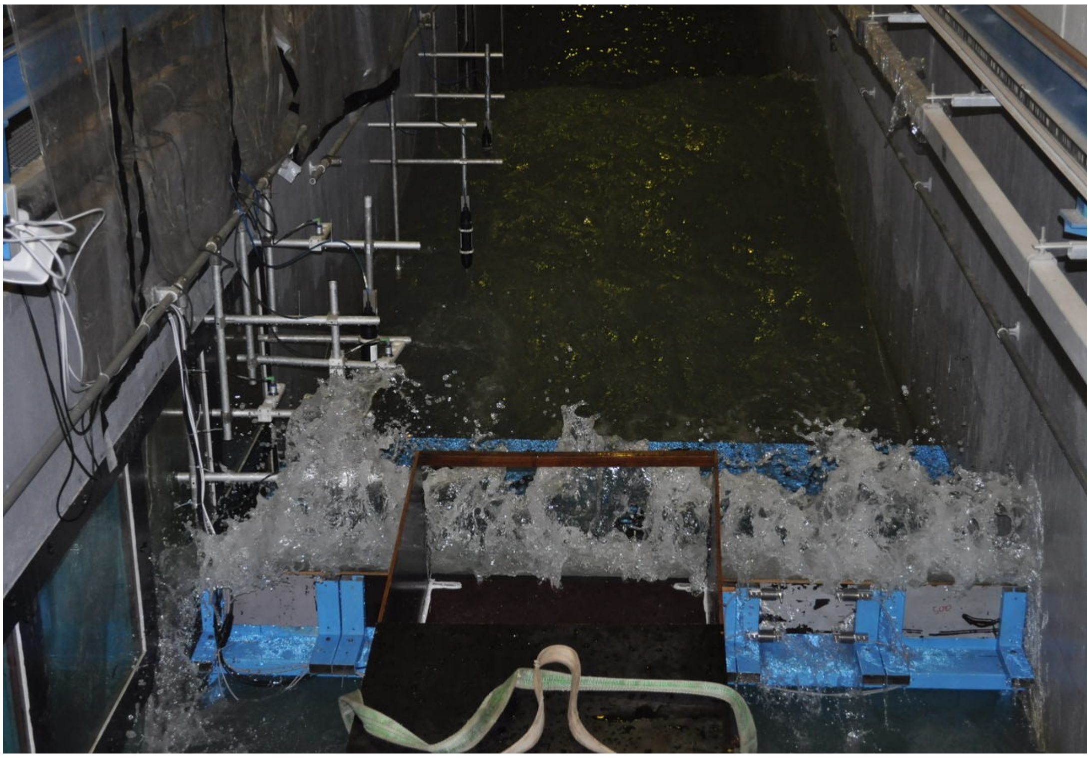
Data Storage Report

Forces on Storm-walls and buildings by wave overtopping

Canal d'Invesitgació I Experimentació Marítima (CIEM), UPC



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Document objective

This document describes the data that was obtained during this project and how it was stored, so that others than the people immediately involved may use the data for their research.

Acknowledgement

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Contents

1 Objectives

In order to reduce wave overtopping and protect the hinterland, storm walls can be built in harbors and at/behind the crest of sloping dikes. These constructions however are also subjected to impacts of the overtopping bore. There exist very few data of the impacting bore, which makes the constructional design of such storm walls difficult.

The focus of this test campaign is to have a deeper look at the post-overtopping process, by measuring flow depths, flow velocities and impacts of a bore which results from an overtopping event over a dike or quay wall.

The analysis will focus on the link between hydraulic and geometrical conditions on the one hand, flow depth, flow velocity and impact forces and pressures on the other hand. Furthermore, the 2nd overtopping process (the overtopping over the storm wall) is also measured.

Tests with and without storm wall are carried out on the quay, while with the dike only tests with storm wall are carried out. Tests can later be carried out in small scale to investigate scale effects, but this is outside the scope of this Hydralab IV project.

Test have been carried out in July and September 2013 at UPC, Barcelona, in the large wave flume. A Froude scale of 1/6 has been selected to carry out all experiments.

1 Experimental setup

1.1 General description

In a discussion with the host of the facility, the geometry was determined to carry out the experiments within the time frame of the project (30 days of access, including the intermediate modifications to the structure).

This discussion and its outcome can be found in the minutes of the meeting of 03/04/2013 and the consecutive mail of Daniel Gonzalez-Marco and Xavi Gironella, from which some important items are repeated here:

- For other Hydralab IV projects, there is a large amount of sand (~300m³) in the flume, which cannot be taken out. It was decided to spread the sand over the flume creating a thick flat layer of 90cm. The rest of the amount of sand was stored at the back of the flume, reducing its available length with about 15m.

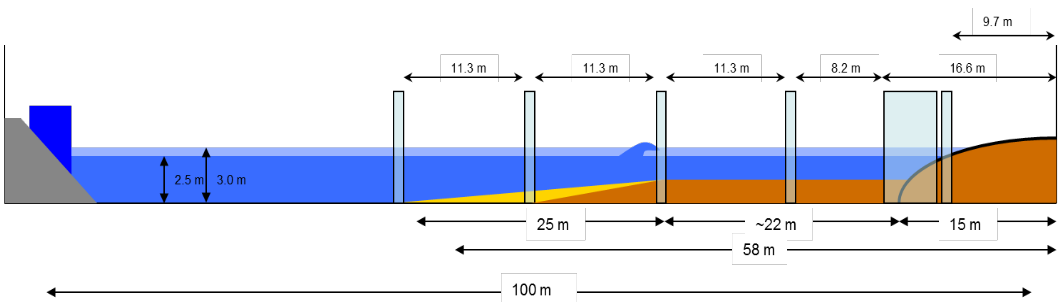


Figure 1 – principle sketch of the sand stored in the flume

- The feasible wave conditions are limited by the wave paddle capacity and the wave breaking criteria. The combination of high waves with long wave periods is no longer possible to achieve. In order to work within the range of possible wave conditions, it was necessary to reduce the scale to 1/6.

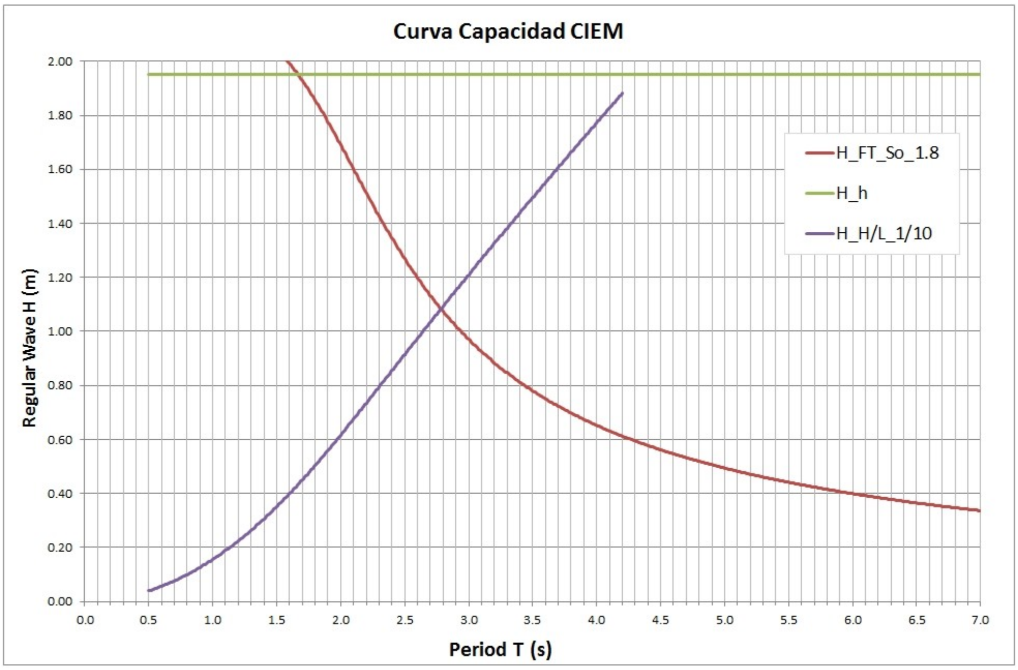


Figure 2 – Performance graph of the CIEM wavemaker with a water depth of 2m (for regular waves, to be divided by 1.8 for irregular waves)

- A last important issue is the lack of an active wave absorption which is not installed at current software to steer the wave paddle. Both structures have a large reflection coefficient, and re-reflection at the wave paddle creates a continuous energy growth. This is a point of discussion for the analysis, since there is no proper solution at this point in the project.

With respect to the above mentioned restrictions, the following structures were designed: a quay wall (Figure 3) and a dike (Figure 4).

Further in this document, both geometries are referred to as “geometry ‘dike’” and “geometry ‘quay wall’”.

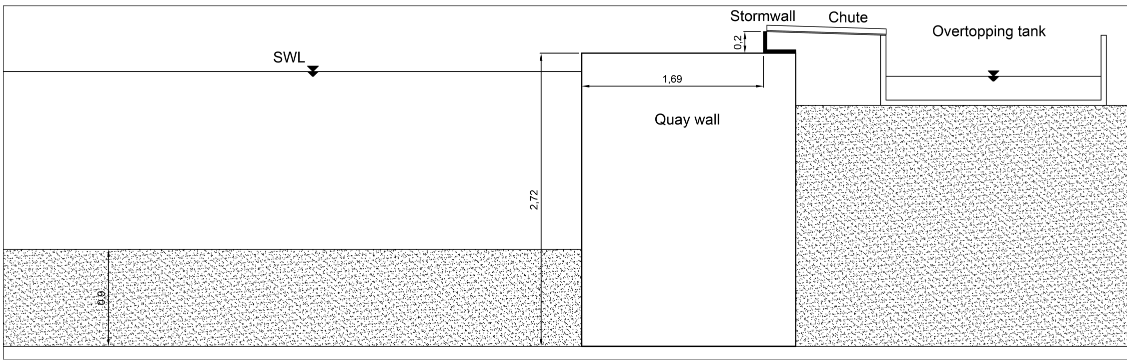


Figure 3 – Design of the quay wall (geometry ‘quay wall’)

The structure is shown in tick black lines, the overtopping tank (OVT) can be seen in the rear side of the structure. In between an overtopping funnel is illustrated.

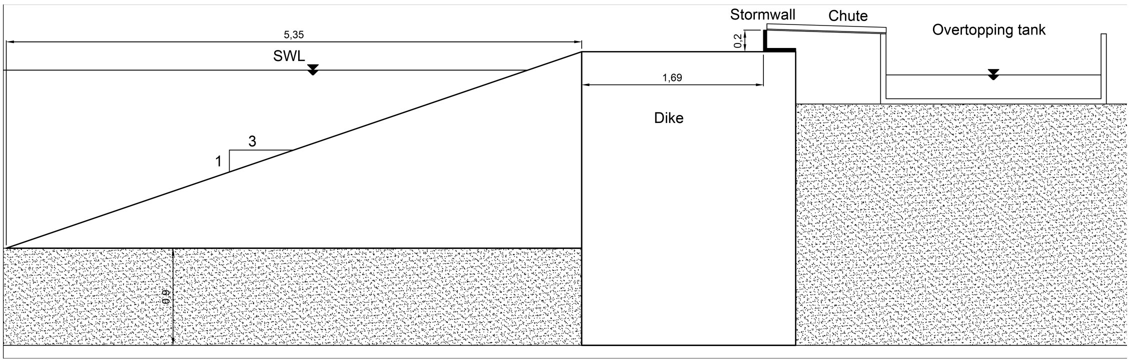


Figure 4 – Design of the sloping dike (geometry 'dike)

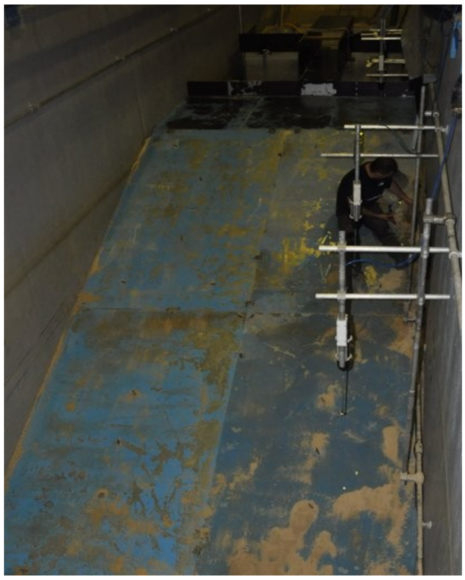


Figure 5 – Quay configuration ont he left while right image presents the dike layout

The profile from the wave paddle starts with the flat concrete bottom of the flume until the initial slope (1/7.77) is found at x = 29.40 m from the wave paddle. This initial slope ends with a constant sand layer of 0.9 m high that goes from x = 36.4 m until the toe of the quay located at x = 70.65 m.

The crest level of the quay is at 2.72 m above the bottom of the flume. The freeboard related to this crest is further on referred to as 'A_C'. At 1.69 m behind the crest, there is a the storm wall of 0.20 high, related to the full scaled situation of a promenade of about 10 m wide and a storm wall of 1.2 m high. The freeboard related to the highest impermeable quote (maximum elevation of dike/quay crest ± storm wall, depending on the configuration) is further on referred as 'R_c'.
On this 1.69 m wide crest, many measurements are being done to record the flow depth and flow velocities. The storm wall itself is equipped with 4 force sensors (on a "free" plate), 3 pressure sensors, and an overtopping box (see further).

The geometry 'dike' is exactly the same but with a slope of 1/3 for the last 5.35 m in front of the quay.

In order to achieve a wide range of R_c/H_{m0}, with respect of changing the water level not too often (time consuming), and within the available range of feasible wave conditions, 3 water levels were selected. The highest water level reaches the crest of the quay, the lowest water level is 0.33 m (or 2 m in prototype) below this crest level. For each water level, 2 to 4 wave heights and 2 different wave periods are selected. They are summarized in the table below, where all values are in model scale. Additionally some tests with short wave period have been carried out for geometry ‘quay wall’ to simulate wind generated waves inside harbours.

*Table 1 – Test program of geometry ‘quay wall’. In yellow the expected overtopping volumes l/m/s are shown**

	h	Hs = 0.17		Hs = 0.25		Hs = 0.33		Hs = 0.42		Hs = 0.50	
		no wall	wall	no wall	wall	no wall	wall	no wall	wall	no wall	wall
Tp 2.86	2.39					2.46	0.04	6.27	0.21		
	2.55			4.34	0.02		0.20		0.83		2.25
	2.72				0.17		0.95		2.88		6.34
Tp 4.08	2.39					2.46	0.04				
	2.55			4.34	0.02		0.22				
	2.72				0.20		1.06		3.16		
Tp short	Tp = 1.67s, Hs = 0.20m, h = 2.72m Tp = 1.63s, Hs = 0.17m, h = 2.72m Tp = 1.42s, Hs = 0.13m, h = 2.72m										

*Table 2 - Test program of geometry ‘dike. In yellow the expected overtopping volumes l/m/s are shown**

	H	Rc	Hs = 0.17	Hs = 0.25	Hs = 0.33	Hs = 0.42	Hs = 0.50
wallwall [l/s/m] [l/s/m]	[m]		[m]		wall [l/s/m]		wall [l/s/m]
Tpwall 2.86 [l/s/m]	2.39	0.53		0.05	0.48	2.00	
	2.55	0.37	0.01	0.29	1.78	5.7	13
	2.72	0.20	0.01	1.44	5.87	14.72	28.6
Tp 4.08	2.39	0.53		0.05	0.51		
	2.55	0.37	0.01	0.31	1.89		
	2.72	0.20	0.13	1.59	6.35	15.75	

* For the quay wall with storm wall, no overtopping formulae exist. The same reduction factors as developed for the geometry dike (see small scale experiments at Ghent University) are used in order to have a first estimation about the overtopping volumes.

* without storm wall, the overtopping volumes are the same with shorter and longer wave period, since the parameter Tp does not appear in the overtopping formulae. With storm wall, the overtopping is almost the same with short and long wave period, but minor changes appear because the factor Tp appears in the reduction factors gamma (however not in the rest of the general overtopping formulae, therefore the differences are only very small). It will be shown from the experiments whether this assumption (Tp is not a dominant parameter in case of overtopping) is valid.

Most of time series will contain 1000 waves (except for the 10 initial tests), given that as stated in the EurOtop Manual (Pullen et al., 2007) “physical model tests suggest that a sea state represented by 1000 random waves will give reasonably consistent results”.

For geometry ‘dike’, only tests with storm wall are in the test program. For geometry ‘quay wall’ both experiments with and without storm wall are listed. The ones without storm wall are conceived to properly look at the overtopping bore, without reflecting on the storm wall and to have a learning process for analyzing such data. For these tests, the secondary, but nevertheless majorly interesting, purpose is to have (some) overtopping data for low-crested structures on a fairly large scale.
Nevertheless, the ones with storm wall are the major part of this research project, and will outnumber the tests without storm wall.

For the tests without storm wall (geometry ‘quay wall’), all panels and the support frame have to be removed from the flume, so that there are no disturbing elements present. Therefore these tests are scheduled at the beginning of the test campaign, and the construction of the storm wall in the flume will only be started afterwards.

The storm wall is made of different panels, in order to possibly remove the parts where no measurements take place. By doing so, the draining of the structure is going much faster, and no obstructive residual water layers stay in front of the storm wall and thereby heavily absorbing a large part of the incoming energy. It will be evaluated during the tests whether we will have a fully closed or partially open wall.

Storm wall configuration

The height of the storm wall is 0.20 m (1.20 m in prototype). The selected option considers the construction of the wall over the entire width of the flume, but in different panels. All different panels of the storm wall should be aligned in one vertical plane.

- F, panel for the force sensors. In total 4 force sensors are fixed to the supporting structure of the wall and the panel is attached to these sensors (width of panel 0.5 m).
- P, panel for the pressure sensors. The panel is fixed to the supporting structure and 3 holes for the pressure sensors are prepared in 1 vertical line (width of panel 0.5 m). The position of the sensors in height is 2.5cm, 10cm and 17.5cm.

- Panels L, M and R contain no measurement equipment and are constructed in such a way that they can be removed if necessary. In this case, the plates will be removed but the supporting frame remains in position. Most of the water will be allowed to pass through (widths of 0.5, 1 and 0.5 m respectively). The choice of making the closed wall partly open, will be made during the experiments. If too much water remains on the crest, damping the incoming waves, the panels L, M and R will be removed.

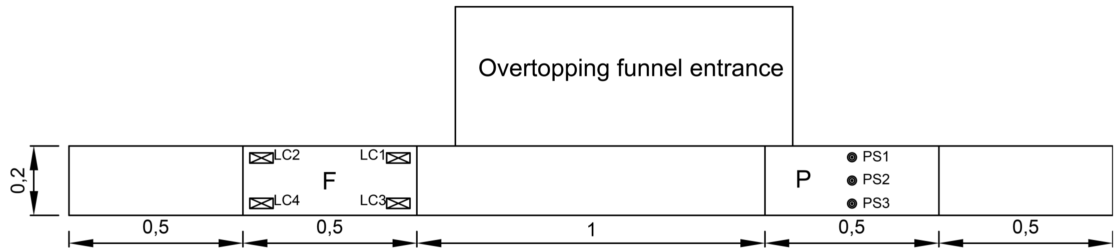


Figure 6 – Storm wall sketch

Overtopping measurements

The overtopping discharge and volumes will be measured by collecting overtopping waves behind the structure in a tank, which is equipped with 3 pressure sensors to measure the

volume. It is expected that very large overtopping will take place during tests without the storm wall and really little volume will be collected under other conditions. Table 1 and 2 present the overtopping volumes in l/m/s expected for the planned conditions. In order to improve the overtopping measurement (expected inaccuracy problems will occur if overtopping volumes are little respect to the measuring tank) a modular volume system is implemented, by reducing the funnel (in case of large overtopping, allowing less water in the tank) or by using a little measurement volume (in case of small overtopping, increasing the accuracy).
The maximum volume of the overtopping tank is 2.5 m^3. In order to allow bigger overtopping volumes a set of two pumps with an average capacity of up to 300 l/min each is installed in the overtopping tank. Once the water reaches a certain level (visually observed) the pumps are (manually) activated and the volume of extracted water is measured by an electromagnetic flow meter installed in the circuit returning the water to the flume.
Further on in this document, the overtopping tank is called 'OVT'

Figure 7 – Overtopping tank on the left with the two submerged pumps and EFM on the right with all the water tubes coming from the OVT and returning to the flume.

Partially open storm wall

The experiments with partially open storm walls do not require overtopping measurements, thereby the experiments with partially open storm walls will focus on the pressure and force distribution along the storm wall, without requiring special adjustments in order to collect a representative amount of overtopping (furthermore, experiments with partially open storm walls cannot be properly considered 2D anymore, so collecting overtopping is not reliable).

1.2 Definition of the coordinate system

The origin of the reference system used is placed in the middle of the stroke of the wave paddle and lies on the rigid bottom of the wave flume

- X follows the direction along the flume and is positive when going towards the shoreline. The absolute 0 is at the wave paddle (which is in position 2), the profiles are referred that way.

- Z is directed vertically. The 0 is located at the upper part of the flume and goes negative until it reach the value of - 4.5 m at the bottom of the flume. **An important note**: the information of the instrumentation written in this report refers to the distance of the probe to the rigid 'bottom' underneath it. This can be the bottom of the flume, the sandy bottom under it (0.9 m above the flume bottom) or the crest of the quay/dike (2.72 m above the flume bottom), depending on the location (X-coordinate) in the flume.

- Y refers to the cross-shore distance of the flume. Just a few notations have been done using this reference and the 0 is at the wall in which the ADV, AWG and Wave

gauges where placed.
Actually this Y-coordinate does not make much sense, since we work in a 2D flume and all values are expected to be constant over the cross-distance of the flume.

1.3 Hydraulic Parameter Range

1.3.1 Water Depth

The water depth at the toe of the paddle will range between 2.39 and 2.72 m at the toe of the wave paddle, with one intermediate level of 2.55 m. The paddle was clamped at the middle position of the hydraulic piston (position 2).
The fixed crest level of the structure is at 2.72 m, meaning this test campaign focuses on low crested structures.

Combination of low water levels with low wave heights are not tested (too low overtopping over the crest, too low impacts on the storm walls), and high water level with the highest waves are also not tested since this is not realistic and would oversize the design of the OVT.

A fixed sand bed of 0.9 m is in the flume, so the active water depth thereby varies from 1.49 m to 1.82 m.

1.3.2 Wave Height

The wave height varies from 0.17 to 0.50 m, increasing in 5 steps of 0.08 m. With respect to the water depth at the toe of the structure, the waves can be classified according to the Overtopping Manual as “non-breaking waves”.

The dimensionless freeboard R_C/H_{m0} varies from 0.0 to 3.1.

1.3.3 Wave period

The largest part of the data set will contain 2 wave periods: 2.86 s and 4.06 s (7 s and 10 s prototype).
A small number of tests in case of the quay wall is carried out with shorter wave periods: 1.67 s, 1.63 s and 1.42 s, in order to simulate wind generated short waves which can occur inside harbor basins.

2 Instrumentation and data acquisition

2.1 Instruments

The characteristics of next instrument are described following:

1. Resistance Wave Gauges
2. Acoustic Wave Gauges (medium range)
3. Pressure Sensors
4. Elelctromagnetic Flowmeter
5. Load Cells at Storm Wall
6. Pressure Sensors at Storm Wall
7. ADV (Acoustic Doppler Velocimeter)
8. Video cameras

2.1.1 Resistance Wave Gauges

Description

The resistance type wave gauges used in the CIEM operate on the principle of measuring the current flowing in an immersed probe which consists of a pair of parallel stainless steel wires (the absence of other support reduces the interaction between the measuring device and the incoming/reflected waves). The current flowing between the probe wires is proportional to the depth of immersion and this current is converted into an output voltage proportional to the instantaneous depth of immersion. The output circuitry is suitable for driving both a chart recorder and a data logger.

Each wave probe needs a wave probe monitor with the energizing and sensing circuits for the operation. Each monitor contains the circuits required to compensate for the resistance of the cable that is connected to the probe. Without this, the output of the wave probe monitor would be non-linear. In order to avoid polarization effects at the probe surface, a high frequency square wave voltage is used to energize the probe. The oscillator that produces this square wave may be set to one of six different frequencies. This allows probes to be used close together without causing any interference.

The current in each probe is detected by measuring the voltage drop across two resistors. Because the measured voltage is alternating, the signal is fed to a precision rectifier to produce a DC voltage proportional to the wave height. This signal feeds a small centre-zero balance indicator and a BNC socket on the front of the panel. The signal is also fed to a preset gain stage that may be set for a gain of between 0.5 and 10. Controls on the front of each wave probe module enable the output signal to be set to zero for any given initial depth of probe immersion. This, together with the gain adjustment, produces a full-scale output of ±10V for all waves.

Application
12 resistive wave gauges (WG) are located along the wall (Y = 0) of the flume, spread over the available length of the flume. Any set of 3 or 4 gauges can be used for reflection analysis to determine the incoming spectral wave height H_{m0} and peak period T_P.

Application range
The steel wires lengths allow detecting any wave height up to 2m.

Calibration
The transformation function (from voltage to depth) is calibrated due the possible changes in the water conductivity (temperature and salinity concentration effects). An overall calibration from wave height to output voltage can be performed by measuring the change in output voltage, raising or lowering the mean water level of the flume.

Data acquisitions
The laboratory works with a global data acquisition system. The data acquisition component support the following hardware manufacturers:

Data Translations boards which is supported by the Open-Layer interface.
National Instruments boards supported by NI-DAQmx 8.6

The component supports data acquisition on several boards at the same time as long as they are from the same manufacturer. The component supports controlling of external equipment through digital and analogical outputs which can be triggered on a specified time or by an input channel. Component supports high throughput using hardware trigger which leads to little cpu utilization for even high sampling frequencies (>1 kHz).

Specifications

Output Signals:	front of monitors ±10V via BNC socket
	rear of case ±10V via 25 way D socket
Gain	0.5, 0.75, 1.0, 1.5, 2.55, 3.75, 6.0, 10.0
Excitation frequency	4.6 kHz to 11.6 kHz
Filter band width	-3dB at 20Hz
Supply voltage	220 or 110V ±10% 40-60Hz
Active length	2000 mm
Diameter	1.5 mm

2.1.2 Acoustic Wave Gauges

Medium Range

Description
The mic+130 from Microsonic is an Acoustic sensor that emit ultrasound pulses that reflect on the measurement object and is received back as an echo.

Application
4 AWG (Acoustic Wave Gauge) are located on the crest of the quay or dike, in order to measure the thickness of the overtopped water layer

Application range
The AWG can measure within 0.20 m up to 1.7 m from its position

Calibration
One calibration is needed for every device to correlate the output voltage signal to distances.

Data acquisitions
The ultrasound measurement system outputs a voltage proportional to distance of between 0 and 10 V. A calibration straight line, previously done, is applied to the output voltage to transform the intensity signal to the proportional distance.

Specifications

Resolution, sampling rate	up to 0.18 mm
Resolution	from 0.2 m to 1.7 m
Transducer frequency	200 kHz
Voltage output	BNC socket: 0 – 10V
Power supply	230 VAC, 250 mA
Temperature range	-25 / +70 ºC

2.1.3 Pore Pressure Sensors (Ppt)

<u>Description</u>
Provided by STS the ATM/N pressure sensors have the next characteristics

<u>Application</u>
8 PPT's are located along the flume. 5 of them in front of the structure, 3 of them in the OVT. The ones in front of the structure are installed to have a look at wave heights in front of the structure.
The latter are recording the volume of water in the OVT, which allows us to determine the overtopping discharge if we combine this measurement with the electromagnetic flowmeter.

<u>Application range</u>
Up to 100 or 400 mb (1 and 4 m of water respectively)

<u>Calibration</u>
They are calibrated by using a calibrated pipe.

<u>Data acquisitions</u>
The signal intensity output is related, taking into account the calibration curve of each probe, to water height.

<u>Specifications</u>

Accuracy	< 0.5		
Thermal shift	Zero	0.......70ºC	0.06
		-25...85ºC	0.08
	Span	0.......70ºC	0.015
		-25...85ºC	0.02

2.1.4 Electromagnetic Flow Meter

Integral Flowmeter

<u>Description</u>
Provided by Yokogawa, the version ADMAG SE205 has a nominal size connection of 50 mm.

<u>Application</u>

Since the OVT is not big enough to collect all water during the experiments with highest overtopping rates, the water has to be pumped out and registered in order to calculate the overtopping discharge. An electromagnetic flow meter is connected to the tubes, and all water pumped out the OVT passes by this flow meter and is thereby recorded.
A calibration file is necessary, since water can enter the OVT at the same time as water is being pumped out. When the OVT is lifted or tilts (see daily comments at test program), a new calibration file is made.

<u>Calibration</u>
Factory calibration.

<u>Specifications</u>
Repeatability: ± 0.1 % of flowrate (±1 mm/s minimum)

Span in m/s	Accuracy
0.3 to 1	± 0.5 % of span
1 to 10	± 0.25 % of span (at indications below 50% of span)
	± 0.5 % of span (at indications 50% of span or more)

During the planned experiments, considering the use of one pump of 300 l/min ($0.005 m^3/s$), the output velocity should be close to 2.54 m/s, while two pumps (600 l/min) should produce a velocity of 5.09 m/s.

$V = (Pi*d^2)/4$ if $d = 0.05$ m we have a volume of $0.0019634\ m^2$
⇨ $0.005 m^3/s / 0.0019634\ m^2 = 2.54$ m/s

2.1.5 Load Cells At Storm Wall

Description
Provided by HBM, the version Z6FC3 is a bending beam load cell with a maximum capacity of 50 Kg. Bending beam load cells are the most widely used types of load cells. During a measurement, weight acts on the load cell's metal spring element and causes elastic deformation. This strain (positive or negative) is converted into an electrical signal by a strain gauge (SG) installed on the spring element. The basic components, i.e. spring element and strain gauge are complemented with additional elements (housing, sealing elements, etc.) protecting the strain gauge elements.

Application
4 force sensors are installed at the corners of the panel ‘F’ (see Figure 6), to record the impact force of the overtopping bore. They are connected to the HBM acquisition, and record at a frequency of 4800Hz.

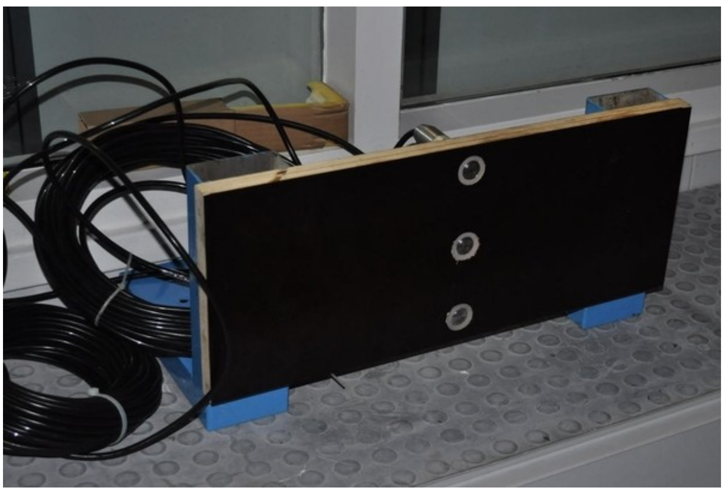
Application range
0 – 50 kg.

Calibration
Factory calibration.

Specifications

- Maximum capacity (E_{max}) 50 Kg
- Minimum load cell verification interval V_{min} 0.009 (% of E_{max})
- Protection class IP68

2.1.6 Pressure Sensors At Storm Wall



Description
Provided by Trafag, TM/N series 22 pressure transmitter for pressure measurement.

Application
3 pressure sensors are installed at the middle axis of the panel 'P' (see Figure 6), to record the impact pressure of the overtopping bore. They are connected to the HBM acquisition, and record at a frequency of 2400Hz.

Application range
-0.3 – 1.2 bar.

Calibration
Factory calibration.

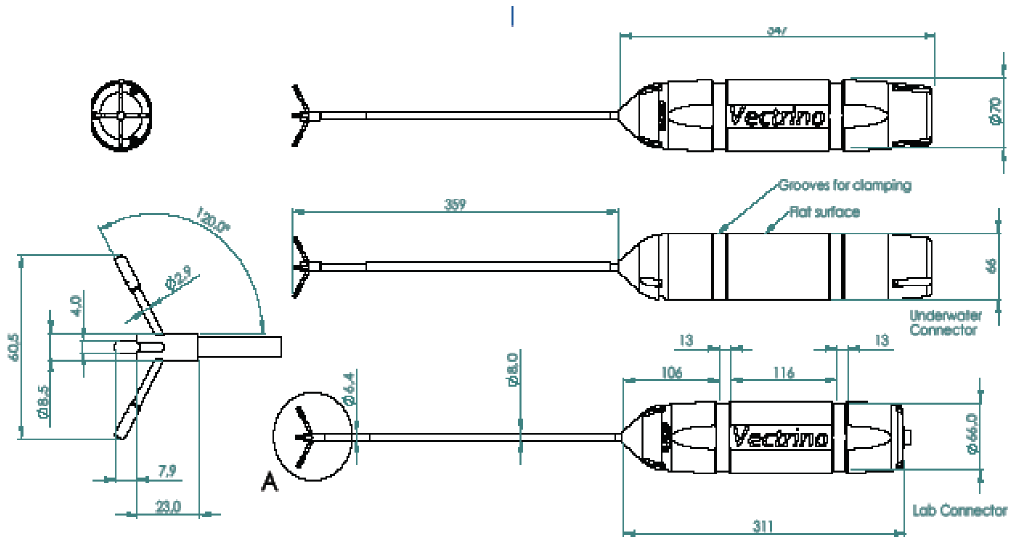
Specifications

Accuracy	< 0.5 % F.S

2.1.7 ADV (Acoustic Doppler Velocimeter)

Description
The Vectrino Velocimeter measures water speed using the Doppler effect. Provided by Nortek the Acoustic Doppler Velocimeter of the Vectrino type have the next characteristics:

The probe consist of four receive transducers, each mounted inside the receiver arm, and a transmit transducer in the centre. The Vectrino uses the Doppler effect to measure current velocity by transmitting short pairs of sound pulses, listening to their echoes and, ultimately, measuring the change in pitch or frequency of the returned sound. Sound does not reflect from the water itself, but rather from particles suspended in the water (zooplankton or sediment). Every probe has a temperature sensor.



Application
4 ADV's are installed in the flume, 2 in front of the structure and 2 at the crest of the structure to measure the flow velocity of the overtopping bore.

Calibration
To calibrate the probe there is a probe check feature within the Nortek software. This has been designed to act as a measurement quality assurance tool, by letting inspect the region where the Vectrino makes its measurements and showing how the signal varies with range.

Data acquisition

The data acquisition has been done by using the software (Polysinc), which allows the synchronization of the measuring ADV (up to 7) and the data synchronization of the acquired information. The information is stored in .vno extension files that later on the program transform to several files (up to 6), from which the date, temperature, velocities, correlation of the signals, intensity of the signal ... can be easily recovered for every probe.

Specifications

Water Velocity Measurements	
Range	±0.01, 0.1, 0.3, 1, 2, 4 m/s*)
Accuracy	±0.5% of measured value ±1 mm/s
Sampling rate (output)	1–25 Hz 1–200 Hz (Vectrino firmware)
Sampling Volume	
Distance from probe	0.05 m
Diameter	6 mm
Height (user selectable)	3–15 mm
Echo Intensity	
Acoustic frequency	10 MHz
Resolution	Linear scale
Dynamic range	25 dB
Sensors	
Temperature Thermistor	embedded in probe
• Range	4°C to 40°C
• Accuracy/Resolution	1°C/0.1°C
• Time response	5 min
Power and data output	
DC Input	12–48 VDC
Peak current	2.5 A at 12 VDC (user selectable)
Max. consumption,	200 Hz 1.5 W
Analog outputs	3 channels standard, one for each velocity component. Output range is 0–5 V, scaling is selectable.
Environmental	
Operating temperature	5°C to 45°C
Storage temperature	15°C to 60°C

2.1.8 Video Equipment

Description

Mobotix M22 and M24. Are a set of Web based cameras that allow the recording of experiments with a nice Resolution (2048 x 1536). They are installed in the flume and linked to a QNAP server (Vio Star VS-4016U) in order to record the interesting locations of the ongoing experiments.

Application

2 cameras are installed, one looking from the front towards the structure, the other looking from the backside to the top of the crest and overtopping tray.

2.2 Definition of time origin and instrument synchronization

The wave generation and most of the measuring equipment (resistive and acoustic wave gauges signals, Pressure Sensors and synchronization signals of other equipment) are recorded in the general acquisition system. External equipment should be triggered with an external TTL signal that links all signals in the same time reference. The general acquisition system works at 40 Hz.

The ADV acquisition frequency is 100 Hz. The HBM acquisition system that will control the load cells works at 4800 Hz, for pressure sensors it is 2400 Hz and 50 Hz to receive the trigger signal that launches it.

3 Experimental procedure and test program

Sketch and explanation of the different equipment along the flume. Please not that the times here reported at which the OVT box has been emptied are just orientative. You can find exactly the time and emptied volume in the data files.

Equipment position:

The Resistant Wave Gauges were placed at:

X (m)	ID
7.72 m	WG0
26.01	WG1
28.51	WG2
30.54	WG3
44.51	WG4
47.51	WG5
50.52	WG6
53.52	WG7
56.56	WG8
59.55	WG9
62.55	WG10
27.02	WG12

The Acoustic Wave Gauges were placed at:

	X (m)	ID
AWG0	70.89	AWG604
AWG3	71.31	AWG613
AWG1	71.68	AWG606
AWG2	72.22	AWG607

The Pore Pressure Sensors were placed at:

	X (m)	Z (m)	ID
PPT0	67.69	0.41	235
PPT1	69.52	0.41	237
PPT2	77.01	0.05	056
PPT3	75.31	0.05	065
PPT4	77.01	0.05	059
PPT5	65.89	0.37	307
PPT6	62.55	0.135	236
PPT7	64.39	0.47	302

where z is the distance from the sandy bottom.

All deployed PPT had a measuring range of 0-400 mb with the exception of PPT 2, 3 and 4 (with ID 056, 065 and 059 respectively) that had a measuring range of 0-100 mb. This three PPT were located within the OVT. One at the front (PPT3) and two in the rear part of the tank (PPT2 and 4).

The ADV were placed at:

X (m)	ADV	ID	D/S	COM	Bottom distance (m)	
67.82	ADV0	0388	S	13	1.48	Master
69.67	ADV1	0376	S	8	1.47	
71.06	ADV2	0392	S	11	0.09	
71.73	ADV3	0446	S	12	0.07	

Note: the bottom distance is the distance from the ADV measuring transmitter to the rigid bottom. ADV 0 and 1 are in front of the structure, and thereby giving it's distance to the sand bottom in the flume. ADV 2 and 3 are above the crest of the structure, and the bottom distance is 9 resp. 7 cm above the crest level. These distances are at their starting position (ADV 2 and 3 were changed during experiments since the initial distance was too large, see notes of the experiments)

Camera location along the flume

Camera	**x position**	**direction of view**
Ciemlab 1	x = 62.01 m	looking towards the structure
Ciemlab 2	x = 74.71 m	on top of structure

Day by day explanation of the more relevant events occurring during the experiments

25/07/2013
Leen and Ivan are present to carry out the experiments.

Two tests were done in order to record the eigenfrequency of the structure and stormwall.

We had to stop due to refrigeration after just one experiment. The refrigeration system had air bubbles and did not operate as it should.

We had problems with AWG3 that is not working properly. The ADV deployed at 9 cm above the crest must be decreased up to 3 cm because they are far from the water layer on the Quay.

26/07/2013

We have decreased the ADV 2 and 3 (392 and 446) up to 3 cm from the Quay, we have changed AWG 3 and we have changed the camera location to record the top of the Quay.

260713_1. We have connected 1 pump to drain the OVT during the experiment. During all other experiments we will be using two pumps when draining the tank.

OVT inclination 2.16°.

After test 260713_2 we fill the flume up to 2.55 m.

260713_3 we had three events during which the waves in the rear of the Quay were big enough to enter in the OVT. The amount of water was not important considering the volume of water in the box but we have to solve that.

260713_4 we had a black out at all the university and therefore everything went off for several minutes. After that we have not started any of the servers neither the wave paddle. We started the pumps around minute 14 to drain the OVT.
The test was aborted and repeated the 29th.

29/07/2013

We have installed two frontal wood panels to avoid the waves in between the Quay and the OVT to produce an extra overtopping that enters the OVT. Figure 8 presents the frontal panels and also the lateral panels (this last ones were installed on 31/07/2013) that were later on installed in the box to avoid the water entering in the box for bigger wave conditions.

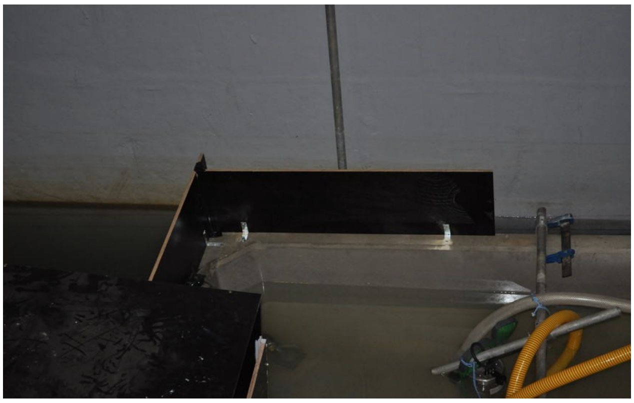


Figure 8 – Frontal and lateral wood panels installed at the OVT

After the panel installation we do tests 7 and 9 which are a repetition of the last two performed tests that had the problems of water entrainment and black out.

30/07/2013

Today the storm wall is installed.

We move ADV1 (376) because it is too close to the Quay and the reflux of water at that side of the Quay is affecting this measurements.

The ADV is relocated at:

X (m)	**ADV**	**ID**	**D/S**	**COM**	**Bottom distance (m)**
65.74	ADV1	0376	S	8	1.43 m

The distribution of the pressure sensors at the storm wall follows the next scheme: Pressure sensor 1 (top at 17.5 cm from Quay), pressure sensor 2 (middle at 10 cm from Quay) and pressure sensor 3 (lower at 2.5 cm from Quay). The distances are from the Quay to the center of the pressure sensor. They are aligned and in the center of the panel. The data of this equipment is saved in the HBM system files.

We have installed the load cells following the next scheme. LC1 (top right), LC2 (top left), LC3 (lower right) and LC4 (low left). Position when looking at the panel having the wave paddle at our back (Y=0 is now located at the right side).

We have changed the overtopping collecting box and now instead of using the one that has an aperture of 0.48 m we use the bigger that has an aperture of 0.97 m.

31/07/2013

310713_0, water is entering the OVT at one or both sides of the OVT, this Overtopping measurements are useless.

After this test we add the two side panels already presented at figure 8

310713_1, the measurements of one load cell (LC1) was having a weird behavior and it may be caused by some friction on the upper corner of the Load Cell panel. We have removed it and reduced 2 mm that area and 1 mm in the lower part of the panel. It is impossible that now we have any kind of friction between the load cell panels and the other panels.

310713_4, there is some water entering the OVT under the panels of wood. The rise of the water level in the rear of the quay together with the waves in the rear side of the quay produced by overtopping waves induce that some water from the rear side enters the OVT. This amount of water is limited and it happened under certain conditions (more than three consecutive important overtopping events over the storm wall) and during this events we expect that water filtration is less or around 10% of the water that is entering the box due through the funnel. In any case this must be considered when doing the data analysis.

310713_6, a plastic box has been used to measure the overtopping due to the limited amount of expected overtopping. PPT3 (065) has been the pressure sensor that has been put in the plastic box. This cases will need a special calibration (310713_5). Between time stamp 1672 and 1715 s we have changed the first OVT for a second one that was empty and ready.

Leen leaves after the tests of today. Ivan will do last few days before summer holiday alone.

01/08/2013

010813_0. We used a plastic box in order to properly measure the limited expected overtopping volumes, despite that this time we had to change the box several time and in one case, replacement 3, the box was filled by a nearly unique event and some water was lost (it filled too fast) before changing the box. The box was replaced once full for another one at the next times: 661-700, 948-978, 1390-1415, 1780-1814, 1858-?, 2275-2300, 2726-2745, 3095-3120.
The calculations however gave similar wave overtopping for 310713_06 as for 010813_0, since the parameter T_P is no part of the overtopping formulae. This test proves there is an influence: larger period = larger overtopping for vertical wall.

After test 010813_0 the water level has been adjusted to 2.39 m.

AWG2 (607) has been lifted up to a safer distance because due to splash on the storm wall was being fully covered by water at some wave conditions. It has also been displaced 10 cm towards the beginning of the Quay

	X (m)	**ID**
AWG2	72.12	AWG607

02/08/2013

We fill the flume up to 2.72m.

Test 020813_3 was aborted due to problems on wave generation.

04/09/2013

We have lifted the OVT 0.25 m so now the water will no longer enter in the box along the sides at 2.55 m water level and most probable it will allow us to do some experiments measuring overtopping at 2.72 m.
By letting water in and out the flume, the sand underneath the OVT box suffered differential settlements, making the OVT box tilt a little towards the structure. The front and the half of the sides has vertical panels to prevent water coming in through the front or the sides. (The main tilting of the structure occurred at the beginning of the experiments, previous to the first experiment because we had to fill the flume and empty it again in order to change 2 PPT which were not measuring correctly)

09/09/2013
(Koen arrives)

We start experiments with water level at 2.55 in order to do the repetition tests of test 13, with the same and different seeding numbers.

The ADV computer crashes during the first experiment and I have to replace it. The configuration for the ADV is maintained as before but changing the Com configuration

Com 7	0446	3
Com 8	0376	1
Com 9	0392	2
Com10	0388	0

090913_1 The ADV has been splitted in 9 different files, one every 4-5 minutes due to the fact that the computer was preconfigured to do that. This only happens for this test, afterwards the configuration of the computer was changed and ADV information is again stored in 1 file.

After tests 090913_2 I've moved the last AWG from 0.26 cm to the storm wall to 0.39 cm to the storm wall because it was being submerged by the water splashes.
Different seeding number gave much more overtopping (+/- double as 090913_1)

After test 090913_3 I've put the same time to both computers HBM and ADV acquisition systems (there was a time gap between the HBM and the new computer of ADV). We also start filling the flume up to 2.72 m

090913_5. The overtopping measurements after minute 6th are useless due to the fact that the pumps have not been able to empty the overtopping volume.

- Water is coming in along the sides (mostly left side, space between wall and OVT is smaller here)
- OVT is full, and the water inside the OVT reaches the front panels. There are openings in this front panel where some chains are put through, so water is leaking (poring) out of this opening.

At the end of this test we have drained the OVT and it took the pumps around 7' 40'' to empty the box. If we assume a volume for the OVT of 2500 l, considering the tilting of the box towards the wave paddle, that means that the pumps that should be extracting the water at 600 l / min are working at nearly half of its rate. That should be induced by the squashing of the rubber tube that brings the water from the EMF to the flume. That squashing should be importantly reducing the capacity of the pumps and we'll have to solve that problem.

10/09/2013

100913_0. The pumps have been working three times during the experiment.

start	stop
12'	15' 50''
26' 50''	30' 27''
42' 10''	46' 50''

After this test we have changed the overtopping collecting box from the one of 0.96 m to the one of 0.49 m (smaller opening, less water entering, hopefully the pumps can drain the OVT fast enough now)

100913_1. It is a calibration test for the pressure sensors of the OVT when using the EMF.

100913_2. The pumps have been working three times during the experiment.

start	stop
4'	6' 50''
11' 20''	14' 30''
22' 50''	29' 20''
41' 15''	48' 40''

53' 20''   55'

Around minute 42' we had a group of 3-4 waves that produce some water entering to the OVT through one of the sides of the box. Another wave produced more water entering the box three minutes later.

At minute 53' four more events have allowed water entering the OVT through the left side.

100913_4. We started the pumps at 6' 16 and we have stopped the pumps at the end of the experiment. From minute 16 until minute 33 the overtopping measurements are useless because the overtopping volume was bigger than the draining power of the pumps. At minute 39 some waves produce water entrance through the left side of the box.
There was so much water in the OVT that it was above the concrete level. Apart from water entrance along the sides, there is also water leaking out the box through some openings in the front panel.

The idea is to squeeze a sponge between the left side of the OVT and the wall (the most narrow side) to calm down the water and avoid water entering the OVT along this side.
The holes in the front panel have been taped, but is not 100% waterproof. The idea is also to further reduce the OVT entrance with 2x10cm (screwing a piece of wood of 10cm wide at both inner sides of the entrance), to decrease the amount of water in the OVT.
The tubes after the EMF will also be doubled, to increase the pump capacity.
Last test of the initial program of quay wall (Hs = 0.42, Tp = 4.08, d = 2.72m) is skipped since it's already late in the evening, and it's a test with a lot of overtopping which cant properly be measured before all issues are solved.
Tomorrow is national holiday, on Thursday-Friday-Monday the quay will be changed to a dike, and the above mentioned ideas will be executed to improve large overtopping measurements.

13/09/2013

Analysis of the overtopping measurements, some comments.
The OVT is tilted a little (around 2 º), but the minimum water level left in the OVT is always higher than the highest point of the ground surface. This means the bottom surface area of the filled OVT is always a square with known distances. By means of the heights, measured by the PPT's in the OVT, we are able to calculate the volume of overtopping during the test.

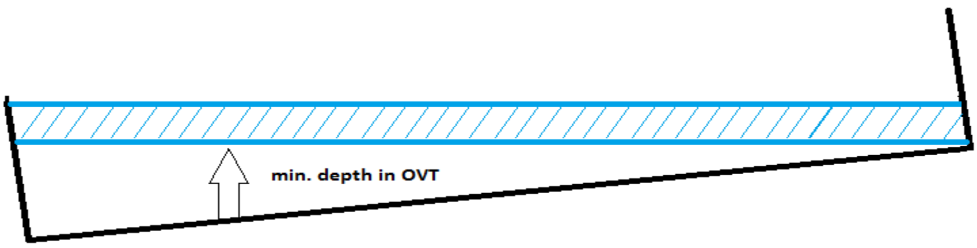


Figure 9 – Overotpping tank is tilted around 2 º, deeper in the part closer to the wave paddle.

However, when the pumps have been active to drain the OVT, the measurements of the EMF (electromagnetic flow meter) have to be combined with the ones of the PPT.
If from time X to Y a certain amount of water has been distracted, we could cumulate this volume to the PPT recordings, for example at time step Y (doesn't really matter whether you do it at X or Y or at the end, since we are (at this moment) only focusing on the total amount of water over the duration of the whole test.

The EMF has an output in voltage, which is transformable to m/s according to the fabricant's calibration. By knowing the m² of the opening (50mm), the volume/s through the EMF can be calculated, which gives us the volume during the time the pump was working.

When looking at the graph of test 310713_2, we noticed the following problem: the voltage is not constant when the pump was not working! This means there is water running through the

EMF!! The tubes connected to the EMF have no closing valve, and both end of the tubes are in the water which means they act as communicating barrels.
If the water in the flume was at 2.39m (at the rear side of the quay, where the output-tube of the EMF was placed), and if the water in the OVT was a little higher, the water from the OVT has been draining (very little) towards the rear side of the flume.
Remark that we need to check all EMF-files, even the ones where the pump has not been operational. It can be that water has passed through it, and the overtopping volumes from the PPT's have to be corrected by the recordings of the EMF.

In any case, the tube coming from the EMF will no longer have its end under the water surface at the rear side from now on. This will be the end of communicating barrels gone and the problem should be solved. Nevertheless, we keep a close eye on it!

18/09/2013

After one week working in the flume the experiment has suffered the next upgrades:

- OVT box has been lifted 0.25 m in order to improve the overtopping measurements at water level of 2.55 and 2.72.
- The dike configuration in front of the Quay has been build and the wave gauges have been calibrated while filling the flume.
- The hosepipe in the rear of the EMF has been substituted by a rigid PVC construction that split the water exit in two hosepipes with no turns and therefore increases the flow rate when pumping the water out of the OVT box.
- Several equipment have been moved in order to allow the dike construction

	X (m)	**Z (m)**	**ID**
PPT0	66.45	0.34	235
PPT1	67.34	0.13	237
PPT5	65.63	0.07	307
PPT6	62.58	0.13	236
PPT7	64.31	0.48	302

The absolute distance of this sensors relative to the concrete bottom of the flume is
Absolute z = 1.87 for PPT 0
Absolute z = 1.9 for PPT 1
Absolute z = 1.37 for PPT 5
Absolute z = 1.03 for PPT 6
Absolute z = 1.38 for PPT 7

The Acoustic Wave Gauges were placed at:

	X (m)	**ID**
AWG0	70.88	AWG604
AWG3	71.35	AWG613
AWG1	71.64	AWG606
AWG2	71.96	AWG607

The ADV were placed at:

X (m)	**ADV**	**ID**	**D/S**	**Bottom distance (m)**	
67.65	ADV0	0388	S	0.61	Master
65.74	ADV1	0376	S	1.05	
71.06	ADV2	0392	S	0.03	
71.66	ADV3	0446	S	0.03	

During the initial test 180913_0 we have had an important amount of problems. Despite the metallic plates protection and the picks to hold it the sand is moving from under the plates and the dike is not stable. We finish this test but we'll have to redo everything and do it better to hold the wave to be tested. This initial test has been done with a water level of 2.39 m

Figure 10 – Sediment moved from the lower part of the metallic plate to the upper part of it.

25/09/2013

In order to improve the dike configuration a set of 4 metallic pieces have been done and welded to the Front of the Quay (left of Figure 12). This structures were used to hold iron plates of 1 cm thicknes that were also welded to a U beam going from right to left of the flume at two meters distance of the Quay (right of Figure 12). This construction was covered again with the 6 mm metallic plates previously used. The upper and lower layer of plates were welded and some pikes were used to improve the holding to the sandy slope.

Figure 11 – Reinforcement installed in the under the metallic 6 mm plates.

Figure 12 – Final dike configuration.

Despite all this reinforcements we had to keep to welding the different plates along the ongoing experiments because the energy of the waves was distroying the weldings between the upper and lower plates.

We have filled the flume up to 2.39 and we keep on running the experiments.

250913_0 we do the overtopping measurements with the little box. We had to empty this box 6 times during the experiment at minutes ??, 12, 23, 32, 42 and 55. This is the last experiment with the little overtopping box.

26/09/2013

The entrance of the OVT box is shifted to the one with 0.48 m.

260913_0. The trigger with the ADV has not properly worked and the HBM system failed to record the data.

The flume is filled after this test up to 2.55 m

260913_4. Due to the Overtopping volumes we have emptied the OVT box at 2135-2251 seconds after starting generation.

30/09/2013

We fill the flume up to 2.72 m

300913_1, we emptied the OVT box during the experiment 1520-1860 s.

300913_2, we emptied the OVT box during the experiment 460-811, 1320-1892, ??-2733 s.

300913_3. We just empty the OVT to do the calibration of the OVT box

300913_4, we emptied the OVT box during the experiment 615-835, 1120-1624, 1940-2300 s. There have been two events with a overtopping discharge that went over the entrance of the OVT collecting box

01/10/2013

011013_0 The Overtopping measurements are useless. The pilling up of water in the rearside of the dike is so big that the water is entering entering in the OVT box. Load cell measurements will be also difficult to analyze due tot he water movement behind the storm wall (see video test_53.avi for a better comprehension).

We had to stop the experiment at the end of 011013_0 due to the lifting of the left flat part of the model. The water within the Quay is importantly pushing this pieces of wood and we can not risk that they get free in the middle of an experiment.

Table 3.3: Test program

Test	Hs (m)	Tp (s)	h	Filename	Remarks
No storm wall					
1	0.33	2.86	2.39	250713_1	500 waves, OVT entrance 0.48 m. AWG 3 did not measure at all. ADV at 9 cm from Quay
2	0.33	2.86	2.39	260713_0	500 waves, OVT entrance. 0.48 m. All tests without storm wall have 500 waves.
3	0.42	2.86	2.39	260713_1	
4	0.33	4.08	2.39	260713_2	
5	0.25	2.86	2.55	260713_3	Some overtopping over the OVT.
6	0.25	4.08	2.55	260713_4	During this last experiment we had a black out in our campus and everything was lost
7	0.25	2.86	2.55	290713_0	Repeat test 5 to avoid overtopping over the OVT.
8				290713_1	We empty the OVT to obtain a calibration file (pressure sensors vs volume) Only 4 channels are recorded: the 3 PPTs in the OVT + the EMF
9	0.25	4.08	2.55	290713_2	Repeat test 6 to avoid overtopping and finish the time series.
10				290713_3	We empty the OVT to obtain a calibration file (pressure sensors vs volume)
Storm wall					
11	0.33	4.08	2.55	310713_0	1000 waves from now on. OVT entrance 0.97 m. Overtopping data useless (water entering at OVT sides)
12	0.33	2.86	2.55	310713_1	
13	0.42	2.86	2.55	310713_2	
14				310713_3	We empty the OVT to obtain a calibration file (pressure sensors vs volume)
15	0.5	2.86	2.55	310713_4	We had overtopping under the frontal piece of wood due to the water level rise between the quay and the OVT. (see the comments along daily explanation)
16				310713_5	We empty the OVT to obtain a calibration file (pressure sensors vs volume)
17	0.25	2.86	2.55	310713_6	overtopping measured in a little plastic box, when t = 1672 and 1715 s we change from box 1 (full) to box 2.
18	0.25	4.08	2.55	010813_0	little box to measure overtopping, some water lost while changing from 2nd to 3rd box
19	0.33	2.86	2.39	010813_1	
20	0.42	2.86	2.39	010813_2	

21	0.33	4.08	2.39	010813_3	
22	0.2	1.67	**2.72**	020813_0	Test with small wave period
23	0.25	2.86	2.72	020813_1	
24	0.33	2.86	2.72	020813_2	
25	0.25	4.08	2.72	020813_3	Aborted test.
26	0.17	1.63	2.72	020813_4	Test with small wave period
27	0.42	2.86	**2.55**	090913_1	Seeding number = 1. Repetition case of test 13. 1 Adv file every 4 minutes.
28	0.42	2.86	2.55	090913_2	Seeding number = 2, Repetition case of test 13 (same spectrum, different seeding number) many more overtopping noticed than the test before.
29	0.42	2.86	2.55	090913_3	Seeding number = 1. Repetition case of test 13
30	0.13	1.42	**2.72**	090913_4	Test with small wave period
31	0.42	2.86	2.72	090913_5	Overtopping measurements are useless. Overtopping bigger than pump power.
32	0.25	4.08	2.72	100913_0	
33			2.72	100913_1	We empty the OVT to obtain a calibration file (pressure sensors vs volume)
34	0.33	4.08	2.72	100913_2	
35	0.5	2.86	2.72	100913_4	

Experiments with the quay wall are over, changing to dike (12/9 → 16/9)

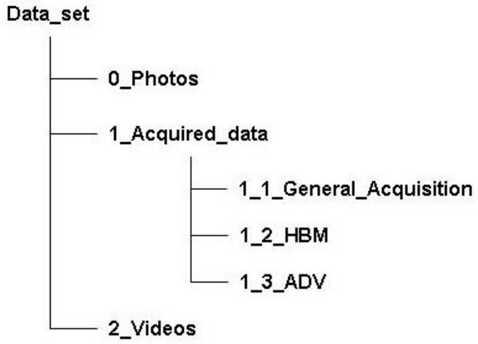
Test	**Hs (m)**	**Tp (s)**	**h**	**Filename**	Remarks
36	0.25	2.86	**2.39**	180913_0	little box. OVT entrance 0.97 m.
37	0.25	4.08	2.39	250913_0	little box
38	0.33	4.08	2.39	250913_1	
39	0.33	2.86	2.39	250913_2	
40	0.42	2.86	2.39	260913_0	Automatic trigger failed for ADV and HBM failed recording the data. OVT entrance 0.48 m.
41	0.33	2.86	**2.55**	260913_1	
42	0.33	4.08	2.55	260913_2	
43	0.42	2.86	2.55	260913_3	

44	0.5	2.86	2.55	260913_4	
45	0.42	2.86	2.55	270913_0	Repetition of case 43
46	0.42	2.86	2.55	270913_1	Repetition of case 43 and 45
47	0.42	2.86	2.55	270913_2	Seeding number = 1
48	0.33	2.86	**2.72**	300913_1	
49	0.33	4.08	2.72	300913_2	
50			2.72	300913_3	We empty the OVT to obtain a calibration file (pressure sensors vs volume)
51	0.42	2.86	2.72	300913_4	
52			2.72	300913_5	We empty the OVT to obtain a calibration file (pressure sensors vs volume)
53	0.42	4.08	2.72	011013_0	We stop the experiment due to breaking of the flat part of the model. Useless overtopping measurements.

Notes on the experimental tests:

4 Organization of data files

The data files are organized following the next scheme:



In the previous Table, the filename of each experiment can be found and correlated with the data storage information. The filename can be found with a .txt extension for the general acquisition data and a .vno extension for the ADV acquisition data. There are mainly three groups of files.

1. .txt files are in 1_1_General_Acquisition. These files contain the information acquired directly by the general acquisition system of the wave paddle, which controls the absolute time reference, resistive and acoustic wave gauges signals, pore pressure sensors, electromagnetic flowmeter fluxes and synchronization signals of other equipment. The format of these files is the described by: five initial rows in which the frequency of the acquisition can be seen in the second row, and the acquisition channel name and measuring units can be read in the sixth row. The information of each probe is found consecutively in time considering the acquisition frequency used at the experiment.
2. HBM files, found in 1_2_HBM, come in four different files. There is one '.TSX' file which is the header of the test information and three '.MAT' matlab files have the information of the three different used acquisition frequencies (2400 Hz for the pressure sensors, 50 Hz for the Trigger and 4800 Hz for the Load Cells). The different files SRG1 for pressure sensors, SRG2 for Trigger and SRG3 for Load Cells can be directly loaded using matlab.
3. .vno files are in 1_3_ADV/raw. This second group is formed by the ADV information acquired by means of the Polysink Software. These files can be extracted directly with the aid of this software (providing velocities, correlation, signal amplitude, signal to noise ratio, temperature and control files) or can be converted by the “Nortek file converter” and analyzed by using the WinADV software freely available on the net. (free version of both programs can be found at www.nortek-as.com). The 1_3_ADV/converted files is the section where six txt files (.amp. for amplitude information; .cor. for correlation information; .ctl. for control information; .snr. for the signal to noise ration information; .tem. for the temperature information; and .vel. for the velocity information) have been obtained from each binary .vno files.
4. The web cam videos are saved in different folders (one for each camera). Inside that folder there is one folder for each day and within that there is another folder for each tested hour. The videos are splitted automatically every 15 minutes and therefore the files include all what was recorded at that time. The time correlation of videos and tests can be extracted from the test programme table, the folder and file video names and the time stamp within each video.