physical modelling tests on xstream

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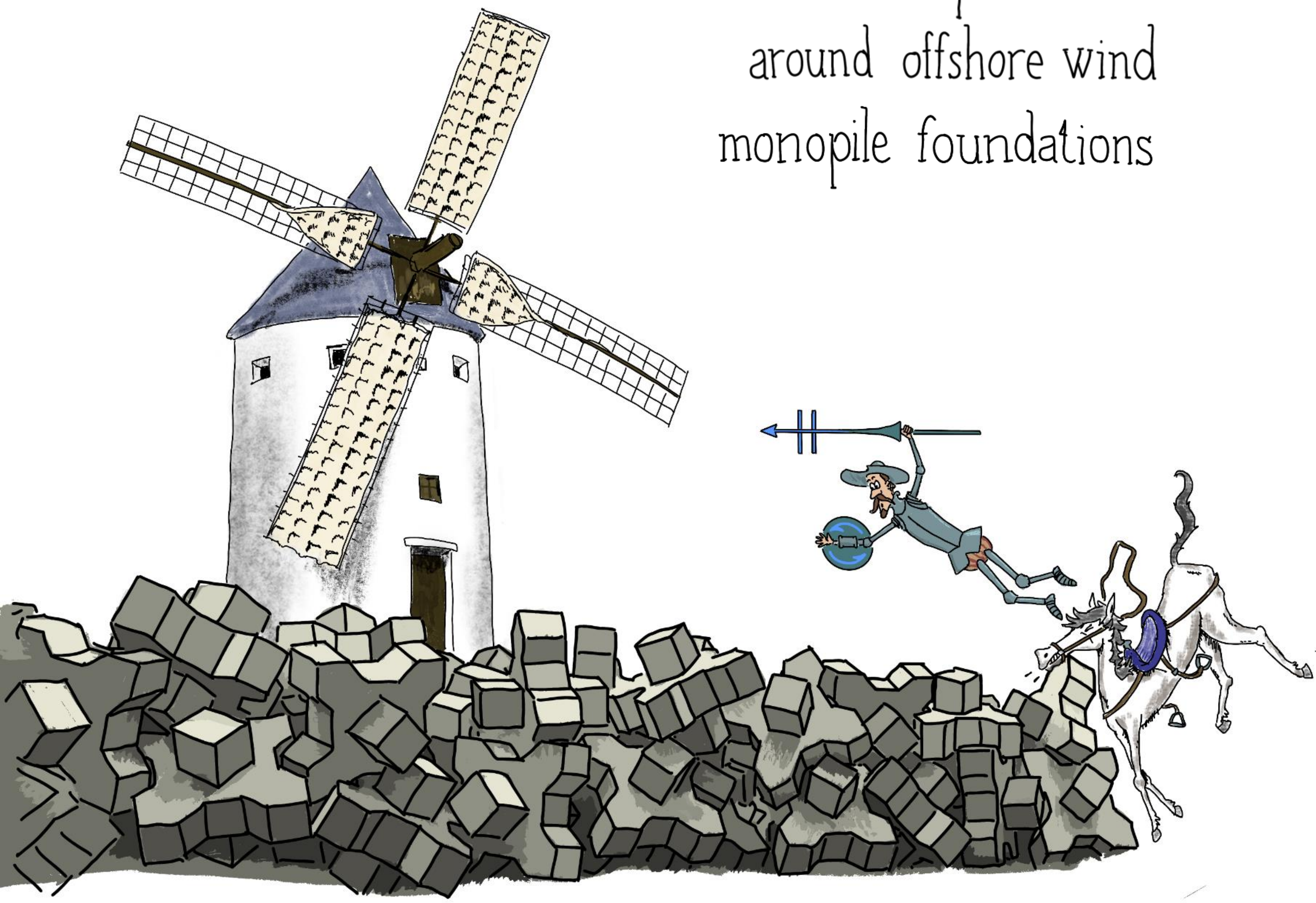

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MSc Thesis

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风向转变时
有人筑墙
有人造风车

when the winds of change blow,
some people build walls,
some people build windmills

(Chinese proverb)

acknowledgments

So many things to be thankful for, so many people involved; some turns of events or adjustments of plans, and a whole process by which the present thesis came to stand. I would abundantly like to thank my graduation committee from the bottom of my heart for all attention, insights and guidance during this process, on many different fronts, and principally in Delft, Gouda, and intermediate places. Bas H., thank you so much for leading the committee so effectively, and for your support during the whole process, even as I faced personal challenges and obstacles. Marcel, thank you so much for upgrading the team with so much knowledge, always giving such an insightful input. Michael, thank you so much for your good company all this learning time, your sharp eye, and your motivational pushes that you might not be aware of. Coen, thanks a lot for your support, for the practical knowledge, and for the informal yet so relevant talks. Bas R., many thanks for sharing your expertise, drive and inspiration, and mainly for introducing me to this adventure. Additionally I'm very thankful to every person granting me all kinds of practical help, both in the university and in the laboratory. Thank you all!

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abstract

Scour protections around monopile foundations of offshore wind turbines usually rely on loose rock as the main material, and on traditional construction methodologies. But how would a concrete prefabricated element perform instead of rock? This question, together with the particular focus on Xstream as main element, is at the heart of this master thesis. The research goal is to determine and describe the hydrodynamic stability of the Xstream elements, focusing on their application near monopile foundations under wave-only loading. The test program is mainly based on the conditions at the southern North Sea.

While two main authors (Izbash (1935) and Shields (1936)) have set the foundation of the principles of stability of rocks under flows, the proliferation of offshore wind energy (and of submarine cables) motivated the creation of the JIP-HaSPro (Handbook of Scour and Cable Protection Methods), greatly based on studies by Broekema et al. (2023), and used in a considerable measure for this research.

The present study was conducted as a physical modelling test program in the laboratory of BAM in Gouda, in a flume with a wave generator. A scale of 1:15.71 was used. Due to logistical reasons, two distorted scales were applied: the first (and main) distorted scale, with which correctly scaled orbital velocities near the bed were generated, while smaller water depths and wave heights (fitting in the flume's height) could be applied; the second distorted scale consisted in the reduction of the pile diameter, so that it fitted in the flume's width (this made the results somewhat conservative compared to the original prototype pile diameter of 10m); half monopile was adopted, adjacent to one of the flume walls. A rectangular form was adopted for the model scour protection, still conscious that a circular shape concentric with the monopile is the most suitable. The layer thicknesses were based on packing densities related to area. No sediment was used, i.e. the block layer was laid on a fixed bed.

A group of 6 test series were carried out, each featuring a different layer thickness and two placing methods with different packing density as a result. Each test series consisted of 8 wave conditions with the same peak period ($T_{p,m}$ = 3.2 s) and significant wave heights varying from 0.08m to 0.26m. The tests were 40 minutes long, aiming for a number of 1000 waves. Three types of movement were observed during the tests: rocking, internal displacements (i.e. all displacements larger than about 1 unit diameter), and removal from the protection (external displacements). The data collected consisted of *a.* wave data, measured by the wave gauges and processed in WaveLab; and *b.* block movement data, based on observations aimed at the three types of movement.

The first feature noticed during the tests was the formation of patterns of erosion and deposition within the construction area, in the form of a trench and a mound, next to the half monopile and right behind it, respectively.

The amount of blocks rocking grew gradually with the wave conditions, while both the internal and external displacements showed a delayed growing tendency with scattered peaks. The highest observed amount of blocks rocking was 15 units during a sample of 1 minute; the highest observed amount of blocks internally displaced was 16 units during a sample of 15 minutes; and the highest observed amount of blocks removed from the construction was 6 units during a full test, and cumulatively, 16 elements throughout a full test series.

One of the tests featuring a maximum in mobility, concretely of elements internally displaced, was observed to additionally have a local concentration area of movement, next to the monopile. A close analysis was run to connect this maximum to the possible failure in the construction, which didn't take place. This test corresponded to a thickness of roughly 2½ times the main block dimension, and a measured H_{m0} of 21 cm.

A look at the initiation of motion made it possible to visualize the relationship between the three types of movement, particularly the first movement each of them was observed. The accuracy in regarding them as sequential stages was tested, resulting in a consistent relation for the thickest half of the layers tested, but not for the thinnest half.

The main conclusions from this research can be summed up as follows:

- The Xstream-based protection featured observable clusters of several units that were seen to move at the same time, attributable to interlocking.
- The wave conditions used for the tests featured values of θ_{top} going up to 0.032, and KC_w-values going up to 4.13. θ_{top}, the dimensionless Shields stress at the top of the protection, was calculated by linear wave theory for a flat bed (without the monopile present), assuming $k_s = 0.052$ (calculated following the HaSPro) and using H_s as the wave height.
- Two main erosion locations were observed, within the construction (particularly close to the monopile) and in the edges.
- The wave conditions used didn't lead to a failure of the structure. The closest point to failure was some fraying of the thinnest layer in the rear edge (16 units along the edge, which had a length of ~28 times the main block dimension). The most attacked sector in the inner construction area featured a local damage of roughly 10% of the units present in the area.
- No major difference in performance was observed between the layer thicknesses, except the thinnest layer, which showed less cohesiveness than all other configurations. Thicker layers, however, did show a more consistent relationship between the moments of initiation of motion for the three types of movement.
- No major difference in performance was observed between the blocks installed manually in dry and the ones dropped from the surface, except regarding the blocks removed from the structure, which were mostly blocks lying loose due to the dispersion when dropped. Besides this, the difference was mostly related to the efficiency in the amount of blocks installed.

list of symbols

a	wave amplitude
c_1 to c_5	HaSPro formula coefficients
d	stone (and block) diameter, general
d_*	dimensionless grain (and block) diameter
d_{*m}	dimensionless block diameter, model
d_{*p}	dimensionless block diameter, prototype
D_p, D_{pile}	pile diameter
F_D	drag force on a grain
F_F	friction force on a grain
F_L	lift force on a grain
F_S	shear force on a grain
g	gravity acceleration
h_m	water depth, non-distorted model
h_{md}	water depth, distorted model
h_{top} (= $h_{top,md}$)	water depth at top of scour protection (model)
H_{m0} (= $H_{m0,md}$)	significant wave height, measured (distorted scale)
H_{max} (= $H_{max,md}$)	maximum wave height, measured (distorted scale)
H_{ref}	reference wave height (H_s = 8.1 m)
$H_{s,m}$	significant wave height, non-distorted model
$H_{s,md}$	significant wave height, distorted model
k	wave number
k_s	equivalent roughness height
K_V	velocity coefficient in stone stability
KC	Keulegan-Carpenter number
KC_{tot}	KC number, total (= $KC_w + n \cdot KC_c$)
$KC_{w,max}$	maximum wave-related KC in test program
L	wave length (general)
MOB	HaSPro mobility parameter

MOB_{top}	HaSPro mobility parameter at top of layer
N_X	scale factor of property X
S	scour protection deformation
t	scour protection layer thickness
T	wave period
T_p	peak period
$T_{p,m}$	peak period, model
u_*	shear velocity
u_{*c}	critical shear velocity
u_c	critical velocity (Izbash)
u_m	max. wave orbital velocity
$\hat{u}_w$	wave orbital velocity fluctuations at bed
$\hat{u}_{w,m}$	wave orbital velocity fluctuations at bed, model
u_x, u_z	wave orbital velocity components
$\hat{u}_x$, $\hat{u}_z$	wave orbital velocity fluctuations' components
U_{md}	Ursell number, distorted model
W	submerged weight (grain)
Δ	relative density
θ	Shields parameter (offshore)
θ_{cr}	Critical Shields parameter (offshore)
θ_{top}	Shields parameter (offshore), top of protection layer
$\theta_{top,max}$	maximum Shields value in test program, top of protection layer
ρ_s	density of stone (and block)
ρ_w	density of water
τ	shear stress
τ_c	critical shear stress
ψ	Shields parameter (general)
ψ_c	critical Shields parameter (general)
ω	angular velocity of waves

test nomenclature key

1L	"one layer", layer of Xstream elements with 1 times the amount of blocks per unit area corresponding to the packing density found for a layer with a thickness of 1 times the main block dimension *d*
1½L	"one and a half layer", layer with 1.5 times the amount of blocks per area used for layer thickness 1L
2L	"two layers", layer with 2 times the amount of blocks per area used for layer thickness 1L
2½L	"two and a half layers", layer with 2.5 times the amount of blocks per area used for layer thickness 1L
3L	"three layers", layer with 3 times the amount of blocks per area used for layer thickness 1L

types of movement

R	rocking
ID	internal displacements
X	removal (external displacements)

layer thickness

test configuration / placing method:

H: hand-placed in dry

M: dropped from water surface

H-3L-R50

test series

wave climate

color key:

H-2L

H-2½L

H-3L

H-1L

H-1½L

M-2L

		$H_{s,md}$ (m)
R30	wave climate with a $H_{s,md}$ corresponding to $H_{s,p}$ = 30% of H_{ref}	0.08
R40	wave climate with a $H_{s,md}$ corresponding to $H_{s,p}$ = 40% of H_{ref}	0.11
R50	wave climate with a $H_{s,md}$ corresponding to $H_{s,p}$ = 50% of H_{ref}	0.13
R60	wave climate with a $H_{s,md}$ corresponding to $H_{s,p}$ = 60% of H_{ref}	0.16
R70	wave climate with a $H_{s,md}$ corresponding to $H_{s,p}$ = 70% of H_{ref}	0.19
R80	wave climate with a $H_{s,md}$ corresponding to $H_{s,p}$ = 80% of H_{ref}	0.21
R90	wave climate with a $H_{s,md}$ corresponding to $H_{s,p}$ = 90% of H_{ref}	0.24
R100	wave climate with a $H_{s,md}$ corresponding to $H_{s,p}$ = 100% of H_{ref}	0.27

table of contents

1 introduction

1.1 background

In this unique moment in time in which wind energy, despite being one of the oldest sources of energy, shows a new, fresh sparkle of appeal amidst the ongoing green paradigm, ingenuity has taken it to the seas, where the space is open and full of opportunities. Among the challenges faced by this variant of wind energy we can name the foundation of the wind turbines, taking into account waves, currents, sediment transport, and the subsequent erosion and sedimentation mechanisms.

Fig. 1. Offshore wind farm

Source: energiaestretegica.com

The current way to mitigate the effects of these mechanisms and, in particular, to avoid scour from compromising the structure and its foundation consists of bed protection layers, also called scour protections, mainly designed as layers of stones in different sizes.

On a different front, prefabricated concrete blocks have been used for more than half a century to dissipate the wave energy on breakwaters and other coastal structures. The high porosity and interlocking are big advantages in their design, and diverse variants have been designed and patented during the years. One of them is BAM's Xbloc, developed in 2001 and applied all around the world.

More recently, a reduced variant of the Xbloc, called Xstream, has been applied in rivers, mainly in groynes. Additional research has been conducted trying to find diversified applications for the Xstream elements. One of those applications is the main reason for this study: as the main element in scour protections around the foundations of offshore wind turbines.

This distinct application is a trailblazing combination. However, research on even the traditional construction methods of scour protection has fallen behind, after being approached more empirically. This stresses the need not only to expand the scientific knowledge in this field, but to provide a firm foundation. This study is an attempt to contribute to this aim, and a call for further investigation.

1.2 problem description

Within the framework described above, the concrete case study of offshore wind turbines in the North Sea is considered. The North Sea is not only close to home, but a place where the construction of offshore wind farms is proliferating. A selection from its typical features constitute the main input parameters for this study, as can be seen later on in this report; for now, to define the problem, it can be mentioned that the intended prototype consists of a monopile as the chosen wind turbine foundation on a fine sand seabed. A scour protection layer is conceived around the monopile, and, as mentioned before, the protection layer will be composed of Xstream elements.

1.3 research objective

This context sets the stage for the present study. The main research question is: **What is the hydraulic stability of Xstream as the main element in scour protection structures around offshore monopiles under wave loading?**

In the scope of this question, the following secondary questions are touched:

- how can a scour protection built with Xstream elements be defined? which can be its dimensions, appearance and parameters?
- how can damage and hydraulic load be characterized and quantified?
- what is the effect of varying the layer thickness and the packing density of blocks in the stability?
- which areas of the construction will be more prone to feature mobility, and how?

Fig. 2. Xstream elements in a flexible groyne

Source: xbloc.com

Fig. 3. Scale model of Xstream element

2 theoretical framework

2.1 introduction

There are multiple types of offshore wind turbine foundations, chosen primarily based on water depth, and among which monopile foundations are the most common [Chen *et al.*, 2016, as quoted by Welzel, 2021].

The main forms of water motion in the sea are two, waves and currents, which interact primarily with the seabed applying shear stresses [Nielsen, 2011, as quoted by Arboleda Chávez *et al.*, 2019]. In the presence of a monopile the flow patterns become more complex and turbulent, with an amplification of the shear stresses around the base as a result. This amplification increases the erodible potential of the flow, causing scour to develop around a cylinder structure.

2.1.1 *Waves*

There are different wave theories, which are analytical approaches to waves and their inherent velocity patterns [Holthuijsen, 2007; Welzel, 2021]. A main distinction is made between the linear wave theory and the non-linear ones. The linear wave theory (Airy), despite the limitations of both its assumptions and its boundary conditions, has a wide range of applicability [Young, 1999].

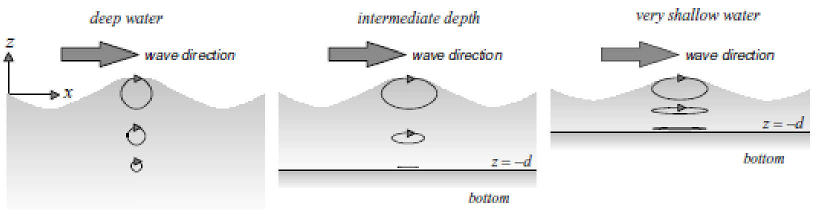


Fig. 2.1. Orbital motion under waves for different depths

[Source: Holthuijsen, 2007]

From the linear wave theory and its dispersion relation we can obtain, among others, the orbital velocities:

$$u_x = \hat{u}_x \cdot \sin(\omega t - kx)$$

$$u_z = \hat{u}_x \cdot \cos(\omega t - kx)$$

with

$$\hat{u}_x = \omega \cdot a \cdot \frac{\cosh[k(h+z)]}{\sinh(kh)}$$

$$\hat{u}_z = \omega \cdot a \cdot \frac{\sinh[k(h+z)]}{\sinh(kh)}$$

2.1.2 *Hydrodynamics around a cylindrical pile*

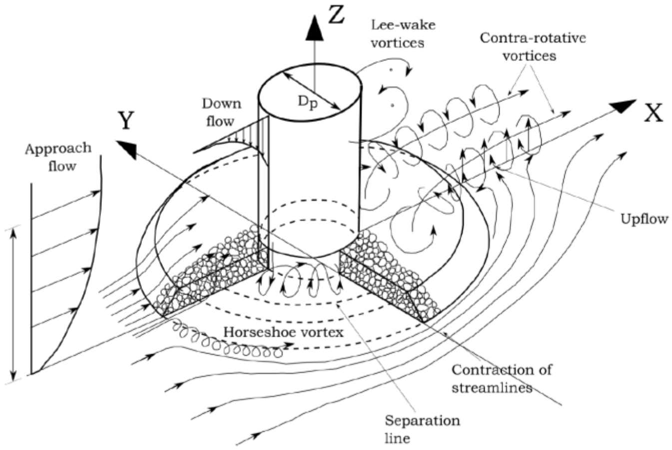


Fig. 2.2. Flow patterns around a monopile with scour protection

[Source: JIP HaSPro, 2023, after Petersen *et al.*,2015]

The effects caused by the interaction between a monopile and the movement of the surrounding water depends on the type of motion, i.e. whether the water is moving in the form of a current or in the form of waves. The component corresponding to currents is very important for two reasons: *a.* the developing of a more complex system of vortices, called the horseshoe vortices (see figure 2.2), which endorse the motion of bed material; and *b.* the net transport of the suspended material, given the non-zero mean velocity. In the case of waves, which are the main subject in this study, the interaction between the monopile and the water in motion is related to the Keulegan-Carpenter number:

$$KC = u_m \cdot T / D_p$$

where u_m is the maximum value of the undisturbed orbital velocity at the bed, T is the wave period and D_p is the diameter of the monopile [Keulegan and Carpenter, 1958, as quoted by Welzel, 2021]. Unlike for currents, where horseshoe vortices are dominant, in the case of waves they are generated for KC > 6; in the same way, while in the case of currents the bed shear stress experiences amplification factors up to $\mathcal{O}(10)$, in the case of waves this amplification has a maximum of $\mathcal{O}(4)$ [Sumer *et al.*, 1997, as quoted by Welzel, 2021]. Additionally, for waves, vortex shedding is the main cause of scouring [Sumer and Fredsøe, 2001, as quoted by Welzel, 2021]. See figure 2.3.

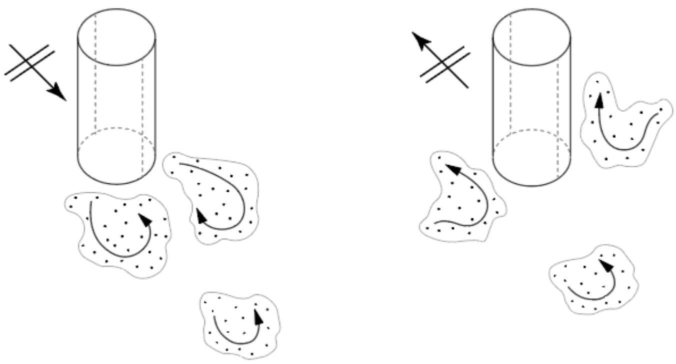


Fig. 2.3. Scouring by vortex shedding under wave conditions, for each half cycle of the wave

[Source: Welzel, 2021]

2.2 stability of stone

The stability criteria for stone and other non-cohesive granular material are based greatly on the research by Izbash and Shields. Izbash focuses on the forces acting on a single grain, while Shields takes the shear stress of the fluid on the bed into account [Schiereck, 2007; van den Berg, 2019].

2.2.1 *Forces on a single grain*

In the situation of uniform flow, the balance of forces acting on a single grain is the basic concept to study both stability and mobility of granular material. Active and resisting forces taken into account are:

drag force	F_D
shear force (water-grain)	F_S
lift force	F_L
friction force (grain-grain)	F_F
submerged weight (grain)	W

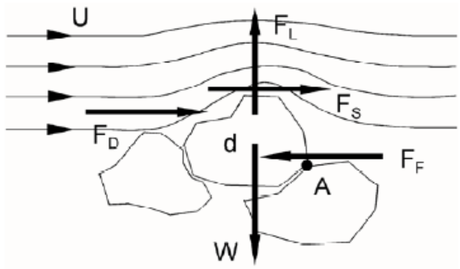


Fig. 2.3. Forces acting on a singular grain under flow conditions

Source: Schiereck, 2007 [ref]

A schematisation of these forces can be seen in figure 2.3.

The elaboration of the balance of forces and momentum reaches the following expression:

$$u_c^2 \propto \Delta \cdot g \cdot d \qquad => \qquad u_c^2 = K \cdot \Delta \cdot g \cdot d$$

Accelerated flow

The acceleration in a flow creates a pressure difference on a stone, resulting in a net force, in the same direction as the direction of the acceleration [Dessens, 2004, as referenced by Hollander, 2015]. See figure 2.4. An important note is that the forces associated to the accelerated flow are applicable in waves, or also in turbulent motion associated to currents. The following 2 sections (the approaches by Izbash and Shields) don't take these into account.

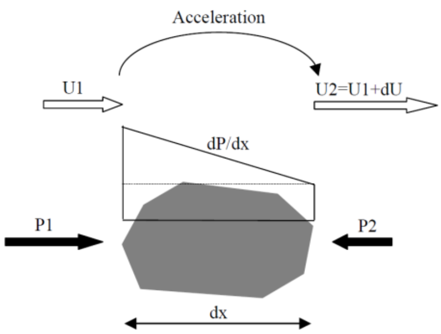


Fig. 2.4. Pressure differences due to acceleration

[Source: Dessens, 2004]

2.2.2 *Izbash*

Izbash (1935) came to the following expression:

$$u_c = 1{,}2 \cdot \sqrt{2 \cdot \Delta \cdot g \cdot d} \qquad => \qquad \frac{u_c}{\sqrt{\Delta \cdot g \cdot d}} = 1{,}7$$

This means that, in the general expression, K = 2,88, so that

$$u_c^2 = 2{,}88 \cdot \Delta \cdot g \cdot d$$

One should note that the information given in this formula is limited and general, and that's why Shields' approach is preferred for more detail.

2.2.3 *Shields*

In the case of Shields (1936), the shear force is the one taken into account, relating the dimensionless shear stress to a particle Reynolds number:

$$\psi_c = \frac{\tau_c}{(\rho_s - \rho_w) \cdot g \cdot d} = \frac{u_{*c}^2}{\Delta \cdot g \cdot d} = f(Re_*) = f(u_{*c} \cdot d/\nu)$$

The threshold of motion will then be related to a critical value of the bed shear stress.

For high Re_* values (and, hence, large grain sizes), the value of ψ_c is constant, no longer dependent on Re_*.

Waves and modified Shields

Given that the approaches by Izbash and Shields are based on works with currents, research was necessary to connect it to oscillating flow. Sleath (1978) summarized the findings by various investigations in a modified Shields diagram that can be related directly to the original Shields. See figure 2.6.

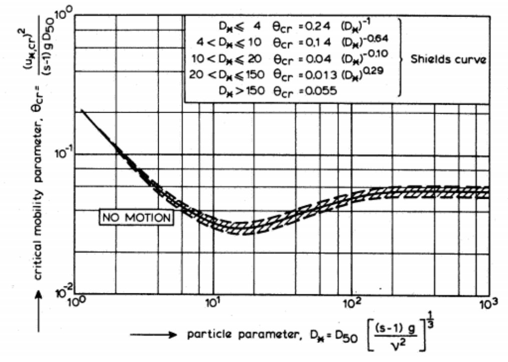


Fig. 2.5. Shields diagram

[Source: Hollander, 2015, after Shields-van Rijn, 1984]

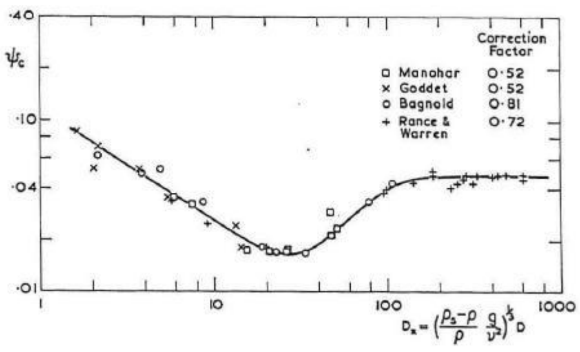


Fig. 2.6. Modified Shields diagram

[Source: Hollander, 2015, after Sleath, 1978]

2.2.4 *Initiation of motion*

Motion is initiated when a critical threshold of a flow velocity of bed shear stress is surpassed, that is, when the resisting forces on a single grain are too small to withstand the active forces. As the flow velocity and the bed shear stress are also affected by turbulence, the initiation of motion is also a probabilistic process [Welzel, 2021]. Also, in the case of Shields, that considers the whole bed structure, the threshold of motion isn't defined as clearly, and as a result, e.g. the movement of one particle might not be considered as movement [Jantzen, 2020].

In relation to this, many authors have considered different ways to define the stages of motion. For example, Kramer (1939) considered 4 stages, while Breusers (1968) considered 7. Caution is due as the definition of each layer or the limits between them are neither objective nor rigid; however, in all cases the measurements for the highest stage, corresponding to 'general transport', are located slightly above the Shields curve [Dey, 1999, as quoted by Miedema, 2019].

2.3 scour protection design

In this section an overview of key elements in the JIP-HaSPro (Joint Industry Project Handbook of Scour and Cable Protection Methods, [Deltares, 2024]) is given, particularly the elements relevant to this study. Some fundamentals in the design process are: scour prediction, scour mitigation strategies, and design of scour protections around monopile foundations. This approach contemplates particularly the use of loose rock, and that implies a knowledge gap regarding prefabricated concrete elements, among which the Xstream.

In the performance share of the design process, three main aspects are considered:

- external stability
- interface stability
- flexibility

The external stability, related to the resistance of the material against deformations due to hydraulic loads, is the aspect dealt with in this research. The approach used in the JIP-HaSPro is based on a study conducted by Broekema *et al.* (2024) featuring a prediction model of the deformations in scour protections. This deformation is written in relation to the pile diameter, as a function of two parameters: the relative rock mobility on top of the scour protection (MOB_{top}) and the total KC number related to both current and waves (KC_{tot}). The study led to the following expression:

$$\frac{S}{D_{pile}} = f(KC_{tot}) \cdot c_1 \cdot {MOB_{top}}^{c_2} \qquad \text{with} \qquad f(KC_{tot}) = 1 + \frac{c_3}{1+\exp\left[-c_4 \cdot KC_{tot} + c_5\right]}$$

Individually, the two parameters are derived from a bigger set of input parameters related to hydrodynamic conditions and rock grading characteristics. The mobility parameter is expressed as follows:

$$MOB = \frac{\theta}{\theta_{cr}}$$

where θ denotes the Shields parameter (and will be used in the remainder of this report instead of ψ, given the use of θ in offshore engineering contexts). In this case the mobility parameter is the combined current and wave related mobility parameter. The subscript MOB_{top} in the deformation expression is related to the mobility on top of the scour protection, which is found by Broekema *et al.* to have a better correlation with the scour protection deformations.

Furthermore, the total KC-number (KC_{tot}) is the summation of the current-related and wave-related KC numbers, and it depends on the relative angle between currents and waves. The KC-number is not directly a load parameter; however, Sumer *et al.* (1997) demonstrated that larger KC-numbers are associated with larger bed shear stress amplifications [Broekema *et al.*, 2024]. In the deformation expression this is accounted for with a correction in sigmoid function form. The total KC-number is defined as follows:

$$KC_{tot} = \begin{cases} KC_w + KC_c & \text{for } u_c \geq 0 \quad \text{(waves following current)} \\ KC_w + 2KC_c & \text{for } u_c < 0 \quad \text{(waves opposing current)} \end{cases}$$

In this study, however, only the wave-related component is relevant.

2.4 the xstream block

The Xstream block is a smaller variant of the Xbloc, a breakwater block made of concrete developed by the BAM around twenty years ago and widely used for breakwaters and sea defences. The Xstream was years later developed to be applied in rivers as flexible groynes. The Xbloc and Xstream are recognizable by their X-form. This form facilitates the placement of the bloc, as well as the interlocking between elements. While the regular concrete block is the most common, a variant made with a higher density concrete can be used. The most common dimension used for the Xstream blocks is a height of 30 cm, but it can be also varied up to 40 cm. The weight of the block is a bit above the 20 kg. The main dimensions can be seen in figure 2.7. (There is also a variant called XstreamPlus consisting on a correspondingly downsized version of the Xbase, a variant of the Xbloc without one of the protuberances; in this study only the regular Xstream was taken into account).

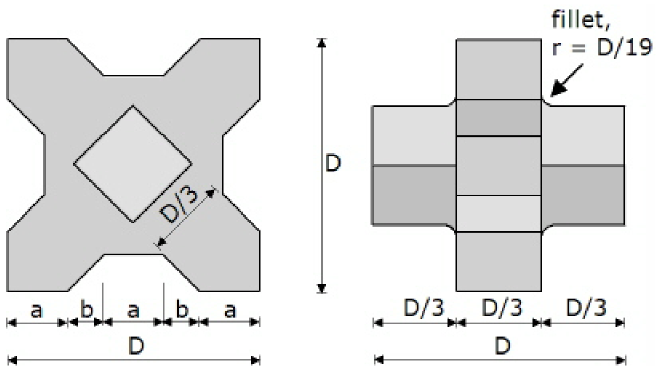


Fig. 2.7. Dimensions and geometry of the Xbloc and Xstream

[Source: van Zwicht, 2009]

Fig. 2.8. Xstream element prototype

[Source: Wetser, 2016]

2.5 scaling

A basic principle of physical modelling is the concept of similarity, by which the model reproduces the reality, or prototype, as accurately as possible, in order to complement or enhance the theoretical and mathematical part of the problem [Hughes, 1993]. The ideal situation would be a model that is completely similar, by which all relevant parameters (in dimensionless form) from the prototype are maintained in the model. In the case of dimension X:

$$N_X = \frac{X_p}{X_m}$$

where N is the prototype-to-model scale ratio, or scale factor.

2.5.1 *Hydraulic criteria*

In the case of hydraulics, complete similarity isn't achievable in physical modelling. A way to simplify this problem is to consider only the forces that play a major role in the model. This is done by considering different dimensionless parameters used in hydraulics, such as: the Froude number, the Reynolds number, the Weber number, the Cauchy number, etc. The most relevant (and familiar) in hydraulic engineering are the Froude number and the Reynolds number: the first one considers the relationship between the inertial and gravitational forces, while the latter compares the inertial to the viscous forces.

In this study, gravity plays the main role, and therefore the Froude number can be used as the basis for the scaling, requiring the Froude number to be the same in the prototype and in the model, and from this relationship all scale factors are obtained. This is called the Froude criterion.

2.5.2 *Froude scaling*

The Froude number reads:

$$Fr = \frac{V}{\sqrt{g \cdot L}}$$

Requiring the Froude number to be the same in the prototype and in the model would imply that

$$N_{Fr} = 1 \qquad => \qquad \frac{N_V}{\sqrt{N_g \cdot N_L}} = 1$$

These relationships yield most of the scale factors needed for the scale model. In chapter 3 a detailed listing of them will be given.

3 methodology

3.1 test facilities

3.1.1 *Location*

The tests were carried out in the flume at BAM's water laboratory in Gouda. The flume is 25m long, 1m deep and roughly 0.6m wide, featuring a wave generator and a wave absorber. The wave generator is controlled by a computer in which both regular sine waves and irregular, JONSWAP-spectrum waves can be entered, and in the same way all output from the wave gauges can be received and processed.

Additionally, the laboratory includes a workshop with all necessary tools, where all woodwork was done on all the fixed elements in the setup.

Fig. 3.1. Wave generator

3.1.2 *Instruments*

Wave measurements were possible by means of resistive wave gauges present in the flume. Additionally, block movements were recorded (both photos and videos) using four GoPro-cameras, which were partly mounted on fixed elements around the setup, partly on tripods.

3.2 model scale xstream elements

Due to the wide application of Xbloc and Xstream, and the scale modelling carried out by the company in all sorts of projects, a wide supply of scaled blocks are available. However, a relatively small model block was preferable due to the scaling of the prototype situation (relatively deeper water compared to block size). The blocks are manufactured by third parties, which use a relatively heavy synthetic material. The model block characteristics can be seen in table 3.1.

Property	Amount
Unit height (d) (cm)	2,1
Unit weight (gr)	7,2
Density (kg/m3)	2341
Total amount of blocks	3000

Table 3.1 Model block properties

An important thing to note is that the blocks used for the tests were the smallest available. More on this will be explained in the next section.

3.3 considerations on scaling

3.3.1 *Theory recapitulation*

As described in chapter 2, the dimensions are taken based on the Froude criterion. The scale factors are given in table 3.2.

Parameter	Dimensions	Scale factor
Wave height	L	N_L
Water depth		
Wave length		
Block size		
Layer thickness		
Monopile diameter		
Peak period	T	$N_L^{0,5}$
Test duration		
Orbital velocity	LT^{-1}	$N_L^{0,5}$
Gravity acceleration	LT^{-2}	1
Block density	ML^{-3}	N_ρ

Table 3.2. Main scale factors

Ideally, a physical model represents the prototype situation. A first simplification is applying the Froude criterion to deal with the main force relationships. Further simplifications are required in view of other constraints, such as: *a.* the 2D-character of the flume, as opposed to 3D; *b.* the difficulty of recreating the challenges of placing blocks in the bottom of the sea with all accuracy; *c.* the interaction with the sediment, which was not a part of this study. The major challenge that arose in the process will be explained in the following section.

3.3.2 *Choice of a distorted scale*

From the generic situation presented in chapter 1 as the problem description to a concrete test situation, the initial considerations are defined by two features. The first one is the depth, the second is the pile diameter. The wave conditions will be evaluated later. The depth taken corresponds to the Dutch side of the southern North Sea, which is an area of interest for offshore wind energy. A depth of 24m is taken as basis depth for this study. The basis choice for the monopile diameter was 10m, as this is the common monopile diameter in the North Sea. These initial conditions are connected to further considerations in section 3.4.1.

These features, however, create a conflict of boundary conditions. The scale factors of both the monopile size and the water depth would be limited by the flume dimensions, creating *minimum* scale factors; on the other hand, the available block size also creates a *maximum* scale factor. The conflict appears due to the fact that both the maximum and the minimum scale factors are mutually exclusive: the block can't be smaller, the flume can't be bigger. The chosen alternative is a *distorted scale model*, keeping the scaled orbital velocities near the bottom (which are the parameter of interest in this study due to its influence on the block stability), and translating them to corresponding wave heights that would fit in the available water depth. The orbital velocities were kept and its frequency, hence keeping the wave period.

Additionally, the monopile diameter was reduced to fit in the flume. To achieve the largest possible, half cylinder was taken, adjacent to the wall. The diameter was taken such that the blockage of the cylinder and the resulting increase in the flow velocity was acceptable. This increase is estimated to be between 1% and 2%, based on the solution for two-dimensional potential flow around a cylinder. (An important note is that the prototype pile diameter was hereby reduced to 4.71m instead of 10m, as the obtained KC-values would differ otherwise. This reduction is a second scale distortion and is to be taken separately from the first one; however, in the remainder of this report, the first scale distortion is referred to as the main distorted scale.)

A graphic depiction of the parameters in both the regular scale and the distorted scale can be seen in figure 3.2, and a comparison between both is depicted in figure 3.3. Table 3.3 lists the main parameters playing a role in the distorted scale; the full parameters taken into account are given further in section 3.5.1.

	Prototype	Model, regular	Model, distorted
Scale factor	1	15.71	15.71
Water depth (m)	24	1.53	0.60
Block size (m)	0,33	0.021	0,021
Monopile diameter (m)	~~10~~ *4.71*	~~0.63~~ *0.3*	0.3

Table 3.3. Distorted scale

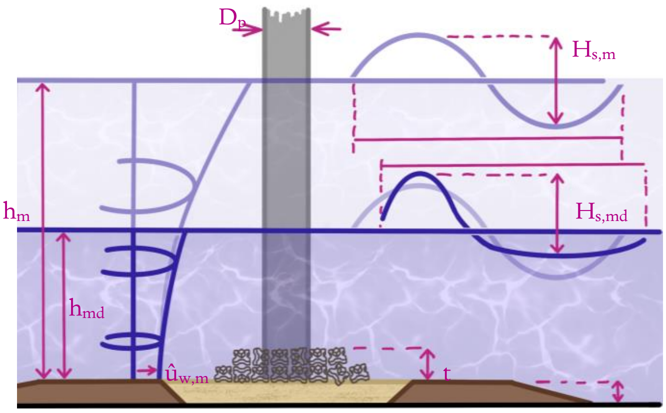


Fig. 3.2. Regular and distorted scales

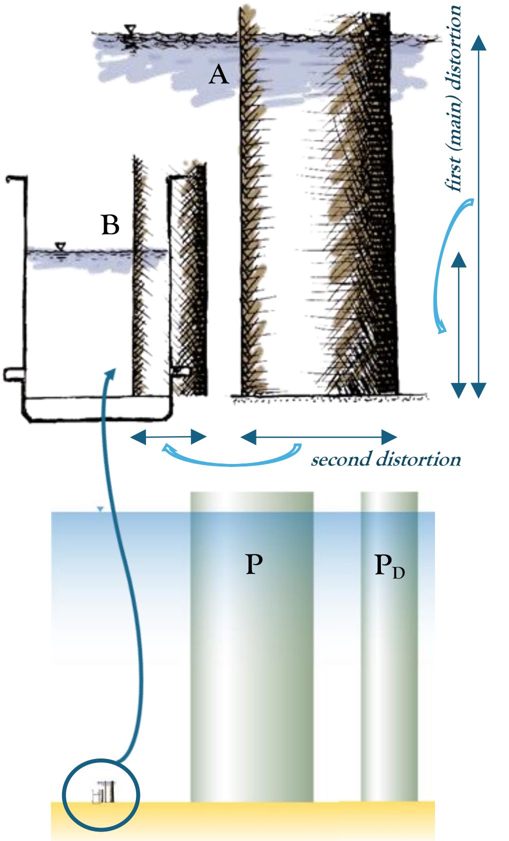


Fig. 3.3. Water depth and monopile in original undistorted (A) and distorted (B) model scales, superimposed on the available cross section. The original prototype pile diameter (P) was not achievable; the prototype value (P_D) corresponding to the distorted cylinder (B) taken for the experiments is shown.

3.4 test setup

3.4.1 *Considerations and initial conditions*

The most relevant considerations, regarding scale, were already explained in the previous section. Additional considerations were taken in the process of designing the test setup, here are some of the related thoughts.

Location in the flume:
The test area was located in the fifth section of the flume, which corresponds to roughly 8,5 m from the wave generator. Enough distance (roughly 1.1 · L) is achieved so that waves get fully developed.

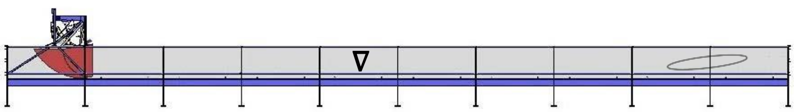


Fig. 3.4. Side view of the wave flume, with the test area indicated

Source: van Zwicht (2009)

Bottom elevation structure

Mainly in order to have the possibility to enhance the test program with tests with bed material, a bottom elevation structure was installed, consisting of wood sections that raised the level of the protection layer a total of 9 cm. A particular challenge in deciding the height of this structure was connected to the fact that the flume's structure has a steel beam containing the flume walls, and the visibility between 16 and 21 cm from the bottom of the flume is covered.

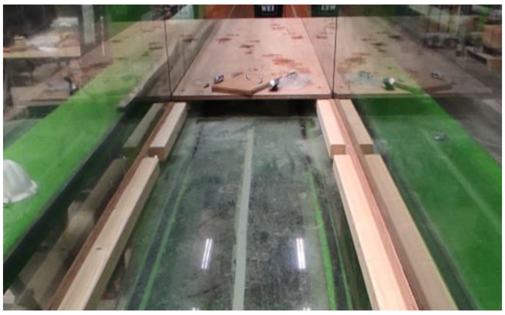


Fig. 3.5. Bottom elevation structure

Depth

This connects directly to / with the decision about the water depth, which had to be balanced: on one hand, enough water depth was needed to generate waves as sinusoidal as possible, and on the other hand, enough space between the water surface and the edge of the flume was necessary to make big waves. A water depth deemed balanced was 60cm from the wooden construction, for a total of 69cm in the flume.

Fig. 3.6. Semicircular and rectangular layouts

Semicircular vs. rectangular

About the shape of the top view of the layer, in initial trial tests two alternatives were evaluated: **semicircular** (concentric with the monopile), considered more realistic, or **rectangular** (from side to side of the flume), more schematized (see figure 3.6). Based on this trial the rectangular shape was chosen, to enable straightforward analysis.

3.4.2 *Scour protection layer characteristics*

Available amount of blocks

As mentioned in the previous section, the scale was defined on the basis of the smallest block available. However, this also meant that the amount of available blocks, which was also limited (3000 pieces), defined the dimensions of the scour protection layer in the model, starting by its thickness and obtaining its area.

Definition of layer thickness

The amount of available blocks (3000) was both limited and rounded off. This contributed to the use, in this research, of a definition of 'layer' tied to the amount of blocks (i.e. 1000 blocks per layer in the construction). The layer thickness, therefore, needed to be measured manually, after defining the packing density (see next paragraph for details). The thickness was measured for a different numbers of layers. ***N.B.***: while a way to measure the thickness in breakwaters is the thickness coefficient (format: nH), in this study the adopted format is tied to the amount of blocks per area (format: nL). It's important not to confuse the two (they may differ mainly due to the interlocking); however, in table 3.4 a measure of both

Fig. 3.7. Measurement of layer thickness

	# layers	# blocks/m² (in model)	thickness (t)	thickness coefficient	obtained by
1L	1	2518.14	2,15 cm	1.02H	measuring
1½L	*1,5*	3777.21	*3,13 cm*	*1.49H*	*interpolation*
2L	2	5036.28	4,1 cm	1.95H	measuring
2½L	*2,5*	6295.35	*5,06 cm*	*2.41H*	*interpolation*
3L	3	7554.42	6 cm	2.86H	measuring

Table 3.4. Scaled model layer thickness values

is given. This measuring was made by building two wooden boxes, one inside of the other and with only one degree of freedom (like a square piston), so that the space between the parallel surfaces of both box bottoms could be used to measure the block layers, in amounts corresponding to one, two, and three layers. See figure 3.7 and table 3.4.

Packing density

In the course of the preparations it became clear that the packing density of the blocks needed to be re-established from the design guidelines made for the Xbloc, taken as a first reference in absence of similar instructions for Xstream. In first instance one would think it's applicable to both elements equally since the shape is the same; however, there are two main differences between the application of Xbloc and the particular use of Xstream in this study: one, the Xbloc elements are placed individually, which allows for more care; and two, the Xbloc-layers are mostly visible and mostly inclined (meaning that gravity plays a role in the packing density). In the case of a scour protection layer on the seabed, all this features were not applicable. Additionally, a 1-layer configuration of Xbloc is common, but the question is whether it would be sufficient for Xstream in the case studied; hence, multiple thicknesses were tested.

The practical implication of this surfaced in the process of measuring the layer thickness: using the packing density in the Xbloc guidelines would yield a packing density of 120 blocks per area of 10H x 10H, and that was impossible to fit without pushing with the hands. The practical solution of that was to find an amount of blocks for which no pushing (no compaction) was needed. This came at about 111 blocks per area of 10H x 10H. In the prototype this area equals 3.3m x 3.3m = 10.89m² (10.2 units/m²/layer); in the model, this comes down to 21cm x 21cm = 441cm² (2518.14 units/m²/layer).

Protection layer area

With this packing density, and the available amount of blocks mentioned before, the model protection layer area was calculated. With the purpose to test a maximum of 3 layers of blocks, this means 1000 blocks per layer available. The area of the protection layer is, then, 1000/(111/441) = 3973cm² on model scale.

Placing method

A part of its thought process of the packing density included seeing the way blocks are placed in a scour protection as one of the test variables, which could potentially yield differences in the results. The default method used to lay the blocks in the construction was measuring the amount of blocks needed (weighing them in bulk) dividing them in three big areas or regions of the scour protection, and then laying them on the required thickness. To measure the right thickness, the flume would be filled up to the layer thickness, using the surface as the reference. This resulted in a neat construction, modelling the ideal situation. More on that can be found in Appendix B.

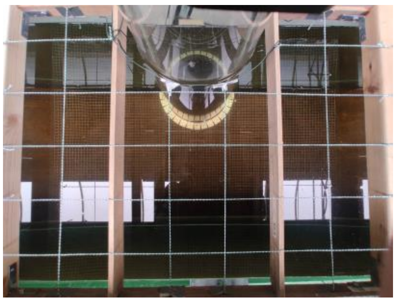


Fig. 3.8. Raster used to drop blocks from the surface

However, as the real situation can be very different, a way to meet the potential deviations during the block placement was to introduce an extra series of tests in which the blocks were dropped from the surface, creating a raster close to the surface as seen in figure 3.8, every area with a corresponding amount of blocks for 2 layers (more on that in the next section, and in Appendix C).

3.4.3 *The setup*

From all the aforementioned, the test setup can be distilled in the following set of figures:

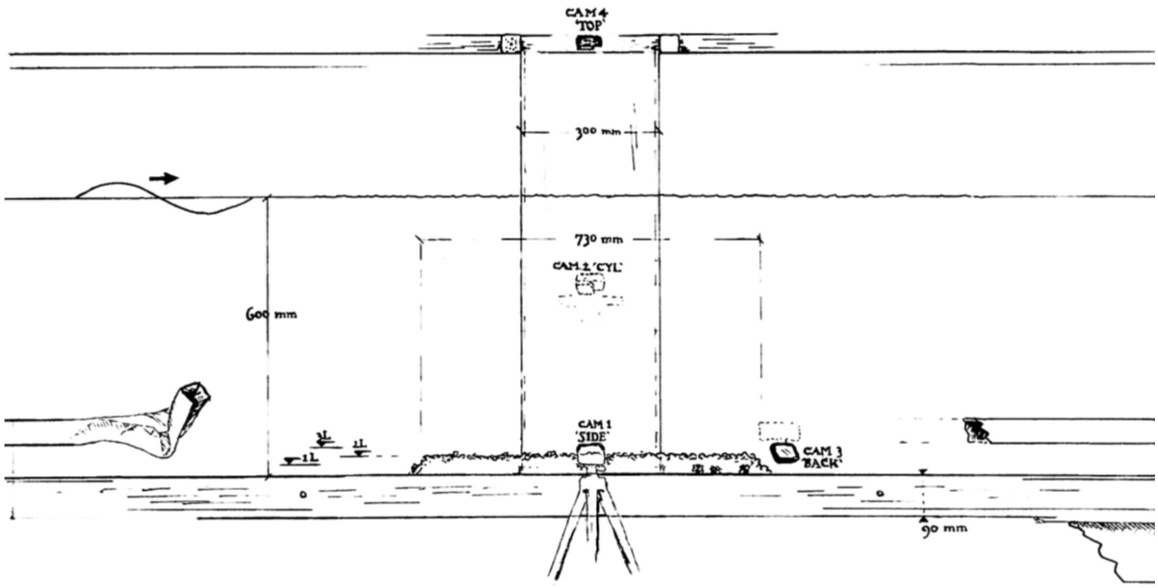


Fig. 3.9. Side view (close-up) of the test setup

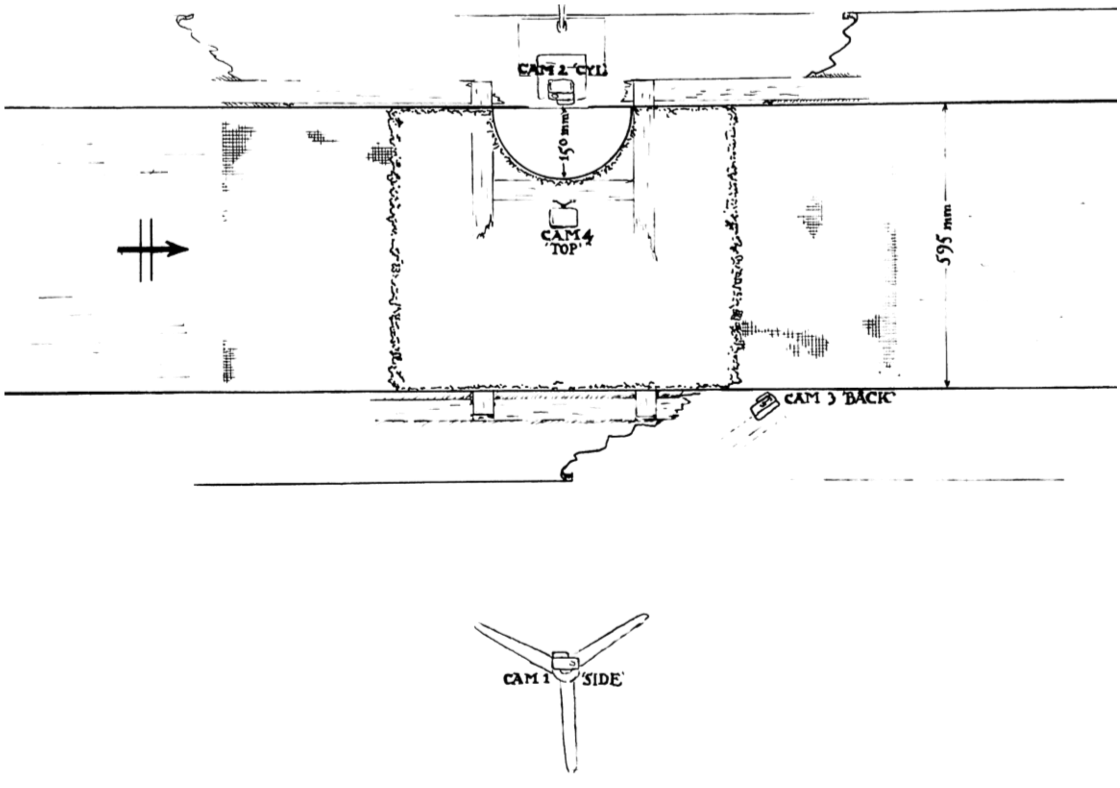


Fig. 3.10. Top view of the test setup

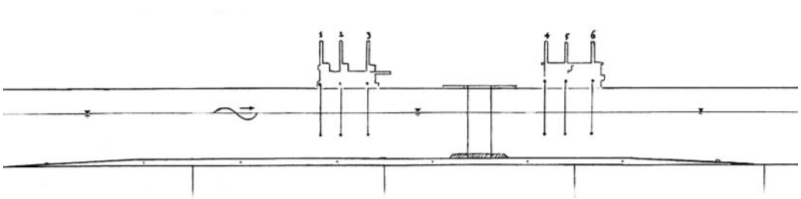


Fig. 3.11. Side view (general outlook) of the test setup, including the bottom elevation structure and the position of the 6 wave gauges

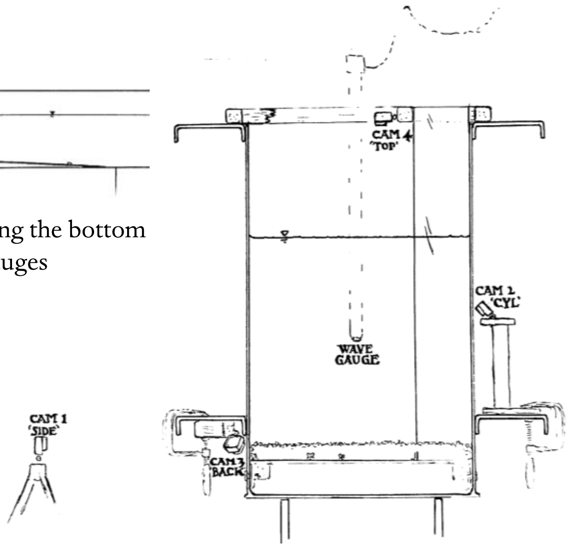


Fig. 3.12. Cross-section view of the test setup

3.5 test program

3.5.1 *Wave conditions*

In the process of choosing the basis for the wave conditions, the wave climate corresponding to the southern North Sea was considered for a return period of 50 years, which is usually taken into account in designing scour protections for wind turbine foundations [Deltares, 2023]. The wave climate for the selected area features a significant wave height that varies per location, as well as the associated peak period. In view of these variations, reference values for the 50-year return period were taken for the significant wave height (8.1 m) and the peak period (12.8 s). The set of wave conditions was composed of incremental variations of the significant wave height (based on percentages of the reference value, H_{ref} = 8.1 m), with a constant peak period, so that the resulting orbital velocity variations would follow the same pattern. The input values (including the Ursell number, used to verify the applicability of the linear wave theory) for the wave conditions used for the tests can be seen in table 3.5.

		Prototype values			Distorted model values			
Wave condition	% H_{ref}	H_s (m)	T_p (s)	$\hat{u}_w$ (m/s)	$\hat{u}_{w,m}$ (m/s)	$H_{s,md}$ (m)	$T_{p,m}$ (s)	U_{md} (-)
R30	30%	2.43	12.80	0.40	0.10	0.08	3.23	20,69
R40	40%	3.24	12.80	0.53	0.13	0.11	3.23	27,58
R50	50%	4.05	12.80	0.67	0.17	0.13	3.23	34,48
R60	60%	4.86	12.80	0.80	0.20	0.16	3.23	41,38
R70	70%	5.67	12.80	0.93	0.24	0.19	3.23	48,27
R80	80%	6.48	12.80	1.07	0.27	0.21	3.23	55,17
R90	90%	7.29	12.80	1.20	0.30	0.24	3.23	62,06
R100	100%	8.10	12.80	1.33	0.34	0.27	3.23	68,96

Table 3.5. Wave condition values used for the tests

3.5.2 *Thickness of the bed protection*

Based on the scour protection layer thicknesses and packing density defined in section 3.4.2, the test program was laid out for the three thicknesses measured, and for the thicknesses in between (obtained by interpolating, but taking into account that the increments were nonlinear, see table 3.4). The test series plan is based on the thicknesses as can be seen in table 3.5.

Test series		placing method	# layers	thickness (t)	amount of blocks	# blocks/m²
H-2L	H	installed in dry	2	4.1 cm	2000	5036.28
H-2½L			2.5	5.06 cm	2500	6295.35
H-3L			3	6 cm	3000	7554.42
H-1L			1	2.15 cm	1000	2518.14
H-1½L			1.5	3.13 cm	1500	3777.21
M-2L	M	dropped from water surface	2	4.1 cm	2000	5036.28

Table 3.5. Test series and thicknesses used

3.5.3 *Test sequence*

These 6 test series consisted of all 8 wave conditions applied to each series. Figure 3.13 shows a flow chart followed during the test program.

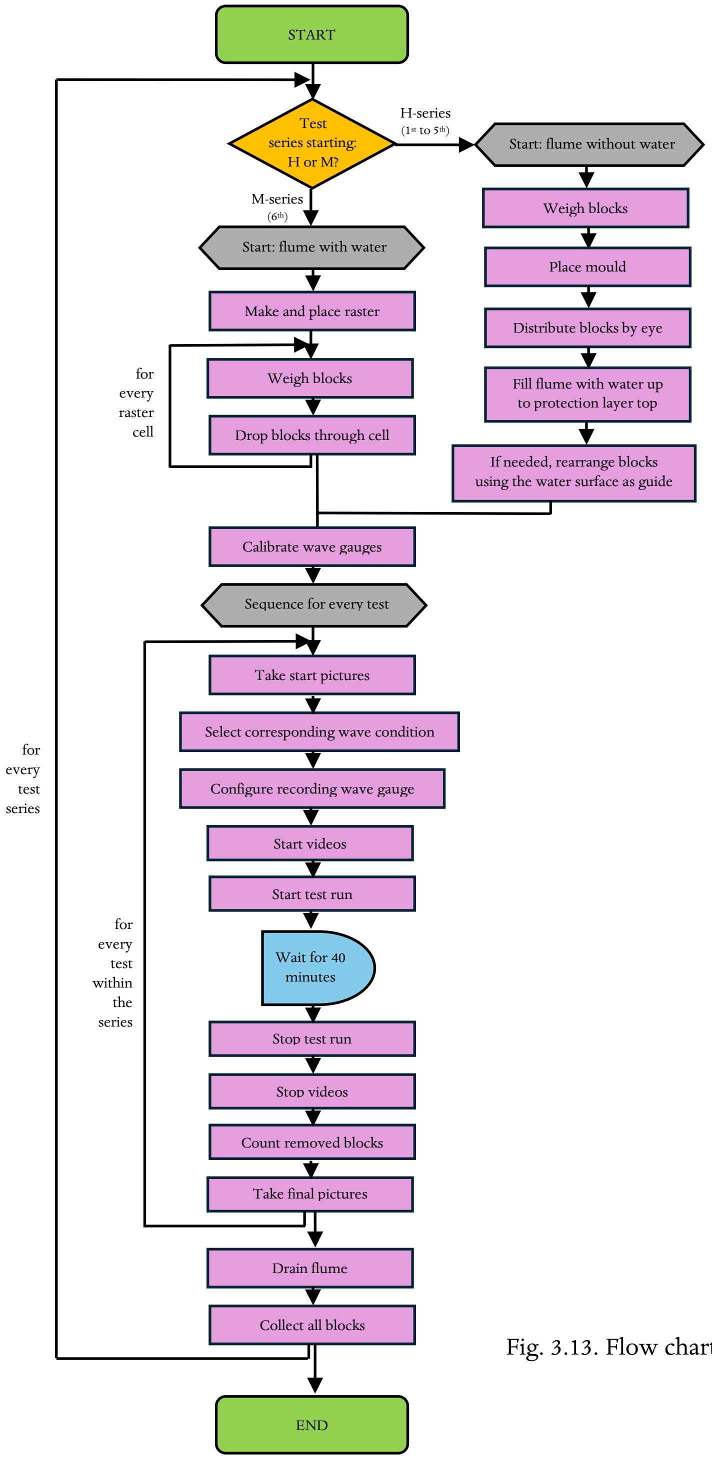


Fig. 3.13. Flow chart of test sequence

4 results

This chapter shows the results obtained in and throughout the tests. After organizing the test output, two main areas can be distinguished to be covered by the results: the waves and the block movements.

4.1 wave measurements

The measurements from the wave gauges were processed with WaveLab. The range of the return data is wide, but can be made concise taking the most relevant parameters, taken from the first set of 3 gauges (located upwave from the setup). In view of the relatively low standard deviation ($\sigma_{Hm0} \leq$ 0.25%, $\sigma_{Hmax} \leq$ 0.8%, $\sigma_{Tm} \leq$ 3%), the measured values of the wave heights and periods are averaged and compared to the target values, as shown in table 4.1. The full table of values can be found in Appendix A.

Wave cond.	**Target values**		**Measured values** (wave condition averaged)			
	$H_{s,md}$ (m)	$T_{p,m}$ (s)	H_{m0} (m)	H_{max} (m)	T_p (s)	T_m (s)
R30	0.08	3.23	0.08	0.15	3.20	2.60
R40	0.11	3.23	0.11	0.21	3.20	2.59
R50	0.13	3.23	0.14	0.27	3.20	2.56
R60	0.16	3.23	0.16	0.30	3.20	2.51
R70	0.19	3.23	0.19	0.35	3.20	2.48
R80	0.21	3.23	0.21	0.37	3.20	2.44
R90	0.24	3.23	0.24	0.39	3.20	2.35
R100	0.26	3.23	0.27	0.40	3.20	2.31

Table 4.1. Target (distorted model) values and measured values of the wave height and wave period

These values can be charted in many ways. A selection is presented below. Figures 4.1 and 4.2 show the target $H_{s,md}$ together with measured values of H_{m0} and H_{max}; figures 4.3 and 4.4 give a comparison between H_{m0} measured for 2 of the test series by the upwave and downwave sets of gauges, i.e. before and after passing the half monopile. (The set of 3 upwave gauges is taken as data basis due to of their higher reliability and lower chances of disruptions, compared to the downwave gauges; however, the disturbance calculated in reduction of H_{m0} remains under the 8%. Variations in the ratio between measurements by upwave and downwave gauges are most likely due to the daily calibration.)

An important note for the reminder of the report is that, while the measured values of H_{m0} and H_{max} are here indicated as such, it shouldn't be forgotten that these are <u>distorted model values</u> and, hence, can (or even should, for the sake of clarity) be written as $H_{m0,md}$ and $H_{max,md}$ as well. Conversion to regular (non-distorted) and prototype values will be less used in this report, and, if so, properly indicated.

Additionally, a 'wave report' was generated using WaveLab, consisting of one page for every test, featuring input parameters, a frequency domain analysis, and a time domain analysis. In figures 4.5 to 4.10 some of

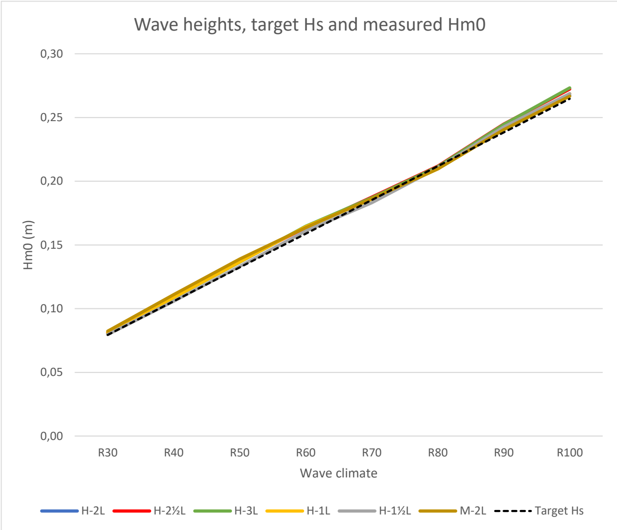


Fig. 4.1. Measured values of H_{m0} compared to target H_s

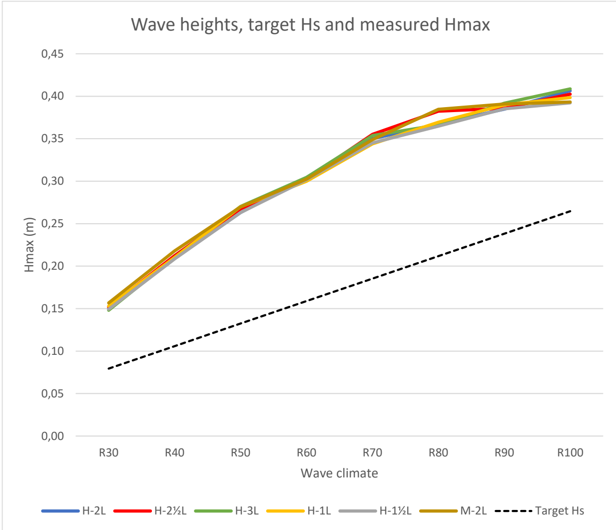


Fig. 4.2. Measured values of H_{max} compared to target H_s

them are presented. The full report can be seen in Appendix D. A note on the visual observations during the tests: the typical non-sinusoidal wave form corresponding to the second order Stokes component was observed during the higher wave conditions. This is confirmed in the wave report figures.

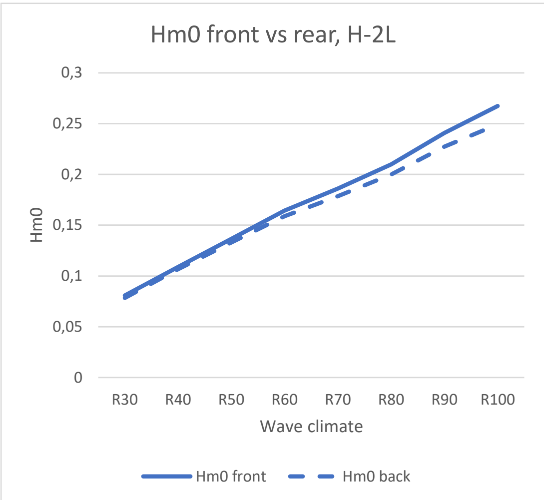


Fig. 4.3. Values of H_{m0} for test series H-2L measured by the front and rear gauge sets

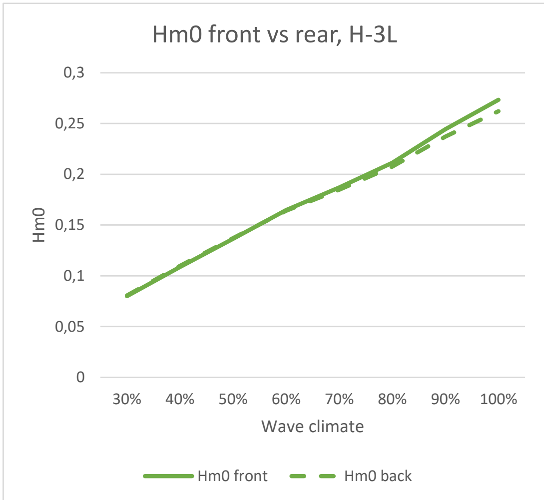


Fig. 4.4. Values of H_{m0} for test series H-3L measured by the front and rear gauge sets

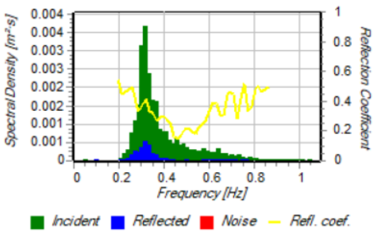


Figure 4.5. Frequency domain analysis chart for test H-1L-R30

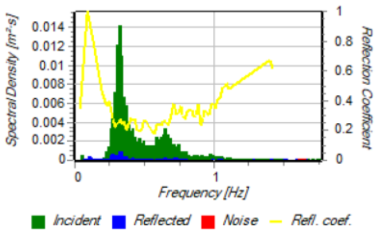


Figure 4.6. Frequency domain analysis chart for test H-1L-R70

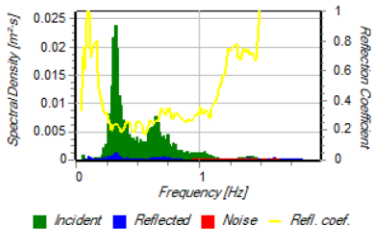


Figure 4.7. Frequency domain analysis chart for test H-1L-R100

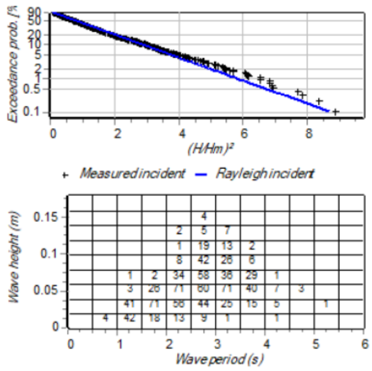


Figure 4.8. Time domain analysis charts for test H-1L-R30

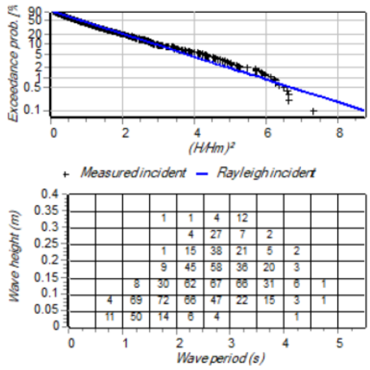


Figure 4.9. Time domain analysis charts for test H-1L-R70

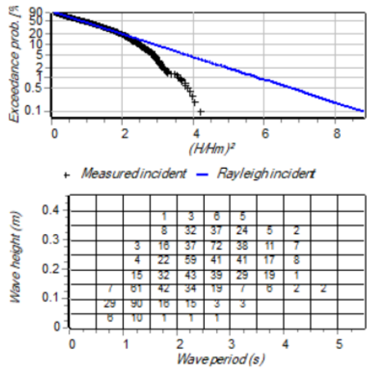


Figure 4.10. Time domain analysis charts for test H-1L-R100

4.2 preliminary results

During the tests it was observed that, as a test series progressed, a trough was formed in front of the half cylinder, i.e. a place of erosion in the contraction point, as well as a mound directly behind the half cylinder, corresponding to deposition after the end of the contraction. This is schematised in figure 4.11, where the (-) corresponds to the trough and the (+) to the mound.

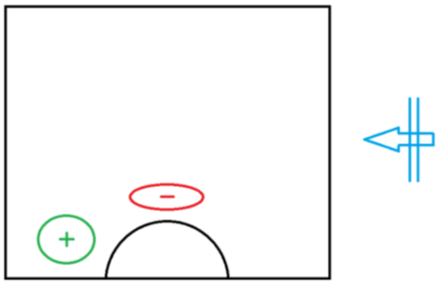


Fig. 4.11. Schematisation of the general erosion and deposition zones, as observed during the tests

A first visual assessment of the mobility was made taking the top camera pictures before and after every test, distinguishing the differences between them, and sketch the differences by eye. See figure 4.12 for a scheme of this procedure.

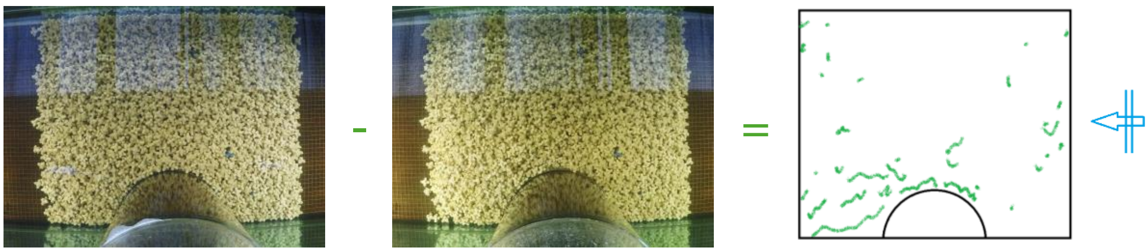


Fig. 4.12. Schematisation of the making of the sketch corresponding to test H-2½L-R80

A note on the scribbles: they are meant to show shades, areas with differences (no tracking is possible with this method). A different colour was used for every wave condition, as specified in figure 4.13. The 48 sketches were then condensed by stacking them by test series, yielding the mappings in figure 4.14.

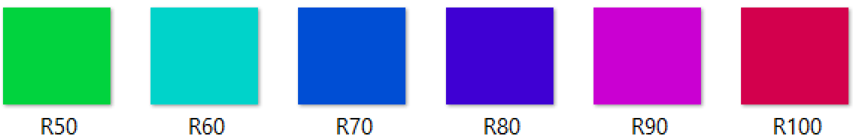


Figure 4.13. Colours used for figures 4.14 and 4.19a to 4.19f

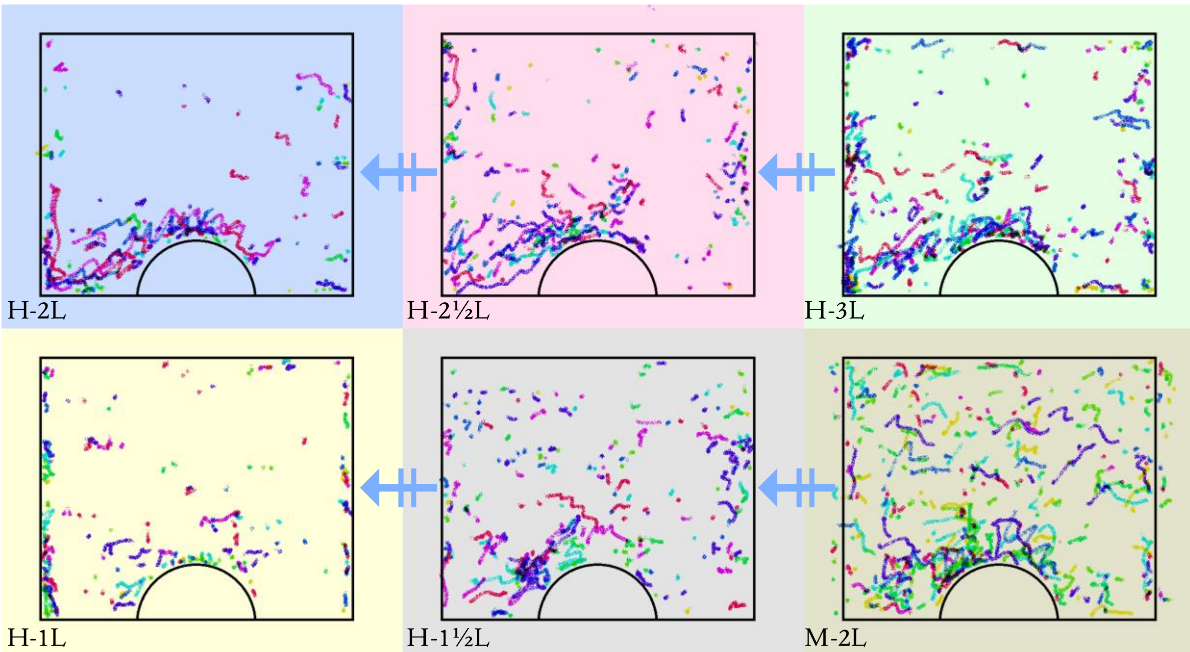


Figure 4.14. Mapping of the differences between the beginning and the end of every test, grouped by test series

4.3 block movements

In this section an account of different movements of the scaled Xstream elements is given, as a result of quantifying them in three different types of movement. These data were obtained by direct observation or through the analysis of the photos and videos taken with the GoPro cameras. The three types of movement to recognize in the tests were: rocking, internal displacement, and removal.

- Rocking: The movement of a block without leaving its place is denoted as rocking.
- Internal displacement: When, unlike by rocking, a block moves leaving its place but still doesn't leave the protection layer, it's indicated as internal displacement.
- Removal: The displacement of a block taking it outside of the surface of the construction means, in the scope of this research, that the block has been removed.

4.3.1 *rocking*

The smallest movement, and first to be observed among the blocks throughout the test sequence, is rocking. Within the definition given for rocking, differences are distinguishable in two directions: one, the scale order of the movement of the block with respect to itself (mostly rotational around one of the block's protuberances), and two, the frequency of the movement (which goes from one-time movements to moving with the wave frequency). An attempt was made to make these variations significant.

In the data obtaining procedure, one minute from one video clip per test was used, always the same clip from the same camera. This one-minute time sample is meant to represent the corresponding test in one and the same way, making the count feasible. Two things were measured: the amount of blocks rocking, and the amount of individual rocking movements. The results can be appreciated in tables 4.2 and 4.3, correspondingly plotted in figures 4.15 and 4.16.

Wave condition	Number of rocking blocks					
	H-2L	H-2½L	H-3L	H-1L	H-1½L	M-2L
R30	0	0	0	0	0	0
R40	2	3	1	3	0	1
R50	6	6	1	3	3	2
R60	5	8	5	7	5	9
R70	9	7	5	11	8	9
R80	9	13	7	10	10	11
R90	12	9	5	14	13	10
R100	14	11	8	15	7	13
Total	*57*	*57*	*32*	*63*	*46*	*55*

Table 4.2. Number of blocks rocking during a 1-minute sample

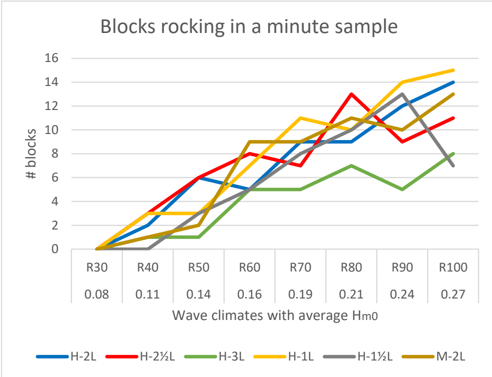


Fig. 4.15. Number of blocks rocking during a 1-minute sample

Wave condition	Number of individual rocking movements					
	H-2L	H-2½L	H-3L	H-1L	H-1½L	M-2L
R30	0	0	0	0	0	0
R40	18	4	7	11	0	1
R50	37	15	1	5	8	2
R60	46	35	21	11	9	9
R70	50	45	29	15	24	52
R80	27	57	18	41	40	38
R90	50	78	23	52	25	103
R100	48	26	38	95	35	103
Total	*276*	*260*	*137*	*230*	*141*	*308*

Table 4.3. Number of rocking movements during the sample

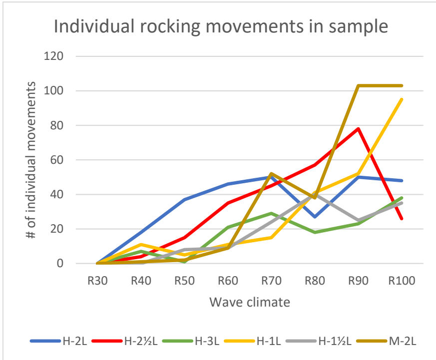


Fig. 4.16. Number of rocking movements during the sample

These data can be organised further to view the average amount of rocking movements per block (table 4.4, fig. 4.17) and the rocking movements expressed in percentage of each series' total (table 4.5, fig. 4.18).

Wave condition	Average individual movements per block						avg. / run
	H-2L	H-2½L	H-3L	H-1L	H-1½L	M-2L	
R30	---	---	---	---	---	---	---
R40	9.00	1.33	7.00	3.67	---	1.00	*4.40*
R50	6.17	2.50	1.00	1.67	2.67	1.00	*2.50*
R60	9.20	4.38	4.20	1.57	1.80	1.00	*3.69*
R70	5.56	6.43	5.80	1.36	3.00	5.78	*4.65*
R80	3.00	4.38	2.57	4.10	4.00	3.45	*3.59*
R90	4.17	8.67	4.60	3.71	1.92	10.30	*5.56*
R100	3.43	2.36	4.75	6.33	5.00	7.92	*4.97*
Average	5.79	4.29	4.27	3.20	3.06	4.35	***4.19***

Table 4.4. Average number of rocking movements per block (1 min.)

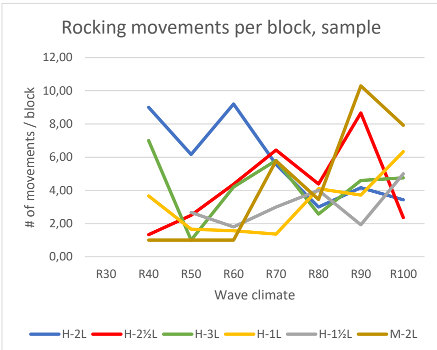


Fig. 4.17. Average of individual rocking movements per block

Wave condition	Rocking movements, % of corresponding test series					
	H-2L	H-2½L	H-3L	H-1L	H-1½L	M-2L
R30	0.00	0.00	0.00	0.00	0.00	0.00
R40	6.52	1.54	5.11	4.78	0.00	0.32
R50	13.41	5.77	0.73	2.17	5.67	0.65
R60	16.67	13.46	15.33	4.78	6.38	2.92
R70	18.12	17.31	21.17	6.52	17.02	16.88
R80	9.78	21.92	13.14	17.83	28.37	12.34
R90	18.12	30.00	16.79	22.61	17.73	33.44
R100	17.39	10.00	27.74	41.30	24.82	33.44
Total	*100*	*100*	*100*	*100*	*100*	*100*

Table 4.5. Rocking movements as percentage of test series

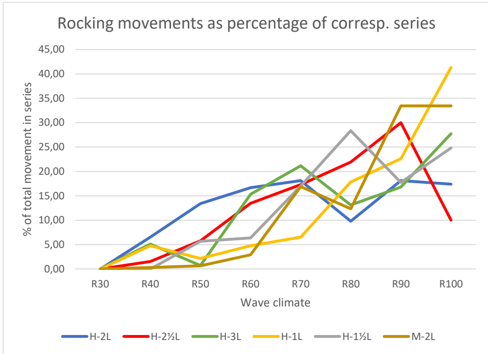


Fig. 4.18. Rocking movements as percentage of total movements within series

4.3.2 *internal displacements*

For the internal displacements a procedure was adopted, using videos in the same way as done for rocking, but taking a time sample of five minutes instead of one. In the course of the sample, both the <u>blocks</u> displacing internally and the <u>individual displacements</u> (the movements) were counted. The sample is longer given the higher threshold of internal displacements compared to rocking. The individual displacements were made countable defining one of them as *the translation movement of a block within the cycle of a wave*. This allows for a distinction between the individual *blocks* being displaced and the number of *movements* themselves, which can potentially occur to the same block. An important point to note is the need to determinate the limit between rocking and internal displacements, based on 1. the distance travelled, which was taken to be at least once the main dimension of the block; and two, the non-returning character of the movement (unless it happened on a later stage). The results, which initially follow the same structure as the results for rocking, are shown in the tables below: in table 4.6 and figure 4.19 the amount of internally displaced blocks counted during the time sample; in table 4.7 and figure 4.20 the individual displacements are tabulated and plotted; table 4.8 and figure 4.21 correspond to the average displacements performed by one block, and in table 4.9 and figure 4.22 the displacements as percentage of the total number of displacements in the corresponding test series.

Wave condition	Number of blocks internally displaced					
	H-2L	H-2½L	H-3L	H-1L	H-1½L	M-2L
R30	0	0	0	0	0	0
R40	0	0	0	0	0	0
R50	0	0	0	0	2	0
R60	0	0	0	0	1	2
R70	2	3	1	0	2	3
R80	4	16	6	2	7	4
R90	12	2	11	0	1	3
R100	10	9	9	0	5	5
Total	*28*	*30*	*27*	*2*	*18*	*17*

Table 4.6. Number of blocks internally displaced during a 5-minute time sample

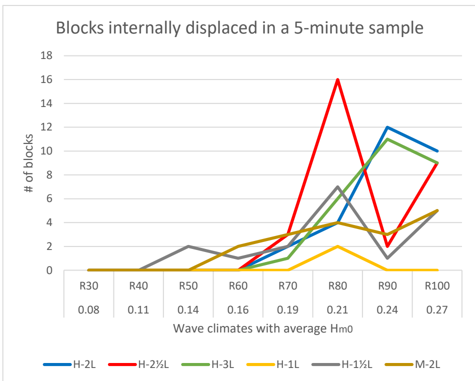


Fig. 4.19. Number of internally displaced blocks during the 5-minute sample

Wave condition	Number of individual displacements					
	H-2L	H-2½L	H-3L	H-1L	H-1½L	M-2L
R30	0	0	0	0	0	0
R40	0	0	0	0	0	0
R50	0	0	0	0	4	0
R60	0	0	0	0	2	2
R70	5	5	1	0	4	4
R80	8	58	16	4	11	7
R90	41	6	37	0	2	7
R100	24	47	33	0	16	10
Total	*78*	*116*	*87*	*4*	*39*	*30*

Table 4.7. Number of internal displacements during the sample

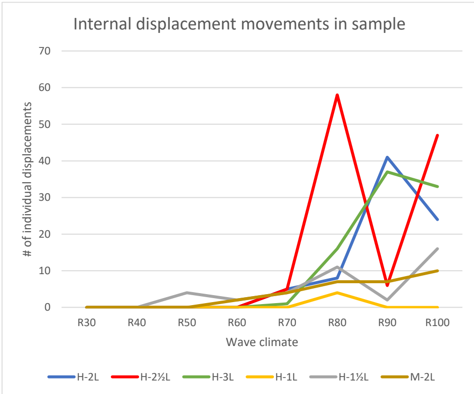


Fig. 4.20. Number of internal displacements during the 5-minute sample

Wave condition	Average individual displacements per block						avg. /run
	H-2L	H-2½L	H-3L	H-1L	H-1½L	M-2L	
R30	---	---	---	---	---	---	---
R40	---	---	---	---	---	---	---
R50	---	---	---	---	2.00	---	*2.00*
R60	---	---	---	---	2.00	1.00	*1.50*
R70	2.50	1.67	1.00	---	2.00	1.33	*1.70*
R80	2.00	3.63	2.67	2.00	1.57	1.75	*2.27*
R90	3.42	3.00	3.36	---	2.00	2.33	*2.82*
R100	2.40	5.22	3.67	---	3.20	2.00	*3.30*
Average	*2.58*	*3.38*	*2.67*	*2.00*	*2.13*	*1.68*	***2.26***

Table 4.8. Average number of internal displacements per block

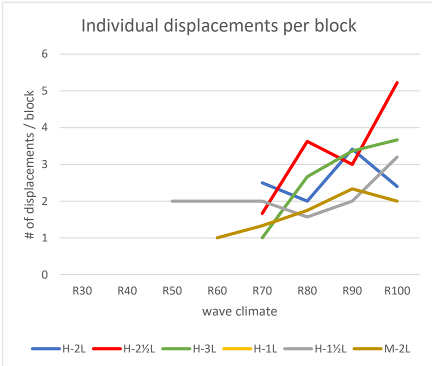


Fig. 4.21. Average of individual displacements per block

Wave condition	Internal displacements, % of corresponding test series					
	H-2L	H-2½L	H-3L	H-1L	H-1½L	M-2L
R30	0.00	0.00	0.00	0.00	0.00	0.00
R40	0.00	0.00	0.00	0.00	0.00	0.00
R50	0.00	0.00	0.00	0.00	10.26	0.00
R60	0.00	0.00	0.00	0.00	5.13	6.67
R70	6.41	4.31	1.15	0.00	10.26	13.33
R80	10.26	50.00	18.39	100.00	28.21	23.33
R90	52.56	5.17	42.53	0.00	5.13	23.33
R100	30.77	40.52	37.93	0.00	41.03	33.33
Total	100.00	100.00	100.00	100.00	100.00	100.00

Table 4.9. Internal displacements as percentage of test series

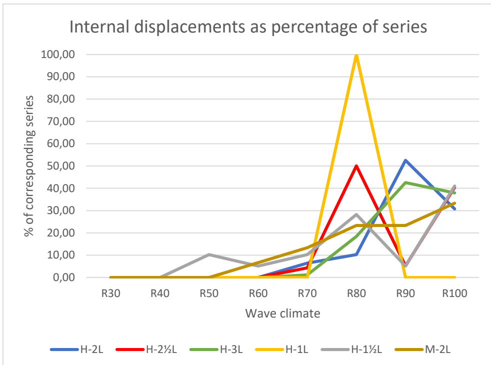
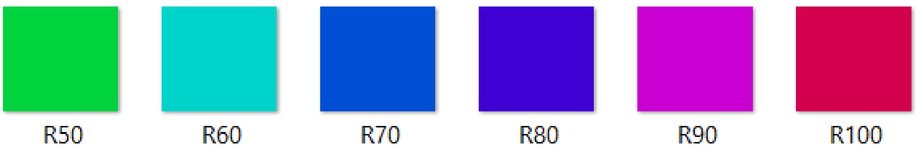


Fig. 4.22. Internal displacements as percentage of total movements within series

The original location of every block displaced during the time sample is also mapped. See figures 4.23a to 4.23f for the locations. Since this is a sample, the goal is to show the patterns in the locations. The colours used for the graphics appear below.



Colours used for tables 4.19a to 4.19f and 4.20

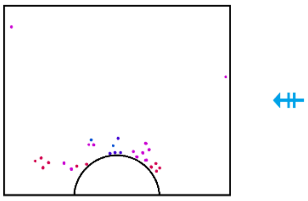


Figure 4.23a. Original locations of internally moved blocks, H-2L

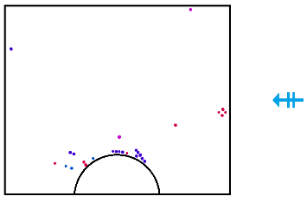


Figure 4.23b. Original locations of internally moved blocks, H-2½L

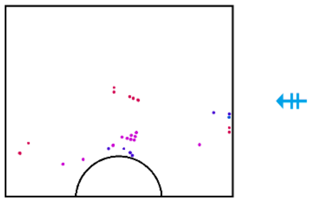


Figure 4.23c. Original locations of internally moved blocks, H-3L

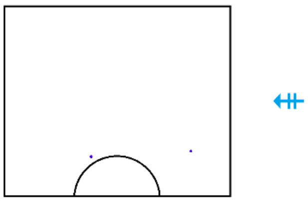


Figure 4.23d. Original locations of internally moved blocks, H-1L

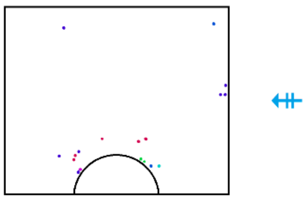


Figure 4.23e. Original locations of internally moved blocks, H-1½L

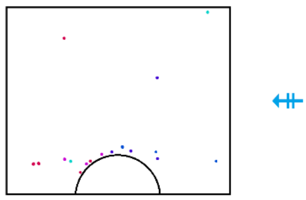


Figure 4.23f. Original locations of internally moved blocks, M-2L

4.3.3 *block removal*

The removal implies that the block is far away of the construction, defined in either of the following: as removal from the metal grid or mesh located under the block layer, out of the angle of the last camera, or, in the clearest way, rolled down the rear ramp of the wooden construction. This made it also unambiguous to count the blocks after every test. The following tables and figures are presented: the number of blocks removed per test (table 4.10, figure 4.24), the number of blocks removed, cumulative throughout the test series (table 4.11, figure 4.25), and the blocks removed expressed in percentages of the whole construction (table 4.12, figure 4.26) and the corresponding series (table 4.13, figure 4.27).

Wave condition	Number of blocks removed from protection layer					
	H-2L	H-2½L	H-3L	H-1L	H-1½L	M-2L
R30	0	0	0	0	0	0
R40	0	0	0	0	0	0
R50	0	0	0	3	0	6
R60	0	0	0	6	1	2
R70	1	0	0	1	2	2
R80	2	2	1	2	0	1
R90	4	1	2	1	2	2
R100	3	1	1	3	0	0
Total	*10*	*4*	*4*	*16*	*5*	*13*

Table 4.10. Number of blocks removed from the construction during every test

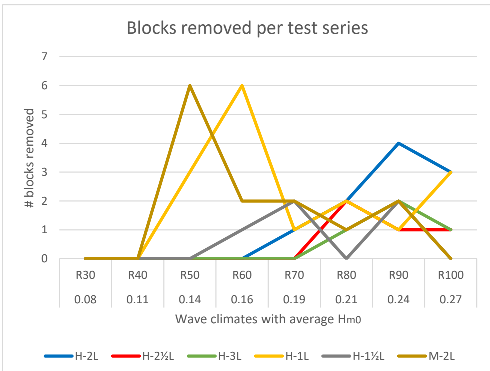


Fig. 4.24. Number of blocks removed from the construction, per test series

Wave condition	Number of blocks removed, cumulative					
	H-2L	H-2½L	H-3L	H-1L	H-1½L	M-2L
R30	0	0	0	0	0	0
R40	0	0	0	0	0	0
R50	0	0	0	3	0	6
R60	0	0	0	9	1	8
R70	1	0	0	10	3	10
R80	3	2	1	12	3	11
R90	7	3	3	13	5	13
R100	10	4	4	16	5	13

Table 4.11. Number of blocks removed from the construction during every test, cumulative

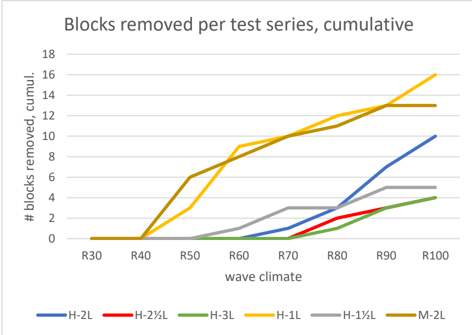


Fig. 4.25. Number of blocks removed from the construction, per test series, cumulative

Wave condition	# blocks removed, as percentage of the whole layer					
	H-2L	H-2½L	H-3L	H-1L	H-1½L	M-2L
R30	0.00	0.00	0.00	0.00	0.00	0.00
R40	0.00	0.00	0.00	0.00	0.00	0.00
R50	0.00	0.00	0.00	0.30	0.00	0.30
R60	0.00	0.00	0.00	0.60	0.07	0.10
R70	0.05	0.00	0.00	0.10	0.13	0.10
R80	0.10	0.08	0.03	0.20	0.00	0.05
R90	0.20	0.04	0.07	0.10	0.13	0.10
R100	0.15	0.04	0.03	0.30	0.00	0.00
Total	*0.50*	*0.16*	*0.13*	*1.60*	*0.33*	*0.65*

Table 4.12. Number of blocks removed, as percentage of the whole scour protection layer (the total of the blocks used)

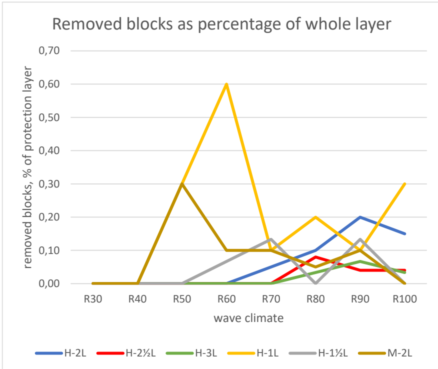


Fig. 4.26. Number of blocks removed, as percentage of the whole layer

Wave condition	# of blocks removed, % of total in test series					
	H-2L	H-2½L	H-3L	H-1L	H-1½L	M-2L
R30	0.00	0.00	0.00	0.00	0.00	0.00
R40	0.00	0.00	0.00	0.00	0.00	0.00
R50	0.00	0.00	0.00	18.75	0.00	46.15
R60	0.00	0.00	0.00	37.50	20.00	15.38
R70	10.00	0.00	0.00	6.25	40.00	15.38
R80	20.00	50.00	25.00	12.50	0.00	7.69
R90	40.00	25.00	50.00	6.25	40.00	15.38
R100	30.00	25.00	25.00	18.75	0.00	0.00
Total	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*

Table 4.13. Number of blocks removed, as percentage of the whole corresponding test series

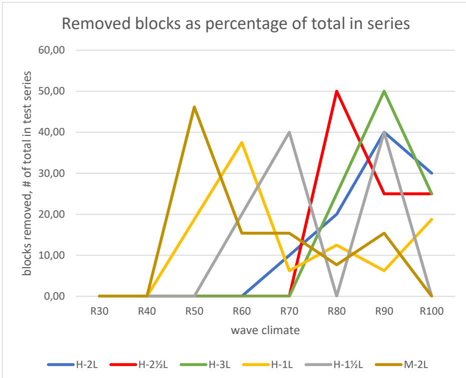


Fig. 4.27. Number of blocks removed, as percentage of the whole test series

For 3 of the 6 test series, the removed blocks were individually followed backwards to track the original position in the protection layer (see figure 4.28). The numbers indicate the order in which they were removed from the construction.

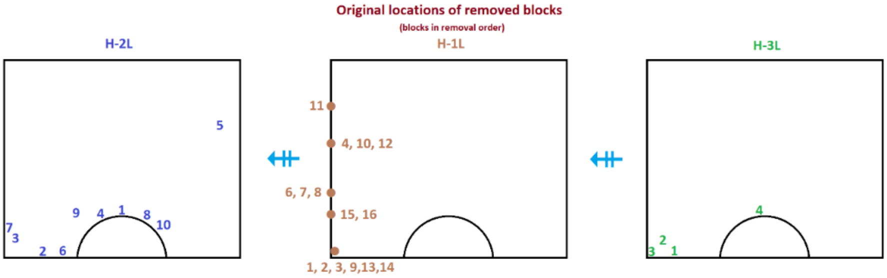


Figure 4.28. Original locations of the removed blocks for test series H-2L, H-1L and H-3L

4.3.4 *superposition of charts*

The following figures show comparisons of the rocking, the internal displacements, and the block removal for the six test series. The data compared are expressed in percentage of the total of the corresponding movement for the corresponding test series, and are taken from tables 4.5, 4.9 and 4.13. (***N.B.*** the idea of the graphics is that the integral of each curve should amount to 100%)

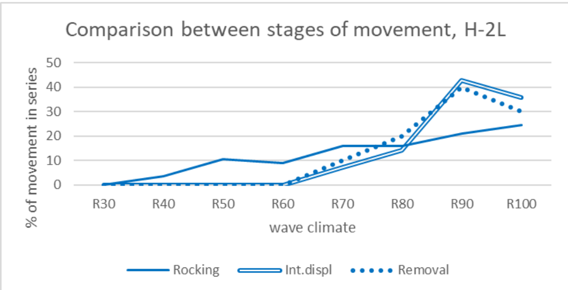


Figure 4.29a. Comparison between different modes of block movement for series H-2L

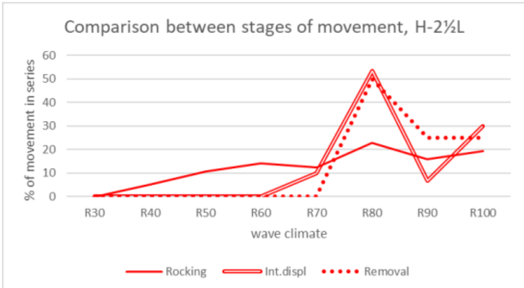


Figure 4.29b. Comparison between different modes of block movement for series H-2½L

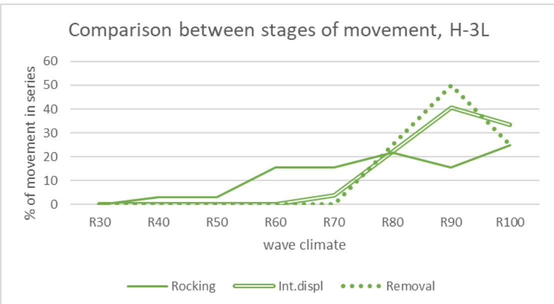


Figure 4.29c. Comparison between different modes of block movement for series H-3L

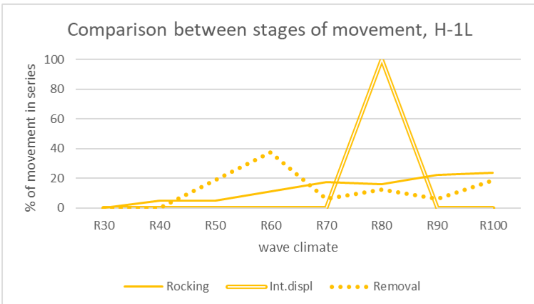


Figure 4.29d. Comparison between different modes of block movement for series H-1L

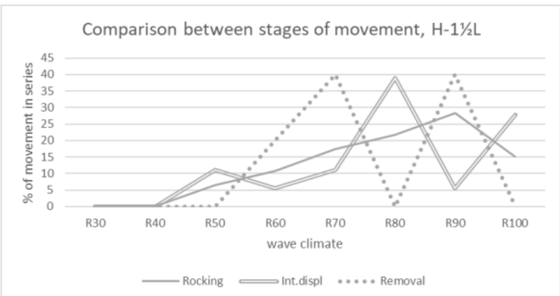


Figure 4.29e. Comparison between different modes of block movement for series H-1½L

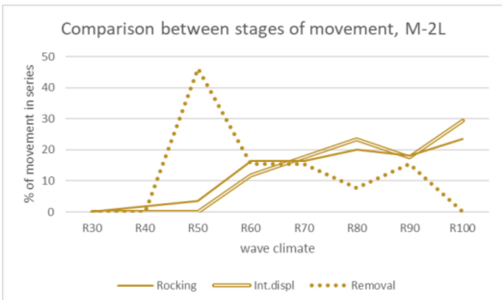


Figure 4.29f. Comparison between different modes of block movement for series M-2L

5 analysis

5.1 preliminaries

5.1.1 *Data focus areas*

The analysis stage of this study showed that there are many ways to look at data. Some were already presented in chapter 4, some became particularly relevant in the present chapter. Some particularities in the form of the graphs also caught the eye, e.g. the presence of peaks in the data on internal and external displacements.

In the process of analysis, four of those emphasized areas were recognized as focal points. The pictograms below are an attempt to make these clear, particularly in sections 5.2 to 5.4. Three of them are localizable in most of the graphics in chapter 4, and are here presented on a simple, generic depiction; a relevant note is that they are presented as continuous lines, while in reality the tests represented discrete values of $H_{s,md}$. The fourth one takes the location into account.

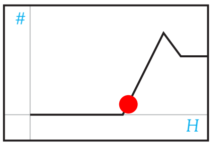
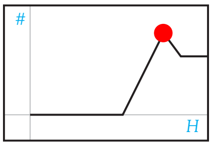
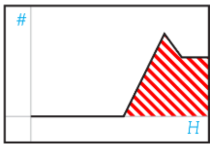
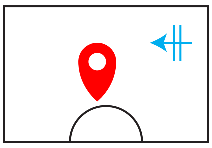
	Initiation of motion The point of first time non-zero movement observed in a test series.
	Peak in movement The maximum point in the amount of movement observed in a test series.
	Cumulative movement The total (cumulative) movement observed during a test series, i.e. the theoretical integral of the graphic of movement
	Location A distinction on observed movement based on location within the model scour protection

Table 5.1. Areas focused on in the data analysis

5.1.2 *External stability parameters*

The external stability of the scour protection layer as defined by the JIP-HaSPro (see section 2.3) depends on two parameters, the MOB_{top} and the KC_{tot}. Both parameters are based on the combination of waves and currents; in this study, the current-based component is zero.

The MOB_{top} is defined as the ratio between θ and $θ_{cr}$. In this chapter, the focus will be on θ, which is the value obtainable from the wave data (see section 4.1). The calculation sequence is described in the HaSPro. The same holds for the KC-numbers (in this case KC_{tot} = KC_w).

In table 5.2 the values are listed for all tests with the wave condition R100. The domain of Shields values within the Sleath graphic can be seen in figure 5.1, for both

Test	H_{m0}	θ	KC
H-2L-R100	0.2672	0.0296	3.89
H-2½L-R100	0.2723	0.0313	4.04
H-3L-R100	0.2733	0.0323	4.13
H-1L-R100	0.2687	0.0283	3.77
H-1½L-R100	0.2687	0.0291	3.84
M-2L-R100	0.2695	0.0300	3.93

Table 5.2. Shields and KC-values for tests R100

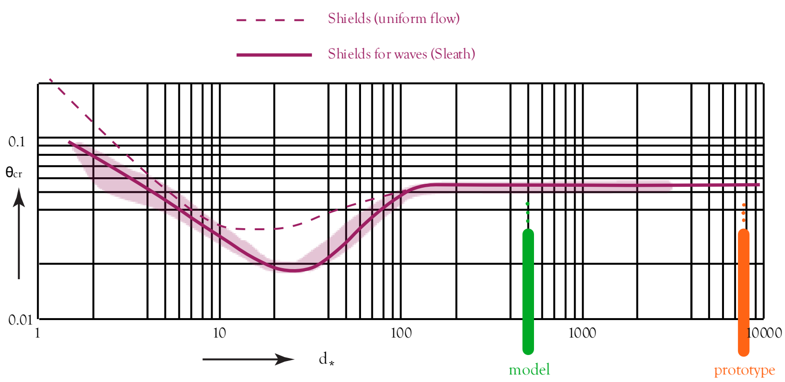


Fig. 5.1. Domain of tests in a modified-Shields graphic

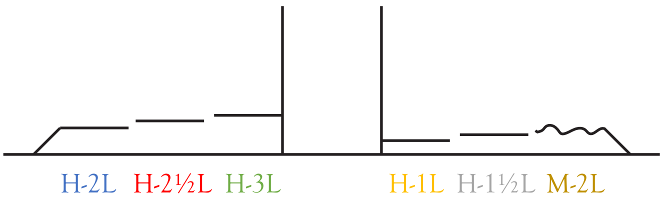


Fig. 5.2. Scheme of test series with layer thicknesses

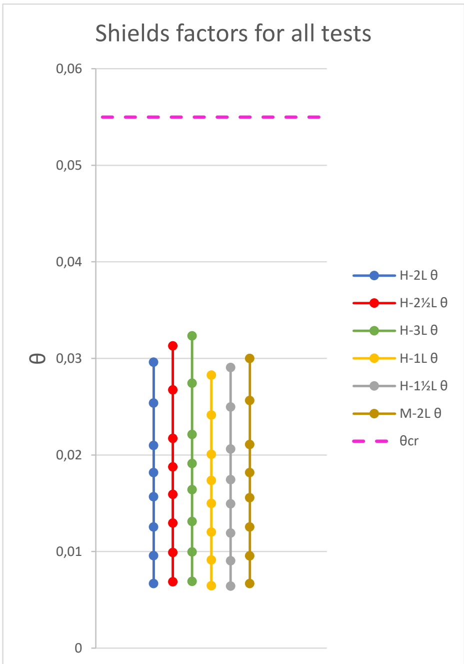


Fig. 5.3. Shields' values for every test series. (***N.B.***: the value of $θ_{cr}$ here corresponds to the value known for granular material, though technically unknown for Xstream)

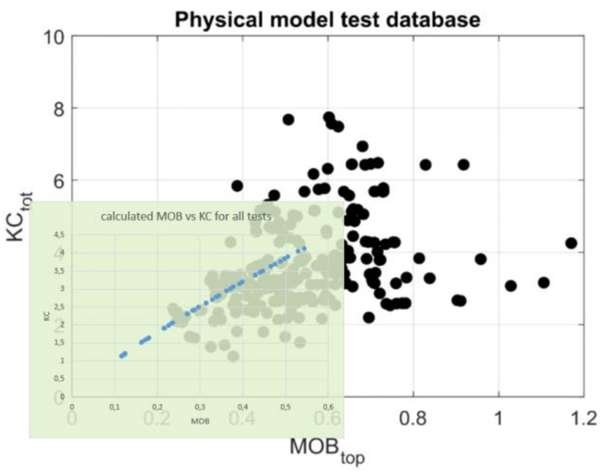
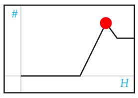


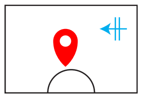
Fig. 5.4. Superposition of the ranges of the current tests and the tests used for the JIP-HaSPro (Broekema *et al.*, 2023)

model and prototype values (d_{*m} = 495, d_{*p} = 7780). The differences between the layer thicknesses tested means different values of h_{top}, which contribute to different values of the Shields parameter (figures 5.2 and 5.3). The superposition of a plot of the values of MOB vs. KC of the tests in this study on those of the tests Broekema *et al.* (2023) are shown in figure 5.4.

5.2 limit state analysis

5.2.1 *Processing of critical test results*





Considering the diversity and perceived scattering (and even randomness) of results yielded during the tests (see chapter 4), attempts to determine the decisive results are crucial in order to establish a relationship between the wave data and the behaviour observed in the scour protection. However, during the test program, with the used wave conditions stretching the capacities of the flume, no significant damage was recorded, i.e. the point of (total) failure was not reached.

One of those attempts is to consider the <u>maximum recorded concentration of movement</u>, both in time (a specific test with a peak in movement) and in space (a specific location where the movements recorded during that test were concentrated). In this case, the goal is not to provide a design formula, but to get as close as possible to the unknown point of failure for the sake of analysis. An important implication of this is that this point of maximum movement involves *one* test, and can't thus be taken as the general picture of damage.

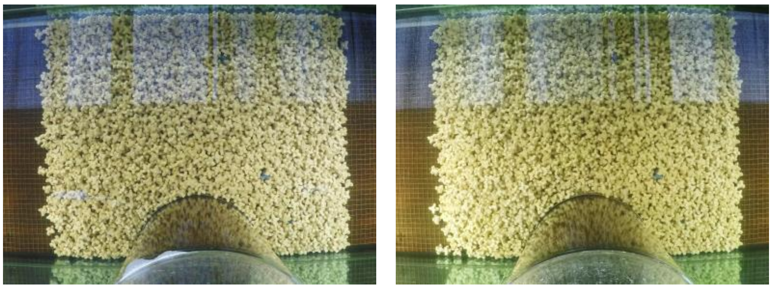


Fig. 5.5. Top pictures from before and after test H-2½L-R80

The test for which this was valid was test H-2½L-R80 (see fig. 5.5), which featured: *a.* a peak in internal displacements (see fig. 4.19), and a relative peak in external displacements (taking into account that the totals for this test series are minimal); and *b.* the block positions at the start of the internal displacements (mapped in fig. 4.23b) are concentrated around the half monopile. This means that there's a clear correspondence with the following general observations playing a critical role throughout the test program:

- the clearly visible areas of erosion and accretion during most of the tests, mentioned in section 4.2;
- the peaks in movement, seen in the result plots

Regarding the concentration of movement: on one side, this can be accounted for by the local velocity variations caused by the half monopile which constitutes a horizontal constriction, in which a velocity factor K_V should be taken into account; unfortunately, there are only approximations to the value of K_V and further research is needed with measurements of the local velocities. On the other hand, some caution is due when considering the measurements of this particular data peak, in view of the apparent deviation, which could as well indicate a weak spot in the construction, between the protection layer and the monopile.

After the analysis of both the erosion map and the top pictures taken before and after test H-2½L-R80, a critical area was defined for this specific case as an annular sector (see fig. 5.6). ***N.B.***: two things shouldn't be forgotten: *a.* this concentration was observed for this test only; and *b.* this area is an approximation, as well as the erosion map.

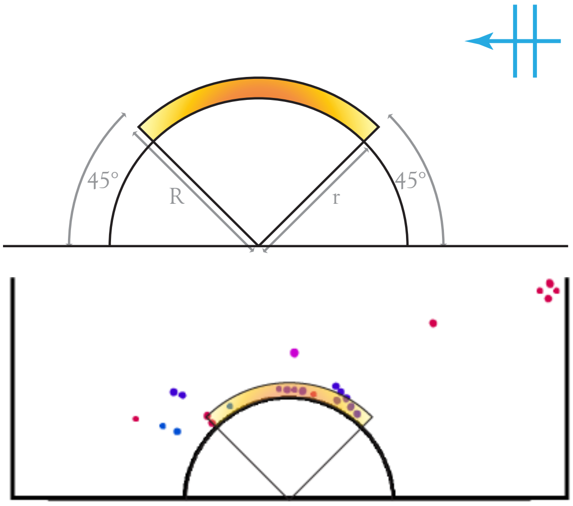


Fig. 5.6. Critical area defined for H-2½L-R80 (below: superimposed with the erosion map in figure 4.23b)

The area of this approximated strip around the half monopile equals 211,77 cm². In the construction process of the scour protection model, its area was defined as 3973 cm², and every layer thickness was linked to an amount of blocks (see section 3.4.2 and table 3.5). From here it can be found that, for this thickness (2½L, t=5.06cm), the packing density related to surface equals 0.63 blocks/cm², which means that there are 133,4 blocks located in the critical area. From here, taking the results from chapter 4, the peak movement for internal displacements for test H-2½L-R80 is 16 blocks in 5 minutes 13 of which are roughly located within the annular sector, which corresponds to 10% of the blocks within that area. Adding the other 3 blocks observed to move from the area (during test H-2½L-R100) this percentage adds up to 12%.

If these amounts are extended to the whole 40-minute test by extrapolating, a total of 128 blocks emerge. This is slightly less than the packing density found before, and would mean that, at the end of the test series, only 5 blocks would have remained. It should be noted that the extrapolation, though it is the right way to apply it in statistics, was clearly not a reflection of the end result after the test.

5.2.2 *Assessment of damage*

In general, the erosion trench formed during every test series, visible especially in the thicker layers. However, no measurement of the trench was made, neither by counting blocks nor measuring volumes or depths. The general observation was that the trench didn't reach the bottom of the layer, meaning that the wood underneath was not visible.

However, a close examination of the pictures at the end of the test series analysed above (H-2½L) shows a spot, adjacent to the half cylinder, where the bottom is visible through the joint of the blocks and the half cylinder. An estimation of the area in the photograph indicates that it is roughly the half of the main block dimension squared (see figure 5.7).


Fig. 5.7. Detail in top picture from after test H-2½L-R80

5.3 initiation of motion

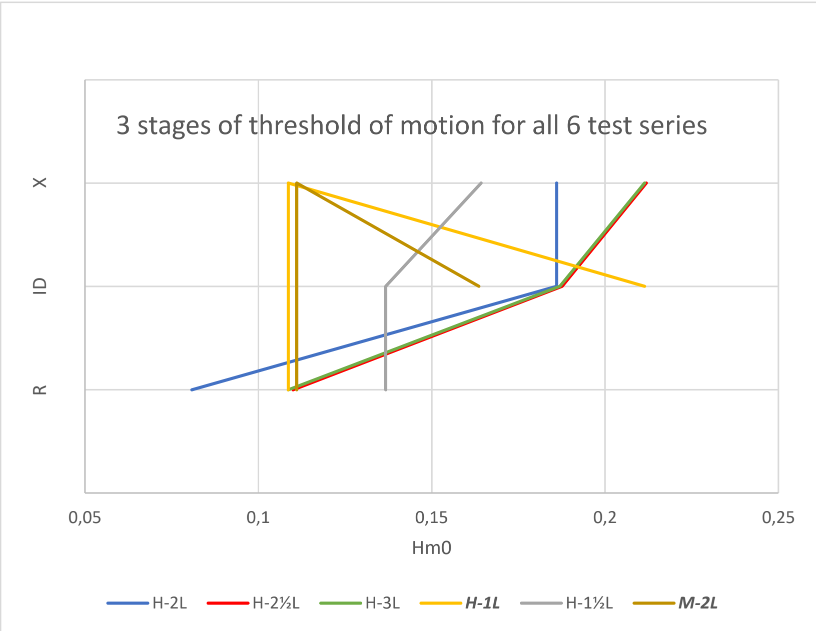
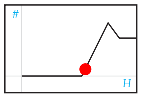


Fig. 5.8. Order in which stages of motion are started



In chapter 4, a distinction was made between 3 types of movement (rocking, internal displacements, and removal), defining a way to make each of them countable. A further key moment to perceive for every type of movement is the initiation of motion. A way in which the big picture of the beginning of movement can be determined in this study is the test in which the number of blocks counted within each of the three movement types is non-zero (sections 4.3.1, 4.3.2 and 4.3.3). This can be observed in figure 5.8 and verified with the visual observations recorded in the logbook. The two series indicated in italic (H-1L and M-2L) deviate from the trend followed by the remaining test series, i.e. the order in which stages are reached.

5.4 comparison between layer configurations

In the test program, the layer configurations featured two main variations: the layer thickness and the packing density (the latter was modified by means of the placing method). This section deals with the differences observed.

5.4.1 *Effect of the layer thickness*

The goal of having a variety of layer thicknesses was to compare their performances. This comparison was sometimes easy, sometimes more difficult, in view of

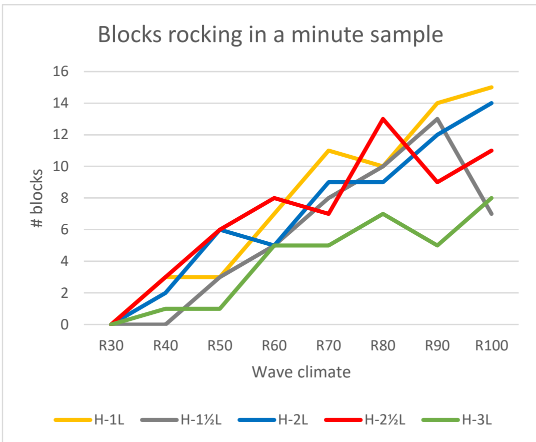
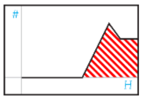


Fig. 5.9. Number of blocks rocking during a 1-minute sample

the seemingly random behaviour of the graphics (see figures 5.9, 5.10, and 5.11). As an alternative way to look at the data, a comparison was made between the cumulative values for all layer thicknesses (only with blocks installed in dry), put together in table 5.3 and figure 5.12. (***N.B.*** the only true totals are the values for the removed blocks; the sum of the remaining results, based on samples, are rather an indication.)



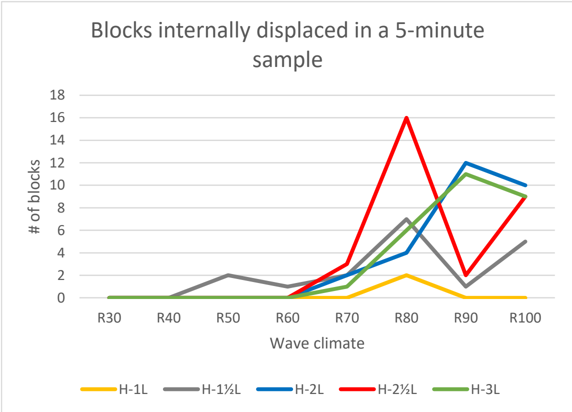


Fig. 5.10. Number of internally displaced blocks during the 5-minute sample

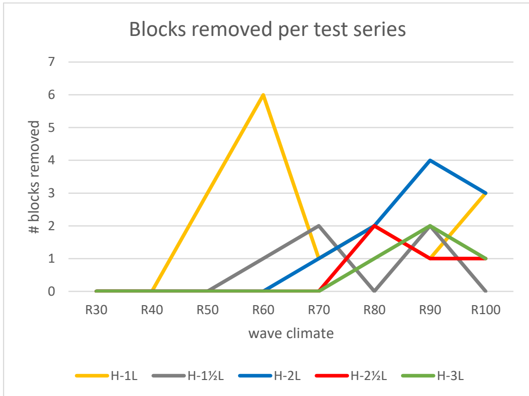


Fig. 5.11. Number of blocks removed from the construction, per test series

In the case of rocking, a visible difference appeared with the thickest layer, in which less rocking was observed compared to all other tests. For removed blocks, there was a difference in the amount of blocks between the thickness in H-1L and all other layer thicknesses.

In the case of the internal displacements, a different trend appeared: the thinner layers showed less displaced blocks (in absolute numbers), and the amount was augmented towards the thicker layers, in which it stabilised. The graphics show that, after the wave conditions reached a certain level (measured in H_{m0}), the internal displacements had sudden peaks (especially for the thickest layers).

Test series	Type of movement		
	R	*ID*	X
H-2L	*63*	*2*	16
H-2½L	*46*	*18*	5
H-3L	*57*	*28*	10
H-1L	*57*	*30*	4
H-1½L	*32*	*27*	4

Table 5.3. Total blocks moving per type of movement *(values of R and ID are an indication)*

A further examination on the initiation of motion in the previous section shows that there was no big difference between the moments in which the first movement was observed, particularly in the thickest layers. These layers also needed a larger increase in wave height to go from the first rocking through the first internally displaced block to the first removed block, compared to the thinnest layers. In the case of series H-1L the first block was removed before there was any internal displacement.

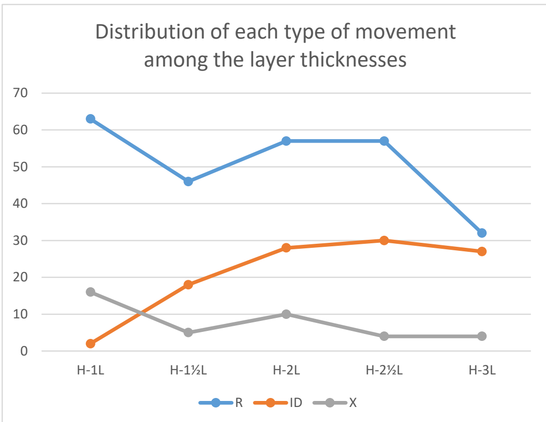


Fig. 5.12. Graphic depiction of table 5.3

A conclusion based on data is that there doesn't seem to be a significant difference between the layer thicknesses; however, an examination on the damage of the thinnest layer (particularly removed blocks) including a visual assessment shows that its integrity wasn't completely kept in the edges, potentially implying a reduction in the effective diameter of a prototype scour protection layer.

5.4.2 *Effect of the packing density by means of the installation method*

To visualize the effect of the packing density, the M-2L test series was introduced, in which the blocks were dropped from the water surface instead of the usual manual placing in dry, which was the case of all the H-series (see section 3.4.2). In this section a comparison of the appearances is shown (see figure 5.13) and the random pattern followed by the blocks while falling (see figure 5.14). For more specifications on the building of this configuration see Appendix C.

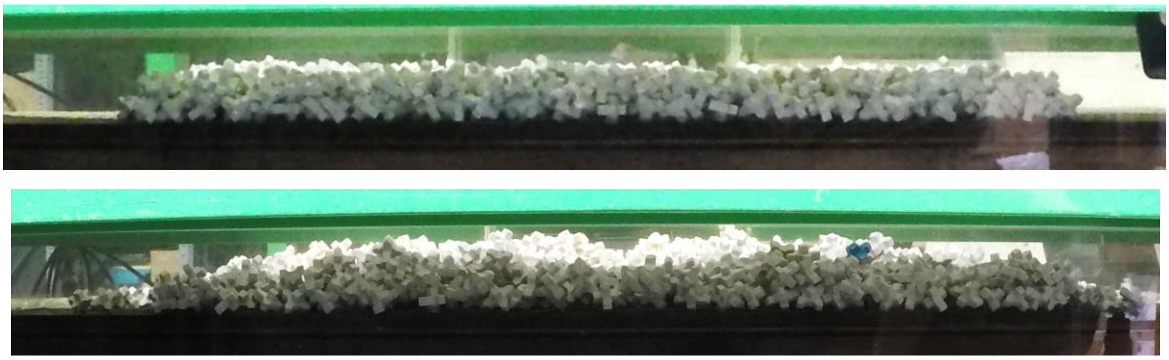


Fig. 5.13. Comparison of the layer surfaces with blocks manually placed (H-2L, above) and dropped from the water surface (M-2L, below)

Comparing test series M-2L with its counterpart, test H-2L (see figure 5.15), yields no big difference in rocking, while the internal displacements in H-2L relatively peak in the last wave conditions. The big difference comes with the removed blocks, for which the blocks in the M-series peak at the beginning, becoming stable later. This is explainable on the basis of the blocks lying loose after being dropped from the surface, and being the first ones to be removed.

A comparison of M-2L with test series H-1L yields a resemblance in the behaviour of the removed blocks (see figure 5.16). In this case, both test series feature a peak in the beginning, awakening the presumption that the blocks at the edge of the construction in series H-1L are essentially close to acting as loose blocks.

Comparing the internal displacements, the graphics show that the internal displacements in series M-2L didn't show any peak, compared to the remaining tests.

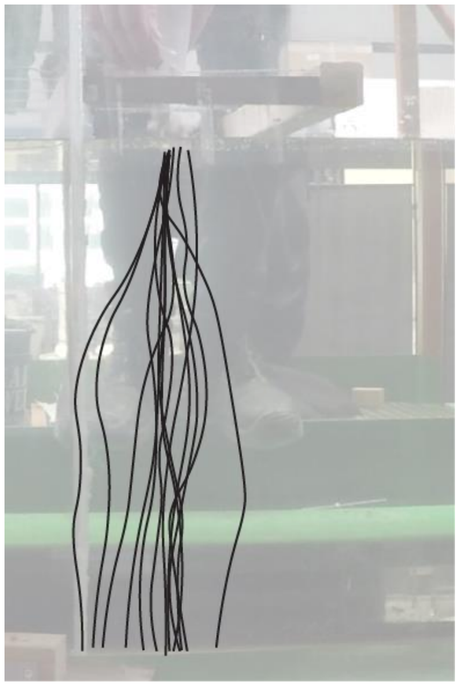


Fig. 5.14. Paths followed by one batch blocks dropped from the surface

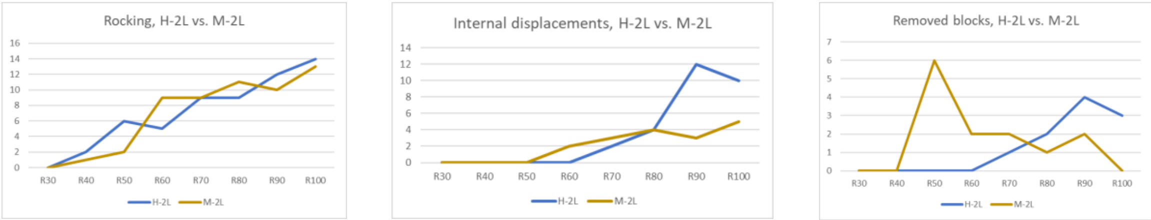


Figure 5.15. Comparison between test series H-2L and M-2L

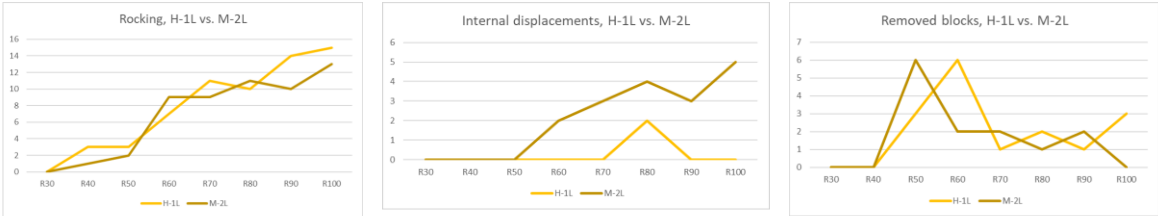


Figure 5.16. Comparison between test series H-1L and M-2L

The conclusion is that there is not a big difference in the installation method either, except maybe for the amount of blocks that get wasted in the process, falling outside of the construction.

6 discussion

In this chapter, some matters that arose during the research will be addressed. An attempt was made to sort these in relevant categories, and to keep the glance at the big picture balanced with the details.

6.1 on waves

Measurements boast the main role as a fact-based foundation. Nevertheless, visual observations can contain the soul of the experience in the physical modelling program, even if its subjectivity might be deemed out of place. In section 4.1, wave data provide an anchor for the subsequent mobility measurements and analysis; incidentally, a glimpse of what was perceived during the tests was mentioned.

6.1.1 *Visually observed wave features*

The following list features some of what was observed *in situ* during the tests:

- wave 'trains', a frequent phenomenon in which high waves came in a consecutive group, which enhanced the block movement
- from wave condition R70 on, waves became more violent as they grew in height, interacting with (among other elements) the half monopile, causing water to splatter out of the flume
- additionally, with this growth in height, waves started showing the typical Stokes second-order form, as mentioned at the end of section 4.1; in the last wave conditions some of them broke

These observations might be related to the evolution shown in figures 4.5 to 4.7 and 4.8 to 4.10, as well as the flattening behaviour of maximum waves seen in Figure 4.2. Also, these are possible indicators that, despite the use of a distorted scale (which was introduced mainly due to the unavailability of larger facilities), the wave conditions were demanding the maximum capacity of the flume.

6.1.2 *Alternative graphic rendering of wave data*

Another observation was related to the fact that the beginning of movement generally came with the higher waves of the running condition (more on that in section 6.4). Based on this, one might suggest the association of the start of movement with the higher portions of the wave spectrum, at least as an aid to create a more accurate mapping of the relationship between waves and their impact. In view of the availability of the wave data processed by WaveLab, featuring quantile wave heights, an alternative view of the progression of damage can be offered. Figure 6.1 shows a possibility of how this might look like. Hypothetically, a certain mobility might be measurable by locating it in the graph, in the progressive order as it happens, just as in this test program.

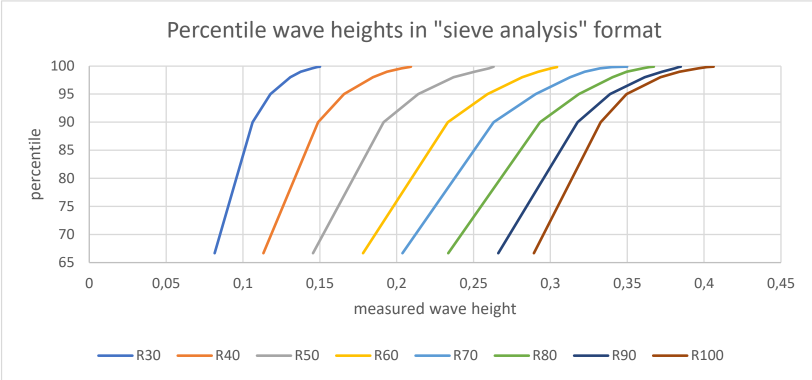


Fig. 6.1. Wave heights analysed by WaveLab for test series H-2L

6.2 on the stability approach

As mentioned in the previous section, the start of movement was observable with the higher waves. Additionally, a phenomenon already touched on was the clear formation of a trench next to the half monopile (i.e. an erosion zone), as well as a mound right behind it (i.e. deposition).

6.2.1 *Flow constriction due to the half monopile*

The tendency observed was that an area of intensification of movement with respect to the total of the scour protection surface was common next to the half monopile. A possible explanation is the flow constriction caused by the presence of the half monopile, which occupied ¼ of the cross section of the flume. As a result, changes in the velocity and the presence of acceleration and deceleration are expected, with the consequences that they would bring to the block mobility. It should be noted that these thoughts on velocity and acceleration are conceived mainly focused on current flow, but also applicable to the flow corresponding to orbital motions.

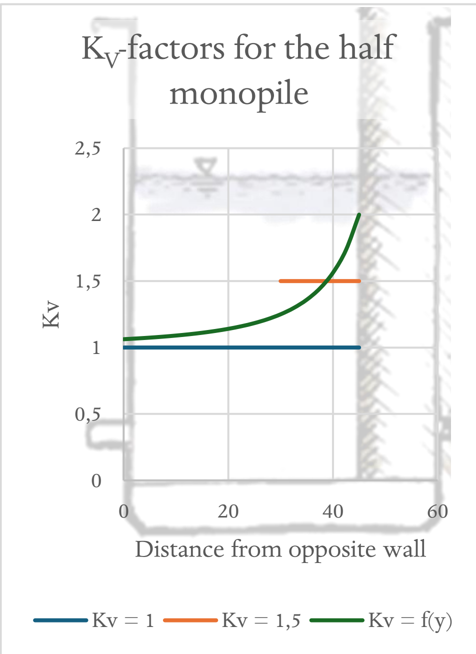


Fig. 6.2. Possible K_v-factors around the half monopile

<u>Velocity amplification</u>

When encountering a constriction, the flow lines become narrow due to continuity, which translates into a local higher velocity, and then into a higher shear stress, which would mean that, locally, the mobility is higher. There are different estimates of the velocity coefficient (K_V), as well as the solution for two-dimensional potential flow around a cylinder, already used in chapter 3 to determine the model pile diameter. While values of K_V vary, and a conservative value would be e.g. 1.5, a potential flow calculation for a distance of 1 block dimension away from the half monopile indicates that the velocity factor amounts to 1.77 at the narrowest point, decreasing with the distance from the pile. An approximate rendering based on this can be seen in figure 6.2.

<u>Acceleration and deceleration</u>

While section 2.2 already touched on acceleration (*du/dx*), in the case of the constriction due to the monopile both positive and negative accelerations happen, alternating depending on the wave phase (*du/dt*). An additional complexity is added with deceleration, corresponding to the increase of turbulence. A difficulty in estimating the acceleration using the potential flow approach is that it considers the flow to have no vorticity, which wouldn't yield a realistic view of the phenomena. As a visual observation related to this, flow separation lines were occasionally clear during the tests. A conceptual impression of the local accelerations can be seen in figure 6.3.

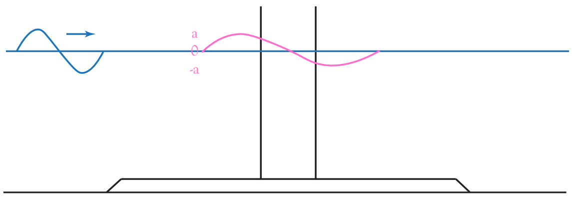


Fig. 6.3. Side view of a possible acceleration scheme around the monopile

<u>Local Shields parameter</u>

The thoughts above regarding velocity variations, as well as the observations during the tests (especially close to the monopile), appeals to the suggestion to use a local Shields parameter. Additionally, a parameter based on the maximum wave height (in view of the considerations in the previous section) might be useful, even though this might not seem imperative to cover knowledge gaps. It is important to realize that the Shields parameter that is used to quantify the flow in the present report (see figure 5.3) is based on certain definitions (use of H_{m0} as wave height, and amplification of monopile not taken into account) that can also be chosen differently. Different definitions will change the value. This is illustrated in figure 6.4.

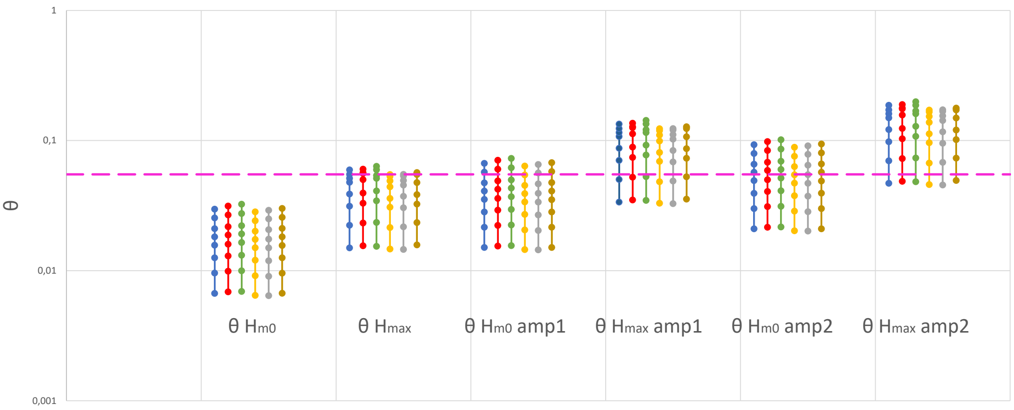


Fig. 6.4. Shields factors for orbital velocities corresponding to H_{m0} and H_{max}, for unamplified values and for two K_v factors (K_v=1.5 and K_v=1.74). The colours correspond to the different test series.

6.2.2 *On the stages of movement*

To quote Schiereck (2001): "The threshold of movement is a subjective matter when judged in an experiment". In section 2.2.4 this was addressed, including examples of aproaches, some of them more countable than others; some, like Breusers' stages, are based on currents and not on waves. Since there ave been different versions of the superposition of Breusers' stages on a Shields diagram, a potential addition might be to create a corresponding graph on the variation made by Sleath (see figure 6.5).

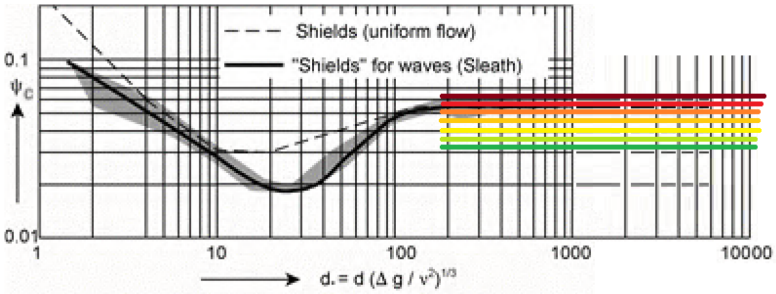


Fig. 6.5. A possible depiction of Breusers' stages for waves, superimposed on a modified-Shields graphic

In the present study, a rather simplified set of 3 types of movements, also thought of as stages. However, the order proved not to be as obvious to be labelled 'stages', and some considerations can be named.

First, if we consider the realm of prefabricated concrete blocks, which came to prominence with breakwaters, these stages would be easier to notice, for different reasons: *a.* the blocks are bigger, which would mean that there's a smaller amount of them, and that they are relying more on each other; *b.* the breakwater's armour layer is inclined, which means that, again, the blocks are supporting each other; and *c.* the packing density is higher, as mentioned in section 3.4.2., and that might also help them to be a more compact system. Additionally, it appears straightforward to say that there's one direction in which the armour elements would move, and that is downward, towards the toe. This way, the idea that rocking is followed by internal displacements and the latter by external displacements seems more sequential and any undefined limits between stages or altered order sounds almost unthinkable. In the case of a scour protection layer built using smaller blocks, its horizontality and a larger amount of them would mean that the main areas demanding attention (the edges and the vicinity of the monopile) are functioning more independently, i.e. that the scour protection works more like a parallel system, while a breakwater's armour layer would function more like a serial system.

Fig. 6.6. Appearance of the downwave edge of the layer corresponding to test series H-1L

Second, these two main areas of focus are related to two of the three main design aspects of a scour protection area, according to the HaSPro: the external stability and the flexibility. In this framework, both the internal and the external displacements play a role that can be, depending on the situation, more crucial than the other; during the tests the main role tended to point at the internal displacements for the area close to the pile, and the external displacements close to the edge. In the first case, there were more thicknesses showing a related dynamic; in the second case, it was practically reduced to the test series H-1L (and M-2L, if we count the blocks that were removed likely as a part of finding an equilibrium situation).

Third, the order in which the threshold of motion was reached differed from layer to layer, as shown in chapter 5. In view of the reflections above, this might mean a critical point that differed with the layer thickness: in the thinner layers there was more edge movement, while in the thicker layers there was more movement around the half monopile.

Four, it's good to be aware that the definitions of movement might have played a role in the moments in which the threshold of motion was reached, concretely for the removed blocks, which were defined as such after they were clearly detached from the structure. In some cases, mostly in thicker layers, the blocks were separated from the structure, but lingered for a while, presumably sheltered by the edge, which stood higher; this was clearly not happening for the thinnest layer, when blocks started getting away from the structure rather soon (see figure 6.6).

Five, it's equally good to take into account the possibility that the first four considerations could likely be altered if tests are done either: *a.* with bed material, or *b.* using a non-distorted scale. An example of (a) is the likelihood that the layer thickness used in series H-1L will behave differently regarding internal displacements, because the blocks might soon no longer stand on the same level.

6.2.3 *A unified system to evaluate damage*

The thoughts on the previous section are an appeal to consider adopting a system to evaluate stages of motion that is both consistent and unified. But this might be desirable for the way evaluate damage too. There are many methods to do it, varying between numbers of units, volumes, depths, percentages of volume or depth/thickness, and so on. Methods can also vary depending on the author, the school or institute, or (most comprehensibly) the type and size of the structure involved. However, missing links between them can be perceived. Consequently, the question arises whether a consistent system has already been conceived or suggested. The motivation for the genesis of the HaSPro was also "the observation that no good and generically applicable design formulae and guidelines exist to protect offshore structures against scour". In this sense, steps were taken in a direction consistent with this line of thinking.

6.2.4 *On the comparison between performances of layer thicknesses*

In chapter 5, different ways of looking at the results were introduced. Particularly the comparison between layer thicknesses was not necessarily straightforward, there was no clear pattern to pinpoint the difference. An example of this is the seeming dichotomy of the graphics in figures 5.8 and 5.12, put here next to each other in figures 6.7a and 6.7b.

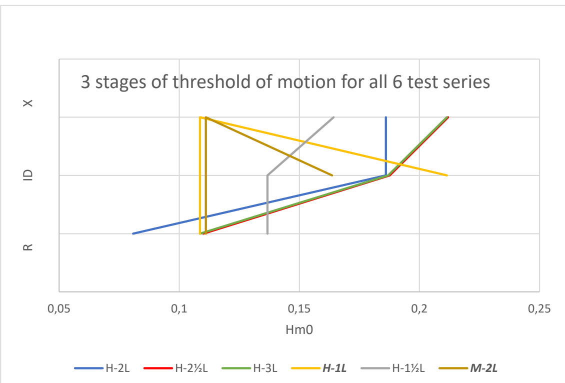


Figure 6.7a. Order in which stages of motion are started

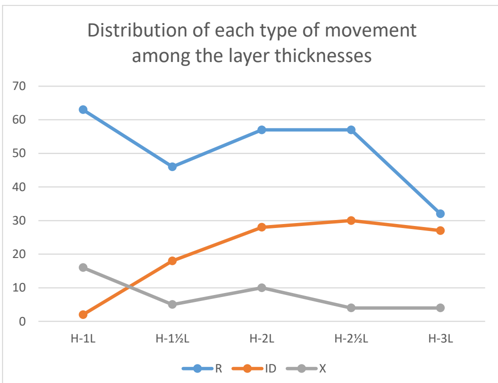


Figure 6.7b. Comparison between cumulative movement values for each layer thickness

Figure 6.7a describes the moments in which each threshold is reached for the first time every test series, i.e. the variation in time is taken into account; in the meanwhile, figure 6.7b shows the difference in the cumulative damage, which means that the variation in time is not pictured. On the other hand, figure 6.7a doesn't consider amounts of movement (as fig. 6.7b does), but only the start of it.

While this parallel might be helpful in the design process by showing different angles on the same thing (namely the comparison between the layer thicknesses), not all their features add to the clarity and can deserve a share of discussion.

Reliability of thicker layers

While major differences between the performances of layer thicknesses seem lacking, a pattern observed in graphic 6.7a might show a ray of clarity: when making the comparison, the thinner layers (and the M-2L series) show a more erratic behaviour, but from the thickness corresponding to test series H-2L the pattern stabilizes. As an elaboration of this, the sequence in reaching the different thresholds of motion was not only the same in order, but also in time for the thickest layers, i.e. the wave condition in which they happened tended to be the same as the layer thickness augmented: test series H-2½L and H-3L are identical, closely followed by series H-2L. This makes it possible to divide the test series into three more 'unstable' (corresponding to the thinnest layers, including series M-2L) and three 'stable' (linked to the thickest layers). A particular effect of this is that, when the beginning of rocking is reached, the next threshold can be expected to happen a more defined (and larger) number of wave conditions further on for the thicker layers than for the thinner ones, which were less predictable and furthermore 'jumped' to the next stage of motion relatively sooner. Based on this, the 'stable' thicknesses can be deemed more reliable in their performance.

Increase of total internal displacements with the thickness

On the other hand, looking at the total (cumulative) internal displacements in figure 6.7b, a seemingly inverse trend was observed: there were more internal displacements in the thicker layers than in the thinner. As the cherry on top, a remarkable feature is that the curve is smooth, contrary to most of the plots corresponding to the three ways of movement distinguished in chapter 4. In an effort to explain this, the low amount in internal displacements for the thinnest layer might be due to the fact that all blocks were placed in the same height, and consequently, very little drag and shear forces were experienced by the blocks as none of them were protruding (except on the edges, where more damage was observed). For the remaining layers, two possibilities can be contemplated: one, layer 1½L was experienced as more difficult to distribute during the construction, and blocks were observed to preferentially reach the bottom than to stay at mid-height within the layer, by which the bottom side of the layer may well had a higher packing density than the top, affecting the performance in a positive way; and two, an indefinite plausibility arises that the internal displacements increase with the layer thickness because the water has more blocks to satisfy the transport capacity, purely looking at the graph.

6.2.5 *Validity of JIP-HaSPro for Xstream*

Staying in the subject of the JIP-HaSPro, which was welcomed and adopted in the course of this research, even so, debate is due as to whether or not it was the best method to use for prefabricated concrete blocks. Some of the reasons for this allusion are:

- The main method described in the HaSPro is based on the use of loose rock.

- A considerable part of the method is based on tests on rock, which are subsequently examined to tailor the formulae presented.

Fig. 6.7. Difference in smoothness between the layers corresponding to tests H-1L (above) and M-2L (below)

Some examples can be given of parameters taken into account in the HaSPro that might vary for prefabricated elements like Xstream:

- θ_{cr} (the critical Shields value): a general value that is value for rocks was taken (i.e. θ_{cr}=0.055), but further validation might be needed for blocks like Xstream.
- k_s (equivalent roughness height): this can be very different for Xstream, as it can be affected by the dimension of the protuberances of the block, smaller than the dimension of the block itself. In figure 6.7 a comparison is made between the apparent smoothness of two configurations of layers.
- d (block diameter): first, there's no gradation of the block, which might be of importance in the related Shields calculations; and second, the main dimension of the block has a different ratio to its weight, which is a part of definitions like e.g. the nominal diameter of a stone. This can be seen in figure 6.8.

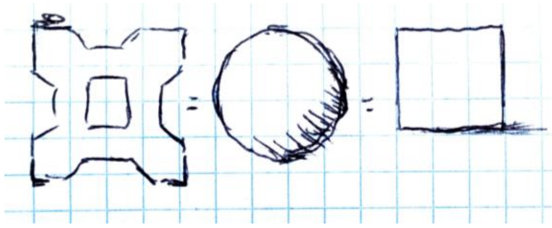


Fig. 6.8. A comparison between Xstream, a sphere and a cube with the same volume and hence weight

Especially the last point will be addressed in next section, together with interlocking, which was part of the motivation for the realisation of this study.

6.3 on the xstream element and interlocking

As briefly addressed in the last section, some observations can be given about working with Xstream, even though, for a great deal, more research is necessary. One of the most prominent is interlocking, which was directly taken into account in the design process, as well as a great share of the prefabricated concrete blocks used in armour layers.

6.3.1 *A possible approach to interlocking*

Figure 6.9 shows a variation on the single grain approach, in which two grains (in this case, blocks) are connected by interlocking. This depends on the angle of the forces, i.e. on the direction of the flow. In a brief inspection it can be suggested that the forces and moments are expected to increase with the introduction of interlocking.

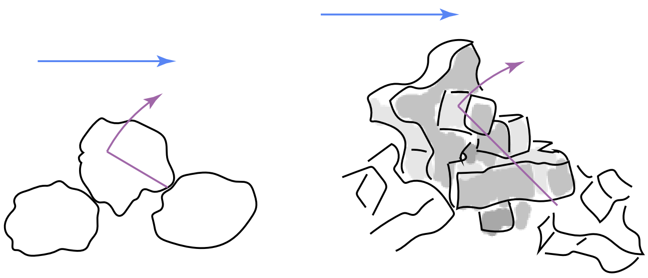


Fig. 6.9. A hypothetical depiction of interlocking in a 'double grain' system, showing an increase in moments

6.3.2 *Observations during the tests*

Two main effects that might be connected to interlocking were observed: the fraying of the thinnest layer, and cluster movements.

Fraying of the layer corresponding to test series H-1L

In test series H-1L it was observed that blocks started to be removed from the structure at an early stage, and that, as opposed to the remaining test series, all of them came from the posterior edge (downwave), adopting the appearance of the layer being frayed away (see figure 6.6, earlier in this chapter).

A possible explanation is that, while the packing density was chosen such that no extra force was necessary to locate the blocks on the same level (see section 3.4.2), this was not enough to keep a single layer together. As an example, test series H-1½L performed much better, which indicates that there's already a significant difference with an increase of 50% in the amount of blocks. This creates room to speculate that interlocking works much better in three dimensions than in two: the extra dimension in interlocking is brought with a thickness of more than one block dimension, active also in the z-direction. See figure 6.10 for a depiction.

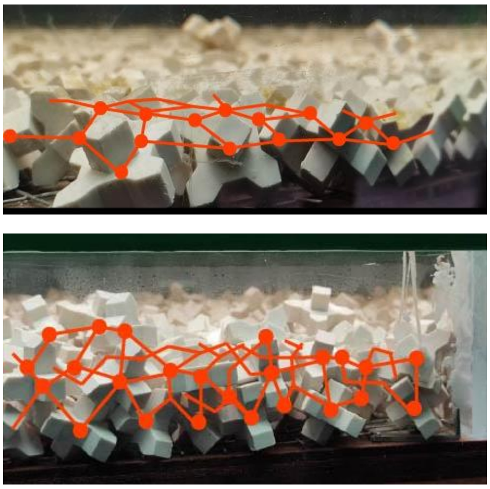


Fig. 6.10. Difference between the 'truss' patterns connection points: H-1L (2D, above) and H-2L (3D, below)

Cluster movements

One of the modes of movement that was very present consisted in groups of blocks that moved together, in 'lumps' or 'clusters'. This was observed in both internal displacements and the beginning of external displacements (when more blocks were detached from the structure). A first speculation about that can lead to the thought that such movement of granular material occurs only if it is cohesive and thus not for sand or bigger, and that this might be the effect of interlocking at work.

An example of the observations of this can be seen in the sequence below. (Needless to say, the movement is much less clear in pictures than in the video, but some important differences are noticeable)

Figure 6.11a. Before the cluster movement

Figure 6.11b. Cluster movement starts, a crack is visible

Figure 6.11c. Blocks start a cluster displacement, leaving a hole behind

A possible elaboration on the cluster movements can be their association with some of the (sudden) peaks in the internal displacements. As mentioned in chapter 5, there was a seeming randomness in the results; however, this randomness did not affect the rocking, but only the internal and external displacements (A related question would then be whether a repetition of the tests would yield the same results). From the results it's also likely that this happens when the packing density is higher, and that its dynamic behaviour resembles that of an earthquake, in which pressure is built up to be then released in a sudden event.

A general conclusion in view of all the considerations above is that interlocking can be believed to contribute to stability, plausibly increasing the critical value of Shields for Xstream (θ_{cr}).

6.4 model effects

6.4.1 *General*

One of what can be counted as a model effects is the location of the trench and the mound. A reference for comparison is the patterns found by van Steijn *et al.* (2023), one of which is chosen based on the absence of currents. The system in the present study is located a bit differently (see figure 6.12), and lacks the most downwave erosion area. This is, presumably, due to the absence of the lee-wake vortices, which are cut by the wall whose plane divides the monopile in half.

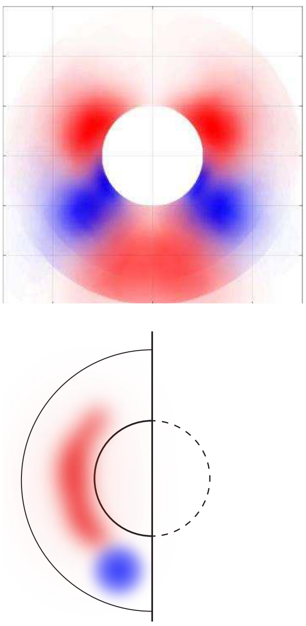


Fig. 6.12. Difference between the deformation patterns corresponding to v.Steijn *et al.* (2023) (above) and this study (below, more generic and based more on observations than on data)

Other example of a model effect happened at the beginning of test series H-3L. When, after arraying the blocks in dry, the flume was filled with water, there was a chance that there were bubbles underneath the bottom elevation structure, which were released between the cracks and crevices with the first waves. Some of the blocks in H-3L were touched by one of those bubble trains at the beginning of test R-30, showing some movement but only a block was several tests later removed from the construction. See figure 6.13.

Fig. 6.13. Bubbles at the beginning of test series H-3L

6.4.2 *Distorted scale effects*

The use of distorted scales was one of the significant features in this research, and might have been the consideration that, though necessary, affected the test process the most; for this reason, an evaluation of distorted scale effects is most pertinent. Was there more or less damage established by using a distorted scale, compared to the regular, non-distorted scale?

Effects associated to the first (main) scale distortion

The first scale distortion featured the scaling of orbital velocities, which were then transformed into corresponding waves that would fit in the flume. Some repercussions of doing so included:

- an increase in the relationship $H_{s,md}/h$ by aprox. 30% (compared to $H_{s,m}/h$), which also increases the probability of breaking waves;
- a difference in Ursell numbers by a factor close to 4, introducing second (and higher) order Stokes waves.

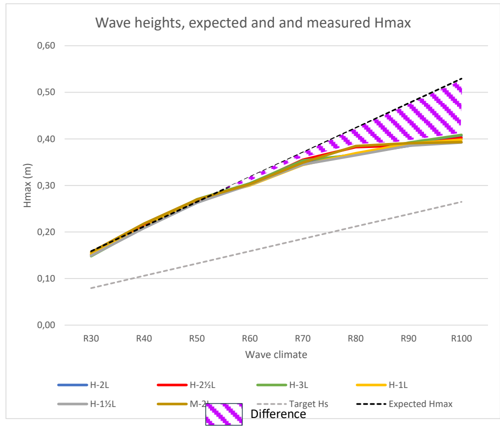


Fig. 6.14. Difference between expected and measured values of H_{max}

Additionally, some local wave reflection (resonating on certain periods) on the half monopile was discerned in additional posterior tests, that clarified the observations of odd wave patterns around the monopile. By this observation, the wave heights are expected to have been affected in some measure, increasing at moments and places, and becoming even steeper.

These attributes, both theoretical and observed, can be related to some observations mentioned in section 6.1.1, and the subsequent discussion. Most relevant is the flattening of H_{max}, visible in figures 4.2 and 4.10. In figure 6.14 a modification is shown, which shows that, by the comparison between the expected H_{max} (a factor of about $2 \cdot H_{s,md}$, according to Holthuijsen, 2007) and the measured values, the difference is clear, a full area corresponding to the 'lost' wave heights. Since (as mentioned in section 6.1.2) the threshold of motion was observed to be reached with the biggest waves, this difference can be translated as a deficit, because a considerable share of non-reached maxima would have had the potential to cause more damage than the observed during the last wave conditions in the test series.

The possible causes for this flattening can be:

- the breaking of waves (a direct consequence of the main scale distortion)
- the arrival to the capacity limit of the flume (causing water to spill out by the highest waves)

Based on all of this we can rather safely suspect the first (main) scale distortion to have contributed to non-conservative results.

Effects associated to the second scale distortion

The second scale distortion consisted in reducing the model pile diameter, so that it fitted in the flume without interfering significantly with the velocities, taking into account the opposite flume wall (thus limiting yet another model effect). The main consequence of this distortion was translated into obtaining a higher KC number than the intended prototype, which leads to larger bed shear stress amplifications and, hence, to potentially more damage. This is a basis to assume that the second scale distortion contributed to conservative results.

This conclusion points in the opposite direction than the former, somehow balancing each other, and limiting the non-conservative component. However, a non-distorted scale can be especially desirable if accuracy is needed.

7 conclusions and recommendations

7.1 conclusions

During the physical model test program, a variety of scour protection layer thicknesses built using scaled Xstream elements were tested on a range of 8 wave conditions that varied the value of $H_{s,md}$ between 0.08 and 0.26m, while a model $T_{p,m}$ value of 3.2s was kept. Attention was paid to three types of movement: rocking, internal displacements, and removal. These movements were quantified by visual counting techniques. The conclusions from this research can be grouped in different categories.

7.1.1 *General*

The most important parameters in this study are θ_{top} (Shields parameter at the top of the scour protection) and KC (Keulegan-Carpenter number). Both parameters were related to waves only.

$$\theta_{top} = \frac{\tau_{top}}{(\rho_s - \rho_w) \cdot g \cdot d} \qquad KC = \frac{u_m \cdot T_p}{D_{pile}}$$

where d is the main block dimension. The wave conditions used for the tests featured Shields values up to a maximum of $\theta_{top,max} = 0.032$, and Keulegan-Carpenter values up to a maximum of $KC = 4.13$. Two main damage locations were observed, within the construction area and in the edges.

The most remarkable deformation pattern within the construction area was the formation of an erosion trench next to the half monopile (see figure 7.1, in green), as well as a mound roughly behind it (at the downwave side).

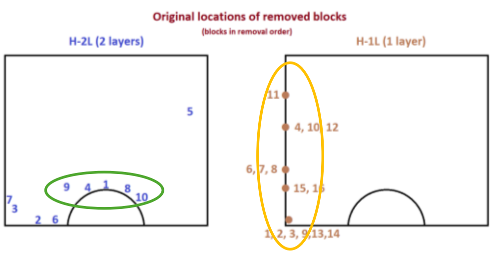


Fig. 7.1. Original locations of all blocks removed in test series H-2L and H-1L. The numbers indicate the order of removal.

Regarding the damage within the construction area, for the range underneath the values given above, the damage in the protection layer didn't reach the point in which the surface underneath was uncovered for most of the layer thicknesses (the exception being the thinnest layer tested, corresponding to test series H-1L). Among the remaining thickness configurations, test H-2½L-R80 featured a damage area corresponding to half the block size, together with the most extreme internal displacements recorded (16 blocks), which additionally represented the highest local internal displacement concentration (10% of the blocks in that area).

Regarding the damage in the edges, the only remarkable damage was once again on the thinnest layer, the downwave edge of which lost a considerable amount of blocks. The amount of units removed in this layer was only roughly matched by the setup corresponding to test series M-2L, for which the blocks were dropped from the water surface, some of them falling outside of the construction area.

These two areas of vulnerability are illustrated in figure 7.1, which shows the original location of all the removed blocks during the test series H-1L (mostly edge movement) and H-2L (mostly internal).

The important conclusion on damage is that total failure was not achieved with the largest wave conditions achievable in the flume. All test configurations proved to be stable enough for the generated wave conditions.

7.1.2 *Effect of the layer thickness*

Besides the relatively poor performance of the layer corresponding to test series H-1L, there wasn't a major difference between the performance of the layers with different thicknesses. The test series featured peaks in activity, mainly of internal displacements, that seemed random and didn't offer a clear basis for comparison between layers (see figures below).

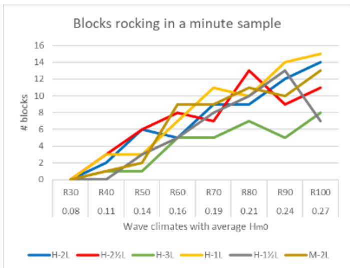


Figure 7.2. Blocks rocking in a minute sample

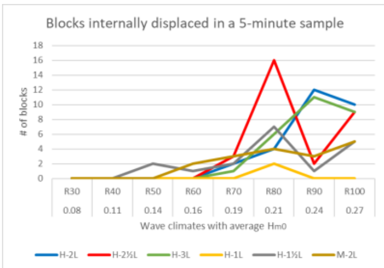


Figure 7.3. Blocks internally displaced in a 5-minute sample

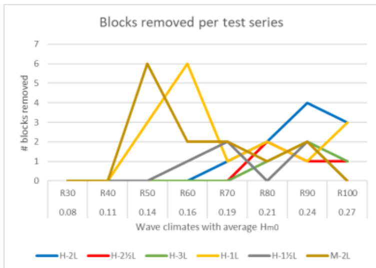


Figure 7.4. Blocks removed from the structure during a whole test

A feature that does shed a clearer light on the comparison between layers is the moment of start of movement, when a layer goes from zero to non-zero movement within the three types of movement. Additionally, considering the three types of movement as stages of motion, the order and the pattern they follow in reaching the threshold of motions is a clear indication to prefer thicker layers. See figure 7.5 (here plotted in terms of θ_{top}).

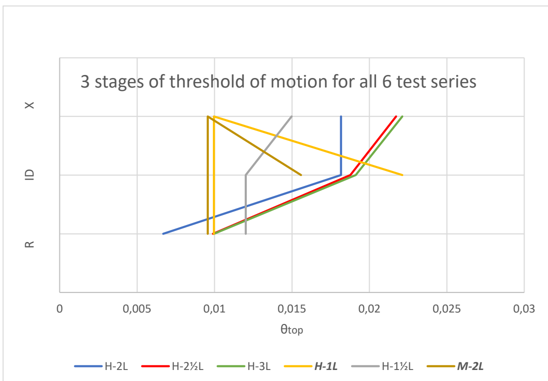


Fig. 7.5. Arrival order at every stage of motion

7.1.3 *Effect of the packing density by means of the installation method*

There was not a big difference in performance between the protection layer where the blocks were dropped from the surface (M-2L series) and the layer with corresponding thickness where the blocks were manually placed in dry (H-2L series). The only difference is the peak in removal of blocks, accounted for by the units that fell outside of the construction area when dropped from the surface area. This peak was otherwise only observed in test series H-1L. Also, a general observation is that, when the blocks were dropped from the water surface, besides featuring an uneven surface, the first block movements were considered an attempt of the configuration to reach an equilibrium situation. In this matter, the smooth scour protection can be deemed more preferable, if feasible.

7.1.4 *On areas more prone to show mobility*

The trench in the proximity of the half monopile, mentioned in section 7.1.1, corresponds to the location that showed the most prominent movement pattern, whose intensity clearly surpassed that of the rest of the construction. While exact measurements would be needed to confirm this with exact numbers, a presupposition can be held that it is attributable to the velocity increase due to the flow contraction next to the half monopile, influencing the orbital motions associated with the waves and hence causing higher shear stresses.

7.1.5 *Design values*

According to the findings in the process of this research, and the definitions of failure corresponding to an underlayer exposure equal to an area 4 times the size of a block (its main dimension squared), the construction of a scour protection layer for values of $\theta_{top} \leq 0.032$ and $KC_w \leq 4.13$ is stable for layers equal or thicker than 1½ times the main dimension of the block, which corresponds to the prototype value of 15.3 Xstream blocks per square meter of construction. However, a layer equal or thicker than 2 times the main dimension of the block is advisable (20.4 Xstream blocks per square meter), as that is the reliable area based on the conclusions on the beginning and stages of movement; additionally, this value accounts for the construction methods dealt with in this research.

However, it is important to note that, due to the exploratory nature of this test program (and the need for validation tests), the lack of results connected to the failure of the structure, and the absence of tests with sediment to investigate the interface stability, it’s not recommended to design scour protections based on the present results.

7.1.6 *On the definition of a protection layer using Xstream elements*

Regarding the process of creating a concept of a scour protection layer using Xstream as the main element, a first approach was achieved regarding the armour layer. While a circular form is functional for the layout of a scour protection around a monopile, the tests were performed on rectangular constructions to enable a more simple analysis. Additionally, the layer thicknesses were defined based on the packing density. Two differences with the traditional scour protections made with loose rock is that the Xstream-based protection has a higher porosity, and can feature cluster movements due to interlocking; the features were otherwise similar, and the parameters used for the traditional ones could be applicable, with as most important θ_{top} and KC_{tot}. Further research is necessary to determine the value of θ_{cr} for Xstream.

7.2 recommendations

Within the framework of scour protection systems and stability under waves, much research has been done and attempts have been made to unify the contributions to the field. In this aspect, there is much room for extra connections and many knowledge gaps to bridge. This study is intended as a step in that direction; however, it brings the insight as well that there are many steps to follow. Some of them will be in the same direction, some of them will take a broader view into account. A share of the recommendations connected to potential following steps are listed next.

Tests with sediment
The tests realised in the present research shed light about the stability; nevertheless, a big factor of interest is connected to the interaction of the bed protection with the bed material.

Tests on a non-distorted scale
Despite the insights received using distorted scales, the question arises if there are blind spots regarding the limitations or differences brought by their use; these blind spots might be perceived by means of physical model tests with a regular, non-distorted scale.

Repetitive tests
In view of the notion that randomness in the tests might have played a role, it would be very interesting to undertake repetitive tests, to assess this possibility.

Tests on interlocking
While tests on Xstream allowed for a glimpse of the effect of interlocking, much more clarity is needed to have a proper idea of its effect, especially in contexts with more mobility.

Tests with both waves and currents
While it was a possibility to carry them out and there were different ways, more or less scientifically justifiable, tests with both waves and currents didn't happen in this study, but would be very relevant for a complete picture.

Validation of JIP-HaSPro for prefabricated concrete blocks
It would be interesting, although certainly extensive, to work on validating the parameters and formulae in the JIP-HaSPro for their use with prefabricated concrete blocks.

Standard for the stages of movement
The development of a more objective standard to define the stages of movement for both currents and waves, however potentially difficult due to the subjectivity of the concept of threshold of motion, could yield extra clarity and uniformity in the related research and applicability.

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A

appendix: wave table

The full tables referred to in chapter 4 read:

Wave climate	Target value	Measured values											
		H-2L		H-2½L		H-3L		H-1L		H-1½L		M-2L	
	$H_{s,md}$ (m)	H_{m0} (m)	H_{max} (m)	H_{m0} (m)	H_{max} (m)	H_{m0} (m)	H_{max} (m)	H_{m0} (m)	H_{max} (m)	H_{m0} (m)	H_{max} (m)	H_{m0} (m)	H_{max} (m)
R30	0.08	0.08	0.15	0.08	0.15	0.08	0.15	0.08	0.15	0.08	0.15	0.08	0.16
R40	0.11	0.11	0.21	0.11	0.21	0.11	0.21	0.11	0.21	0.11	0.21	0.11	0.22
R50	0.13	0.14	0.26	0.14	0.27	0.14	0.27	0.14	0.27	0.13	0.26	0.14	0.27
R60	0.16	0.16	0.30	0.16	0.30	0.16	0.30	0.16	0.30	0.16	0.30	0.16	0.30
R70	0.19	0.19	0.35	0.19	0.36	0.19	0.35	0.19	0.34	0.18	0.35	0.19	0.35
R80	0.21	0.21	0.37	0.21	0.38	0.21	0.37	0.21	0.37	0.21	0.36	0.21	0.38
R90	0.24	0.24	0.38	0.24	0.39	0.24	0.39	0.24	0.39	0.24	0.39	0.24	0.39
R100	0.26	0.27	0.41	0.27	0.40	0.27	0.41	0.27	0.40	0.27	0.39	0.27	0.39

Table A.1. Target and measured values of the wave height

Wave climate	Target value	Measured values											
		H-2L		H-2½L		H-3L		H-1L		H-1½L		M-2L	
	$T_{p.m}$ (s)	T_p (s)	T_m (s)	T_p (s)	T_m (s)	T_p (s)	T_m (s)	T_p (s)	T_m (s)	T_p (s)	T_m (s)	T_p (s)	T_m (s)
R30	3.23	3.20	2.59	3.20	2.61	3.20	2.60	3.20	2.60	3.20	2.61	3.20	2.61
R40	3.23	3.20	2.59	3.20	2.59	3.20	2.58	3.20	2.58	3.20	2.60	3.20	2.59
R50	3.23	3.20	2.56	3.20	2.55	3.20	2.56	3.20	2.57	3.20	2.57	3.20	2.55
R60	3.23	3.20	2.51	3.20	2.51	3.20	2.51	3.20	2.51	3.20	2.51	3.20	2.51
R70	3.23	3.20	2.47	3.20	2.48	3.20	2.47	3.20	2.48	3.20	2.49	3.20	2.48
R80	3.23	3.20	2.46	3.20	2.43	3.20	2.44	3.20	2.44	3.20	2.44	3.20	2.43
R90	3.23	3.20	2.35	3.20	2.35	3.20	2.37	3.20	2.36	3.20	2.36	3.20	2.31
R100	3.23	3.20	2.33	3.20	2.32	3.20	2.33	3.20	2.33	3.20	2.32	3.20	2.24

Table A.2. Target and measured values of the wave period

Wave climate	Target value	Measured values					
		H-2L	H-2½L	H-3L	H-1L	H-1½L	M-2L
	Number of waves						
R30	~1000	923	925	924	919	921	918
R40	~1000	929	928	931	924	1025	927
R50	~1000	934	936	937	932	939	940
R60	~1000	967	955	956	955	958	958
R70	~1000	967	971	970	964	968	966
R80	~1000	982	977	992	982	988	989
R90	~1000	1015	1021	1012	1016	1022	1037
R100	~1000	1032	1031	1030	1034	1035	1069

Table A.3. Target and actual numbers of waves

B appendix: building of h-series

The distribution of blocks for all H-series, that is, the ones in which the blocks were placed in dry (with an empty flume) was calculated as follows:

1) Determination of scour protection area using the layer thickness data

After obtaining the layer thickness data (see section 3.4.2 and table 3.4), the scour protection area was found such that all 3000 available blocks were distributed with the amount of blocks determined for the thickest layer:

# layers	blocks/(10 · d)² /layer	blocks/(10 · d)²	blocks/m²
1	111.05	111.05	2518.14
1,5		166.575	3777.21
2		222.1	5036.28
2,5		277.625	6295.35
3		333.15	7554.42

Table B.1. Blocks per layer thickness (I)

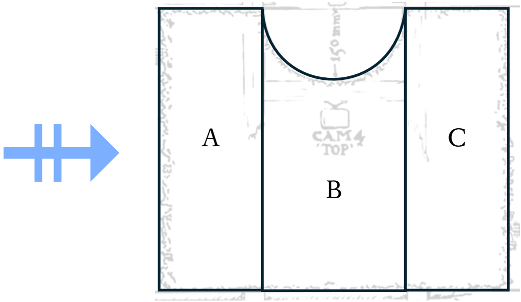
This comes down to:

$$A = \frac{total\ blocks}{blocks\ per\ square\ meter, thickest\ layer} = \frac{3000}{7554.42} = 0.3971\ m^2$$

2) Division of the scour protection area in 3 sections

The area of the scour protection is to be distributed around the monopile with it in the center of the length dimension, which is found calculating the construction area if the half monopile area is subtracted, and dividing it by the width of the flume, 59.5 cm. The resulting area can be seen as three natural sections: the front section, the middle section (corresponding exactly to the diameter of the half monopile), and the rear section. See following page for a depiction of the sections. Their areas are:

A: 1249.5 cm²
B: 1472.2 cm²
C: 1249.5 cm²



3) Distribution of blocks in the sections

The blocks are then distributed in each section using the values calculated above, and obtaining the values seen as follows:

# layers	# blocks section A	# blocks section B	# blocks section C
1	315	371	315
1,5	472	556	472
2	629	742	629
2,5	787	927	787
3	944	1112	944

Table B.2. Blocks per layer thickness (II)

4) Determination of the weight of blocks allocated

The way of measuring the blocks in each section is done by taking the weight, which is faster than counting. Using the known block density (see table 3.1), table B.3 is the same as table B.2, but with weights:

# layers	wt. blocks section A	wt. blocks section B	wt. blocks section C
1	2.27 kg	2.67 kg	2.27 kg
1,5	3.40 kg	4.00 kg	3.40 kg
2	4.53 kg	5.34 kg	4.53 kg
2,5	5.66 kg	6.67 kg	5.66 kg
3	6.80 kg	8.01 kg	6.80 kg

Table B.3. Weight of total blocks per layer thickness

<u>Design values corresponding to the packing density used</u>

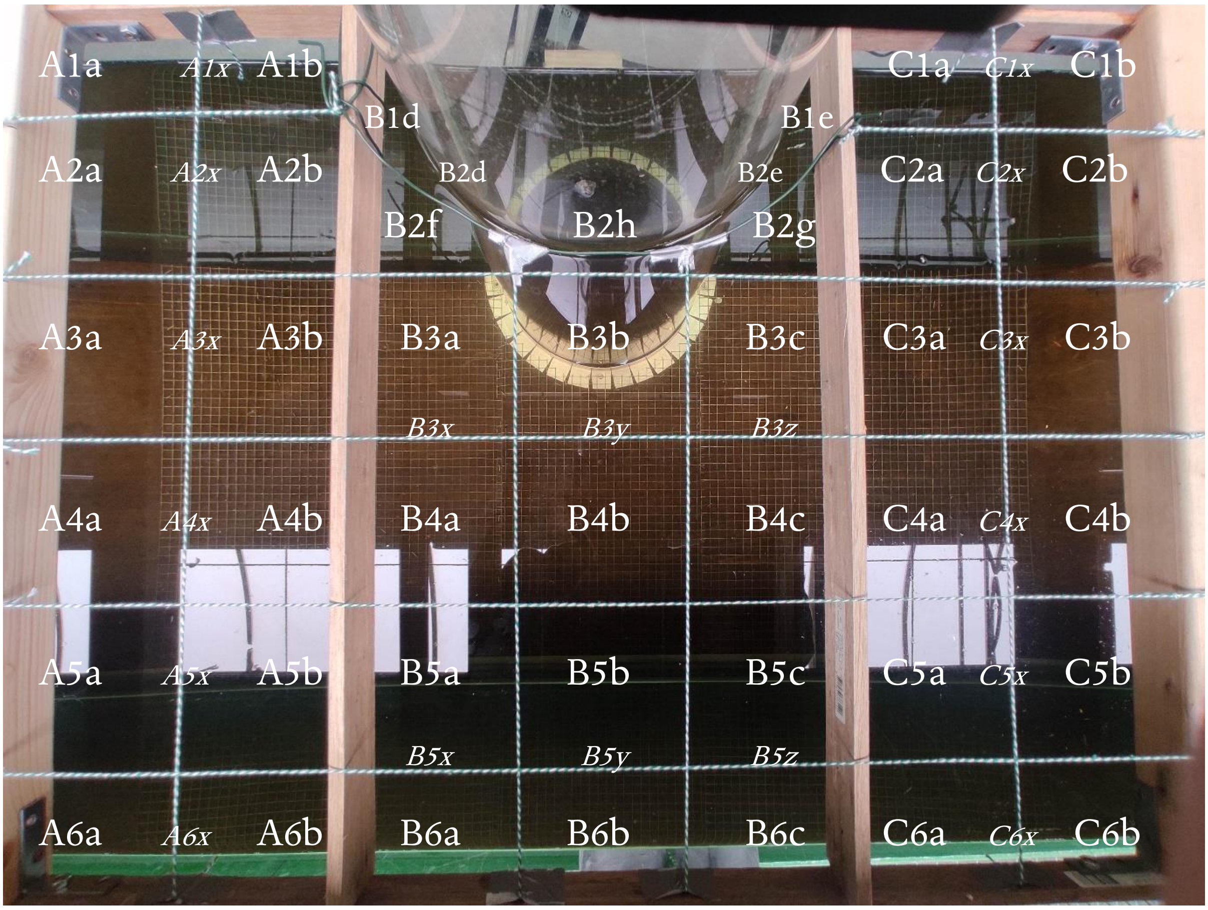
The corresponding prototype values of the amount of blocks used per layer thickness are:

# layers	blocks per m², model	area scale factor	blocks per m², prototype
1	2518.14	$(15.71)^2 = 246.94$	10,2
1,5	3777.21		15,3
2	5036.28		20,4
2,5	6295.35		25,5
3	7554.42		30,6

Table B.2. Blocks per layer thickness (II)

appendix: building of m-series

The distribution of blocks in the raster made for M-series can be seen as:



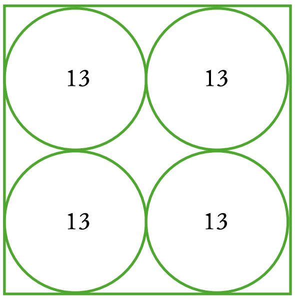
The distribution of blocks in the M-series was a mirroring of the distribution for series H-2L. What here corresponds to the capital letters A, B and C had a total of:

A: 630 units
B: 742 units
C: 630 units

The areas of every square cell (areas ending in -a, -b, and -c) in the raster is equal (error is deemed insignificant). The B-section has extra blocks, to be distributed in the trapezoidal areas (B2f and B2g). The totals correspond to an amount of blocks per square cell of 52.5. The half block is solved by introducing the places ending in -x, -y and -z, where the block corresponding to the remainder half blocks in two adjacent cells is dropped. The distribution looks like this:

- All areas ending in -a, -b, and -c: 52 blocks
- All locations ending in -d and -e: 11 blocks
- Location ending in -h: 10 blocks
- All areas ending in -f and -g: 28 blocks
- All locations ending in -x, -y and -z: 1 block

Next, the square cell areas are divided in 4 equal areas, in each of which 13 blocks are dropped:



appendix: wave report

D

Reflection Analysis

Input Parameters

Generel

Data file:	*D:\...\batch 2\Output\H-1L-R30.txt*		
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*		
Water depth:	*0.6 m*		
Length scale (Prototype/Model):	*1*		
Skipped lines	*Header: 6*	*Start: 0*	*End: 0*

Bandpass filtering (Only for period calc.)

Freq. lower bound:	*0.104 Hz*
Freq. upper bound:	*0.938 Hz*

Freq. Domain Analysis

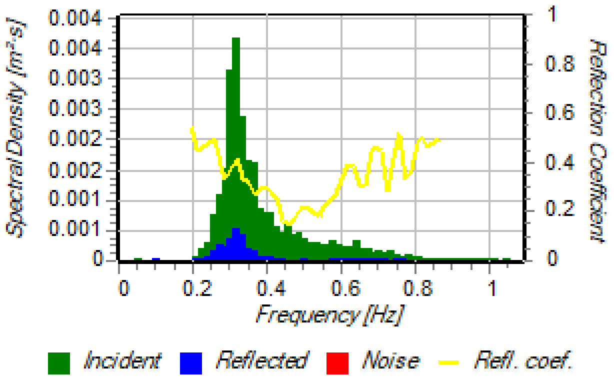
Overlap of subseries:	*20%*
Cosine taper width:	*20%*
Data No. in FFT block:	*4096*
Number of FFT blocks:	*46*

Time Domain Analysis

Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*61*
Hilbert filter length:	*2048*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	*2*	*3*	*4*
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

Frequency Domain Analysis

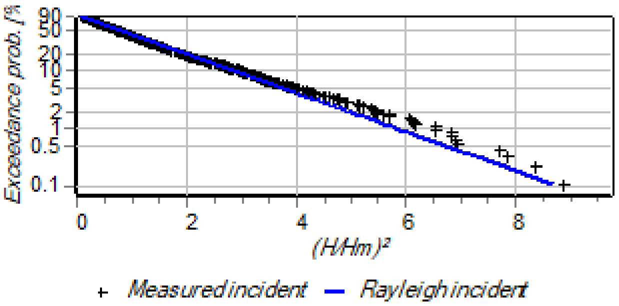


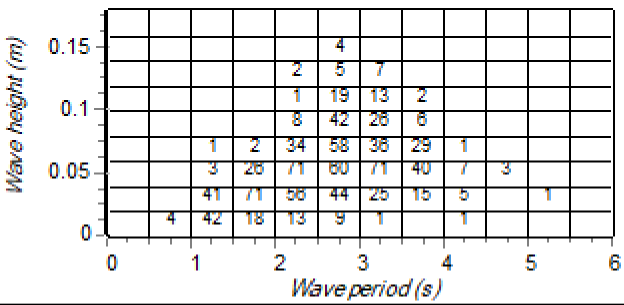
Overall amplitude reflection coefficient: *36.2%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.08143*	*0.02947*
Peak wave period T_P (s):	*3.2*	*3.2*
Energy wave period $T_{-1,0}$ (s):	*2.835*	*3.05*
Mean wave period $T_{0,1}$ (s):	*2.597*	*2.734*
Mean wave period $T_{0,2}$ (s):	*2.459*	*2.542*
Spectral width (Broadness):	*0.6165*	*0.688*
Spectral width (Narrowness):	*0.3404*	*0.3958*

Time Domain Analysis

Overall amplitude reflection coefficient: *35.9%*





	Incident	**Reflected**
Number of waves:	923	863
Mean wave height H_m (m):	*0.05138*	*0.02032*
Mean wave period T_m(s):	*2.598*	*2.777*
Sig. wave height H_s (m):	*0.08239*	*0.03033*
$T_{H_{1/3}}$ (s):	*2.934*	*3.136*
H_{max} (m):	*0.153*	*0.05104*
T_{Hmax} (s):	*2.918*	*3.194*
$H_{1/10}$ (m):	*0.1073*	*0.03637*
$H_{1/50}$ (m):	*0.1322*	*0.04272*
$H_{1/100}$ (m)	*0.1396*	*0.04516*
$H_{1/250}$ (m):	*0.1475*	*0.04769*
$H_{0.1\%}$ (m):	*Not enough data*	*Not enough data*
$H_{1\%}$ (m):	*0.1315*	*0.04238*
$H_{2\%}$ (m):	*0.1201*	*0.03868*
$H_{10\%}$ (m)	*0.0894*	*0.03213*
Groupiness factor GF:	*1.149*	*0.9735*
Skewness b1:	*0.4936*	*0.2304*
Kurtosis b2:	*3.69*	*2.946*

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Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*1 of 48*

Reflection Analysis

Input Parameters

Generel		**Freq. Domain Analysis**	
Data file:	*D:\...\batch 2\Output\H-1L-R40.txt*	*Overlap of subseries:*	*20%*
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*	*Cosine taper width:*	*20%*
Water depth:	*0.6 m*	*Data No. in FFT block:*	*4096*
Length scale (Prototype/Model):	*1*	*Number of FFT blocks:*	*46*
Skipped lines	*Header: 6 Start: 0 End: 0*		

Bandpass filtering (Only for period calc.)

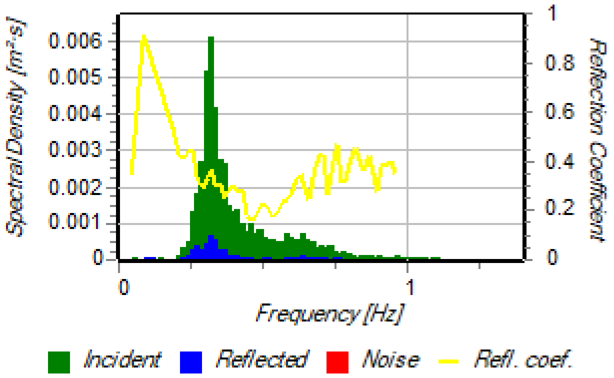
Freq. lower bound:	*0.104 Hz*
Freq. upper bound:	*0.938 Hz*

Time Domain Analysis

Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*61*
Hilbert filter length:	*2048*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	*2*	*3*	*4*
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

Frequency Domain Analysis

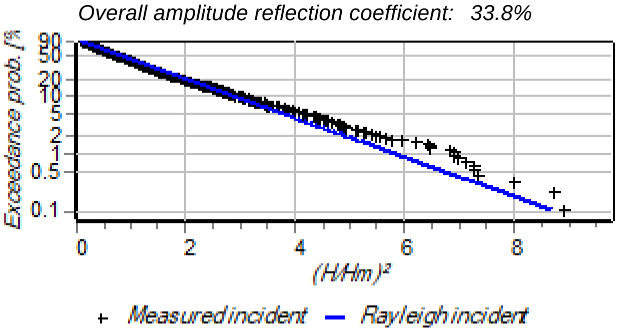


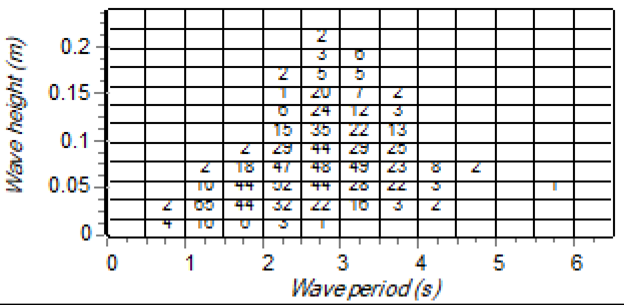
Overall amplitude reflection coefficient: *33.7%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.1088*	*0.03664*
Peak wave period T_P (s):	*3.2*	*3.2*
Energy wave period $T_{-1,0}$ (s):	*2.781*	*3.013*
Mean wave period $T_{0,1}$ (s):	*2.515*	*2.63*
Mean wave period $T_{0,2}$ (s):	*2.367*	*2.426*
Spectral width (Broadness):	*0.6264*	*0.6882*
Spectral width (Narrowness):	*0.3593*	*0.4188*

Time Domain Analysis

Overall amplitude reflection coefficient: *33.8%*





	Incident	**Reflected**
Number of waves:	929	889
Mean wave height H_m (m):	*0.07038*	*0.02677*
Mean wave period T_m (s):	*2.582*	*2.696*
Sig. wave height H_s (m):	*0.1133*	*0.03841*
$T_{H_{1/3}}$ (s):	*2.939*	*3.027*
H_{max} (m):	*0.2101*	*0.06547*
T_{Hmax} (s):	*2.855*	*2.786*
$H_{1/10}$ (m):	*0.1487*	*0.04601*
$H_{1/50}$ (m):	*0.1846*	*0.05452*
$H_{1/100}$ (m)	*0.1938*	*0.05828*
$H_{1/250}$ (m):	*0.2029*	*0.06171*
$H_{0.1\%}$ (m):	*Not enough data*	*Not enough data*
$H_{1\%}$ (m):	*0.1849*	*0.05382*
$H_{2\%}$ (m):	*0.1665*	*0.04884*
$H_{10\%}$ (m)	*0.1228*	*0.04035*
Groupiness factor GF:	*1.231*	*0.9837*
Skewness b1:	*0.6637*	*0.2207*
Kurtosis b2:	*4.028*	*2.977*

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Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*2 of 48*

Reflection Analysis

Input Parameters

Generel

Data file:	*D:\...\batch 2\Output\H-1L-R50.txt*
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*
Water depth:	*0.6 m*
Length scale (Prototype/Model):	*1*
Skipped lines	*Header: 6 Start: 0 End: 0*

Bandpass filtering (Only for period calc.)

Freq. lower bound:	*0.104 Hz*
Freq. upper bound:	*0.938 Hz*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	*2*	*3*	*4*
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

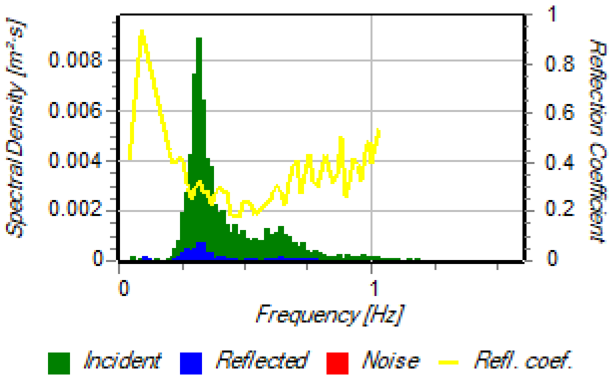
Freq. Domain Analysis

Overlap of subseries:	*20%*
Cosine taper width:	*20%*
Data No. in FFT block:	*4096*
Number of FFT blocks:	*46*

Time Domain Analysis

Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*61*
Hilbert filter length:	*2048*

Frequency Domain Analysis

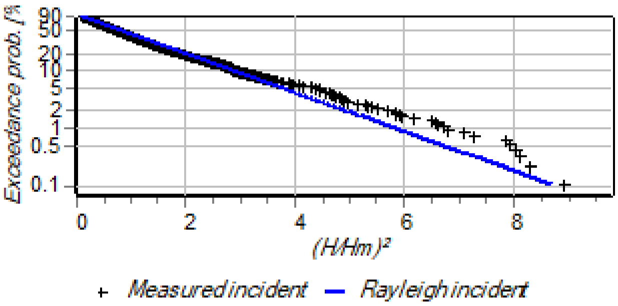


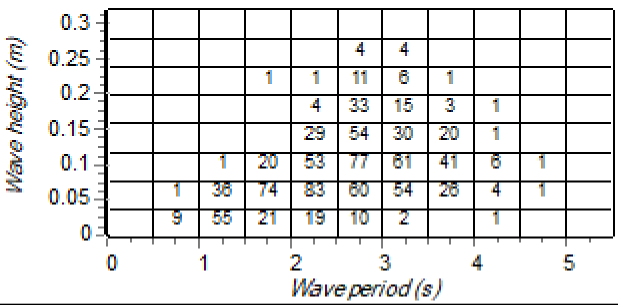
Overall amplitude reflection coefficient: *32.2%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.1367*	*0.04404*
Peak wave period T_P (s):	*3.2*	*3.2*
Energy wave period $T_{-1,0}$ (s):	*2.729*	*3*
Mean wave period $T_{0,1}$ (s):	*2.439*	*2.545*
Mean wave period $T_{0,2}$ (s):	*2.285*	*2.332*
Spectral width (Broadness):	*0.631*	*0.686*
Spectral width (Narrowness):	*0.3735*	*0.4376*

Time Domain Analysis

Overall amplitude reflection coefficient: *32.4%*





	Incident	**Reflected**
Number of waves:	934	943
Mean wave height H_m (m):	*0.09031*	*0.03301*
Mean wave period T_m (s):	*2.569*	*2.542*
Sig. wave height H_s (m):	*0.1458*	*0.04695*
$T_{H_{1/3}}$ (s):	*2.937*	*2.833*
H_{max} (m):	*0.2698*	*0.08343*
T_{Hmax} (s):	*2.883*	*2.973*
$H_{1/10}$ (m):	*0.1919*	*0.05665*
$H_{1/50}$ (m):	*0.2381*	*0.06785*
$H_{1/100}$ (m)	*0.2517*	*0.07107*
$H_{1/250}$ (m):	*0.2612*	*0.07509*
$H_{0.1\%}$ (m):	*Not enough data*	*Not enough data*
$H_{1\%}$ (m):	*0.2352*	*0.06731*
$H_{2\%}$ (m):	*0.2165*	*0.06247*
$H_{10\%}$ (m)	*0.1558*	*0.04919*
Groupiness factor GF:	*1.29*	*1.026*
Skewness b1:	*0.7929*	*0.2043*
Kurtosis b2:	*4.331*	*3.126*

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Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*3 of 48*

Reflection Analysis

Input Parameters

Generel

Data file:	*D:\...\batch 2\Output\H-1L-R60.txt*
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*
Water depth:	*0.6 m*
Length scale (Prototype/Model):	*1*
Skipped lines	*Header: 6 Start: 0 End: 0*

Bandpass filtering (Only for period calc.)

Freq. lower bound:	*0.104 Hz*
Freq. upper bound:	*0.938 Hz*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	*2*	*3*	*4*
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

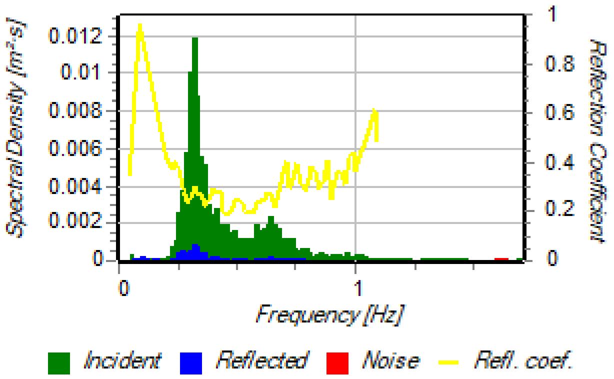
Freq. Domain Analysis

Overlap of subseries:	*20%*
Cosine taper width:	*20%*
Data No. in FFT block:	*4096*
Number of FFT blocks:	*47*

Time Domain Analysis

Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*61*
Hilbert filter length:	*2048*

Frequency Domain Analysis

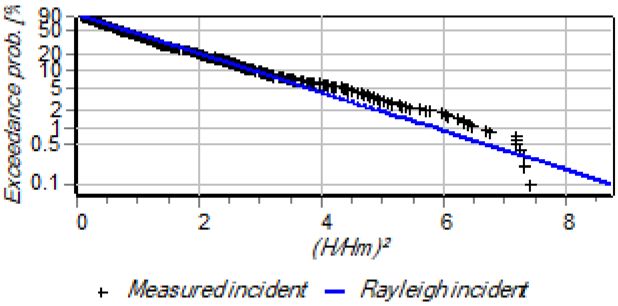


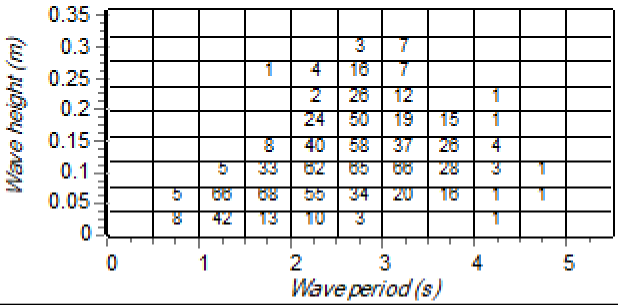
Overall amplitude reflection coefficient: *31.9%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.1643*	*0.05241*
Peak wave period T_P (s):	*3.2*	*3.2*
Energy wave period $T_{-1,0}$ (s):	*2.677*	*2.995*
Mean wave period $T_{0,1}$ (s):	*2.366*	*2.469*
Mean wave period $T_{0,2}$ (s):	*2.21*	*2.25*
Spectral width (Broadness):	*0.6306*	*0.6808*
Spectral width (Narrowness):	*0.3836*	*0.452*

Time Domain Analysis

Overall amplitude reflection coefficient: *32%*





	Incident	**Reflected**
Number of waves:	967	997
Mean wave height H_m (m):	*0.1102*	*0.04073*
Mean wave period T_m (s):	*2.513*	*2.436*
Sig. wave height H_s (m):	*0.1779*	*0.05741*
$T_{H_{1/3}}$ (s):	*2.895*	*2.658*
H_{max} (m):	*0.2999*	*0.08745*
T_{Hmax} (s):	*2.987*	*2.849*
$H_{1/10}$ (m):	*0.2328*	*0.06923*
$H_{1/50}$ (m):	*0.2831*	*0.08*
$H_{1/100}$ (m)	*0.2933*	*0.08273*
$H_{1/250}$ (m):	*0.2981*	*0.08538*
$H_{0.1\%}$ (m):	*Not enough data*	*Not enough data*
$H_{1\%}$ (m):	*0.2816*	*0.08018*
$H_{2\%}$ (m):	*0.2643*	*0.07474*
$H_{10\%}$ (m)	*0.1908*	*0.06065*
Groupiness factor GF:	*1.298*	*1.068*
Skewness b1:	*0.8492*	*0.1894*
Kurtosis b2:	*4.388*	*3.29*

Delta Marine Consultants

Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*4 of 48*

Reflection Analysis

Input Parameters

Generel

Data file:	*D:\...\batch 2\Output\H-1L-R70.txt*
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*
Water depth:	*0.6 m*
Length scale (Prototype/Model):	*1*
Skipped lines	*Header: 6 Start: 0 End: 0*

Bandpass filtering (Only for period calc.)

Freq. lower bound:	*0.104 Hz*
Freq. upper bound:	*0.938 Hz*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	*2*	*3*	*4*
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

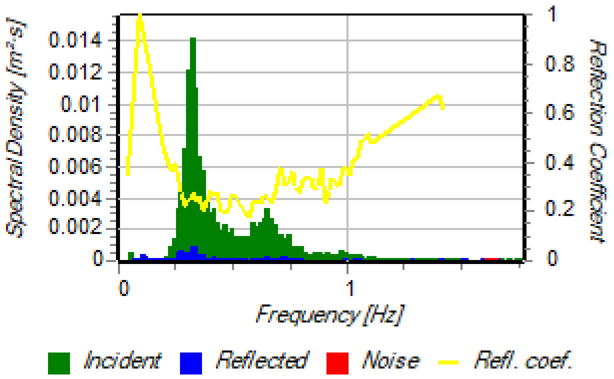
Freq. Domain Analysis

Overlap of subseries:	*20%*
Cosine taper width:	*20%*
Data No. in FFT block:	*4096*
Number of FFT blocks:	*46*

Time Domain Analysis

Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*61*
Hilbert filter length:	*2048*

Frequency Domain Analysis

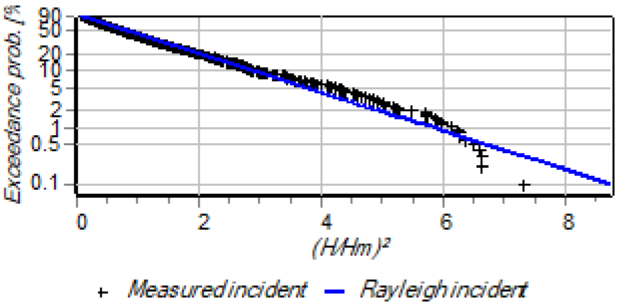


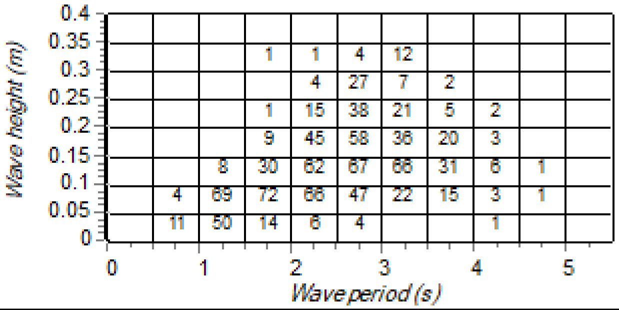
Overall amplitude reflection coefficient: *31.9%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.1859*	*0.0592*
Peak wave period T_P (s):	*3.2*	*3.2*
Energy wave period $T_{-1,0}$ (s):	*2.645*	*3.013*
Mean wave period $T_{0,1}$ (s):	*2.32*	*2.423*
Mean wave period $T_{0,2}$ (s):	*2.162*	*2.198*
Spectral width (Broadness):	*0.6293*	*0.678*
Spectral width (Narrowness):	*0.3891*	*0.4642*

Time Domain Analysis

Overall amplitude reflection coefficient: *32.1%*





	Incident	**Reflected**
Number of waves:	967	1015
Mean wave height H_m (m):	*0.1271*	*0.04679*
Mean wave period T_m (s):	*2.48*	*2.363*
Sig. wave height H_s (m):	*0.2049*	*0.06626*
$T_{H_{1/3}}$ (s):	*2.858*	*2.635*
H_{max} (m):	*0.344*	*0.1137*
T_{Hmax} (s):	*3.08*	*3.162*
$H_{1/10}$ (m):	*0.2649*	*0.0818*
$H_{1/50}$ (m):	*0.3147*	*0.1004*
$H_{1/100}$ (m)	*0.324*	*0.1062*
$H_{1/250}$ (m):	*0.3313*	*0.1119*
$H_{0.1\%}$ (m):	*Not enough data*	*0.1137*
$H_{1\%}$ (m):	*0.3152*	*0.09749*
$H_{2\%}$ (m):	*0.2956*	*0.09196*
$H_{10\%}$ (m)	*0.2189*	*0.06917*
Groupiness factor GF:	*1.279*	*1.126*
Skewness b1:	*0.8644*	*0.1999*
Kurtosis b2:	*4.333*	*3.482*

Delta Marine Consultants

Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*5 of 48*

Reflection Analysis

Input Parameters

Generel

Data file:	*D:\...\batch 2\Output\H-1L-R80.txt*
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*
Water depth:	*0.6 m*
Length scale (Prototype/Model):	*1*
Skipped lines	*Header: 6 Start: 0 End: 0*

Bandpass filtering (Only for period calc.)

Freq. lower bound:	*0.104 Hz*
Freq. upper bound:	*0.938 Hz*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	*2*	*3*	*4*
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

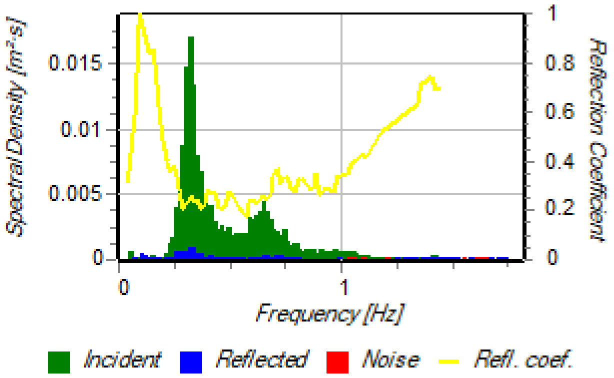
Freq. Domain Analysis

Overlap of subseries:	*20%*
Cosine taper width:	*20%*
Data No. in FFT block:	*4096*
Number of FFT blocks:	*46*

Time Domain Analysis

Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*61*
Hilbert filter length:	*2048*

Frequency Domain Analysis

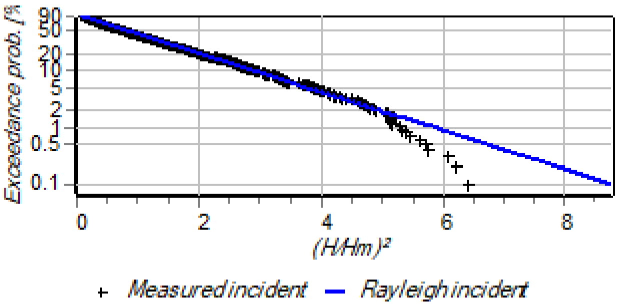


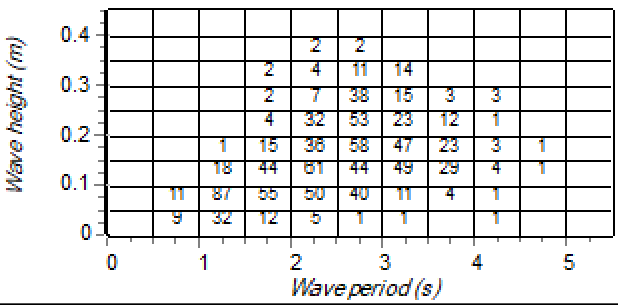
Overall amplitude reflection coefficient: *32%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.2097*	*0.06715*
Peak wave period T_P (s):	*3.2*	*3.2*
Energy wave period $T_{-1,0}$ (s):	*2.611*	*3.037*
Mean wave period $T_{0,1}$ (s):	*2.275*	*2.374*
Mean wave period $T_{0,2}$ (s):	*2.117*	*2.143*
Spectral width (Broadness):	*0.6268*	*0.6753*
Spectral width (Narrowness):	*0.3932*	*0.477*

Time Domain Analysis

Overall amplitude reflection coefficient: *32.1%*





	Incident	**Reflected**
Number of waves:	982	1046
Mean wave height H_m (m):	*0.1459*	*0.05374*
Mean wave period T_m (s):	*2.443*	*2.288*
Sig. wave height H_s (m):	*0.2331*	*0.07603*
$T_{H_{1/3}}$ (s):	*2.821*	*2.563*
H_{max} (m):	*0.3693*	*0.135*
T_{Hmax} (s):	*2.884*	*1.663*
$H_{1/10}$ (m):	*0.2928*	*0.09367*
$H_{1/50}$ (m):	*0.3392*	*0.1158*
$H_{1/100}$ (m)	*0.3491*	*0.1225*
$H_{1/250}$ (m):	*0.3609*	*0.1278*
$H_{0.1\%}$ (m):	*Not enough data*	*0.1346*
$H_{1\%}$ (m):	*0.3358*	*0.1144*
$H_{2\%}$ (m):	*0.3246*	*0.1031*
$H_{10\%}$ (m)	*0.2513*	*0.07883*
Groupiness factor GF:	*1.233*	*1.15*
Skewness b1:	*0.867*	*0.1834*
Kurtosis b2:	*4.139*	*3.572*

Delta Marine Consultants

Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*6 of 48*

Reflection Analysis

Input Parameters

Generel

Data file:	*D:\...\batch 2\Output\H-1L-R90.txt*
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*
Water depth:	*0.6 m*
Length scale (Prototype/Model):	*1*
Skipped lines	*Header: 6 Start: 0 End: 0*

Bandpass filtering (Only for period calc.)

Freq. lower bound:	*0.104 Hz*
Freq. upper bound:	*0.938 Hz*

Freq. Domain Analysis

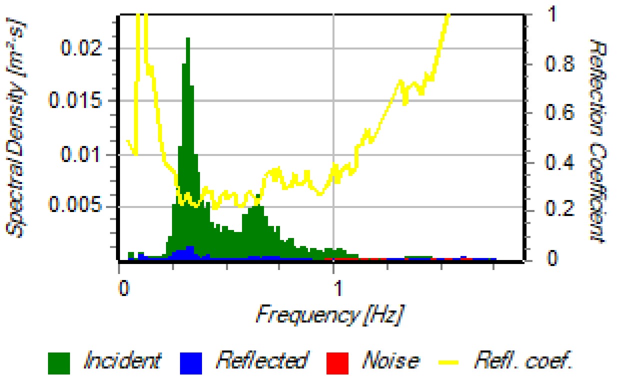
Overlap of subseries:	*20%*
Cosine taper width:	*20%*
Data No. in FFT block:	*4096*
Number of FFT blocks:	*46*

Time Domain Analysis

Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*61*
Hilbert filter length:	*2048*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	*2*	*3*	*4*
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

Frequency Domain Analysis

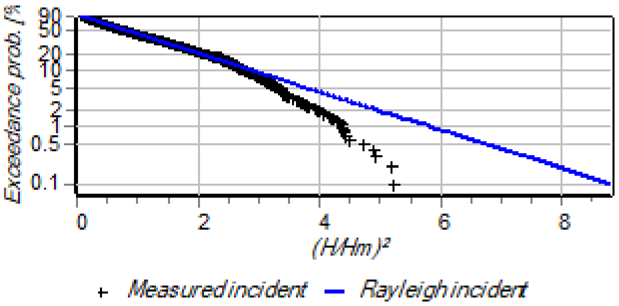


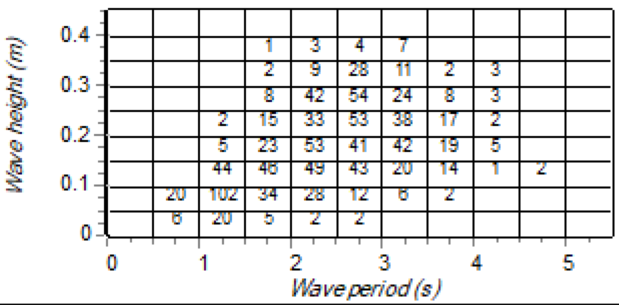
Overall amplitude reflection coefficient: *33.7%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.2414*	*0.08137*
Peak wave period T_P (s):	*3.2*	*3.2*
Energy wave period $T_{-1,0}$ (s):	*2.57*	*2.923*
Mean wave period $T_{0,1}$ (s):	*2.223*	*2.286*
Mean wave period $T_{0,2}$ (s):	*2.066*	*2.069*
Spectral width (Broadness):	*0.6231*	*0.6625*
Spectral width (Narrowness):	*0.3969*	*0.47*

Time Domain Analysis

Overall amplitude reflection coefficient: *34.1%*





	Incident	**Reflected**
Number of waves:	1015	1074
Mean wave height H_m (m):	*0.1707*	*0.06589*
Mean wave period T_m (s):	*2.362*	*2.232*
Sig. wave height H_s (m):	*0.2672*	*0.09178*
$T_{H_{1/3}}$ (s):	*2.779*	*2.52*
H_{max} (m):	*0.3898*	*0.1598*
T_{Hmax} (s):	*2.274*	*3.589*
$H_{1/10}$ (m):	*0.3171*	*0.1111*
$H_{1/50}$ (m):	*0.359*	*0.1291*
$H_{1/100}$ (m)	*0.3697*	*0.1335*
$H_{1/250}$ (m):	*0.3836*	*0.1408*
$H_{0.1\%}$ (m):	*0.3898*	*0.1584*
$H_{1\%}$ (m):	*0.357*	*0.1267*
$H_{2\%}$ (m):	*0.3407*	*0.1221*
$H_{10\%}$ (m)	*0.2858*	*0.09658*
Groupiness factor GF:	*1.146*	*1.107*
Skewness b1:	*0.8453*	*0.1836*
Kurtosis b2:	*3.795*	*3.4*

Delta Marine Consultants

Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*7 of 48*

Reflection Analysis

Input Parameters

Generel

Data file:	*D:\...\batch 2\Output\H-1L-R100.txt*
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*
Water depth:	*0.6 m*
Length scale (Prototype/Model):	*1*
Skipped lines	*Header: 6 Start: 0 End: 0*

Bandpass filtering (Only for period calc.)

Freq. lower bound:	*0.104 Hz*
Freq. upper bound:	*0.938 Hz*

Freq. Domain Analysis

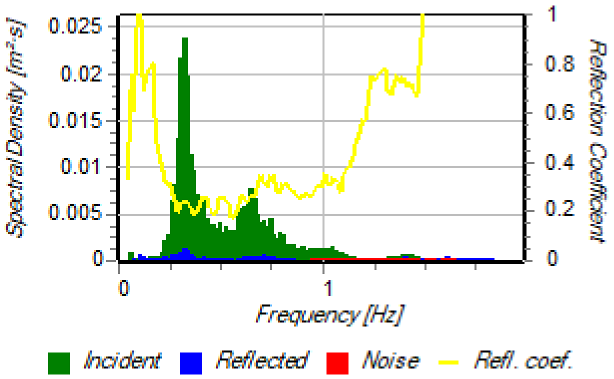
Overlap of subseries:	*20%*
Cosine taper width:	*20%*
Data No. in FFT block:	*4096*
Number of FFT blocks:	*46*

Time Domain Analysis

Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*61*
Hilbert filter length:	*2048*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	*2*	*3*	*4*
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

Frequency Domain Analysis

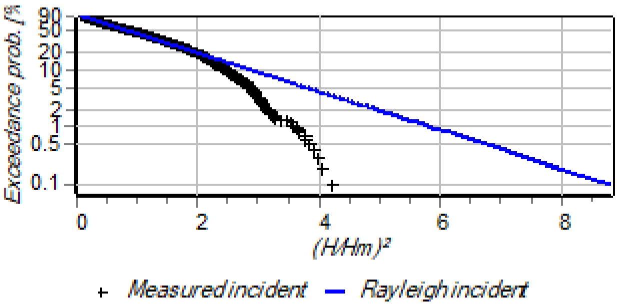


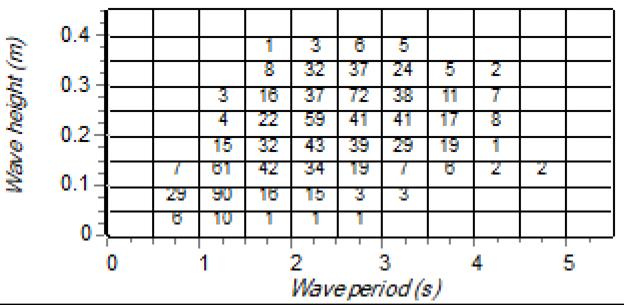
Overall amplitude reflection coefficient: *32.1%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.2687*	*0.08637*
Peak wave period T_P (s):	*3.2*	*3.2*
Energy wave period $T_{-1,0}$ (s):	*2.54*	*2.825*
Mean wave period $T_{0,1}$ (s):	*2.183*	*2.186*
Mean wave period $T_{0,2}$ (s):	*2.027*	*1.983*
Spectral width (Broadness):	*0.6201*	*0.6431*
Spectral width (Narrowness):	*0.3995*	*0.4635*

Time Domain Analysis

Overall amplitude reflection coefficient: *32.2%*





	Incident	**Reflected**
Number of waves:	1032	1137
Mean wave height H_m (m):	*0.1941*	*0.07069*
Mean wave period T_m (s):	*2.325*	*2.109*
Sig. wave height H_s (m):	*0.2901*	*0.09775*
$T_{H_{1/3}}$ (s):	*2.742*	*2.443*
H_{max} (m):	*0.3984*	*0.1628*
T_{Hmax} (s):	*1.842*	*2.099*
$H_{1/10}$ (m):	*0.3318*	*0.1172*
$H_{1/50}$ (m):	*0.3666*	*0.1368*
$H_{1/100}$ (m)	*0.3801*	*0.1437*
$H_{1/250}$ (m):	*0.3894*	*0.1522*
$H_{0.1\%}$ (m):	*0.3981*	*0.1625*
$H_{1\%}$ (m):	*0.369*	*0.1343*
$H_{2\%}$ (m):	*0.3459*	*0.1276*
$H_{10\%}$ (m)	*0.3054*	*0.1029*
Groupiness factor GF:	*1.046*	*1.107*
Skewness b1:	*0.7656*	*0.1657*
Kurtosis b2:	*3.411*	*3.382*

Delta Marine Consultants

Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*8 of 48*

Reflection Analysis

Input Parameters

Generel

Data file:	*D:\...\batch 2\Output\H-2L-R30.txt*
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*
Water depth:	*0.6 m*
Length scale (Prototype/Model):	*1*
Skipped lines	*Header: 6 Start: 0 End: 0*

Bandpass filtering (Only for period calc.)

Freq. lower bound:	*0.104 Hz*
Freq. upper bound:	*0.938 Hz*

Freq. Domain Analysis

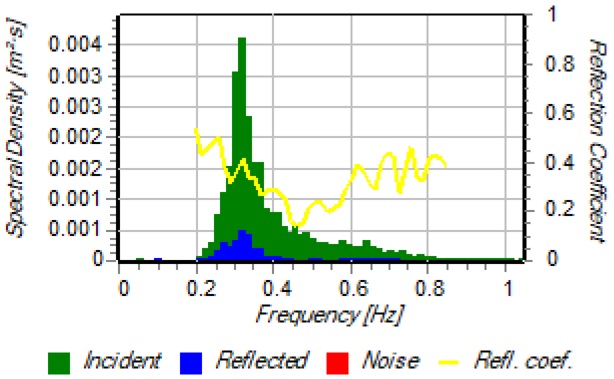
Overlap of subseries:	*20%*
Cosine taper width:	*20%*
Data No. in FFT block:	*4096*
Number of FFT blocks:	*46*

Time Domain Analysis

Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*61*
Hilbert filter length:	*2048*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	*2*	*3*	*4*
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

Frequency Domain Analysis

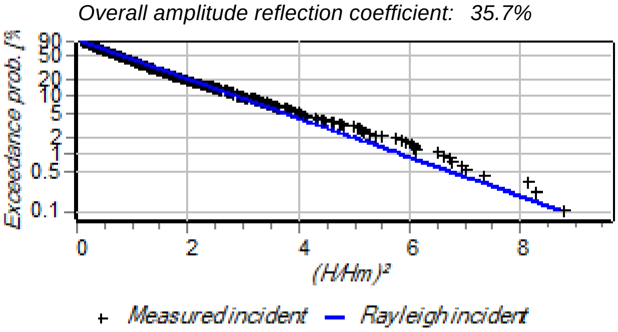


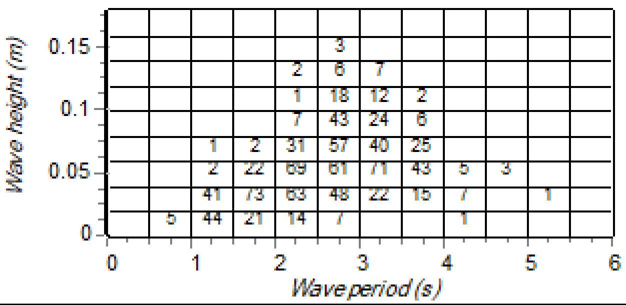
Overall amplitude reflection coefficient: *35.7%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.08083*	*0.02889*
Peak wave period T_P (s):	*3.2*	*3.2*
Energy wave period $T_{-1,0}$ (s):	*2.837*	*3.075*
Mean wave period $T_{0,1}$ (s):	*2.599*	*2.774*
Mean wave period $T_{0,2}$ (s):	*2.461*	*2.592*
Spectral width (Broadness):	*0.6163*	*0.677*
Spectral width (Narrowness):	*0.3402*	*0.3813*

Time Domain Analysis

Overall amplitude reflection coefficient: *35.7%*





	Incident	**Reflected**
Number of waves:	925	846
Mean wave height H_m (m):	*0.0507*	*0.01979*
Mean wave period T_m (s):	*2.592*	*2.833*
Sig. wave height H_s (m):	*0.0815*	*0.0295*
$T_{H_{1/3}}$ (s):	*2.94*	*3.135*
H_{max} (m):	*0.1501*	*0.04885*
T_{Hmax} (s):	*2.922*	*3.071*
$H_{1/10}$ (m):	*0.1062*	*0.03559*
$H_{1/50}$ (m):	*0.1307*	*0.04189*
$H_{1/100}$ (m)	*0.1375*	*0.04425*
$H_{1/250}$ (m):	*0.145*	*0.04614*
$H_{0.1\%}$ (m):	*Not enough data*	*Not enough data*
$H_{1\%}$ (m):	*0.1301*	*0.04096*
$H_{2\%}$ (m):	*0.1201*	*0.03858*
$H_{10\%}$ (m)	*0.08807*	*0.03141*
Groupiness factor GF:	*1.16*	*0.9738*
Skewness b1:	*0.5118*	*0.21*
Kurtosis b2:	*3.695*	*2.952*

Delta Marine Consultants

Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*9 of 48*

Reflection Analysis

Input Parameters

Generel

Data file:	*D:\...\batch 2\Output\H-2L-R40.txt*
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*
Water depth:	*0.6 m*
Length scale (Prototype/Model):	*1*
Skipped lines	*Header: 6 Start: 0 End: 0*

Bandpass filtering (Only for period calc.)

Freq. lower bound:	*0.104 Hz*
Freq. upper bound:	*0.938 Hz*

Freq. Domain Analysis

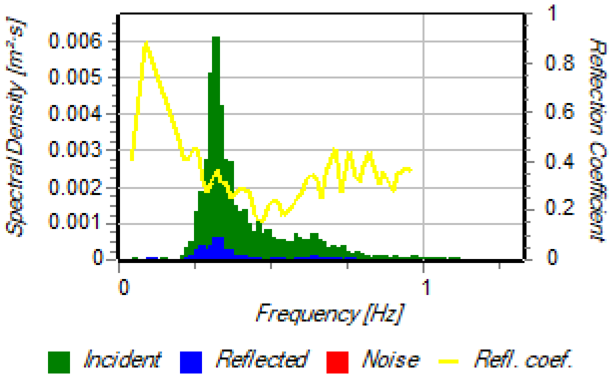
Overlap of subseries:	*20%*
Cosine taper width:	*20%*
Data No. in FFT block:	*4096*
Number of FFT blocks:	*46*

Time Domain Analysis

Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*61*
Hilbert filter length:	*2048*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	*2*	*3*	*4*
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

Frequency Domain Analysis

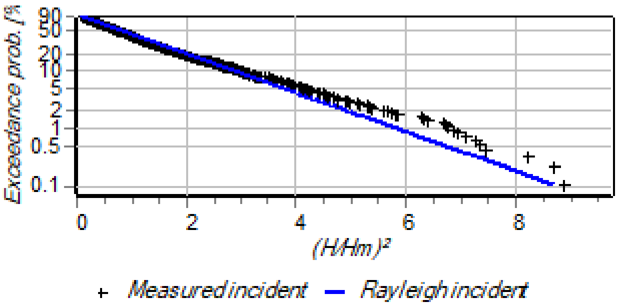


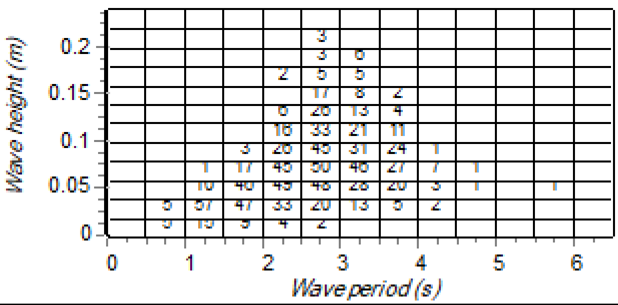
Overall amplitude reflection coefficient: *33.3%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.109*	*0.03633*
Peak wave period T_P (s):	*3.2*	*3.2*
Energy wave period $T_{-1,0}$ (s):	*2.781*	*3.018*
Mean wave period $T_{0,1}$ (s):	*2.516*	*2.64*
Mean wave period $T_{0,2}$ (s):	*2.368*	*2.44*
Spectral width (Broadness):	*0.626*	*0.6823*
Spectral width (Narrowness):	*0.3589*	*0.4127*

Time Domain Analysis

Overall amplitude reflection coefficient: *33.6%*





	Incident	**Reflected**
Number of waves:	928	892
Mean wave height H_m (m):	*0.07026*	*0.02601*
Mean wave period T_m (s):	*2.585*	*2.686*
Sig. wave height H_s (m):	*0.1132*	*0.03771*
$T_{H_{1/3}}$ (s):	*2.937*	*2.997*
H_{max} (m):	*0.2093*	*0.06332*
T_{Hmax} (s):	*2.852*	*2.258*
$H_{1/10}$ (m):	*0.1488*	*0.04586*
$H_{1/50}$ (m):	*0.1845*	*0.0553*
$H_{1/100}$ (m)	*0.1936*	*0.05859*
$H_{1/250}$ (m):	*0.2032*	*0.06145*
$H_{0.1\%}$ (m):	*Not enough data*	*Not enough data*
$H_{1\%}$ (m):	*0.1837*	*0.05504*
$H_{2\%}$ (m):	*0.1677*	*0.05*
$H_{10\%}$ (m)	*0.1225*	*0.04*
Groupiness factor GF:	*1.232*	*0.9986*
Skewness b1:	*0.6745*	*0.2048*
Kurtosis b2:	*4.04*	*3.034*

Delta Marine Consultants

Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*10 of 48*

Reflection Analysis

Input Parameters

Generel

Data file:	*D:\...\batch 2\Output\H-2L-R50.txt*
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*
Water depth:	*0.6 m*
Length scale (Prototype/Model):	*1*
Skipped lines	*Header: 6 Start: 0 End: 0*

Bandpass filtering (Only for period calc.)

Freq. lower bound:	*0.104 Hz*
Freq. upper bound:	*0.938 Hz*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	*2*	*3*	*4*
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

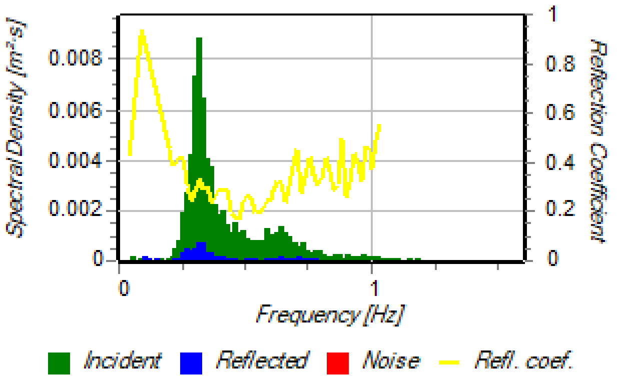
Freq. Domain Analysis

Overlap of subseries:	*20%*
Cosine taper width:	*20%*
Data No. in FFT block:	*4096*
Number of FFT blocks:	*46*

Time Domain Analysis

Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*61*
Hilbert filter length:	*2048*

Frequency Domain Analysis

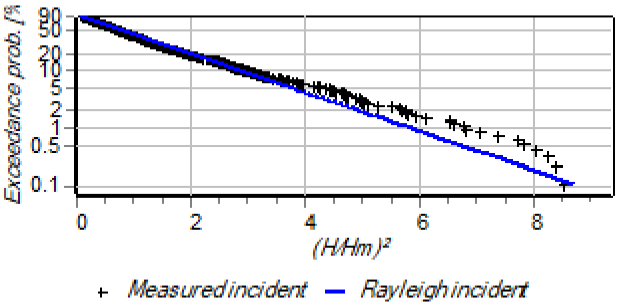


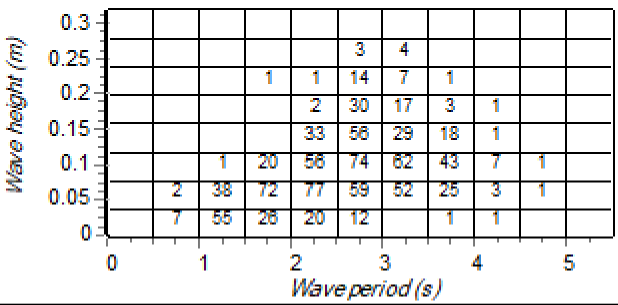
Overall amplitude reflection coefficient: *32.6%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.1365*	*0.04445*
Peak wave period T_P (s):	*3.2*	*3.2*
Energy wave period $T_{-1,0}$ (s):	*2.729*	*2.996*
Mean wave period $T_{0,1}$ (s):	*2.438*	*2.537*
Mean wave period $T_{0,2}$ (s):	*2.284*	*2.326*
Spectral width (Broadness):	*0.6308*	*0.6809*
Spectral width (Narrowness):	*0.3736*	*0.4351*

Time Domain Analysis

Overall amplitude reflection coefficient: *32.6%*





	Incident	**Reflected**
Number of waves:	936	943
Mean wave height H_m (m):	*0.09019*	*0.03318*
Mean wave period T_m (s):	*2.563*	*2.542*
Sig. wave height H_s (m):	*0.1455*	*0.04727*
$T_{H_{1/3}}$ (s):	*2.935*	*2.787*
H_{max} (m):	*0.2631*	*0.08565*
T_{Hmax} (s):	*2.878*	*2.984*
$H_{1/10}$ (m):	*0.1915*	*0.05675*
$H_{1/50}$ (m):	*0.237*	*0.06882*
$H_{1/100}$ (m)	*0.2506*	*0.073*
$H_{1/250}$ (m):	*0.26*	*0.07837*
$H_{0.1\%}$ (m):	*Not enough data*	*Not enough data*
$H_{1\%}$ (m):	*0.235*	*0.06754*
$H_{2\%}$ (m):	*0.2162*	*0.06036*
$H_{10\%}$ (m)	*0.1569*	*0.04951*
Groupiness factor GF:	*1.285*	*1.034*
Skewness b1:	*0.783*	*0.1945*
Kurtosis b2:	*4.308*	*3.15*

Delta Marine Consultants

Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*11 of 48*

Reflection Analysis

Input Parameters

Generel

Data file:	*D:\...\batch 2\Output\H-2L-R60.txt*
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*
Water depth:	*0.6 m*
Length scale (Prototype/Model):	*1*
Skipped lines	*Header: 6 Start: 0 End: 0*

Bandpass filtering (Only for period calc.)

Freq. lower bound:	*0.104 Hz*
Freq. upper bound:	*0.938 Hz*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	*2*	*3*	*4*
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

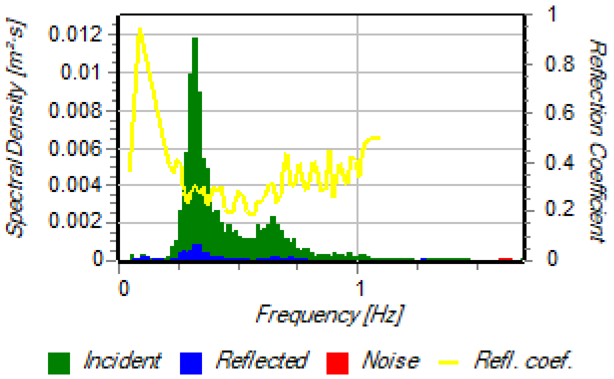
Freq. Domain Analysis

Overlap of subseries:	*20%*
Cosine taper width:	*20%*
Data No. in FFT block:	*4096*
Number of FFT blocks:	*46*

Time Domain Analysis

Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*61*
Hilbert filter length:	*2048*

Frequency Domain Analysis

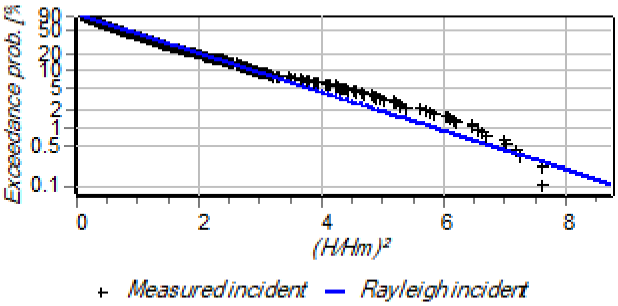


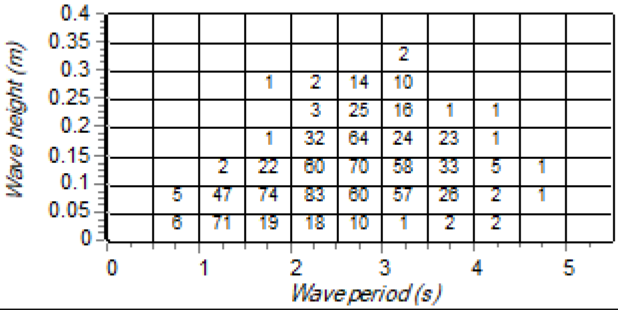
Overall amplitude reflection coefficient: *32.7%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.1644*	*0.05378*
Peak wave period T_P (s):	*3.2*	*3.2*
Energy wave period $T_{-1,0}$ (s):	*2.679*	*2.988*
Mean wave period $T_{0,1}$ (s):	*2.367*	*2.464*
Mean wave period $T_{0,2}$ (s):	*2.21*	*2.248*
Spectral width (Broadness):	*0.6307*	*0.677*
Spectral width (Narrowness):	*0.3837*	*0.4485*

Time Domain Analysis

Overall amplitude reflection coefficient: *32.9%*





	Incident	**Reflected**
Number of waves:	955	983
Mean wave height H_m (m):	*0.1103*	*0.04147*
Mean wave period T_m (s):	*2.511*	*2.438*
Sig. wave height H_s (m):	*0.1781*	*0.05877*
$T_{H_{1/3}}$ (s):	*2.883*	*2.687*
H_{max} (m):	*0.3043*	*0.1067*
T_{Hmax} (s):	*3.046*	*3.143*
$H_{1/10}$ (m):	*0.2333*	*0.0714*
$H_{1/50}$ (m):	*0.2817*	*0.0851*
$H_{1/100}$ (m)	*0.2921*	*0.08897*
$H_{1/250}$ (m):	*0.3004*	*0.09612*
$H_{0.1\%}$ (m):	*Not enough data*	*Not enough data*
$H_{1\%}$ (m):	*0.2811*	*0.08271*
$H_{2\%}$ (m):	*0.2635*	*0.07942*
$H_{10\%}$ (m)	*0.1892*	*0.06172*
Groupiness factor GF:	*1.295*	*1.064*
Skewness b1:	*0.8418*	*0.2011*
Kurtosis b2:	*4.367*	*3.255*

Delta Marine Consultants

Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*12 of 48*

Reflection Analysis

Input Parameters

Generel

Data file: D:\...\batch 2\Output\H-2L-R70.txt
Sample frequency: 128 Hz (Downsampled to 64 Hz)
Water depth: 0.6 m
Length scale (Prototype/Model): 1
Skipped lines Header: 6 Start: 0 End: 0

Bandpass filtering (Only for period calc.)

Freq. lower bound: 0.104 Hz
Freq. upper bound: 0.938 Hz

	Gauge 1	Gauge 2	Gauge 3
Channel number:	2	3	4
Calibration function:	1.0*X	1.0*X	1.0*X
X-coordinate:	0.0 m	0.3 m	0.7 m

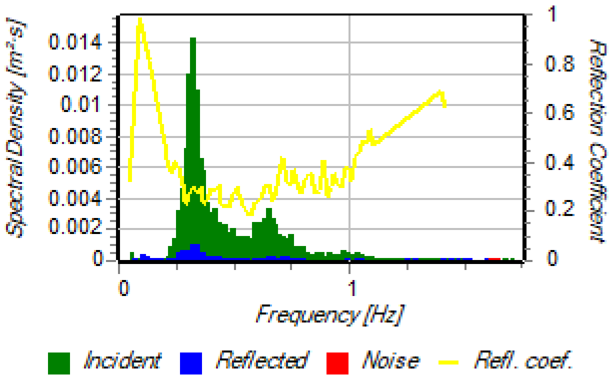
Freq. Domain Analysis

Overlap of subseries: 20%
Cosine taper width: 20%
Data No. in FFT block: 4096
Number of FFT blocks: 46

Time Domain Analysis

Output timeseries at x-coordinate: 0.3333 m
Min. points between downcrossings: 61
Hilbert filter length: 2048

Frequency Domain Analysis

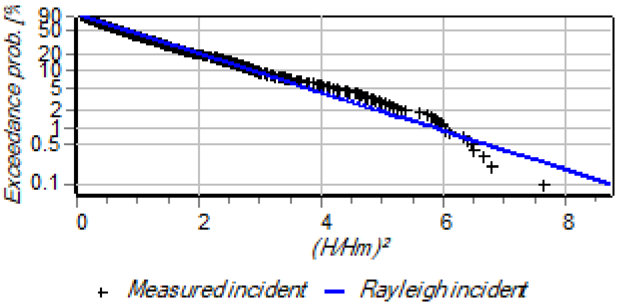


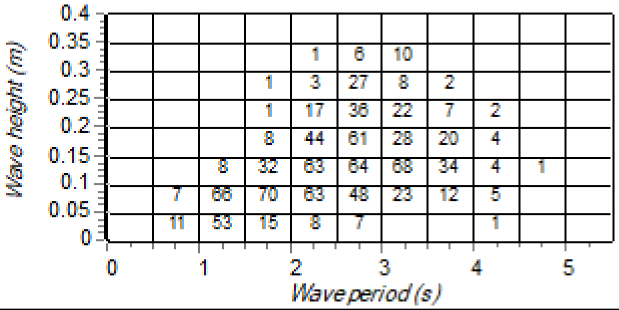
Overall amplitude reflection coefficient: 33.3%

	Incident	Reflected
Sig. wave height H_{m0} (m):	0.186	0.06185
Peak wave period T_P (s):	3.2	3.2
Energy wave period $T_{-1,0}$ (s):	2.647	2.999
Mean wave period $T_{0,1}$ (s):	2.322	2.432
Mean wave period $T_{0,2}$ (s):	2.164	2.213
Spectral width (Broadness):	0.6295	0.6748
Spectral width (Narrowness):	0.3891	0.4563

Time Domain Analysis

Overall amplitude reflection coefficient: 33.3%





	Incident	Reflected
Number of waves:	971	1014
Mean wave height H_m (m):	0.1265	0.04828
Mean wave period T_m (s):	2.471	2.363
Sig. wave height H_s (m):	0.2037	0.06828
$T_{H_{1/3}}$ (s):	2.865	2.619
H_{max} (m):	0.35	0.1282
T_{Hmax} (s):	3.096	3.098
$H_{1/10}$ (m):	0.2631	0.08377
$H_{1/50}$ (m):	0.3129	0.1039
$H_{1/100}$ (m)	0.3223	0.1099
$H_{1/250}$ (m):	0.3323	0.1151
$H_{0.1\%}$ (m):	Not enough data	0.128
$H_{1\%}$ (m):	0.3096	0.1043
$H_{2\%}$ (m):	0.2924	0.09219
$H_{10\%}$ (m)	0.2178	0.07171
Groupiness factor GF:	1.277	1.098
Skewness b1:	0.8621	0.2122
Kurtosis b2:	4.32	3.388

Delta Marine Consultants

Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*13 of 48*

Reflection Analysis

Input Parameters

Generel

Data file:	*D:\...\batch 2\Output\H-2L-R80.txt*
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*
Water depth:	*0.6 m*
Length scale (Prototype/Model):	*1*
Skipped lines	*Header: 6 Start: 0 End: 0*

Bandpass filtering (Only for period calc.)

Freq. lower bound:	*0.104 Hz*
Freq. upper bound:	*0.938 Hz*

Freq. Domain Analysis

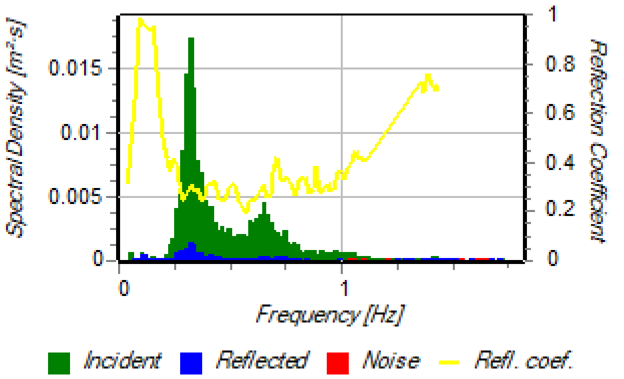
Overlap of subseries:	*20%*
Cosine taper width:	*20%*
Data No. in FFT block:	*4096*
Number of FFT blocks:	*46*

Time Domain Analysis

Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*61*
Hilbert filter length:	*2048*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	*2*	*3*	*4*
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

Frequency Domain Analysis

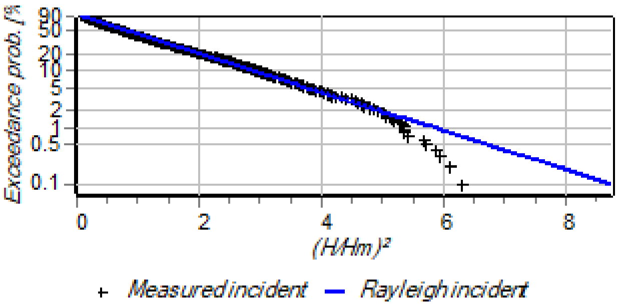


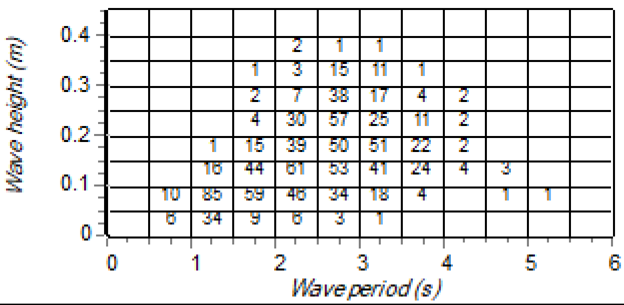
Overall amplitude reflection coefficient: *34.8%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.2098*	*0.07302*
Peak wave period T_P (s):	*3.2*	*3.2*
Energy wave period $T_{-1,0}$ (s):	*2.61*	*3.018*
Mean wave period $T_{0,1}$ (s):	*2.273*	*2.415*
Mean wave period $T_{0,2}$ (s):	*2.115*	*2.193*
Spectral width (Broadness):	*0.6267*	*0.6728*
Spectral width (Narrowness):	*0.3935*	*0.4615*

Time Domain Analysis

Overall amplitude reflection coefficient: *34.9%*





	Incident	**Reflected**
Number of waves:	977	1027
Mean wave height H_m (m):	*0.1462*	*0.05743*
Mean wave period T_m (s):	*2.455*	*2.334*
Sig. wave height H_s (m):	*0.2335*	*0.08074*
$T_{H_{1/3}}$ (s):	*2.843*	*2.643*
H_{max} (m):	*0.3673*	*0.1428*
T_{Hmax} (s):	*2.167*	*2.976*
$H_{1/10}$ (m):	*0.2933*	*0.09928*
$H_{1/50}$ (m):	*0.3404*	*0.1236*
$H_{1/100}$ (m)	*0.3496*	*0.1325*
$H_{1/250}$ (m):	*0.36*	*0.1392*
$H_{0.1\%}$ (m):	*Not enough data*	*0.1428*
$H_{1\%}$ (m):	*0.338*	*0.1239*
$H_{2\%}$ (m):	*0.3255*	*0.1086*
$H_{10\%}$ (m)	*0.2531*	*0.0846*
Groupiness factor GF:	*1.238*	*1.106*
Skewness b1:	*0.8713*	*0.2069*
Kurtosis b2:	*4.171*	*3.387*

Delta Marine Consultants

Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*14 of 48*

Reflection Analysis

Input Parameters

Generel

Data file:	*D:\...\batch 2\Output\H-2L-R90.txt*
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*
Water depth:	*0.6 m*
Length scale (Prototype/Model):	*1*
Skipped lines	*Header: 6 Start: 0 End: 0*

Bandpass filtering (Only for period calc.)

Freq. lower bound:	*0.104 Hz*
Freq. upper bound:	*0.938 Hz*

Freq. Domain Analysis

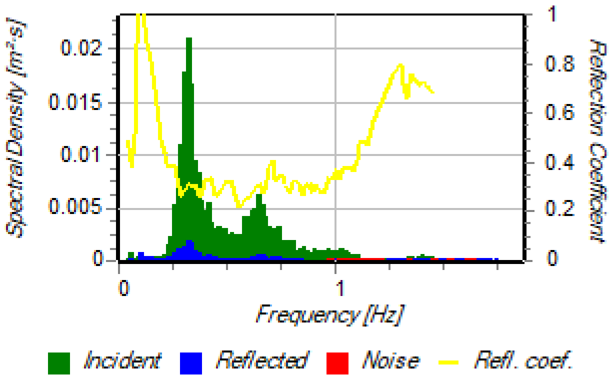
Overlap of subseries:	*20%*
Cosine taper width:	*20%*
Data No. in FFT block:	*4096*
Number of FFT blocks:	*46*

Time Domain Analysis

Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*61*
Hilbert filter length:	*2048*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	*2*	*3*	*4*
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

Frequency Domain Analysis

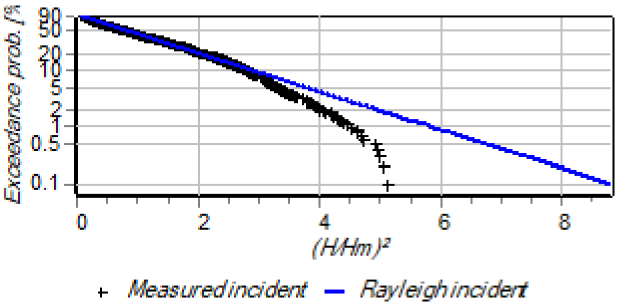


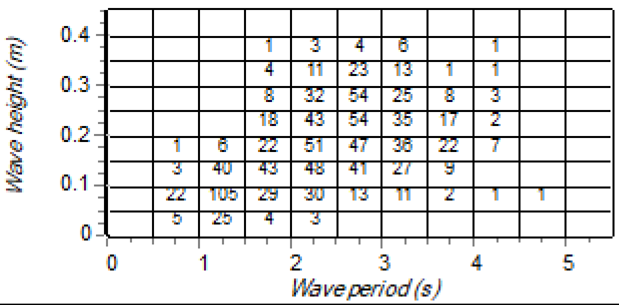
Overall amplitude reflection coefficient: *36.2%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.2408*	*0.08727*
Peak wave period T_P (s):	*3.2*	*3.2*
Energy wave period $T_{-1,0}$ (s):	*2.577*	*2.957*
Mean wave period $T_{0,1}$ (s):	*2.225*	*2.371*
Mean wave period $T_{0,2}$ (s):	*2.067*	*2.156*
Spectral width (Broadness):	*0.6245*	*0.666*
Spectral width (Narrowness):	*0.3984*	*0.4576*

Time Domain Analysis

Overall amplitude reflection coefficient: *36.3%*





	Incident	**Reflected**
Number of waves:	1021	1040
Mean wave height H_m (m):	*0.1699*	*0.06993*
Mean wave period T_m (s):	*2.35*	*2.301*
Sig. wave height H_s (m):	*0.2661*	*0.09625*
$T_{H_{1/3}}$ (s):	*2.751*	*2.65*
H_{max} (m):	*0.3848*	*0.1723*
T_{Hmax} (s):	*1.794*	*3.079*
$H_{1/10}$ (m):	*0.3176*	*0.1167*
$H_{1/50}$ (m):	*0.3614*	*0.1432*
$H_{1/100}$ (m)	*0.3727*	*0.1529*
$H_{1/250}$ (m):	*0.381*	*0.1623*
$H_{0.1\%}$ (m):	*0.3848*	*0.1722*
$H_{1\%}$ (m):	*0.3608*	*0.1422*
$H_{2\%}$ (m):	*0.3409*	*0.1282*
$H_{10\%}$ (m)	*0.2855*	*0.1011*
Groupiness factor GF:	*1.152*	*1.084*
Skewness b1:	*0.8484*	*0.2491*
Kurtosis b2:	*3.836*	*3.3*

Delta Marine Consultants

Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*15 of 48*

Reflection Analysis

Input Parameters

Generel

Data file:	*D:\...\batch 2\Output\H-2L-R100.txt*
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*
Water depth:	*0.6 m*
Length scale (Prototype/Model):	*1*
Skipped lines	*Header: 6 Start: 0 End: 0*

Bandpass filtering (Only for period calc.)

Freq. lower bound:	*0.104 Hz*
Freq. upper bound:	*0.938 Hz*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	*2*	*3*	*4*
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

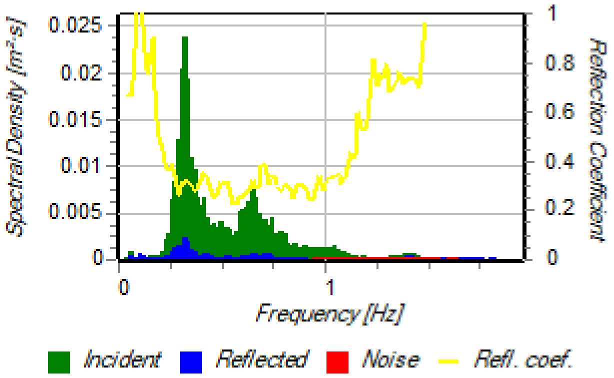
Freq. Domain Analysis

Overlap of subseries:	*20%*
Cosine taper width:	*20%*
Data No. in FFT block:	*4096*
Number of FFT blocks:	*46*

Time Domain Analysis

Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*61*
Hilbert filter length:	*2048*

Frequency Domain Analysis

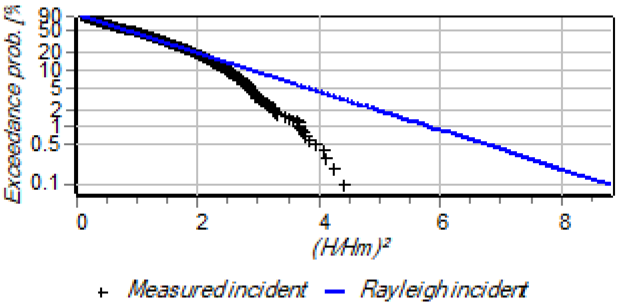


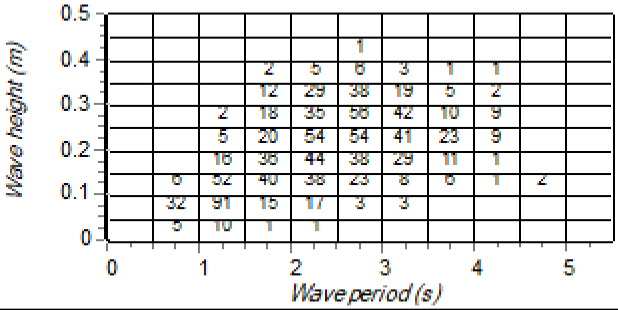
Overall amplitude reflection coefficient: *36.9%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.2672*	*0.09854*
Peak wave period T_P (s):	*3.2*	*3.2*
Energy wave period $T_{-1,0}$ (s):	*2.542*	*2.918*
Mean wave period $T_{0,1}$ (s):	*2.182*	*2.338*
Mean wave period $T_{0,2}$ (s):	*2.025*	*2.127*
Spectral width (Broadness):	*0.6211*	*0.6611*
Spectral width (Narrowness):	*0.401*	*0.4555*

Time Domain Analysis

Overall amplitude reflection coefficient: *36.8%*





	Incident	**Reflected**
Number of waves:	1031	1048
Mean wave height H_m (m):	*0.1935*	*0.08011*
Mean wave period T_m (s):	*2.327*	*2.287*
Sig. wave height H_s (m):	*0.2892*	*0.1102*
$T_{H_{1/3}}$ (s):	*2.732*	*2.634*
H_{max} (m):	*0.4065*	*0.2175*
T_{Hmax} (s):	*2.845*	*2.962*
$H_{1/10}$ (m):	*0.3327*	*0.1314*
$H_{1/50}$ (m):	*0.3716*	*0.1575*
$H_{1/100}$ (m)	*0.384*	*0.1692*
$H_{1/250}$ (m):	*0.3963*	*0.1839*
$H_{0.1\%}$ (m):	*0.4062*	*0.2154*
$H_{1\%}$ (m):	*0.3716*	*0.1519*
$H_{2\%}$ (m):	*0.3489*	*0.1413*
$H_{10\%}$ (m)	*0.3067*	*0.1135*
Groupiness factor GF:	*1.059*	*1.067*
Skewness b1:	*0.7868*	*0.2131*
Kurtosis b2:	*3.471*	*3.254*

Delta Marine Consultants

Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*16 of 48*

Reflection Analysis

Input Parameters

Generel

Data file:	*D:\...\batch 2\Output\H-3L-R30.txt*
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*
Water depth:	*0.6 m*
Length scale (Prototype/Model):	*1*
Skipped lines	*Header: 6 Start: 0 End: 0*

Bandpass filtering (Only for period calc.)

Freq. lower bound:	*0.104 Hz*
Freq. upper bound:	*0.938 Hz*

Freq. Domain Analysis

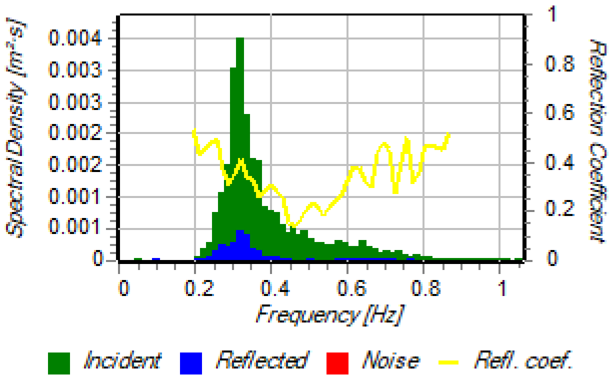
Overlap of subseries:	*20%*
Cosine taper width:	*20%*
Data No. in FFT block:	*4096*
Number of FFT blocks:	*46*

Time Domain Analysis

Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*61*
Hilbert filter length:	*2048*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	*2*	*3*	*4*
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

Frequency Domain Analysis

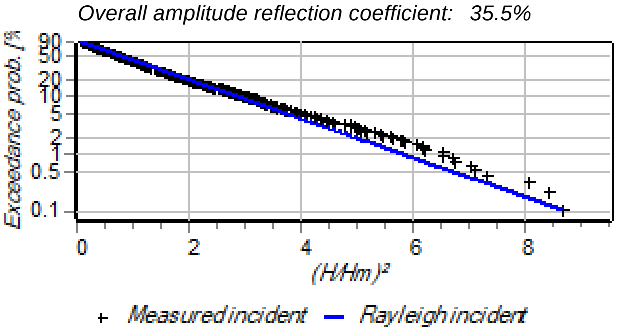


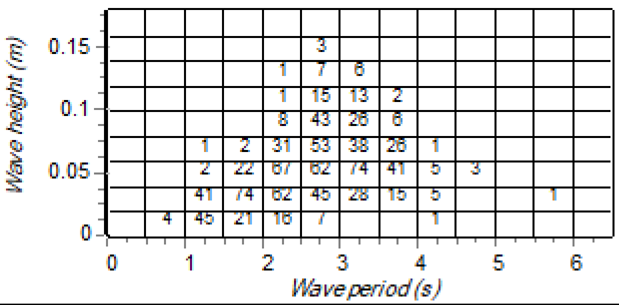
Overall amplitude reflection coefficient: *35.5%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.08005*	*0.02845*
Peak wave period T_P (s):	*3.2*	*3.2*
Energy wave period $T_{-1,0}$ (s):	*2.837*	*3.044*
Mean wave period $T_{0,1}$ (s):	*2.6*	*2.725*
Mean wave period $T_{0,2}$ (s):	*2.462*	*2.534*
Spectral width (Broadness):	*0.6159*	*0.6867*
Spectral width (Narrowness):	*0.3396*	*0.3959*

Time Domain Analysis

Overall amplitude reflection coefficient: *35.5%*





	Incident	**Reflected**
Number of waves:	924	870
Mean wave height H_m (m):	*0.05026*	*0.01941*
Mean wave period T_m (s):	*2.595*	*2.756*
Sig. wave height H_s (m):	*0.08078*	*0.02897*
$T_{H_{1/3}}$ (s):	*2.939*	*3.107*
H_{max} (m):	*0.1481*	*0.04866*
T_{Hmax} (s):	*2.93*	*3.234*
$H_{1/10}$ (m):	*0.1053*	*0.0347*
$H_{1/50}$ (m):	*0.1298*	*0.04122*
$H_{1/100}$ (m)	*0.1364*	*0.04323*
$H_{1/250}$ (m):	*0.1438*	*0.04498*
$H_{0.1\%}$ (m):	*Not enough data*	*Not enough data*
$H_{1\%}$ (m):	*0.1285*	*0.04065*
$H_{2\%}$ (m):	*0.1193*	*0.0383*
$H_{10\%}$ (m)	*0.08789*	*0.03054*
Groupiness factor GF:	*1.167*	*0.973*
Skewness b1:	*0.5086*	*0.1946*
Kurtosis b2:	*3.716*	*2.947*

Delta Marine Consultants

Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*17 of 48*

Reflection Analysis

Input Parameters

Generel

Data file:	*D:\...\batch 2\Output\H-3L-R40.txt*
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*
Water depth:	*0.6 m*
Length scale (Prototype/Model):	*1*
Skipped lines	*Header: 6 Start: 0 End: 0*

Bandpass filtering (Only for period calc.)

Freq. lower bound:	*0.104 Hz*
Freq. upper bound:	*0.938 Hz*

Freq. Domain Analysis

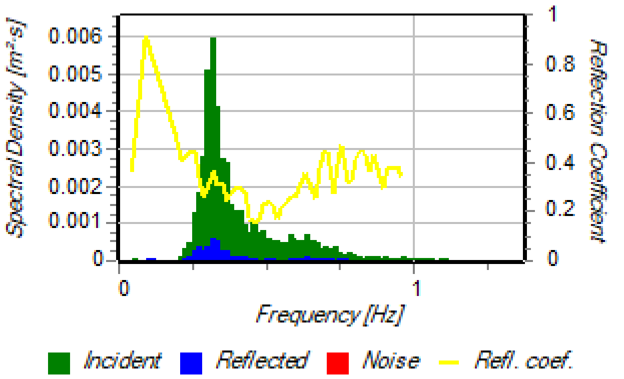
Overlap of subseries:	*20%*
Cosine taper width:	*20%*
Data No. in FFT block:	*4096*
Number of FFT blocks:	*46*

Time Domain Analysis

Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*61*
Hilbert filter length:	*2048*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	*2*	*3*	*4*
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

Frequency Domain Analysis

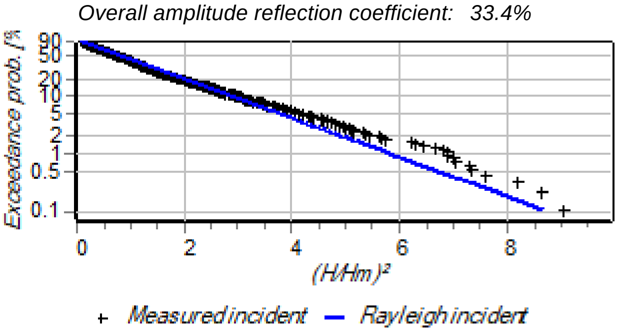


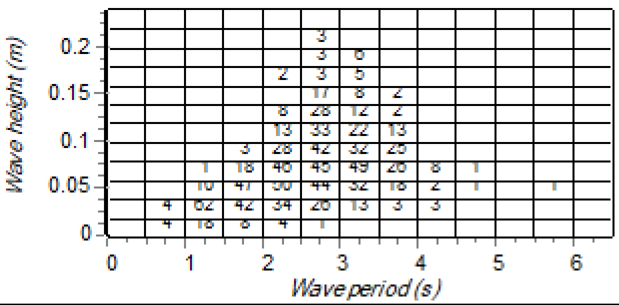
Overall amplitude reflection coefficient: *33.3%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.1086*	*0.03613*
Peak wave period T_P (s):	*3.2*	*3.2*
Energy wave period $T_{-1,0}$ (s):	*2.782*	*2.99*
Mean wave period $T_{0,1}$ (s):	*2.517*	*2.601*
Mean wave period $T_{0,2}$ (s):	*2.369*	*2.397*
Spectral width (Broadness):	*0.6261*	*0.6854*
Spectral width (Narrowness):	*0.3588*	*0.4206*

Time Domain Analysis

Overall amplitude reflection coefficient: *33.4%*





	Incident	**Reflected**
Number of waves:	931	906
Mean wave height H_m (m):	*0.06989*	*0.0261*
Mean wave period T_m (s):	*2.577*	*2.646*
Sig. wave height H_s (m):	*0.1125*	*0.03786*
$T_{H_{1/3}}$ (s):	*2.941*	*2.979*
H_{max} (m):	*0.2103*	*0.06655*
T_{Hmax} (s):	*2.846*	*2.261*
$H_{1/10}$ (m):	*0.1478*	*0.04573*
$H_{1/50}$ (m):	*0.1837*	*0.05428*
$H_{1/100}$ (m)	*0.1932*	*0.05806*
$H_{1/250}$ (m):	*0.2029*	*0.06143*
$H_{0.1\%}$ (m):	*Not enough data*	*Not enough data*
$H_{1\%}$ (m):	*0.1835*	*0.05348*
$H_{2\%}$ (m):	*0.166*	*0.04887*
$H_{10\%}$ (m)	*0.1222*	*0.04003*
Groupiness factor GF:	*1.235*	*0.9956*
Skewness b1:	*0.6702*	*0.1737*
Kurtosis b2:	*4.044*	*3.026*

Delta Marine Consultants

Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*18 of 48*

Reflection Analysis

Input Parameters

Generel

Data file:	*D:\...\batch 2\Output\H-3L-R50.txt*
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*
Water depth:	*0.6 m*
Length scale (Prototype/Model):	*1*
Skipped lines	*Header: 6 Start: 0 End: 0*

Bandpass filtering (Only for period calc.)

Freq. lower bound:	*0.104 Hz*
Freq. upper bound:	*0.938 Hz*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	*2*	*3*	*4*
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

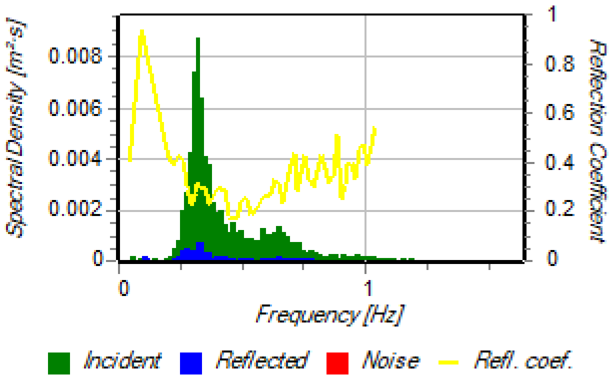
Freq. Domain Analysis

Overlap of subseries:	*20%*
Cosine taper width:	*20%*
Data No. in FFT block:	*4096*
Number of FFT blocks:	*46*

Time Domain Analysis

Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*61*
Hilbert filter length:	*2048*

Frequency Domain Analysis

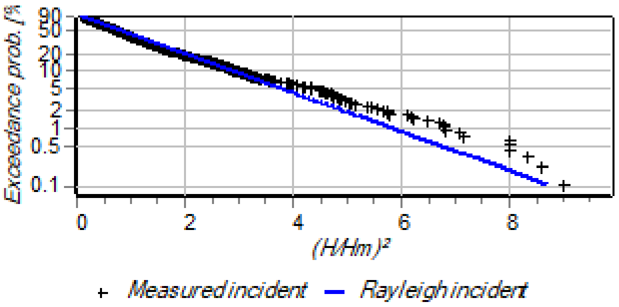


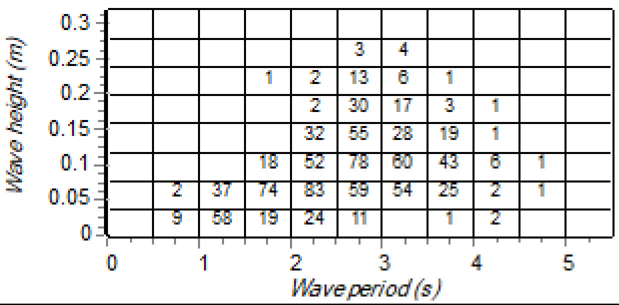
Overall amplitude reflection coefficient: *32.2%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.1365*	*0.04398*
Peak wave period T_P (s):	*3.2*	*3.2*
Energy wave period $T_{-1,0}$ (s):	*2.729*	*2.961*
Mean wave period $T_{0,1}$ (s):	*2.438*	*2.503*
Mean wave period $T_{0,2}$ (s):	*2.284*	*2.294*
Spectral width (Broadness):	*0.6309*	*0.6788*
Spectral width (Narrowness):	*0.3736*	*0.4365*

Time Domain Analysis

Overall amplitude reflection coefficient: *32.4%*





	Incident	**Reflected**
Number of waves:	937	945
Mean wave height H_m (m):	*0.09015*	*0.03332*
Mean wave period T_m (s):	*2.559*	*2.537*
Sig. wave height H_s (m):	*0.1455*	*0.04741*
$T_{H_{1/3}}$ (s):	*2.938*	*2.755*
H_{max} (m):	*0.2702*	*0.07535*
T_{Hmax} (s):	*2.885*	*2.801*
$H_{1/10}$ (m):	*0.192*	*0.05707*
$H_{1/50}$ (m):	*0.2386*	*0.06752*
$H_{1/100}$ (m)	*0.2521*	*0.0705*
$H_{1/250}$ (m):	*0.2629*	*0.07375*
$H_{0.1\%}$ (m):	*Not enough data*	*Not enough data*
$H_{1\%}$ (m):	*0.2352*	*0.06751*
$H_{2\%}$ (m):	*0.2156*	*0.06216*
$H_{10\%}$ (m)	*0.156*	*0.05046*
Groupiness factor GF:	*1.294*	*1.04*
Skewness b1:	*0.7932*	*0.1665*
Kurtosis b2:	*4.348*	*3.174*

Delta Marine Consultants

Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*19 of 48*

Reflection Analysis

Input Parameters

Generel

Data file:	*D:\...\batch 2\Output\H-3L-R60.txt*
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*
Water depth:	*0.6 m*
Length scale (Prototype/Model):	*1*
Skipped lines	*Header: 6 Start: 0 End: 0*

Bandpass filtering (Only for period calc.)

Freq. lower bound:	*0.104 Hz*
Freq. upper bound:	*0.938 Hz*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	*2*	*3*	*4*
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

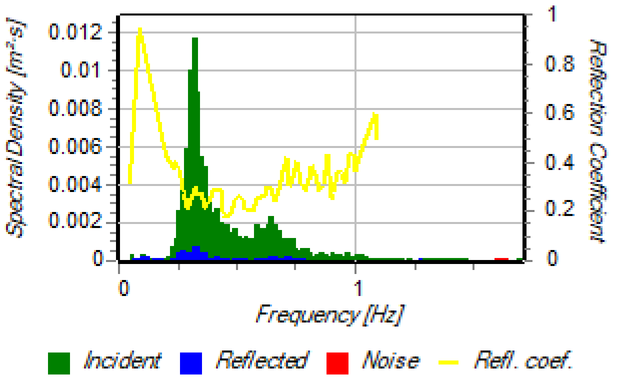
Freq. Domain Analysis

Overlap of subseries:	*20%*
Cosine taper width:	*20%*
Data No. in FFT block:	*4096*
Number of FFT blocks:	*46*

Time Domain Analysis

Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*61*
Hilbert filter length:	*2048*

Frequency Domain Analysis

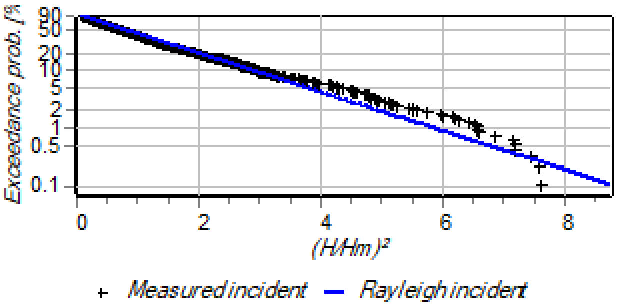


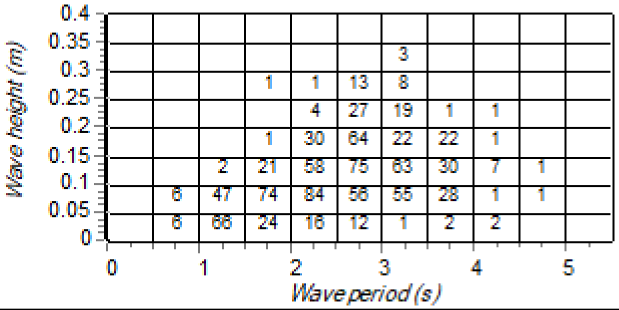
Overall amplitude reflection coefficient: *31.9%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.1647*	*0.05256*
Peak wave period T_P (s):	*3.2*	*3.048*
Energy wave period $T_{-1,0}$ (s):	*2.68*	*2.964*
Mean wave period $T_{0,1}$ (s):	*2.369*	*2.43*
Mean wave period $T_{0,2}$ (s):	*2.212*	*2.216*
Spectral width (Broadness):	*0.6309*	*0.6731*
Spectral width (Narrowness):	*0.3835*	*0.4507*

Time Domain Analysis

Overall amplitude reflection coefficient: *32%*





	Incident	**Reflected**
Number of waves:	956	996
Mean wave height H_m (m):	*0.1106*	*0.04076*
Mean wave period T_m (s):	*2.509*	*2.406*
Sig. wave height H_s (m):	*0.1786*	*0.05791*
$T_{H_{1/3}}$ (s):	*2.872*	*2.58*
H_{max} (m):	*0.3044*	*0.09215*
T_{Hmax} (s):	*3.02*	*2.038*
$H_{1/10}$ (m):	*0.2336*	*0.06991*
$H_{1/50}$ (m):	*0.2835*	*0.08212*
$H_{1/100}$ (m)	*0.2941*	*0.08515*
$H_{1/250}$ (m):	*0.3018*	*0.08751*
$H_{0.1\%}$ (m):	*Not enough data*	*Not enough data*
$H_{1\%}$ (m):	*0.283*	*0.08226*
$H_{2\%}$ (m):	*0.261*	*0.07663*
$H_{10\%}$ (m)	*0.1907*	*0.06172*
Groupiness factor GF:	*1.299*	*1.079*
Skewness b1:	*0.8478*	*0.1669*
Kurtosis b2:	*4.394*	*3.316*

Delta Marine Consultants

Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*20 of 48*

Reflection Analysis

Input Parameters

Generel

Data file:	*D:\...\batch 2\Output\H-3L-R70.txt*
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*
Water depth:	*0.6 m*
Length scale (Prototype/Model):	*1*
Skipped lines	*Header: 6 Start: 0 End: 0*

Bandpass filtering (Only for period calc.)

Freq. lower bound:	*0.104 Hz*
Freq. upper bound:	*0.938 Hz*

Freq. Domain Analysis

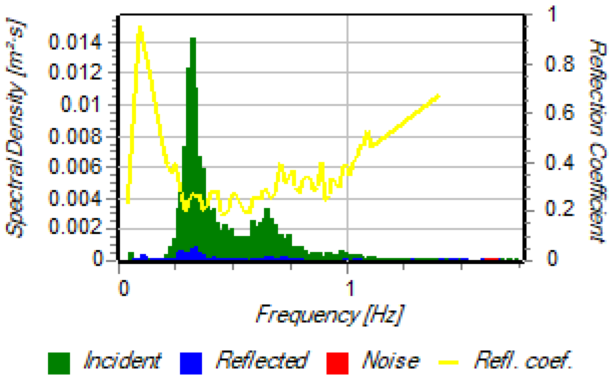
Overlap of subseries:	*20%*
Cosine taper width:	*20%*
Data No. in FFT block:	*4096*
Number of FFT blocks:	*46*

Time Domain Analysis

Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*61*
Hilbert filter length:	*2048*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	*2*	*3*	*4*
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

Frequency Domain Analysis

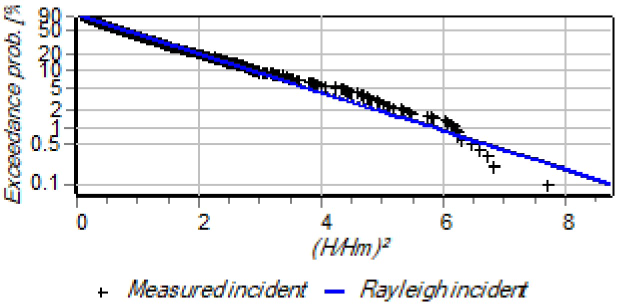


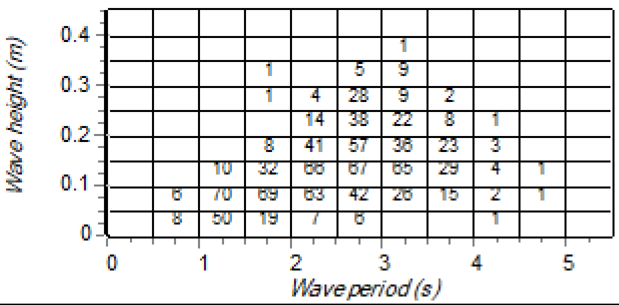
Overall amplitude reflection coefficient: *31.8%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.187*	*0.05955*
Peak wave period T_P (s):	*3.2*	*3.048*
Energy wave period $T_{-1,0}$ (s):	*2.645*	*2.953*
Mean wave period $T_{0,1}$ (s):	*2.32*	*2.374*
Mean wave period $T_{0,2}$ (s):	*2.162*	*2.158*
Spectral width (Broadness):	*0.6296*	*0.6682*
Spectral width (Narrowness):	*0.3894*	*0.4588*

Time Domain Analysis

Overall amplitude reflection coefficient: *32%*





	Incident	**Reflected**
Number of waves:	970	1044
Mean wave height H_m (m):	*0.1274*	*0.04669*
Mean wave period T_m (s):	*2.473*	*2.295*
Sig. wave height H_s (m):	*0.2054*	*0.06625*
$T_{H_{1/3}}$ (s):	*2.878*	*2.491*
H_{max} (m):	*0.3538*	*0.1149*
T_{Hmax} (s):	*3.083*	*1.607*
$H_{1/10}$ (m):	*0.2658*	*0.08173*
$H_{1/50}$ (m):	*0.3158*	*0.09944*
$H_{1/100}$ (m)	*0.326*	*0.1054*
$H_{1/250}$ (m):	*0.3363*	*0.1115*
$H_{0.1\%}$ (m):	*Not enough data*	*0.1148*
$H_{1\%}$ (m):	*0.3166*	*0.09824*
$H_{2\%}$ (m):	*0.2946*	*0.08983*
$H_{10\%}$ (m)	*0.2194*	*0.06998*
Groupiness factor GF:	*1.284*	*1.128*
Skewness b1:	*0.8742*	*0.1686*
Kurtosis b2:	*4.349*	*3.474*

Delta Marine Consultants

Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*21 of 48*

Reflection Analysis

Input Parameters

Generel

Data file:	*D:\...\batch 2\Output\H-3L-R80.txt*
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*
Water depth:	*0.6 m*
Length scale (Prototype/Model):	*1*
Skipped lines	*Header: 6 Start: 0 End: 0*

Bandpass filtering (Only for period calc.)

Freq. lower bound:	*0.104 Hz*
Freq. upper bound:	*0.938 Hz*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	*2*	*3*	*4*
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

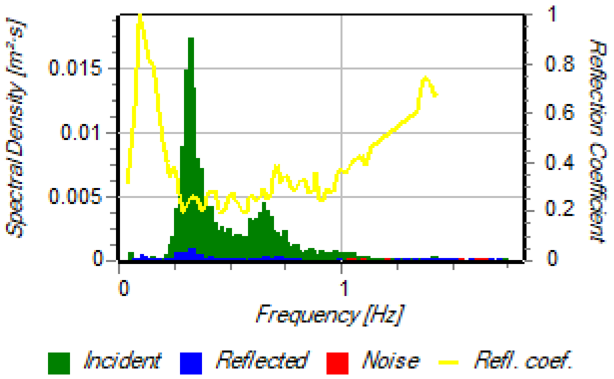
Freq. Domain Analysis

Overlap of subseries:	*20%*
Cosine taper width:	*20%*
Data No. in FFT block:	*4096*
Number of FFT blocks:	*47*

Time Domain Analysis

Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*61*
Hilbert filter length:	*2048*

Frequency Domain Analysis

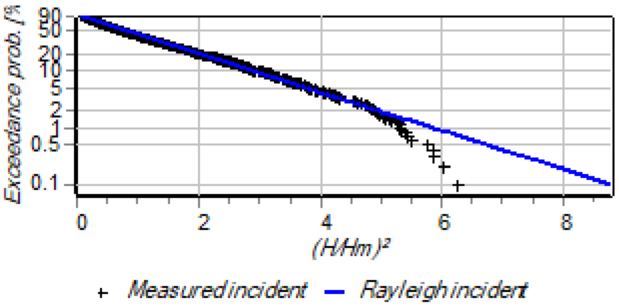


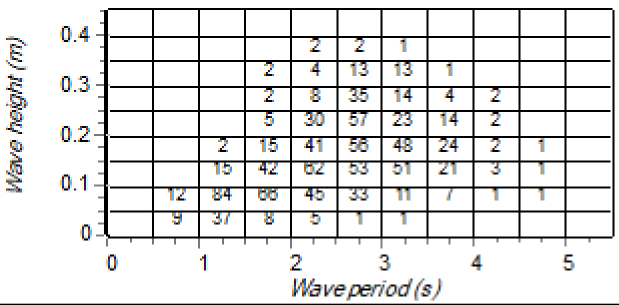
Overall amplitude reflection coefficient: *32.1%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.2114*	*0.06778*
Peak wave period T_P (s):	*3.2*	*3.048*
Energy wave period $T_{-1,0}$ (s):	*2.609*	*2.969*
Mean wave period $T_{0,1}$ (s):	*2.273*	*2.33*
Mean wave period $T_{0,2}$ (s):	*2.115*	*2.111*
Spectral width (Broadness):	*0.6263*	*0.6628*
Spectral width (Narrowness):	*0.3932*	*0.4668*

Time Domain Analysis

Overall amplitude reflection coefficient: *32.1%*





	Incident	**Reflected**
Number of waves:	992	1078
Mean wave height H_m (m):	*0.1465*	*0.05397*
Mean wave period T_m (s):	*2.438*	*2.242*
Sig. wave height H_s (m):	*0.2343*	*0.07664*
$T_{H_{1/3}}$ (s):	*2.841*	*2.455*
H_{max} (m):	*0.3661*	*0.1315*
T_{Hmax} (s):	*2.154*	*1.595*
$H_{1/10}$ (m):	*0.2944*	*0.09362*
$H_{1/50}$ (m):	*0.3396*	*0.1145*
$H_{1/100}$ (m)	*0.3489*	*0.1222*
$H_{1/250}$ (m):	*0.3588*	*0.1292*
$H_{0.1\%}$ (m):	*Not enough data*	*0.1314*
$H_{1\%}$ (m):	*0.3378*	*0.1142*
$H_{2\%}$ (m):	*0.325*	*0.1022*
$H_{10\%}$ (m)	*0.2536*	*0.08095*
Groupiness factor GF:	*1.23*	*1.14*
Skewness b1:	*0.8651*	*0.1615*
Kurtosis b2:	*4.132*	*3.543*

Delta Marine Consultants

Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*22 of 48*

Reflection Analysis

Input Parameters

Generel

Data file:	*D:\...\batch 2\Output\H-3L-R90.txt*
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*
Water depth:	*0.6 m*
Length scale (Prototype/Model):	*1*
Skipped lines	*Header: 6 Start: 0 End: 0*

Bandpass filtering (Only for period calc.)

Freq. lower bound:	*0.104 Hz*
Freq. upper bound:	*0.938 Hz*

Freq. Domain Analysis

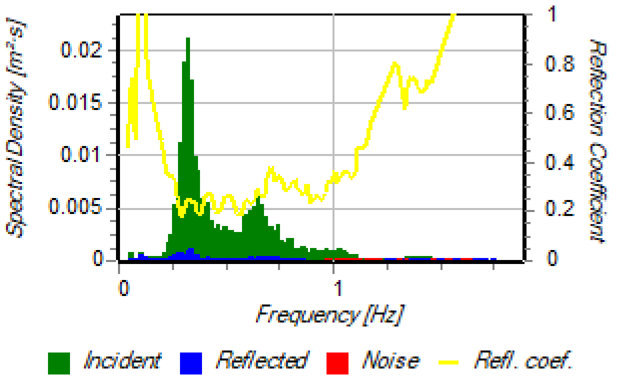
Overlap of subseries:	*20%*
Cosine taper width:	*20%*
Data No. in FFT block:	*4096*
Number of FFT blocks:	*46*

Time Domain Analysis

Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*61*
Hilbert filter length:	*2048*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	*2*	*3*	*4*
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

Frequency Domain Analysis

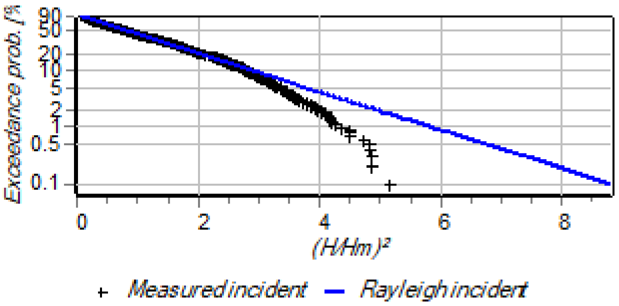


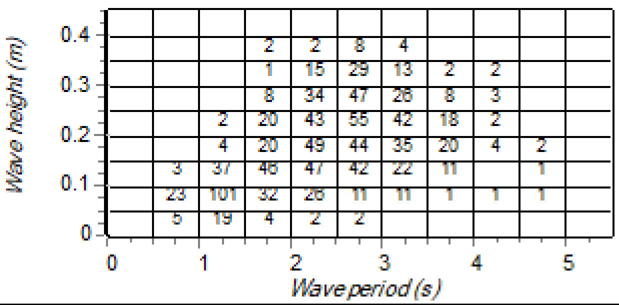
Overall amplitude reflection coefficient: *32.1%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.2445*	*0.07849*
Peak wave period T_P (s):	*3.2*	*3.048*
Energy wave period $T_{-1,0}$ (s):	*2.573*	*2.932*
Mean wave period $T_{0,1}$ (s):	*2.224*	*2.263*
Mean wave period $T_{0,2}$ (s):	*2.067*	*2.047*
Spectral width (Broadness):	*0.6236*	*0.6553*
Spectral width (Narrowness):	*0.3973*	*0.471*

Time Domain Analysis

Overall amplitude reflection coefficient: *32.2%*





	Incident	**Reflected**
Number of waves:	1012	1104
Mean wave height H_m (m):	*0.1729*	*0.06391*
Mean wave period T_m (s):	*2.37*	*2.171*
Sig. wave height H_s (m):	*0.2702*	*0.0888*
$T_{H_{1/3}}$ (s):	*2.744*	*2.375*
H_{max} (m):	*0.3919*	*0.1687*
T_{Hmax} (s):	*1.805*	*3.071*
$H_{1/10}$ (m):	*0.3221*	*0.1086*
$H_{1/50}$ (m):	*0.3628*	*0.131*
$H_{1/100}$ (m)	*0.3745*	*0.1408*
$H_{1/250}$ (m):	*0.3833*	*0.1516*
$H_{0.1\%}$ (m):	*0.3918*	*0.1668*
$H_{1\%}$ (m):	*0.3602*	*0.1273*
$H_{2\%}$ (m):	*0.3445*	*0.1186*
$H_{10\%}$ (m)	*0.2894*	*0.09337*
Groupiness factor GF:	*1.149*	*1.127*
Skewness b1:	*0.8477*	*0.1452*
Kurtosis b2:	*3.806*	*3.448*

Delta Marine Consultants

Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*23 of 48*

Reflection Analysis

Input Parameters

Generel

Data file:	*D:\...\batch 2\Output\H-3L-R100.txt*
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*
Water depth:	*0.6 m*
Length scale (Prototype/Model):	*1*
Skipped lines	*Header: 6 Start: 0 End: 0*

Bandpass filtering (Only for period calc.)

Freq. lower bound:	*0.104 Hz*
Freq. upper bound:	*0.938 Hz*

Freq. Domain Analysis

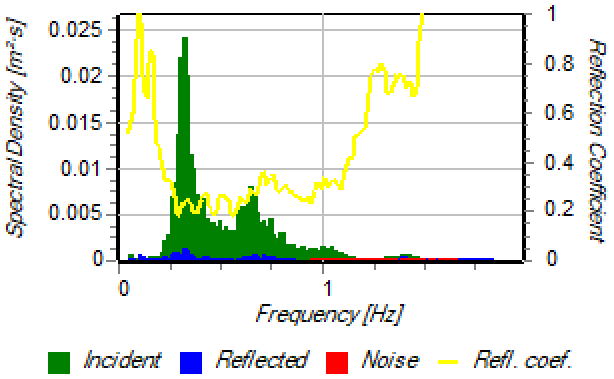
Overlap of subseries:	*20%*
Cosine taper width:	*20%*
Data No. in FFT block:	*4096*
Number of FFT blocks:	*46*

Time Domain Analysis

Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*61*
Hilbert filter length:	*2048*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	*2*	*3*	*4*
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

Frequency Domain Analysis

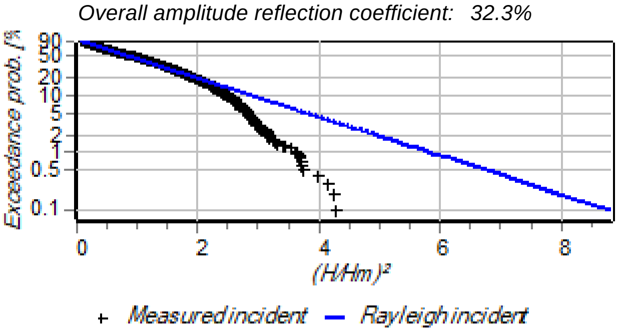


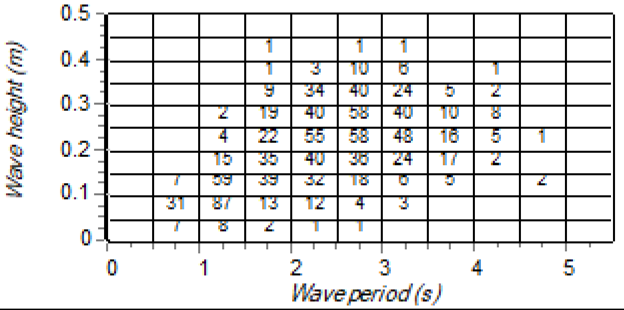
Overall amplitude reflection coefficient: *32.3%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.2733*	*0.0883*
Peak wave period T_P (s):	*3.2*	*3.2*
Energy wave period $T_{-1,0}$ (s):	*2.541*	*2.827*
Mean wave period $T_{0,1}$ (s):	*2.185*	*2.2*
Mean wave period $T_{0,2}$ (s):	*2.029*	*1.998*
Spectral width (Broadness):	*0.6205*	*0.6432*
Spectral width (Narrowness):	*0.3995*	*0.4612*

Time Domain Analysis

Overall amplitude reflection coefficient: *32.3%*





	Incident	**Reflected**
Number of waves:	1030	1142
Mean wave height H_m (m):	*0.1979*	*0.07231*
Mean wave period T_m (s):	*2.328*	*2.101*
Sig. wave height H_s (m):	*0.295*	*0.09898*
$T_{H_{1/3}}$ (s):	*2.75*	*2.34*
H_{max} (m):	*0.4087*	*0.1803*
T_{Hmax} (s):	*1.842*	*3.619*
$H_{1/10}$ (m):	*0.3376*	*0.1184*
$H_{1/50}$ (m):	*0.3745*	*0.1401*
$H_{1/100}$ (m)	*0.389*	*0.1483*
$H_{1/250}$ (m):	*0.4027*	*0.1617*
$H_{0.1\%}$ (m):	*0.4087*	*0.1783*
$H_{1\%}$ (m):	*0.3771*	*0.1366*
$H_{2\%}$ (m):	*0.3515*	*0.1277*
$H_{10\%}$ (m)	*0.3133*	*0.1044*
Groupiness factor GF:	*1.047*	*1.096*
Skewness b1:	*0.776*	*0.1438*
Kurtosis b2:	*3.421*	*3.34*

Delta Marine Consultants

Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*24 of 48*

Reflection Analysis

Input Parameters

Generel

Data file:	*D:\...\batch 2\Output\H-15L-R30.txt*
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*
Water depth:	*0.6 m*
Length scale (Prototype/Model):	*1*
Skipped lines	*Header: 6 Start: 0 End: 0*

Bandpass filtering (Only for period calc.)

Freq. lower bound:	*0.104 Hz*
Freq. upper bound:	*0.938 Hz*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	*2*	*3*	*4*
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

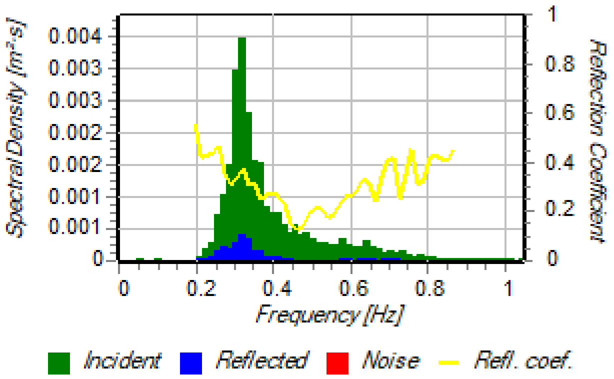
Freq. Domain Analysis

Overlap of subseries:	*20%*
Cosine taper width:	*20%*
Data No. in FFT block:	*4096*
Number of FFT blocks:	*46*

Time Domain Analysis

Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*61*
Hilbert filter length:	*2048*

Frequency Domain Analysis

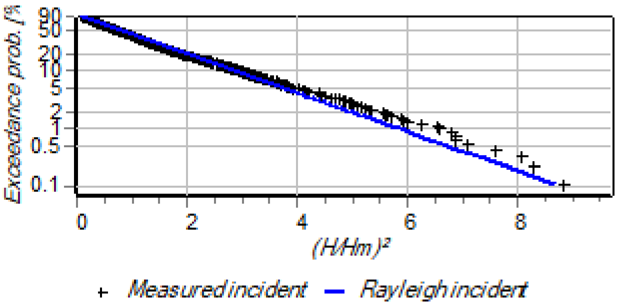


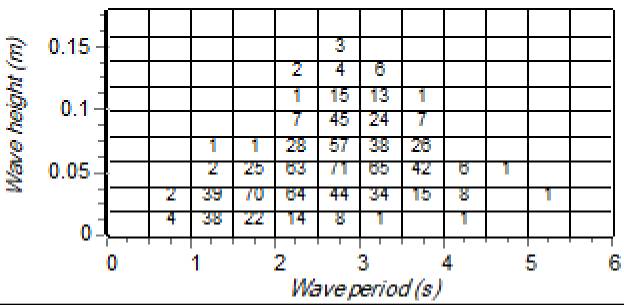
Overall amplitude reflection coefficient: *33.2%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.07961*	*0.0264*
Peak wave period T_P (s):	*3.2*	*3.2*
Energy wave period $T_{-1,0}$ (s):	*2.836*	*3.082*
Mean wave period $T_{0,1}$ (s):	*2.598*	*2.771*
Mean wave period $T_{0,2}$ (s):	*2.459*	*2.581*
Spectral width (Broadness):	*0.6164*	*0.6885*
Spectral width (Narrowness):	*0.3404*	*0.3907*

Time Domain Analysis

Overall amplitude reflection coefficient: *32.6%*





	Incident	**Reflected**
Number of waves:	919	850
Mean wave height H_m (m):	*0.05025*	*0.01834*
Mean wave period T_m(s):	*2.609*	*2.82*
Sig. wave height H_s (m):	*0.0804*	*0.02674*
$T_{H_{1/3}}$ (s):	*2.949*	*3.17*
H_{max} (m):	*0.1493*	*0.04187*
T_{Hmax} (s):	*2.916*	*3.151*
$H_{1/10}$ (m):	*0.1047*	*0.03224*
$H_{1/50}$ (m):	*0.1292*	*0.03768*
$H_{1/100}$ (m)	*0.1368*	*0.0398*
$H_{1/250}$ (m):	*0.1443*	*0.04137*
$H_{0.1\%}$ (m):	*Not enough data*	*Not enough data*
$H_{1\%}$ (m):	*0.1287*	*0.03734*
$H_{2\%}$ (m):	*0.1177*	*0.03438*
$H_{10\%}$ (m)	*0.08735*	*0.02846*
Groupiness factor GF:	*1.142*	*0.9387*
Skewness b1:	*0.4974*	*0.1316*
Kurtosis b2:	*3.684*	*2.83*

Delta Marine Consultants

Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*25 of 48*

Reflection Analysis

Input Parameters

Generel

Data file:	*D:\...\batch 2\Output\H-15L-R40.txt*
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*
Water depth:	*0.6 m*
Length scale (Prototype/Model):	*1*
Skipped lines	*Header: 6 Start: 0 End: 0*

Bandpass filtering (Only for period calc.)

Freq. lower bound:	*0.104 Hz*
Freq. upper bound:	*0.938 Hz*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	*2*	*3*	*4*
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

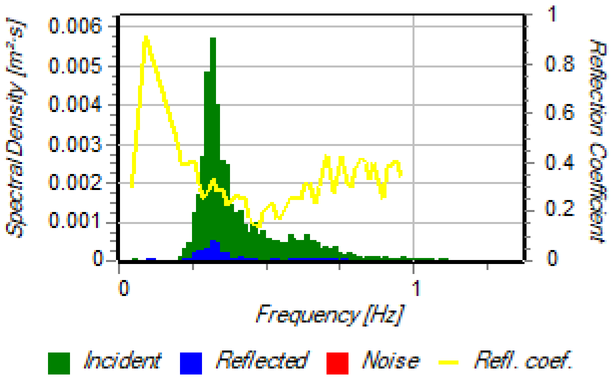
Freq. Domain Analysis

Overlap of subseries:	*20%*
Cosine taper width:	*20%*
Data No. in FFT block:	*4096*
Number of FFT blocks:	*46*

Time Domain Analysis

Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*61*
Hilbert filter length:	*2048*

Frequency Domain Analysis

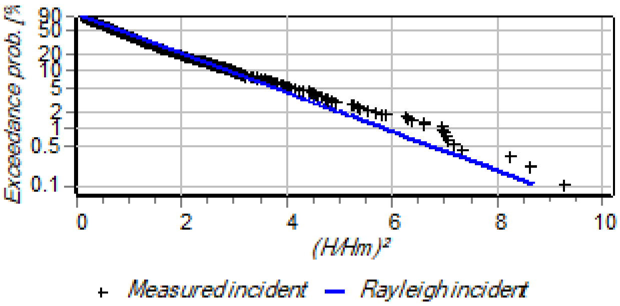


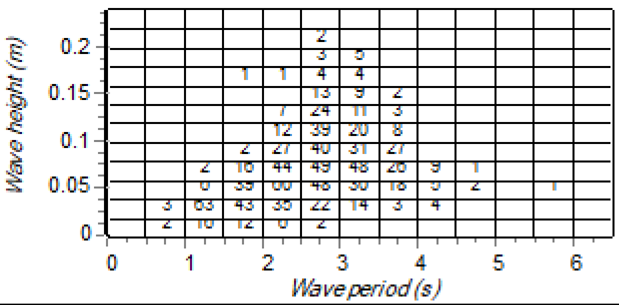
Overall amplitude reflection coefficient: *31%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.1059*	*0.03283*
Peak wave period T_P (s):	*3.2*	*3.2*
Energy wave period $T_{-1,0}$ (s):	*2.782*	*3.02*
Mean wave period $T_{0,1}$ (s):	*2.516*	*2.618*
Mean wave period $T_{0,2}$ (s):	*2.368*	*2.409*
Spectral width (Broadness):	*0.6268*	*0.6899*
Spectral width (Narrowness):	*0.3594*	*0.4248*

Time Domain Analysis

Overall amplitude reflection coefficient: *31.1%*





	Incident	**Reflected**
Number of waves:	924	911
Mean wave height H_m (m):	*0.06856*	*0.02374*
Mean wave period T_m (s):	*2.595*	*2.633*
Sig. wave height H_s (m):	*0.1102*	*0.03424*
$T_{H_{1/3}}$ (s):	*2.93*	*2.973*
H_{max} (m):	*0.2085*	*0.05791*
T_{Hmax} (s):	*2.847*	*2.167*
$H_{1/10}$ (m):	*0.1449*	*0.04157*
$H_{1/50}$ (m):	*0.1798*	*0.05017*
$H_{1/100}$ (m)	*0.1888*	*0.05281*
$H_{1/250}$ (m):	*0.199*	*0.05574*
$H_{0.1\%}$ (m):	*Not enough data*	*Not enough data*
$H_{1\%}$ (m):	*0.1806*	*0.04936*
$H_{2\%}$ (m):	*0.1623*	*0.04574*
$H_{10\%}$ (m)	*0.1189*	*0.0356*
Groupiness factor GF:	*1.232*	*0.9998*
Skewness b1:	*0.662*	*0.1384*
Kurtosis b2:	*4.029*	*3.026*

Delta Marine Consultants

Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*26 of 48*

Reflection Analysis

Input Parameters

Generel

Data file:	*D:\...\batch 2\Output\H-15L-R50.txt*
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*
Water depth:	*0.6 m*
Length scale (Prototype/Model):	*1*
Skipped lines	*Header: 6 Start: 0 End: 0*

Bandpass filtering (Only for period calc.)

Freq. lower bound:	*0.104 Hz*
Freq. upper bound:	*0.938 Hz*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	*2*	*3*	*4*
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

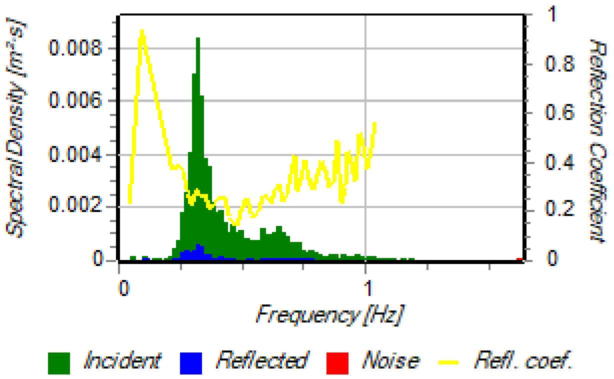
Freq. Domain Analysis

Overlap of subseries:	*20%*
Cosine taper width:	*20%*
Data No. in FFT block:	*4096*
Number of FFT blocks:	*46*

Time Domain Analysis

Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*61*
Hilbert filter length:	*2048*

Frequency Domain Analysis

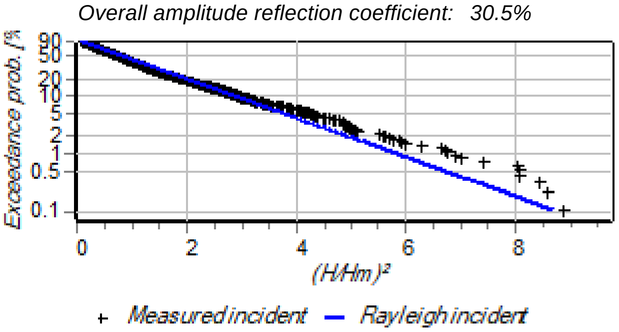


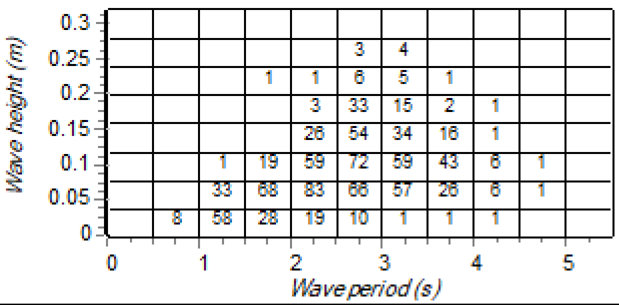
Overall amplitude reflection coefficient: *30.4%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.1332*	*0.04041*
Peak wave period T_P (s):	*3.2*	*3.2*
Energy wave period $T_{-1,0}$ (s):	*2.727*	*2.974*
Mean wave period $T_{0,1}$ (s):	*2.436*	*2.496*
Mean wave period $T_{0,2}$ (s):	*2.282*	*2.281*
Spectral width (Broadness):	*0.6314*	*0.6828*
Spectral width (Narrowness):	*0.3742*	*0.4445*

Time Domain Analysis

Overall amplitude reflection coefficient: *30.5%*





	Incident	**Reflected**
Number of waves:	932	962
Mean wave height H_m (m):	*0.08833*	*0.03057*
Mean wave period T_m (s):	*2.573*	*2.492*
Sig. wave height H_s (m):	*0.1423*	*0.04351*
$T_{H_{1/3}}$ (s):	*2.931*	*2.745*
H_{max} (m):	*0.263*	*0.07723*
T_{Hmax} (s):	*2.853*	*3.106*
$H_{1/10}$ (m):	*0.1876*	*0.05305*
$H_{1/50}$ (m):	*0.2332*	*0.0634*
$H_{1/100}$ (m)	*0.2478*	*0.06689*
$H_{1/250}$ (m):	*0.2579*	*0.07132*
$H_{0.1\%}$ (m):	*Not enough data*	*Not enough data*
$H_{1\%}$ (m):	*0.231*	*0.06254*
$H_{2\%}$ (m):	*0.2098*	*0.05825*
$H_{10\%}$ (m)	*0.153*	*0.04598*
Groupiness factor GF:	*1.29*	*1.062*
Skewness b1:	*0.7853*	*0.1546*
Kurtosis b2:	*4.332*	*3.235*

Delta Marine Consultants

Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*27 of 48*

Reflection Analysis

Input Parameters

Generel

Data file:	*D:\...\batch 2\Output\H-15L-R60.txt*
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*
Water depth:	*0.6 m*
Length scale (Prototype/Model):	*1*
Skipped lines	*Header: 6 Start: 0 End: 0*

Bandpass filtering (Only for period calc.)

Freq. lower bound:	*0.104 Hz*
Freq. upper bound:	*0.938 Hz*

Freq. Domain Analysis

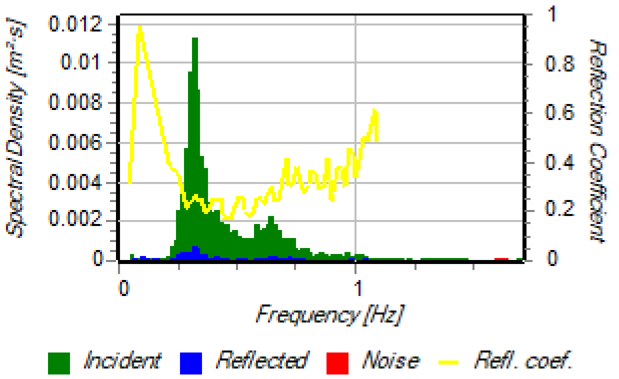
Overlap of subseries:	*20%*
Cosine taper width:	*20%*
Data No. in FFT block:	*4096*
Number of FFT blocks:	*46*

Time Domain Analysis

Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*61*
Hilbert filter length:	*2048*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	*2*	*3*	*4*
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

Frequency Domain Analysis

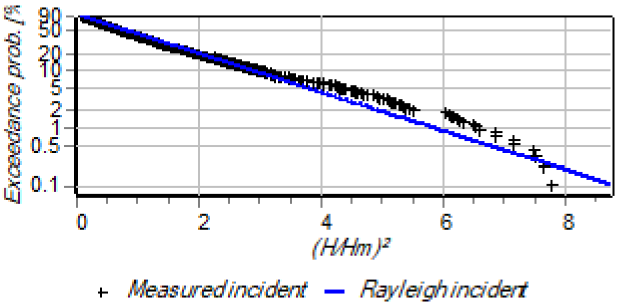


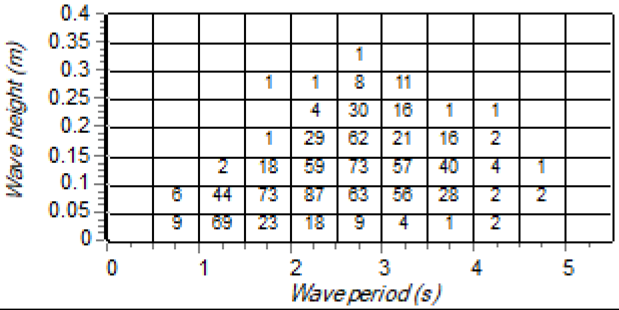
Overall amplitude reflection coefficient: *30.5%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.161*	*0.04917*
Peak wave period T_P (s):	*3.2*	*3.2*
Energy wave period $T_{-1,0}$ (s):	*2.678*	*2.981*
Mean wave period $T_{0,1}$ (s):	*2.367*	*2.422*
Mean wave period $T_{0,2}$ (s):	*2.21*	*2.201*
Spectral width (Broadness):	*0.6312*	*0.6763*
Spectral width (Narrowness):	*0.3839*	*0.4588*

Time Domain Analysis

Overall amplitude reflection coefficient: *30.7%*





	Incident	**Reflected**
Number of waves:	955	1007
Mean wave height H_m (m):	*0.1083*	*0.03823*
Mean wave period T_m (s):	*2.511*	*2.38*
Sig. wave height H_s (m):	*0.1751*	*0.05432*
$T_{H_{1/3}}$ (s):	*2.878*	*2.604*
H_{max} (m):	*0.3016*	*0.08946*
T_{Hmax} (s):	*2.995*	*3.194*
$H_{1/10}$ (m):	*0.23*	*0.06638*
$H_{1/50}$ (m):	*0.279*	*0.07942*
$H_{1/100}$ (m)	*0.2898*	*0.08312*
$H_{1/250}$ (m):	*0.2982*	*0.08754*
$H_{0.1\%}$ (m):	*Not enough data*	*0.08945*
$H_{1\%}$ (m):	*0.2771*	*0.07739*
$H_{2\%}$ (m):	*0.2541*	*0.07394*
$H_{10\%}$ (m)	*0.1896*	*0.05684*
Groupiness factor GF:	*1.3*	*1.119*
Skewness b1:	*0.8424*	*0.1708*
Kurtosis b2:	*4.391*	*3.459*

Delta Marine Consultants

Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*28 of 48*

Reflection Analysis

Input Parameters

Generel

Data file:	*D:\...\batch 2\Output\H-15L-R70.txt*
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*
Water depth:	*0.6 m*
Length scale (Prototype/Model):	*1*
Skipped lines	*Header: 6 Start: 0 End: 0*

Bandpass filtering (Only for period calc.)

Freq. lower bound:	*0.104 Hz*
Freq. upper bound:	*0.938 Hz*

Freq. Domain Analysis

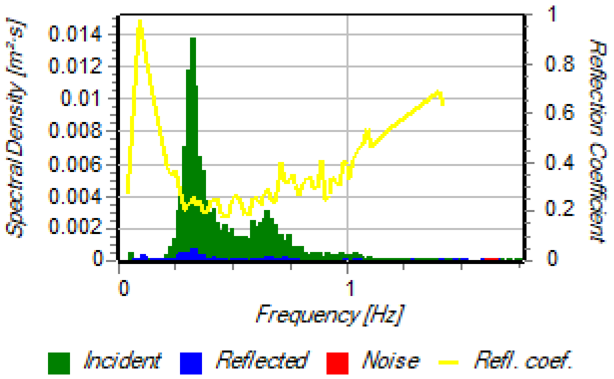
Overlap of subseries:	*20%*
Cosine taper width:	*20%*
Data No. in FFT block:	*4096*
Number of FFT blocks:	*46*

Time Domain Analysis

Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*61*
Hilbert filter length:	*2048*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	*2*	*3*	*4*
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

Frequency Domain Analysis

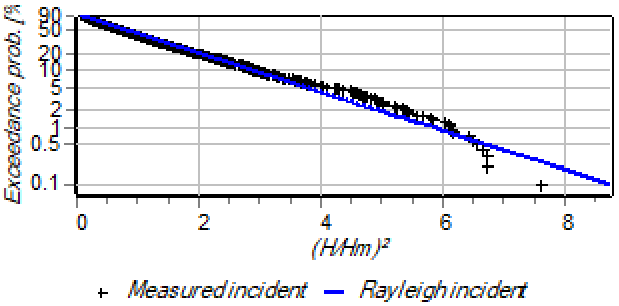


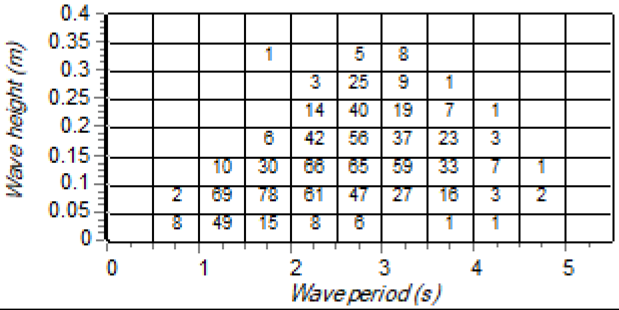
Overall amplitude reflection coefficient: *30.8%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.1831*	*0.05639*
Peak wave period T_P (s):	*3.2*	*3.2*
Energy wave period $T_{-1,0}$ (s):	*2.647*	*2.997*
Mean wave period $T_{0,1}$ (s):	*2.323*	*2.375*
Mean wave period $T_{0,2}$ (s):	*2.165*	*2.15*
Spectral width (Broadness):	*0.6296*	*0.6726*
Spectral width (Narrowness):	*0.389*	*0.469*

Time Domain Analysis

Overall amplitude reflection coefficient: *30.9%*





	Incident	**Reflected**
Number of waves:	964	1036
Mean wave height H_m (m):	*0.1253*	*0.04447*
Mean wave period T_m (s):	*2.488*	*2.313*
Sig. wave height H_s (m):	*0.2016*	*0.06299*
$T_{H_{1/3}}$ (s):	*2.856*	*2.507*
H_{max} (m):	*0.3451*	*0.117*
T_{Hmax} (s):	*3.086*	*3.142*
$H_{1/10}$ (m):	*0.2602*	*0.07745*
$H_{1/50}$ (m):	*0.31*	*0.09612*
$H_{1/100}$ (m)	*0.321*	*0.1021*
$H_{1/250}$ (m):	*0.3297*	*0.1086*
$H_{0.1\%}$ (m):	*Not enough data*	*0.1167*
$H_{1\%}$ (m):	*0.3099*	*0.09535*
$H_{2\%}$ (m):	*0.2911*	*0.08559*
$H_{10\%}$ (m)	*0.2158*	*0.06615*
Groupiness factor GF:	*1.276*	*1.154*
Skewness b1:	*0.8504*	*0.1849*
Kurtosis b2:	*4.304*	*3.609*

Delta Marine Consultants

Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*29 of 48*

Reflection Analysis

Input Parameters

Generel

Data file:	*D:\...\batch 2\Output\H-15L-R80.txt*
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*
Water depth:	*0.6 m*
Length scale (Prototype/Model):	*1*
Skipped lines	*Header: 6 Start: 0 End: 0*

Bandpass filtering (Only for period calc.)

Freq. lower bound:	*0.104 Hz*
Freq. upper bound:	*0.938 Hz*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	*2*	*3*	*4*
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

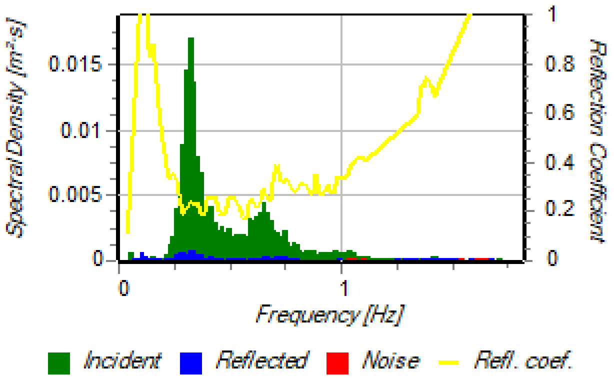
Freq. Domain Analysis

Overlap of subseries:	*20%*
Cosine taper width:	*20%*
Data No. in FFT block:	*4096*
Number of FFT blocks:	*46*

Time Domain Analysis

Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*61*
Hilbert filter length:	*2048*

Frequency Domain Analysis

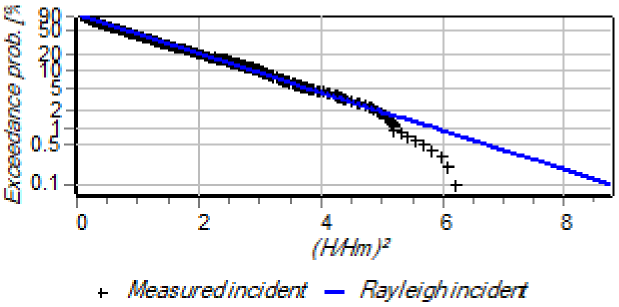


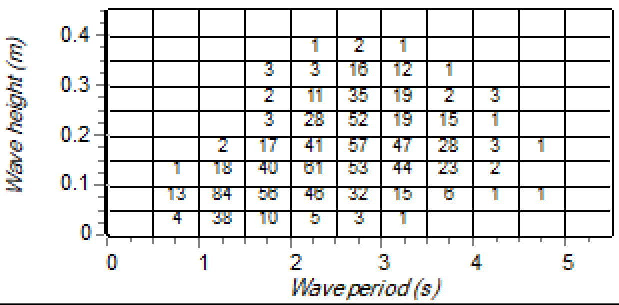
Overall amplitude reflection coefficient: *31.2%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.2105*	*0.06559*
Peak wave period T_P (s):	*3.2*	*3.048*
Energy wave period $T_{-1,0}$ (s):	*2.613*	*3.012*
Mean wave period $T_{0,1}$ (s):	*2.277*	*2.332*
Mean wave period $T_{0,2}$ (s):	*2.119*	*2.104*
Spectral width (Broadness):	*0.6268*	*0.6686*
Spectral width (Narrowness):	*0.3932*	*0.4779*

Time Domain Analysis

Overall amplitude reflection coefficient: *31.3%*





	Incident	**Reflected**
Number of waves:	982	1079
Mean wave height H_m (m):	0.1464	0.05212
Mean wave period T_m (s):	2.443	2.221
Sig. wave height H_s (m):	0.2337	0.07369
$T_{H_{1/3}}$ (s):	2.842	2.406
H_{max} (m):	0.3647	0.131
T_{Hmax} (s):	2.915	2.903
$H_{1/10}$ (m):	0.293	0.09086
$H_{1/50}$ (m):	0.3387	0.1127
$H_{1/100}$ (m)	0.3479	0.1212
$H_{1/250}$ (m):	0.3592	0.1283
$H_{0.1\%}$ (m):	Not enough data	0.1308
$H_{1\%}$ (m):	0.3333	0.1117
$H_{2\%}$ (m):	0.3255	0.09952
$H_{10\%}$ (m)	0.2554	0.07821
Groupiness factor GF:	1.231	1.157
Skewness b1:	0.8644	0.1592
Kurtosis b2:	4.132	3.583

Delta Marine Consultants

Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*30 of 48*

Reflection Analysis

Input Parameters

Generel

Data file:	*D:\...\batch 2\Output\H-15L-R90.txt*
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*
Water depth:	*0.6 m*
Length scale (Prototype/Model):	*1*
Skipped lines	*Header: 6 Start: 0 End: 0*

Bandpass filtering (Only for period calc.)

Freq. lower bound:	*0.104 Hz*
Freq. upper bound:	*0.938 Hz*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	*2*	*3*	*4*
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

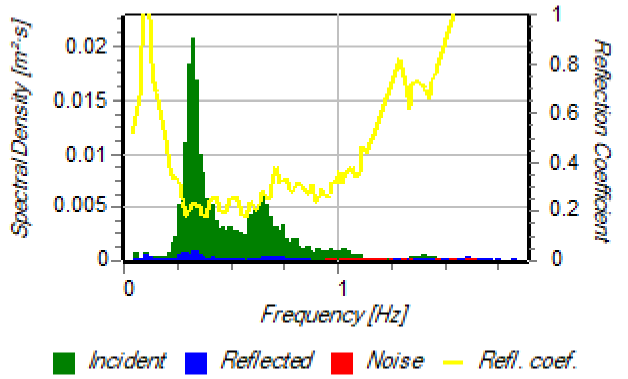
Freq. Domain Analysis

Overlap of subseries:	*20%*
Cosine taper width:	*20%*
Data No. in FFT block:	*4096*
Number of FFT blocks:	*46*

Time Domain Analysis

Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*61*
Hilbert filter length:	*2048*

Frequency Domain Analysis

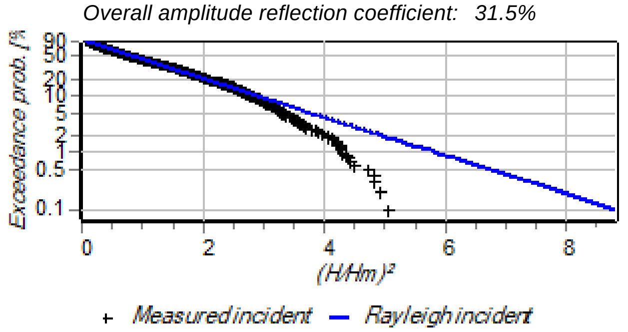


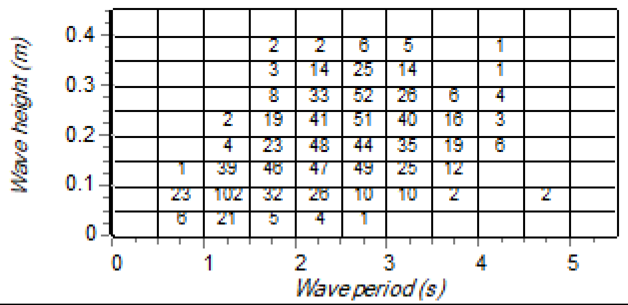
Overall amplitude reflection coefficient: *31.6%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.2426*	*0.07673*
Peak wave period T_P (s):	*3.2*	*3.048*
Energy wave period $T_{-1,0}$ (s):	*2.571*	*2.946*
Mean wave period $T_{0,1}$ (s):	*2.222*	*2.255*
Mean wave period $T_{0,2}$ (s):	*2.065*	*2.036*
Spectral width (Broadness):	*0.6232*	*0.6576*
Spectral width (Narrowness):	*0.3974*	*0.477*

Time Domain Analysis

Overall amplitude reflection coefficient: *31.5%*





	Incident	**Reflected**
Number of waves:	1016	1115
Mean wave height H_m (m):	*0.1712*	*0.0623*
Mean wave period T_m (s):	*2.361*	*2.147*
Sig. wave height H_s (m):	*0.2679*	*0.0866*
$T_{H_{1/3}}$ (s):	*2.762*	*2.392*
H_{max} (m):	*0.3852*	*0.1642*
T_{Hmax} (s):	*2.501*	*3.022*
$H_{1/10}$ (m):	*0.319*	*0.1061*
$H_{1/50}$ (m):	*0.3589*	*0.1291*
$H_{1/100}$ (m)	*0.3681*	*0.1396*
$H_{1/250}$ (m):	*0.3793*	*0.1523*
$H_{0.1\%}$ (m):	*0.3852*	*0.1632*
$H_{1\%}$ (m):	*0.3542*	*0.1245*
$H_{2\%}$ (m):	*0.3452*	*0.1147*
$H_{10\%}$ (m)	*0.2874*	*0.08975*
Groupiness factor GF:	*1.148*	*1.131*
Skewness b1:	*0.8426*	*0.1579*
Kurtosis b2:	*3.809*	*3.479*

Delta Marine Consultants

Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*31 of 48*

Reflection Analysis

Input Parameters

Generel

Data file:	*D:\...\batch 2\Output\H-15L-R100.txt*
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*
Water depth:	*0.6 m*
Length scale (Prototype/Model):	*1*
Skipped lines	*Header: 6 Start: 0 End: 0*

Bandpass filtering (Only for period calc.)

Freq. lower bound:	*0.104 Hz*
Freq. upper bound:	*0.938 Hz*

Freq. Domain Analysis

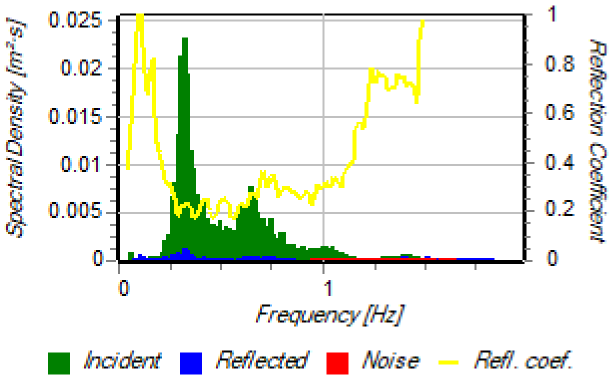
Overlap of subseries:	*20%*
Cosine taper width:	*20%*
Data No. in FFT block:	*4096*
Number of FFT blocks:	*46*

Time Domain Analysis

Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*61*
Hilbert filter length:	*2048*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	*2*	*3*	*4*
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

Frequency Domain Analysis

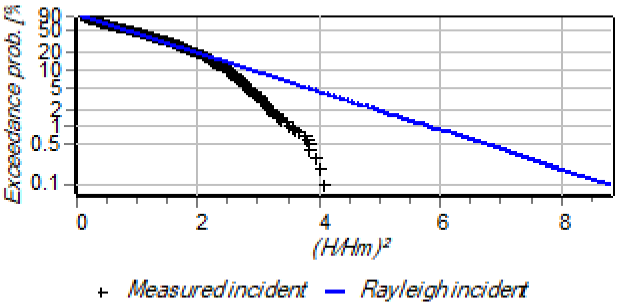


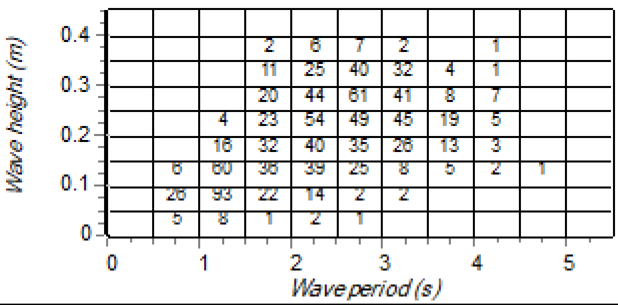
Overall amplitude reflection coefficient: *31.7%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.2687*	*0.08527*
Peak wave period T_P (s):	*3.2*	*3.2*
Energy wave period $T_{-1,0}$ (s):	*2.535*	*2.872*
Mean wave period $T_{0,1}$ (s):	*2.18*	*2.197*
Mean wave period $T_{0,2}$ (s):	*2.025*	*1.987*
Spectral width (Broadness):	*0.6187*	*0.6479*
Spectral width (Narrowness):	*0.3986*	*0.4718*

Time Domain Analysis

Overall amplitude reflection coefficient: *31.8%*





	Incident	**Reflected**
Number of waves:	1034	1132
Mean wave height H_m (m):	*0.1945*	*0.0707*
Mean wave period T_m (s):	*2.319*	*2.119*
Sig. wave height H_s (m):	*0.2914*	*0.09724*
$T_{H_{1/3}}$ (s):	*2.741*	*2.361*
H_{max} (m):	*0.3922*	*0.1673*
T_{Hmax} (s):	*1.866*	*3.458*
$H_{1/10}$ (m):	*0.3324*	*0.1156*
$H_{1/50}$ (m):	*0.3674*	*0.1314*
$H_{1/100}$ (m)	*0.3795*	*0.1359*
$H_{1/250}$ (m):	*0.3872*	*0.1427*
$H_{0.1\%}$ (m):	*0.3921*	*0.1637*
$H_{1\%}$ (m):	*0.3668*	*0.1295*
$H_{2\%}$ (m):	*0.3473*	*0.1249*
$H_{10\%}$ (m)	*0.3079*	*0.1022*
Groupiness factor GF:	*1.05*	*1.1*
Skewness b1:	*0.7882*	*0.1215*
Kurtosis b2:	*3.445*	*3.367*

Delta Marine Consultants

Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*32 of 48*

Reflection Analysis

Input Parameters

Generel

Data file:	*D:\...\batch 2\Output\H-25L-R30.txt*
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*
Water depth:	*0.6 m*
Length scale (Prototype/Model):	*1*
Skipped lines	*Header: 6 Start: 0 End: 0*

Bandpass filtering (Only for period calc.)

Freq. lower bound:	*0.104 Hz*
Freq. upper bound:	*0.938 Hz*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	*2*	*3*	*4*
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

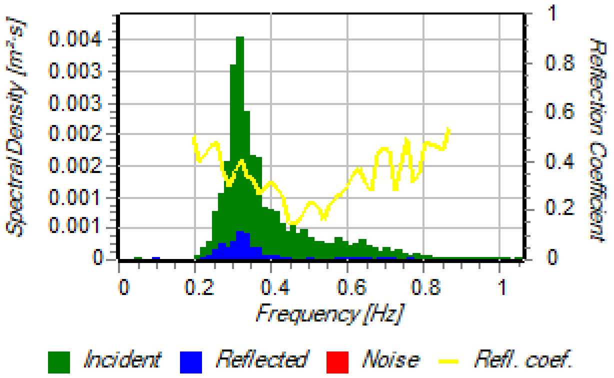
Freq. Domain Analysis

Overlap of subseries:	*20%*
Cosine taper width:	*20%*
Data No. in FFT block:	*4096*
Number of FFT blocks:	*46*

Time Domain Analysis

Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*61*
Hilbert filter length:	*2048*

Frequency Domain Analysis

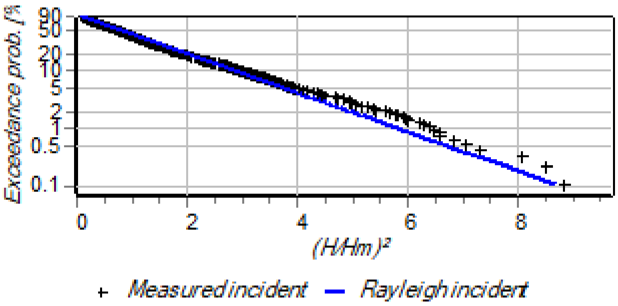


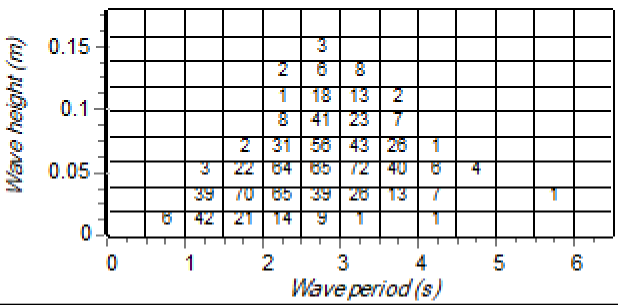
Overall amplitude reflection coefficient: *35.1%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.08113*	*0.02844*
Peak wave period T_P (s):	*3.2*	*3.2*
Energy wave period $T_{-1,0}$ (s):	*2.833*	*3.027*
Mean wave period $T_{0,1}$ (s):	*2.594*	*2.708*
Mean wave period $T_{0,2}$ (s):	*2.456*	*2.519*
Spectral width (Broadness):	*0.6163*	*0.686*
Spectral width (Narrowness):	*0.3407*	*0.3956*

Time Domain Analysis

Overall amplitude reflection coefficient: *35.1%*





	Incident	**Reflected**
Number of waves:	921	870
Mean wave height H_m (m):	*0.05111*	*0.01953*
Mean wave period T_m (s):	*2.605*	*2.755*
Sig. wave height H_s (m):	*0.08211*	*0.02892*
$T_{H_{1/3}}$ (s):	*2.945*	*3.07*
H_{max} (m):	*0.1519*	*0.04769*
T_{Hmax} (s):	*2.926*	*3.217*
$H_{1/10}$ (m):	*0.107*	*0.03454*
$H_{1/50}$ (m):	*0.1317*	*0.04051*
$H_{1/100}$ (m)	*0.1383*	*0.04285*
$H_{1/250}$ (m):	*0.1468*	*0.04531*
$H_{0.1\%}$ (m):	*Not enough data*	*Not enough data*
$H_{1\%}$ (m):	*0.13*	*0.03957*
$H_{2\%}$ (m):	*0.1215*	*0.03765*
$H_{10\%}$ (m)	*0.08875*	*0.03052*
Groupiness factor GF:	*1.172*	*0.9629*
Skewness b1:	*0.5305*	*0.1865*
Kurtosis b2:	*3.739*	*2.915*

Delta Marine Consultants

Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*33 of 48*

Reflection Analysis

Input Parameters

Generel

Data file:	*D:\...\batch 2\Output\H-25L-R40.txt*
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*
Water depth:	*0.6 m*
Length scale (Prototype/Model):	*1*
Skipped lines	*Header: 6 Start: 0 End: 0*

Bandpass filtering (Only for period calc.)

Freq. lower bound:	*0.104 Hz*
Freq. upper bound:	*0.938 Hz*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	*2*	*3*	*4*
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

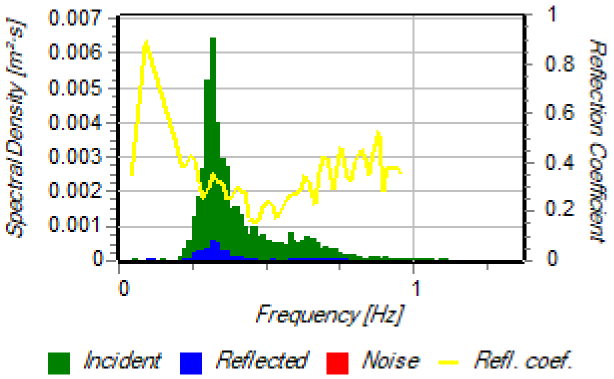
Freq. Domain Analysis

Overlap of subseries:	*20%*
Cosine taper width:	*20%*
Data No. in FFT block:	*4096*
Number of FFT blocks:	*51*

Time Domain Analysis

Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*61*
Hilbert filter length:	*2048*

Frequency Domain Analysis

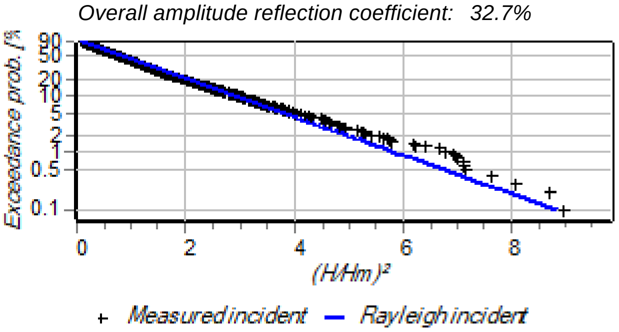


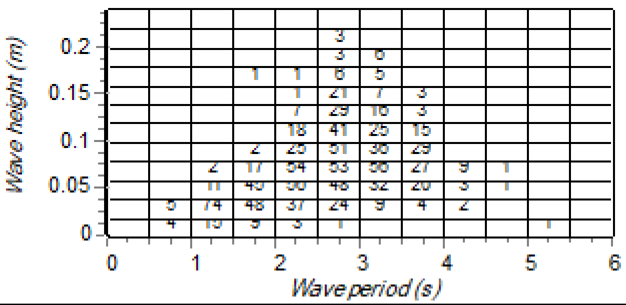
Overall amplitude reflection coefficient: *32.5%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.11*	*0.03577*
Peak wave period T_P (s):	*3.2*	*3.2*
Energy wave period $T_{-1,0}$ (s):	*2.779*	*2.964*
Mean wave period $T_{0,1}$ (s):	*2.513*	*2.572*
Mean wave period $T_{0,2}$ (s):	*2.364*	*2.371*
Spectral width (Broadness):	*0.6273*	*0.682*
Spectral width (Narrowness):	*0.3601*	*0.4199*

Time Domain Analysis

Overall amplitude reflection coefficient: *32.7%*





	Incident	**Reflected**
Number of waves:	1025	1016
Mean wave height H_m (m):	*0.07106*	*0.02566*
Mean wave period T_m (s):	*2.589*	*2.611*
Sig. wave height H_s (m):	*0.1137*	*0.03718*
$T_{H_{1/3}}$ (s):	*2.955*	*2.929*
H_{max} (m):	*0.2124*	*0.06493*
T_{Hmax} (s):	*2.859*	*2.955*
$H_{1/10}$ (m):	*0.1482*	*0.04475*
$H_{1/50}$ (m):	*0.1845*	*0.05415*
$H_{1/100}$ (m)	*0.1948*	*0.05818*
$H_{1/250}$ (m):	*0.2046*	*0.06183*
$H_{0.1\%}$ (m):	*0.2123*	*0.0649*
$H_{1\%}$ (m):	*0.1862*	*0.05447*
$H_{2\%}$ (m):	*0.1663*	*0.04801*
$H_{10\%}$ (m)	*0.1238*	*0.03908*
Groupiness factor GF:	*1.219*	*0.9911*
Skewness b1:	*0.6692*	*0.1608*
Kurtosis b2:	*3.98*	*3.017*

Delta Marine Consultants

Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*34 of 48*

Reflection Analysis

Input Parameters

Generel

Data file:	*D:\...\batch 2\Output\H-25L-R50.txt*
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*
Water depth:	*0.6 m*
Length scale (Prototype/Model):	*1*
Skipped lines	*Header: 6 Start: 0 End: 0*

Bandpass filtering (Only for period calc.)

Freq. lower bound:	*0.104 Hz*
Freq. upper bound:	*0.938 Hz*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	*2*	*3*	*4*
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

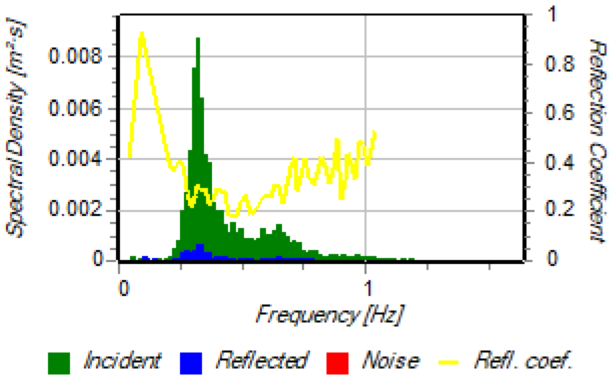
Freq. Domain Analysis

Overlap of subseries:	*20%*
Cosine taper width:	*20%*
Data No. in FFT block:	*4096*
Number of FFT blocks:	*46*

Time Domain Analysis

Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*61*
Hilbert filter length:	*2048*

Frequency Domain Analysis

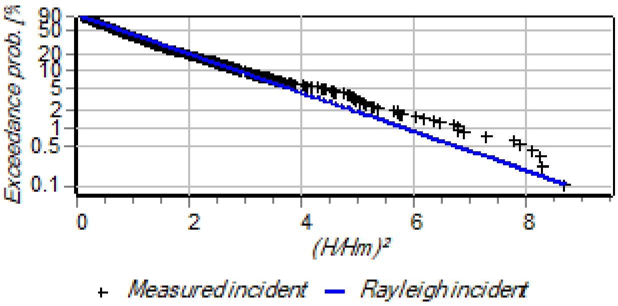


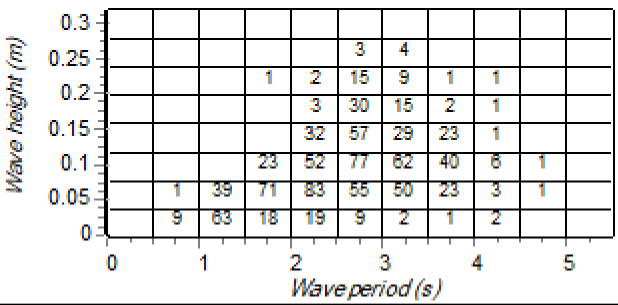
Overall amplitude reflection coefficient: *31.5%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.1376*	*0.04327*
Peak wave period T_P (s):	*3.2*	*3.048*
Energy wave period $T_{-1,0}$ (s):	*2.724*	*2.951*
Mean wave period $T_{0,1}$ (s):	*2.431*	*2.476*
Mean wave period $T_{0,2}$ (s):	*2.277*	*2.266*
Spectral width (Broadness):	*0.6308*	*0.6776*
Spectral width (Narrowness):	*0.3746*	*0.4399*

Time Domain Analysis

Overall amplitude reflection coefficient: *31.6%*





	Incident	**Reflected**
Number of waves:	939	972
Mean wave height H_m (m):	*0.09089*	*0.03256*
Mean wave period T_m (s):	*2.554*	*2.467*
Sig. wave height H_s (m):	*0.1468*	*0.04644*
$T_{H_{1/3}}$ (s):	*2.927*	*2.718*
H_{max} (m):	*0.2675*	*0.07451*
T_{Hmax} (s):	*2.89*	*2.911*
$H_{1/10}$ (m):	*0.1932*	*0.05588*
$H_{1/50}$ (m):	*0.2387*	*0.06496*
$H_{1/100}$ (m)	*0.2524*	*0.06699*
$H_{1/250}$ (m):	*0.2624*	*0.06883*
$H_{0.1\%}$ (m):	*Not enough data*	*Not enough data*
$H_{1\%}$ (m):	*0.2366*	*0.06486*
$H_{2\%}$ (m):	*0.2173*	*0.06107*
$H_{10\%}$ (m)	*0.1579*	*0.04936*
Groupiness factor GF:	*1.29*	*1.042*
Skewness b1:	*0.7957*	*0.1608*
Kurtosis b2:	*4.34*	*3.193*

Delta Marine Consultants

Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*35 of 48*

Reflection Analysis

Input Parameters

Generel

Data file:	*D:\...\batch 2\Output\H-25L-R70.txt*
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*
Water depth:	*0.6 m*
Length scale (Prototype/Model):	*1*
Skipped lines	*Header: 6 Start: 0 End: 0*

Bandpass filtering (Only for period calc.)

Freq. lower bound:	*0.104 Hz*
Freq. upper bound:	*0.938 Hz*

Freq. Domain Analysis

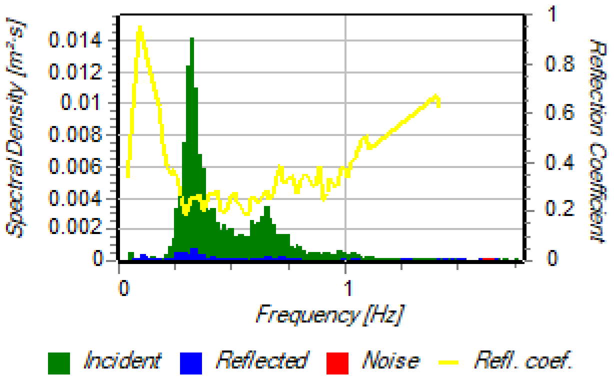
Overlap of subseries:	*20%*
Cosine taper width:	*20%*
Data No. in FFT block:	*4096*
Number of FFT blocks:	*46*

Time Domain Analysis

Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*61*
Hilbert filter length:	*2048*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	*2*	*3*	*4*
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

Frequency Domain Analysis

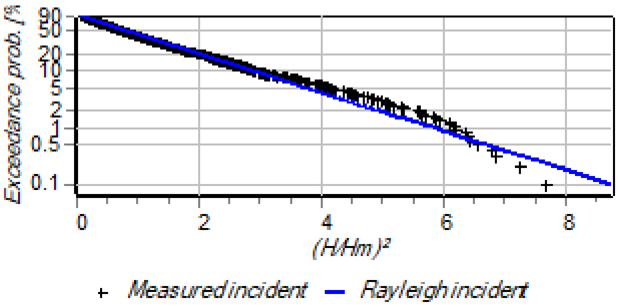


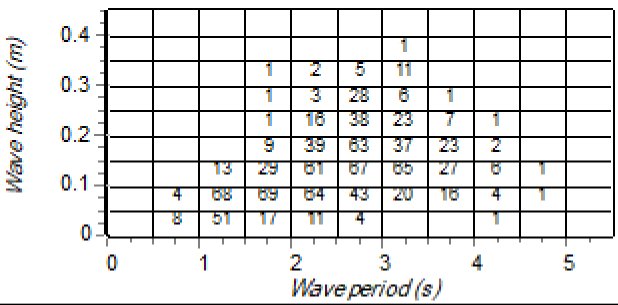
Overall amplitude reflection coefficient: *31.5%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.1876*	*0.05902*
Peak wave period T_P (s):	*3.2*	*3.048*
Energy wave period $T_{-1,0}$ (s):	*2.643*	*2.969*
Mean wave period $T_{0,1}$ (s):	*2.315*	*2.356*
Mean wave period $T_{0,2}$ (s):	*2.157*	*2.137*
Spectral width (Broadness):	*0.6293*	*0.667*
Spectral width (Narrowness):	*0.3901*	*0.4635*

Time Domain Analysis

Overall amplitude reflection coefficient: *31.5%*





	Incident	**Reflected**
Number of waves:	968	1062
Mean wave height H_m (m):	*0.1283*	*0.04595*
Mean wave period T_m (s):	*2.477*	*2.256*
Sig. wave height H_s (m):	*0.2065*	*0.06524*
$T_{H_{1/3}}$ (s):	*2.875*	*2.444*
H_{max} (m):	*0.3551*	*0.1141*
T_{Hmax} (s):	*3.083*	*1.63*
$H_{1/10}$ (m):	*0.2673*	*0.0804*
$H_{1/50}$ (m):	*0.3204*	*0.09893*
$H_{1/100}$ (m)	*0.3313*	*0.1057*
$H_{1/250}$ (m):	*0.3428*	*0.1114*
$H_{0.1\%}$ (m):	*Not enough data*	*0.1141*
$H_{1\%}$ (m):	*0.319*	*0.09741*
$H_{2\%}$ (m):	*0.3032*	*0.08824*
$H_{10\%}$ (m)	*0.2189*	*0.06918*
Groupiness factor GF:	*1.28*	*1.141*
Skewness b1:	*0.8611*	*0.1573*
Kurtosis b2:	*4.33*	*3.536*

Delta Marine Consultants

Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*37 of 48*

Reflection Analysis

Input Parameters

Generel

Data file:	*D:\...\batch 2\Output\H-25L-R80.txt*
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*
Water depth:	*0.6 m*
Length scale (Prototype/Model):	*1*
Skipped lines	*Header: 6 Start: 0 End: 0*

Bandpass filtering (Only for period calc.)

Freq. lower bound:	*0.104 Hz*
Freq. upper bound:	*0.938 Hz*

Freq. Domain Analysis

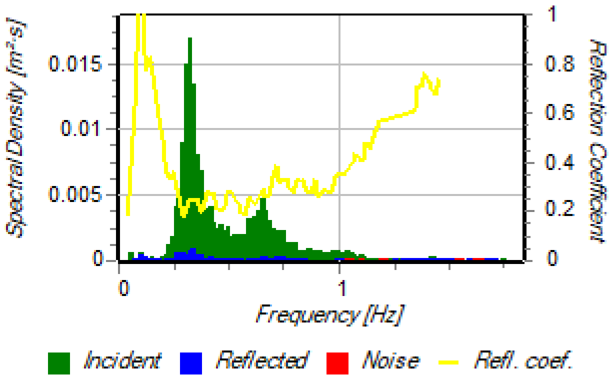
Overlap of subseries:	*20%*
Cosine taper width:	*20%*
Data No. in FFT block:	*4096*
Number of FFT blocks:	*46*

Time Domain Analysis

Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*61*
Hilbert filter length:	*2048*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	*2*	*3*	*4*
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

Frequency Domain Analysis

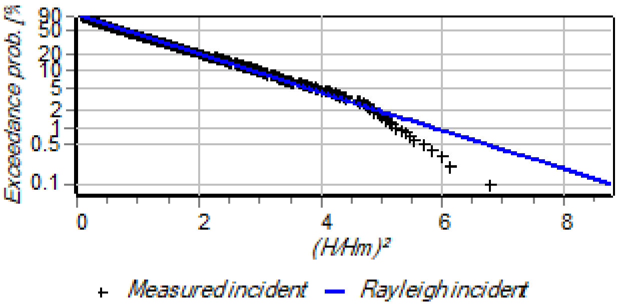


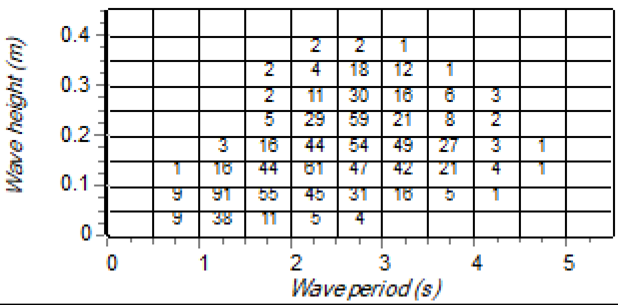
Overall amplitude reflection coefficient: *31.7%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.2119*	*0.06713*
Peak wave period T_P (s):	*3.2*	*3.048*
Energy wave period $T_{-1,0}$ (s):	*2.608*	*2.937*
Mean wave period $T_{0,1}$ (s):	*2.269*	*2.297*
Mean wave period $T_{0,2}$ (s):	*2.111*	*2.082*
Spectral width (Broadness):	*0.6265*	*0.6583*
Spectral width (Narrowness):	*0.3941*	*0.4657*

Time Domain Analysis

Overall amplitude reflection coefficient: *31.8%*





	Incident	**Reflected**
Number of waves:	988	1095
Mean wave height H_m (m):	*0.147*	*0.05323*
Mean wave period T_m (s):	*2.427*	*2.189*
Sig. wave height H_s (m):	*0.2355*	*0.07552*
$T_{H_{1/3}}$ (s):	*2.839*	*2.365*
H_{max} (m):	*0.3824*	*0.1299*
T_{Hmax} (s):	*2.901*	*2.812*
$H_{1/10}$ (m):	*0.2958*	*0.09237*
$H_{1/50}$ (m):	*0.3406*	*0.1142*
$H_{1/100}$ (m)	*0.352*	*0.1215*
$H_{1/250}$ (m):	*0.3653*	*0.1281*
$H_{0.1\%}$ (m):	*Not enough data*	*0.1298*
$H_{1\%}$ (m):	*0.3364*	*0.1109*
$H_{2\%}$ (m):	*0.3246*	*0.1031*
$H_{10\%}$ (m)	*0.2549*	*0.07936*
Groupiness factor GF:	*1.234*	*1.153*
Skewness b1:	*0.8718*	*0.1671*
Kurtosis b2:	*4.145*	*3.575*

Delta Marine Consultants

Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*38 of 48*

Reflection Analysis

Input Parameters

Generel				**Freq. Domain Analysis**	
Data file:	*D:\...\batch 2\Output\H-25L-R90.txt*			*Overlap of subseries:*	*20%*
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*			*Cosine taper width:*	*20%*
Water depth:	*0.6 m*			*Data No. in FFT block:*	*4096*
Length scale (Prototype/Model):	*1*			*Number of FFT blocks:*	*46*
Skipped lines	*Header: 6*	*Start: 0*	*End: 0*		

Time Domain Analysis

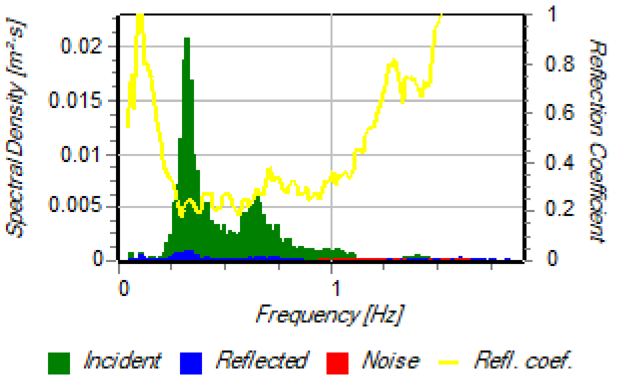
Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*61*
Hilbert filter length:	*2048*

Bandpass filtering (Only for period calc.)

Freq. lower bound:	*0.104 Hz*
Freq. upper bound:	*0.938 Hz*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	2	3	4
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

Frequency Domain Analysis

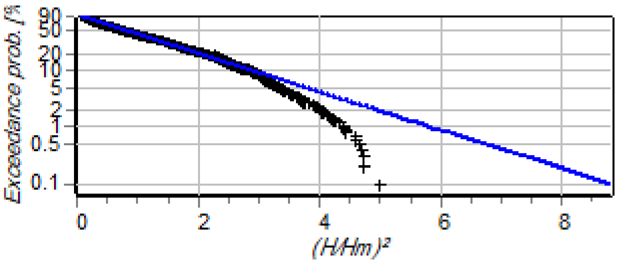


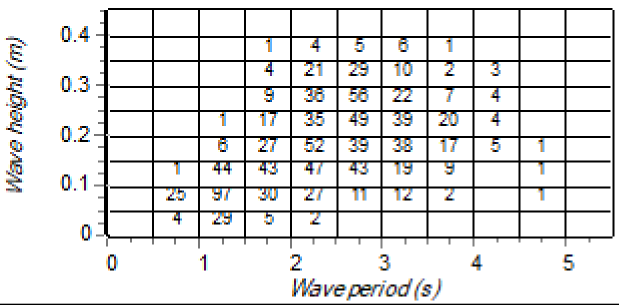
Overall amplitude reflection coefficient: *32.3%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.2448*	*0.07898*
Peak wave period T_P (s):	*3.2*	*3.048*
Energy wave period $T_{-1,0}$ (s):	*2.57*	*2.924*
Mean wave period $T_{0,1}$ (s):	*2.218*	*2.248*
Mean wave period $T_{0,2}$ (s):	*2.061*	*2.035*
Spectral width (Broadness):	*0.6232*	*0.6519*
Spectral width (Narrowness):	*0.3981*	*0.4698*

Time Domain Analysis

Overall amplitude reflection coefficient: *32.2%*





	Incident	**Reflected**
Number of waves:	1022	1120
Mean wave height H_m (m):	*0.1727*	*0.0635*
Mean wave period T_m(s):	*2.347*	*2.137*
Sig. wave height H_s (m):	*0.2709*	*0.0892*
$T_{H_{1/3}}$ (s):	*2.751*	*2.348*
H_{max} (m):	*0.3859*	*0.1703*
T_{Hmax} (s):	*2.52*	*3.131*
$H_{1/10}$ (m):	*0.323*	*0.1087*
$H_{1/50}$ (m):	*0.3621*	*0.1285*
$H_{1/100}$ (m)	*0.3712*	*0.1372*
$H_{1/250}$ (m):	*0.3776*	*0.1491*
$H_{0.1\%}$ (m):	*0.3856*	*0.1671*
$H_{1\%}$ (m):	*0.3626*	*0.1243*
$H_{2\%}$ (m):	*0.3469*	*0.1181*
$H_{10\%}$ (m)	*0.2939*	*0.09408*
Groupiness factor GF:	*1.146*	*1.144*
Skewness b1:	*0.8396*	*0.1291*
Kurtosis b2:	*3.802*	*3.483*

Delta Marine Consultants

Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*39 of 48*

Reflection Analysis

Input Parameters

Generel

Data file:	*D:\...\batch 2\Output\H-25L-R100.txt*
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*
Water depth:	*0.6 m*
Length scale (Prototype/Model):	*1*
Skipped lines	*Header: 6 Start: 0 End: 0*

Bandpass filtering (Only for period calc.)

Freq. lower bound:	*0.104 Hz*
Freq. upper bound:	*0.938 Hz*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	*2*	*3*	*4*
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

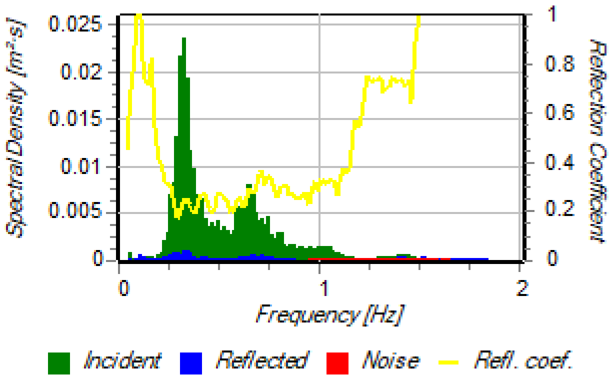
Freq. Domain Analysis

Overlap of subseries:	*20%*
Cosine taper width:	*20%*
Data No. in FFT block:	*4096*
Number of FFT blocks:	*46*

Time Domain Analysis

Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*61*
Hilbert filter length:	*2048*

Frequency Domain Analysis

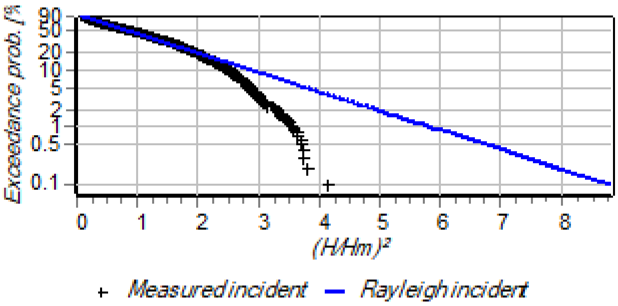


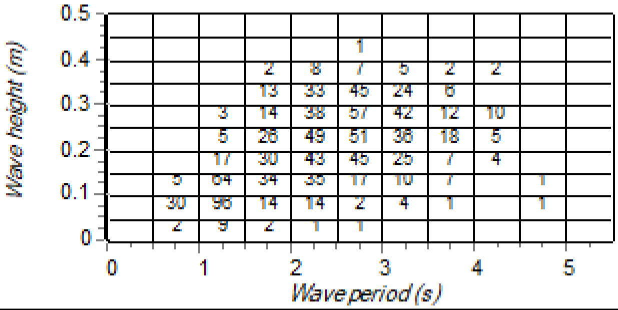
Overall amplitude reflection coefficient: *32.6%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.2723*	*0.08868*
Peak wave period T_P (s):	*3.2*	*3.048*
Energy wave period $T_{-1,0}$ (s):	*2.537*	*2.805*
Mean wave period $T_{0,1}$ (s):	*2.177*	*2.175*
Mean wave period $T_{0,2}$ (s):	*2.021*	*1.977*
Spectral width (Broadness):	*0.6199*	*0.6381*
Spectral width (Narrowness):	*0.4004*	*0.4583*

Time Domain Analysis

Overall amplitude reflection coefficient: *32.5%*





	Incident	**Reflected**
Number of waves:	1035	1146
Mean wave height H_m (m):	*0.1977*	*0.07294*
Mean wave period T_m (s):	*2.317*	*2.094*
Sig. wave height H_s (m):	*0.2962*	*0.1004*
$T_{H_{1/3}}$ (s):	*2.759*	*2.291*
H_{max} (m):	*0.4025*	*0.1906*
T_{Hmax} (s):	*2.864*	*3.687*
$H_{1/10}$ (m):	*0.339*	*0.119*
$H_{1/50}$ (m):	*0.3733*	*0.1421*
$H_{1/100}$ (m)	*0.3815*	*0.1505*
$H_{1/250}$ (m):	*0.388*	*0.1635*
$H_{0.1\%}$ (m):	*0.4019*	*0.1868*
$H_{1\%}$ (m):	*0.3731*	*0.1375*
$H_{2\%}$ (m):	*0.3589*	*0.1273*
$H_{10\%}$ (m)	*0.3138*	*0.1053*
Groupiness factor GF:	*1.05*	*1.118*
Skewness b1:	*0.78*	*0.1246*
Kurtosis b2:	*3.444*	*3.425*

Delta Marine Consultants

Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*40 of 48*

Reflection Analysis

Input Parameters

Generel

Data file:	*D:\...\batch 2\Output\M-2L-R30.txt*
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*
Water depth:	*0.6 m*
Length scale (Prototype/Model):	*1*
Skipped lines	*Header: 6 Start: 0 End: 0*

Bandpass filtering (Only for period calc.)

Freq. lower bound:	*0.104 Hz*
Freq. upper bound:	*0.938 Hz*

Freq. Domain Analysis

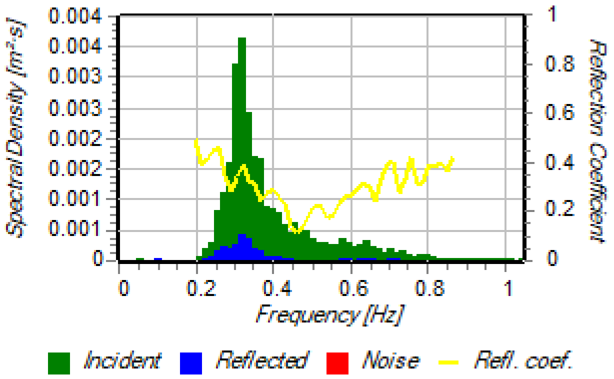
Overlap of subseries:	*20%*
Cosine taper width:	*20%*
Data No. in FFT block:	*4096*
Number of FFT blocks:	*46*

Time Domain Analysis

Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*61*
Hilbert filter length:	*2048*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	*2*	*3*	*4*
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

Frequency Domain Analysis

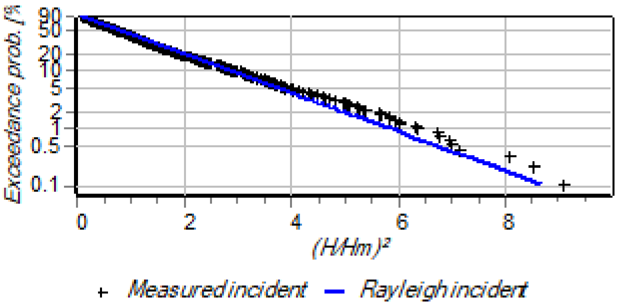


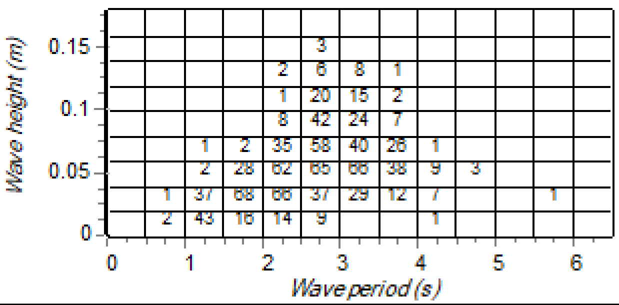
Overall amplitude reflection coefficient: *33%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.08233*	*0.02717*
Peak wave period T_P (s):	*3.2*	*3.2*
Energy wave period $T_{-1,0}$ (s):	*2.833*	*3.076*
Mean wave period $T_{0,1}$ (s):	*2.594*	*2.773*
Mean wave period $T_{0,2}$ (s):	*2.455*	*2.589*
Spectral width (Broadness):	*0.6168*	*0.6832*
Spectral width (Narrowness):	*0.3411*	*0.3843*

Time Domain Analysis

Overall amplitude reflection coefficient: *33.1%*





	Incident	**Reflected**
Number of waves:	918	847
Mean wave height H_m (m):	*0.05203*	*0.01897*
Mean wave period T_m (s):	*2.612*	*2.83*
Sig. wave height H_s (m):	*0.0833*	*0.02753*
$T_{H_{1/3}}$ (s):	*2.934*	*3.127*
H_{max} (m):	*0.1567*	*0.04288*
T_{Hmax} (s):	*2.909*	*3.179*
$H_{1/10}$ (m):	*0.1085*	*0.03306*
$H_{1/50}$ (m):	*0.1335*	*0.03864*
$H_{1/100}$ (m)	*0.1411*	*0.04071*
$H_{1/250}$ (m):	*0.1497*	*0.04271*
$H_{0.1\%}$ (m):	*Not enough data*	*Not enough data*
$H_{1\%}$ (m):	*0.1311*	*0.0374*
$H_{2\%}$ (m):	*0.1226*	*0.03577*
$H_{10\%}$ (m)	*0.09136*	*0.02897*
Groupiness factor GF:	*1.165*	*0.9324*
Skewness b1:	*0.5233*	*0.09319*
Kurtosis b2:	*3.715*	*2.819*

Delta Marine Consultants

Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*41 of 48*

Reflection Analysis

Input Parameters

Generel

Data file:	*D:\...\batch 2\Output\M-2L-R40.txt*		
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*		
Water depth:	*0.6 m*		
Length scale (Prototype/Model):	*1*		
Skipped lines	*Header: 6*	*Start: 0*	*End: 0*

Bandpass filtering (Only for period calc.)

Freq. lower bound:	*0.104 Hz*
Freq. upper bound:	*0.938 Hz*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	2	3	4
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

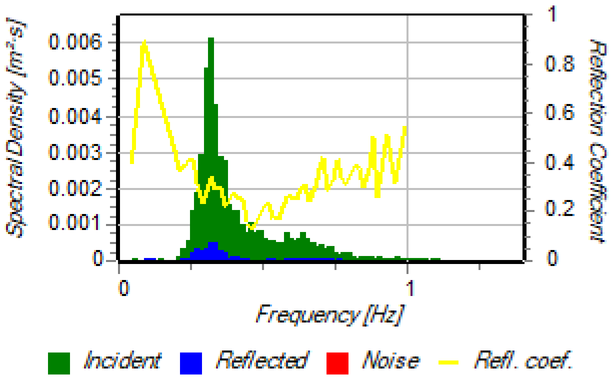
Freq. Domain Analysis

Overlap of subseries:	*20%*
Cosine taper width:	*20%*
Data No. in FFT block:	*4096*
Number of FFT blocks:	*46*

Time Domain Analysis

Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*61*
Hilbert filter length:	*2048*

Frequency Domain Analysis

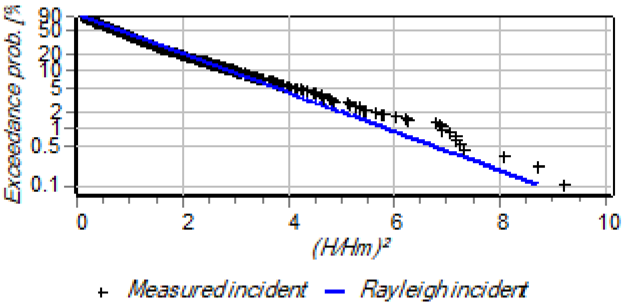


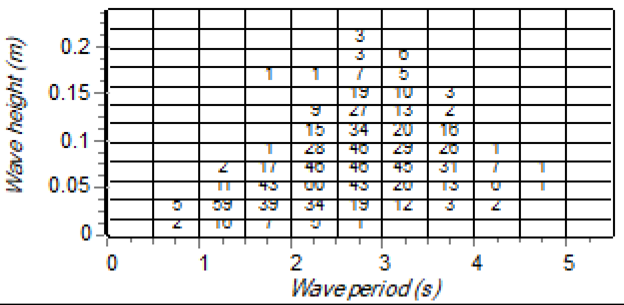
Overall amplitude reflection coefficient: *31%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.1111*	*0.03442*
Peak wave period T_P (s):	*3.2*	*3.2*
Energy wave period $T_{-1,0}$ (s):	*2.777*	*3.014*
Mean wave period $T_{0,1}$ (s):	*2.508*	*2.618*
Mean wave period $T_{0,2}$ (s):	*2.36*	*2.412*
Spectral width (Broadness):	*0.6271*	*0.687*
Spectral width (Narrowness):	*0.3608*	*0.4214*

Time Domain Analysis

Overall amplitude reflection coefficient: *31%*





	Incident	**Reflected**
Number of waves:	927	908
Mean wave height H_m (m):	*0.07189*	*0.02502*
Mean wave period T_m (s):	*2.587*	*2.642*
Sig. wave height H_s (m):	*0.1156*	*0.03579*
$T_{H_{1/3}}$ (s):	*2.952*	*2.904*
H_{max} (m):	*0.2179*	*0.0631*
T_{Hmax} (s):	*2.866*	*2.208*
$H_{1/10}$ (m):	*0.1518*	*0.04317*
$H_{1/50}$ (m):	*0.1883*	*0.05148*
$H_{1/100}$ (m)	*0.1981*	*0.05476*
$H_{1/250}$ (m):	*0.208*	*0.05804*
$H_{0.1\%}$ (m):	*Not enough data*	*Not enough data*
$H_{1\%}$ (m):	*0.1888*	*0.05126*
$H_{2\%}$ (m):	*0.1692*	*0.04606*
$H_{10\%}$ (m)	*0.125*	*0.0382*
Groupiness factor GF:	*1.233*	*0.9908*
Skewness b1:	*0.6767*	*0.111*
Kurtosis b2:	*4.047*	*3.013*

Delta Marine Consultants

Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*42 of 48*

Reflection Analysis

Input Parameters

Generel

Data file:	*D:\...\batch 2\Output\M-2L-R50.txt*
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*
Water depth:	*0.6 m*
Length scale (Prototype/Model):	*1*
Skipped lines	*Header: 6 Start: 0 End: 0*

Bandpass filtering (Only for period calc.)

Freq. lower bound:	*0.104 Hz*
Freq. upper bound:	*0.938 Hz*

Freq. Domain Analysis

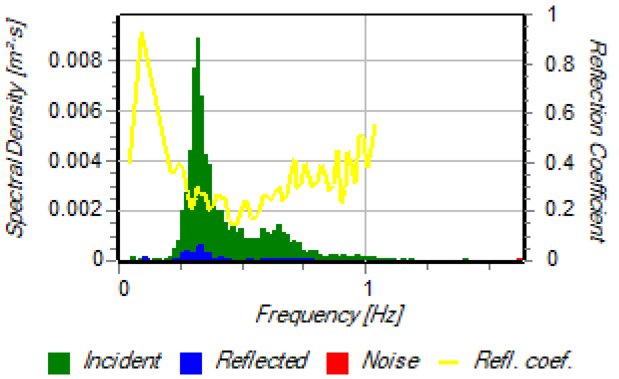
Overlap of subseries:	*20%*
Cosine taper width:	*20%*
Data No. in FFT block:	*4096*
Number of FFT blocks:	*46*

Time Domain Analysis

Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*61*
Hilbert filter length:	*2048*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	*2*	*3*	*4*
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

Frequency Domain Analysis

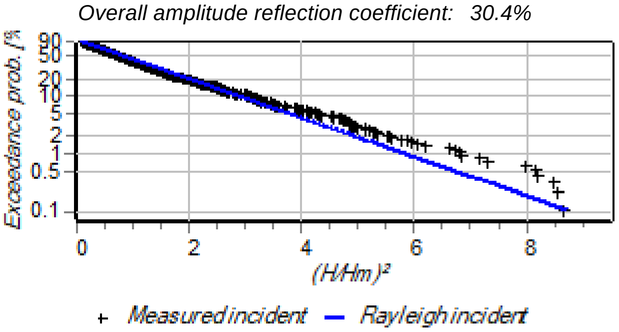


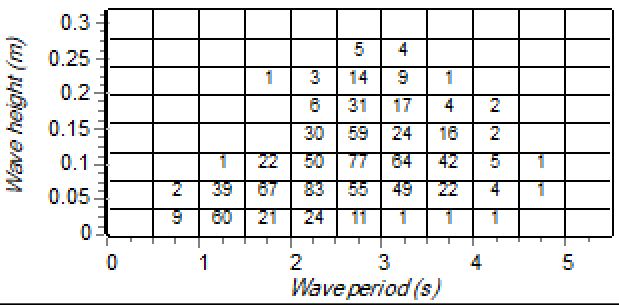
Overall amplitude reflection coefficient: *30.3%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.1389*	*0.04205*
Peak wave period T_P (s):	*3.2*	*3.048*
Energy wave period $T_{-1,0}$ (s):	*2.722*	*2.979*
Mean wave period $T_{0,1}$ (s):	*2.429*	*2.495*
Mean wave period $T_{0,2}$ (s):	*2.274*	*2.281*
Spectral width (Broadness):	*0.6314*	*0.6812*
Spectral width (Narrowness):	*0.3752*	*0.4438*

Time Domain Analysis

Overall amplitude reflection coefficient: *30.4%*





	Incident	**Reflected**
Number of waves:	940	957
Mean wave height H_m (m):	*0.09174*	*0.03212*
Mean wave period T_m (s):	*2.551*	*2.504*
Sig. wave height H_s (m):	*0.1483*	*0.04543*
$T_{H_{1/3}}$ (s):	*2.912*	*2.721*
H_{max} (m):	*0.2697*	*0.0707*
T_{Hmax} (s):	*2.878*	*3.104*
$H_{1/10}$ (m):	*0.1953*	*0.05463*
$H_{1/50}$ (m):	*0.2418*	*0.06399*
$H_{1/100}$ (m)	*0.2571*	*0.06673*
$H_{1/250}$ (m):	*0.2671*	*0.06894*
$H_{0.1\%}$ (m):	*Not enough data*	*Not enough data*
$H_{1\%}$ (m):	*0.2397*	*0.06383*
$H_{2\%}$ (m):	*0.2166*	*0.05936*
$H_{10\%}$ (m)	*0.1614*	*0.04797*
Groupiness factor GF:	*1.292*	*1.054*
Skewness b1:	*0.7981*	*0.115*
Kurtosis b2:	*4.349*	*3.218*

Delta Marine Consultants

Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*43 of 48*

Reflection Analysis

Input Parameters

Generel

Data file:	*D:\...\batch 2\Output\M-2L-R70.txt*
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*
Water depth:	*0.6 m*
Length scale (Prototype/Model):	*1*
Skipped lines	*Header: 6 Start: 0 End: 0*

Bandpass filtering (Only for period calc.)

Freq. lower bound:	*0.104 Hz*
Freq. upper bound:	*0.938 Hz*

Freq. Domain Analysis

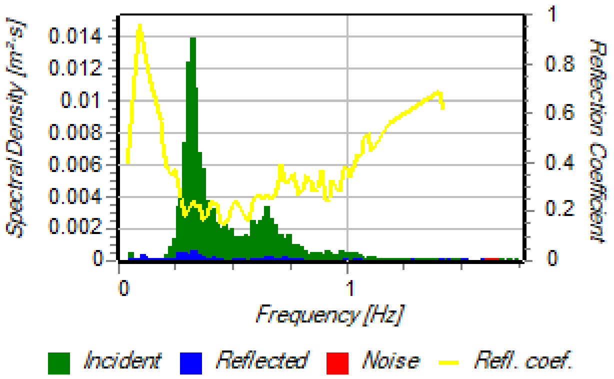
Overlap of subseries:	*20%*
Cosine taper width:	*20%*
Data No. in FFT block:	*4096*
Number of FFT blocks:	*46*

Time Domain Analysis

Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*61*
Hilbert filter length:	*2048*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	*2*	*3*	*4*
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

Frequency Domain Analysis

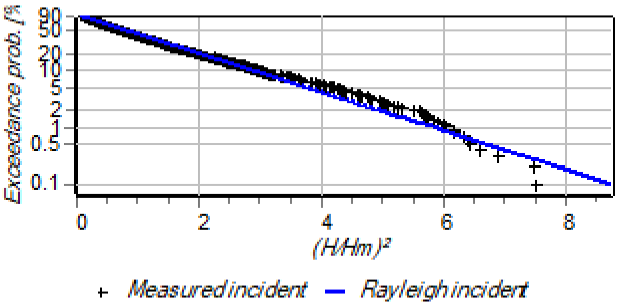


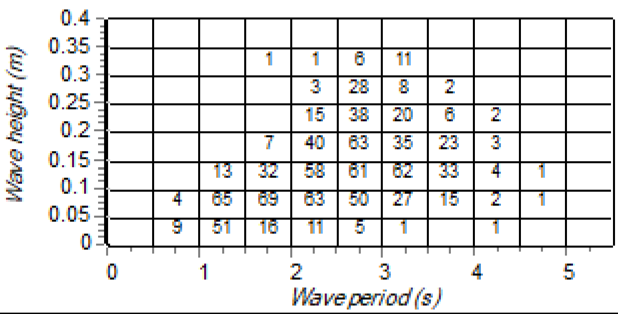
Overall amplitude reflection coefficient: *30.2%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.1863*	*0.05629*
Peak wave period T_P (s):	*3.2*	*3.048*
Energy wave period $T_{-1,0}$ (s):	*2.643*	*2.993*
Mean wave period $T_{0,1}$ (s):	*2.316*	*2.343*
Mean wave period $T_{0,2}$ (s):	*2.158*	*2.116*
Spectral width (Broadness):	*0.6291*	*0.6697*
Spectral width (Narrowness):	*0.3897*	*0.4751*

Time Domain Analysis

Overall amplitude reflection coefficient: *30.2%*





	Incident	**Reflected**
Number of waves:	966	1055
Mean wave height H_m (m):	*0.1273*	*0.04461*
Mean wave period T_m (s):	*2.482*	*2.273*
Sig. wave height H_s (m):	*0.2052*	*0.06395*
$T_{H_{1/3}}$ (s):	*2.875*	*2.446*
H_{max} (m):	*0.349*	*0.1136*
T_{Hmax} (s):	*3.072*	*1.778*
$H_{1/10}$ (m):	*0.2658*	*0.07882*
$H_{1/50}$ (m):	*0.3163*	*0.0948*
$H_{1/100}$ (m)	*0.3271*	*0.1023*
$H_{1/250}$ (m):	*0.34*	*0.1089*
$H_{0.1\%}$ (m):	*Not enough data*	*0.1134*
$H_{1\%}$ (m):	*0.3134*	*0.09256*
$H_{2\%}$ (m):	*0.3006*	*0.08494*
$H_{10\%}$ (m)	*0.2207*	*0.06835*
Groupiness factor GF:	*1.284*	*1.171*
Skewness b1:	*0.8738*	*0.1203*
Kurtosis b2:	*4.34*	*3.67*

Delta Marine Consultants

Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*45 of 48*

Reflection Analysis

Input Parameters

Generel

Data file:	*D:\...\batch 2\Output\M-2L-R80.txt*
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*
Water depth:	*0.6 m*
Length scale (Prototype/Model):	*1*
Skipped lines	*Header: 6 Start: 0 End: 0*

Bandpass filtering (Only for period calc.)

Freq. lower bound:	*0.104 Hz*
Freq. upper bound:	*0.938 Hz*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	*2*	*3*	*4*
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

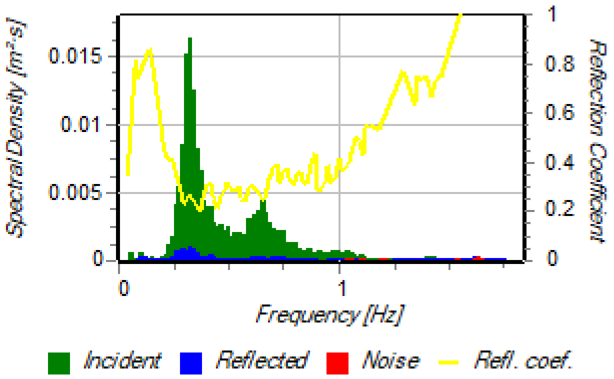
Freq. Domain Analysis

Overlap of subseries:	*20%*
Cosine taper width:	*20%*
Data No. in FFT block:	*4096*
Number of FFT blocks:	*46*

Time Domain Analysis

Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*61*
Hilbert filter length:	*2048*

Frequency Domain Analysis

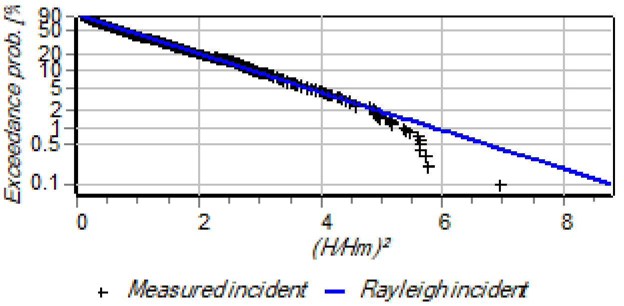


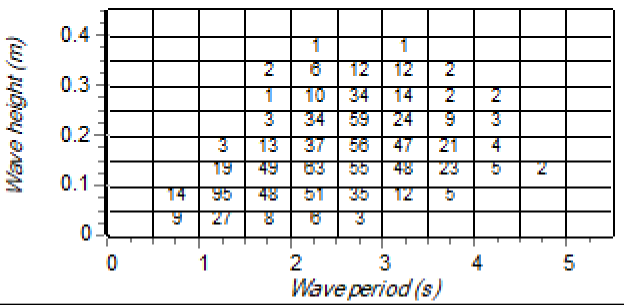
Overall amplitude reflection coefficient: *34.3%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.2097*	*0.07194*
Peak wave period T_P (s):	*3.2*	*3.2*
Energy wave period $T_{-1,0}$ (s):	*2.609*	*2.907*
Mean wave period $T_{0,1}$ (s):	*2.271*	*2.3*
Mean wave period $T_{0,2}$ (s):	*2.113*	*2.088*
Spectral width (Broadness):	*0.6264*	*0.6597*
Spectral width (Narrowness):	*0.3936*	*0.4621*

Time Domain Analysis

Overall amplitude reflection coefficient: *34.4%*





	Incident	**Reflected**
Number of waves:	989	1093
Mean wave height H_m (m):	*0.1458*	*0.05604*
Mean wave period T_m (s):	*2.426*	*2.194*
Sig. wave height H_s (m):	*0.2327*	*0.08111*
$T_{H_{1/3}}$ (s):	*2.843*	*2.46*
H_{max} (m):	*0.3846*	*0.1462*
T_{Hmax} (s):	*2.368*	*1.782*
$H_{1/10}$ (m):	*0.2912*	*0.09999*
$H_{1/50}$ (m):	*0.3373*	*0.1209*
$H_{1/100}$ (m)	*0.3485*	*0.129*
$H_{1/250}$ (m):	*0.3577*	*0.1355*
$H_{0.1\%}$ (m):	*Not enough data*	*0.1452*
$H_{1\%}$ (m):	*0.3374*	*0.1194*
$H_{2\%}$ (m):	*0.3216*	*0.1091*
$H_{10\%}$ (m)	*0.2509*	*0.08488*
Groupiness factor GF:	*1.228*	*1.174*
Skewness b1:	*0.8559*	*0.1962*
Kurtosis b2:	*4.108*	*3.673*

Delta Marine Consultants

Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*46 of 48*

Reflection Analysis

Input Parameters

Generel

Data file:	*D:\...\batch 2\Output\M-2L-R90.txt*
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*
Water depth:	*0.6 m*
Length scale (Prototype/Model):	*1*
Skipped lines	*Header: 6 Start: 0 End: 0*

Bandpass filtering (Only for period calc.)

Freq. lower bound:	*0.109 Hz*
Freq. upper bound:	*0.984 Hz*

Freq. Domain Analysis

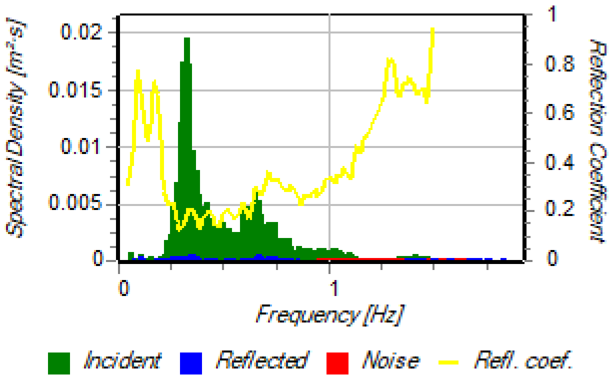
Overlap of subseries:	*20%*
Cosine taper width:	*20%*
Data No. in FFT block:	*4096*
Number of FFT blocks:	*46*

Time Domain Analysis

Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*59*
Hilbert filter length:	*2048*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	*2*	*3*	*4*
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

Frequency Domain Analysis

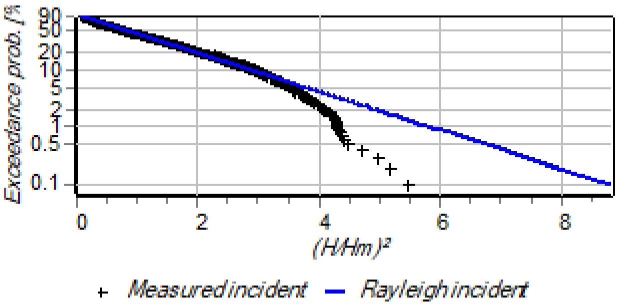


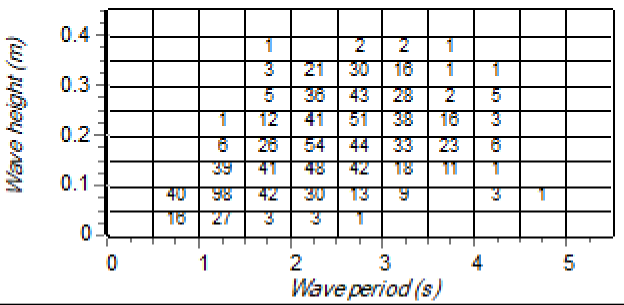
Overall amplitude reflection coefficient: *28.4%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.2404*	*0.06826*
Peak wave period T_p (s):	*3.2*	*3.048*
Energy wave period $T_{-1,0}$ (s):	*2.542*	*2.53*
Mean wave period $T_{0,1}$ (s):	*2.184*	*1.963*
Mean wave period $T_{0,2}$ (s):	*2.021*	*1.799*
Spectral width (Broadness):	*0.6363*	*0.6056*
Spectral width (Narrowness):	*0.4087*	*0.437*

Time Domain Analysis

Overall amplitude reflection coefficient: *28.4%*





	Incident	**Reflected**
Number of waves:	1037	1289
Mean wave height H_m (m):	*0.1672*	*0.05512*
Mean wave period T_m (s):	*2.313*	*1.86*
Sig. wave height H_s (m):	*0.265*	*0.07891*
$T_{H_{1/3}}$ (s):	*2.756*	*1.947*
H_{max} (m):	*0.3908*	*0.1257*
T_{Hmax} (s):	*3.12*	*2.152*
$H_{1/10}$ (m):	*0.318*	*0.09796*
$H_{1/50}$ (m):	*0.3511*	*0.1134*
$H_{1/100}$ (m)	*0.3596*	*0.1175*
$H_{1/250}$ (m):	*0.3757*	*0.1213*
$H_{0.1\%}$ (m):	*0.3904*	*0.1245*
$H_{1\%}$ (m):	*0.3455*	*0.1131*
$H_{2\%}$ (m):	*0.3378*	*0.1069*
$H_{10\%}$ (m)	*0.2889*	*0.08511*
Groupiness factor GF:	*1.151*	*1.165*
Skewness b1:	*0.8514*	*-0.008345*
Kurtosis b2:	*3.842*	*3.614*

Delta Marine Consultants

Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*47 of 48*

Reflection Analysis

Input Parameters

Generel

Data file:	*D:\...\batch 2\Output\M-2L-R100.txt*
Sample frequency:	*128 Hz (Downsampled to 64 Hz)*
Water depth:	*0.6 m*
Length scale (Prototype/Model):	*1*
Skipped lines	*Header: 6 Start: 0 End: 0*

Bandpass filtering (Only for period calc.)

Freq. lower bound:	*0.109 Hz*
Freq. upper bound:	*0.984 Hz*

Freq. Domain Analysis

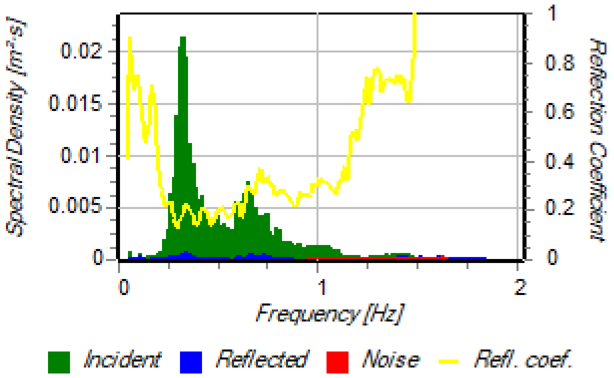
Overlap of subseries:	*20%*
Cosine taper width:	*20%*
Data No. in FFT block:	*4096*
Number of FFT blocks:	*46*

Time Domain Analysis

Output timeseries at x-coordinate:	*0.3333 m*
Min. points between downcrossings:	*59*
Hilbert filter length:	*2048*

	Gauge 1	*Gauge 2*	*Gauge 3*
Channel number:	*2*	*3*	*4*
Calibration function:	*1.0*X*	*1.0*X*	*1.0*X*
X-coordinate:	*0.0 m*	*0.3 m*	*0.7 m*

Frequency Domain Analysis

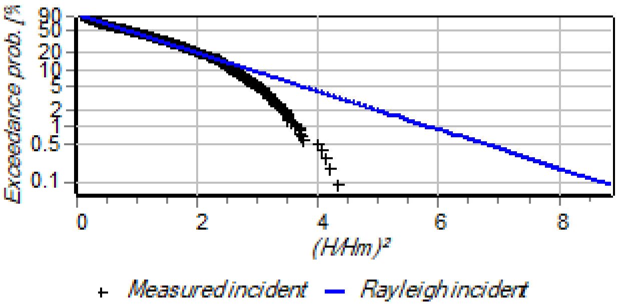


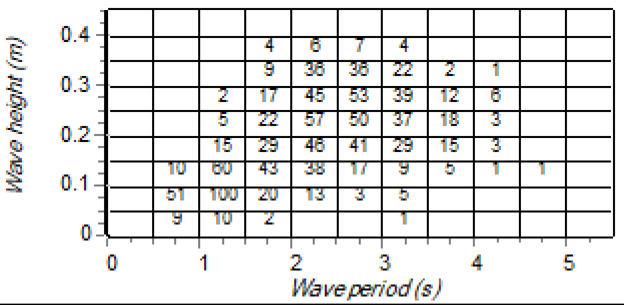
Overall amplitude reflection coefficient: *29.5%*

	Incident	**Reflected**
Sig. wave height H_{m0} (m):	*0.2667*	*0.07869*
Peak wave period T_P (s):	*3.2*	*3.048*
Energy wave period $T_{-1,0}$ (s):	*2.499*	*2.476*
Mean wave period $T_{0,1}$ (s):	*2.133*	*1.938*
Mean wave period $T_{0,2}$ (s):	*1.974*	*1.782*
Spectral width (Broadness):	*0.6313*	*0.5973*
Spectral width (Narrowness):	*0.4102*	*0.4285*

Time Domain Analysis

Overall amplitude reflection coefficient: *29.5%*





	Incident	**Reflected**
Number of waves:	1069	1303
Mean wave height H_m (m):	*0.1892*	*0.06412*
Mean wave period T_m (s):	*2.244*	*1.84*
Sig. wave height H_s (m):	*0.2888*	*0.0907*
$T_{H_{1/3}}$ (s):	*2.683*	*1.99*
H_{max} (m):	*0.3932*	*0.1428*
T_{Hmax} (s):	*1.919*	*1.881*
$H_{1/10}$ (m):	*0.3324*	*0.1106*
$H_{1/50}$ (m):	*0.3638*	*0.1263*
$H_{1/100}$ (m)	*0.3738*	*0.1312*
$H_{1/250}$ (m):	*0.3859*	*0.1359*
$H_{0.1\%}$ (m):	*0.3928*	*0.1418*
$H_{1\%}$ (m):	*0.3616*	*0.1259*
$H_{2\%}$ (m):	*0.3506*	*0.1197*
$H_{10\%}$ (m)	*0.3061*	*0.09786*
Groupiness factor GF:	*1.059*	*1.158*
Skewness b1:	*0.8081*	*0.03839*
Kurtosis b2:	*3.496*	*3.517*

Delta Marine Consultants

Project title	
Drawn by	
Date	*27. Nov 2024*
Remarks	
Page	*48 of 48*