Data storage report

Wave Loads on Walls
WaLoWa
Delta Flume, Deltares

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Document objective

This data storage plan describes the experimental program and how tests should be performed. When all data has been obtained, the data storage plan is updated to a data storage report. In the data storage report, the data is described so that others can use them.

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Contents

WaLoWa
Wave Loads on Walls

1 Objectives

The coastal area worldwide is comparably densely populated and in 2000 half of the major cities counting more than 500,000 inhabitants were located within 50 km of the coastline (UNEP, 2006). The attractiveness of the coasts lead to an increased number of buildings and assets close to the coastline. At the same time, the sea level rises and an increased storminess is expected in the future. As projected in the latest synthesis report of the intergovernmental panel on climate change (IPCC) the global sea mean level rise will exceed the observed rate of 2 mm/year (1971-2010) in the 21st century (IPCC, 2014). When vulnerability in the coastal area and probability for flooding increases, the risk for inhabitants, accompanying industry and infrastructure also goes up. This is especially true for countries with low topographies compared to the sea level, such as Belgium, Netherlands, Denmark, part of UK or many areas in Indonesia. Increased water level and storminess lead to larger loads on coastal structures, such as dikes and storm walls or buildings. To improve the resilience of low-lying coastlines, well designed storm walls on top of a dike are an important part of the coastal protection strategy to counteract the increased risk of flooding. These structures are now considered a feasible alternative to protect urban areas against flooding and are often integrated into the promenade to reduce social and environmental impact. To protect the people and property behind from flooding and wave attack a reliable design based on the actual wave forces is aimed for. Additionally sand nourishments are widely used as an adaptive measure to counter sea level rise, whereby the foreshores are becoming more shallow. Hence, the following objectives will be addressed within the scope of this project:

(1) Study of overtopped wave loads on walls in shallow foreshore conditions. The total impact force and force distribution on a wall on top of a dike are studied by analyzing the measurement from load cells and pressure sensors respectively. Eventually the impact force will be related to the incoming wave and geometrical parameters

(2) Study of scale effects for overtopped wave impacts by comparing the results from small scale test (1/25) with the results from the large scale experiments (1/4.3). The most important scale effect is the air entrainment. Therefore attention has been paid to measure and observe the aeration of the impacting flow at the wall

(3) Study of the sandy foreshore evolution by analyzing bed profile and sand concentration measurements. The results are also used to further calibrate the XBeach model

(4) Furthermore numerical model calibration of SWASH, with the wave conditions until the dike toe will be done and the model used to calculate the incoming wave parameters for a set-up without dike-promenade-wall structure and therefore without the influence of reflected waves. A numerical model calibration of a high resolution SPH model will be done with the impact measurements and coupled to the wave parameters from the SWASH model

(5) Study of layer thickness and velocity of the overtopped bore to investigate overtopping bore parameters, relate them to the impact at the wall and calculate instantaneous overtopping discharge. The study of bichromatic waves will help to understand the complex interaction between incoming and reflected bore on the promenade.

(6) Finally, a study of new measurement techniques such as using a laser scanner to cover the whole chain of overtopping wave impact parameters. Starting from the wave heights at the dike to, the overtopping wave characteristics, and overtopping flow formation until impact on the wall and run-up at the wall

2 Experimental setup

2.1 General description

The study of overtopped wave loads on vertical walls requires a large-scale wave flume facility to validate and extend the small-scale experiments conducted at Ghent University and Flanders Hydraulics Research. It is the objective of this study to design an experimental set-up comparable to these small-scale experiments, which again are based on typical coastal profiles

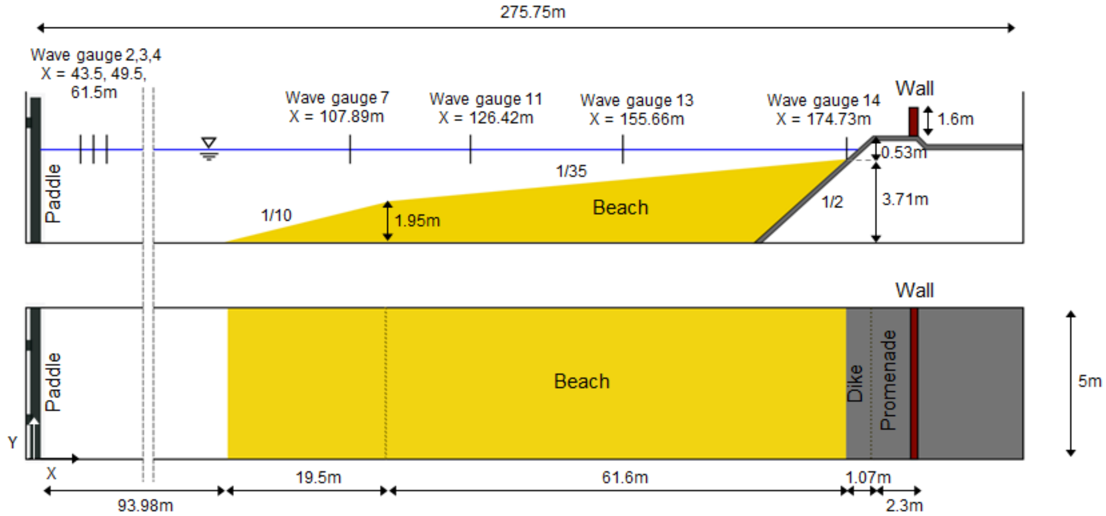

Figure 2-1: Model geometry WaLoWa

at the sandy coasts of the North Sea. A foreshore of compacted sand is constructed within the Delta Flume. The foreshore starts at location X = 93.98 m from the paddle and is comprised of a transition slope (1/10) until 1.95 m flume height and attached a beach slope (1/35) until 3.71 m flume height (see Figure 2-1). The total foreshore length is therefore 81.1m. The end of the foreshore is the dike toe location X = 175.08 m from the paddle. Connected to the foreshore is a 0.53 m high dike structure with a 1/2 slope. On the dike a 2.32m wide promenade is build and at the end of the promenade a non-overtopped wall of 1.6 m height is constructed (ANNEX Q). The promenade has a 1/100 seaward slope to facilitate drainage of water. The model scale is 1/4.3.

2.2 Definition of the coordinate system

The global coordinate system for the Delta Flume is originated at the lower right corner of the wave paddle when standing with the back to the paddle. The positive X-direction is defined in the main flume axis pointing towards the model. The positive Y-direction is defined in cross flume direction and the positive Z-direction is pointing upwards from the flume bottom. X,Y and Z are written in capital letters.

A local coordinate system is originated at the dike crest location on the same side of the flume as the global coordinate system (Figure 2-2). With positive x-direction in main flume direction pointing towards the wall. Positive y-direction in cross flume axis and positive z-direction pointing upwards. x,y and z are written in small letters. The local coordinate systems corresponds to X = 176.15 m, Y = 0 m and Z = 4.24 m of the global coordinate system

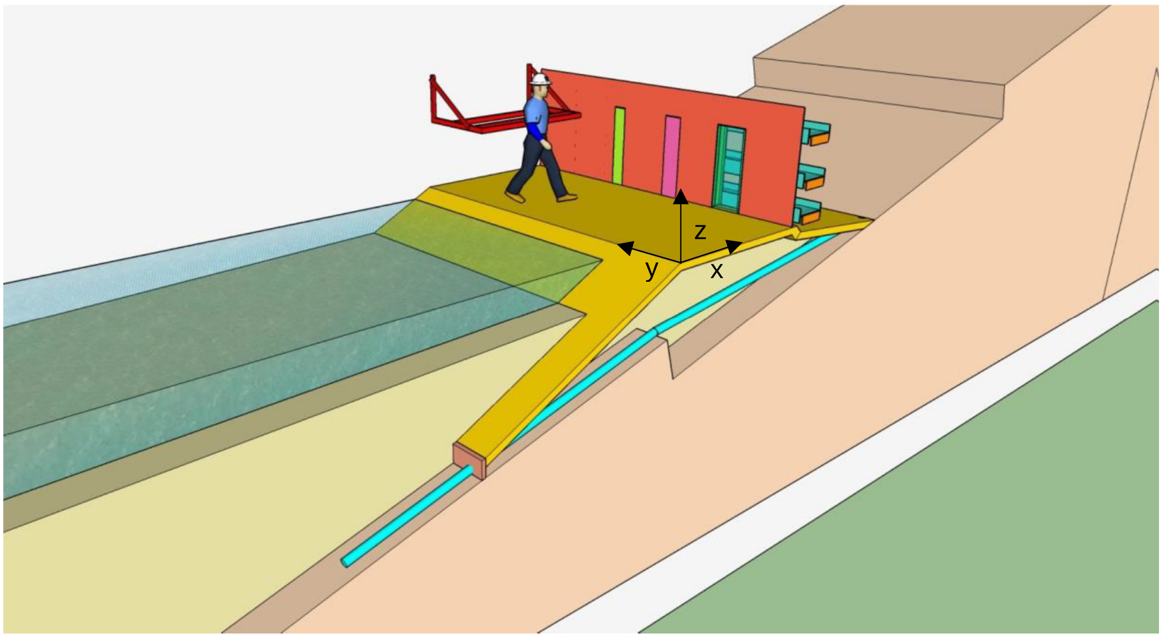

Figure 2-2: Local coordinate system (corresponds to X = 176.15 m, Y = 0 m and Z = 4.24 m of global coordinate system, originated at the wave paddle)

2.3 Relevant fixed parameters

A sand with a sieve curve characteristic as shown inFigure 2- Figure 2-3 was used. The D_{50}

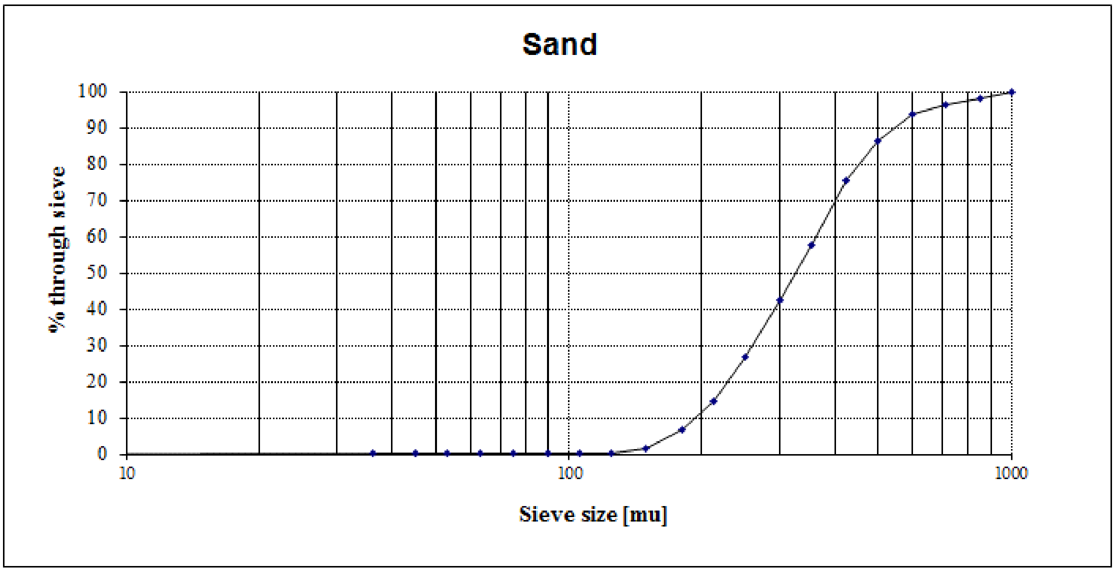

Figure 2-3: Sieve curve of applied sand (D_{50}=320mu)

was 320mu. This sand was only installed for the 0.4m top layer over the entire foreshore. Below the 0.4m top layer was a sand with D_{50} = 230mu installed. The erosion depth over the entire foreshore never exceeded 0.4m during the tests.

3 Instrumentation and data acquisition

The exact location of all instruments is given in the autocad file in ANNEX B.

3.1 Instruments

3.1.1 Wave gauges

- Description

Figure 3-1: Box cover around reference electrode (left) and wires of resistance wave gauge and reference electrode below (right)

7 resistance wave gauges installed at the flume wall were used. WHM2, WHM3, WHM4 at the offshore location (horizontal bottom) for reflection analysis with reference electrode at the lower part of the gauge. WHM7, WHM11, WHM13, were installed along the foreshore and WHM14 at the dike toe. For WHM13 and WHM14 the reference electrode was moved further offshore to be fully submerged at all times. Also for WHM7 and WHM11 a wooden box was constructed around the reference electrode to avoid covering of sand (Figure 3-1). The wooden box was covered with a transmissible geotextile on top to let the flume water inside. Exact locations are given in ANNEX B.

- Calibration

The wave gauges were calibrated by raising and lowering the water level before and after the test program. The calibration values before and after the test program are given in the Table 3-1. Where C_0 and C_1 are the parameters of a linear calibration function.

Table 3-1: Calibration factors wave gauges

Wave gauge	Calibration before test	Calibration after test
WHM02	C_0=5.5066, C_1=0.4418	C_0=5.5214, C_1=0.4457
WHM03	C_0=5.5066, C_1=0.4446	C_0=5.5072, C_1=0.4479
WHM04	C_0=5.5065, C_1=0.4481	C_0=5.6129, C_1=0.4730
WHM07	C_0=5.5310, C_1=0.4452	(scattered output voltage)
WHM11	C_0=7.9743, C_1=0.6927	C_0=3.2653, C_1=0.1524
WHM13	C_0=7.0468, C_1=0.4404	C_0=6.9815, C_1=0.4319
WHM14	C_0=7.4489, C_1=0.4343	C_0=7.5676, C_1=0.4525

- Data acquisition

The measurement frequency is 1000Hz and the data is recorded by the main data acquisition system.

- Comments

Some wave gauges showed drift in the signal over time (probably the reason was long test duration and change in water temperature due to water mixing above the foreshore). Also, they were not showing the correct water level in the beginning, so recalibration was done after the test program. Find more information in the test logbook in ANNEX A.

3.1.2 WaveGuide wave radar

- Description

The radar was mounted 7-8m above the water surface and the beam divergence angle was 5° (half top angle). Exact location is given in ANNEX B. The specification sheet is given in ANNEX D.

Figure 3-2: WaveGuide radar

- Application range

Applied 7-8m above the water level

- Calibration

No additional calibration. Water level accuracy 1cm

- Data acquisition

5Hz sampling frequency on separate measurement PC. Synchronisation is roughly done by using the information from the computer clock and will later be done manually against the closest wave gauge signal (Wave gauge 13 until testID WLW_Irr_2_F and after that wave gauge 14).

- Comments

Wave radar was relocated before testID WLW_Irr_2_F to measure at the dike toe location. Find more information in the test logbook in ANNEX A.

3.1.3 Kulite HKM-379 (M) pressure sensors

- Description

15 Kulite HKM-379 (M) pressure sensors (DRO1-DRO15) were applied and installed in a separated plate integrated into the steel wall (Figure 3-3). First pressure sensor was installed 2cm above the bottom, following pressure sensors were installed with 7cm spacing and for the upper pressure sensors with 12cm spacing. Exact locations are given in ANNEX B. The specification sheet is given in ANNEX F.

Figure 3-3: Kulite HKM-379 (M) pressure sensor

- Application range

1 bar maximum pressure

- Calibration

0-10 Volts covered 0-1bar. Linear calibration with C_1=1.

- Data acquisition

The signal from the pressure sensors was sampled at 1000Hz and recorded by the main data acquisition system.

- Comments

Some of the pressure sensors showed a drift over the time series or larger noise in the signal. See the test logbook in ANNEX A for more information.

3.1.1 HBM U9 load cells

- Description

2 compression load cells of type HBM U9 were installed (Figure 3-4). They were installed between a hollow profile (force measurement section) and the IPE500 beams of the support structure. The hollow profile hang in a prefabricated opening in the steel wall and was additionally supported to the side to avoid rotation. The small gaps (<1cm) between hollow profile and steel wall were covered with tape. KRM01 is the upper load cell and KRM02 the lower load cell. Exact locations can be found in ANNEX B.

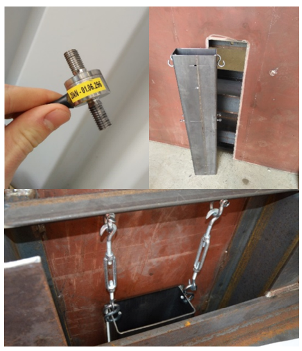

Figure 3-4: 2kN HBM U9 load cell (upper left) and hollow force measurement section

- Application range

20kN maximum force

- Calibration

The output voltage between 0-5V was converted to kN using the calibration factor C_1 = 0.4. Accuracy better than 1% and absolute error less than 10N. The calibration sheet is given in ANNEX G.

- Data acquisition

The signal from the load cells was sampled at 1000Hz and recorded by the main data acquisition system.

- Comments

The load cells were unscrewed and tightened before testID WLW_Irr_1_F_R to release tension due to temperature deformation. Due to additional support towards the side probably a fraction of the total force was lost in the measured signal, since it is take by the side support. Find more information in the test logbook in ANNEX A.

3.1.1 Wave gauges on promenade

- Description

4 Resistive type wave gauges were installed on the promenade (Figure 3-5). The foot with the reference electrode was submerged 5cm in a bucket of water installed on the promenade. The total bucket depth was 12cm. Exact locations are given in ANNEX B.

Figure 3-5: Resisitve wave gauge

- Application range

The measurement range was 1m

- Calibration

The wave gauges were calibrated by raising the water level in steps over the entire height of the gauge. This was done after the test program. Linear calibration factors are given in Table 3-2 to convert 0-10V to an output in m. (The calibration sheet as given in ANNEX E contains values for calibration in clean water conditions done in 2015)

Table 3-2: Calibration factors wave gauges on promenade

Wave gauge	Calibration value
WLDM1	C_0=4.7180, C_1=0.0491
WLDM2	C_0=4.7248, C_1=0.0496
WLDM3	C_0=4.7254, C_1=0.0484
WLDM4	C_0=4.7261, C_1=0.0479

- Data acquisition

The signal of the wave gauges is sampled at 1000Hz and recorded with the main data acquisition system

- Comments

The buckets for the reference electrode were flushed with water before each tests to remove the sand inside and provide flume water to the reference electrode. The reference electrode was not covered with sand in any test.

3.1.1 MaxSonar HRXL/ Honeywell 943 M18 ultrasonic distance sensors

- Description

4 ultrasonic distance sensors were used: 3 HRXL-MaxSonar sensors (UDS1-UDS3) and 1 Honeywell 943 M18 sensor (UDS4). Exact locations are given in ANNEX B. The specification sheet is given in ANNEX H (HRXL) and ANNEX I (Honeywell).

Figure 3-6: Ultrasonic distance sensors attached to wooden frame

- Application range

HRXL MaxSonar: Min sensing distance 0.3m and max. sensing distance 5m. Resolution = 5mm. Honeywell 943 M18: Min sensing distance 0.2m, max. sensing distance 2m. Repetability 0.2% (=2mm) and resolution 2mm.

- Calibration

UDS1- UDS3 the output in mm were derived using the calibration factors in Table 3-3. The calibration factors for UDS1-UDS3 are derived from the specification sheet stating that Ouput [mm] = 5120/Voltage power supply(=4.994V). Output Voltages between 0-5V were measured. The calibration sheet for UDS4 gives a linear calibration factor C_1=200.

Table 3-3: Calibration factors ultrasonic distance sensors

Ultrasonic distance sensor	Calibration value
UDS1 (HRXL)	1025.641026
UDS2 (HRXL)	1025.641026
UDS3 (HRXL)	1025.641026
UDS4 (Honeywell)	200

Wrong calibration value for UDS4 (1025.641026 instead of 200) until testID Bi_02_4 was used. Starting from testID WLW_Irr_1_F the correct calibration value (200) was used. Note that you can always recalculate the distances by using the .raw file from the main data acquisition (output in voltage) and convert it to distances by using the correct calibration factors.

- Data acquisition

Signals from both sensors are sampled by the main data acquisition system with 1000Hz. Note that the max. refresh rate of UDS1-UDS3 was 7.5Hz and for UDS4 was 40Hz.

- Comments

UDS1-UDS3 have temperature compensation. Ultrasonic distance sensors run in simultaneous mode (synchronised measurement pulse) and were set to free run mode before testID WLW_Irr_1_F. Also, UDS1 and UDS4 switched position before test Bi_01_6. Find more information in the test logbook in ANNEX A

3.1.1 Valeport 802 electro-magnetic current meter

- Description

The Valeport 802 model with a discuss diameter 3.2cm was used (Figure 3-7). A ~1.6cm high water body was required below the sensor to measure reliable. +-1% measurement accuracy and 12mm/s signal noise at 1m/s flow velocity are given in the specification sheet in ANNEX J. Exact locations are given in ANNEX B.

Figure 3-7: Electro-magnetic current meter as installed

- Application range

Fully submerged it can record flow velocities +-5m/s.

- Calibration

An output voltage between 0-10V was measured and converted to m/s by using the linear calibration factors C_0=-5, C_1=1. -5m/s. BUT: since a digital-analog converter was installed the output voltages should have been converted using the linear calibration factors C_0=-5.0984, C_1=1 in x-direction and calibration factors C_0=-5.128, C_1=1 in y-direction. It is therefore recommended to use the raw data file (in voltage) and do the conversion again.

- Data acquisition

The signal was recorded with 1000Hz by the main data acquisition system. The measurement frequency of the sensor itself had a 16Hz update rate and a delay of 5 samples (take care when synchronizing with other signals, to correct for this shift).

- Comments

A digital- analogue output converter was constructed by Ghent University. The sensor had difficulties when changing from dry to wet conditions and the other way round. Once fully submerged it gave a stable measurement.
Positive Y-direction of the sensor is in line with the positive main flume X-axis. Positive X direction of the sensor is in line with the negative cross flume Y-axis. Note that from test WLW_Irr_2_F onwards the positive axis directions of the sensor are the other way round (device rotated around 180°). The height of the sensor above the bottom was adjusted from 5cm to 3cm before testID Bi_02_4. Find more information in the test logbook in ANNEX A.

3.1.1 Airmar flow meter S300 paddle wheels

- Description

4 Airmar flow meter S300 paddle wheels were installed on the promenade to measure the overtopping flow velocities (Figure 3-8). Exact locations are given in ANNEX B. The specification sheet is given in ANNEX K.

Figure 3-8: 4 Airmar paddle wheels attached to M10 screw

- Application range

The sensor can cover a flow range between ~0.5m/s (increasing nonlinearity below this value, see ANNEX K) and 20.5m/s

- Calibration

The range of output voltages between 0-5 Volt was converted into a velocity m/s with calibration factor C1 = 5.3588 from the calibration sheet in ANNEX K.

- Data acquisition

The signals are sampled by the main data acquisition system with 1000Hz. Anyhow the pulse rate of the sensor depends on the speed of the flow and is approximately 4Hz/m/s.

- Comments

The sensor is usually used in a different set-up (mounted in ship hull to measure ship velocity) and the results need to be treated carefully. The sensor measure only positive velocities, no matter if the flow was incoming or outgoing. Also the paddle blades have a different front and back shape, suggesting that they are designed to measure only one way. The height of the sensor above the bottom was adjusted from 5cm to 3cm before testID Bi_02_4. Find more information in the test logbook in ANNEX A.

3.1.1 High speed camera

- Description

The high speed camera was placed behind the observation window in the steel wall, monitoring the impacting flow (Figure 3-9). Exact locations are given in ANNEX B. The camera-lense combination was IOIndustries Flare 2M280CCX and Fujinon HF12.5SA-1 12.5mm respectively. The specification sheets are given in ANNEX L.

Figure 3-9: High speed camera position looking through observation window

- Calibration

A multilinear grid was pressed against the observation window while recording to correct for frame distortation and have a length information. Additionally markers were painted on the window. In order to get a depth of view information an improvised method with a tape measure was used.

- Data acquisition

100 frames per second for the first 20 minutes of the test. Synchronisation was achieved by using red LEDs within the field of view which were giving a light pulse together with the start of the main data acquisition system.

- Comments

Installation of high speed camera was done before testID WLW_Irr_1_F. Find more information in the test logbook in ANNEX A. Lighting was provided from behind the observation window and several layers of bubble wrap paper were used to diffuse the light.

3.1.1 GoPro Hero5 video camera

- Description

3 GoPro Hero5 cameras were installed (Figure 3-10). One on the sidewall, one behind the observation window in the steel wall and one from the measurement carriage providing a topview of the promenade. Exact locations are given in ANNEX B. The specification sheet is given in ANNEX M.

Figure 3-10: GoPro camera from side wall (left) and attached to scaffold structure (right) below the light sources

- Calibration

Markers on the sidewall and observation window, as well as fixed points on the steel wall were used for frame correction.

- Data acquisition

The sampling rate was 60 frames per second with a resolution of 2.7k (2704px*1520px). Spatial resolution was always smaller than 2mm in the areas of interest (wall, promenade, dike). Line mode to avoid the fish eye effect was used. Synchronisation achieved by using red LEDs within the field of view which were giving a light pulse together with the start of the main data acquisition system. Find more detailed settings in ANNEX M.

- Comments

Three artificial light sources used. One topview light (32000 Lumen), attached to the measurement carriage above the topview GoPro. One light (21000 Lumen) from the sidewall above the sidewall GoPro and one light (16800 Lumen) from behind the observation window in the steel wall.

3.1.1 Void-fraction meter

- Description

The void-fraction meter was installed in an opening in the steel wall, 0.3m from the bottom and 0.2m apart from the observation window (Figure 3-11). Two glasfiber sensor heads transmitted a light pulse and detect reflection in case there is water infront of the sensor

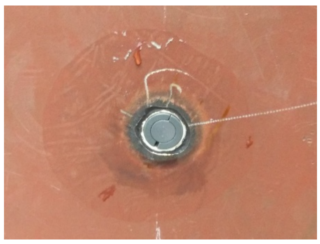

Figure 3-11: Void-fraction meter flash mounted in steel wall

(and no reflection if there is air). Exact locations are given in ANNEX B. The specification sheet is given in ANNEX N.

- Calibration

-

- Data acquisition

The signal was recorded at 10kHz on a seperate PC, for synchronisation purposes the signal was also recorded at 1000Hz by the main data acquisition system. The first 20min of each tests were recorded.

- Comments

The device was installed before testID WLW_Irr_3_F. Find more information in the test logbook ANNEX A.

3.1.1 SICK LMS511 laser profiler

- Description

The profiler was mounted at the left flume sidewall (when standing with the back to the paddle), approximately 5m above the dike toe location (Figure 3-12). A slant angle of 26° was used. Profile measurement covers the water at the dike toe until ~10m offshore, the dike, promenade and wall. This resulted in an field of view of 114°. The measured line was approximately in the middle of the flume (~y = 2.7m) between the force and pressure measurement section in the steel wall. The exact location of the SICK laser is given in ANNEX B. The specification sheet is given in ANNEX O.

Figure 3-12: SICK laser profiler attached at the upper edge of the flume wall

- Calibration

Objects with a defined length in the scan were used to introduce a length scale to the measurement. Additionally objects were placed in defined distances on the promenade within the field of view to get another length information.

- Data acquisition

The measurement frequency was 35Hz with an angular resolution of 0.25°. The signal was recorded on a separate PC but a synchronization pulse was send when starting the main data acquisition system.

- Comments

Foamy water surface resulted in good reflection. Fog filter was switched off, and only single echo recording was used.

3.1.1 ASM-IV-N Argus surface meter

- Description

The ASM measured the sand concentration in the water column and was placed at x = -2.47m offshore of the dike crest location (Figure 3-13). The device was equipped with 144 laser sensors with 1cm vertical spacing. Exact location is given in ANNEX B. The specification sheet is given in ANNEX P.

- Calibration

A calibration file from previous experiments in sandy conditions was used.

- Data acquisition

The measurement interval was set to 1s and 60 measurements per cycle (with a total cycle time set to 60 s) were recorded with no pause interval between cycles (break=0) for tests bi_01_4+bi_01_5. From tests bi_01_6_+_bi_02_4, the total cycle time was reduced to 5 s, with 5 samples per cycle, without changing the sampling interval (=1 s) and the break (0 s). The ASM is synchronized using the internal computer clock. The computer clock was checked against the time of the computer from the main data acquisition every day. Given the fact the the device is only recording at a measurement frequency of 1s the synchronization in the order of 1s should have been achieved. The signal is recorded on a board computer and read out after the test.

Figure 3-13: ASM as installed

- Comments

Mostly the ASM was started in the morning and measured the entire day. This means several tests can be included in one measurement file, while the start and stop times are recorded in the output files.

3.1.1 Mechanical profiler

- Description

The mechanical profiler was developed within Deltares and consists of a profiler wheel which is attached to a measurement hinge/arm fixed to the measurement carriage (Figure 3-14). The carriage was moved after the test over the foreshore and the height changes of the profiler wheel were recorded.

Figure 3-14: Mechanical wheel (white) profiler

- Calibration

Calibration done by Deltares

- Data acquisition

The location in x-flume direction was determined using a laser distance meter targeting to a fixed point at the end of the flume. One center profile over the entire foreshore length and 4 lateral profiles (0.2m and 0.4m apart from the centerline) until about 30m offshore from the dike toe were measured after each irregular wave test or group of bichromatic waves. Find an overview of the monitored sections in ANNEX C. Also the times when a profile measurement was done are indicated in the test logbook in ANNEX A. The measurement frequency was set to 200 Hz and changed to 100Hz from the testID bi_02_04.

- Comments

Reference location is the dike crest (where the 1/2 dike slope goes over to the 1/100 slope of the promenade). Only the centerline was measured until the promenade, while the other profiles were referenced to the centerline using the length information in the flume x-axis direction.

3.2 Definition of time origin and instrument synchronization

The time origin will be set by a synchronization pulse from the main data acquisition system for each test. Hence, all devices attached to the main data acquisition system are automatically synchronized (wave gauges, layer thickness gauges on promenade, ultrasonic distance sensors, paddle wheels, electro-magnetic current meter, pressure sensors, load cells). The laser scanner is also able to receive the synchronization pulse but must be in measuring mode before the synchronization pulse is send. The ASM will be synchronized using the internal computer clock and comparing it to the computer clock of the main data acquisition system. No synchronization down to the second is required for the ASM. The void fraction meter is attached to a separate PC measuring with 10kHz (but is also recorded with 1000Hz by the main data acquisition system, hence synchronized). The GoPro and high-speed cameras are synchronized with the main data acquisition system via a light pulse send simultaneously with the synchronization pulse and 'seen' in the GoPro recordings. The wave radar is synchronized by comparing the computer clock to the time in the main data acquisition system.

3.3 Measured parameters

The measured parameters are given in Table 3-4. From these parameters additional parameters such as spectral and significant wave height, spectral and peak wave period or the force distribution over the wall height, maximum and averaged impact forces are computed.

Table 3-4: Measured parameters and units

Parameter	Symbol	SI-Unit
Water surface elevation	η	m
Sand concentration	SSC	g/m³
Bottom profile	d	m
Layer thickness on promenade	h	m
Layer velocity on promenade	v	m/s
Impact force on wall	F	$kg*m/s^2 = N$
Impact pressure on wall	P	$kg/m*s^2 = Pa$
Void-fraction in front of wall	I	-
High speed camera recording from behind wall	-	-
Laser profile of dike, promenade and wall	R, θ	m, °
Video recordings from top, side and behind wall	-	-

4 Experimental procedure and test program

In column 1 of the test program (Table 4-1) the date of the test is given and in column 2 the testID. Column 3 contains the number of waves (as specified before the tests, not measured). Column 4 contains the water levels at the paddle based on the measured and averaged water levels of wave gauge 2,3 and 4 at the beginning of each test (no waves). Column 5 and 6 give the water depth at the toe of the structure and the freeboard. These values are derived based on the measured water level at the paddle and the geometry of the model. Column 7 and 8 contain the wave parameters after reflection analysis for wave gauge 2,3 and 4 (see Figure 2-1) with wavelab. For the Bichromatic tests the desired amplitude and frequency is given. The test length in column 9 is the time the main data acquisition system was recording. Where;

WLW: WaLoWa
Irr: Irregular waves
Bi: Bichromatic waves
F: First order waves
S: Second order waves
R: Repetition

Table 4-1: Test program WaLoWa as conducted

Start-End time of measurement file	Test ID	Waves	h_{paddle}	h_{toe}	R_c	H_s	T_p	Test length
[yyyymmddhhmmss-yyyymmddhhmmss]	[-]	[-]	[m]	[m]	[m]	[m]	[s]	[s]
20170320160828-20170320161258	Bi_01_4	~18	3.99	0.28	0.25	a_1=0.5 a_2=0.4	f_1=0.174 f_2=0.142	270
20170320165123-20170320165442	Bi_01_5	~18	4.00	0.29	0.24	a_1=0.5 a_2=0.45	f_1=0.174 f_2=0.142	199
20170321111203-20170321111545	Bi_01_6	~18	4.01	0.30	0.23	a_1=0.5 a_2=0.5	f_1=0.174 f_2=0.142	222
20170321132146-20170321132522	Bi_02_4	~18	4.13	0.42	0.11	a_1=0.45 a_2=0.36	f_1=0.19 f_2=0.155	216
20170322120435-20170322135404	WLW_Irr_1_F	1000	3.99	0.28	0.25	1.05	6.21	6569
20170323110341-20170323153130	WLW_Irr_2_F	3000	4.00	0.29	0.24	0.92	5.85	16069
20170327094743-20170327141546	WLW_Irr_2_S	3000	3.99	0.28	0.25	0.92	5.85	16083
20170328092537-20170328135319	WLW_Irr_3_F	3000	4.12	0.41	0.12	0.92	5.85	16062
20170329100547-20170329100914	Bi_02_5	~18	4.14	0.43	0.10	a_1=0.45 a_2=0.405	f_1=0.19 f_2=0.155	207
20170329101634-20170329102003	Bi_02_6	~18	4.14	0.43	0.10	a_1=0.45 a_2=0.428	f_1=0.19 f_2=0.155	209
20170329103237-20170329103603	Bi_02_6_R	~18	4.14	0.43	0.10	a_1=0.45 a_2=0.428	f_1=0.19 f_2=0.155	206
20170329133508-20170329144109	WLW_Irr_8_F	1000	4.13	0.42	0.11	0.49	4.1	3961
20170330084020-20170330102018	WLW_Irr_4_F	1000	3.79	0.08	0.45	0.87	5.69	5998
20170330131321-20170330150201	WLW_Irr_5_F	1000	3.78	0.07	0.46	1.05	6.21	6520
20170331085701-20170331104356	WLW_Irr_1_F_R	1000	4.01	0.30	0.23	1.06	6.21	6415
20170331125904-20170331142843	WLW_Irr_7_F	1000	4.00	0.29	0.24	0.65	5.00	5379
20170403091025-20170403133843	WLW_Irr_2_F_R	3000	4.01	0.30	0.23	0.92	5.85	16098
20170403151218-20170403151536	Bi_01_6_R	~18	4.01	0.30	0.23	a_1=0.5 a_2=0.5	f_1=0.174 f_2=0.142	198
20170404091430-20170404092007	Bi_03_6	~18	3.77	0.06	0.47	a_1=0.3 a_2=0.3	f_1=0.174 f_2=0.142	337
20170404092829-20170404093420	Bi_03_6_1	~18	3.77	0.06	0.47	a_1=0.3 a_2=0.35	f_1=0.174 f_2=0.142	351
20170404094458-20170404095029	Bi_03_6_2	~18	3.76	0.05	0.48	a_1=0.3 a_2=0.35	f_1=0.158 f_2=0.129	331
20170404115239-20170404131803	WLW_Irr_6_F	1000	3.77	0.06	0.47	0.65	5.12	5124

5 Data post-processing

Only original data files are provided on the Ghent University server (section 6), no further processing has been done to these files.

6 Organization of data files

A share point within Ghent University can be accessed for authorized users via the link below. You can ask authorization from Maximilian Streicher (email: maximilian.streicher@ugent.be).

https://sharepoint.ugent.be/projects/201701571/

All users have read and write access, BUT the folder structure and content should not be changed. If Users want to exchange e.g. analysis results they can use the 07 Filesharing folder. After sharing the data should be deleted. All other folders should only be used to download the data inside.
Besides the synoptic data (GoPro, high speed camera, void-fraction meter, laser scanner), all data files are stored on the sharepoint server and can be downloaded by the users. The data is structured as followed:

- ➔ WaLoWa Data
  - o 01 Meta information
    - ▪ 01 Data storage report.pdf
    - ▪ 02 ANNEX
      - ANNEX A - Test logbook.xlsx
      - ANNEX B - Instrument location.dwg
      - ANNEX C - Profile measurement sections.pdf
      - ANNEX D - Wave radar (WaveGuide).pdf
      - ANNEX E - Wave gauges on promenade.pdf
      - ANNEX F - Pressure sensor (Kulite HKM 375-M).pdf
      - ANNEX G - Load cell (HBM U9).pdf
      - ANNEX H - Ultrasonic distance s. (HRXL MaxSonar).pdf
      - ANNEX I - Ultrasonic distance s. (Honeywell 943 M18).pdf
      - ANNEX J - Electromagnetic current meter (Valeport 802).pdf
      - ANNEX K - Paddle wheels (Airmar flow meter S300).pdf
      - ANNEX L - High speed camera.txt
      - ANNEX M - Cameras (GoPro Hero5).txt
      - ANNEX N - Void-fraction meter.txt
      - ANNEX O - Laser profiler (SICK LMS511).pdf
      - ANNEX P - Argus surface meter (ASM).pdf
      - ANNEX Q - Steel wall layout
  - o 02 Acquired data
    - ▪ 01 Paddle steering files
    - ▪ 02 Main data acquisition system
    - ▪ 03 Wave radar
    - ▪ 04 ASM
    - ▪ 05 Profiler
    - ▪ 06 High speed camera
    - ▪ 07 Laser scanner
    - ▪ 08 Void-fraction meter
    - ▪ 09 GoPro
  - o 03 Picture
  - o 04 Video
  - o 05 Presentation
  - o 06 Publication
  - o 07 Filesharing

Additionally the data is stored in the following locations:

- 2 External hard drives at Ghent University with all data

- 2 External hard drives at TU Delft with synoptic data (high speed camera, void-fraction meter, GoPro recording, laser scanner)
- Deltares server with all data
- Profile and ASM data at University of Bari

In Table 6-1 the output file format for each measurement device is given.

Table 6-1: Output file specifications

Data file	Format	Column: Instrument [Unit]	Comments
Main data acquisition <testID>.asc	ASCI	1: Time [ms] 2: Wave gauge Whm01 [m] 3: Wave gauge Whm02 [m] 4: Wave gauge Whm03 [m] 5: Wave gauge Whm04 [m] 6: Wave gauge Whm05 [m] 7: Wave gauge Whm06 [m] 8: temp in measurement box [°C] 9: Wave gauge Whm07 [m] 10: Wave gauge Whm08 [m] 11: Wave gauge Whm09 [m] 12: Wave gauge Whm10 [m] 13 Wave gauge Whm11 [m] 14: Wave gauge Whm13 [m] 15: Wave gauge Whm14 [m] 16: UDS1 [mm] 17: UDS2 [mm] 18: UDS3 [mm] 19: UDS4 [mm] 20: EMS-X [m/s] 21: EMS-Y [m/s] 22: WLDM1 [mm] 23: WLDM2 [mm] 24: WLDM3 [mm] 25: WLDM4 [mm] 26: FoidFrac1 [-] 27: FoidFrac2 [-] 28: PaddleWheel1 [m/s] 29: PaddleWheel2 [m/s] 30: PaddleWheel3 [m/s] 31: PaddleWheel4 [m/s] 32: KRM01 [kN] 33: KRM02 [kN] 34: DRO01 [bar] 35: DRO02 [bar] 36: DRO03 [bar] 37: DRO04 [bar] 38: DRO05 [bar] 39: DRO06 [bar] 40: DRO07 [bar] 41: DRO08 [bar] 42: DRO09 [bar] 43: DRO10 [bar] 44: DRO11 [bar] 45: DRO12 [bar] 46: DRO13 [bar] 47: DRO14 [bar] 48: DRO15 [bar]	Data converted to dimension using calibration factors
Main data acquisition <testID>.raw	ASCI	1: Wave gauge Whm01 [V] 2: Wave gauge Whm02 [V]	Raw data (measured

		3: Wave gauge Whm03 [V] 4: Wave gauge Whm04 [V] 5: Wave gauge Whm05 [V] 6: Wave gauge Whm06 [V] 7: Wave gauge Whm07 [V] 8 Wave gauge Whm08 [V] 9 Wave gauge Whm09 [V] 10: Wave gauge Whm10 [V] 11 Wave gauge Whm11 [V] 12: Wave gauge Whm12 [V] 13: Wave gauge Whm13 [V] 14: Wave gauge Whm14 [V] 15: UDS1 [V] 16: UDS2 [V] 17: UDS3 [V] 18: UDS4 [V] 19: EMS-X [V] 20: EMS-Y [V] 21: WLDM1 [V] 22: WLDM2 [V] 23: WLDM3 [V] 24: WLDM4 [V] 25: FoidFrac1 [V] 26: FoidFrac2 [V] 27: PaddleWheel1 [V] 28: PaddleWheel2 [V] 29: PaddleWheel3 [V] 30: PaddleWheel4 [V] 31: KRM01 [V] 32: KRM02 [V] 33: DRO01 [V] 34: DRO02 [V] 35: DRO03 [V] 36: DRO04 [V] 37: DRO05 [V] 38: DRO06 [V] 39: DRO07 [V] 40: DRO08 [V] 41: DRO09 [V] 42: DRO10 [V] 43: DRO11 [V] 44: DRO12 [V] 45: DRO13 [V] 46: DRO14 [V] 47: DRO15 [V]	Voltage)
Main data acquisition <testID>.dat	Binary	-	Data in binary form
Main data acquisition <testID>.seq	ASCI	-	File format binary
Main data acquisition <testID>.set	ASCI	-	Instrument settings (calibration factors, output dimension,…)
Wave radar	ASCI	1: time start at 1.1.1970, GMT [ms] 2: water level [m]	Water level needs to be calibrated with wave gauge zero from same location

Profiler <testID_ray>.asc	ASCI	1: time [ms] 2: x-distance [m] 3: elevation beam [m] 4: elevation wheel [m] 5: total elevation [m]	Data converted to dimension using calibration factors (not always, for some files still in Volt)
Profiler <testID_ray>.raw	ASCI	1: x-distance [V] 2: elevation beam [V] 3: elevation wheel [V] 4: total elevation [V]	Raw data (measured Voltage)
Profiler <testID_ray>.dat	Binary	-	Data in binary form
Profiler <testID_ray>.seq	ASCI	-	File format binary
Profiler <testID_ray>.set	ASCI	-	Instrument settings (calibration factors, output dimension,…)
ASM <testID>.san	Binary	-	ASMA software to convert to text file
Laser profiler LMS5xx_FieldEval_Pro_ <startdate_starttime_stoptime>	CSV	-	Output from SOPAS conversion
Laser profiler <testID>.data	Binary	-	SOPAS software to convert to text file
Void-fraction meter <testID>.raw	ASCI	1: sync. pulse [V] 2: First sensor [V] 3: Second sensor [V]	Raw data (measured Voltage)
Void-fraction meter <testID>.dat	Binary	-	Data in binary form
Void-fraction meter <testID>.seq	ASCI	-	File format binary
Void-fraction meter <testID>.set	ASCI	-	Instrument settings (calibration factors, output dimension,…)
High speed camera	JPEG	-	100 images per second
GoPros	MP4	-	-

7 Remarks

The data is available for the User Group of the WaLoWa project for 2 years, starting from the end of the experiments on 04.04.2017. After 2 years the data is free to be used by anyone.

A Appendices (seperate files)

ANNEX A	Test logbook.xlsx
ANNEX B	Instrument location.dwg
ANNEX C	Profile measurement sections.pdf
ANNEX D	Wave radar (WaveGuide).pdf
ANNEX E	Wave gauges on promenade.pdf
ANNEX F	Pressure sensors (Kulite HKM-379 M).pdf
ANNEX G	Load cells (HBM U9).pdf
ANNEX H	Ultrasonic distance sensor (HRXL MaxSonar).pdf
ANNEX I	Ultrasonic distance sensor (Honeywell).pdf
ANNEX J	Electromagnetic current meter (Valeport 802).pdf
ANNEX K	Paddle wheels (Airmar flow meter S300).pdf
ANNEX L	High speed camera.pdf
ANNEX M	Cameras (GoPro Hero5).pdf
ANNEX N	Void-fraction meter.txt
ANNEX O	Laser profiler (SICK LMS511).pdf
ANNEX P	Argus surface meter (ASM).pdf
ANNEX Q	Steel wall.pdf