3.01	14.146	0.066	1.55	0.090	3.20	0.07	1.825	0.22	0.16	0.028	0.174	0.005	0.129
R6F1C2	0.297	3.01	14.146	0.051	3.01	0.050	3.20	0.07	1.825	0.17	0.17	0.021	0.236	0.005	0.129
R1F2C2	0.454	2.13	7.084	0.157	2.13	0.017	2.13	0.27	1.825	0.04	0.35	0.064	0.595	0.038	0.258
R2F2C2	0.347	2.13	7.084	0.128	2.13	0.001	51.20	0.27	1.825	0.00	0.37	0.049	0.778	0.038	0.258
R3F2C2	0.535	2.69	11.298	0.180	2.13	0.022	1.70	0.27	1.825	0.04	0.34	0.047	0.505	0.024	0.162
R4F2C2	0.360	2.69	11.298	0.085	2.69	0.003	2.70	0.27	1.825	0.01	0.24	0.032	0.750	0.024	0.162
R5F2C2	0.371	3.01	14.146	0.079	1.55	0.007	3.20	0.27	1.825	0.02	0.21	0.026	0.728	0.019	0.129
R6F2C2	0.268	3.01	14.146	0.055	1.55	0.004	3.01	0.27	1.825	0.01	0.21	0.019	1.007	0.019	0.129
R1F3C2	0.497	2.13	7.084	0.126	2.13	0.124	2.13	-0.13	1.825	0.25	0.25	0.070	-0.262	-0.018	0.258
R2F3C2	0.348	2.13	7.084	0.083	2.13	0.092	2.13	-0.13	1.825	0.26	0.24	0.049	-0.374	-0.018	0.258
R3F3C2	0.474	2.69	11.298	0.079	2.69	0.092	2.13	-0.13	1.825	0.19	0.17	0.042	-0.274	-0.012	0.162
R4F3C2	0.339	2.69	11.298	0.047	2.69	0.114	2.02	-0.13	1.825	0.33	0.14	0.030	-0.383	-0.012	0.162
R5F3C2	0.416	3.01	14.146	0.056	3.01	0.139	3.20	-0.13	1.825	0.33	0.13	0.029	-0.313	-0.009	0.129
R6F3C2	0.302	3.01	14.146	0.045	3.01	0.105	3.20	-0.13	1.825	0.35	0.15	0.021	-0.430	-0.009	0.129

Table 9. Results.

References

Hughes, S.A. (1993). *Laboratory Wave Reflection Analysis Using Co-located Gages*, Coastal Engineering, Ed Elsevier, Vol. 20, pp 223-247.