Hydraulic Performance of Xbloc+ Armor Unit

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Technische Universiteit Delft

TU Delft Delft University of Technology

Challenge the future

Hydraulic Performance of Xbloc+ Armor Unit

by

María Belén Rada Mora

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Master of Science in

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CoMEM

HYDRAULIC PERFOMANCE OF XBLOC+ ARMOR UNIT

Delft University of Technology
July 10th, 2017

María Belén Rada Mora

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CoMEM Master Thesis

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Salutis mutis amperigiles
enfermus bursis surcitis
por la felicidad de la paja toquilla y los pueblos cultos.

Jorge Rada Chávez

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SUMMARY

In recent years, the use of Xbloc units has increased exponentially. However, the placement of this unit is not always done as randomly as it should be and consequently, the stability of the armor is affected. In order to overcome this problem, Delta Marine Consultants is developing a new armor unit called Xbloc+ that has a regular placement. In this research, the hydraulic performance of version 1 and 2 of this block are analyzed. Small scale tests were performed in a 2D wave flume in order to analyze the damage, rocking and the (partially and fully) displacement of units. In total, 1 series of tests were performed with Xbloc+$_{v1}$ and 6 series with Xbloc+$_{v2}$. To analyze the influence of the wave steepness and the slope angle, three wave steepness were tested (Sop = 2%, 4% and 6%) and tests were conducted in two different slope angles (1:2 and 3:4). Each series is formed by several sub tests conducted with increasing wave heights (and wave period in order to maintain a constant wave steepness). Tests were carried out until the failure of the armor slope was reached in order to completely define the failure mechanism. Furthermore, tests after failure where also executed to further investigate the stability of the armor after the damage has started.

Results obtained from the laboratory tests provided an overall understanding of how the Xbloc+ performs under certain conditions. It was perceived that the permeability of the armor layer is low as it happens often with single layer units. Thus, the pressure gradient between the underlayer and armor layer is significantly high creating an uplift pressure that leads to a revetment-like failure mechanism.

Although the failure mechanism can be related to both slopes used during the laboratory tests, (3:4 and 1:2), the behavior of the armor layer differed completely between slopes. On a steeper slope, the armor layer remained undamaged for wave heights significantly higher than the design wave. However, once one unit was fully displaced, the damage was quite destructive.

In contrast, on a milder slope, failure occurred much faster but the damage was not as aggressive. Moreover, after the failure was reached, the structure gained a new level of stability in which remained to provide shelter without reflecting significant damage.

Furthermore, the wave height variation did not have much influence as the wave steepness. There was a noticeable difference between the performance of the structure during swell and wind waves. During swell waves, it could be seen that not only failure was achieved faster but it caused much more damage to the structure, while during wind waves the structure had a higher stability.

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As unbelievable as it seems, my CoMEM experience is coming to an end. A time full of the most amazing experiences a person could ever wish for, a period for learning not only about courses and science, but also about yourself and all that you are capable of.

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NOTATION

Symbol	Description	Units
F_D	Drag force	N
C_D	Drag coefficient	[-]
ρ_w	Water density	kg/m^3
u	Flow velocity in run-up or run-down	m/s
A_i	Exposed area to flow where i = D (drag), L(lift) or S(shear)	m^2
F_S	Shear force	N
C_S	Shear coefficient	[-]
F_L	Lift force	N
C_L	Lift coefficient	[-]
W	Weight of the armour unit	N
D_{n50}	Median nominal diameter	m
ρ_c	Concrete density	kg/m^3
F_I	Inertia	N
C_M	Mass coefficient	[-]
F_F	Friction force	N
F_w	Wave force	N
H	Wave height	m
μ	Friction coefficient in Eq.2.6	[-]
K_D	Stability coefficient	[-]
φ	Angle of repose of the armour	deg
α	Angle between structure slope and horizontal	deg
ξ_{op}	Spectral breaker parameter based on Sop	[-]
$H_{1/3}$	Significant wave height defined as highest one-third of wave heights	m
H_s	Significant wave height = H1/3	m
L_{op}	wave length based on Tp in deep water	m
T_p	Spectral peak wave period	s
N_{od}	Damage number due to displaced units	[-]
D_n	Nominal diameter of concrete armour unit	m
N_{or}	Damage number due to rocking units	[-]
N_{omov}	Total number of moving units	[-]
Δ	Relative density	[-]
N	Number of waves	[-]
S	Dimensionless damage level	[-]
c_s	Coefficient for surging waves	[-]
c_{pl}	Coefficient for plunging waves	[-]
P	Permeability coefficient of the structure	[-]
ξ_m	Spectral breaker parameter based on Tm	[-]
U	Velocity of the fluid	m/s
L	Length of the fluid	m

Symbol	Description	Units
μ	Dynamic viscosity	kg/ms
Re	Reynolds number	[-]
Fr	Froude number	[-]
g	Gravity (=9.81)	m/s^2
T	wave period	s
$T_{1/3}$	Significant wave period	s
T_m	Mean wave period	s
V	Volume of the unit	m^3
D	Width of the unit	m
β	Coefficient in Eq.3.2	[-]
α	Shape coefficient in Eq.3.1	[-]
h	Water depth	m
h_t	Water depth on the toe	m
H_{design} or H_D	Design significant wave height	m
s_{op}	Wave steepness based on L_{0p}	[-]
N_s	Stability number	[-]
k_T	Permeability of the top layer	m/s
k_F	Permeability of the filter layer	m/s
ϕ_F	Pressure at the filter layer	Pa
ϕ_T	Pressure at the top layer	Pa
Λ	Leakage length	m
$R_{d2\%max}$	Maximum 2%-wave run-down	m
n_{displ}	Number of partially or completely displaced units	[-]
B_{tests}	Width of the test area	m
γ	Peak-emhancement factor from JONSWAP-spectrum	[-]
P_{armour}	porosity of the armour layer (%)	[-]
N	packing density	1/100 m^2
d_T	layer thinckness	m
d_F	filter thickness	m

1

INTRODUCTION

The contents of this chapter represent an overall introduction of the research project. Its purpose is to help the reader to fully understand the objective and aims of the analysis of a new concrete unit, Xbloc+. Initially, section 1.1 provides an overview on breakwaters. Section 1.2 introduces the main problem, which will be analyzed throughout this report. Following, section 1.3 gives the objectives of this research while section 1.4 provides the general methodology to achieve the aforementioned objectives.

1.1. BREAKWATERS

Breakwaters are structural configurations used world wide to decrease the waves effects, providing shelter and protection for population as well as for vessels, ports facilities, and other natural or man-made marine constructions. Although there are different types of breakwaters - such as floating, monolithic, and rubble mound- this research project focuses only on the ruble mound type.

As shown in figure 1.1, a rubble mound breakwater consists of a core of fine quarry material, an underlayer of bigger material, a toe berm, and an armor layer, which can be made out of stones or concrete units placed in a double or single layer.

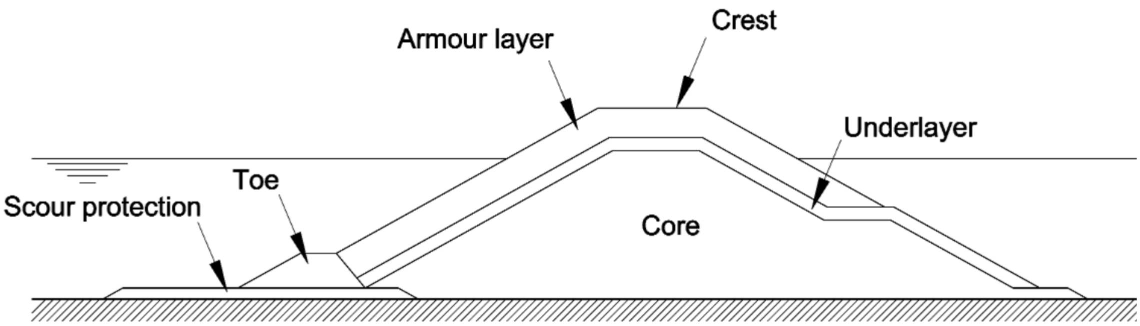

Figure 1.1: Conventional breakwater scheme [6]

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The thickness of each layer is dependent on several factors like for instance wave climate or characteristics of the concrete unit/armor rock. Some of the most used concrete units are:

(a) Xbloc

(b) Accropode II

(c) Cube

(d) Tetrapod

(e) Dolos

Figure 1.2: Commonly used concrete units.

1.2. PROBLEM DESCRIPTION

The Xbloc is a compact armor unit with large structural strength. This type of unit is placed on a predefined grid; the orientation of individual blocks varies randomly and is thus not prescribed. The latter is the main difference between Xbloc and other single layer interlocking armor units **[18]**.

In recent years, the use of Xbloc units has increased exponentially. Although this type of unit has a high resistance to wave impact, high interlocking forces, among other things, the placement is a key parameter that can affect the stability of the armor. Since the placement is not always entirely random, the armor becomes more regularly placed than irregular, which not only increases the amount of units needed (less volume occupied than what was initially calculated), but also reduces the interlocking forces.

The need to have a unit that, although is being regularly placed, is driven by interlocking forces rather than friction forces has been growing and subsequently, Delta Marine Consultants developed a new armor unit called Xbloc+. Given that the shape, mass, placement style and breakwater conditions influence the rocking mechanism, the new unit must undergo several tests to see its functionality.

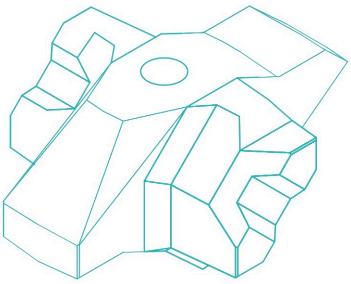

Figure 1.3: New concrete unit, Xbloc+.

1.3. OBJECTIVE

Following the problem description discussed above, the main objective of this research is determined as:

Understand and analyze the failure mechanisms of the Xbloc+ and how the stability of the structure is affected.

1.4. RESEARCH QUESTIONS

In order to achieve the main objective of this thesis, some research questions were established:

- What are the main failure mechanisms of the Xbloc+?
- Which slope is more suitable for Xbloc+?
- How is the stability affected by variations in wave height and wave steepness?
- How do the measured displacement, damage units, and stability numbers differ with other single layer units?

1.5. RESEARCH METHODOLOGY

The following steps provide the methodology to reach the afore mentioned objective:

1. Obtaining knowledge on the different failure mechanisms of a single layer armor concrete unit by analyzing previously conducted researches.
2. Achieving understanding on the stability and functionality of Xbloc+ by:
   (a) Performing several laboratory tests which will investigate the functionality and efficiency of the new concrete unit.
   (b) Analyzing the failure mechanisms and behavior patterns that might occur during laboratory tests.
3. Comparing existing concrete units such as Xbloc and Cube in order to prove Xbloc+ efficiency.

1.6. THESIS OUTLINE

Chapter 1 outlines the main problem, objectives, and general approach for this study. Chapter 2 provides a summary of the concepts and background information relevant to stability of a concrete unit armor layer. Chapter 3 reviews the model setup used during lab tests with all the necessary details to rebuild the model again if needed. Chapter 4 introduces the results and analysis of this research. Chapter 5 features a discussion of the findings and Chapter 6 summarizes the main conclusions and provides recommendations for future studies. The appendices include the complete results.

2
Literature Review

The purpose of the literature review is to introduce concepts related to the stability of the armor layer and the possible failure mechanisms that can occur during the performance of the tests. This chapter also provides information about the existing types of concrete units and the respective failure mechanisms.

2.1. Concrete Units

When it comes to armor units, many countries face the scarcity of rocks in their landscape, and therefore there is a need to either import rocks, or use alternative options like concrete units. Importing armor rocks increases cost not only of transportation, but also storage. The use of concrete units, most of which are unreinforced, can substitute quarry stones, especially when heavy armor is required. As a result, several types of concrete armor units were created and are currently in use worldwide:

Armour unit	Country	Year	Armour unit	Country	Year
Cube	–	–	Antifer Cube	France	1973
Tetrapod	France	1950	Seabee	Australia	1978
Tribar	USA	1958	Accropode	France	1980
Modified cube	USA	1959	Shed	UK	1982
Stabit	UK	1961	Haro	Belgium	1984
Akmon	NL	1962	Diode	UK	1984
Tripod	NL	1962	Hollow Cube	Germany	1991
Dolos	RSA	1963	Core-loc	USA	1996
Cob	UK	1969	Xbloc	NL	2003

Figure 2.1: History of concrete armor unit development [6].

Each unit has its own characteristics like hydraulic stability, cost, or structural strength. Each characteristic makes it appropriate for certain situations as well as inadequate for some others. With passing years, safety requirements have become more stern due to failure of structures. Furthermore, with the increase in the variety of concrete units, different possibilities regarding position of the concrete units or the number of layers utilized among other options were investigated. Thus, the classifications as shown in 2.2 were derived.

Placement pattern	Number of layers	Shape	Stability factor (main contribution)		
			Own weight	Interlocking	Friction
Random	Double layer	Simple	Cube, Antifer Cube, Modified Cube		
			Tetrapod, Akmon, Tripod	Tetrapod, Akmon, Tripod	
		Complex		Stabit, Dolos	
	Single layer	Simple	Cube		Cube
		Complex		Stabit, Accropode, Core-loc, Xbloc	
Uniform	Single layer	Simple	Haro		Seabee, Haro
		Complex			Cob, Shed, Tribar, Diode

Figure 2.2: Classification of concrete units **[6]**.

Concrete armor units can be used in single- and double-layer systems depending on the type of armor unit **[6]**. Although 2-layer systems are efficient and reliable, when increasing the weight to increase stability - greater than 20 or 30 tons - the rocking movement and placing of the units might lead to breakage and damage of the structure, which reduces its efficiency, resistance, and durability. Since 1980 armor units have been placed in a single layer with higher safety margins for the hydraulic design and increased structural strength of individual units **[18]**.

Van der Meer (1999) examined the wave height resistance of both single and double layer armor from which he concluded that single layers are more efficient in case of higher waves due to their interlocking properties. Furthermore, additional maintenance in a conventional 2-layer system compared to one-layer system can be reduced with the use of appropriate design of single layer armor **[18]**.

It is important to mention that, as much advantages single layer armors have, there are also disadvantages. For example, failure of one layer systems shows much more fragile characteristics compared to double layer systems **[6][25]**. Another important example is that the use of one layer armor systems might increase the rate of overtopping discharge **[14]**. This results in higher safety coefficients for single layer armors due to the failing mechanism. Therefore, it is necessary to understand the behavior of one layer systems in order to use this system properly in the design of rubble mound breakwater **[24]**.

2.2. Wave loads

A wave field is usually characterized by the significant wave height, H_s, and the peak period T_p **[20]**. H_s is defined as the average height of the highest third part of the waves in a wave field, while T_p is the peak period of the wave spectrum, the period with the maximum energy density. H_s, in combination with the Rayleigh distribution, characterizes the state of the sea at a certain moment. This state of the sea can change every hour or so, giving different values for H_s, which also has a distribution in time, the so-called long-term distribution. Every wave induces certain loads and pressures to the structure which are discussed in the following section.

2.2.1. Loads And Forces Acting On Armor Elements

Although the magnitude differs, stones and concrete units undergo the same loads and wave induced forces as shown in figure 2.3.

- The drag force (F_D), also called fluid resistance or fluid friction, is a force acting opposite to the relative motion of any object moving with respect to a surrounding fluid **[11]**.

$$F_D = C_D \cdot \rho_w \cdot u^2 \cdot A_D \tag{2.1}$$

where

C_D is the drag coefficient;

ρ_W is the density of water;

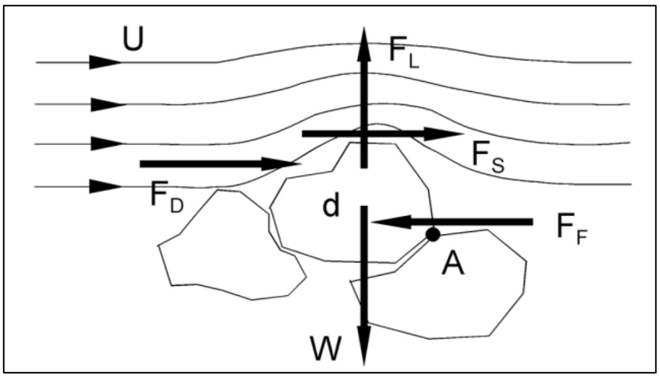

Figure 2.3: Forces acting on an armor element **[20]**.

u is the flow velocity in run-up or run-down in meters per second [m/s];

A_D is the exposed area to flow in squared meters [m^2].

- The shear force (F_S) is caused by the friction between the water and the stone or unit **[23]**

$$F_S = C_S \cdot \rho_w \cdot u^2 \cdot A_S \tag{2.2}$$

where

C_S is the shear coefficient;

A_S is the surface area of the exposed of armor unit in squared meters [m^2].

- The lift force (F_L) is the resulting pressure difference of the change in velocity between the top and bottom side of the unit. This pressure induces an upward directed force and includes the buoyancy of the unit.

$$F_L = C_L \cdot \rho_w \cdot u^2 \cdot A_L \tag{2.3}$$

where

C_L is the lift coefficient;

- Weight (W) of the unit.

$$W = (\rho_c - \rho_w) \cdot D_{n50}^3 \cdot g \tag{2.4}$$

where

ρ_c is the density of concrete;

g is gravitational acceleration in meters per squared second [m/s^2];

D_{n50} median nominal diameter in meters.

- Inertia (F_I) is the representation of the amount of resistance to a variation in velocity.

$$F_I = \rho_c \cdot D_{n50}^3 \cdot \left(C_M \cdot \frac{\mathrm{d}u}{\mathrm{d}t}\right) \tag{2.5}$$

where

C_M is the mass coefficient.

- Friction force (F_F) is the result of the influence of the weight and the friction coefficient, which is a property of the stone or material of the unit. This force is parallel to the surface, either upward or downward, but contrary to the direction of the wave force **[28]**.

$$F_F = W \cdot \mu \tag{2.6}$$

where

μ is the friction coefficient.

– Wave force (FW) is the amount of force that the wave induces into the rock, and is parallel to the surface.

$$F_W = \rho_W \cdot g \cdot D_{n50}^3 \cdot H \tag{2.7}$$

where

H is the wave height.

It can be seen that the shape of the armor unit and the period of the wave play an important role in the equations. Furthermore, the relation between the wave force, the wave height, and the armor element size indicate the dominance of drag forces, whereas acceleration forces are neglected **[28]**.

2.3. ARMOR STABILITY

In order to achieve stability, the wave forces should be less than the balancing forces, meaning that the element is motionless. Therefore, and even though this is a simplification of the forces acting on the element,

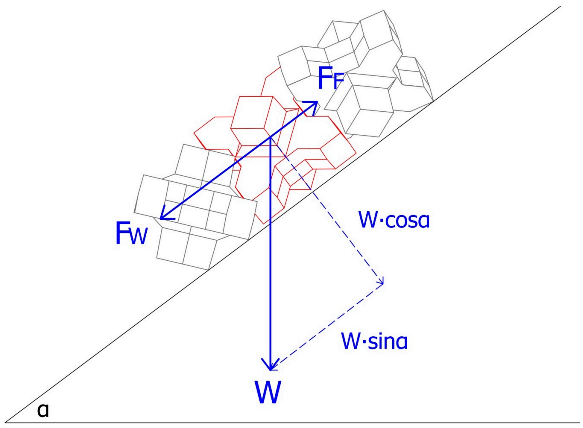

Figure 2.4: Simplification of forces acting on an armor unit on a slope.

the stability - in case of down-rush - can be obtain as:

$$F_W < K_D[F_F + W] \tag{2.8}$$

Replacing with equations 2.4, 2.6, and 2.7:

$$\begin{aligned} \rho_W g D_{n50}^3 H &< K_D[\mu W + W] \\ \rho_W g D_{n50}^3 H &< K_D[\mu W \cos\alpha + W \sin\alpha] \\ \rho_W g D_{n50}^3 H &< K_D[(\rho_c - \rho_w) \cdot D_{n50}^3 \cdot g(\mu \cos\alpha + \sin\alpha)] \\ \frac{H}{\Delta D_{n50}} &< K_D[\mu \cos\alpha + \sin\alpha] \end{aligned} \tag{2.9}$$

Where K_D represents an empirical stability coefficient.

Equation 2.10 was first obtained by Iribarren(1938). Since the equation presented above is a simplification of the system of forces acting on the armor element, Irribarren's formula is stated as:

$$\frac{H}{\Delta D_{n50}} < K_D[\tan\varphi \cos\alpha + \sin\alpha] \tag{2.10}$$

where φ is the angle of repose of the armor, the coefficient K_D includes some level of damage as well as all other influencing parameters not explicitly included in the formulae **[5]**.

2.3.1. HUDSON FORMULA

Following Iribarren's work, Hudson modified equation 2.10 and introduced equation 2.11 and the required block weight equation based on a down-rush situation by replacing (cos α - sin α) with cot α and including the friction factor μ within the stability coefficient.

$$\frac{H}{\Delta D_{n50}} < [K_D \cot\alpha]^{1/3} \tag{2.11}$$

$$W \geq \frac{\rho_c g H^3}{K_D \Delta^3 \cot\alpha} \tag{2.12}$$

Moreover, the higher the stability number, the higher waves can be accommodated by the same stone size **[28]**.

2.3.2. VAN DER MEER FORMULA

Van der Meer's formula takes a slightly different approach by including some factors like wave steepness, permeability of the underlayer and damage of the armor layer. Nevertheless, it does not contain a stability coefficient. Furthermore, the stability equation varies depending on the armor unit (quarry stones or concrete units). Since not all of the parameters from this formulae are relevant for this research, only the definition of the relevant factors are explained on the following lines:

WAVE STEEPNESS

According to Det Norske Veritas (2011), the wave conditions in a sea state can be divided into two classes: wind seas and swell. Wind seas are generated by local wind, while swell have no relationship to the local wind. Swells are waves that have travelled out of the areas where they were generated. Moderate and low sea states in open sea areas are often composed of both wind sea and swell. Wave steepness is the relationship between the wave height and wavelength, providing information about the wave characteristics. A steepness of s_0=0.01 usually indicates a typical swell sea and values of steepness of s_0=0.04 to 0.06 are representative of a typical wind sea **[14]**. A wave breaks as a result of instability which develops when the wave can no longer exist. Furthermore, this instability occurs because a wave is very steep or because the water is very shallow or a combination of both reasons **[20]**.Hence, a modification of the wave steepness has an effect on the stability of the wave and the breaking parameter. The breaking parameter, or Iribarren number, is obtained by the following formula **[1]**:

$$\xi_{op} = \frac{\tan\alpha}{\left(\frac{H_s}{L_{op}}\right)^{1/2}} \tag{2.13}$$

where

ξ_{op} is the Iribarren number;

tanα is the slope of the structure;

H_s is the significant wave height;

L_{op} is the wave length calculated with T_p in deep water.

$$L_{op} = 1.56 T_p^2 \tag{2.14}$$

The classification of the different values of the Iribarren number is depicted in Figure 2.5. The transition between breaking and non-breaking lies around $\xi \approx 2.5$ - 3 **[1][20]**.

DAMAGE

As it was previously mentioned, a distinction is made depending on the armor type. Damage on structures with rock armor can be calculated differently than a concrete armor layer structure. Since in the case of a concrete unit armor layer it is not common to constantly measure the profile of the structure, damage can be defined as the relative damage, N_{od}, which is the actual number of units displaced related to a width (along the longitudinal axis of the structure) of one nominal diameter D_n **[25]**. Depending on the type of concrete unit, the D_n changes. In the case of cubes D_n is equal to one of the sides of the cube; in the case of tetrapods, D_n = 0.65 D, where D is the height of the unit; and for Xbloc, $D_n = 1/\sqrt{3}$ D where D is the height of the unit. It is imperative to mention that within the definition of damage, not only displaced and broken units are

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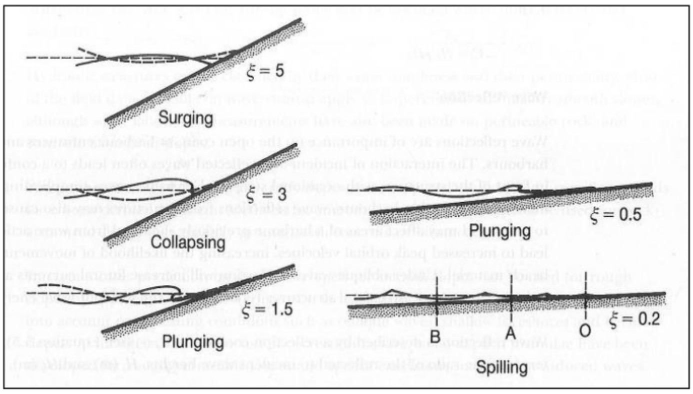

Figure 2.5: Type of breaking waves on a slope.

accounted for, but units moving or rocking within a range of motion as well. The damage number needs a subscript in order to distinguish between these types of damage **[26]**. Moreover, in the case of a randomly placed concrete unit armor layer, Muttray & Reedijk (2009) stated that the damage can be represented by:

- Damage number N_{od}: Number of displaced armor units within a strip of breakwater slope of width D_n (nominal diameter of armor units);

- Damage number N_d: Number of displaced armor units referred to the total number of armor units placed within a certain range from design water level (a range of ± 1.5 H_D - design wave height - is typically considered).

On the other hand, Verhagen et al. (2012) described damage as:

- Damage due to displaced units represented by N_{od}.

- Damage due to blocks that might break because they are rocking against each other represented by N_{or}.

- The total number of moving units, N_{omov}, which is equal to the number of displaced blocks, plus the number of rocking blocks ($N_{omov} = N_{od} + N_{or}$)

FORMULAE

Van der Meer also makes a distinction on the type of breaking wave. Therefore, the stability formulas can be written as:

- For plunging waves:

$$\frac{H}{\Delta D_{n50}} = c_{pl} P^{0.18} \frac{S}{\sqrt{N}}^{0.2} \xi_m^{-0.5} \tag{2.15}$$

- For surging waves:

$$\frac{H}{\Delta D_{n50}} = c_s P^{-0.13} \frac{S}{\sqrt{N}}^{0.2} \xi_m^P \sqrt{\cot\alpha} \tag{2.16}$$

2.3.3. INTERLOCKING CAPABILITY

It is of major importance to understand how the interlocking capability of an unit relates to its stability. The stability of concrete armor layers relies mainly on 2 factors: their own weight and interlocking **[23]**.As it was previously mentioned in section 2.3, the scheme presented is a basic simplification of the real forces system acting on the unit.

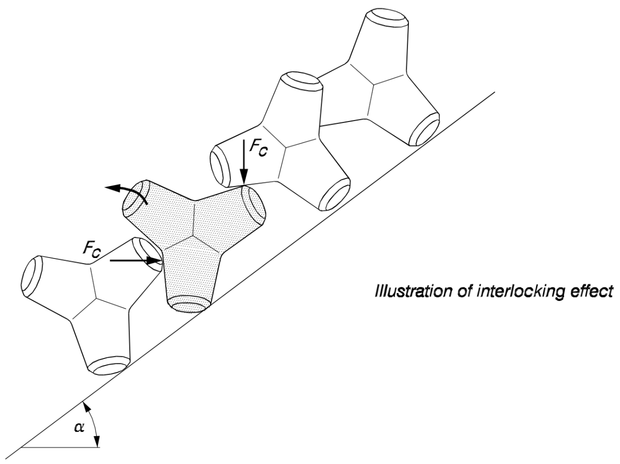

Figure 2.6: Interlocking effect of concrete units [3].

Furthermore, when analyzing a concrete unit, its complex shape and design introduces a more complicated force system as shown in 2.6. According to Broere (2015) , the stability can be defined as the ratio between loads and strength of an armor layer, hence, a function of the waves and strength of structure due to its geometry. Moreover, the strength of a concrete unit can be divided into 3 main mechanisms: gravity, friction, and interlocking. The interaction between them relates fundamentally to the unit's shape and placement, while placement is directly related to packing density. Although the slope is not considered by previous authors among these interactions, it is of extreme importance to understand how the slope affects the mechanisms and collaboration, which allows to say that it will determine the governing interaction. Even though the afore mentioned applies for both rocks and concrete units, the behavior and results is not the same as it is shown in Figure 2.7.

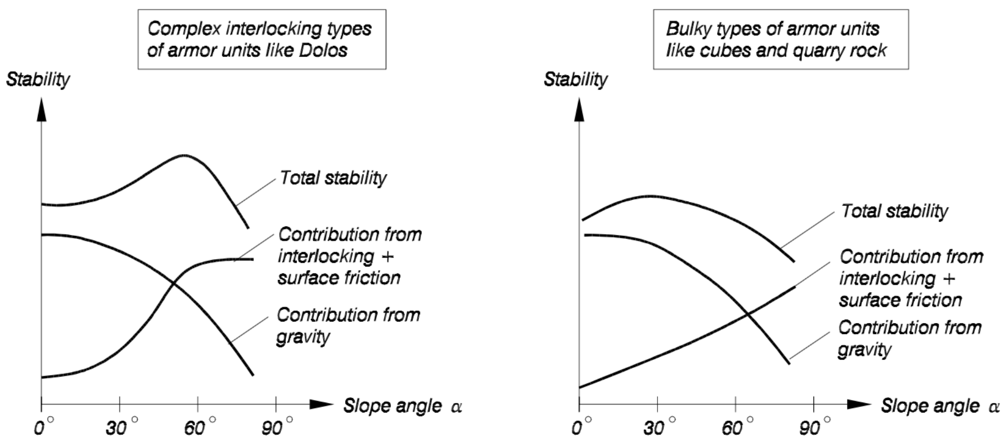

Figure 2.7: Influence of interlocking capability on stability [3].

2.4. FAILURE MODES

In general, it is important to have an overall idea of the failure mechanisms in the structure as it is shown in Figure 2.8. Protections seldom fail because of an underestimation of the loads of 10%; most protections fail because a mechanism has been neglected [20]. Therefore, although is not possible to have an exact calculation of some of these mechanisms, a general understanding of them can prevent an unbalanced design.

2

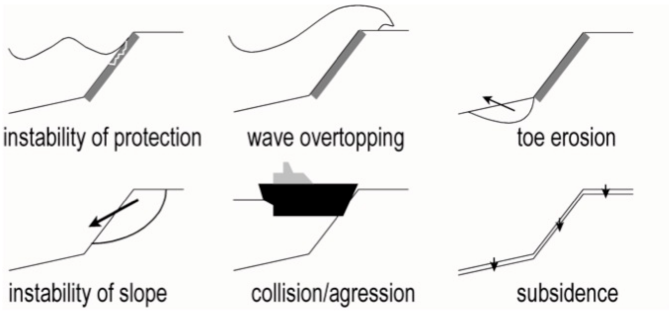

Figure 2.8: General failure mechanisms of the structure **[20]**.

Following the scope of this research, the main focus will remain among the first mechanism: "instabiliy of protection". By no means, this states that this is the most important failure mechanism. If the protection is too low, overtopping may damage the revetment, or if the angle of the slope is not appropriate, then instability of the slope can be of micro or macro nature **[20]**.
Figure 2.9 provides an overview of the typical failure mechanisms that occur in an armor layer and further in this section, each mechanism will be explained in the same order for better understanding.

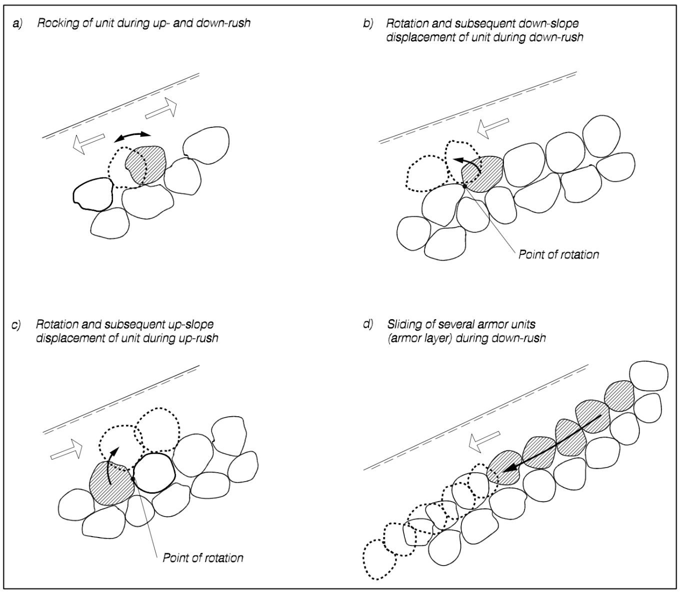

Figure 2.9: Typical failure mechanisms of the armor layer **[3]**.

2.4.1. ROCKING

Armor units which are not completely clamped between each other have some space to move (an overturning motion) upslope or downslope **[23]**.The up-rush motion of the water causes an upslope movement of the units, while the down-rush will try to move the armor elements downslope. Since the wave has a cyclic nature, the resulting movement of the elements in the armor layer is called "rocking", which can lead to settlement of the armor, displacements of units and damage to the structure.

2.4.2. ROTATION AND SUBSEQUENT DOWN-SLOPE DISPLACEMENT OF UNIT DURING DOWN-RUSH

Gravity and downrush movement of the water can cause the armor units to be displaced (rolling) out of their original position **[23]**.This resulting rolling movement can increase damage to the structure since there will be interaction with different parts of the slope. Therefore, breakage of the elements is highly possible. This failure mechanism can also be a recurrent process since it can be repeated several times until the unit reaches the toe of the structure where it cannot roll down anymore.

2.4.3. ROTATION AND SUBSEQUENT UP-SLOPE DISPLACEMENT OF UNIT DURING UP-RUSH

This failure mechanism has the same process as the one previously mentioned, "Rotation and subsequent down-slope displacement of unit during down-rush", but in the opposite direction.

2.4.4. SLIDING

As well as all the previously mentioned mechanisms, the down-rush movement can cause damages in the armor layer. Particularly in this failure mechanism, the movement can cause the armor units to slide downslope, which also relates to the strength and stability of the toe of the structure. An important remark is that this failure mechanism is not the same as "settlement". Settlement refers to the collective displacement of the armor layer, and structure. Although in both cases the stability of the structure is compromised, during sliding, the entire layer slides due to loss of support while in the latter the packing density increases or decreases, do to the relocation of the armor units.

2.4.5. UPLIFT

Although this failure mechanism is not displayed in Figure 2.9, it is considered fairly common. This is caused not only by the wave forces and motion but also by hydraulic pressures from the core of the structure. It is imperative to mention that pressure due to permeability, or lack of it, of the core should be studied in depth since repercussions on the structure can occur.

2.5. WAVE GENERATION

Ocean waves are irregular and random in shape, height, length, and speed of propagation. A real sea state is best described by a random wave model **[10]**.Structures with significant dynamic response require stochastic modeling of the sea surface and its kinematics by time series. A sea state is specified by a wave frequency spectrum with a given significant wave height, a representative frequency, a mean propagation direction and a spreading function.

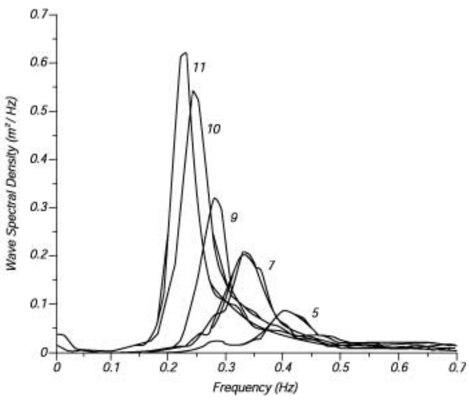

Figure 2.10: Wave spectrum of a developing sea for different fetches **[15]**.

The JONSWAP spectrum mainly bases on the assumption that the wave spectrum is never fully developed as it is assumed in the Pierson-Moskowitz Spectrum. Furthermore, it can be said that the JONSWAP (2.18) spectrum equals the Pierson-Moskowitz spectrum multiplied by an extra peak enhancement factor represented by γ (2.17).

$$S_{PM}(\omega) = \frac{5}{16} H_S^2 \omega_P^4 \omega^{-5} \exp\left(-\frac{5}{4}\left(\frac{\omega}{\omega_P}\right)^{-4}\right) \tag{2.17}$$

$$S(\omega) = A_\gamma S_{PM}(\omega) \gamma^{\exp\left(-0.5\left(\frac{\omega-\omega_P}{\omega_P}\right)^2\right)} \tag{2.18}$$

2.6. SCALING AND PHYSICAL MODELING

2.6.1. SCALING

In order to create a physical model experiment, the model itself must exemplify the situation as much as possible, otherwise, results will not be representative, and its validity would become null. Therefore, there

2

are different types of similarities required depending on the nature of the study performed.

GEOMETRIC SIMILITUDE

This similitude corresponds to the shape of the structure, which means that the linear dimensions between the prototype and model have the same ratio **[27]**. Regardless of the changes in the flow or motions and interaction between the structure and waves, the shape must remain similar.

KINEMATICAL SIMILITUDE

On the other hand, this similitude disregards whether the shape of the model and prototype are similar but focusses more on whether the motions occurring on the structure resembles the actual prototype or not.

DYNAMIC SIMILITUDE

The dynamic similarity refers to forces acting on the model which must be similar to the ones acting on the prototype. By achieving this, it can be said that the ratios of all the vectorial forces are equal.

2.6.2. FROUDE AND REYNOLDS' SCALING

Once the required similarities are understood, then the most relevant forces need to be defined so that these can be scaled correctly in order to prevent undesired effects during lab tests. The most important and influential forces, in terms of wave action, are gravity, pressure, and inertial forces. These forces are represented and scaled within the Froude number which is given by equation 2.19:

$$Fr = \frac{U}{\sqrt{gL}} \tag{2.19}$$

$$Re = \frac{\rho U L}{\mu} \tag{2.20}$$

where

U is the velocity of the fluid in meter per second [m/s];

ρ is the density of the fluid in kilograms per cubic meter [kg/m^3];

g is gravitational acceleration in meter per squared seconds [m/s^2];

μ is the viscosity of the fluid pascal seconds [Pa $/cdot$ s];

L_{op} is the length of the fluid in meter [m].

Moreover, other forces such as viscosity and surface tension are included in other laws like Reynolds and Weber's respectively. Since not all the forces can be scaled correctly in the same model, some of them are neglected along the process, therefore, becoming errors from scaling effects. Reliable results from scaled models can only be expected by fulfilling Froude's and Reynolds' law (equation 2.20) simultaneously. This is however not possible so that scale effects cannot be avoided when performing scaled model tests **[14]**.
As a result, it can be said that by maintaining a turbulent flow, this criterion is assumed to be satisfied. Furthermore, table 2.1 summarizes the minimum Reynolds number obtained from several studies. Therefore,

Researcher	Reynolds number
Dai and kamel (1969)	3×10^4
Jensen and Klinting (1983)	6×10^3
Oumeraci (1984)	3×10^4
Shimada et el (1986)	4×10^5
Van der Meer (1988)	4×10^4
Jensen (1989) core	5×10^3
Jensen (1989) armor layer	4×10^4

Table 2.1: Wave characteristics

the best approximation of scaling a prototype into a model is to use the Froude model criterion. According to Van Zwicht (2009) the Froude model criterion should be applied when the inertial forces are primarily balanced by the gravitational forces. As a result, the model Froude number must be equal to the prototype Froude number.

$$\left(\frac{U}{\sqrt{gL}}\right)_P = \left(\frac{U}{\sqrt{gL}}\right)_m \tag{2.21}$$

2.6.3. SCALING EFFECTS

Although it is impossible to achieve a perfect and complete similitude between the prototype and the model, the scaling process must try to prevent certain undesired effects so the results of the tests are representative of reality. Scale and model effects result from incorrect reproduction of a prototype water-structure interaction in the scale model. One of the most common scaling effects relates to the core of the structure and its permeability. The permeability of the core material influences armor layer stability, wave run-up and overtopping **[4]**. By scaling the core geometrically, the material will be reduced to a minor size with small pore sizes, making an almost impermeable core, inducing laminar flow with higher down-rush pressures and, hence, lower stability.

From the observation of physical model studies some generic rules have been derived in order to avoid scale effects **[14]**. The smaller the model is, the more effects will appear, and, as a result, the best way to prevent scaling effects is to make the model as big as possible (regarding the laboratory' capability).

The effects of surface tension can be avoided by defining wave periods larger than T=0.35s and wave heights larger than Hs=5 cm. Besides, water depths in the model should be larger than d=20cm. Otherwise, dampening of the waves might occur.

2.6.4. MODEL AND MEASUREMENT EFFECTS

Just as the scaling effects, during the experiments there can also be model and laboratory effects. Model or laboratory effects originate from the incorrect reproduction of the prototype structure, geometry and waves and currents, or due to the boundary conditions of a wave flume (side walls, wave paddle, etc.) **[14]**. It is important to consider that the effects of the wind is also not included in the model although there is the reproduction of the waves, which represents an important model effect. Even though modeling techniques have been developing for years, there is still uncertainty in how to correct some model effects.

Furthermore, there are also effects resulting form the measurement equipment used during the lab tests, which represent big errors when comparing prototype-model results and even 2 similar models. It is therefore essential to quantify the effects and the uncertainty related to the different techniques available **[14]**.

3
Model Setup

The main objective of this model is to represent a real-life situation in which the Xbloc+ performance was evaluated. In this chapter the model setup is explained along with dimensions and materials used in the experiments. Due to the continuous development of the new unit, 2 different units were tested. Since some dimensions and volume of the unit changed, the model suffered several modifications which are also specified during this chapter. The amount of tests and specifications are also included in section 3.6.

3.1. Wave flume

The hydraulic tests were performed at Delta Marine Consultants' laboratory located in Utrecht. Flume characteristics are:

	[m]
Length	25.0
Width	0.6
Height	1.0
Max. Water Depth	0.7
Hmax	0.3*

Table 3.1: Flume charactristics
(*depending on the water depth)

The flume is equipped with an "Edinburgh Designs piston" type of wave generator, which is able to produce not only regular but irregular waves as well. The unit uses a displacement technique that allows perfect flat front piston action but generates no back wave. Moreover, it measures the reflective wave and corrects the paddle motion to absorb it. The resultant wave field is totally predictable even with highly reflective models **[13]**.

Figure 3.1: Delta Marine Consultant's wave flume in Utrecht.

3.2. HYDRAULIC PARAMETERS

3.2.1. WAVE GENERATION

The hydraulic tests were performed using irregular waves and JONSWAP spectrum. Moreover, 3 shape parameters were used as an input to create the wave spectrum: γ, σ_a, and σ_b. For a standard JONSWAP-spectrum. the mean values of these shape parameters are $\gamma = 3.3$, $\sigma_a = 0.07$ and $\sigma_b = 0.09$.

3.2.2. WAVE ANALYSIS

The signal from the wave gauges was analyzed with a software developed by the University of Aalburg called WaveLab3, which is based on the Mansard and Fuke (1980) method requiring simultaneous measurements at three different positions. The wave gauges must be placed close to each other on a parallel line to the wave propagation.

3.2.3. SIGNIFICANT WAVE HEIGHT H_s

The significant wave heights used for the tests were obtained from the Hudson formula (equation 2.12) with a K_D of 12.00 and are shown in table 3.5.

For further calculations, the value of H_s used was the one measured at the toe of the structure since that is when it acts on the structure. The wave in deep water will still undergo changes until it reaches the breakwater. Note that since the weight of the armor unit changed during the modification, the wave height also changed so depending on the unit being tested, the wave height varies.

3.2.4. WAVE PERIOD

In terms of wave period, different definitions can also be used for a wave spectrum such as the peak period, T_p, the average period, T_m or the significant period $T_{1/3}$. However, for future calculations T_p measured in deep water was used.

3.2.5. WAVE STEEPNESS

Three different types of wave steepness were tested to have a better representation of reality (2%, 4%, and 6%). Moreover, different breaking types occurred during the experiments when the slope and wave steepness varied (Table 3.5).

3.2.6. STORM DURATION

Hydraulic model tests are generally performed with 1000 waves. In prototype, 1000 waves represent a storm of 3 hours with a mean wave period of 10 seconds. For interlocking armor units is assumed that most of the damage has occurred after 1000 waves **[27]**.

Therefore, each test had a duration of 1000 waves.

3.2.7. WATER DEPTH

The minimal water depth required is 3 times the significant wave height (H_s) in order to generate the desired wave height, which results in a water depth of 50 cm measured in front of the wave maker. The water depth at the toe of the structure was 21 cm which puts the structure in intermediate waters, meaning that some effects will appear on the wave climate like shoaling.

3.3. STRUCTURAL PARAMETERS

Even though physical model tests are meant to be representative of a real situation, the following tests are not based on any prototype. Nevertheless, the overall scale of the model is approximately 1:50.

3.3.1. CORE

As previously mentioned in 2.6.3, scaling the core has been a struggle for years since is not yet understood in its entirety. Furthermore, the core cannot be scale geometrically since it will change the interaction between the flow and the structure. So in order to prevent this effects, Burcharth (1990) method was used. The method result in a diameter for the core material in the model such that the Froude scaling holds for a characteristic pore velocity. The Reynolds' law was also considered in this process. Since it is impossible to satisfy both, Froude and Reynold's law, the scaling was based on the Froude number and a turbulent flow was kept so the Reynold's law could be assumed as satisfied. Following Wolters (2015), in order to prevent scale effects the core must be conformed of stones larger than 7mm and maintain a Reynolds' number greater than 300. As a result the D_{n50} was set to be 9.6 mm and only one grading was used to build the core of the structure (8-11 mm). Since the Reynolds' number requirement was not met, meaning that the flow is more laminar than in the prototype, the model is considered as conservative due to the viscous effects affecting the stability of the structure.

3.3.2. UNDERLAYER

Following a conservative approach based on Verhagen (2012), it was found that the underlayer must be "geometrically impermeable". Therefore, the weight ratio between the armor and underlayer should be kept between 1/10 and 1/15 (d_{n50} ratio between 2 and 3). Consequently the underlayer was build of stones of grading 11.2 - 16 mm, and has a D_{n50} of 13.0 mm as shown in table 3.4.

3.3.3. XBLOC+ PROPERTIES AND CHARACTERISTICS

Due to the results obtained from previous research and the first series of test of the present study (see section 4.2), the armor unit suffered some modifications. In order to increase the permeability of the armor layer, a hole was done at the center of the unit, inducing variations in volume and permeability. Consequently, "Xbloc+$_{v1}$" means the initial unit, whilst "Xbloc+$_{v2}$" means the unit with the hole. On the other hand, when referring to "Xbloc+", it means that the situation applies in both cases with no differentiation whatsoever.

NOMINAL DIAMETER (D_N)

The nominal diameter is used, not only to obtain certain dimensions of the structure but the stability number as well. Therefore, it is an extremely important parameter. The characteristic length of this unit is the width, D. As a result, the nominal diameter (D_n) is obtain in relation with the width and not with the height as it is often calculated.

$$D_n = D \times \alpha \tag{3.1}$$

where D is the width and α is a shape coefficient. These coefficient was obtained by relating D_n with the volume.

$$\begin{aligned} V &= D^3 \times \beta \\ D_n &= \sqrt[3]{V} = D\sqrt[3]{\beta} \\ \alpha &= \sqrt[3]{\beta} \end{aligned} \tag{3.2}$$

The volume of the unit is obtained by multiplying the cubed characteristic length times a coefficient (β). This coefficient was calculated relating the volume occupied by the unit within a grid as shown in the figure 3.2.

For the Xbloc+$_{v1}$, it was calculated that the unit occupies 43.8% of the grid and, therefore, the values for α and D_n result as 0.63 and 2.949 cm respectively. In the case of the Xbloc+$_{v2}$, as the mass of the armor unit changes, the nominal diameter D_n has to change as well, even though the original dimensions of the unit remain the same. Consequently, the α coefficient becomes 0.62 and, therefore, the nominal diameter reduces to 2.906 cm.

XBLOC+ DIMENSIONS

As previously mentioned, the characteristic length of this unit is the width, therefore all other dimensions are obtained by applying a coefficient.

$$\begin{aligned} Height &= \frac{Width}{2.0} \\ Length &= \frac{Width}{0.8} \end{aligned} \tag{3.3}$$

As a result, the dimensions of the unit used for testing are summarized in the following table:

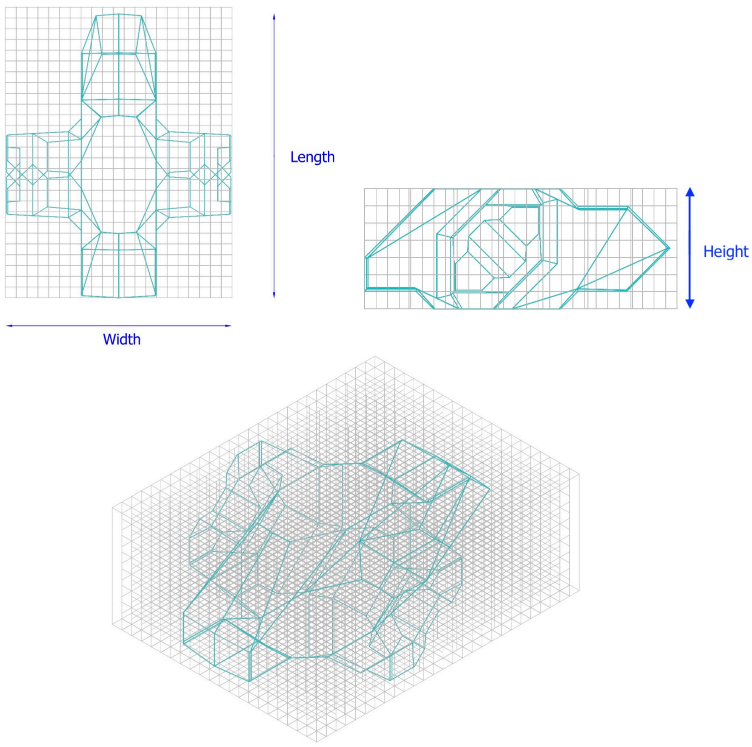

Figure 3.2: Calculation of shape coefficient.

	[cm]
Width	4.700
Height	2.350
Length	5.875
Dn (v1)	2.949
Dn (v2)	2.906

Table 3.2: Dimensions of Xbloc+

ARMOR LAYER

Commonly, the D_n represents the thickness in case of a single armor layer. Given the shape of this new unit, the D_n and the layer thickness are not the same. Following the same methodology previously explained, it was obtained that a coefficient of 0.76 should be multiplied by the characteristic length in order to obtain the thickness of the armor layer in both cases (Xbloc+$_{v1}$ and Xbloc+$_{v2}$). In the following table the dimensions and measurements of the Xbloc+$_{v2}$ are shown and the variability with respect to each other:

3.3.4. TOE AND CREST OF THE STRUCTURE

Although the toe and crest stability is out of the scope of this research, both parts were not fixed and, as a result, the tests were more realistic.
The placement of the concrete units in the crest was not yet designed and therefore the units were only placed until the beginning of the crest and supported with stones with a grading of 16 - 22.4 mm. Furthermore the toe was designed using the Van de Meer equation and then translated to a standard grading.

$$\frac{H_s}{\Delta D_{n50}} = \left(6.2 \cdot \left(\frac{h_t}{h}\right)^{2.7} + 2\right) \cdot N_{od} \tag{3.4}$$

Using a N_{od} equal to 0.5, the stability number results of 4.1.

3.3.5. MATERIALS

The following table summarizes the required material for both models:

	D_n	Width	Height	Length	Layer Thickness	Separation in X-direction	Separation in Y-direction	Volume per unit of surface area
D_n	**1.00**	0.62	1.24	0.50	0.82	0.56	0.98	1.80
Width	1.61	**1.00**	2.00	0.80	1.32	0.91	1.59	2.91
Height	0.81	0.50	**1.00**	0.40	0.66	0.45	0.79	1.45
Length	2.02	1.25	2.50	**1.00**	1.64	1.14	1.98	3.63
Layer Thickness	1.23	0.76	1.52	0.61	**1.00**	0.69	1.21	2.21
Separation in X-direction	1.77	1.10	2.20	0.88	1.45	**1.00**	1.75	3.20
Separation in Y-direction	1.02	0.63	1.26	0.50	0.83	0.57	**1.00**	1.83
Volume per unit of surface area	0.55	0.34	0.69	0.28	0.45	0.31	0.55	**1.00**

Table 3.3: Ratio (left value divided by top value) between Xbloc+$_{v2}$ dimensions.

	Weight [N]	D_{n50} [mm]
Core	0.012	9.6
Underlayer	0.055	13.0
Armor (Xbloc+$_{v1}$)	0.575	2.95
Armor (Xbloc+$_{v2}$)	0.548	2.91

Table 3.4: Materials used for the construction of the model.

3.3.6. PLACEMENT OF ARMOR LAYER

The unit placement pattern has a major influence on the hydraulic stability of the armor layer, as the Xbloc+ relies on its interlocking capabilities although placed uniformly. Even though the influence of the placement on the hydraulic stability is out of the scope of this research it is important to understand how the armor units were placed in order to understand how the whole model worked.

STAGGERED GRID

The main idea of the placement grid is the use of a staggered grid, this result in a diamond-shaped pattern, as show in the figure below. A diamond-shaped pattern can be characterized by 2 values, horizontal and upslope distance, which are crucial in the design of the placement grid **[18][21]**. The units where placed on the structure uniformly. The design separation in X-direction is 1.1 times the width of the unit while the separation in Y-direction (up-slope) is 0.63 times the width of the unit in a way that each row rests and interlocks as much as possible with the previous one as shown in the figures below:

PACKING DENSITY

The most important aspect of the placement grid is its packing density. When the achieved placement deviates from the design grid, it is possible to directly see the influence on packing density and it can then be decided to replace the unit or a whole section **[21]**. For straight sections with a staggered placement pattern the packing density can be used to describe the quality of placement **[23]** . Depending on the armor unit, the packing density can vary freely by placing the units as far or close as wanted. In the case of the Xbloc+, the shape and geometry of the unit does not allow much variation (approximately 2%) without compromising the stability of the armor layer.

3.3.7. FORESHORE

A 1:30-foreshore was used for the model based on previous experiments performed by Delta Marine Consultants. Furthermore, including a foreshore forces waves to travel in intermediate water which induces shoaling and several more processes, making the system more complex and realistic.

3

Figure 3.3: Placement of armor units

3.3.8. INNER SLOPE

Given that the inner slope of the structure is out of the scope of this research, it was fixed with glued stones to prevent it from failing.

3.4. TEST PROGRAM

In order to understand the results, it is important to understand the tests performed. Three parameters were varied to see the effect on the stability of the structure.

3.4.1. WAVE STEEPNESS

As previously mentioned, in order to represent a real-life situation, wind waves and swell must be tested. As a result, 3 wave steepness were used during the experiments: 0.02, 0.04, and 0.06.

3.4.2. WAVE HEIGHT

Using equation 2.12, the design wave height was obtained (see table 3.5). During each series of tests, the wave height was incremented by 20%, from 60% till 100%, and after that, increments of only 10% were made so small changes could be noticed. The tests were performed until failure was achieved ($N_{od\ \mathrm{Partial + Full\ Displacement}} \geq 0.5$) or wave start breaking due to depth limitation.

3.4.3. SLOPE

As mentioned in section 2.1, interlocking units work better in a steeper slope. Therefore, two different slopes were tested: 3:4 and 1:2.

3.5. PERFORMED TESTS

The following table summarizes the tests performed:

Unit	Series	Slope	$H_{s\text{-design}}$ [cm]	Wave Steepness	ξ_{op}	Number of Waves
Xbloc+$_{v1}$	1	3:4	9.52	4%	Surging	1000
Xbloc+$_{v2}$	2		9.38	4%	Surging	
	3			2%	Surging	
	4			6%	Collapsing	
	5	1:2	10.74	2%	Surging	
	6			4%	Collapsing	
	7			6%	Plunging	

Table 3.5: Target wave characteristics near the structure.

3.6. Equipment Location and Cross Section

Due to positioning of connection points for the foreshore in the flume the structure had to be shifted 0.4m backwards to facilitate observations. Therefore, there is a flat transition of 0.4 m from the foreshore to the structure.

Two sets of wave gauges were used in order to measure waves in deep water conditions and near the structure. At each location 3 wave gauge were used to improve the accuracy of measurements. The distance between the wave gauges is 0.3 m between the first and the second gauge, and 0.7 m between the first and the third gauge based on engineering experience of Delta Marine Consultants team of engineers and the conditions established by Mansard & Funke (1980):

$$\begin{gathered} X_{1-2} = \frac{L_p}{10} \\ \frac{L_p}{6} < X_{1-3} < \frac{L_p}{3} and X_{1-3} \neq \frac{3L_p}{10} \end{gathered} \tag{3.5}$$

Two cameras where used to record the tests. The first camera was located at the top and as perpendicular to the structure as possible so displacements and settlements could be measured. The second camera was located at the right side of the flume in order to have a complete picture of the tests.

See appendix A for the model schemes (3:4 and 1:2 slope, and the equipment location) used during lab tests like for instance figure 3.4.

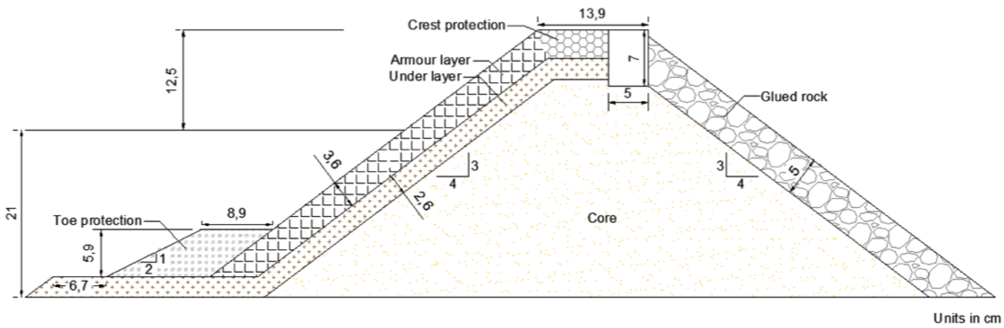

Figure 3.4: Cross-section design (Slope 3:4)

3.7. Preparation for the tests

Before each test there is a series of steps that were done in order to assure its correct performance. After building the armor layer, measurements were taken in order to calculate the packing density of every series. The next step was to calibrated the necessary equipment. After that, a revision of the wave generation files was done in order to prevent generating the wrong test. Finally, setting up the cameras and checking that they were in the exact same position so pictures could be compared. A picture was taken at the beginning of the test so the displacement of the units could be measured and compared with other tests.

3.8. DATA COLLECTION

During the test, the amount of rocking units was counted as well as any other anomaly occurring during the length of the test. After the completion of each test, pictures were taken and the wave files were revised in order to see whether the wave height was reached or not or if there was any error with the data files.

4

Results and Analysis

In this chapter, the results obtained from the performed tests are presented, as well as the corresponding analysis. First, the generated wave climate will be analized in section 4.1 in order to understand whether the design conditions were achieved. The failure mechanism is described in section 4.2 explaining how the failure is achieved in both slopes (3:4 and 1:2) while section 4.3 provides an insight on the different type of movements and displacements that occur during the tests. Furthermore, the damage and damage area are included followed by the calculations of the leakage length.

4.1. Wave climate

The design wave height was calculated following the Hudson formula(equation 2.12), as it is previously stated in section 3.2. Although this values were used as an input for the wave generator to reproduce, the measured wave climate is not exactly the same. Therefore, a comparison between the calculated and measured conditions are presented in the following figures.

Figure 4.1 provides information of the generated wave climate on a 3:4 slope, while the following image (figure 4.2) provides data from the wave climate on a 1:2 slope. In both cases, the left-hand side refers to the measured and calculated wave height, while the right-hand side refers to the wave steepness. This measurements where taken near the structure (intermediate water).

> **Note:** The information regarding each test series can be found in table 3.5 in Chapter 3.

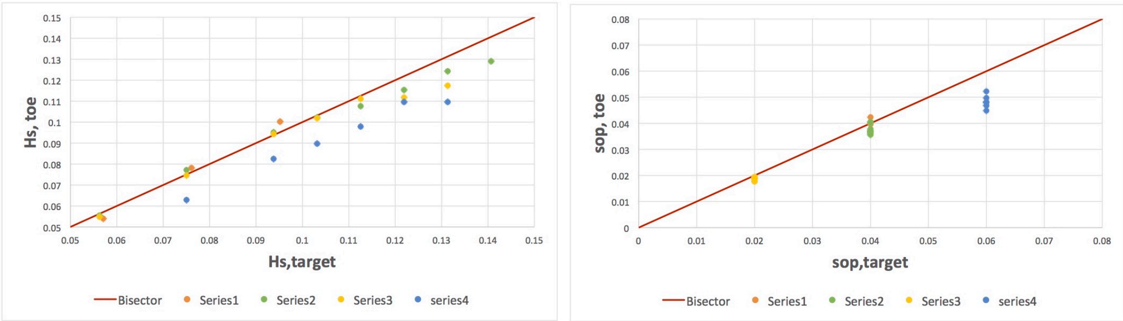

Figure 4.1: Wave conditions during Tests Series 1-4 on a 3:4 slope measured in front of the structure.

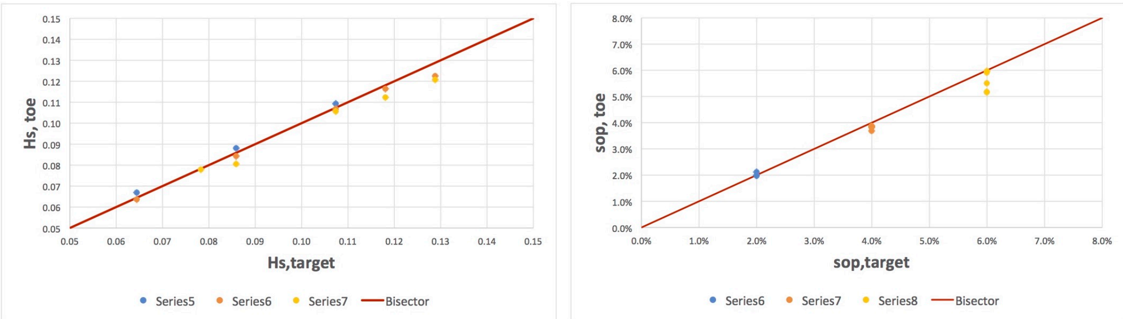

Figure 4.2: Wave conditions during Tests Series 5-7 on a 1:2 slope in front of the structure.

It can be seen that, as the wave height increases, there is a significant difference between the target and measured wave height. By comparing the wave height in deep water, it can be seen that the generated waves surpassed the target height, consequently, it can be concluded that the difference in wave height in front of the structure relates to the breaking of waves. Since the wave height is increasing by 10-20%, and the water depth remains constant, the waves become depth-limited and as a result start breaking. This is shown below in figure 4.4 as a deviation of measurements from the Rayleigh distribution for wave heights, and in figure 4.5 as a deviation from target spectrum.

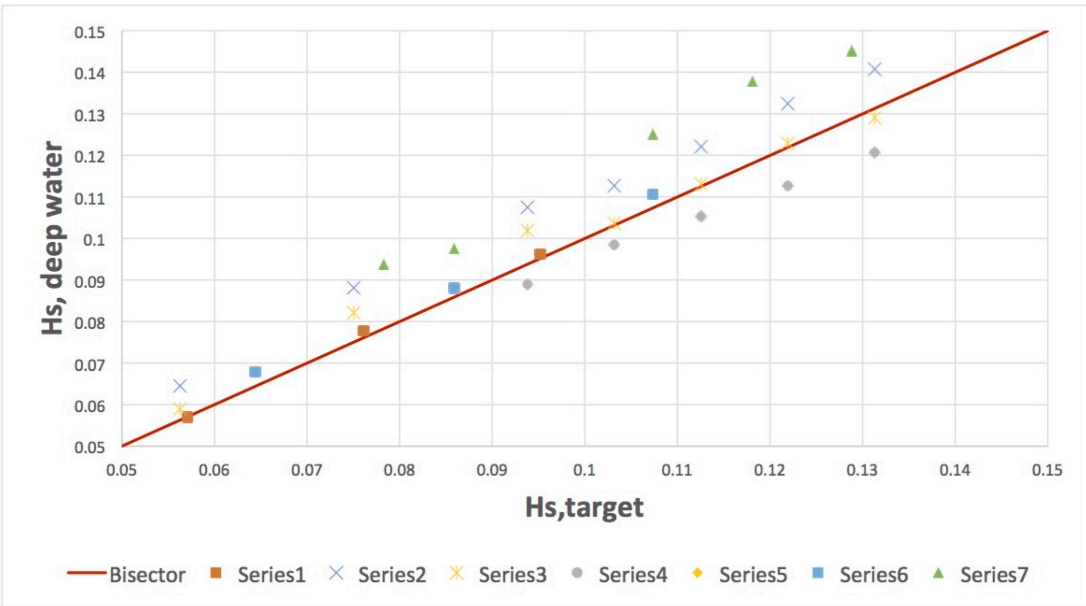

Figure 4.3: Wave conditions measured in deepwater during Series 1-7.

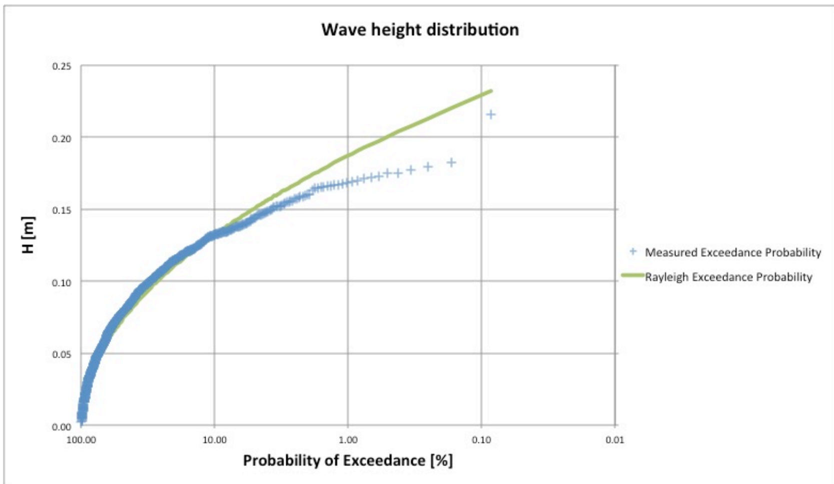

Figure 4.4: Wave exceedance during Series 2, test 5 (150% of design wave height - Ns = 3.47).

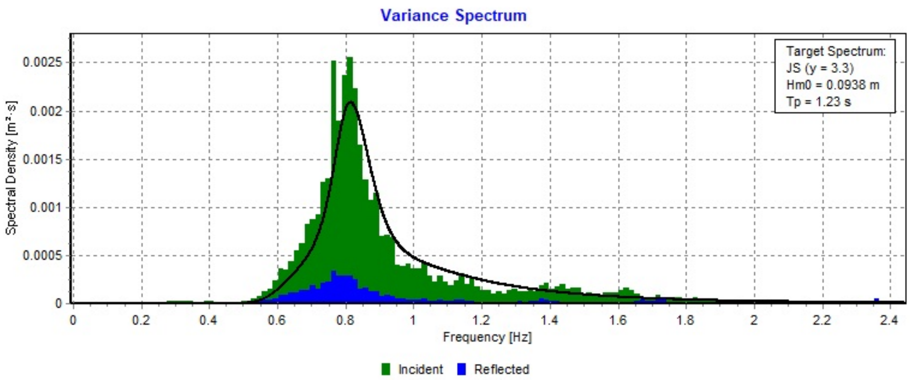

Figure 4.5: Wave Spectrum during Series 2, test 5 (150% of design wave height - Ns = 3.47).

Furthermore, it can be said that the design wave climate was successfully generated by the wave paddle. All measurements obtained during the experiments are shown in Appendix B, table B.1).

Note: The results presented in this and the following chapters will be introduced as follows:

- Color red and blue will be used to represent slopes 1:2 and 3:4 respectively;
- Wave steepness of 2% is represented by a rectangular marker;
- Wave steepness of 4% is represented by a circular marker;
- Wave steepness of 6% is represented by a triangular marker.

4.2. FAILURE MECHANISMS

During the tests, a main failure mechanism for slope was observed based on section 2.4. All extractions occurred by rotation out of the armor layer either up- or down-slope after the unit was pushed (translated) out of the structure. The failure occurred at different times and places, meaning that the process is somewhat stochastic and varied depending on several factors like for instance, wave height, wave steepness and slope angle.

In case of the steeper slope (3:4), units mostly came out of the structure by rotation out of the armor layer down-slope after one (in some cases 2) of the following situations:

1. A unit was displaced forward from the underlayer.
2. A unit was slightly rotated backwards (see figure 4.6).
3. A unit was twisted to either side.

Figure 4.6: Xbloc+ slightly rotated backwards.

However, for the milder slope, there was no indication before the failure occurred. Some displacement and rotation could be seen almost at the time when the failure or extraction occurred, meaning that everything happened within one test (1000 waves approximately). A qualitative sequence of the unit journey until failure is shown in the following figures (figures 4.7 and 4.8). Forces involved are also indicated, giving a overall look of the process the structure undergoes during tests until one or more armor units are pushed out of their original place. Note that due to the angles and shape of the unit, the bottom and upper unit does not provide enough resistance, leaving room for the unit below to come out.

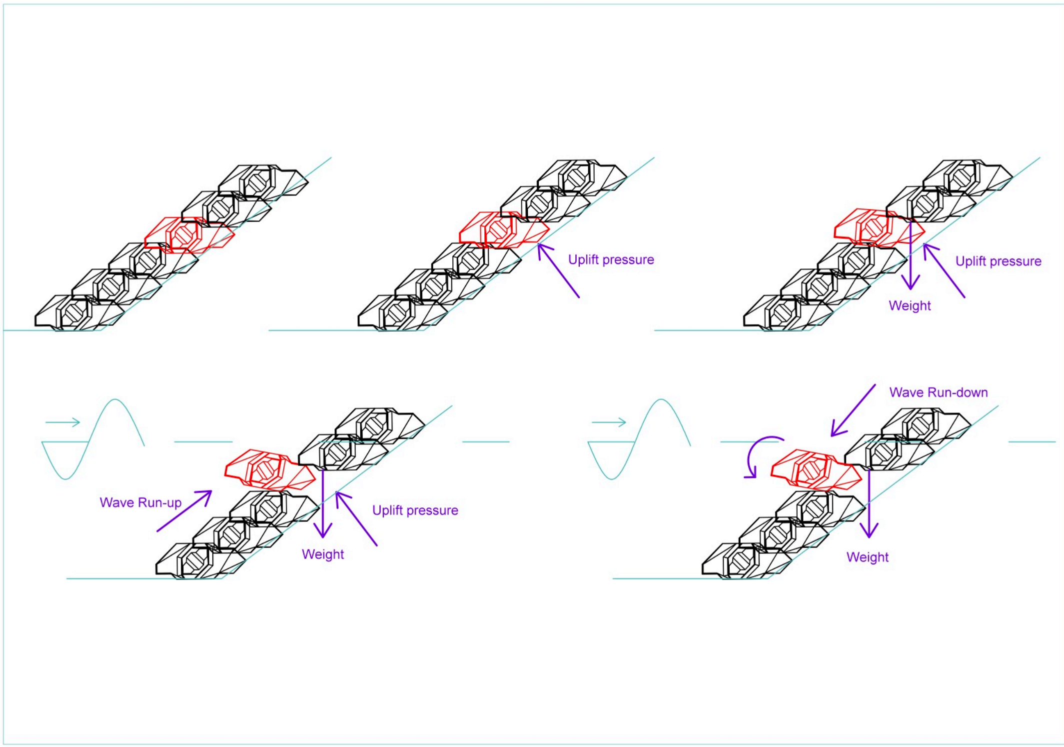

Figure 4.7: Failure mechanisms during test series 1-4 (3:4 slope).

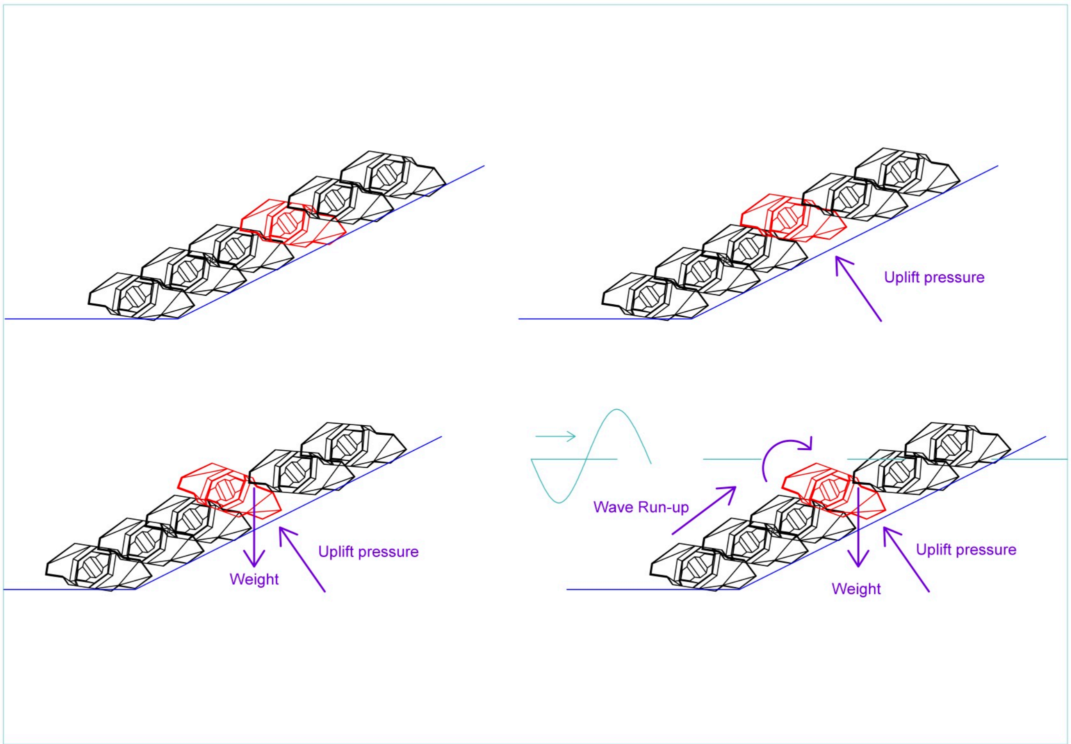

Figure 4.8: Failure mechanisms during test series 5-7 (1:2 slope).

The uplift pressure could be the result of 2 situations:

– Due to wave downrush, uplift forces are increased (rapid change in phreatic level).

– If the porosity on the armor layer is significantly smaller than the underlayer's porosity, the pressure gradient between the underlayer and armor layer increases, creating a higher uplift pressure which pushes the blocks outside of the structure.

4.2.1. LEAKAGE LENGTH

As it is known there are several types of protections against waves. Each one of them will undergo the same type of loads, while the behavior and dimensions are completely different. The differences between each type of protection lie in the transfer functions from the external to the internal load and from the internal load to the response of the structure (strength) **[12]**. During previous studies of the Xbloc+$_{v1}$, it had been noticed that the structures' failure is achieved almost at the design wave height (Ns ≈ 2.65) while the Xbloc+$_{v2}$ (for differences between both Xbloc+$_{v1}$ and Xbloc+$_{v2}$ see section 3.3.3)has no damage at that stage.
During the test series1, it was seen that the unit was lifted up from the underlayer as if the pressure gradient was too high between the armor and underlayer. In order to calculate the flow on the top and underlayer, the following equations were followed:

$$v_T = k_T \frac{(\phi_F - \phi_T)}{d_T} \tag{4.1}$$

$$v_F = -k_F \frac{\mathrm{d}\phi_F}{\mathrm{d}x} \tag{4.2}$$

Based on continuity equation ($v_T \cdot d_T = vF \cdot d_F$), then:

$$(\phi_F - \phi_T) = -\Lambda \frac{\mathrm{d}^2\phi_F}{\mathrm{d}x^2} \tag{4.3}$$

where

v_T is the flow through the top layer.

v_F is the flow through the filter layer.

k_T is the permeability of the top layer in meters per second [m/s].

k_F is the permeability of the filter layer in meters per second [m/s].

ϕ_T is the pressure at the top layer in Pascal [Pa].

ϕ_F is the pressure at the filter layer in Pascal [Pa].

Λ is the leakage length.

From this equation it can be seen that the head difference over the armor layer depends directly on the leakage length Λ, which is defined as the length of protection in which the flow resistance through top layer and filter layer are the same **[7][20]**. Consequently, the leakage length was revised using the following formula **[19]**:

$$\begin{gathered} \frac{d_T}{k_T\Lambda} = \frac{\Lambda}{k_F d_F} \\ \Lambda = \sqrt{\frac{k_F d_F d_T}{k_T}} \end{gathered} \tag{4.4}$$

The most important parameter on the leakage length calculations is the permeability/porosity of the armor layer because of its high influence on the hydraulic response of the structure. In order to compare both types of Xbloc+, the porosity was calculated based on the areas where the water is able to infiltrate (grey areas depicted in figure 4.9) from which the results in table 4.1 were obtained.
Note that porosity is often calculated as stated in equation C.1, but for this research, the calculations were made differently and consequently the parameter is named porosity$_{\text{surface}}$.
For more information about the leakage length and porosity calculations see appendix C.

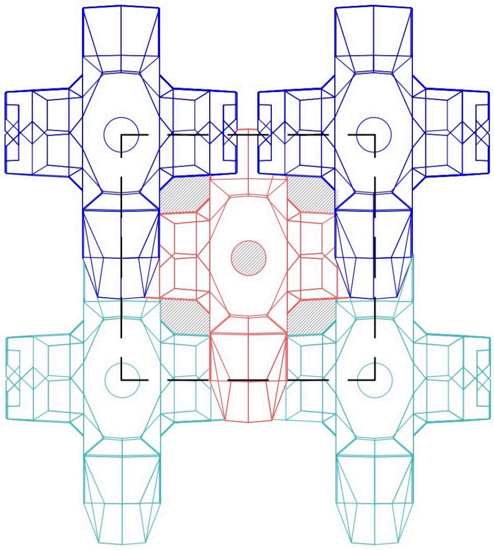

Figure 4.9: Representation of areas where water is infiltrated.

	Dn [cm]	Porosity Underlayer	Porosity$_{surface}$	Underlayer Thickness [cm]	Armor Layer Thickness [cm]	Λ
Xbloc+$_{v1}$	2.949	35%	11%	2.60	3.57	5.70
Xbloc+$_{v2}$	2.906		15%			4.66

Table 4.1: Leakage length calculation for Xbloc+$_{v1}$ and Xbloc+$_{v2}$
Porosity of the underlayer was obtained based on the Rock Manual's thickness and porosity in narrow gradation table.

It can be inferred that a small value of Λ is the most favorable situation for an armor layer stability since there is no head difference across the top layer, while a large leakage length means that the armor layer is relatively impermeable compared to the underlayer, increasing the pressure gradients, leading to uprush and downrush velocities and drag forces on the individual stones. As it is seen from the calculations, the Xbloc+ has a leakage length representative of a semipermeable revetment. Although the difference in porosity$_{surface}$ between version 1 and version 2 of the unit is not significantly high, the small change represents a large difference on the stability of the structure. The main failure mode of a placed block revetment is the instability of the block because of the higher pressure forces from the inner side of the revetment (upwards forces) than the sum of deadweight and friction forces (downward forces). Therefore, the Xbloc+ has a revetment-like failure mechanism.

4.3. MOVEMENT OF ARMOR UNITS

During testing, several type of movements could be seen. These were classified and measured differently for more accuracy and will be explained in detail along this section.

4.3.1. ROCKING

Rocking in these tests is defined as the continuous and regular movement of one or more armor units. The rocking movement of the units (constant movement of an unit due to the cyclic nature of the wave) were counted manually during the tests. The location of the units is shown in the following figure:

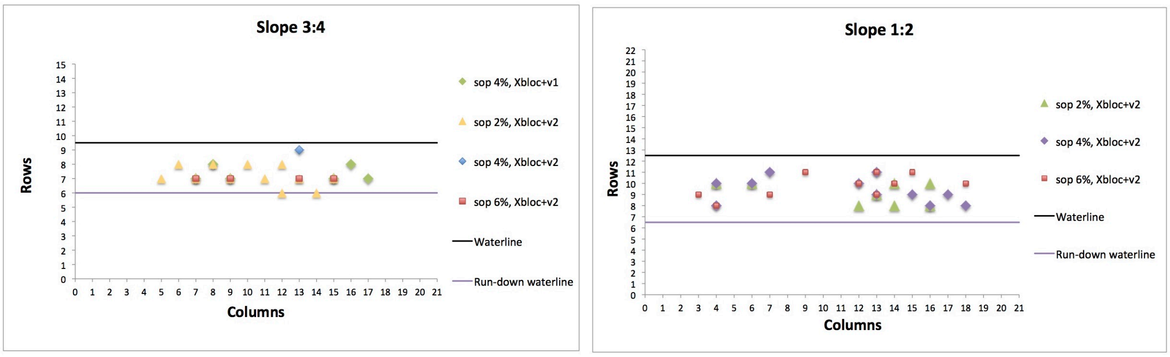

Figure 4.10: Location of rocking units during tests in both 3:4, and 1:2 slopes.

As seen in the previous graphs, all of the rocking units were located below the waterline. Note that in some cases, the location of the units is the same for several tests although it is hard to observe it in the graph due to its size. Furthermore, this relates to the area where the run-down occurs as it is indicated on each figure. The wave run-down calculations were based on the Rock Manual (2007) which states the following formula:

$$R_{d2\%max} = -1.5H_s \tag{4.5}$$

Although the areas are similar for both slopes (meaning in both cases the area remains between the waterline and run-down waterline), the movement of the blocks and time of occurrence was different. In terms of the type of movement, during test series 1-4 (3:4 slope), it was seen that the units rocked while the flow was moving downwards and upwards (wave run-down and run-up respectively).

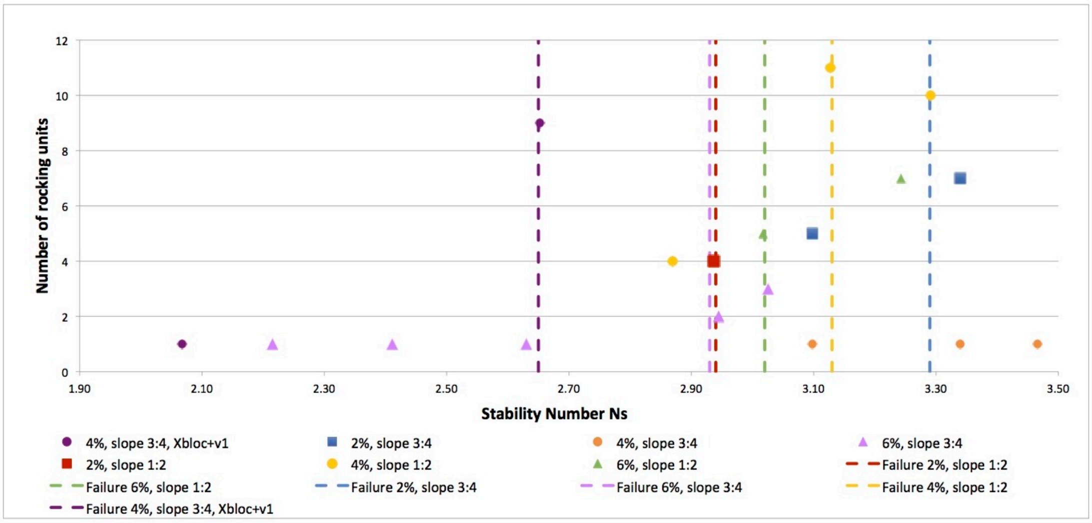

Figure 4.11: Variation in occurrence of rocking units with respect to the stability number at which failure was reached.

In relation with the time of occurrence, during the first set of tests (1-4) rocking units started appearing around the design wave height (Hs = 9.38 cm, Ns = 2.52) with the exception of series 1 in which rocking units appears since the first test. During series 5-7, rocking units appeared at the moment or after a unit was fully displaced (figure 4.11). Thus, it can be concluded that on a steeper slope, rocking units might have an effect on the failure of the structure, while on a flatter slope, they do not.
Also, the wave steepness has an influence on rocking units as it can be seen in figure 4.12. When comparing wave steepness, the curve varies, as for instance, during the series 2-4 (3:4 slope), the 4% steepness has a flat trendline while a 2% steepness has an exponential one. However, it is shown that it remains constant during the same wave steepness even in a different slope angle (both 2% wave steepness have the same trendline in slope 3:4 and 1:2), with the exception of the 4% wave steepness in which failure was not reached in a 3:4 slope.

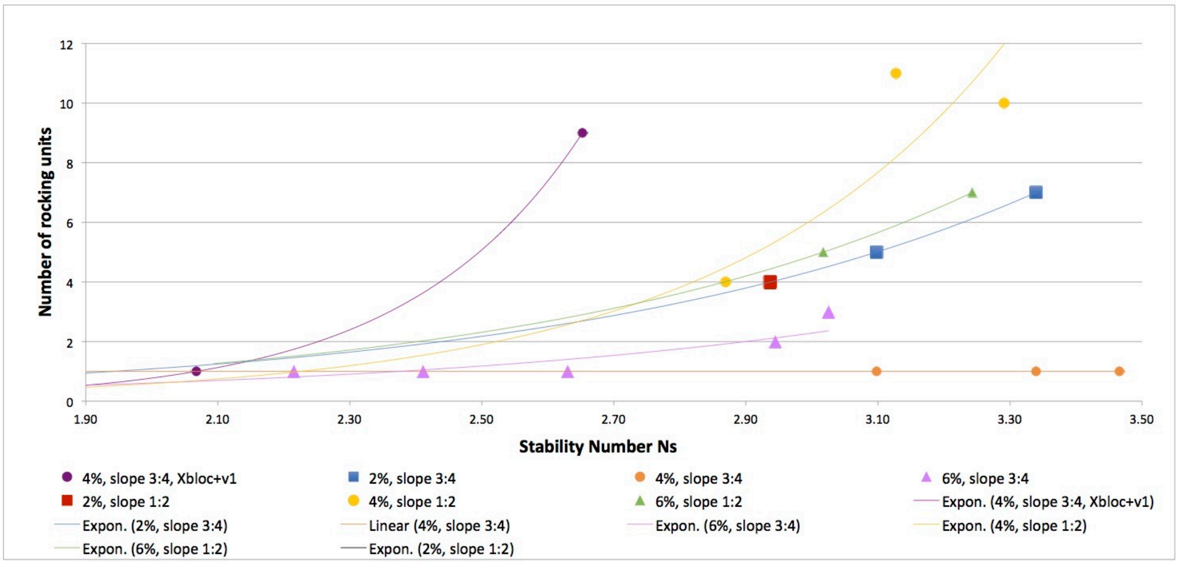

Figure 4.12: Variation of the amount of rocking units with respect to the wave steepness .

Another important fact is that it was observed that the units rocking where not the ones that displaced first from the structure.

4.3.2. DISPLACED UNITS

As previously explained in section 5.1, the the amount of partially and fully displaced units were calculated using photographs of the tests and AutoCAD software. Furthermore, several images where obtained, for example figure 4.13, in which the initial placement of the units is represented by dots while the figure behind it depicts the final location of the units. All the results from the calculations can be found on appendix D.

Figure 4.13: Displacement of units occurred during Series 3.

Displacement of less than 0.2 D_n were neglected. Displacements between 0.2 D_n - D_n were accounted as "Partially Displaced Units". Greater movements than D_n were considered as fully displaced.

PARTIALLY DISPLACED UNITS

During each test, the displacement was calculated as shown in figure 4.14.

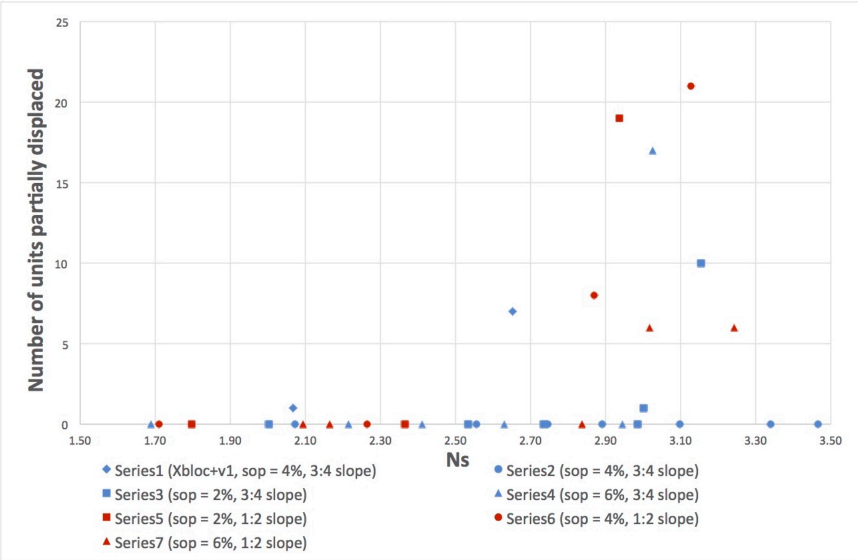

Figure 4.14: Units partially displaced per test during series 1-7.

Moreover, results differ when measured per test than when measured from initial - final test as shown in the next figure. This relates to the direction in which the unit is moving.

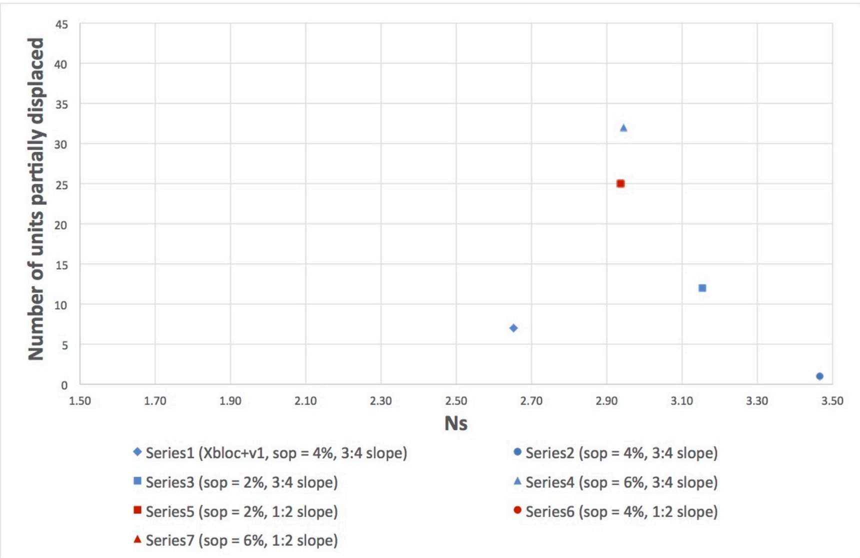

Figure 4.15: Units partially displaced during series 1-7 calculated by comparing only initial and final test.

FULLY DISPLACED UNITS

Based on the boundaries afore mentioned, the results shown in figure 4.16 are obtained. Note that there is no progression of the displacement, which means that all displacements occurred during one tests and not progressively throughout the entire series, which is shown in figure 4.17.

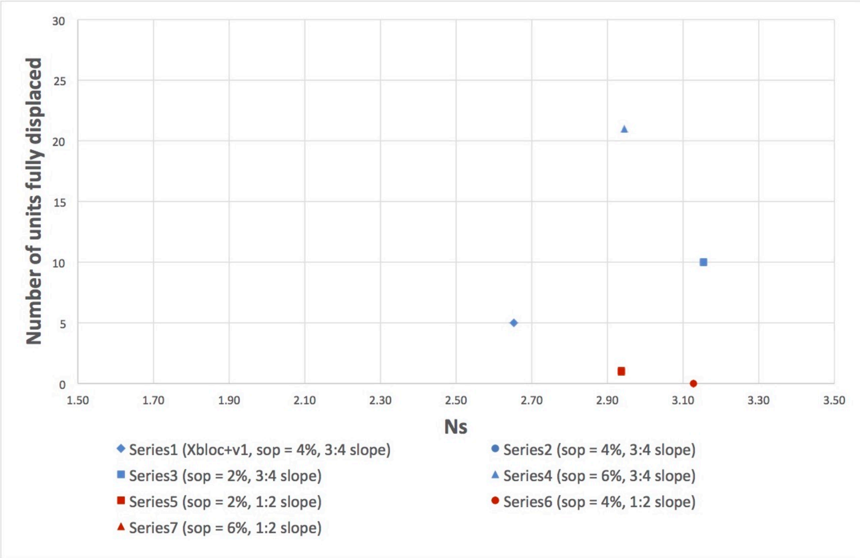

Figure 4.16: Units fully displaced during series 1-7 calculated by comparing only initial and final test.

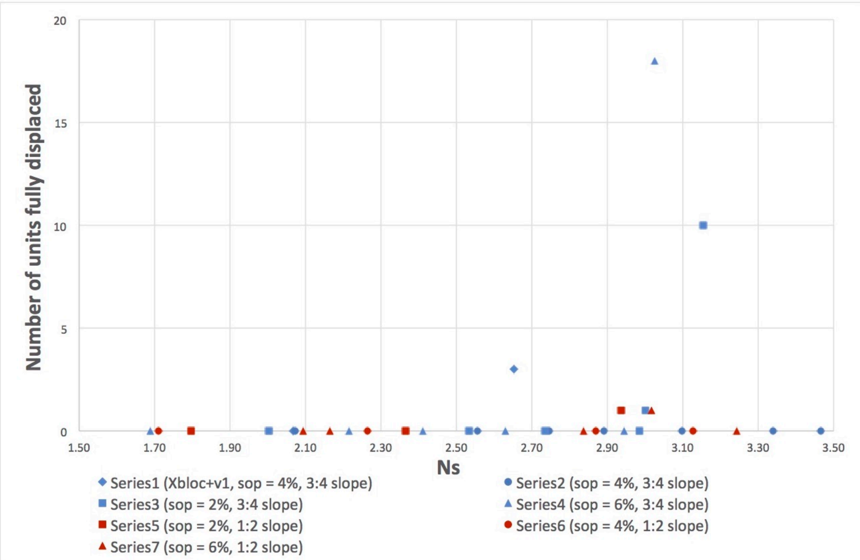

Figure 4.17: Units fully displaced per test during series 1-7.

Tables with complete data and results from calculations of displacements are shown in appendix D.

4.4. DAMAGE

In order to calculate the damage of the armor layer, a clear definition of this parameter must be explained. Following Tulsi (2016), Verhagen et al. (2012), and Van der Meer (1991) recommendations, Nod (damage within a strip) will be used, hence the following formula:

$$N_{od} = \frac{n_{displ}}{B_{test}/D_n} \tag{4.6}$$

where

n_{displ} is the number of partially or completely displaced;

B_{test} width of the test area in meters;

Consequently, the damage was calculated using both partially and fully displacement calculations.

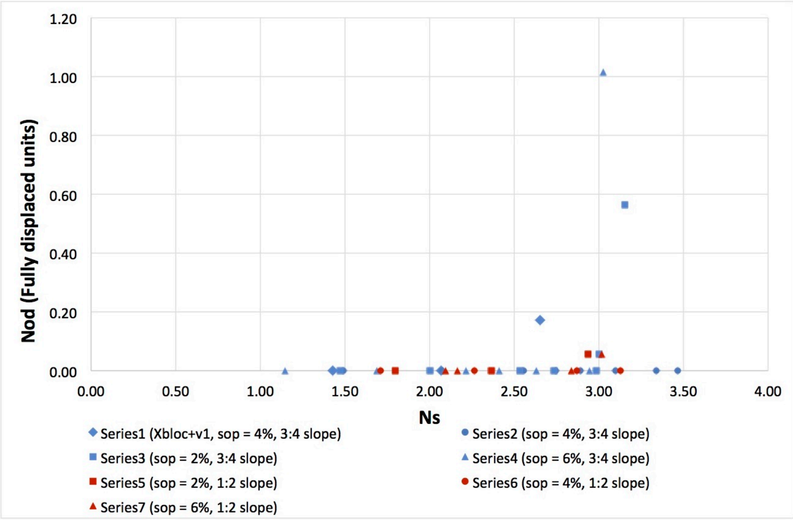

Figure 4.18: Damage as a result of fully displaced units during series 1-7.

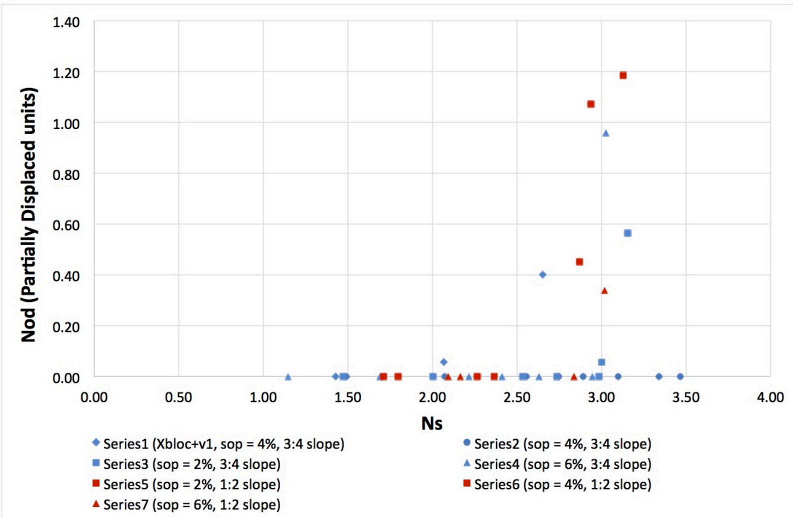

Figure 4.19: Damage as a result of partially displaced units during series 1-7.

All the before-after pictures from all tests can be found on appendix E.

4.5. INITIATION OF DAMAGE

In order to know if there is any indication of the start of damage, by tracking the movements of the first fully displaced unit, the following graph is obtained.

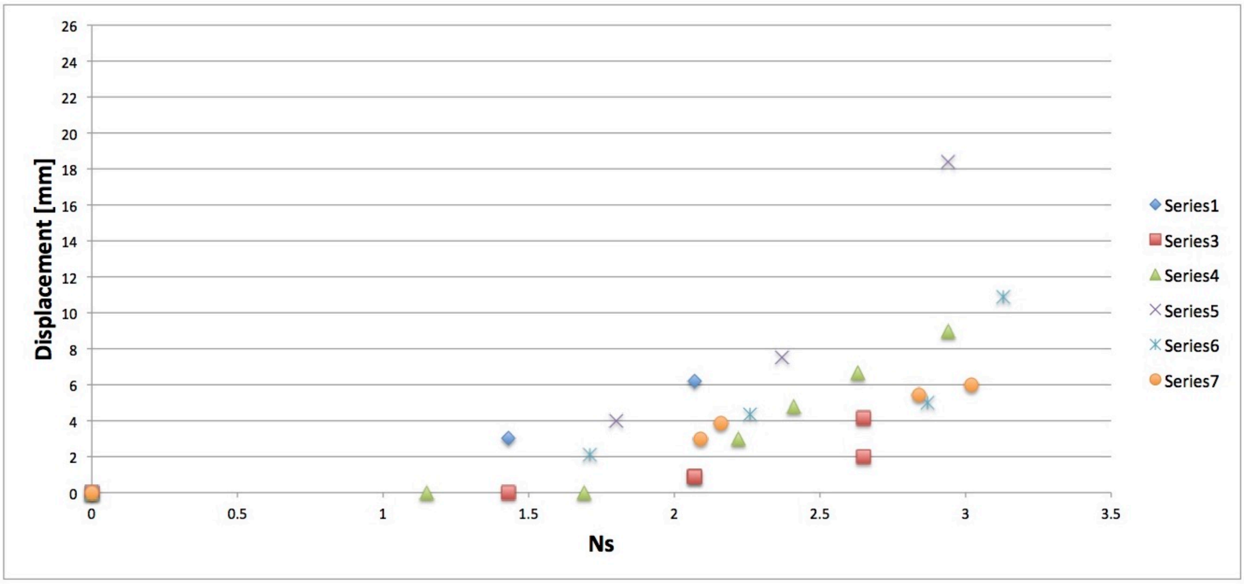

Figure 4.20: Displacement progression of first unit fully displaced during series 1-7.

This shows that there is no indication of the beginning of damage. Units are constantly moving but in a controlled way until the applied forces are higher than the resisting ones. Note that measurements are taken before and after the tests are performed but no measurements are taken during the tests which means that there is a lot of data that is not accounted for.

4.5.1. INFLUENCE OF THE PLACEMENT OF THE ARMOR LAYER ON DAMAGE PROGRESSION

Packing density and placement of the armor units is of extreme importance since it is directly correlated to the stability of the armor layer and structure. While testing the Xbloc+, two series of tests of 2% and 4% wave steepness tests were performed, using the same wave file input and model scheme (3:4 slope).
During the first 2 series (one of each wave steepness), there was a malfunction on the wave gauges and therefore, the tests data is not accurate, making it impossible to use it for further calculations. Nevertheless, failure was achieved during swell tests (2% wave steepness) and it was seen that the damage progression was extremely fast once the first unit came out of the structure (around 150 waves). During the repetition of the tests, the failure mechanism remained the same but the damage progression was significantly longer (over 600 waves). The placement of both tests is shown in the figure below in which the first tests is shown on the left side, while the second (improved placement of armor layer) is located on the right side. During the process of

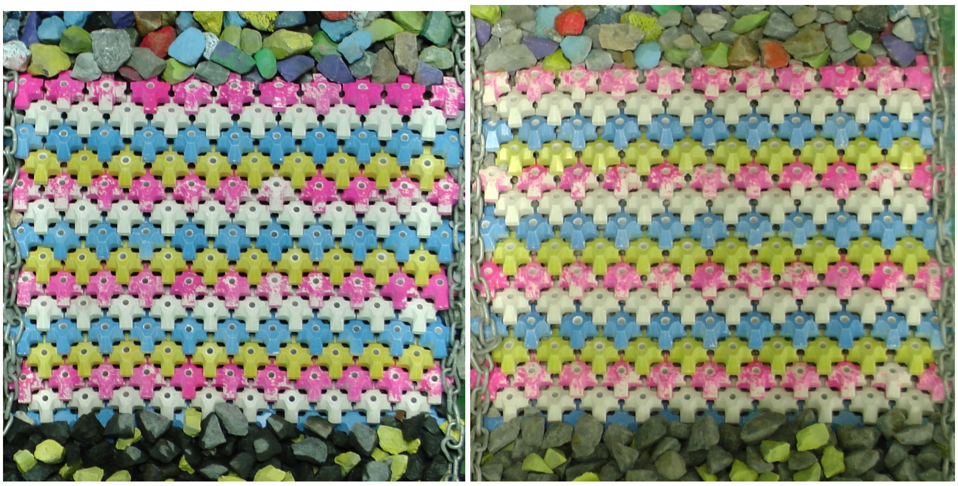

Figure 4.21: Placement of armor layer during series 3.

building the model for the first tests, the placement was correct but not as exact as the second test. The units were placed as good as possible without taking the time of checking one by one. In the latter test every unit was placed as perfectly as possible, checking whether is was supported on every side, including the connection to the underlayer. Note that the difference between placements is so small that the packing density does not vary between tests (the same 158 units were used in every 3:4 slope test), but it cannot be neglected due to the major difference it causes on the stability of the structure. Consequently, the corresponding response to each placement is shown in figure 4.22.

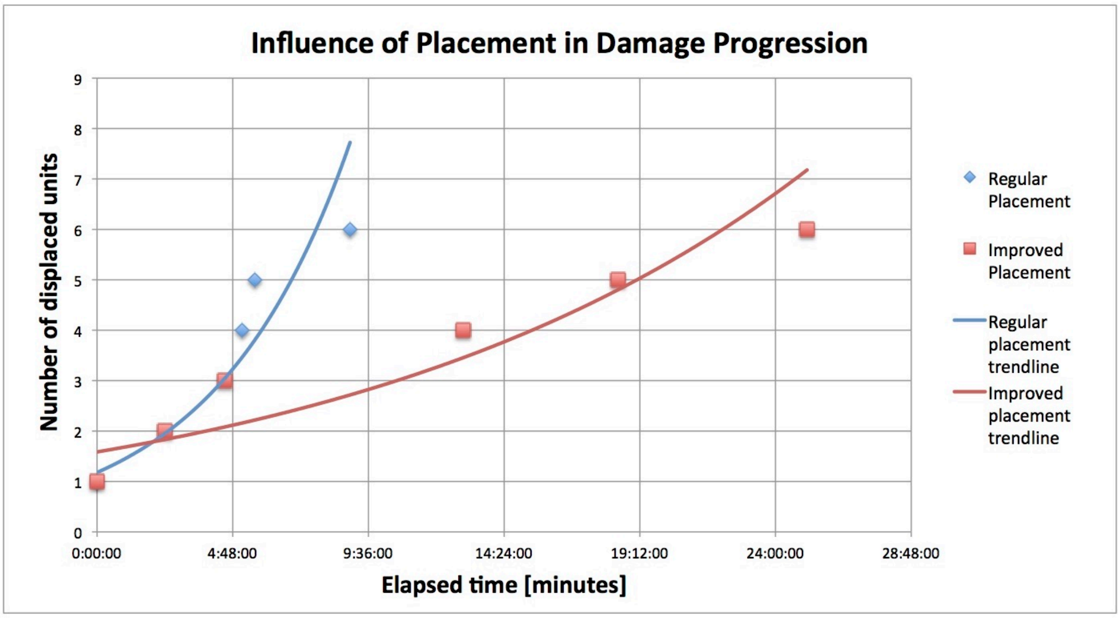

Figure 4.22: Damage progression variation with different placement of armor units during 2% wave steepness test in a 3:4 slope (series 3).

The Xbloc+ is designed to have a spacing of 1.1 D and 0.63 D horizontal and vertically respectively. From both tests the distance between units was calculated and the mean, maximum and minimum distances were obtained.

Distance in x-direction				
	Mean [cm]	**Standard Deviation**	**Maximum [cm]**	**Minimum [cm]**
Series 3 v1	5.00	0.18	5.41	4.65
Series 3 v2	5.24	0.14	5.36	4.90

Distance in y-direction				
	Mean [cm]	**Standard Deviation**	**Maximum [cm]**	**Minimum [cm]**
Series 3 v1	3.17	0.15	3.58	2.74
Series 3 v2	3.25	0.11	3.58	2.96

Table 4.2: Distance between units during series 3 version 1 and 2.

As it can be seen from the results above (table 4.2), there is more variation in spacing between units in the first version of the test than in the second version as the standard deviation is larger. By comparing these values to figure 4.22, it can be inferred that a greater variation in separation between units, relates to a lower stability. Furthermore, a construction tolerance was calculated and shown in the following table:

	Mean	Maximum	Minimum
X-direction	1.8 D_n	1.8 D_n	1.8 D_n
Y-direction	1.08 D_n	1.13 D_n	1.02 D_n

Table 4.3: Distance between units during series 3 version 1 and 2.

4.5.2. INFLUENCE OF THE SLOPE ANGLE ON DAMAGE PROGRESSION

The slope angle of a breakwater structure is, just as packing density, an important parameter which has a significant effect on the stability. Depending on the armor unit, the slope varies to enhance the functionality of the armor block. In the case of units working by interlocking forces, a steeper slope is recommended (3:4 or 1:1.5). On the other hand, concrete units that rely on friction more than any other restoring force are usually placed on a milder slope (1:2).

Xbloc+ was tested into 2 slopes (as described in chapter 3) and it was found that the armor layer is more resistant in a steeper slope since the failure was achieved on a stability number of approximately 3 (for results see appendix B table B.1).

The failure mechanism (section 4.2), and behavior after damage was also found to be different between slopes. As shown in figure 4.23, after the first unit fell out of the structure (around a wave height of 11 cm and a stability number of , the damage increased exponentially. On a flatter slope, the failure started for a wave height of 10 cm (stability number of approximately 3.40) but the damage progression was, overall, much slower. After damage started (meaning one unit flipped over or fell out of the structure), several units followed quickly, especially in the 6% wave steepness test. Nevertheless, after a period of time, it seemed like the structure achieved a certain level of stability from which no more damage was perceived, which can be observed in figure 4.23 represented by the flat trendline for the 2% and 6% tests. In case of the 4% test, 5 units fully displaced within 5 minutes. Nonetheless, the structure slowly showed damage and has the longest progression in comparison with the rest of the series in either slope.

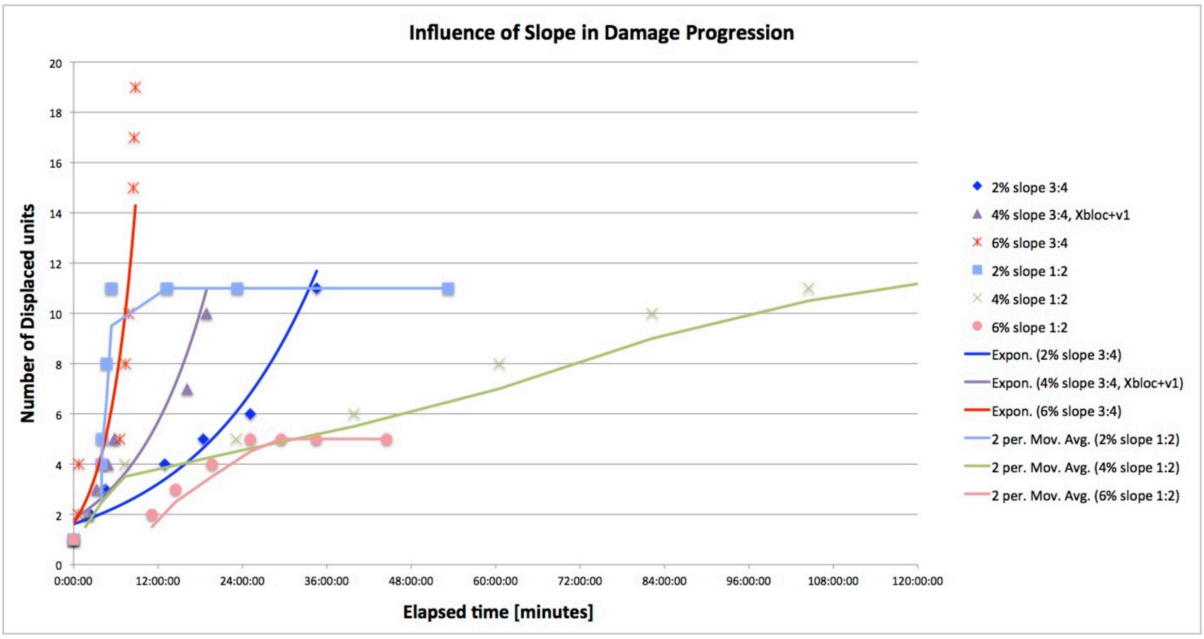

Figure 4.23: Damage progression variation with slope angle.

Note that only 8 units were account for in order to make a fair comparison of the damage progression between both slopes.

After achieving failure on a 1:2 slope, 2 more tests were performed with an increased wave height in order to see how much damage was gained. Therefore, the structure underwent a storm of approximately 5 hours (2 tests of 1000 waves each) and the displacement calculations showed the following results:

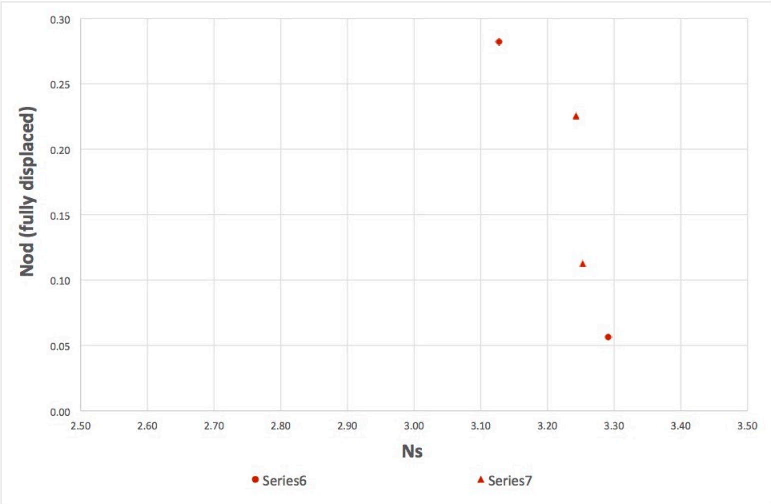

Figure 4.24: Damage measured after failure is achieved during series 6-7.

From figure 4.24, it can be seen that after failure is reached, the damage does not increase significantly even though the structure was undergoing wave heights higher than the estimated design wave height.

4.5.3. RISK AREA

After all tests were performed, the most affected areas were determined as shown in figure 4.25. Furthermore, figure 4.27 provides and overview of the common risk areas based on the results obtained from series 1-7.

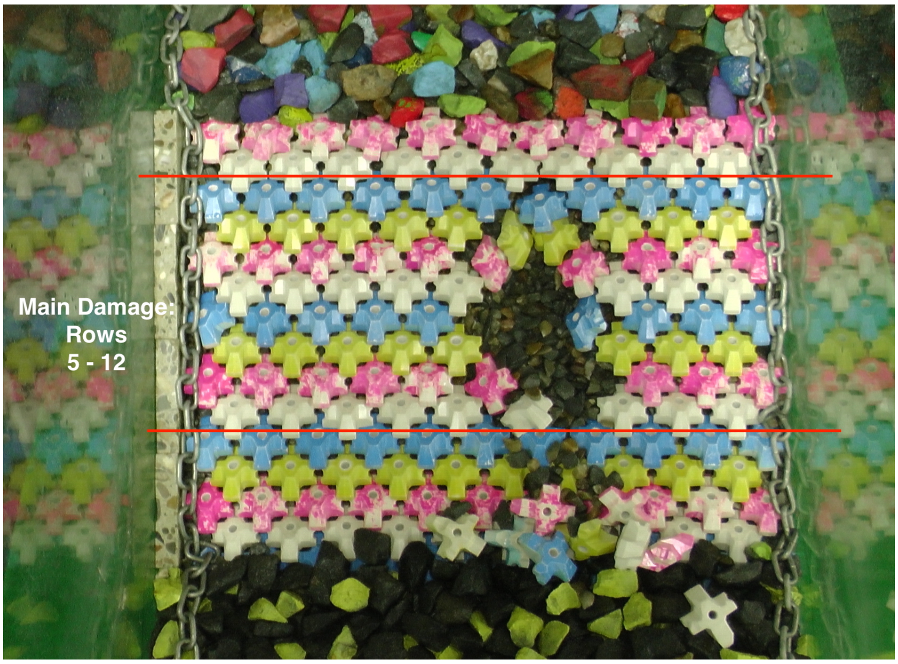

Figure 4.25: Damaged area occurred during Series 3.

From visual observations during the tests, the damage mostly occurs between the mean water level and the run-down waterline, and, as the damage increased, the affected area expanded reaching higher and lower levels than the waterline and run-down waterline. Although the run-down and run-up results from the same wave, the forces and pressures created by these 2 situations are different. During the wave run-up, the resulting forces have an opposite direction to gravitational forces while during the wave run-down, the forces are applied in the same direction causing:

– A drag force on the armor layer caused by the flow moving downwards of the slope.

– A uplift pressure and outward flow near the point of the maximum wave run-down caused by the encounter of the downward flow (from the wave run-down) and the upward flow (from the incoming wave).

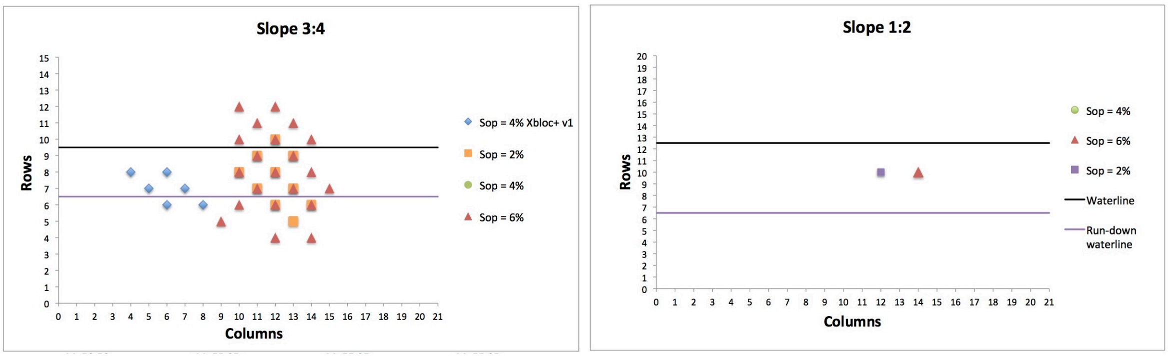

Figure 4.26: Risk ares based on results of series 1-7.

Bear in mind that the wave run-up leads to overtopping and potential failure of the back slope of the structure, but for the tests presented in this study, the wave run-up is less hazardous.

From all the results, the distribution of the damage among the rows was obtained.

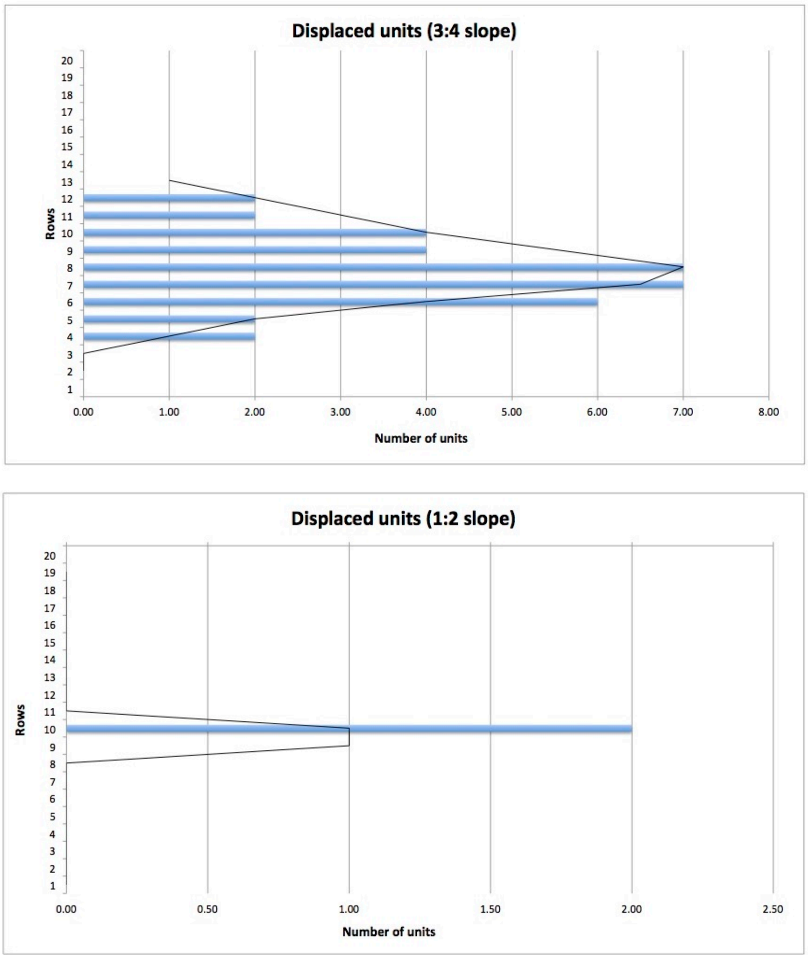

Figure 4.27: Displacements distribution based on results of series 1-7.

These graphs show that the fully displaced units can be approximated by a Gaussian distribution regardless of the slope angle. Therefore the probability of failure occurring on a specific row can be calculated. Since from figure 4.26 and 4.27 it can be perceived that the measurements in the 1:2 slope are not as accurate as in the 3:4 slope, a new method of measurement is considered and will be discussed further in section **??**.

5
Discussion

This chapter discusses the results presented in Chapter 4, identifies improvements to measurements, and suggests opportunities for future research. First, the accuracy of the instruments used to measure the different parameters throughout the tests is discussed in section 5.1. Section 5.2 introduces new calculations involving a new methodology for measuring the individual displacement of the units along with a discussion about its relation to damage and failure of the structure. Sections 5.3, 5.4, and 5.6 discuss about the influence of the placement, failure mechanisms and damage respectively. This chapter ends with a discussion about the comparison between the new Xbloc+ and other single layer concrete units in section 5.7.

5.1. Accuracy of Measurements

Although measurements were taken as precise as possible, there are always errors. These errors may occur due to human error or due to lack of accuracy in measuring devices. During this research, several parameters were measured such as:

- Wave height;
- Wave period;
- Test duration;
- Water depth;
- Slope angle;
- Displacement of units.

5.1.1. Wave Height and Period

Using WaveLab3 software, a spectral analysis was performed from which the wave height and period were obtained. The accuracy of this calculations relies mostly on the wave gauges' readings. The accuracy of the equipment is set to be 0.01 - 0.1 mm and consequently there was an error in measurements. In order to calculate the measurement error, the signals from the wave gauges were superimposed, showing the difference in readings, and therefore the error. Figure 5.1 shows the signals from the wave gauges from where the error was calculated to be 0.35%.

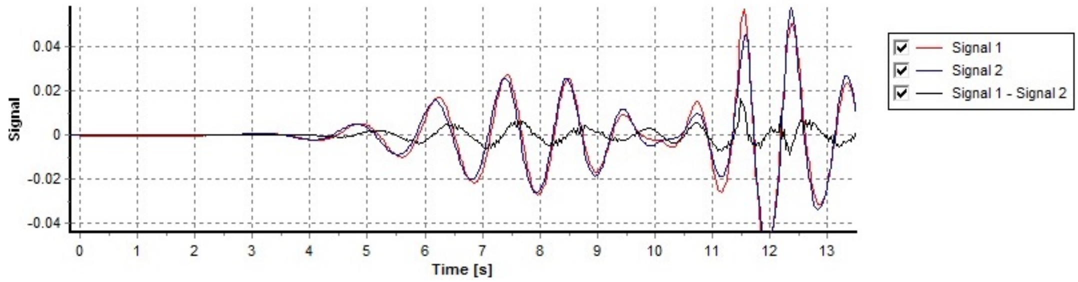

Figure 5.1: Time series of wave gauge signal at deep water.

5.1.2. TEST DURATION

The duration of the tests was set to be 1000 waves, which means that depending on the test, the duration (in seconds) varied due to the wave period. The wave data recorder provided a measurement of the duration of the test, therefore, although the initiation and end of the test is manually done, the accuracy of the test is not affected.

5.1.3. WATER DEPTH

Since overtopping was also being measured during tests, water depth had to be measured constantly since a decrease on the water depth can induce wave breaking, and consequently affecting the results. Hence, a ruler was fixed to the glass to avoid errors in measurements due to different positioning of the instrument. As a result, little variations were found, so the effect of water depth fluctuations can be neglected and the error of measuring water depth can be considered irrelevant.

5.1.4. SLOPE ANGLE

After the necessary calculations, a detailed blueprint was created in AutoCAD, and with it, the structure was built. Even though the structure was manually built, the drawing was used as a guideline by redrawing it on the flume glass. The error of the construction of the slope and deviation of the angle is neglected.

5.1.5. DISPLACEMENT OF UNITS

In order to calculate the distance displaced by each unit, pictures where taken at the beginning and end of each test. Using those pictures and by using AutoCAD, the coordinates of each location were obtained and by subtracting the initial position minus the final position, the direction and displacement were calculated. Note that the unit is moving in a 3D environment while the calculations are made on a 2D plane, and as a result, some movements are not being detected. Even though during this process, a scale factor was considered in order for the calculations to be as precise as possible, it is important to mention that there is a certain level of distortion in the pictures due to the angle of the camera and state of the water. If the picture was take while water was not a 100% still, a greater distance appeared during calculations. Consequently the error was estimated to be 1%.

5.2. MOVEMENT OF UNITS

5.2.1. ROCKING

Hofland (2005) measured turbulence induced motions of flow over a rock bed and observed mostly rotation under moving stones. Since armor units are presumed to have a similar behavior, a rotational movement of the units was expected during testing and accounted for as shown in the Results and Analysis section. This movement is assumed to occur due to the cyclic nature of the wave but since it remains between the waterline and the run-down waterline, this hints that the resulting drag forces have a higher effect on the units.

Since the measurements were taken from observations and pictures, it is hard to relate the effect of

the rocking units to the failure mechanism or the first unit extracted but it is of extreme importance to understand the consequences of any rocking unit.
While rocking, there are external forces applied on the unit and, therefore, some momentum as well. The movement stops after collision is achieved which means that the unit reaches another unit. Transfer of momentum must be happening during this process which was not accounted for in this research. It was observed that the units rocking where not the ones that displaced first from the structure but how the rocking units affect the rest of the armor layer was neither defined nor measured.

5.2.2. Displacement Of the Armor Layer Units

The main objective of the displacement computation was to gain information about the failure of the structure. By knowing the distance a specific unit moved, it could be related to the beginning of damage which not only allows to predict when failure will occur, but it also helps preventing grave damage of the structure.
It was perceived that since in a milder slope there was more rotation than translation, by tracking the displacement from one of the corners of the unit rather than the center, more information could be obtained (figure 5.2). Hence, with this method, rotation is measured while translation is measured by tracking the center of the unit. The result is shown in figures 5.3 and 5.4:

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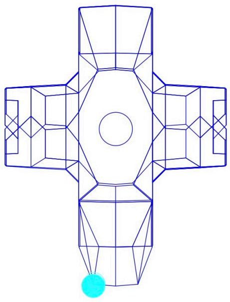

Figure 5.2: Location of the tracking point for new method of calculations.

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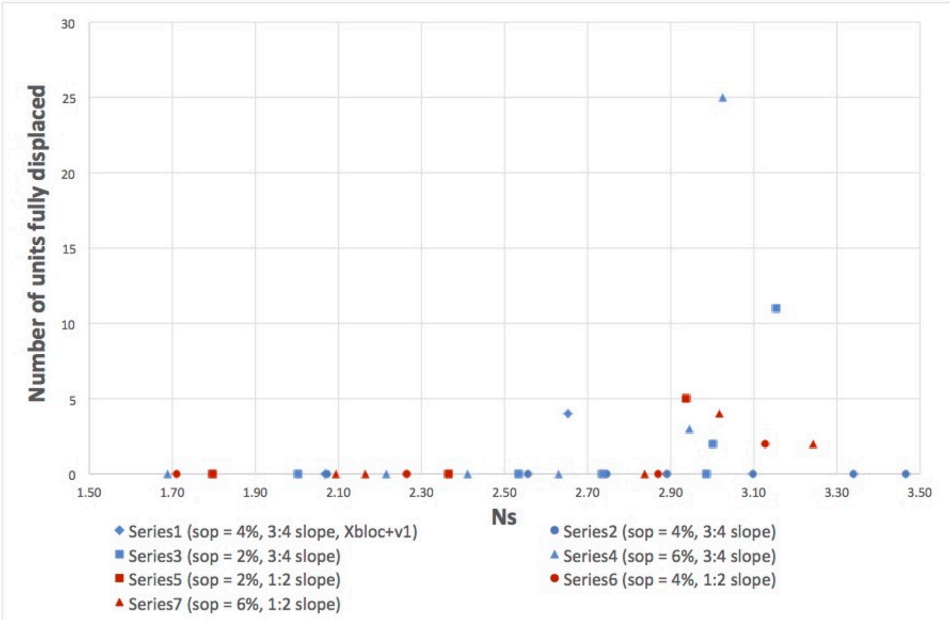
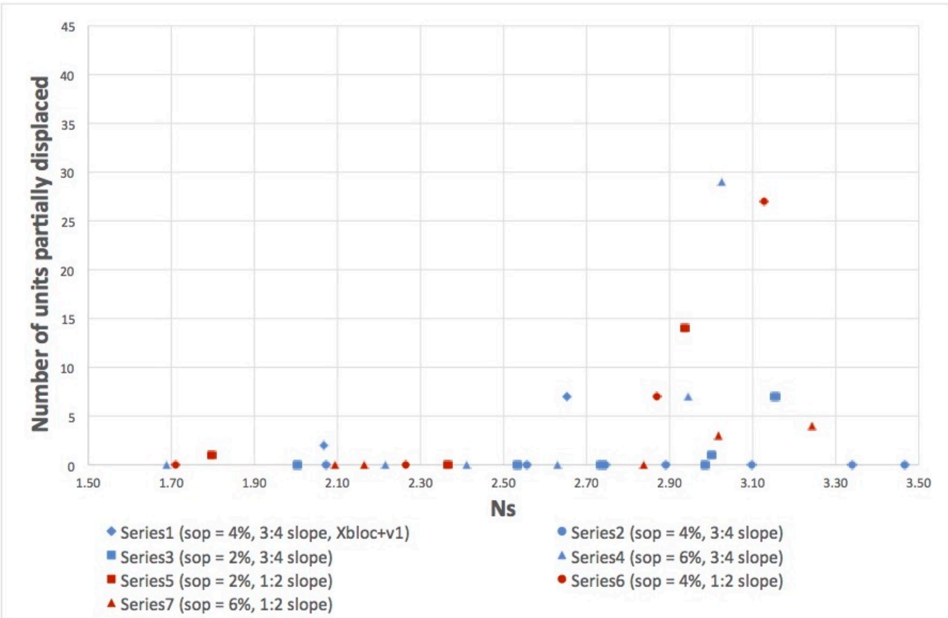
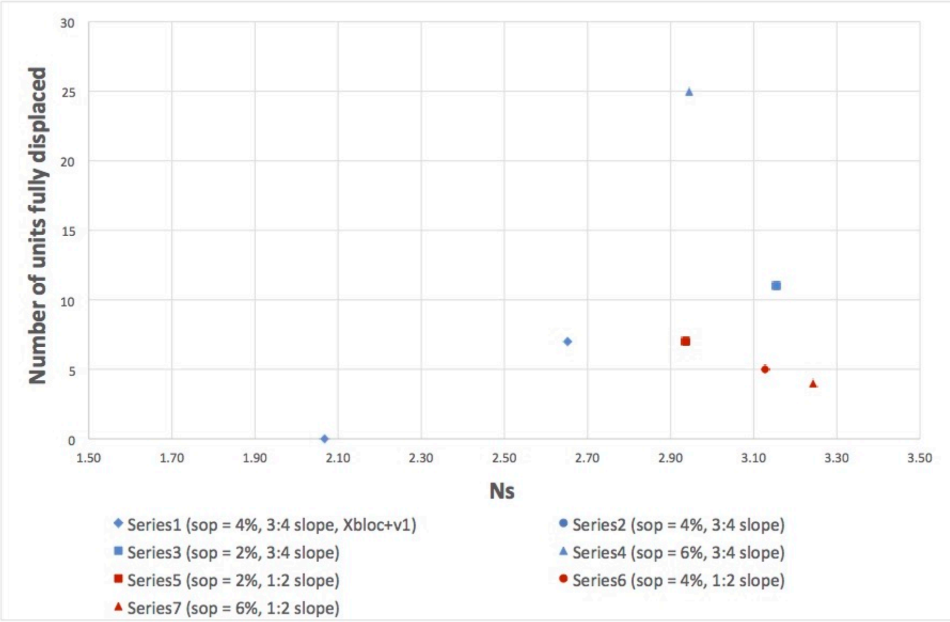


(a) Units fully displaced.

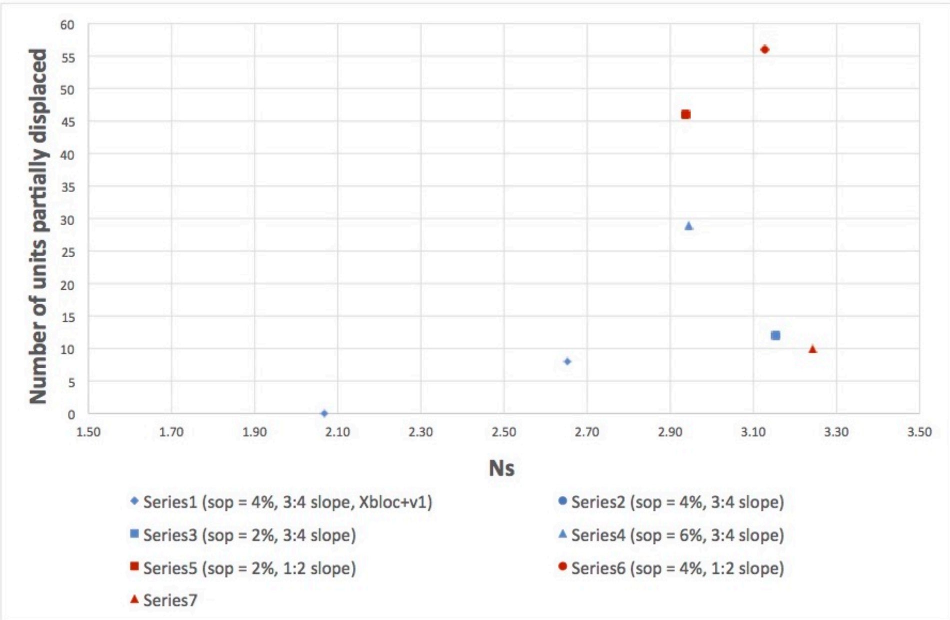


(b) Units partially displaced.

Figure 5.3: Results from new method of calculations for units individual displacement per test during series 1-7.



(a) Units fully displaced.



(b) Units partially displaced.

Figure 5.4: Results from new method of calculations for units individual displacement obtained by comparing only initial and final test.

By comparing the previous figures with the ones presented in Chapter 4 (figures 4.14 - 4.17), it can be observed that a bigger difference in the displaced distance is reflected in the number of partially displaced units than in the fully displaced units. This relates to the fact that the distance is not long enough to change to the following category (meaning that although in the first method the displacement is calculated to be 5 mm, and in the second method the result is 10mm, the displacement still remains as a partial displacement). This is shown in the following example (figure 5.9), in which the difference in displacements obtained from series 7 is provided. As it can be seen, most of the displacements are not significant with the exception of a few units which rotated more than translated.

Rows	Columns 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
20		-1.45		-0.80		1.32		-0.38		1.29		1.09		0.60		-1.02		-0.68	
19	2.53		1.67		2.68		3.87		1.32		1.95		2.67		2.68		1.85		-1.24
18		0.43		1.70		1.32		2.61		1.51		3.95		1.41		2.65		0.91	
17	1.58		0.19		0.46		0.52		1.92		2.22		3.01		0.89		1.39		1.54
16		1.53		2.84		1.45		0.96		0.02		3.34		1.88		0.80		0.31	
15	-0.03		2.78		2.09		0.81		0.38		0.51		1.24		0.34		0.74		0.73
14		2.98		1.26		3.05		-0.03		0.39		0.55		1.09		2.00		1.43	
13	0.70		3.49		2.41		1.28		0.42		1.38		1.63		-0.24		1.14		1.62
12		0.28		-0.57		0.55		0.87		2.31		2.81		1.21		1.59		-1.26	
11	-0.47		0.82		1.54		3.25		1.45		-1.60		2.32		3.67		0.96		1.44
10		2.55		-0.82		1.55		1.20		1.74		3.17		-8.36		0.61		0.87	
9	-0.21		0.88		0.02		0.71		0.02		28.75		15.77		-1.65		-0.77		0.07
8		0.46		-1.03		-1.08		1.27		-1.80		20.08		-0.37		0.36		-0.58	
7	1.57		0.93		-0.12		-1.51		-0.19		-1.32		0.03		1.72		-0.40		0.51
6		-0.83		-1.12		-0.24		-1.23		-0.17		1.73		0.63		1.37		0.63	
5	-0.59		0.51		-0.69		-0.34		0.04		-0.43		0.48		0.09		0.76		-0.43
4		2.83		0.45		1.48		-0.39		-1.29		0.01		1.04		0.83		0.35	
3	-1.01		1.18		0.34		-1.37		0.14		-0.16		0.41		0.43		1.80		2.38
2		1.46		0.82		-0.90		-0.39		-0.40		-0.87		-0.49		-0.32		2.11	
1	-1.03		-2.56		-0.88		-0.77		1.12		0.09		3.80		-1.01		2.45		2.82

Figure 5.5: Difference in displacement calculation methods. These values were obtained by subtracting the second method (corner-to-corner measurements) minus the first method (center-to-center measurements).

Consequently, the new risk areas and damage distribution are shown in figure 5.6 and 5.7.

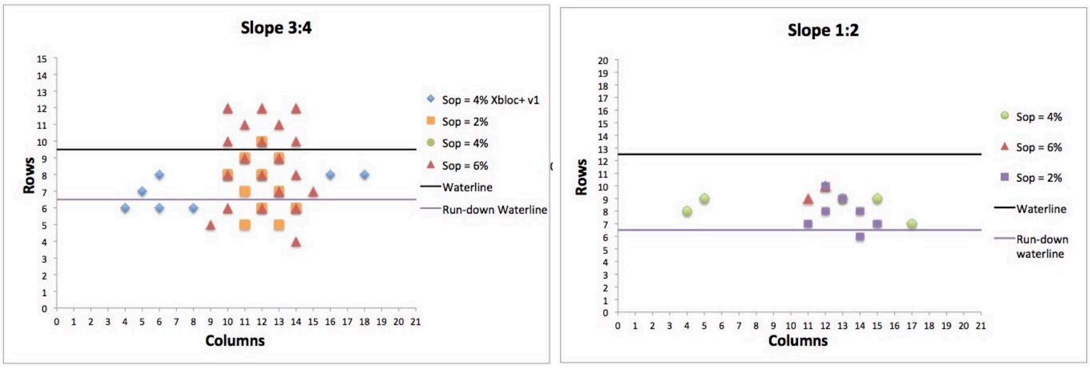


Figure 5.6: Risk ares based on results of series 1-7 using corner-to-corner measurements.

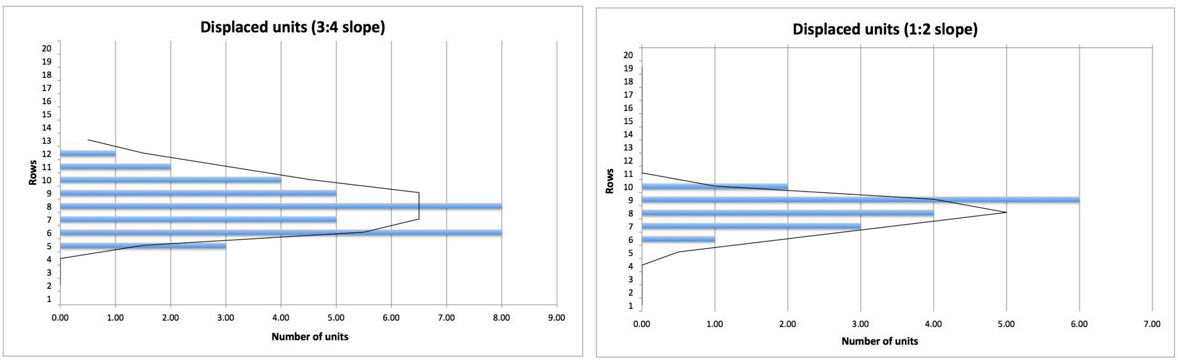


Figure 5.7: Displacements distribution based on results of series 1-7 using corner-to-corner measurements.

Furthermore, when analyzing the initiation of damage, from first calculations (center-to-center measurements), there is no relation between the distance moved by an unit and the beginning of damage (see figure 5.8), as it was mentioned in the previous chapter. From the second method of measuring the distance (corner-to-corner measurements), although displacements are significantly bigger, there is still no relation to the beginning of damage.

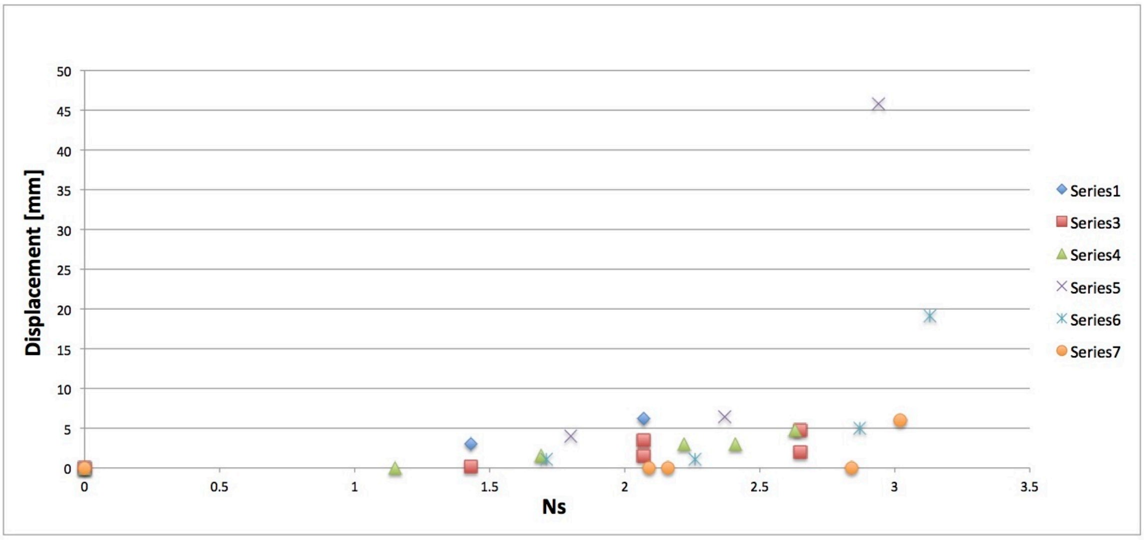


Figure 5.8: Displacement progression of first unit fully displaced during series 1-7 using new method (corner-to-corner measurements).

These results either mean that the first unit to come out of the structure is stochastic (implying that it is not possible to know when is going to fail the structure) or that the time elapsed from the moment the damage starts till complete failure is so fast that is not possible to measure with the method used for the testing.

If the displacement of the unit is random, and is not possible to determine the beginning of damage, then the structure must be over-designed and conservative in order to prevent any type of displacement and future damage to the structure. Consequently the following boundaries appear:

- A bigger structure which includes:
  - More material;
  - Bigger area to fit the structure;
  - Larger storage area to cast and store the armor units;
  - Larger concrete volumes for larger concrete units.
- More capacity in construction equipment;
- Longer construction time;
- Larger project budget.

On the other hand, the possibility of the development of damage being too fast for the calculation methods used is highly probable. Figure 5.9 provides an overlook of the damage progression in series 5. As it can be seen, pictures a and b were taken at the beginning of the test Ns 2.37 & 2.94 respectively while picture c shows the state of the structure at the end of the test Ns = 2.94. Between the first test, displacements are barely noticeable, however, within the last test, when failure is achieved, the damage is significant.

Since there is no data or measurements during the test apart from visual observations, there is no way to define if there is a distance that could be established as the beginning of damage. Therefore, for future researches, pictures must be taken within a shorter period of time in order to achieve a conclusion of whether the displacement occurs stochastically or the evolution of damage is too fast.

5.3. PLACEMENT

One of the things that was found the hardest was the placement of the units. The process was divided into 2 phases:

1. First, second and third row, and
2. Remaining rows until crest.

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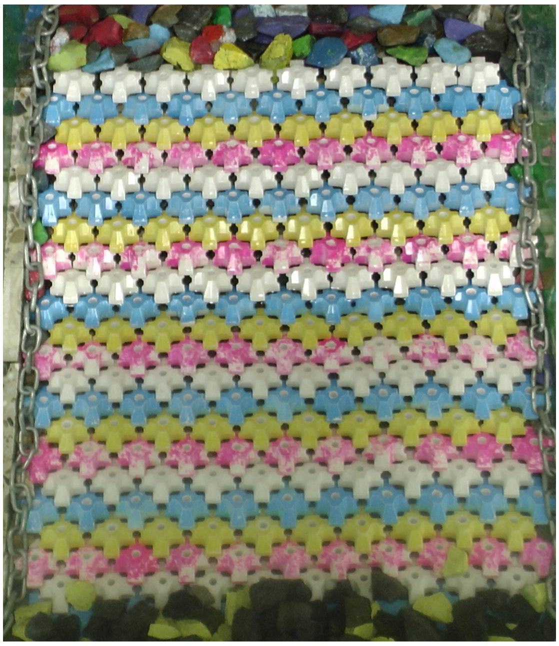
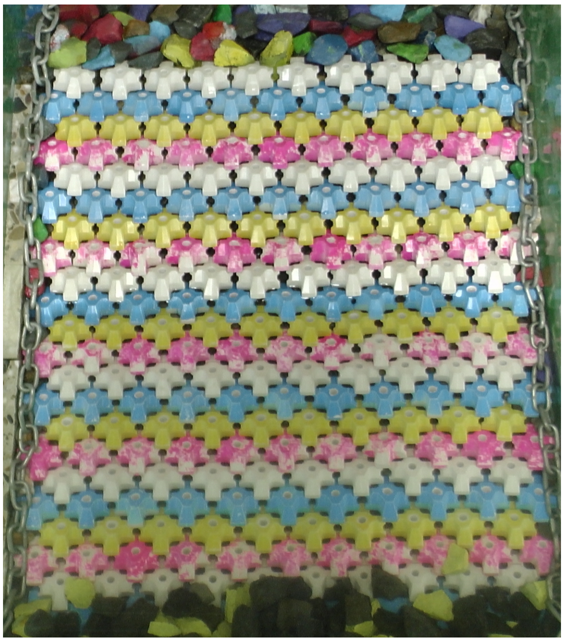
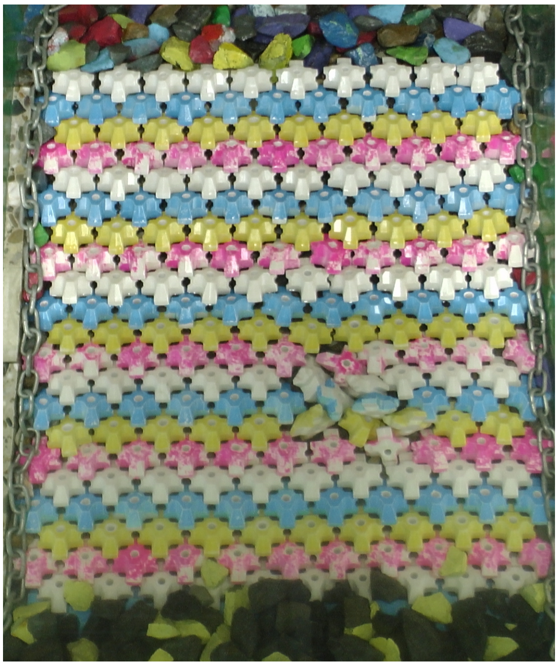


(a) Beginning of test Ns = 2.37



(b) Beginning of test Ns = 2.94



(c) End of test Ns = 2.37

Figure 5.9: Evolution of damage during series 5.

Phase 1 took as much time as phase 2 even though it only entitled less than 30% of the entire structure (without considering the crest, toe and chains). It was also the most important rows out of the complete structure. If this phase was not completed correctly, the mistakes were not perceived immediately but later on higher rows such as seventh or eighth, which are associated to the risk areas (see figure 4.26). Moreover, in order to fix the situation, all units had to be removed and replaced.
Since the placement has a strong influence on the damage progression of the structure (see section 4.5.1), and in the construction time, it is an crucial parameter to look into. The time it took to have a "perfect" placement was double as long as the "regular" placement which means that the construction cost increases. Also, it is important to mention that in reality, achieving the perfect placement or fixing phase 1 after starting phase 2 is highly unlikely (if not impossible) to happened.
Moreover, placement under water is difficult and given that placing the first rows is the hardest part of the construction using this unit, it's a subject of extreme importance. Although there is certain equipment that helps situating the units correctly, sometimes it is impossible to have accurate guidance due to turbid water. Hence, there are 2 critical factors to consider and study further:

1. Placement methods;
2. Situations in which placement is easier.

Placing the units is relatively easy using our hands and scaled units but, what happens when a crane is involved? Since it is not possible to try using an actual crane and real size Xbloc+, it might be interesting trying different techniques in which the armor layer is built without being inside the flume, like for instance from the top of the flume. Other possible test is to build the armor layer without an empty flume which would resemble a little more real life although the turbidity is not accounted for.
Note that this type of unit could be better fitted for medium to large tidal ranges areas in which the loads in low water are usually small and there is more dry area to place the units.

5.4. STABILITY AND DAMAGE OF THE ARMOR LAYER

In terms of stability, there are two main questions that come into sight for different reasons. The first question is: when is the Xbloc+ more stable? In order to answer that question, another question must be answer first: what is stability? If a structure is considered stable until failure is achieved then it can be said that Xbloc+ is more stable when placed on a steeper structure (3:4 slope). However, if a structure is considered stable when even after failure provides shelter and protection, then the answer differs to a milder slope.
During the tests on a 3:4 slope, failure was achieved around a stability number of 3.15. Units fell off the structure leaving units around them without support and unprotected to wave action and most importantly, they left an exposed underlayer. The damage inflicted on the underlayer was quite significant. After removing the armor layer, the underlayer had to be repaired due to large irregularities and deformations.
During 1:2 slope tests, failure was achieved on a lower stability number compared to the previous slope ($Ns \approx 3$). Although the failure mechanism is similar (this was shown in the previous chapter section 4.2 and will be discussed further in the following section) the type of damage is completely different. Units during these series did not fall out of the structure but rather rotated and remained on the slope, meaning 2 important things: the underlayer was never exposed to wave action, and that the units around the rotated Xbloc+ still had support. The difference between the damage on the structure is shown in the following figures:

As a result, damage on the underlayer was hardly perceived. Although it was not tested, and since the underlayer did not have deformations, the armor layer could be fixed without removing the complete layer (just by removing it until the damaged rows and replacing them).
It is indispensable to mention that after failure is achieved, during series 5-7 it was perceived as if the structure reached another level of stability. As shown in figure 4.23, the structure did not suffer major damages after failure is achieved. Due to time limitation, tests were not able to be conducted until changes in stability could be recognized. Nevertheless, this is an important parameter to look into on future studies because it could possibly give us more information to work with when making a decision and designing a breakwater.
Another essential question is during which wave climate is more appropriate to use this type of unit.

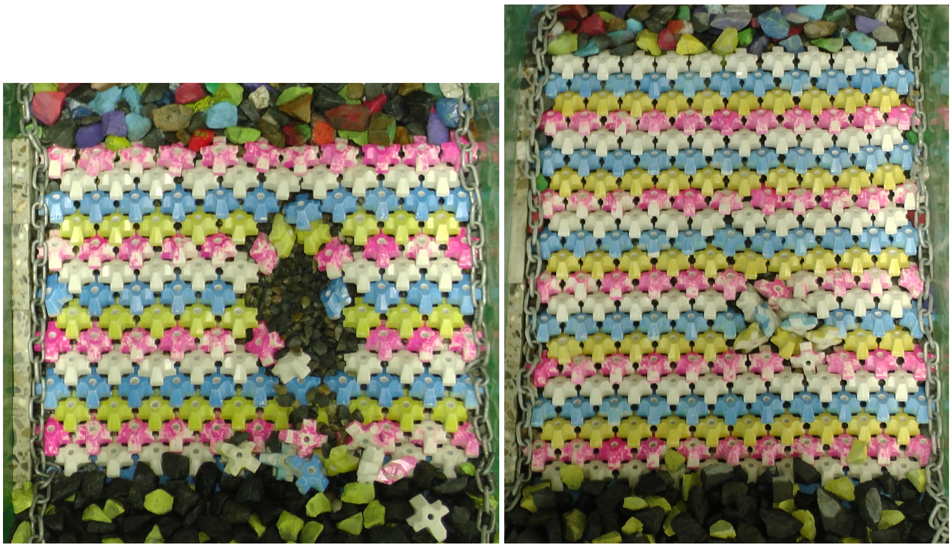


Figure 5.10: Final state of the structure after swell waves on a 3:4 (left) and 1:2 (right) slope Failure occurred at a stability number of 3.15 (140% Hs) and 2.94 (100% Hs) respectively.

From the results it can be inferred that the most critical situation is swell waves regardless of the slope angle. Although failure is reached faster than during the other 2 wave steepnesses (4% and 6%), it can be said that the structure is stable during this type of situation. It also can be said that the structure behaves better absorbing energy rather than reflecting it.

5.5. Influence of the Foreshore

The foreshore slope is an important parameter to consider due to the fact that the Iribarren number indicates that, for a slope, the notion "steep" and "gentle" are relative **[20]**. A slope of 1:100 is considered as gentle for wind waves whereas for swell is considered very steep. Therefore, it can be said that the slope used during the tests does not represent "mild" conditions.
As previously mentioned, although the breaker parameter was calculated, a lot of plunging waves were seen during tests especially in the 4% wave steepness, which indicates that the foreshore had indeed some influence on the wave climate.

5.6. Failure Mechanism

As it was mentioned, the new armor unit has a revetment-like failure mechanism. From this, several questions arise such as:

1. Is this behavior due to scaling effects?
2. Would the stability of the structure improve if the layer thickness changes?
3. Would the behavior of the structure be different if the porosity of the underlayer reduces?

It is known that scaling is not only complicated but also impossible to achieve to perfection. If the flow through the core is not turbulent, then scale effects are most likely to appear inducing situations that would not appear in real life which makes the model and tests obsolete. If the model was not scaled properly, the failure mechanism could be the result of scaling effects altering the behavior of the structure rather than the actual performance of the Xbloc+ armor units on a specific environment.
In terms of a revetment, if the layer thickness reduces, the leakage length reduces as well, which should mean that the stability increases. However, even if the failure mechanism resembles the one from revetments, an armor layer and a revetment differ in functionality and behavior which signify that not necessarily the response to the change in thickness will remain the same. Following the same reasoning, the succeeding question can be answered.
A high leakage length implies that the pressure gradient between the underlayer and armor layer is high

and that the armor layer is relatively impermeable in comparison to the underlayer. This suggest that there are 2 solutions, either increase the porosity on the armor layer or decrease the porosity on the underlayer. This should result in a smaller pressure gradient, resulting in less uplift pressure. Moreover, if uplift pressure is reduced, then amor layer units should not be pushed forward and drag forces might be less critical. Consequently, the failure mechanism would differ completely.
Note that this reasoning, since is for revetments (no use of underlayer but a filter layer instead or placement is directly on the core), does not account for the relation between the underlayer and core, and therefore more studies should be done. If the porosity of the underlayer and core is reduced, then this could imply that on a model scale, the core turns somewhat impermeable inducing the appearance of scale effects.
Also, it has to be consider that the K_D factors that have been determined with the Hudson formula are only valid for breakwater type structures with a porous core. Therefore, if the solution to this type of failure mechanism is to make the underlayer and core less impermeable, the K_D value must be reviewed.

5.7. COMPARISON BETWEEN OTHER SINGLE LAYER CONCRETE UNITS

Comparing units provides a helpful insight on the decision making while designing a breakwater. Since Xbloc+ is a brand new unit, there is not enough data to make a proper comparison. Hence, in this case, in order to make a fair comparison, units should be tested under the same conditions. Nevertheless, table 5.7 shows provides an overview of three different units in which certain design characteristics can be compared.
Since the porosity$_{surface}$ seems to be a dominant parameter in the stability of the Xbloc+, this parameter was also determined for Cubes and Xbloc using the same methodology. Just as figure 4.9, figure 5.11 represents the areas where water is able to flow freely when using Cubes or Xbloc units for the armor layer. From these results, the leakage length was calculated and compared in table 5.7.

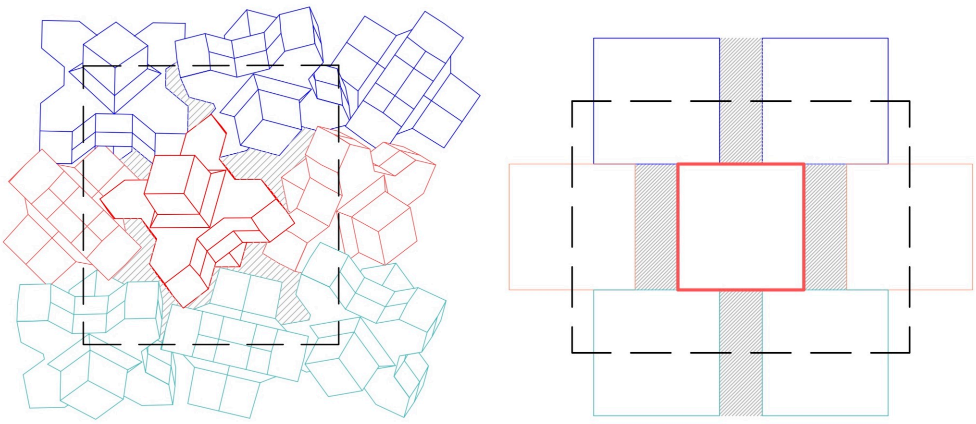


Figure 5.11: Representation of areas where water is infiltrated while using Xbloc and Cubes.

	Xbloc+$_{v2}$	Xbloc	Cube
K_D	12	16	7
$Ns_{design} = H_s/\Delta D_n$	2.52	2.77	2.2
Porosity$_{surface}$	15%	35%	20%
Leakage length (Λ)	4.66	2.52	4.77
Damage N_{od}	0	0.5	0
Damage	0%	5%	0%
Volume of concrete per m^2 on slope	$0.0019H_s^3$	$0.0018H_s^3$	$0.0030H_s^3$
Relative volume of concrete	100%	95%	153%

Note that the porosity$_{surface}$ depends on the packing density of the design. For this calculations, the size and distance between units were based on Tuan Nam Le's research "Rocking Revisited 1, Rocking of a Single

Cube on a Breakwater Slope" **[16]**, and the Xbloc Design Guidelines **[8]**.
Table 5.7 provides the volume of concrete per m^2 on a slope in relation to a certain wave height. From that, a relative volume of concrete was obtain in which is shown that the Xbloc and Xbloc+ uses a similar amount of concrete, whilst Cubes needs 50% more concrete increasing the price of the construction.

5.7.1. FAILURE MECHANISM

From the results presented in Chapter 4 section 4.2, and in comparison with table 5.7 it can be said that due to the $\text{porosity}_{\text{surface}}$, this unit is more relatable to Cubes than Xbloc. Both units have a significantly lower $\text{porosity}_{\text{surface}}$ and therefore, a higher leakage length. Thus, uplift pressures are the dominant factors in the stability of both units. Having said that, it is crucial to understand that an advantage of the Xbloc+ against the Cube is the interlocking capabilities. Although it is not as high as Xbloc (in which this occurs somewhat instantaneously), it does present the ability to engage with the units around increasing the restoring forces. It is still unknown how strong this forces are but for future studies, modifying some of the angles or geometry of the unit could increase it.

6
CONCLUSION

This is the concluding chapter of this research in which conclusions, and recommendations are included based on the explanations given in the previous chapters.

6.1. CONCLUSIONS

At the beginning of this study, several main research questions were established. Based on the outcome of the study, the key findings are as follows:

1. **What are the main failure mechanisms of the Xbloc+?**
   It was perceived that the permeability of the armor layer is low as it happens often with single layer units. Thus, the pressure gradient between the underlayer and armor layer is significantly high creating an uplift pressure that leads to a revetment-like failure mechanism.
2. **Which slope is more suitable for Xbloc+?**
   The behavior of the armor layer differed completely between slopes. On a steeper slope, the armor layer remained undamaged for wave heights significantly higher than the design wave. However, once one unit was fully displaced, the damage was quite destructive. Moreover, the damage progression was quite fast, leaving the underlayer totally unprotected, which caused important damage to the structure.
   On a milder slope, failure occurred much faster but the damage was not as aggressive, which allowed the structure to find a new level of stability and remain functional for more than 1000 waves (equivalent to a 3-hour storm approximately). Therefore, it can be said that in terms of failure, the armor layer stability is higher on a steeper slope. However, in terms of behavior of the structure after failure is achieved, the Xbloc+ has a better performance during a milder slope.
3. **How is the stability affected by variations in wave height and wave steepness?**
   The wave height variation did not have much influence as the wave steepness. There was a noticeable difference between the performance of the structure during swell and wind waves. During swell waves, it could be seen that not only failure was achieved faster but it caused much more damage to the structure, while during wind waves the structure had a higher stability.
4. **How the measured displacement, damage units, and stability numbers differ with other single layer units?**
   In order to create a fair comparison, units must be tested under the same environment and circumstances. Since this was not possible, a general comparison was made. From the results obtained from laboratory tests, it can be seen that the Xbloc+ has more of a similar behavior to Cubes rather than Xbloc for several reasons, like for instance failure mechanism and porosity.

6.2. RECOMMENDATIONS

Based on the findings of this research, several recommendations for future research are proposed:

1. **Investigate Rocking Influence On Stability**
   Although on a 1:2 slope the rocking movement of units started after failure was achieved, on a steeper slope rocking units were constantly present since after the second or third test. Considering that only

visual measurements were taken, the influence of rocking units was not accounted for. In order to see how the constant movement enhances or not failure, other equipment, such as accelerometers, should be used.

2. **Damage Progression**
   Since from the results it can be concluded that the damage progression is fast enough to start and reach failure within 1000 waves, implementing a new methodology of measuring displacement (like for instance waterproof camera that allows not only a closer look to the structure but a mcould provide more information about the beginning of damage.
3. **Influence Of Placement Of Armor Layer**
   Placement of the armor layer was found to have an influence on the damage progression as it was seen that a more uniform placement prolongs the progression of the damage of the structure. However, since this was obtained from comparing only 2 tests, there is not enough information to know how influential this parameter is. Therefore, more tests should be performed to provide a better understanding of how the placement of the armor units could enhance the stability of the structure once failure had begun and whether it is worth or not the increment in the project-s cost due to a longer construction time.
4. **Placing The Armor Layer**
   While building the model, it was found that the hardest and most time consuming part was placing the armor units. Therefore, further studies should be conducted to see whether it is possible or not to place the units correctly under the construction tolerance (table 4.3) with a full flume or something resembling a crane.
5. **Variation Of Layer Thickness**
   Based on the results and analysis presented in Chapter 4, more tests should be performed in order to understand the variation in stability due to a variation in the layer thickness, like for instance variating the thickness between 1 and 5 D_{n50}.
6. **Variation Xbloc+$_{v2}$'s Hole Diameter**
   Since the porosity$_{surface}$ was found to be a relevant parameter, a variation in the diameter of the hole in the unit could also make a significant increase on the stability due to the increment on the porosity$_{surface}$.

6

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A

CROSS-SECTION

This appendix includes detailed cross-sections of the models used for the lab tests.

A

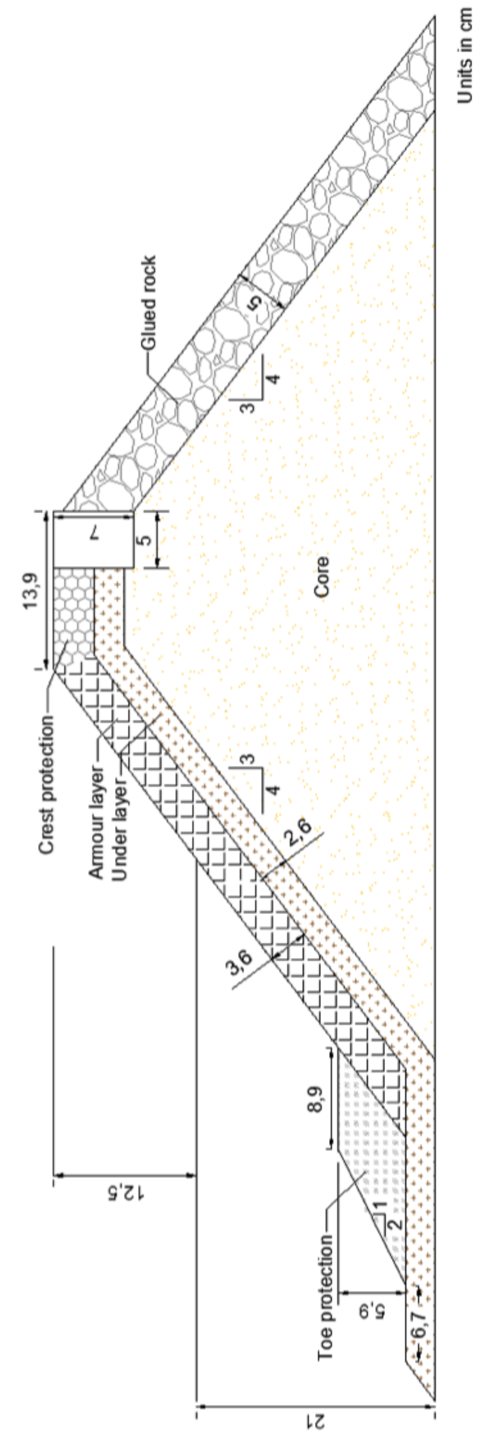
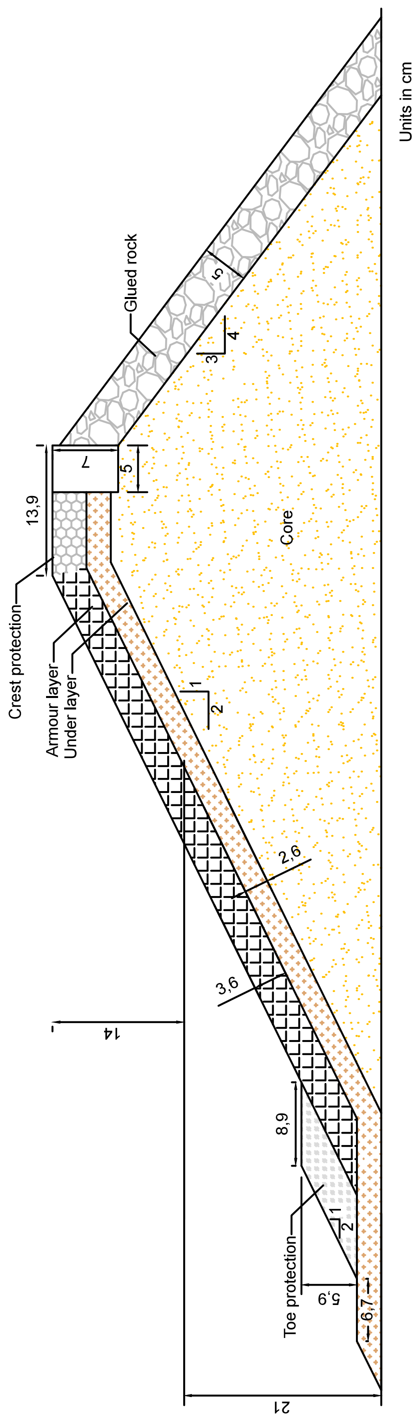
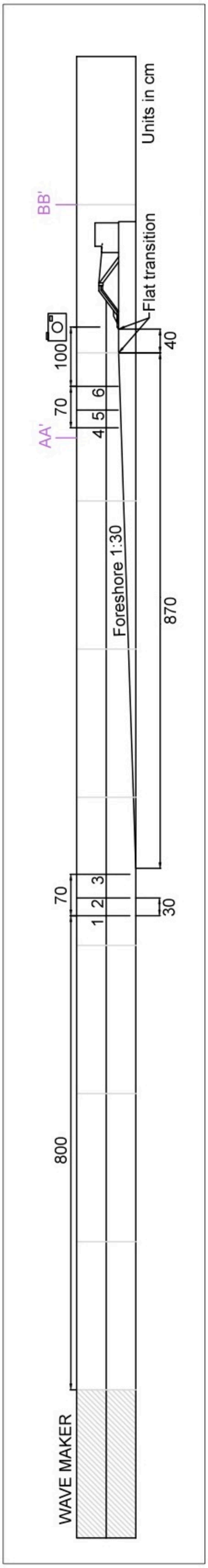


Figure A.1: Cross-section design (Slope 3:4)



Glued rock
5
3
4
Units in cm
7
5
13,9
Core
Crest protection
Armour layer
Under layer
1
2
2,6
3,6
14
8,9
Toe protection
1
2
5,9
6,7
21


Units in cm
BB'
Flat transition
40
100
70
6
5
4
AA'
Foreshore 1:30
870
70
3
2
1
30
800
WAVE MAKER

B
WAVE CLIMATE

The following table presents the measured and calculated conditions for each series and test. As it was previously explained, the tests were performed until failure was achieved. During test series 2 (wave steepness of 4% on a 3:4 slope), tests did not continue from 150% due to breaking waves.

B

				Calculated Conditions				Measured Conditions			
Series	**Unit**	**Slope**	**%H_{design}**	**$H_{s\text{-}design}$ [cm]**	**Tp [sec]**	**s_{op}**	**Ns**	**H_s [cm]**	**Tp [sec]**	**s_{op}**	**Ns**
1	Xbloc+$_{v1}$	**3:4**	60	5.71	0.96	4%	1.51	5.39	0.97	4%	1.43
			80	7.61	1.10		2.01	7.81	1.12		2.07
			100	9.52	1.24		2.52	10.02	1.23		2.65
2	Xbloc+$_{v2}$		60	5.63	0.95	4%	1.51	5.55	0.97	4%	1.49
			80	7.50	1.10		2.02	7.71	1.10		2.07
			100	9.38	1.23		2.52	9.51	1.23		2.56
			110	10.32	1.29		2.77	10.22	1.33		2.75
			120	11.26	1.34		3.02	10.76	1.36		2.89
			130	12.19	1.40		3.28	11.53	1.42		3.10
			140	13.13	1.45		3.53	12.43	1.49		3.34
			150	14.07	1.50		3.78	12.90	1.52		3.47
3			60	5.63	1.34	2%	1.51	5.48	1.36	2%	1.47
			80	7.50	1.55		2.02	7.46	1.60		2.00
			100	9.38	1.73		2.52	9.43	1.78		2.53
			110	10.32	1.82		2.77	10.18	1.83		2.74
			120	11.26	1.90		3.02	11.11	1.94		2.98
			130	12.19	1.98		3.28	11.17	2.00		3.00
			140	13.13	2.05		3.53	11.74	2.07		3.15
4			60	5.63	0.78	6%	1.51	4.27	0.78	5%	1.15
			80	7.50	0.90		2.02	6.29	0.93		1.69
			100	9.38	1.00		2.52	8.25	1.05		2.22
			110	10.32	1.05		2.77	8.97	1.05		2.41
			120	11.26	1.10		3.02	9.79	1.12		2.63
			130	12.19	1.14		3.28	10.96	1.21		2.94
			140	13.13	1.18		3.53	11.26	1.21		3.03
5		1:2	60	6.44	1.44	2%	1.73	6.69	1.42	2%	1.80
			80	8.59	1.66		2.31	8.80	1.68		2.37
			100	10.74	1.86		2.88	10.93	1.88		2.94
6			60	6.44	1.02	4%	1.73	6.37	1.03	4%	1.71
			80	8.59	1.17		2.31	8.43	1.19		2.26
			100	10.74	1.31		2.88	10.68	1.33		2.87
			110	11.81	1.38		3.17	11.64	1.42		3.13
7			66	7.83	0.91	6%	2.10	7.79	0.91	6%	2.09
			80	8.59	0.96		2.31	8.06	1.00	5%	2.16
			100	10.74	1.07		2.88	10.56	1.14		2.84
			110	11.81	1.12		3.17	11.23	1.10		3.02
			110	12.88	1.17		3.46	12.07	1.19		3.24

Table B.1: Calculated and measured wave conditions.

C

WAVE - STRUCTURE INTERACTION

In this chapter, better explanation of the wave - structure interaction is described. During this process, the importance of porosity is described, as well as the method used to calculate the porosity* of the armor.

C.1. WAVE - STRUCTURE INTERACTION

As explained in Chapter 2, wave induces several pressure and forces on a breakwater, meaning that there is an important water-structure interaction that should be further analized.

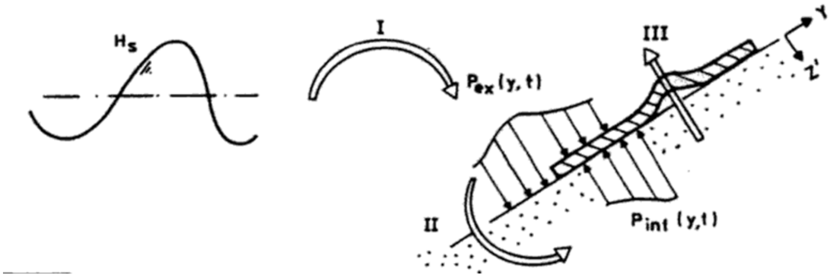


Figure C.1: Representation of the water - structure interaction divided into 3 phases **[19]**.

As shown in the previous figure, there are 3 phases during this interaction:

1. Transfer from the hydraulic conditions to the protection layer as an external load;
2. Transfer from the protection layer to the inner layer as an internal load;
3. Response of the structure.

C.1.1. PHASE I

There are several factors influencing the incoming waves like for instance, the foreshore, which induces incoming waves to shoal and subsequently, some of the waves break. The remaining waves will reach the structure where they will break, dependent on the slope and the wave steepness expressed by the Iribarren number (equation 2.13). Each type of wave has a different impact on the structure, some of them are more dangerous than others.

C.1.2. PHASE II

During this phase, the loads and pressures are transferred from the protection to the filter layer. This transfer depends only on the type of protection layer. Three main categories are identified (figure **??**):

1. Loose grains (rock, rip-rap);
2. Coherent (placed block revetment);
3. Cohesive and impervious (asphalt, concrete, clay).

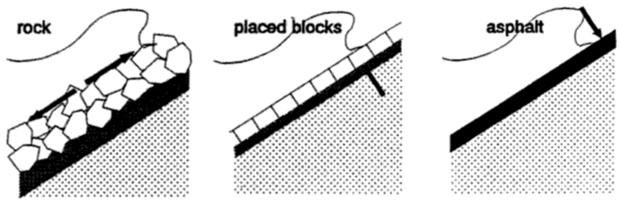


Figure C.2: Three main types of protection against waves **[19]**.

Although the magnitude of loads is constant, the transfer functions differ between the types of protection as it is shown by the arrows in figure C.2. A mathematical way to measure the transfer of loads is by means of the so-called leakage length, Λ. The leakage length is the length of protection in which the flow resistance through cover layer and filter layer are the same **[7][19]**.The leakage length is defined by equation 4.4 in chapter 4.

C.1.3. PHASE III

Phase I and II focus mainly of the loads being applied to the different parts of the structure, while phase III relates with material properties and strength.

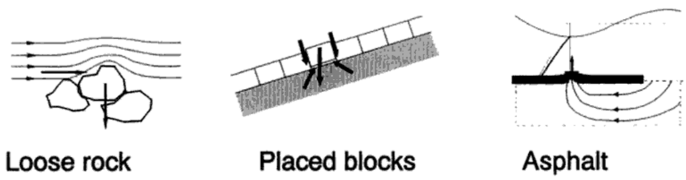


Figure C.3: Strength of protection layers **[19]**.

When the protection layer is made out of loose rock, the strength is derived from the gravitational force or weight. However, when placed blocks are used instead, the weight is not as dominant as it friction (figure C.3). In an asphalt or concrete protection, the structure is more sensible to the wave climate. When the wave climate is mainly based on wind waves, pressure fluctuations are faster (since they are short waves) and consequently, the uplift force is not strong enough to lift the entire protection. This means that, the stiffness and weight of the protection layer represent the restoration force. In an opposite situation, during swell or tidal waves, pressure fluctuations are significantly slower due to the wavelength, which creates higher uplift pressures even if the restoring forces are the same. Furthermore, apart from the aforementioned differences between the different protections, the following table provides some typical values for each situation.

Parameter	"Rocks"	"Blocks"	"Asphalt"
d_{TOP} (m)	0.5	0.25	1
d_{FILTER} (m)	0.25	0.2	2
k_{TOP} (m/s)	0.5	0.001	"0"
k_{FILTER} (m/s)	0.1	0.05	0.0001
Λ (m)	0.15	1.5	"∞"
L (m)	1-2	1-2	1-2

Figure C.4: Typical Values of the parameter for the 3 types of protections **[19]**.

From this table, it can be seen that the parameter that suffers the biggest changes is the porosity, meaning that the porosity is the most influential parameter on the leakage length calculations.

C.2. POROSITY

Porosity is normally obtained following this equation:

$$P_{armor} = 1 - \frac{V \cdot N}{h \cdot 100} \tag{C.1}$$

where

P_{armor} is the porosity of the armor layer [%]

V is the unit's volume [m^3]

N is the packing density [1/100 m^2]

d_T is the layer thickness [m]

The following values indicate the porosity for certain single layer concrete units:

Unit	Porosity
Xbloc+$_{v1}$	56.2%
Xbloc+$_{v2}$	59.2%
Xbloc	61%
Cube	47%

Table C.1: Porosity for concrete units **[6]**.

Using this characteristic values, the leakage length was obtained:

Unit	Λ
Xbloc+$_{v1}$	2.40
Xbloc+$_{v2}$	2.34
Xbloc	2.05
Cube	3.11

Table C.2: Leakage length calculations based on values obtained from the Rock Manual.

From this table, it can be seen that the leakage length of both Xbloc+, and Xbloc are very similar and can be classified as the second category of protection layer (placed blocks). In case of the Cube, the leakage length value is significantly higher which means that uplift pressures have a higher influence on the failure mechanism of this unit.
From the results obtained from the lab tests and the analysis presented in Chapter 4, it can be seen that the failure mechanism of the Xbloc+ (v1 and v2) has a higher resemblance to the Cube than the Xbloc. For this reason a different approach must be taken when calculating the porosity of the armor layer and consequently, the parameter porosity* is obtained. The porosity* of the armor layer was calculated using areas instead of volumes as it commonly done. The grey areas depicted in figure C.5 represent the areas in which water is able to pass through, wether towards (wave run-up) or outside of the structure (wave run-down) when using a Xbloc+$_{v2}$. These areas, in relation to the total area of occupancy of the unit (meaning the area marked by the black dashed line), gives us the percentage in which the water is able to flow freely.

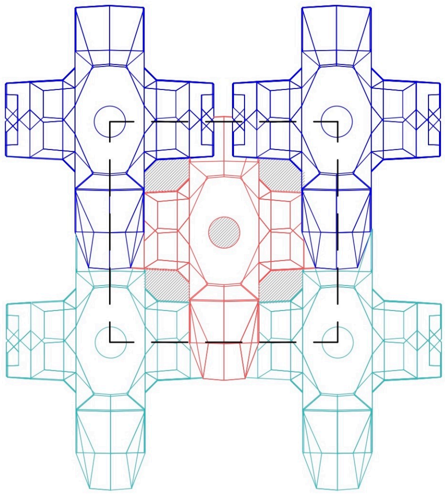


Figure C.5: Representation of areas where water is infiltrated when using Xbloc+.

Following the same procedure with the rest of the concrete units previously mentioned, and as depicted by figures C.6, the following values were obtained:

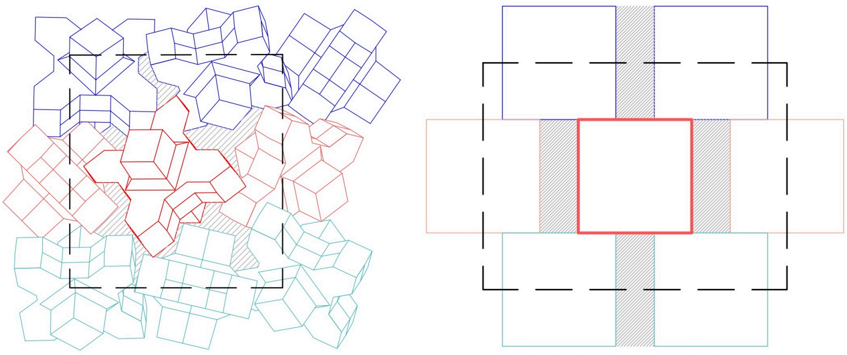


Figure C.6: Representation of areas where water is infiltrated when using Xbloc+.

Unit	**Porosity***	**Λ***
Xbloc+$_{v1}$	12%	5.20
Xbloc+$_{v2}$	17%	4.37
Xbloc	35%	3.16
Cube	10%	6.75

Table C.3: Leakage length calculations using the new calculated parameter.

D

Displacement

In this appendix, displacement calculations from both methods are presented.

D.1. Graphic Results

The following figures provide the initial location of the units represented by white dots and the final location of the units represented by the picture underneath them. Both methods are exposed side by side for better comparison.

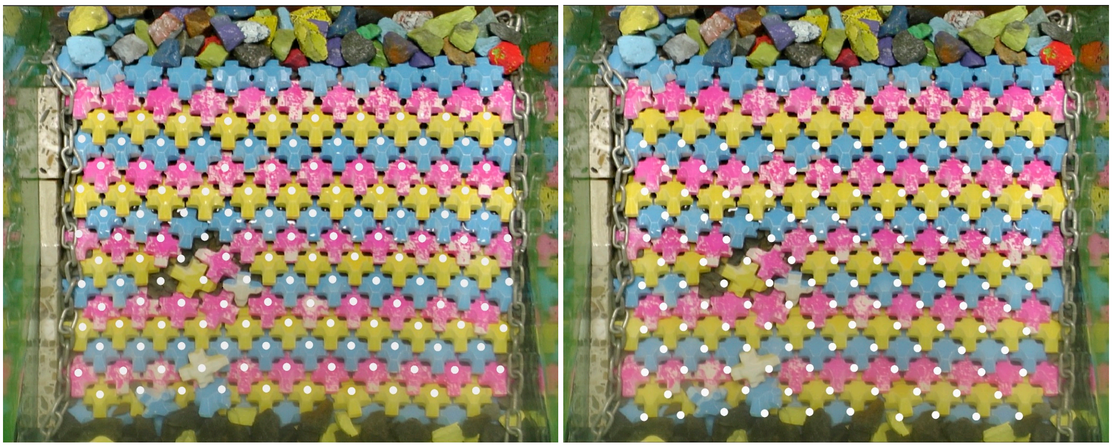


Figure D.1: Displacement of armor layer units during tests from Series1.

Figure D.2: Displacement of armor layer units during tests from Series2.

Figure D.3: Displacement of armor layer units during tests from Series3.

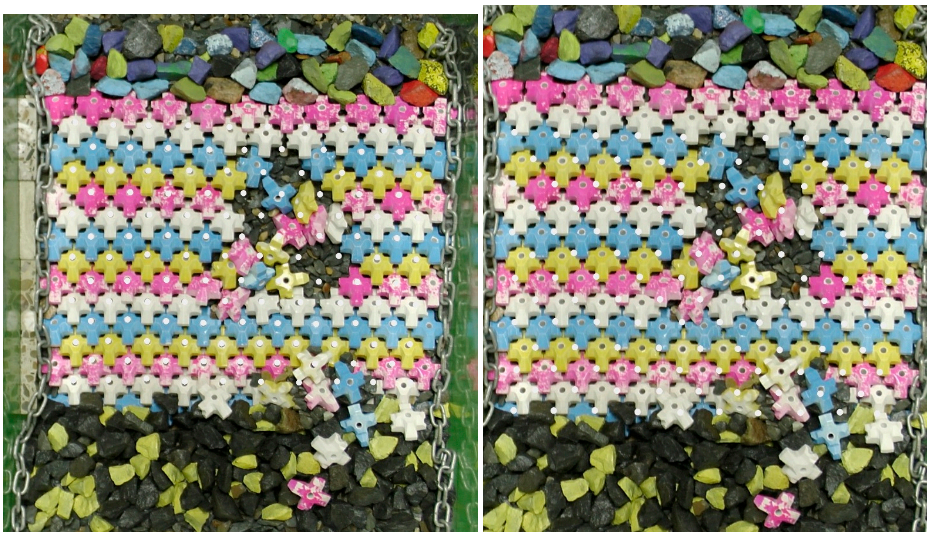


Figure D.4: Displacement of armor layer units during tests from Series4.

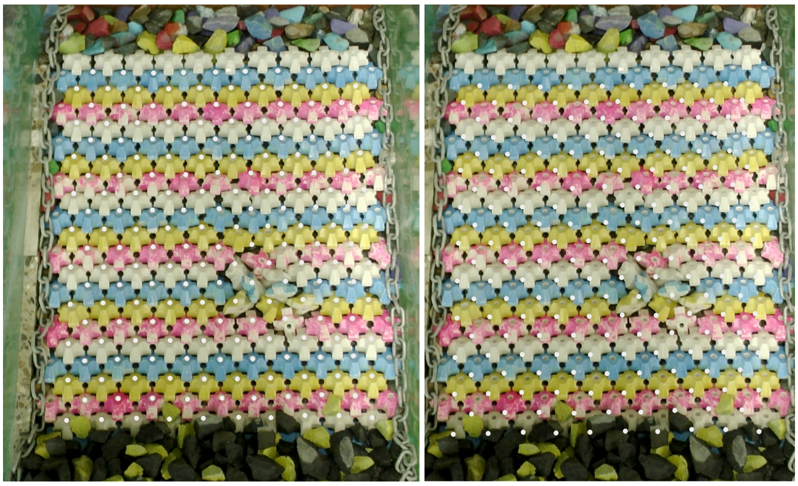


Figure D.5: Displacement of armor layer units during tests from Series5.

Figure D.6: Displacement of armor layer units during tests from Series6.

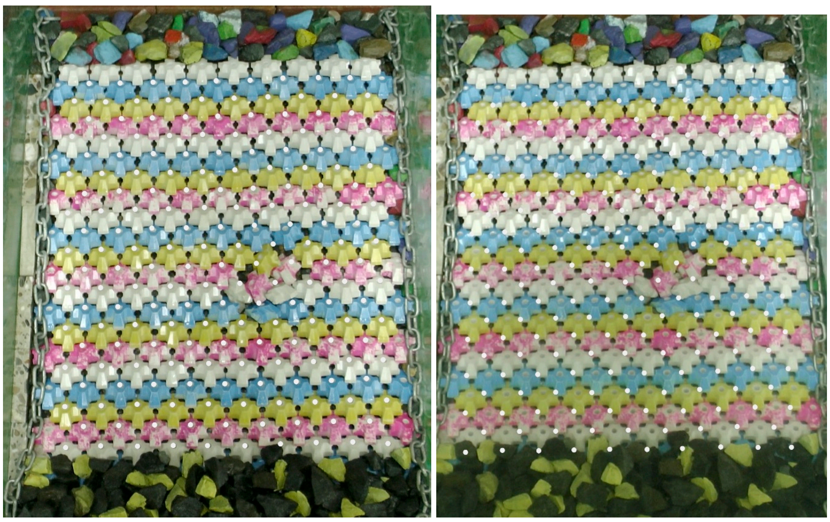


Figure D.7: Displacement of armor layer units during tests from Series7.

D.2. NUMERICAL RESULTS

All values presented in this section are in millimetres [mm]. Partially displaced and fully displaced units are identified with the following colors:

Partially Displaced

Fully Displaced

D.2.1. SERIES 1

CENTER-TO-CENTER MEASUREMENTS

Hs = 5.39 cm, Ns =1.43

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	0.83		1.62		1.20		0.45		0.76		0.58		0.62		0.99		1.27		1.32
12		2.22		2.07		1.05		0.97		1.08		0.66		1.07		0.56		0.66	
11	1.61		0.69		1.32		1.22		0.61		1.55		0.40		2.59		2.65		1.27
10		1.80		0.68		0.67		0.96		1.47		1.35		0.34		0.34		0.34	
9	1.71		3.13		0.34		0.34		0.94		1.24		3.55		2.69		1.48		0.34
8		0.76		0.36		2.58		2.13		1.05		2.25		1.61		3.06		0.34	
7	0.34		0.34		0.34		0.75		0.34		1.30		2.09		2.55		2.70		0.34
6		1.30		3.96		1.30		0.73		0.97		2.09		1.82		1.14		0.96	
5	0.34		2.26		3.58		1.13		1.78		1.36		1.29		0.93		1.96		1.61
4		0.34		0.34		0.34		0.34		0.34		0.34		0.34		0.33		1.59	
3	0.34		0.34		1.28		0.34		1.88		0.68		1.32		2.92		0.93		2.55
2		0.34		0.34		1.10		2.07		0.34		0.34		0.34		0.34		0.34	
1	0.34		0.34		0.34		0.34		0.34		0.34		0.34		0.34		0.34		0.34

Hs = 7.81 cm, Ns = 2.07

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	4.10		3.19		3.19		3.19		3.19		3.19		2.66		3.19		3.19		3.19
12		0.71		0.71		1.06		0.71		0.71		0.71		0.71		0.71		0.71	
11	2.53		2.53		2.40		2.09		2.67		0.89		2.49		2.60		2.57		2.53
10		2.11		1.88		1.60		0.95		1.78		0.95		0.71		0.71		0.71	
9	1.90		1.90		1.90		1.90		0.61		1.90		3.57		3.56		1.90		1.90
8		3.22		3.21		3.21		3.47		2.25		2.45		2.25		3.23		3.21	
7	2.65		2.65		2.65		6.82		0.32		1.14		1.72		1.92		1.71		2.65
6		0.71		2.14		0.71		0.71		1.42		1.92		2.30		1.15		1.72	
5	3.06		3.57		3.57		1.42		2.25		0.59		1.04		1.92		1.15		1.01
4		0.71		0.71		0.59		0.28		1.04		1.04		0.61		0.59		1.14	
3	0.71		0.71		0.49		1.72		2.30		0.71		0.71		0.71		0.71		0.71
2		3.06		2.71		1.90		3.08		1.92		1.43		1.04		0.71		0.71	
1	0.71		3.44		2.59		1.90		0.91		1.72		1.10		0.71		0.71		0.71

Hs = 10.02 cm, Ns = 2.65

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	4.17		3.41		3.41		3.41		3.41		3.12		2.77		3.41		3.41		1.78
12		1.26		1.01		1.99		0.60		0.78		1.74		0.78		1.40		0.78	
11	0.56		1.45		1.32		1.35		2.37		1.12		2.59		2.74		2.73		2.78
10		0.73		0.40		0.32		0.81		1.66		1.10		0.78		0.78		0.78	
9	2.07		2.07		2.63		7.14		0.59		3.47		3.58		3.69		2.07		2.25
8		3.38		161.22		137.71		16.25		1.80		1.93		1.81		3.19		3.38	
7	2.87		2.87		31.95		140.54		0.08		1.28		1.76		1.88		1.83		2.87
6		0.78		4.89		35.52		2.02		1.34		1.88		2.40		2.33		1.76	
5	3.27		6.48		14.12		5.52		1.09		0.18		0.89		1.88		1.17		1.24
4		0.78		4.10		0.77		0.51		1.03		0.89		0.59		0.77		1.28	
3	0.78		0.78		0.78		1.76		0.73		1.86		1.77		0.78		0.78		0.78
2		1.10		2.89		3.17		1.95		1.88		1.35		1.75		0.78		0.78	
1	3.93		1.05		1.10		0.70		1.08		0.60		0.69		1.89		1.43		0.78

Overall Displacement [mm]

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	1.05		1.68		1.18		0.68		1.05		0.53		0.60		1.18		1.21		2.63
12		3.26		2.94		1.43		1.04		0.87		1.24		0.89		1.85		0.57	
11	1.38		1.37		0.50		1.52		2.11		1.79		0.53		3.05		3.14		1.42
10		0.59		2.09		1.79		1.77		1.49		1.54		0.60		0.60		0.60	
9	1.93		3.71		2.84		7.26		0.96		0.60		4.28		3.27		1.81		1.39
8		0.73		187.01		161.65		17.31		1.13		2.68		0.43		3.68		0.60	
7	0.29		0.60		33.57		172.11		0.60		1.46		2.56		3.11		3.29		0.60
6		1.46		5.91		40.85		2.38		1.01		2.57		2.25		1.37		1.00	
5	0.60		5.03		16.37		5.37		0.51		1.07		1.44		0.95		2.16		1.96
4		0.60		5.22		0.76		0.60		2.21		0.60		0.60		0.59		1.66	
3	0.60		0.60		0.60		0.60		0.91		0.89		0.60		3.25		0.95		3.07
2		1.98		0.60		2.81		2.17		0.60		0.60		2.55		0.60		0.60	
1	3.62		2.90		1.63		1.09		0.87		1.52		2.24		2.51		2.46		0.60

CORNER-TO-CORNER MEASUREMENTS

Hs = 5.39 cm, Ns =1.43

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	2.11		1.90		2.38		2.41		2.35		2.29		2.30		2.07		2.70		2.25
12		2.82		1.97		2.50		2.98		2.06		2.44		2.13		2.16		2.27	
11	2.45		2.12		2.21		2.30		2.61		2.26		2.57		2.28		2.22		1.74
10		2.32		2.35		2.17		2.59		2.05		2.43		2.40		1.83		1.16	
9	1.93		2.30		3.01		2.64		2.52		2.05		2.35		1.99		1.10		2.63
8		2.15		2.14		2.92		2.67		2.34		2.61		1.81		1.22		1.40	
7	1.64		1.77		1.40		2.10		2.59		2.56		1.55		1.63		1.42		1.23
6		2.53		1.65		1.23		1.29		2.58		1.80		1.20		2.10		1.43	
5	1.78		2.08		1.41		1.97		2.52		3.84		1.50		0.95		1.42		1.70
4		1.90		2.53		2.16		2.54		2.16		1.96		2.35		1.16		2.11	
3	1.67		3.20		2.51		3.12		3.20		2.99		2.14		2.32		2.16		2.08
2		1.88		2.03		3.59		1.81		2.84		1.55		1.48		1.81		2.31	
1	2.03		2.97		3.41		2.64		2.81		3.77		1.92		1.41		1.74		3.51

D

Hs = 7.81 cm, Ns = 2.07

Rows	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	1.96		1.40		1.75		0.77		0.33		0.67		0.63		1.32		2.37		2.64
12		1.64		1.73		1.35		0.93		0.47		0.86		0.83		1.45		2.18	
11	1.74		2.07		0.99		0.88		0.26		0.42		1.01		0.84		2.04		2.38
10		1.94		1.92		0.75		1.26		1.09		0.86		1.17		1.96		2.36	
9	2.35		2.09		1.71		2.19		1.54		0.95		1.33		1.57		2.50		2.50
8		1.90		2.09		1.59		2.70		0.75		1.57		1.52		2.32		2.41	
7	1.80		1.68		2.67		5.25		1.72		1.84		2.20		2.09		2.37		4.55
6		2.01		2.54		2.42		2.27		1.61		1.60		1.92		1.79		2.79	
5	1.53		1.99		2.13		1.54		1.91		1.79		2.29		2.32		2.80		4.26
4		2.70		2.43		1.65		2.20		2.03		2.22		2.29		2.62		3.22	
3	1.88		2.67		2.09		1.76		1.96		2.58		2.04		3.03		2.54		4.69
2		1.75		1.64		1.60		2.51		2.42		1.90		2.35		2.09		3.50	
1	0.89		2.39		2.93		2.85		2.01		2.21		2.33		2.22		2.72		5.95

Hs = 10.02 cm, Ns = 2.65

Rows	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	1.15		0.91		2.35		1.01		0.99		1.39		0.79		0.91		1.02		1.63
12		0.91		2.25		0.70		0.71		0.96		0.98		0.85		0.93		0.90	
11	1.36		0.92		2.16		1.07		0.74		0.86		1.56		1.31		1.77		0.76
10		1.95		5.69		2.32		0.61		1.03		0.69		0.69		1.18		1.46	
9	2.48		2.19		7.98		2.67		0.88		0.66		0.38		1.04		1.80		0.93
8		1.37		4.59		50.85		0.43		0.20		0.92		1.18		52.37		694.03	
7	3.27		3.47		121.26		10.14		0.77		0.85		0.74		0.61		1.35		3.87
6		0.40		144.25		139.27		41.08		0.65		0.11		0.71		0.89		1.32	
5	0.65		0.43		4.75		17.50		0.45		0.69		1.58		1.16		1.34		0.43
4		1.34		0.35		1.07		1.15		0.47		0.46		1.42		1.84		2.47	
3	0.34		1.43		2.21		0.98		0.81		1.00		1.86		2.17		1.67		1.82
2		0.58		0.37		1.64		1.05		0.26		1.25		0.66		0.77		1.12	
1	0.82		0.73		2.65		4.56		0.77		1.20		1.39		1.25		1.18		2.24

Overall Displacement [mm]

Rows	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	0.80		0.21		2.76		1.85		2.23		2.97		2.79		3.83		4.64		3.84
12		0.49		2.73		3.09		2.28		2.04		3.48		3.26		3.34		4.37	
11	2.30		1.74		3.91		3.07		2.21		2.66		3.52		3.71		4.07		3.58
10		2.22		7.02		3.58		1.66		2.22		2.97		2.90		2.48		2.39	
9	1.62		3.52		11.73		5.28		2.71		2.82		3.00		3.83		3.35		4.10
8		3.09		7.58		56.29		3.79		3.04		4.59		4.01		52.99		710.83	
7	2.40		3.94		145.53		11.34		3.56		3.11		3.41		2.73		2.21		3.65
6		1.64		171.78		167.23		46.09		4.02		3.57		3.18		4.05		2.80	
5	1.25		2.60		5.17		17.84		4.07		5.97		3.94		3.70		3.00		4.58
4		0.76		3.15		2.15		3.62		3.93		2.89		4.39		2.75		2.32	
3	1.28		2.50		2.39		4.28		4.04		3.95		3.86		3.00		3.06		2.23
2		1.26		3.68		3.83		2.08		3.82		1.74		2.48		2.11		2.23	
1	2.11		3.52		2.11		2.93		4.26		3.36		0.82		2.60		1.84		2.58

D.2.2. SERIES 2

CENTER-TO-CENTER MEASUREMENTS

Hs = 5.55 cm, Ns = 1.49

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	0.00		0.00		0.00		0.00		0.00		2.68		1.77		0.00		0.73		0.61
12		0.00		0.00		1.55		0.00		1.36		1.17		0.43		0.00		0.00	
11	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.54		0.00		0.00
10		0.00		0.00		0.00		0.00		0.86		0.68		0.00		0.91		0.00	
9	0.00		0.00		0.58		0.00		0.00		0.00		0.00		0.00		0.00		1.21
8		0.27		0.00		1.64		1.10		0.79		0.77		0.00		0.54		0.00	
7	0.00		1.25		0.56		3.34		0.68		0.00		0.00		0.00		0.00		0.91
6		0.98		0.95		0.99		0.00		0.00		1.03		0.30		0.00		0.82	
5	0.99		0.91		1.21		0.00		0.00		1.29		0.00		0.00		0.68		0.96
4		0.87		1.23		3.67		0.00		1.25		0.91		0.00		1.06		0.43	
3	0.99		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
2		0.82		0.00		0.99		0.00		0.00		0.00		0.00		0.00		0.41	
1	0.00		0.00		0.00		0.00		0.00		0.00		1.10		0.00		0.68		0.98

Hs = 7.71 cm, Ns = 2.07

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	0.14		0.14		0.00		0.00		0.14		1.64		0.73		2.01		1.47		1.22
12		0.73		0.91		0.79		0.00		1.42		1.25		1.21		1.90		1.65	
11	0.00		0.00		1.25		0.14		2.07		0.00		0.99		0.91		1.77		0.00
10		0.00		0.00		0.00		0.87		0.96		0.77		0.91		0.19		0.96	
9	0.86		0.00		0.86		0.99		0.00		0.96		0.61		0.96		0.14		0.38
8		2.07		1.12		0.77		0.69		0.96		0.68		0.82		0.73		0.98	
7	0.00		1.34		0.61		0.38		0.38		1.25		3.67		1.28		1.39		0.86
6		0.98		0.54		1.10		0.00		0.96		0.95		0.69		0.14		0.68	
5	0.99		0.69		0.73		0.00		0.82		1.06		1.42		1.10		0.68		0.43
4		0.77		1.03		3.67		0.68		0.87		0.77		1.34		0.43		0.43	
3	1.25		1.03		0.79		0.99		0.14		0.87		0.00		0.95		0.00		0.14
2		1.06		0.00		1.34		0.00		0.00		0.96		0.99		0.96		0.41	
1	1.17		1.28		0.49		0.00		0.14		0.00		1.10		0.14		0.77		0.98

Hs = 9.515 cm, Ns = 2.56

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	0.14		0.14		0.00		0.00		0.14		0.87		0.82		1.90		1.25		0.86
12		0.73		0.49		0.54		0.98		0.86		1.91		0.43		0.73		1.09	
11	0.00		0.68		0.87		0.96		0.77		1.36		0.99		0.83		0.91		0.00
10		0.69		0.86		1.16		0.87		1.52		1.25		1.22		0.99		0.96	
9	0.54		1.22		1.12		0.83		0.00		1.10		1.03		1.55		0.87		0.49
8		0.98		0.14		0.68		0.27		1.68		0.95		0.68		1.42		0.86	
7	1.15		1.23		0.83		1.64		0.73		0.99		3.67		1.03		1.39		0.49
6		1.21		1.10		1.10		1.49		0.96		0.99		0.68		1.03		1.34	
5	0.00		1.25		0.83		0.00		1.28		0.68		1.23		1.17		0.87		1.22
4		1.22		0.14		1.47		0.86		0.96		1.10		0.96		1.23		0.99	
3	0.30		0.14		1.09		0.73		0.96		0.86		1.28		0.49		0.00		0.14
2		0.30		1.09		0.82		1.36		0.00		1.42		1.36		1.47		1.70	
1	0.86		0.68		1.40		1.12		1.28		1.06		1.85		1.52		0.83		1.64

Hs = 10.22 cm, Ns = 2.75

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	0.00		1.09		0.00		0.00		1.03		1.83		2.04		1.79		2.28		1.54
12		1.42		1.36		1.44		0.98		1.34		2.04		1.47		2.72		1.25	
11	1.36		0.68		0.79		0.87		1.12		1.21		2.41		1.44		1.72		1.66
10		1.89		0.82		0.49		1.28		2.32		1.77		1.29		2.07		2.25	
9	1.25		1.22		1.55		1.94		1.28		1.85		1.64		1.85		1.52		0.95
8		1.90		1.70		0.69		0.79		1.85		0.96		1.49		1.66		1.66	
7	1.77		1.55		0.82		1.74		1.03		1.64		0.95		1.21		1.44		1.55
6		1.55		1.52		0.68		1.49		0.00		1.54		1.52		2.04		1.39	
5	0.00		1.40		1.92		0.00		1.85		1.09		1.70		1.83		1.58		0.73
4		0.00		1.25		0.49		0.91		1.28		0.79		1.81		1.25		0.99	
3	1.70		1.16		1.64		0.79		1.06		1.52		1.28		1.21		0.00		0.00
2		1.77		1.09		1.47		1.36		0.00		1.81		1.55		2.42		1.70	
1	1.93		1.93		0.27		1.12		1.40		1.06		1.85		1.55		1.64		1.64

Hs = 10.76 cm, Ns = 2.89

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	0.00		1.28		0.99		0.00		0.68		1.42		1.25		0.68		0.68		0.68
12		1.42		0.68		0.27		1.40		0.79		1.85		0.27		1.64		0.27	
11	2.15		0.98		0.56		1.10		0.69		0.96		1.39		0.91		1.55		1.66
10		1.63		0.27		0.96		1.28		1.90		0.86		0.87		0.41		1.03	
9	0.68		0.00		1.40		0.73		1.37		1.25		1.34		2.98		1.73		0.00
8		1.92		1.12		1.16		0.73		0.96		0.96		0.00		1.58		0.30	
7	1.63		1.21		0.00		0.82		0.96		0.95		0.95		0.49		1.96		1.89
6		0.96		1.52		0.19		1.25		0.00		1.09		1.52		1.34		1.39	
5	0.00		1.09		1.17		0.00		0.00		1.09		0.00		0.73		1.42		1.47
4		0.00		1.36		1.03		0.00		1.17		0.00		1.52		0.00		1.89	
3	2.07		0.00		1.63		0.00		0.00		1.22		0.00		0.96		0.00		1.65
2		1.83		0.00		0.00		0.91		0.00		1.28		1.17		1.77		0.68	
1	2.13		2.21		0.43		1.49		0.77		0.77		0.96		1.25		1.06		1.89

Hs = 11.53 cm, Ns = 3.10

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	1.15		1.70		1.74		1.17		2.26		1.58		1.52		0.98		1.55		0.98
12		2.15		0.69		1.12		1.39		1.21		1.55		1.09		1.36		0.91	
11	1.47		1.77		0.82		0.19		1.10		0.54		1.10		3.46		0.73		1.39
10		2.45		1.10		2.04		1.12		1.12		1.22		0.98		0.86		1.10	
9	1.42		1.17		1.77		1.42		1.47		1.44		0.96		2.85		1.55		0.43
8		1.25		1.65		2.28		0.69		1.21		1.42		1.06		1.10		0.68	
7	0.27		1.59		0.79		0.86		0.96		1.16		1.12		0.87		2.31		1.39
6		0.96		1.09		0.61		0.43		1.15		1.42		1.16		0.87		1.06	
5	1.17		0.86		1.17		0.73		1.17		1.10		1.17		1.77		0.95		1.46
4		1.25		0.14		1.25		1.06		0.14		1.37		0.86		0.83		2.28	
3	1.77		1.17		0.96		1.16		1.25		0.41		0.96		1.42		0.69		1.15
2		0.73		1.06		1.25		0.30		1.06		1.37		1.81		1.03		1.28	
1	0.99		1.06		0.58		0.69		1.39		1.25		0.14		1.77		1.81		1.10

D

Hs = 12.43 cm, Ns = 3.34

Rows	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	1.94		1.23		1.39		0.96		0.68		0.38		0.91		0.27		0.38		1.55
12		1.39		0.68		0.58		1.12		0.77		0.96		0.86		0.43		0.68	
11	0.96		0.98		0.83		0.30		0.43		0.68		0.14		0.14		0.49		0.56
10		0.38		0.43		0.87		0.98		0.83		0.69		0.91		1.17		0.69	
9	1.73		0.41		0.19		0.98		1.06		1.12		0.58		3.73		0.43		0.00
8		0.27		0.83		0.41		0.43		0.69		1.06		2.58		0.49		0.30	
7	0.73		0.38		0.79		1.94		0.96		1.10		0.00		0.69		0.56		0.68
6		0.79		0.73		0.49		0.43		1.10		0.91		0.87		0.68		0.83	
5	1.40		1.03		0.68		0.83		1.23		0.96		0.30		1.34		0.56		0.54
4		1.34		0.82		1.28		1.52		0.30		0.00		0.00		1.12		0.54	
3	0.91		1.25		0.68		1.16		0.82		0.41		0.61		1.52		1.10		0.41
2		0.27		0.73		0.30		0.41		0.98		0.68		0.69		0.14		0.49	
1	0.96		0.91		0.30		0.69		0.14		0.00		0.30		0.69		0.98		0.38

Hs = 12.90 cm, Ns = 3.47

Rows	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	0.00		0.00		0.00		1.83		2.25		1.34		0.00		1.55		0.00		0.00
12		0.00		0.00		0.79		0.00		1.89		1.25		0.00		0.00		0.00	
11	1.58		0.00		0.82		0.79		0.00		0.00		1.17		1.34		0.00		0.00
10		1.25		0.95		0.98		1.25		1.44		1.03		1.06		0.00		0.00	
9	0.00		0.91		0.00		0.00		1.29		0.00		0.00		0.00		0.00		0.00
8		0.27		2.75		1.21		0.68		0.00		0.00		1.70		0.00		0.00	
7	1.49		0.82		0.00		1.64		0.99		0.82		0.00		0.00		0.00		3.02
6		0.00		1.85		0.79		0.00		0.00		0.00		0.68		0.00		0.00	
5	0.00		0.00		0.82		0.00		0.00		0.96		0.79		0.00		0.00		0.00
4		0.00		1.55		0.00		0.00		0.54		0.00		0.00		0.00		0.00	
3	1.73		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
2		0.91		0.00		0.82		1.22		0.00		0.00		0.61		0.41		0.00	
1	1.16		0.79		0.00		0.00		1.15		0.00		0.00		0.00		0.00		0.00

Overall Displacement [mm]

Rows	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	1.97		0.56		0.41		1.26		0.62		3.23		1.63		2.78		2.21		4.13
12		1.39		0.00		1.50		1.66		3.51		0.54		1.06		1.82		2.77	
11	2.46		0.00		0.87		1.67		1.48		2.14		0.31		1.09		2.47		0.60
10		1.49		1.17		1.49		0.50		1.73		0.70		2.72		1.20		2.02	
9	1.61		1.20		1.56		1.03		1.35		2.31		1.56		1.77		2.12		0.00
8		3.90		3.14		1.86		0.70		0.69		1.09		1.02		1.82		1.97	
7	1.02		2.22		0.81		1.26		0.93		0.99		0.00		0.74		2.04		5.58
6		1.20		1.20		1.90		1.55		1.12		0.93		0.58		0.80		0.83	
5	1.42		2.08		1.09		0.83		1.32		0.00		0.83		0.31		1.36		2.07
4		1.36		2.19		1.35		1.61		1.30		0.00		0.00		1.20		1.49	
3	2.40		1.29		1.88		1.17		0.88		1.75		0.62		1.61		1.16		1.34
2		2.59		0.78		0.99		1.50		1.00		0.68		1.80		1.98		1.10	
1	2.22		2.22		1.56		1.88		1.34		0.80		1.29		1.06		1.29		1.87

CORNER-TO-CORNER MEASUREMENTS

Hs = 5.55 cm, Ns = 1.49

Rows	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	0.73		0.99		0.91		0.61		0.69		3.10		2.15		0.49		0.56		0.69
12		0.54		1.10		0.27		1.72		2.34		0.96		0.87		1.25		1.29	
11	1.37		0.43		0.56		0.27		0.00		0.30		0.19		0.19		0.87		0.14
10		0.68		1.72		0.68		0.30		0.87		0.98		0.30		0.19		0.38	
9	0.30		1.25		0.30		0.86		1.52		1.25		1.77		0.69		0.56		0.58
8		0.41		1.50		1.21		0.73		1.12		0.56		0.38		1.03		0.87	
7	1.64		1.12		1.72		0.91		1.36		0.73		1.12		1.03		1.36		1.25
6		0.69		0.73		1.10		1.25		0.96		0.49		0.68		1.72		1.21	
5	0.69		0.30		0.14		0.56		0.27		0.91		1.25		0.96		1.64		1.50
4		0.91		0.73		0.61		0.79		0.27		0.56		0.73		1.09		0.87	
3	2.18		0.86		0.41		0.27		0.54		0.38		0.54		0.86		0.69		0.61
2		0.43		1.52		0.69		1.64		0.68		0.96		0.73		0.68		0.30	
1	0.91		0.96		1.36		1.52		3.16		3.05		1.74		1.23		1.10		0.27

Hs = 7.71 cm, Ns = 2.07

Rows	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	2.07		2.37		1.87		1.34		0.83		4.22		3.11		0.92		1.55		1.86
12		1.10		0.61		0.82		2.70		4.24		1.10		1.28		2.12		1.56	
11	2.70		0.73		1.05		0.88		1.37		1.04		1.31		1.17		2.33		0.83
10		1.71		1.22		1.06		1.52		1.06		2.72		2.13		0.62		1.24	
9	1.10		1.25		0.91		2.02		2.50		1.95		2.63		1.79		1.52		2.10
8		1.64		1.15		1.89		1.42		1.42		0.99		1.92		2.29		1.73	
7	2.33		1.34		2.29		2.30		1.79		1.42		1.26		2.00		2.04		1.56
6		1.68		0.96		2.13		1.74		1.69		1.70		1.63		2.51		2.01	
5	1.65		0.83		0.68		1.12		0.95		1.68		1.81		1.79		1.64		1.80
4		1.18		1.17		1.59		1.56		0.68		1.39		1.98		1.47		1.73	
3	3.33		0.61		2.13		0.70		1.10		0.69		1.22		2.11		0.96		1.29
2		1.26		0.79		2.21		2.60		0.98		2.06		1.59		1.17		1.72	
1	1.68		0.95		2.32		3.84		4.54		3.46		3.42		3.72		1.79		4.14

Hs = 9.515 cm, Ns = 2.56

Rows	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	0.82		0.43		0.49		0.19		0.61		0.38		0.73		0.58		0.61		1.28
12		0.86		0.58		0.27		0.38		0.68		0.68		0.14		1.17		1.58	
11	0.61		0.96		1.25		0.69		0.95		0.91		1.10		0.30		1.77		1.46
10		1.39		0.86		0.96		0.49		1.15		0.56		0.54		0.38		0.61	
9	0.43		0.98		1.22		0.82		1.79		1.50		1.23		1.36		1.10		1.16
8		1.58		1.34		0.41		0.83		0.96		0.30		1.55		1.34		0.96	
7	0.68		0.30		1.64		0.99		1.29		0.49		0.86		0.69		1.03		1.12
6		0.19		2.73		0.77		0.14		0.69		0.49		0.61		1.34		1.44	
5	0.30		0.49		0.69		0.43		0.38		0.43		0.91		0.19		0.19		0.68
4		0.38		0.56		0.96		0.41		0.79		1.16		0.99		0.83		0.30	
3	0.30		0.56		0.14		0.98		0.41		1.90		1.52		1.52		1.68		1.34
2		0.38		0.27		0.43		0.82		1.64		1.68		1.52		0.56		0.96	
1	1.03		0.69		1.10		1.77		0.30		0.54		0.56		2.93		0.43		2.72

Hs = 10.22 cm, Ns = 2.75

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	1.03		1.36		0.30		0.19		0.86		0.49		0.38		0.19		0.27		1.12
12		0.91		0.83		0.61		0.87		0.27		0.61		0.91		0.69		0.41	
11	0.83		0.68		0.43		0.49		0.96		0.14		0.86		0.43		1.10		0.82
10		0.69		0.96		0.19		0.96		0.73		0.61		0.27		0.68		0.54	
9	0.73		0.19		0.61		0.56		1.79		0.68		0.43		0.43		0.30		1.06
8		0.41		1.40		0.43		0.49		0.38		0.49		0.68		0.30		0.96	
7	0.14		0.49		1.25		0.69		0.49		0.27		0.41		0.98		0.19		1.09
6		0.73		1.66		1.10		0.73		0.61		0.14		0.56		0.61		0.69	
5	0.43		0.58		0.68		0.68		1.17		0.68		0.43		0.27		1.68		0.73
4		0.41		0.69		0.83		0.27		1.21		0.14		0.49		0.87		0.73	
3	0.49		0.99		1.03		1.10		0.49		0.73		1.12		0.95		1.64		1.58
2		1.29		0.27		0.49		0.43		1.06		1.54		1.54		1.25		0.86	
1	0.49		0.58		0.79		0.91		0.79		0.61		1.16		1.72		0.99		2.45

Hs = 10.76 cm, Ns = 2.89

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	0.68		0.43		1.10		0.43		1.52		1.03		0.61		0.56		1.66		2.11
12		0.14		0.98		0.41		0.69		0.49		0.30		1.77		0.73		1.15	
11	0.73		1.40		0.79		0.43		0.49		0.61		0.68		1.34		1.74		0.96
10		0.49		0.68		1.29		0.30		0.14		0.83		0.73		0.69		0.77	
9	0.19		0.14		0.83		0.54		1.17		0.61		1.28		1.77		1.70		0.43
8		0.14		0.73		0.49		0.68		0.69		0.54		0.82		1.81		1.93	
7	0.54		0.43		0.95		0.99		0.56		1.73		0.83		1.47		1.40		0.86
6		0.49		0.61		0.43		0.61		0.68		1.10		0.61		1.06		1.06	
5	1.03		0.54		0.54		0.96		0.99		0.27		0.69		1.17		0.96		1.34
4		0.99		0.41		0.14		0.61		0.87		1.10		1.10		0.58		1.16	
3	0.38		0.19		0.61		1.22		0.96		1.06		1.90		0.49		0.95		1.39
2		0.73		0.14		0.68		1.12		0.96		0.99		1.77		1.17		0.86	
1	1.17		0.68		1.10		1.37		0.14		1.83		0.58		1.36		0.19		1.23

Hs = 11.53 cm, Ns = 3.10

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	0.96		0.73		1.03		0.54		1.50		1.89		0.61		1.36		0.69		1.10
12		0.79		0.43		0.27		1.03		1.28		0.68		1.25		1.28		1.34	
11	0.87		0.56		0.79		0.91		0.43		0.87		0.61		0.69		0.98		0.98
10		1.16		0.14		0.61		0.14		0.54		1.23		0.38		0.68		1.12	
9	0.19		0.43		0.19		0.27		0.58		0.73		0.68		0.87		1.21		0.43
8		0.43		0.69		0.43		0.49		0.91		0.00		0.77		0.99		1.28	
7	0.56		0.43		0.69		1.17		1.49		1.66		0.96		0.77		0.91		0.58
6		0.73		0.58		0.43		0.30		0.49		1.12		1.21		0.69		0.96	
5	1.09		0.54		0.69		0.68		0.19		0.61		0.43		0.87		1.34		1.29
4		1.42		0.58		0.86		1.44		0.83		1.25		0.27		0.68		0.91	
3	0.54		0.56		0.43		0.73		0.73		0.30		1.34		0.41		0.79		1.46
2		0.68		0.30		0.79		0.69		1.66		0.73		1.39		1.37		0.30	
1	2.06		0.73		2.04		3.86		2.18		2.04		1.94		4.00		1.22		1.37

Hs = 12.43 cm, Ns = 3.34

Rows	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	0.27		0.73		0.43		0.43		0.56		0.87		0.27		0.56		0.27		0.14
12		0.30		0.00		0.58		0.49		0.56		0.87		0.19		0.56		1.06	
11	0.61		0.49		0.56		0.49		0.43		0.38		0.87		0.91		0.30		0.61
10		0.30		0.86		1.25		0.19		0.69		0.68		0.30		0.69		0.69	
9	0.19		0.49		0.91		1.22		0.86		0.19		0.30		0.30		0.61		0.43
8		1.25		1.23		0.68		1.06		0.30		1.12		0.43		0.54		0.56	
7	0.30		0.77		0.95		0.83		0.91		1.44		0.14		1.06		0.96		0.82
6		0.68		0.49		0.30		0.83		1.34		0.73		0.30		0.27		0.38	
5	0.82		0.43		0.30		0.30		0.58		0.56		0.61		0.73		0.69		1.29
4		1.66		0.96		0.27		0.14		0.49		0.73		0.77		0.68		0.27	
3	0.73		0.19		1.12		0.14		0.49		0.56		0.61		0.69		1.06		1.06
2		0.56		0.77		0.19		0.49		1.10		1.25		0.68		1.28		0.19	
1	0.54		1.12		0.68		1.68		1.55		0.14		1.36		2.07		0.27		0.69

Hs = 12.90 cm, Ns = 3.47

Rows	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	1.10		1.25		0.79		1.09		0.99		1.29		0.96		1.47		0.49		0.30
12		1.06		1.36		0.73		1.22		1.39		1.25		0.68		0.73		0.96	
11	1.47		0.14		0.61		1.06		0.56		1.77		0.96		0.98		0.73		0.68
10		1.85		0.61		1.10		2.23		1.12		0.30		1.55		1.68		1.52	
9	1.55		1.77		0.99		1.44		0.30		0.68		0.79		1.10		0.56		0.43
8		1.34		3.01		1.21		1.10		0.56		0.68		1.25		0.00		0.41	
7	0.87		0.43		0.96		0.99		0.91		0.14		0.96		0.19		1.16		0.79
6		0.68		1.23		1.25		0.19		1.52		1.81		1.06		0.19		0.49	
5	0.19		1.39		1.15		0.49		0.27		0.73		1.15		0.68		0.19		0.86
4		1.28		1.17		0.87		0.83		0.73		0.79		1.10		0.19		0.43	
3	0.87		1.10		1.40		1.34		1.12		0.86		1.15		0.82		0.30		0.87
2		2.06		0.86		1.36		2.12		0.49		0.68		0.95		0.68		0.77	
1	1.54		0.49		0.98		1.15		1.77		2.19		0.91		0.68		1.42		2.61

Overall Displacement [mm]

Rows	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	1.48		0.14		0.58		1.11		0.87		4.28		2.22		1.63		3.12		4.28
12		0.83		1.38		0.80		0.99		2.90		0.95		1.03		2.73		3.54	
11	2.22		0.20		1.05		1.92		0.81		3.02		0.52		0.87		3.08		0.96
10		2.68		2.39		1.64		1.23		2.29		0.29		0.60		0.81		1.71	
9	0.73		1.30		0.71		1.73		0.74		1.64		1.52		2.12		2.54		2.37
8		4.62		3.31		2.53		1.66		0.90		1.17		0.43		1.69		3.32	
7	1.02		1.31		1.82		1.79		0.81		0.27		1.00		1.03		2.79		1.66
6		1.69		1.37		2.04		1.09		1.31		2.12		1.31		0.60		1.97	
5	1.92		1.60		1.34		0.93		0.80		1.42		0.91		1.34		1.40		1.23
4		0.41		0.99		1.80		2.22		1.09		0.46		1.48		0.56		0.64	
3	1.99		0.31		1.20		0.40		1.48		1.56		1.10		2.04		1.09		0.87
2		1.48		1.77		0.83		2.90		0.40		0.78		1.23		1.42		0.96	
1	1.56		0.74		3.86		4.44		3.81		3.43		1.81		0.46		0.68		3.08

D.2.3. SERIES 3

CENTER-TO-CENTER MEASUREMENTS

Hs = 5.48 cm, Ns = 1.47

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
12		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
11	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
10		0.92		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
9	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.15
8		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
7	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.92		0.00
6		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
5	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
4		0.12		0.31		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
3	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
2		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
1	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00

Hs = 7.46 cm, Ns = 2.00

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	0.76		0.76		0.76		0.76		0.76		0.76		0.76		0.76		0.76		0.76
12		0.76		0.76		0.76		0.76		0.76		0.76		0.76		0.76		0.76	
11	0.76		0.76		0.76		0.76		0.76		0.76		0.76		0.76		0.76		0.76
10		1.68		0.76		0.76		0.48		0.76		0.76		0.76		0.76		0.76	
9	0.76		0.76		0.76		0.76		1.36		0.76		0.76		0.76		0.76		0.78
8		0.76		1.93		0.76		0.76		0.76		0.76		0.76		0.76		1.59	
7	0.76		0.76		0.76		0.76		0.76		0.76		0.76		0.76		1.19		0.76
6		0.76		0.76		0.76		0.76		0.76		0.76		0.76		0.76		0.76	
5	0.76		0.76		0.76		0.76		0.76		0.76		0.76		0.76		0.76		1.74
4		0.89		0.46		0.76		0.15		0.76		0.76		1.37		0.76		0.76	
3	0.76		0.76		0.76		0.76		0.76		0.76		0.76		0.76		0.76		0.76
2		1.74		0.76		0.76		0.76		0.76		0.76		0.76		0.76		0.76	
1	0.76		0.76		0.76		0.76		0.76		0.76		0.76		0.76		0.76		0.76

Hs = 9.43 cm, Ns = 2.53

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	0.00		0.00		1.08		0.00		0.43		0.00		0.00		0.00		0.00		0.00
12		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
11	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
10		0.00		0.00		0.00		0.65		0.00		0.00		0.00		1.02		0.00	
9	0.00		0.00		0.00		0.00		0.76		0.00		0.00		0.82		1.10		0.00
8		1.68		0.75		1.31		1.31		1.53		0.00		0.00		1.23		0.48	
7	0.00		1.19		1.16		0.00		0.00		0.00		0.00		0.63		0.68		1.07
6		1.29		1.44		0.00		0.00		0.00		0.68		0.63		0.93		1.22	
5	0.76		0.00		1.11		0.00		0.00		0.00		0.00		0.98		0.68		0.48
4		0.00		0.00		0.00		0.61		0.00		0.93		0.22		0.61		0.97	
3	0.76		1.57		1.38		0.00		0.00		0.46		0.00		0.61		0.89		1.19
2		0.55		0.00		1.07		1.41		0.98		0.98		0.48		1.29		0.00	
1	1.53		0.00		0.00		0.00		0.00		0.00		0.00		0.63		0.00		0.00

Hs = 10.18 cm, Ns = 2.74

Rows	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	0.76		0.76		0.76		0.76		1.11		2.70		1.79		2.47		1.23		0.76
12		0.76		0.98		0.97		0.76		1.62		0.98		0.76		0.63		0.46	
11	0.76		0.76		0.76		0.76		0.93		1.30		1.23		0.46		0.34		0.93
10		0.76		0.76		1.44		0.68		1.86		1.86		0.76		1.08		0.76	
9	1.41		0.76		0.76		0.76		1.62		0.93		1.71		0.22		0.63		1.23
8		1.26		0.93		0.46		1.98		1.30		1.71		2.29		1.10		1.71	
7	2.27		1.51		1.41		1.71		1.37		2.59		2.59		2.22		1.44		1.53
6		1.84		0.22		1.84		1.11		1.37		2.92		1.08		1.51		1.50	
5	3.03		1.84		1.78		1.41		1.50		0.98		1.50		0.97		0.55		0.68
4		1.84		0.55		1.62		1.84		0.98		0.22		1.02		1.71		1.07	
3	1.31		0.76		1.11		1.86		1.79		1.84		1.23		1.07		0.82		0.89
2		0.98		2.48		1.36		1.29		0.78		1.38		0.15		0.93		1.22	
1	0.98		1.91		1.86		1.41		1.71		1.23		1.19		0.22		0.76		1.41

Hs = 11.11 cm, Ns = 2.98

Rows	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	1.19		0.00		0.00		1.36		1.31		0.98		0.97		0.92		0.55		0.98
12		1.98		0.63		0.00		1.08		0.93		1.51		0.98		1.07		0.00	
11	1.11		1.95		0.00		1.23		0.00		0.97		0.76		0.78		0.82		0.34
10		0.86		1.41		0.00		0.00		0.00		0.00		1.26		0.00		0.93	
9	0.00		1.84		1.74		0.00		0.00		0.78		0.86		1.50		0.00		1.22
8		1.89		1.69		1.37		3.04		1.38		1.84		2.90		2.78		3.54	
7	1.98		2.29		1.99		1.84		2.05		2.44		2.31		2.33		1.64		2.59
6		2.52		1.71		1.71		2.13		2.17		2.75		1.64		1.69		2.53	
5	2.29		1.86		2.75		1.86		2.16		1.26		1.68		1.71		1.57		2.32
4		1.98		1.84		2.16		2.60		2.27		1.36		1.64		2.78		1.84	
3	1.71		2.16		1.74		2.41		2.61		1.56		2.25		2.37		1.91		1.22
2		2.14		2.41		2.75		1.38		1.45		1.38		0.00		1.99		0.00	
1	1.69		1.99		1.53		1.93		1.86		1.59		1.65		1.19		0.00		1.38

Hs = 11.17 cm, Ns = 3.00

Rows	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	0.98		1.38		1.41		1.29		1.10		0.63		0.63		0.89		0.78		0.82
12		1.84		1.53		1.84		0.98		0.63		1.73		0.82		0.68		1.78	
11	0.48		1.07		1.31		0.76		0.82		0.34		0.76		1.08		1.08		1.98
10		1.26		0.48		0.34		0.31		0.76		3.09		0.82		0.65		1.41	
9	0.86		0.98		0.92		0.78		1.16		0.63		0.89		0.48		0.48		0.82
8		0.63		0.76		0.43		0.55		2.10		208.10		2.18		0.63		1.08	
7	0.15		1.26		0.31		0.68		1.08		2.75		13.75		1.16		0.48		0.55
6		0.34		0.68		0.68		0.63		0.22		0.63		0.98		0.97		0.48	
5	1.51		0.63		0.22		0.34		1.08		0.48		0.93		0.78		0.93		0.68
4		1.53		1.10		0.48		1.41		0.78		0.65		0.46		0.68		1.02	
3	1.41		0.61		0.48		0.48		1.02		0.15		0.82		0.76		0.55		1.50
2		0.48		0.48		1.19		0.43		0.92		0.61		1.64		0.61		2.27	
1	0.93		0.55		0.63		0.78		0.63		1.11		0.63		0.63		1.95		1.10

Hs = 11.74 cm, Ns = 3.15																			
	Columns																		
Rows	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	0.65		2.08		2.33		0.76		0.65		6.04		6.14		0.76		0.65		0.76
12		2.47		2.81		3.36		0.86		3.14		11.70		3.69		0.98		0.76	
11	0.76		2.66		2.87		0.55		2.60		21.73		19.65		1.93		1.08		2.22
10		1.51		1.45		0.86		0.76		16.21		249.12		17.88		1.53		0.63	
9	1.93		0.97		0.68		0.65		1.37		114.80		378.24		2.22		0.15		0.46
8		0.15		0.63		0.76		1.93		210.15		30.78		11.44		0.63		1.02	
7	0.76		1.62		0.65		0.76		0.89		180.78		165.99		1.53		0.65		0.34
6		0.65		0.86		0.86		1.95		9.76		127.29		179.29		0.65		1.10	
5	0.78		0.86		1.69		0.34		1.02		14.68		243.41		0.76		0.86		0.55
4		0.89		0.97		0.65		0.34		0.46		0.55		0.55		0.55		0.76	
3	0.48		0.61		0.15		0.76		0.63		0.22		0.46		1.22		0.76		0.65
2		0.76		0.76		0.46		0.92		0.86		0.65		0.97		0.65		0.76	
1	0.65		0.63		0.31		0.63		0.65		0.93		1.07		0.78		0.76		0.65

Overall Distance [mm]																			
	Columns																		
Rows	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	1.16		2.61		2.67		1.28		1.16		7.65		6.37		1.28		1.28		1.28
12		2.91		3.92		3.44		1.28		5.54		16.32		5.43		2.58		1.28	
11	1.16		3.33		3.21		1.28		4.79		28.34		24.50		4.02		3.60		1.16
10		3.39		3.44		1.28		1.28		21.42		291.07		21.84		3.74		3.16	
9	0.71		2.92		1.96		1.16		4.00		133.99		441.19		2.82		1.08		1.61
8		1.28		1.16		1.16		3.01		244.76		257.19		13.16		0.89		0.58	
7	1.28		1.16		1.16		1.17		1.16		209.02		210.30		1.16		1.16		1.28
6		1.28		1.28		1.28		1.28		12.01		148.70		205.61		1.16		1.16	
5	1.17		1.28		2.63		1.69		2.32		16.45		272.45		1.16		1.28		1.28
4		1.28		0.49		1.16		0.70		1.57		1.28		1.16		1.16		1.16	
3	1.16		1.16		1.08		0.76		0.81		1.68		1.16		0.23		1.28		1.28
2		1.16		1.28		1.16		1.69		0.56		1.16		1.16		1.16		1.28	
1	1.28		1.16		1.28		1.28		1.28		1.28		1.28		1.16		1.28		1.16

CORNER-TO-CORNER MEASUREMENTS

Hs = 5.48 cm, Ns = 1.47																			
	Columns																		
Rows	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	0.97		0.15		1.02		0.15		1.64		0.93		1.53		0.86		0.55		0.15
12		0.15		0.15		0.48		1.26		0.63		0.48		0.63		0.63		0.31	
11	0.82		1.44		0.55		0.00		0.82		0.76		0.63		0.15		1.11		1.31
10		0.76		0.22		0.15		1.23		0.76		0.43		1.02		0.65		2.33	
9	1.74		2.12		0.61		0.63		0.89		0.89		0.34		0.61		0.65		2.22
8		1.36		1.19		0.93		0.46		0.48		0.15		0.55		0.89		1.02	
7	1.19		1.08		0.68		0.68		0.76		0.43		1.31		1.30		0.55		0.46
6		0.97		1.02		0.98		0.76		0.48		0.55		1.11		0.15		1.19	
5	1.83		1.74		0.89		0.63		1.23		0.98		1.08		1.08		0.97		1.19
4		1.10		1.45		0.98		1.65		1.57		0.22		0.63		2.05		2.29	
3	1.19		1.84		1.26		0.76		0.76		0.43		0.78		0.34		1.19		1.45
2		1.84		1.86		2.20		0.65		0.86		0.65		0.63		0.34		1.23	
1	1.50		3.29		3.36		1.78		0.22		0.55		0.98		0.78		0.93		0.82

Hs = 7.46 cm, Ns = 2.00

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	0.61		0.76		0.48		0.78		0.15		0.97		0.78		0.34		0.68		1.53
12		1.23		1.11		0.78		0.55		1.16		0.34		0.46		0.97		1.59	
11	0.63		0.89		0.34		0.63		0.48		0.76		0.78		1.02		0.48		1.23
10		1.16		0.48		0.78		1.19		0.34		0.92		0.82		0.93		0.43	
9	1.38		1.16		0.82		1.02		0.78		0.92		0.97		0.68		1.64		0.34
8		1.10		1.59		1.26		1.50		0.98		1.16		0.65		0.98		1.26	
7	0.48		1.53		1.69		0.68		0.97		1.11		1.19		1.41		1.11		1.99
6		1.84		0.97		0.98		1.50		1.53		1.19		0.15		1.56		1.53	
5	1.08		1.71		0.93		0.68		0.55		0.97		0.46		0.63		1.16		1.10
4		1.41		1.16		2.01		0.98		1.53		1.38		0.46		0.68		0.68	
3	1.50		0.82		1.08		1.91		1.16		0.76		1.45		1.02		1.44		1.41
2		1.59		0.98		1.07		0.76		0.22		1.11		0.86		1.59		0.48	
1	1.02		1.50		0.76		0.55		0.92		1.71		0.98		0.65		1.89		0.68

Hs = 9.43 cm, Ns = 2.53

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	0.48		0.46		0.46		0.48		1.41		0.48		0.46		1.62		0.78		0.46
12		0.15		0.43		0.76		0.46		0.34		0.34		0.78		0.15		0.15	
11	0.15		0.46		0.43		0.31		0.15		0.93		0.89		0.22		0.15		0.43
10		0.61		0.55		1.23		1.38		0.82		0.55		0.22		0.76		0.65	
9	1.23		0.34		1.08		1.08		0.97		0.55		0.78		1.71		0.82		1.08
8		1.23		0.82		0.63		0.68		0.61		1.69		0.76		0.48		0.55	
7	0.55		0.48		0.22		0.98		0.46		0.98		0.43		1.02		1.38		0.76
6		0.22		1.84		1.53		1.10		1.16		1.41		1.79		0.97		0.76	
5	0.48		1.16		0.78		1.07		0.68		0.86		1.37		1.59		1.53		1.26
4		1.41		1.56		0.68		0.65		0.63		0.00		0.93		1.41		2.20	
3	1.16		1.36		0.89		0.22		0.76		1.08		0.34		0.86		2.53		1.62
2		0.68		0.22		0.55		0.63		0.78		0.68		1.31		1.10		1.99	
1	0.65		0.82		1.79		0.68		0.76		0.46		2.56		1.74		1.36		2.41

Hs = 10.18 cm, Ns = 2.74

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	0.61		1.10		0.48		0.31		0.93		0.31		0.76		0.93		0.68		0.15
12		1.50		1.53		0.68		1.02		0.92		0.82		0.34		0.34		0.48	
11	0.22		0.98		0.34		0.89		1.11		0.63		0.22		0.22		0.22		0.48
10		0.97		0.46		1.62		0.89		0.86		0.34		0.15		0.82		0.82	
9	0.92		1.65		0.89		0.63		1.95		0.55		1.10		0.46		1.30		0.86
8		0.63		1.50		1.79		1.74		1.19		2.37		1.79		1.30		0.76	
7	0.89		1.16		1.08		1.30		1.44		0.61		1.38		0.98		0.68		0.89
6		1.19		0.78		1.26		0.93		0.93		1.69		1.08		1.36		0.86	
5	0.98		0.65		0.93		1.36		0.65		0.76		1.45		0.93		0.76		1.11
4		1.07		1.69		1.02		1.02		0.76		0.76		0.48		1.02		1.84	
3	0.31		0.76		0.89		1.36		0.31		0.15		1.53		0.55		1.36		0.92
2		2.08		1.41		0.48		0.93		0.76		0.55		1.64		0.86		1.11	
1	1.23		1.11		0.76		0.98		0.76		0.63		0.78		0.31		1.86		1.23

D

Hs = 11.11 cm, Ns = 2.98

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	0.15		0.89		0.48		0.98		0.55		0.22		0.68		0.76		1.36		0.76
12		0.63		0.31		0.55		0.46		0.55		0.55		0.22		0.46		0.98	
11	0.98		0.31		1.19		0.92		0.76		0.76		0.34		0.82		0.86		1.19
10		1.41		0.31		0.65		0.34		0.78		0.63		0.55		1.23		0.15	
9	1.86		0.93		2.60		2.66		2.45		2.08		1.59		1.68		2.45		2.22
8		1.86		2.29		2.29		3.05		1.68		2.37		2.75		2.08		1.59	
7	1.89		1.64		1.83		2.61		2.13		2.12		2.60		1.93		2.05		1.89
6		1.71		1.99		1.84		1.69		1.69		2.37		2.59		1.93		2.18	
5	1.89		2.01		1.37		1.53		1.69		2.44		2.44		2.27		1.73		1.99
4		1.50		2.18		1.59		0.78		1.83		1.89		1.89		1.38		2.14	
3	1.83		1.41		1.84		1.69		2.13		1.59		1.38		1.84		1.59		2.04
2		1.86		1.29		2.01		0.68		2.27		1.78		1.86		1.84		1.74	
1	1.16		0.76		0.55		1.69		1.53		0.97		0.82		1.86		0.78		2.01

Hs = 11.17 cm, Ns = 3.00

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	0.92		0.82		1.10		0.89		0.31		0.98		0.97		0.76		0.34		0.43
12		0.78		1.45		1.31		0.97		0.34		0.98		0.55		1.29		0.93	
11	0.97		0.82		1.93		1.26		0.82		0.97		1.59		0.63		1.02		1.07
10		0.82		1.41		1.44		1.38		1.23		2.29		1.36		0.89		0.61	
9	0.63		1.10		0.98		0.76		0.76		2.81		1.08		1.10		0.15		0.43
8		1.31		1.19		0.76		1.53		0.55		173.32		2.48		0.43		1.07	
7	0.48		1.36		0.76		1.30		1.08		9.76		37.08		1.19		1.23		0.68
6		1.19		1.26		0.76		0.61		3.09		1.23		2.96		1.53		0.89	
5	0.98		0.89		0.55		0.63		1.84		0.92		4.05		0.76		1.07		0.55
4		1.08		0.43		0.55		2.33		0.98		1.38		0.76		0.61		0.68	
3	1.74		1.11		1.23		0.82		1.86		0.97		0.68		0.76		0.68		0.93
2		0.43		0.89		0.89		1.26		1.56		0.34		0.78		0.63		0.65	
1	1.19		0.63		0.34		0.78		0.34		0.22		0.89		0.55		1.07		0.46

Overall Distance [mm]																			
	Columns																		
Rows	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	1.61		3.10		3.16		2.85		1.47		4.77		5.04		1.62		2.58		3.39
12		3.65		3.43		3.29		4.30		4.94		17.49		5.13		2.88		2.91	
11	1.74		4.71		1.61		2.23		3.72		18.82		17.40		4.14		3.47		3.21
10		2.66		3.55		4.40		1.67		11.81		252.89		16.75		2.32		3.08	
9	1.96		4.18		1.33		1.62		4.06		419.20		319.88		5.63		1.25		1.78
8		4.11		2.21		1.77		1.46		268.80		212.35		7.43		1.87		2.32	
7	1.64		3.76		2.96		1.08		2.04		177.11		193.00		2.85		2.25		2.16
6		3.15		6.61		2.70		1.43		19.92		117.72		183.22		1.62		2.33	
5	3.94		4.06		5.70		2.20		3.18		37.24		131.96		1.71		1.31		1.84
4		4.36		3.47		3.26		2.18		3.82		1.99		1.74		1.78		2.36	
3	4.32		3.94		3.06		1.79		0.77		2.31		0.94		1.46		2.61		3.16
2		2.95		3.54		2.77		1.98		0.36		1.13		0.70		2.01		2.36	
1	3.57		0.53		4.17		1.62		1.19		0.47		3.37		1.11		3.12		0.00

D.2.4. SERIES 4

CENTER-TO-CENTER MEASUREMENTS

Hs = 4.27 cm, Ns = 1.15																			
	Columns																		
Rows	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
12		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
11	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
10		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
9	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
8		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
7	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.40		0.00
6		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
5	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
4		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
3	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
2		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
1	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00

Hs = 6.29 cm, Ns = 1.69																			
	Columns																		
Rows	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	0.76		0.00		0.00		0.00		0.00		0.00		0.54		0.00		0.97		0.68
12		0.86		0.00		0.00		0.00		0.97		0.00		0.00		0.00		0.00	
11	0.00		0.00		0.97		0.67		0.60		0.38		0.30		0.00		0.72		0.48
10		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
9	1.07		0.86		0.68		0.00		0.00		0.00		0.00		0.54		0.80		0.81
8		0.27		1.15		0.48		0.00		0.00		0.81		0.80		0.00		0.00	
7	0.00		0.55		0.30		0.00		0.00		0.00		0.00		0.00		0.42		0.55
6		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.57	
5	0.67		0.57		0.00		0.86		0.55		0.00		0.54		0.27		0.90		0.00
4		0.00		0.00		0.68		0.72		0.72		0.55		0.76		0.00		0.00	
3	0.95		0.00		0.40		0.67		0.78		0.57		0.68		0.78		0.85		0.78
2		0.90		1.50		0.76		0.67		0.57		0.38		0.72		0.57		0.00	
1	0.76		0.97		0.76		0.38		0.72		0.00		0.68		0.86		0.57		0.00

Hs = 8.25 cm, Ns = 2.22

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	0.86		0.68		0.78		0.97		0.57		0.67		0.55		0.30		0.42		0.72
12		0.78		0.13		0.67		1.02		0.80		0.27		0.27		0.13		0.27	
11	0.90		0.13		0.90		0.72		0.30		0.30		1.05		0.00		0.67		0.57
10		0.85		1.20		0.13		0.13		0.00		0.13		0.85		0.13		0.13	
9	1.08		1.69		1.21		0.85		0.60		1.10		1.35		0.55		0.81		0.90
8		1.35		0.67		0.90		0.90		1.20		0.72		1.15		0.95		0.27	
7	0.13		1.69		0.86		0.97		0.13		0.13		1.50		1.33		0.42		0.60
6		0.13		0.13		0.68		0.13		0.13		1.20		0.13		0.27		0.48	
5	1.15		0.76		0.19		0.78		0.67		0.27		0.85		0.38		0.42		0.48
4		0.48		0.13		0.67		0.42		0.48		0.30		0.40		0.13		0.13	
3	0.86		0.13		0.60		0.55		0.57		0.40		0.48		1.02		0.72		0.72
2		0.85		0.68		0.67		0.60		0.42		0.30		0.60		0.42		0.13	
1	0.67		0.85		0.67		0.76		0.95		0.42		0.72		0.81		0.48		0.13

Hs =8.97 cm, Ns = 2.41

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	0.20		0.72		0.67		0.97		1.05		0.20		0.76		0.71		0.20		2.12
12		0.27		1.08		0.48		0.19		0.86		1.86		0.72		1.45		0.20	
11	0.20		0.80		0.94		0.85		0.81		1.50		1.02		1.51		1.21		1.63
10		0.72		0.60		1.15		1.23		0.90		1.08		1.15		1.37		1.35	
9	0.49		0.60		0.19		1.20		1.62		1.26		1.63		1.63		1.10		1.20
8		0.57		0.42		0.76		1.08		1.74		1.40		1.74		1.23		1.37	
7	1.97		2.21		2.09		2.01		1.90		0.90		2.84		1.53		1.37		2.85
6		0.72		0.67		0.72		0.38		1.23		1.56		1.71		0.90		0.95	
5	0.20		1.10		0.72		0.95		1.82		1.38		1.71		1.45		0.95		1.20
4		0.86		0.72		0.78		1.80		1.50		2.01		2.16		1.15		0.67	
3	0.44		1.20		0.72		0.72		1.71		1.80		1.82		1.34		0.97		1.10
2		0.72		0.72		0.78		1.63		2.34		0.85		1.63		0.97		0.60	
1	0.94		0.85		0.78		0.90		1.62		0.81		1.34		0.95		0.40		1.38

Hs = 9.79 cm, Ns = 2.63

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	1.07		1.23		1.50		1.75		2.18		1.15		2.09		2.08		1.92		2.41
12		0.67		0.30		0.48		1.61		1.87		2.41		1.75		1.70		1.61	
11	1.10		1.50		1.35		1.40		2.03		1.99		1.45		1.71		2.41		2.31
10		1.71		0.97		1.50		1.87		1.38		1.40		1.53		1.53		1.63	
9	0.95		0.90		0.30		1.66		1.23		1.37		1.82		2.28		2.10		2.01
8		0.72		0.97		0.94		0.97		1.08		1.82		1.08		1.95		2.28	
7	1.08		1.75		1.38		2.34		2.76		1.27		3.04		3.11		2.40		4.43
6		1.56		0.85		0.13		0.30		0.68		1.20		1.87		1.27		1.89	
5	0.81		0.94		0.76		0.40		0.94		0.86		0.97		1.75		0.94		2.01
4		1.23		0.95		0.72		1.05		0.97		0.85		0.68		0.97		1.89	
3	1.50		1.32		0.81		0.42		0.00		0.27		1.05		0.95		1.08		1.08
2		0.76		1.26		1.14		0.27		0.19		1.62		0.67		1.40		1.10	
1	0.72		1.44		1.63		1.08		0.13		1.63		0.30		1.53		0.94		1.33

	Hs = 10.96 cm, Ns = 2.94																		
	Columns																		
Rows	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	1.66		1.57		2.16		2.58		2.34		2.38		2.28		0.67		1.47		1.47
12		2.54		2.07		3.46		2.16		2.23		1.53		1.32		0.97		1.40	
11	1.10		1.64		2.50		2.96		2.84		1.99		1.32		1.50		0.72		0.97
10		1.49		1.39		3.02		3.55		3.55		1.20		1.80		1.08		0.76	
9	1.27		2.30		2.90		3.36		2.58		2.57		1.68		1.56		1.20		0.86
8		2.45		1.68		2.79		2.69		2.12		2.44		1.61		2.27		1.21	
7	1.82		2.45		2.57		3.13		2.88		1.40		1.05		0.57		0.00		0.81
6		1.94		1.90		2.63		3.18		2.31		1.48		2.31		1.21		1.07	
5	1.75		2.03		2.08		3.08		2.44		2.44		1.66		1.05		0.67		0.67
4		2.29		1.90		2.97		1.89		2.44		1.88		1.21		0.67		0.27	
3	0.48		1.62		2.41		1.18		2.18		1.45		1.21		0.57		0.57		0.27
2		1.90		1.51		1.18		1.68		1.92		1.66		0.90		0.76		0.68	
1	1.83		1.90		2.97		1.13		1.67		1.66		1.14		0.78		1.23		0.76

	Hs = 11.26 cm, Ns = 3.03																		
	Columns																		
Rows	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	1.69		1.35		1.68		4.36		2.03		4.72		3.70		5.05		1.56		1.41
12		2.48		2.41		2.96		2.94		24.41		66.81		17.08		5.23		2.33	
11	0.86		1.61		2.76		4.42		6.23		112.78		41.51		12.88		3.01		0.60
10		2.23		1.82		4.07		2.71		83.03		45.91		43.78		8.05		2.37	
9	0.83		1.99		1.69		2.71		4.10		328.96		296.01		14.01		4.27		1.54
8		2.19		0.81		3.72		2.22		57.72		268.72		195.64		6.09		3.02	
7	0.60		1.42		2.37		2.99		16.23		47.29		191.38		149.36		4.87		1.56
6		2.11		3.17		3.11		4.32		42.16		291.45		151.73		8.56		4.57	
5	0.61		1.29		2.64		3.64		135.73		8.60		11.10		10.01		5.20		1.79
4		2.01		1.26		3.05		2.79		2.04		27.88		27.74		2.94		1.80	
3	1.48		1.56		2.20		2.28		2.12		2.82		4.10		2.04		1.23		1.61
2		0.13		1.61		2.41		2.55		0.48		1.02		1.89		0.67		1.71	
1	1.04		0.80		1.48		1.89		1.63		1.32		1.08		3.09		1.61		1.63

	Overall Distance [mm]																		
	Columns																		
Rows	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	3.40		4.10		5.72		5.29		5.73		7.00		6.47		6.86		5.19		3.39
12		3.80		3.99		3.66		5.12		29.73		77.06		19.15		7.60		6.23	
11	3.31		3.05		4.71		7.60		10.78		127.90		48.64		15.90		5.14		2.68
10		2.75		5.11		2.99		4.16		93.17		52.33		51.82		10.28		5.62	
9	3.45		3.79		3.67		4.94		7.17		365.97		324.81		18.53		5.63		4.88
8		3.02		3.61		5.41		2.56		65.82		296.45		219.20		7.81		5.62	
7	2.45		3.50		4.09		2.83		19.61		50.33		212.67		167.13		6.61		3.61
6		2.27		1.99		2.10		2.47		45.00		324.16		167.92		11.66		6.38	
5	3.82		2.27		1.24		1.96		150.59		9.21		12.28		11.64		6.47		4.06
4		4.48		3.38		0.50		2.25		1.51		29.63		29.66		4.77		2.95	
3	3.19		3.08		2.14		1.21		0.33		0.60		4.48		3.34		1.90		1.56
2		4.75		2.20		2.75		1.96		2.55		3.28		3.06		1.89		2.95	
1	1.86		4.46		3.97		2.90		2.27		2.37		2.42		3.98		2.08		3.18

CORNER-TO-CORNER MEASUREMENTS

Hs = 4.27 cm, Ns = 1.15

Rows	Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
	13	0.00		0.00		0.00		0.00		0.00		0.48		0.00		0.00		0.00		0.00
	12		0.00		1.56		0.00		0.00		0.00		0.00		0.00		0.00		0.80	
	11	0.00		0.67		0.97		0.00		0.00		0.00		0.00		0.00		0.00		0.19
	10		0.48		0.00		0.86		0.00		1.15		0.00		0.00		0.00		0.00	
	9	2.44		1.05		0.00		0.00		0.00		0.00		0.00		0.00		0.72		0.00
	8		0.00		0.00		0.00		0.00		0.00		1.02		0.00		0.00		0.00	
	7	0.00		0.00		0.00		0.00		0.00		1.08		0.00		0.00		0.00		0.00
	6		0.00		0.95		0.00		0.00		0.00		0.95		0.00		0.00		0.95	
	5	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.60		0.72
	4		1.23		1.48		0.67		0.00		0.67		0.00		1.50		0.00		0.90	
	3	0.42		1.40		0.30		0.00		0.00		0.30		0.00		0.00		0.00		0.00
	2		0.85		0.00		1.10		0.19		0.13		0.95		0.00		0.00		0.00	
	1	0.68		0.00		0.00		0.97		0.00		0.00		0.00		0.85		0.00		0.00

Hs = 6.29 cm, Ns = 1.69

Rows	Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
	13	0.30		0.40		0.00		0.67		1.08		0.94		1.35		0.00		0.97		0.97
	12		1.10		1.68		1.08		0.00		0.76		0.00		0.60		0.00		1.08	
	11	0.27		1.14		0.76		0.00		0.38		1.02		0.72		0.00		1.14		1.23
	10		0.81		0.00		0.55		0.60		1.14		1.20		0.55		0.00		1.15	
	9	1.89		2.28		1.02		1.37		0.94		0.00		1.02		0.00		1.53		0.68
	8		0.42		1.21		1.07		0.81		0.86		1.68		0.19		0.95		0.95	
	7	0.00		0.00		1.66		1.21		0.97		1.71		1.44		1.14		1.87		1.68
	6		1.08		0.00		0.97		1.14		0.97		0.00		1.45		1.15		1.08	
	5	0.19		0.00		0.81		0.60		0.78		0.00		0.00		0.95		0.00		1.20
	4		1.50		0.00		1.08		0.00		0.97		1.05		1.89		0.81		0.00	
	3	0.94		0.00		0.95		0.00		0.00		1.44		0.00		0.00		0.00		0.00
	2		0.00		0.00		0.00		0.00		0.00		1.45		0.00		0.97		0.00	
	1	0.00		0.00		0.00		0.00		1.02		1.75		0.00		1.63		1.33		0.00

Hs = 8.25 cm, Ns = 2.22

Rows	Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
	13	0.00		0.00		0.00		0.00		0.00		0.00		0.40		0.00		1.08		0.00
	12		0.00		0.00		0.00		1.50		0.00		1.02		0.00		1.66		0.38	
	11	0.00		0.00		0.00		0.00		0.81		1.23		0.67		0.00		0.00		0.00
	10		0.68		0.00		0.00		0.67		0.00		1.23		0.00		0.00		1.40	
	9	0.00		1.57		1.61		0.60		0.00		0.00		0.00		0.00		0.81		0.67
	8		1.82		0.55		0.00		0.00		0.00		0.72		0.00		0.00		0.81	
	7	0.67		2.16		0.19		0.00		0.00		1.92		0.00		0.00		0.60		2.05
	6		0.85		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
	5	0.00		0.00		1.23		0.00		0.00		0.68		1.79		0.00		0.00		1.38
	4		1.21		0.85		0.00		0.00		1.07		0.00		0.00		0.90		0.00	
	3	0.00		0.00		0.78		0.00		0.00		1.21		0.00		0.00		0.00		0.54
	2		0.00		0.00		0.00		0.00		0.00		0.00		0.00		1.63		1.08	
	1	0.95		0.97		0.00		0.00		0.00		0.00		0.00		1.23		1.62		0.48

Hs =8.97 cm, Ns = 2.41

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	2.33		2.16		2.29		0.00		0.00		0.58		0.58		1.19		0.58		2.03
12		2.09		2.22		0.00		0.00		0.00		0.00		0.00		0.00		0.58	
11	2.64		1.89		2.50		0.00		0.00		0.00		0.00		0.00		1.89		0.57
10		1.35		2.76		0.00		0.00		0.00		0.00		0.00		1.05		0.00	
9	1.86		1.87		1.56		1.40		0.00		0.00		0.00		0.00		0.85		0.00
8		2.09		2.54		0.00		1.42		0.00		0.00		0.00		1.45		0.95	
7	1.49		1.34		1.86		0.00		0.00		1.50		1.15		1.05		0.76		2.31
6		1.57		1.50		0.78		0.97		1.26		0.60		0.00		0.00		0.97	
5	2.14		2.23		1.34		1.10		0.00		1.10		0.78		0.00		1.80		1.68
4		1.45		1.89		1.69		0.00		0.00		2.16		1.23		0.00		2.28	
3	1.72		1.33		0.97		1.20		0.00		1.32		0.48		0.27		2.67		1.53
2		1.37		1.08		1.89		0.85		0.67		1.63		0.95		1.62		2.68	
1	0.30		0.86		1.21		0.48		1.75		0.95		0.00		1.51		0.42		2.85

Hs = 9.79 cm, Ns = 2.63

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	0.00		0.00		0.00		0.00		0.00		0.00		1.98		1.35		1.63		2.89
12		0.00		0.00		0.00		0.00		1.80		3.17		0.90		0.00		2.71	
11	0.00		0.00		0.00		0.00		0.00		0.00		0.00		1.87		2.97		2.55
10		0.00		0.00		0.00		0.00		0.00		1.44		2.60		2.16		1.99	
9	0.00		0.42		1.14		2.09		0.00		0.00		2.16		0.00		2.56		1.61
8		0.00		0.00		0.00		0.00		0.00		0.00		2.16		1.87		1.50	
7	0.00		0.00		0.00		0.00		0.00		2.20		1.08		0.86		2.47		2.08
6		0.00		0.00		0.97		0.00		1.61		1.47		1.76		0.00		0.00	
5	0.00		0.00		0.00		0.68		0.00		0.00		1.23		2.34		1.66		1.66
4		0.00		0.19		0.42		0.00		0.00		0.00		2.16		0.00		1.34	
3	0.00		1.21		0.86		0.95		0.00		0.00		0.67		1.35		2.43		1.92
2		0.67		0.55		0.42		1.23		1.75		1.35		1.76		0.00		0.00	
1	0.00		0.40		0.86		1.66		1.76		1.56		0.81		2.40		0.00		0.00

Hs = 10.96 cm, Ns = 2.94

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	3.64		2.94		3.18		4.09		1.82		3.09		0.00		3.09		1.66		1.38
12		4.05		4.27		2.95		4.58		2.12		1.38		2.04		2.71		1.89	
11	6.37		3.98		5.05		2.84		4.19		3.56		2.94		2.16		2.84		2.47
10		3.54		3.70		3.41		2.79		1.53		2.01		2.46		2.16		1.23	
9	3.60		2.97		3.75		2.69		3.42		2.84		2.68		2.89		1.63		2.59
8		4.16		3.06		2.57		3.05		4.37		3.11		4.90		2.68		1.50	
7	4.17		3.57		2.64		2.64		3.06		2.47		5.49		0.00		2.15		0.00
6		3.43		3.91		2.76		4.65		3.55		3.28		15.46		2.28		2.24	
5	2.75		3.64		4.17		2.85		4.26		3.65		2.84		3.54		1.14		1.38
4		3.14		4.26		2.94		2.49		2.92		3.29		2.03		0.00		0.00	
3	3.24		2.66		2.38		3.83		2.49		0.00		0.00		0.00		0.00		1.66
2		2.12		3.14		2.68		1.86		0.00		0.00		0.00		0.00		3.88	
1	3.42		2.64		2.49		1.63		0.00		0.00		0.00		0.00		2.99		4.07

Hs = 11.26 cm, Ns = 3.03

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	1.82		3.12		1.75		3.26		4.02		9.69		8.39		5.59		5.76		3.19
12		1.71		2.46		2.84		1.69		14.09		52.99		18.65		5.24		3.04	
11	2.71		2.13		2.87		2.16		0.00		89.45		31.24		10.87		5.97		2.38
10		1.97		2.34		2.52		0.00		69.19		43.76		33.22		7.81		2.57	
9	2.67		2.60		2.65		3.81		0.00		265.14		293.78		9.95		6.45		3.34
8		0.97		2.01		2.49		3.47		44.77		210.34		187.28		7.93		4.64	
7	0.00		0.00		0.00		2.57		9.90		12.99		143.82		93.81		8.81		2.01
6		2.08		2.76		2.15		7.91		34.87		108.74		261.29		10.54		4.90	
5	4.19		3.65		2.19		5.81		91.53		6.88		8.01		9.94		11.16		3.28
4		5.75		2.70		2.94		4.19		4.51		5.63		5.48		3.96		3.44	
3	2.85		2.44		2.14		3.41		2.58		3.59		3.34		3.59		6.84		3.31
2		1.14		1.80		0.57		1.71		1.50		2.88		0.90		0.30		1.69	
1	1.92		2.12		1.56		1.75		1.92		2.28		0.81		2.41		1.63		2.16

Overall Distance [mm]

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
13	2.69		4.29		5.91		6.57		5.67		17.07		10.40		7.35		4.95		2.44
12		2.45		3.93		4.88		4.08		29.78		60.42		20.64		7.20		2.67	
11	2.87		3.21		3.69		2.99		5.07		102.63		38.38		13.10		2.68		3.19
10		3.11		3.17		3.60		3.71		78.28		50.58		39.85		8.72		3.22	
9	2.69		2.82		3.78		3.78		7.19		294.81		323.11		25.91		3.52		2.60
8		1.79		2.43		2.30		7.21		51.77		232.72		212.22		8.66		2.36	
7	2.11		2.24		2.38		5.37		14.38		7.54		163.35		104.82		3.54		2.85
6		2.73		2.49		3.93		11.85		38.44		122.58		299.07		3.18		2.48	
5	2.47		3.10		3.56		3.79		105.35		6.66		12.09		12.55		2.75		2.44
4		3.00		3.61		4.24		10.47		10.23		11.57		11.48		2.76		2.50	
3	2.80		3.39		3.85		3.98		3.86		2.21		2.85		2.93		3.78		3.27
2		0.86		0.00		1.11		0.20		0.13		1.59		0.00		1.00		0.00	
1	0.76		0.00		0.00		0.98		1.12		1.89		0.00		0.80		1.40		0.00

D.2.5. SERIES 5

CENTER-TO-CENTER MEASUREMENTS

Hs = 6.69 cm, Ns = 1.80

Rows	Columns 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
20		0.80		0.63		0.67		2.02		1.76		2.16		2.35		3.53		3.53	
19	0.67		1.01		1.18		1.26		1.64		2.18		2.16		3.46		2.94		4.13
18		1.67		2.06		1.96		2.37		1.45		1.18		2.55		2.86		3.53	
17	0.37		2.16		0.80		0.37		0.82		0.78		0.61		3.28		2.36		3.92
16		1.41		0.99		1.83		1.42		1.58		1.60		1.97		2.37		2.44	
15	1.03		0.99		0.98		0.47		1.18		0.82		0.20		1.12		1.83		2.18
14		2.78		0.92		1.01		1.59		3.16		1.01		3.00		1.27		0.47	
13	0.78		1.22		0.88		1.58		1.25		0.20		2.17		1.22		1.34		2.21
12		1.11		1.23		0.61		1.38		0.86		1.03		1.36		1.42		1.17	
11	1.38		1.63		0.67		1.64		0.25		0.66		0.80		1.09		1.34		1.42
10		2.48		0.61		0.67		1.51		1.48		0.99		1.97		0.80		1.26	
9	1.64		1.79		1.12		1.60		1.73		1.87		1.01		0.42		1.83		1.09
8		2.36		1.83		1.41		1.62		2.02		1.76		1.03		0.62		1.17	
7	1.96		2.30		1.76		1.22		2.60		1.60		1.51		0.62		0.99		0.42
6		2.82		2.18		1.27		1.76		2.54		0.99		2.25		0.20		1.79	
5	3.17		3.53		2.76		1.34		3.09		2.18		2.36		1.26		0.98		1.18
4		3.74		2.78		2.50		2.85		2.33		2.54		2.30		2.06		1.03	
3	4.14		2.78		2.57		2.85		2.18		3.17		1.58		1.45		0.98		0.42
2		3.95		2.72		2.78		2.85		2.90		2.00		1.69		0.74		0.61	
1	4.12		4.53		3.28		3.14		2.92		1.83		1.26		1.34		0.80		0.00

Hs = 8.80 cm, Ns = 2.37

Rows	Columns 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
20		1.01		0.61		0.74		0.42		0.42		0.61		0.74		0.42		0.00	
19	0.00		0.00		0.00		0.00		0.00		1.19		0.98		0.99		0.86		1.03
18		1.48		1.22		0.37		0.00		0.98		1.27		1.18		0.98		1.03	
17	0.50		1.36		0.16		0.92		1.12		1.99		0.86		1.45		1.83		1.99
16		1.58		1.34		1.18		1.22		1.77		2.40		2.42		2.55		0.85	
15	2.44		1.99		1.58		0.99		1.60		1.19		1.09		1.38		2.16		0.76
14		3.65		1.99		1.11		1.58		1.19		1.11		2.36		2.25		0.66	
13	1.87		1.11		2.09		2.82		3.12		1.79		2.84		2.82		2.90		2.50
12		1.79		2.78		1.60		2.67		2.77		3.20		3.53		1.73		2.92	
11	1.97		2.46		1.87		1.99		2.36		3.14		2.09		2.67		3.04		2.35
10		2.05		2.34		1.17		1.22		1.69		2.92		3.73		2.16		2.40	
9	1.87		2.25		1.37		1.09		1.38		1.38		2.90		2.72		3.39		2.83
8		2.16		1.97		1.97		1.60		2.40		3.53		3.56		3.20		2.84	
7	2.75		1.79		1.77		1.93		1.19		1.64		2.75		3.15		2.42		2.98
6		2.84		1.19		1.03		1.03		1.54		1.01		0.42		1.01		2.59	
5	0.61		1.79		1.76		1.45		1.67		1.11		0.61		2.54		1.11		1.01
4		0.78		1.58		0.78		1.37		0.59		0.47		0.39		1.03		0.61	
3	0.42		1.01		1.69		1.03		0.59		0.39		0.62		0.39		1.22		0.80
2		0.16		0.42		0.59		0.42		0.20		0.00		0.20		0.00		0.16	
1	1.03		0.92		1.26		0.39		0.00		0.74		0.32		0.80		0.00		0.98

Hs = 10.93 cm, Ns = 2.94

Rows	Columns 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
20		0.98		1.18		1.18		0.98		1.87		2.25		2.72		1.69		1.34	
19	1.18		0.98		1.18		1.18		0.98		1.99		0.98		3.01		1.18		0.98
18		1.18		3.88		1.18		0.98		1.18		0.98		1.18		4.22		1.18	
17	0.98		1.18		2.71		0.98		0.98		3.78		1.67		4.14		2.82		0.98
16		2.67		1.51		2.67		0.98		2.36		3.01		3.38		6.11		5.14	
15	0.98		0.98		1.18		3.75		1.18		5.76		3.65		4.61		5.33		3.20
14		2.44		2.96		3.42		3.93		4.31		5.67		3.58		4.75		5.38	
13	1.69		3.53		3.56		2.96		2.83		4.78		6.47		4.55		5.50		4.92
12		2.90		2.16		2.63		1.18		3.09		5.76		4.99		5.96		5.38	
11	1.18		2.55		1.18		0.98		2.50		8.26		7.92		4.59		4.80		4.80
10		0.98		1.18		3.54		4.23		4.41		32.62		7.68		6.20		4.44	
9	1.18		1.18		1.18		0.98		3.75		17.92		22.24		5.99		4.74		5.94
8		2.94		3.09		0.98		0.98		2.67		10.87		20.29		6.29		3.94	
7	4.18		3.34		2.67		1.18		3.20		12.23		12.00		1.18		2.85		0.59
6		3.09		2.25		2.82		0.98		0.98		0.98		17.39		2.55		1.51	
5	0.98		3.35		0.98		0.98		0.98		0.98		0.98		2.36		1.03		0.98
4		1.18		0.98		1.18		1.18		1.18		0.98		0.98		1.18		1.18	
3	0.98		0.98		0.98		0.98		0.98		1.18		1.18		1.18		0.98		0.98
2		0.98		1.18		1.18		0.98		1.18		0.98		1.18		1.18		1.18	
1	0.98		1.18		0.98		1.18		1.18		0.98		1.18		0.98		1.18		0.98

Overall Distance [mm]

Rows	Columns 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
20		1.26		1.93		1.36		0.86		1.11		0.99		0.67		1.60		2.40	
19	0.67		0.66		0.00		0.82		0.76		1.26		0.25		0.76		1.27		2.16
18		0.51		2.67		0.67		1.77		0.92		1.09		0.25		2.36		1.45	
17	1.57		4.38		2.05		1.58		1.38		2.91		2.22		2.35		2.48		0.99
16		2.92		1.58		1.93		1.48		2.44		2.99		2.18		2.78		3.87	
15	2.37		2.40		1.76		4.61		2.75		3.85		4.34		2.79		3.08		2.72
14		3.42		4.14		2.96		5.92		6.18		5.79		3.92		2.57		2.49	
13	2.55		3.17		4.34		4.65		7.11		6.21		8.01		1.78		3.31		2.65
12		3.73		4.43		3.53		2.42		5.01		8.45		7.02		3.51		3.49	
11	1.76		4.71		2.52		1.58		4.49		10.93		8.24		5.59		2.89		2.85
10		0.16		2.87		3.92		3.78		5.13		33.08		10.69		2.50		4.61	
9	1.38		1.98		2.18		2.00		3.73		17.17		24.69		8.40		3.57		4.84
8		2.74		3.20		1.64		1.98		2.94		16.33		22.62		8.94		2.72	
7	4.92		2.59		2.76		2.08		2.73		16.67		17.50		18.92		4.33		3.22
6		2.21		1.38		2.55		1.18		2.50		1.11		15.58		6.23		1.34	
5	1.60		1.58		1.12		1.62		2.41		1.18		1.25		3.62		0.25		0.86
4		1.79		1.33		1.28		1.27		1.28		1.98		1.11		0.37		0.92	
3	2.82		1.48		0.95		1.69		1.03		1.97		1.28		0.51		1.22		1.37
2		3.01		1.48		1.36		1.62		1.67		1.23		0.66		1.01		0.59	
1	2.96		2.72		2.10		1.76		1.98		1.59		1.12		0.99		1.97		1.96

CORNER-TO-CORNER MEASUREMENTS

Hs = 6.69 cm, Ns = 1.80

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
20		1.58		1.49		1.56		1.76		1.92		1.27		1.99		0.74		0.63	
19	1.34		1.45		1.35		1.62		1.45		1.76		1.32		1.19		1.09		0.61
18		2.00		1.51		1.87		0.92		1.76		1.75		1.92		1.03		0.37	
17	1.55		1.83		0.76		1.51		1.38		1.95		0.98		1.77		1.60		0.61
16		1.57		1.20		1.39		1.17		1.97		1.77		1.20		1.38		0.51	
15	0.97		1.94		1.17		1.75		1.72		1.57		1.33		1.55		1.69		0.78
14		1.81		1.25		1.71		2.22		3.78		1.17		1.48		1.83		2.00	
13	1.96		1.58		1.08		1.40		2.28		1.93		1.77		2.02		1.95		2.72
12		1.54		1.47		1.15		1.92		2.78		1.56		2.25		2.07		1.62	
11	1.83		1.59		1.59		1.60		5.41		1.91		2.48		2.57		1.35		1.96
10		2.09		1.60		1.58		1.49		2.85		1.97		1.18		1.18		1.80	
9	1.60		1.17		1.67		1.97		1.92		2.25		1.36		1.62		1.55		1.75
8		0.76		1.35		1.36		1.67		3.09		1.98		1.73		1.55		1.46	
7	1.08		0.97		1.09		1.24		1.85		1.58		1.90		2.04		1.73		1.54
6		1.22		0.83		0.90		0.99		2.00		2.20		2.34		1.96		1.15	
5	0.59		1.03		0.97		1.48		1.49		1.57		2.00		1.15		1.73		1.77
4		0.51		1.30		1.59		0.46		2.76		1.40		0.97		1.74		0.77	
3	0.51		0.51		1.28		0.43		1.67		2.07		1.47		1.63		1.54		1.74
2		0.98		1.54		1.91		1.01		1.84		1.94		1.80		1.85		2.05	
1	0.32		0.88		1.48		0.20		0.16		0.82		0.50		1.22		0.67		0.50

Hs = 8.80 cm, Ns = 2.37

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
20		1.97		0.66		0.76		1.03		1.34		1.03		1.11		0.39		0.42	
19	0.61		1.38		1.19		0.80		1.19		1.76		0.99		1.41		0.50		1.11
18		1.09		0.99		1.38		2.44		1.22		0.67		1.18		1.93		1.64	
17	1.38		1.97		0.61		1.60		2.74		1.97		1.64		2.00		1.51		1.01
16		2.06		2.60		1.27		1.58		1.79		2.16		1.99		3.70		1.79	
15	2.74		2.76		1.83		1.76		2.94		2.21		1.79		2.57		2.86		1.18
14		1.18		3.09		1.62		2.18		1.99		2.59		3.56		2.67		2.35	
13	2.50		2.57		2.52		1.96		3.81		1.96		2.83		3.44		2.67		2.42
12		2.78		2.50		1.19		2.76		4.38		3.25		3.25		0.42		2.08	
11	2.52		2.59		2.55		1.19		2.55		3.67		2.59		2.40		3.75		2.46
10		2.10		2.78		1.69		2.21		2.36		3.43		3.53		2.42		1.97	
9	2.73		1.69		2.44		1.38		2.36		2.34		2.83		3.09		2.63		2.92
8		3.20		1.77		1.17		1.76		2.02		2.44		2.78		2.75		3.62	
7	2.78		1.97		1.79		1.42		1.58		2.78		3.75		3.53		2.86		4.75
6		2.18		2.42		2.44		2.48		1.98		1.18		3.46		2.71		2.60	
5	1.83		2.96		2.78		2.36		2.11		0.32		1.09		2.35		1.17		1.36
4		0.50		3.43		0.85		2.58		1.69		0.25		1.49		1.93		0.37	
3	0.66		0.61		1.79		1.49		0.37		0.82		0.16		1.58		0.42		0.78
2		2.63		2.96		1.77		0.51		3.53		1.26		2.37		1.27		0.66	
1	0.76		2.67		0.25		1.80		1.84		1.84		1.82		0.32		1.25		0.51

Hs = 10.93 cm, Ns = 2.94

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
20		3.20		3.92		3.02		3.15		2.18		2.71		2.02		1.86		2.59	
19	2.30		3.14		2.87		3.20		2.86		1.77		2.23		1.33		2.42		2.60
18		2.55		1.51		2.58		3.28		1.51		1.69		1.64		1.12		1.97	
17	3.20		2.02		2.96		2.11		3.59		0.67		1.45		2.09		0.92		2.37
16		2.42		1.27		3.50		3.33		1.40		3.02		1.84		2.48		1.85	
15	1.25		0.85		1.58		0.62		4.34		4.54		4.00		1.99		2.71		4.62
14		0.92		0.80		1.18		3.82		6.02		0.37		3.19		2.34		2.05	
13	2.63		1.18		0.82		1.54		3.60		1.11		3.57		2.42		3.18		4.13
12		2.38		2.00		2.25		4.23		6.98		2.40		2.52		4.06		2.77	
11	3.49		1.63		2.98		2.02		2.00		3.44		5.30		6.46		4.29		4.40
10		1.60		1.40		1.99		1.37		0.99		45.88		6.53		5.55		5.57	
9	0.74		1.94		2.10		1.87		1.73		5.82		28.83		3.20		3.66		5.81
8		0.50		1.40		1.60		1.62		0.00		39.37		30.45		5.09		4.03	
7	5.42		0.78		0.25		1.79		2.20		20.60		11.66		44.40		2.35		0.59
6		0.88		1.22		2.06		2.02		1.54		2.36		57.48		1.59		2.75	
5	2.75		1.42		1.19		1.48		1.85		2.18		2.76		1.94		2.77		2.93
4		1.87		4.44		1.09		1.87		1.77		2.22		2.08		2.67		1.93	
3	2.18		1.87		1.87		1.11		1.18		3.09		1.58		2.21		2.42		2.83
2		2.25		2.59		2.50		1.79		4.36		3.09		4.75		1.57		2.98	
1	0.50		1.23		0.88		1.36		1.29		1.68		0.51		1.05		1.38		1.58

Overall Distance [mm]

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
20		1.40		2.20		1.63		1.54		1.63		3.06		2.65		2.42		2.79	
19	2.08		1.44		3.16		2.72		1.44		1.83		2.34		2.42		2.29		2.00
18		1.59		0.99		2.42		2.06		1.83		3.09		1.34		3.68		2.45	
17	1.48		2.08		0.76		1.48		2.51		3.49		1.18		4.96		3.93		2.54
16		2.83		3.56		1.84		2.98		3.59		3.64		1.93		4.04		3.84	
15	5.14		4.94		2.92		3.78		7.31		4.26		6.75		4.23		3.74		4.28
14		3.28		4.26		5.10		8.85		8.89		4.36		6.28		3.22		3.52	
13	2.46		3.93		5.07		3.58		8.99		6.73		7.84		3.30		4.52		5.01
12		5.60		5.79		5.34		5.50		6.37		8.68		8.00		4.02		3.27	
11	3.69		6.04		4.44		3.51		6.41		9.65		10.44		9.50		4.02		4.88
10		1.79		4.44		4.43		3.33		6.26		45.19		11.09		4.52		6.38	
9	3.95		3.62		4.11		4.42		5.04		6.04		28.32		8.85		4.26		7.38
8		2.30		3.34		2.48		3.96		5.08		39.02		25.25		9.47		4.16	
7	9.19		3.15		2.72		1.87		4.18		22.30		11.78		53.03		6.51		5.45
6		4.08		2.50		2.62		3.99		4.57		2.93		53.74		10.97		3.34	
5	2.23		2.98		2.17		4.03		3.82		1.48		1.74		5.50		3.59		2.84
4		1.63		2.57		2.08		3.12		1.48		3.06		2.72		3.34		3.23	
3	2.59		1.99		2.71		2.50		0.63		2.56		2.14		2.59		3.21		3.23
2		5.76		2.22		2.95		1.85		3.01		1.94		4.31		2.79		4.04	
1	1.09		2.42		1.39		1.55		1.07		1.99		2.00		1.83		1.71		1.64

D.2.6. SERIES 6

CENTER-TO-CENTER MEASUREMENTS

Hs = 6.37 cm, Ns = 1.71

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
20		1.37		1.57		1.37		1.37		1.37		1.37		1.37		1.37		1.37	
19	1.57		1.37		1.37		1.37		1.37		1.57		1.57		1.37		1.57		1.57
18		1.37		1.37		1.96		1.57		1.57		1.57		1.37		1.37		1.37	
17	1.37		3.95		1.57		1.37		1.37		1.37		1.57		1.37		1.37		1.57
16		1.37		3.31		3.64		1.57		1.37		1.57		1.57		1.37		1.57	
15	1.37		1.37		1.37		1.37		1.37		1.37		1.37		1.37		1.37		1.57
14		1.57		1.37		1.37		1.37		1.37		1.37		1.57		1.37		1.37	
13	1.37		2.77		2.85		1.57		1.37		1.37		1.37		1.37		1.40		1.71
12		1.37		3.32		2.57		2.45		1.57		1.37		1.37		1.57		1.37	
11	0.00		0.00		0.00		1.33		0.00		0.00		0.00		0.00		0.00		0.00
10		0.00		1.57		1.60		2.66		3.08		3.08		3.08		3.08		2.48	
9	0.00		2.41		3.74		3.46		3.01		0.00		2.17		2.35		2.24		3.04
8		1.68		1.00		2.94		2.16		1.57		2.65		2.74		2.11		3.89	
7	0.00		2.17		1.22		2.24		2.62		3.46		2.71		2.71		1.73		1.83
6		1.41		3.80		3.97		2.83		2.83		2.35		2.32		2.48		2.40	
5	0.00		0.00		2.41		2.17		2.41		3.13		3.13		3.08		3.06		2.81
4		2.74		0.00		2.53		2.35		2.17		2.24		1.96		2.21		2.83	
3	1.20		1.45		1.79		1.46		1.09		1.71		1.29		1.35		1.24		1.41
2		0.08		0.10		0.06		0.04		0.03		0.09		0.02		0.04		0.03	
1	0.00		0.01		0.00		0.00		0.00		0.00		0.00		0.02		0.00		0.00

Hs = 8.43 cm, Ns = 2.26

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
20		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
19	0.00		0.00		0.00		1.70		0.00		0.00		0.00		0.00		0.00		0.00
18		2.31		1.90		1.99		0.00		0.00		0.00		0.00		0.00		0.00	
17	1.39		0.00		2.32		2.67		1.84		1.84		1.70		2.73		1.70		1.70
16		0.00		0.00		0.00		2.40		2.56		2.32		2.32		2.40		2.32	
15	0.00		0.00		0.00		2.56		2.40		3.55		3.67		0.98		2.54		2.31
14		1.79		3.08		3.08		3.55		3.55		3.39		3.15		3.32		2.65	
13	2.74		0.00		0.00		3.35		3.84		2.48		1.99		3.25		3.74		3.01
12		1.60		0.00		1.92		2.55		4.03		3.97		2.90		2.66		2.90	
11	2.84		0.84		0.84		0.84		4.09		4.09		4.09		2.83		2.73		2.83
10		3.67		1.87		0.00		0.00		2.77		0.00		0.00		0.00		0.00	
9	2.15		0.00		0.00		2.45		2.77		4.15		1.10		1.00		1.87		0.00
8		1.87		1.00		1.50		2.06		1.46		2.29		0.00		2.24		1.18	
7	0.00		0.00		0.00		0.00		0.00		0.00		1.82		0.00		0.00		0.00
6		0.75		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
5	0.00		2.24		2.74		0.00		1.21		0.00		0.00		0.00		0.00		0.00
4		0.00		2.81		1.00		0.00		0.00		0.00		0.00		0.00		0.00	
3	0.00		0.00		0.00		0.62		0.46		0.00		0.00		0.00		0.00		0.00
2		0.62		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
1	0.00		1.46		1.23		0.46		0.78		0.00		0.00		0.00		0.00		0.00

Hs = 10.68 cm, Ns = 2.87																			
	Columns																		
Rows	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
20		1.92		0.75		2.07		2.17		2.62		2.85		2.62		2.81		2.66	
19	2.66		2.66		2.62		2.62		2.85		2.66		2.62		4.38		2.62		2.66
18		1.82		1.00		1.08		2.62		2.62		2.66		3.39		2.74		2.85	
17	2.81		2.66		2.62		0.98		1.25		3.25		2.66		1.50		4.57		3.04
16		3.34		2.66		2.66		2.62		2.62		3.09		0.86		2.81		2.85	
15	3.74		5.02		4.60		1.03		3.23		3.07		1.74		2.66		2.81		2.66
14		4.51		0.97		2.66		2.20		2.32		1.57		1.10		2.18		3.46	
13	0.92		5.37		4.60		2.11		2.01		2.66		0.97		1.57		1.00		0.46
12		3.59		5.07		3.64		1.84		2.57		2.21		1.50		2.85		0.92	
11	2.84		3.37		4.06		3.61		4.33		4.03		2.57		3.27		2.81		2.66
10		2.74		2.40		4.33		5.43		1.94		5.24		2.66		5.00		2.66	
9	3.01		3.46		3.23		2.69		2.30		4.55		3.23		5.82		3.23		1.97
8		2.99		1.85		1.38		1.84		2.21		2.62		1.57		14.82		1.41	
7	1.57		10.36		1.57		3.39		3.14		3.56		3.43		1.97		3.04		1.41
6		1.35		1.58		2.57		4.22		2.35		3.46		2.35		2.98		1.46	
5	2.66		1.16		1.55		3.20		1.16		1.16		1.16		1.25		1.16		2.85
4		1.75		1.90		0.42		1.58		0.65		1.68		2.55		1.65		1.65	
3	2.66		1.41		2.53		1.58		1.58		1.38		1.58		1.58		1.60		1.60
2		0.80		0.80		0.25		1.15		1.75		0.80		1.10		1.15		1.00	
1	2.81		1.08		0.99		2.16		1.38		1.82		0.25		0.50		0.75		1.46

Hs = 11.64 cm, Ns = 3.13																			
	Columns																		
Rows	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
20		0.00		1.75		1.99		0.00		0.00		0.00		0.00		0.00		0.00	
19	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
18		0.00		0.00		0.00		0.00		1.38		3.46		0.00		2.21		0.00	
17	0.00		0.00		0.00		0.00		0.00		0.00		0.00		2.53		2.84		0.00
16		0.00		0.00		0.00		0.00		0.00		1.50		1.75		2.24		1.00	
15	0.00		0.00		0.00		0.00		0.00		1.71		1.76		3.67		4.16		0.00
14		0.00		1.82		1.85		1.77		2.59		0.00		5.38		4.15		0.00	
13	0.00		0.00		2.09		2.17		2.24		6.21		6.88		5.48		1.60		2.80
12		2.24		1.00		1.25		0.25		1.25		3.99		1.75		1.00		4.24	
11	0.00		2.99		5.66		0.00		0.00		5.89		8.36		4.71		4.14		0.00
10		0.00		10.95		9.67		0.00		0.00		13.82		9.21		7.10		4.75	
9	0.00		2.01		13.22		1.90		0.00		12.19		10.00		18.24		6.37		3.19
8		0.00		1.75		0.00		1.25		0.00		1.25		8.73		0.00		5.98	
7	2.11		3.23		1.37		1.25		0.00		0.00		1.25		9.25		17.44		0.00
6		1.29		0.00		0.00		0.00		0.00		0.77		1.55		0.91		0.98	
5	0.00		0.00		1.25		0.86		0.00		1.46		1.46		0.00		0.50		0.00
4		1.99		0.00		0.00		0.00		0.00		0.00		1.99		2.49		2.49	
3	0.00		0.00		0.00		0.00		0.00		0.00		0.97		0.00		0.00		0.00
2		0.00		0.00		0.00		0.00		0.00		0.00		0.95		1.15		1.00	
1	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.86

		Overall Distance [mm]																		
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**
Rows	**20**		0.23		0.20		2.42		0.46		0.97		1.19		0.97		1.16		0.00	
	19	1.19		1.00		0.97		2.29		1.19		1.19		1.16		2.74		1.16		1.19
	18		1.13		0.75		1.30		1.16		2.51		4.45		1.74		1.08		0.19	
	17	1.58		3.48		2.90		1.58		0.75		2.69		2.66		3.27		4.50		2.70
	16		1.71		2.90		3.26		3.40		3.12		3.86		4.03		4.47		4.35	
	15	2.11		3.36		2.95		1.64		3.08		4.80		3.88		4.55		4.81		3.20
	14		2.79		3.08		3.86		5.05		4.08		3.20		5.37		4.46		2.88	
	13	3.61		7.84		8.91		8.82		7.84		11.28		10.80		11.09		1.44		6.63
	12		7.16		11.32		9.60		7.28		11.57		12.64		12.87		10.67		8.77	
	11	2.90		6.86		9.41		4.90		7.65		13.35		14.78		10.39		9.58		5.48
	10		5.49		14.90		14.47		7.64		6.08		20.22		14.82		14.69		9.68	
	9	3.32		7.45		19.49		8.82		6.68		19.77		15.38		24.70		12.95		7.45
	8		3.47		13.92		5.74		6.56		4.97		15.73		8.69		24.70		7.42	
	7	3.33		15.12		3.14		6.74		5.74		6.51		7.00		13.44		14.62		2.29
	6		2.59		2.37		3.53		3.00		2.18		3.08		2.29		2.48		1.93	
	5	2.66		3.37		3.48		3.59		4.71		3.63		3.63		2.27		2.40		3.60
	4		-2.00		2.34		1.91		3.80		1.79		1.91		2.96		1.92		2.69	
	3	2.72		2.43		2.30		3.09		1.56		2.00		2.15		3.80		3.61		3.80
	2		2.09		2.40		1.82		2.17		3.37		3.27		2.90		3.13		3.08	
	1	3.97		3.04		3.19		3.39		3.34		2.98		3.14		2.71		3.04		3.27

CORNER-TO-CORNER MEASUREMENTS

		Hs = 6.37 cm, Ns = 1.71																		
		Columns																		
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Rows	20		0.00		2.55		3.15		1.18		1.87		1.77		1.75		1.82		1.60	
	19	2.15		3.23		2.95		2.98		2.05		1.33		0.00		0.00		2.29		0.00
	18		1.75		0.00		1.41		2.71		2.75		0.00		2.21		1.70		0.00	
	17	1.65		2.71		3.92		2.75		0.00		1.16		0.00		2.78		1.82		0.00
	16		2.24		2.95		2.07		2.37		2.55		1.65		0.00		0.00		0.00	
	15	0.00		2.78		1.57		1.33		2.07		1.57		0.00		1.00		2.78		2.35
	14		0.00		1.87		0.65		1.03		0.00		2.09		1.87		0.00		1.82	
	13	1.76		1.50		1.82		1.41		0.00		1.23		1.00		0.00		1.65		2.18
	12		0.50		2.18		2.09		1.60		0.00		0.00		0.00		0.00		0.00	
	11	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
	10		0.00		0.91		1.50		0.00		0.00		0.00		0.00		1.74		0.00	
	9	0.00		0.00		0.00		0.00		0.00		1.79		2.35		0.00		1.41		1.82
	8		0.00		0.00		1.41		0.00		0.00		0.00		1.29		1.10		0.00	
	7	0.84		0.00		2.78		0.00		0.92		1.16		2.06		1.15		0.65		0.00
	6		1.98		1.96		1.92		0.00		0.00		2.36		1.37		1.16		1.33	
	5	0.00		0.00		0.00		0.00		0.00		0.00		0.00		1.23		0.00		0.00
	4		0.00		0.00		0.00		0.66		0.00		0.00		0.00		0.00		1.99	
	3	0.00		0.00		0.00		0.00		0.00		0.00		1.46		0.00		1.33		1.29
	2		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		1.87	
	1	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00

Hs = 8.43 cm, Ns = 2.26

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
20		1.65		0.00		0.00		0.00		1.96		0.00		0.00		0.00		0.00	
19	0.00		0.00		0.00		0.00		0.00		0.00		1.19		1.96		0.00		0.00
18		0.00		2.24		0.00		0.00		1.60		2.01		1.82		0.00		1.60	
17	0.00		0.00		0.00		0.00		2.94		1.98		3.15		1.60		0.00		0.00
16		1.97		1.19		0.00		1.44		2.35		0.00		0.00		2.47		2.75	
15	2.71		0.00		1.97		1.57		0.98		3.15		2.34		0.00		0.00		0.00
14		0.00		2.57		1.82		3.39		4.77		1.94		0.00		2.66		0.00	
13	0.00		2.11		0.00		2.96		3.39		2.75		1.68		0.00		0.00		0.00
12		0.00		0.00		0.00		2.21		1.19		2.31		1.25		0.00		0.00	
11	0.00		0.00		0.00		0.00		3.65		3.58		0.00		0.00		0.00		0.00
10		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
9	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
8		0.00		0.00		0.00		0.85		1.35		1.77		0.00		0.00		0.00	
7	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
6		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
5	0.00		0.00		0.00		1.76		0.00		0.00		0.00		0.00		0.00		0.00
4		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
3	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
2		0.00		0.00		0.00		0.00		2.23		0.00		0.00		0.00		0.00	
1	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00

Hs = 10.68 cm, Ns = 2.87

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
20		0.00		0.00		0.00		1.70		0.61		1.97		1.41		1.98		0.00	
19	2.07		1.46		2.57		1.60		0.00		2.47		3.08		2.62		2.16		0.00
18		3.42		1.68		3.65		2.76		2.48		2.77		1.84		2.73		1.57	
17	2.94		4.16		2.55		1.50		2.01		2.15		1.75		1.26		2.55		1.41
16		0.86		1.60		1.45		1.92		1.22		3.15		1.75		2.59		1.82	
15	1.44		1.59		1.60		0.00		1.37		1.71		5.33		2.05		2.17		0.00
14		2.18		1.57		2.90		2.20		1.82		1.90		1.26		1.63		4.49	
13	0.91		1.99		3.43		1.70		2.16		1.46		2.05		5.05		1.59		1.58
12		3.56		3.06		3.74		2.17		3.14		1.22		1.60		3.80		2.62	
11	3.29		4.47		4.23		4.45		2.69		0.00		3.75		3.65		2.37		1.50
10		3.41		2.57		3.30		5.21		3.74		3.95		1.98		3.23		3.97	
9	2.69		2.69		3.14		3.14		4.23		3.69		2.90		6.18		2.80		0.00
8		2.40		2.84		2.16		2.40		5.71		2.90		1.70		25.84		2.56	
7	0.00		13.28		1.08		2.66		2.71		1.58		2.21		1.45		3.69		2.63
6		0.00		0.00		0.00		3.75		1.77		2.48		2.96		2.07		1.58	
5	1.33		2.24		2.59		1.68		3.00		1.60		3.58		0.98		2.48		1.40
4		1.25		0.00		1.58		2.56		3.03		2.81		3.90		3.46		0.00	
3	1.99		1.70		1.25		1.23		1.16		1.33		1.60		2.07		1.57		2.18
2		2.24		1.82		0.00		1.73		0.00		2.43		1.79		0.00		0.00	
1	0.00		0.00		0.00		0.00		0.00		0.00		0.00		2.98		3.15		0.00

Hs = 11.64 cm, Ns = 3.13

Rows	Columns 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
20		2.24		2.49		2.24		3.49		1.25		1.99		0.00		3.24		2.99	
19	2.18		4.15		2.06		3.24		3.09		1.41		2.09		3.64		3.65		4.22
18		2.69		1.90		1.94		1.60		1.60		2.99		3.65		4.34		4.23	
17	2.24		2.20		2.81		2.67		3.01		2.56		2.92		4.53		5.31		4.27
16		0.50		3.49		3.99		2.49		2.74		2.74		4.49		4.99		3.99	
15	3.97		3.32		3.85		4.33		4.58		6.08		4.63		5.04		6.55		4.47
14		2.21		3.98		3.19		3.44		4.73		3.47		7.70		3.47		3.30	
13	0.00		2.37		3.91		3.55		4.30		6.46		5.18		5.93		2.53		2.99
12		0.75		1.25		4.49		1.99		3.99		1.50		0.00		1.75		4.99	
11	0.00		3.16		6.98		2.79		2.92		9.29		12.01		7.24		6.48		2.90
10		2.66		9.68		4.97		3.06		3.72		10.32		12.19		10.78		5.82	
9	0.00		6.77		15.28		4.21		4.00		12.35		34.51		14.21		8.13		4.65
8		1.50		37.90		2.99		4.24		1.25		4.24		11.97		5.49		0.00	
7	2.40		2.87		1.94		2.47		0.00		2.84		2.19		23.34		27.05		1.08
6		1.25		1.50		4.19		2.30		2.34		1.46		2.24		2.80		1.75	
5	2.15		2.06		2.83		3.13		2.67		3.52		2.45		0.00		1.59		2.56
4		2.74		1.00		1.99		1.99		3.74		1.50		3.74		3.24		1.25	
3	1.87		1.65		1.82		1.16		0.00		2.01		0.00		0.00		1.15		1.50
2		1.59		0.00		0.00		2.74		2.32		2.09		0.00		2.37		0.00	
1	1.55		3.16		4.97		2.56		3.51		2.01		0.00		0.00		0.00		0.00

Overall Distance [mm]

Rows	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
20		1.72		2.28		3.36		1.22		2.09		2.37		0.13		3.01		0.77	
19	1.94		4.27		3.67		4.16		1.53		1.74		2.69		4.19		4.10		1.22
18		2.61		2.29		2.52		3.47		4.65		3.87		5.28		1.86		2.84	
17	2.51		5.23		5.95		2.85		1.99		3.86		3.42		5.41		3.95		2.66
16		4.33		4.41		4.10		4.29		6.22		4.77		2.37		2.37		4.25	
15	2.95		3.48		5.24		3.48		4.45		6.02		2.35		2.81		5.29		3.20
14		1.38		3.34		3.39		5.13		5.98		3.78		4.06		2.62		4.53	
13	2.59		7.71		8.43		8.06		7.45		10.77		9.45		10.59		4.72		6.50
12		4.27		10.21		6.86		7.46		8.55		11.03		10.99		9.22		5.84	
11	3.29		6.08		9.50		5.90		6.51		12.87		15.73		10.88		8.32		3.88
10		4.86		17.34		15.31		7.67		5.74		14.00		14.15		13.92		8.56	
9	2.69		4.31		30.28		7.22		8.13		22.51		31.50		29.16		10.99		5.35
8		3.56		30.46		5.90		4.76		7.45		20.87		11.07		20.57		2.56	
7	1.58		19.85		4.47		5.11		3.15		4.90		12.55		26.51		30.20		1.55
6		1.99		0.39		1.74		1.60		0.91		2.90		2.31		1.84		1.73	
5	1.82		3.20		3.42		4.29		4.90		2.55		3.40		1.90		2.57		0.35
4		2.35		1.39		2.25		4.36		3.20		1.93		2.31		0.24		1.34	
3	0.66		1.57		1.38		1.63		1.16		1.75		2.05		2.07		2.66		3.90
2		0.16		1.82		0.00		2.94		4.37		4.00		1.79		2.37		1.87	
1	1.55		3.16		4.97		2.56		3.51		2.01		0.00		2.98		3.15		0.00

D.2.7. SERIES CENTER-TO-CENTER — 7 MEASUREMENTS

Hs = 7.79 cm, Ns = 2.09

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
20		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
19	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
18		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
17	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
16		0.00		0.00		0.00		0.00		0.87		0.94		2.73		0.00		1.02	
15	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
14		0.00		0.00		0.00		0.00		0.00		0.00		0.00		2.05		0.00	
13	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		1.50
12		2.05		2.23		1.74		2.68		1.86		3.65		2.00		2.51		3.17	
11	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		3.04
10		0.00		2.13		1.99		0.00		2.23		3.70		3.85		2.65		1.82	
9	1.45		1.93		2.05		3.06		1.99		2.99		3.91		1.62		1.82		1.06
8		2.23		2.65		3.50		3.35		3.77		3.81		1.99		0.00		2.48	
7	0.00		0.00		0.00		0.00		0.00		0.00		0.00		2.17		2.68		2.47
6		0.00		0.00		1.23		1.69		2.36		0.00		1.42		0.00		2.03	
5	1.62		1.62		1.19		2.56		2.24		1.30		0.00		1.50		0.00		2.48
4		1.23		1.38		1.74		1.82		2.51		2.44		1.62		1.22		3.18	
3	2.44		0.00		1.54		1.63		1.45		0.87		2.61		1.19		1.96		0.00
2		1.43		0.00		3.29		2.84		0.81		2.42		2.65		1.26		1.01	
1	2.05		2.89		0.87		1.61		2.05		2.31		1.65		0.00		0.00		1.69

Hs = 8.06 cm, Ns = 2.16

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
20		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
19	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
18		0.00		1.32		1.49		0.00		1.57		1.02		2.19		0.00		0.00	
17	0.00		0.00		0.00		0.00		0.00		0.00		0.63		1.10		0.00		0.00
16		2.60		1.28		1.38		0.99		1.02		1.12		0.62		1.36		0.00	
15	0.00		0.00		0.00		1.86		1.03		1.42		1.45		2.25		2.84		0.00
14		0.00		0.63		1.49		1.70		1.12		1.79		2.25		0.00		1.93	
13	1.49		0.00		1.13		1.79		0.00		0.00		0.00		0.00		0.00		0.00
12		1.26		1.76		0.87		1.65		0.87		1.43		1.01		0.94		1.01	
11	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		1.85
10		0.00		0.00		0.00		2.00		0.00		2.00		2.23		0.00		0.00	
9	0.00		0.51		0.00		0.87		0.61		0.87		1.28		0.41		0.47		0.00
8		0.51		0.00		0.00		1.22		0.99		1.82		1.10		0.63		1.62	
7	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
6		1.49		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
5	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
4		0.00		0.00		0.51		0.00		0.00		0.00		0.00		0.00		0.00	
3	0.00		0.00		0.00		0.51		0.00		0.00		0.00		0.00		0.00		0.00
2		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
1	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00

Hs = 10.56 cm, Ns = 2.84

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
20		1.88		2.05		1.88		2.36		2.23		1.85		1.30		1.85		3.11	
19	0.00		0.00		0.00		0.00		1.99		1.70		2.00		0.00		0.00		0.00
18		0.00		0.00		0.00		0.00		2.32		1.19		1.37		0.00		1.80	
17	0.00		1.06		0.00		2.28		2.05		2.51		2.44		2.36		0.00		0.00
16		0.00		0.00		1.99		1.87		2.32		1.99		0.00		1.62		1.23	
15	2.61		1.45		0.00		2.47		1.55		1.98		0.00		0.00		0.00		0.00
14		0.00		0.00		0.00		1.54		1.80		0.00		0.00		1.49		1.61	
13	0.00		0.00		2.05		1.79		3.15		2.00		3.62		2.31		2.71		1.64
12		0.00		1.17		2.91		1.45		2.13		1.37		2.05		1.49		1.99	
11	0.00		0.00		0.00		0.00		0.00		0.00		2.75		1.88		2.36		2.00
10		0.00		0.00		0.00		2.48		0.00		3.90		3.07		0.00		0.00	
9	0.00		0.00		1.36		0.00		1.87		1.58		0.00		1.41		1.68		0.00
8		0.00		0.00		0.00		0.00		1.17		0.00		2.08		0.88		1.36	
7	0.00		0.00		1.86		3.45		2.32		1.19		0.00		0.00		0.00		0.00
6		0.00		3.48		0.00		1.88		0.00		0.00		0.00		0.00		0.00	
5	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
4		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
3	0.00		0.00		0.00		0.00		0.00		0.00		0.75		0.00		0.94		1.17
2		0.00		0.00		0.00		1.38		0.00		0.00		0.00		0.00		0.00	
1	0.00		0.00		0.00		0.00		0.00		0.00		0.00		2.75		0.00		0.00

Hs = 11.23 cm, Ns = 3.02

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
20		0.51		0.00		0.26		1.79		1.28		1.54		0.26		1.28		0.77	
19	0.51		0.20		0.00		0.00		0.00		0.00		1.25		0.00		0.99		1.24
18		0.00		0.51		0.66		0.43		0.87		0.66		1.02		0.68		1.87	
17	0.26		0.43		1.47		0.66		1.02		0.00		0.00		0.00		1.47		0.00
16		2.56		1.28		0.51		0.77		0.51		0.00		1.28		1.02		1.79	
15	0.31		0.94		1.01		0.20		1.10		1.02		0.43		0.87		0.63		0.81
14		0.47		0.00		1.06		0.00		0.00		2.60		1.98		2.56		1.28	
13	0.31		0.61		0.51		0.78		0.00		0.00		2.31		2.08		0.00		0.88
12		1.79		0.26		0.77		0.26		1.79		0.26		13.32		1.79		2.31	
11	1.69		0.43		0.94		0.68		1.43		3.45		24.97		4.32		0.77		0.99
10		0.51		0.00		0.00		0.37		0.99		29.60		10.38		1.06		1.25	
9	0.47		0.00		0.47		0.75		0.68		13.59		14.16		1.47		0.51		1.36
8		0.77		0.00		0.26		1.02		1.79		7.94		1.79		1.79		0.00	
7	1.01		0.94		0.88		0.63		0.00		1.63		1.25		1.61		1.13		1.54
6		1.41		1.50		0.78		0.75		0.88		0.47		0.81		0.00		0.83	
5	0.31		1.13		0.94		1.10		0.00		1.25		0.77		0.51		0.47		1.12
4		0.00		0.00		1.28		0.77		0.00		1.02		1.28		0.77		1.79	
3	0.00		0.47		0.00		1.10		1.27		0.31		1.06		0.26		0.83		0.61
2		0.26		0.41		0.47		1.02		0.51		1.55		1.02		0.63		0.00	
1	1.13		0.41		1.17		0.88		1.28		0.62		0.87		1.62		0.00		0.47

D

Hs = 12.07 cm, Ns = 3.24

Rows	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
20		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
19	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
18		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
17	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
16		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
15	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
14		0.00		0.00		0.00		0.00		0.00		0.77		1.28		0.00		0.00	
13	0.00		0.00		0.00		0.00		0.00		0.00		2.23		1.62		0.00		0.00
12		0.00		0.00		0.00		0.00		1.79		1.54		12.56		0.00		0.00	
11	0.00		0.00		0.00		0.00		0.00		2.05		24.34		4.18		0.00		0.00
10		0.00		0.00		0.00		0.00		0.00		11.79		13.84		0.00		0.00	
9	0.00		0.00		0.00		1.12		0.00		0.00		14.84		0.00		0.00		0.00
8		0.00		0.00		0.00		0.00		0.51		11.53		0.51		0.00		0.00	
7	0.00		0.00		0.00		0.00		0.00		1.80		0.00		0.00		0.00		0.00
6		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		1.28	
5	0.00		0.00		0.00		0.00		0.00		0.87		0.00		0.00		0.00		0.00
4		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
3	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
2		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
1	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00

Overall Distance [mm]

Columns

Rows	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
20		1.45		2.05		1.06		3.24		2.44		1.55		0.51		1.79		2.31	
19	0.51		0.20		0.00		0.00		1.99		1.70		0.87		0.00		0.99		1.24
18		0.00		0.81		1.19		0.43		1.55		0.51		1.02		0.68		1.72	
17	0.26		0.77		1.47		2.03		2.05		2.51		2.48		2.25		1.47		0.00
16		1.30		1.22		2.03		2.32		2.65		2.17		2.75		1.26		1.06	
15	2.51		1.23		1.01		3.45		2.89		2.05		1.83		1.42		2.88		0.81
14		0.47		0.63		2.17		2.08		2.65		3.18		3.24		1.90		3.23	
13	1.28		0.61		2.56		2.94		3.15		2.00		5.47		2.32		2.71		2.64
12		1.50		1.19		2.74		2.05		3.23		8.72		9.67		2.75		3.53	
11	1.69		0.43		0.94		0.68		1.43		3.45		26.74		5.02		1.65		2.23
10		0.51		2.13		1.99		2.65		2.94		33.79		13.78		1.62		2.67	
9	1.43		1.45		2.65		1.93		3.48		15.67		16.82		2.93		2.73		1.42
8		1.23		2.25		2.88		2.56		4.28		14.28		1.49		1.27		1.83	
7	1.01		0.94		1.74		3.53		2.32		2.75		1.25		1.12		1.85		0.94
6		0.83		2.51		1.37		3.11		1.82		0.47		1.45		0.00		1.26	
5	1.65		1.13		1.06		2.24		2.24		1.68		0.77		1.03		0.47		1.42
4		1.23		1.38		1.79		1.88		2.51		2.48		0.41		0.62		2.03	
3	2.44		0.47		1.54		1.37		1.12		1.02		1.82		0.94		0.81		1.12
2		1.22		0.41		3.14		1.42		0.77		0.87		1.85		1.26		1.01	
1	1.03		2.56		0.88		0.77		1.12		1.74		1.06		1.22		0.00		1.62

CORNER-TO-CORNER MEASUREMENTS

Hs = 7.79 cm, Ns = 2.09

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
20		0.00		0.00		2.38		2.45		2.28		2.08		1.12		0.00		2.51	
19	2.51		3.07		3.14		2.88		3.30		3.65		3.54		2.68		3.10		0.00
18		0.43		2.51		0.00		1.45		2.03		2.24		2.44		2.92		2.64	
17	1.83		2.03		0.00		0.77		4.10		3.50		4.01		3.11		3.34		0.00
16		3.73		2.64		1.80		1.19		1.50		2.91		2.48		2.05		1.37	
15	2.25		4.01		2.61		3.26		2.24		0.00		2.61		1.76		2.47		0.00
14		3.45		1.88		3.29		1.22		3.04		2.56		3.30		5.35		2.64	
13	2.49		2.11		2.92		1.79		2.05		2.73		4.16		2.12		1.82		0.00
12		1.77		0.63		0.00		2.92		2.84		3.86		3.26		1.69		1.45	
11	1.22		1.26		2.48		2.24		2.88		1.85		3.28		3.06		1.62		2.32
10		1.23		0.00		3.53		3.02		2.84		2.65		2.12		3.29		3.26	
9	1.79		0.00		2.68		2.64		1.62		1.93		2.28		1.79		1.93		0.00
8		1.69		1.23		2.25		3.57		2.25		1.30		2.23		1.01		2.67	
7	0.81		0.00		2.44		2.03		0.00		1.43		2.03		3.32		0.00		1.45
6		0.00		0.87		0.51		1.19		1.80		3.19		1.86		3.05		1.88	
5	1.06		0.00		0.37		2.12		1.69		1.83		0.00		0.00		1.23		0.00
4		4.06		1.83		3.28		1.49		0.00		0.00		0.00		1.45		2.38	
3	1.02		1.65		0.00		0.00		0.00		1.62		2.65		1.37		2.61		3.75
2		2.68		1.23		2.24		0.00		0.00		0.00		1.36		0.00		3.13	
1	0.00		0.00		0.00		0.00		1.12		1.83		0.00		0.43		0.00		0.00

Hs = 8.06 cm, Ns = 2.16

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
20		0.00		0.00		0.00		0.41		0.00		0.00		0.00		0.00		0.00	
19	0.00		1.19		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
18		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
17	0.00		0.00		0.00		0.00		2.36		0.00		0.00		0.00		0.00		1.54
16		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
15	0.00		0.00		0.00		0.00		0.00		1.42		0.00		0.00		0.00		1.01
14		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
13	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		1.23
12		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
11	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
10		2.38		1.30		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
9	0.00		1.49		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
8		0.00		0.00		3.14		1.03		0.00		0.00		0.00		0.00		1.55	
7	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		1.58		0.00
6		0.00		0.00		0.00		0.00		0.00		1.87		0.51		1.88		0.00	
5	0.00		1.19		0.00		1.64		0.00		0.00		2.66		2.54		0.00		0.99
4		0.00		0.00		0.00		0.00		1.23		2.49		2.08		0.00		0.00	
3	0.99		0.00		1.87		0.00		0.00		0.00		0.00		0.00		0.00		0.00
2		0.00		0.00		0.00		1.54		2.64		0.00		0.00		0.00		0.00	
1	0.00		0.00		0.00		0.00		0.00		0.00		0.00		3.05		0.00		0.00

Hs = 10.56 cm, Ns = 2.84

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
20		0.00		1.25		0.00		0.00		1.45		0.68		0.00		0.00		0.00	
19	0.87		0.00		0.00		1.03		0.00		0.00		0.00		0.00		0.77		0.00
18		0.00		0.00		2.51		1.65		1.12		2.23		0.00		0.00		0.00	
17	0.00		0.00		1.99		2.24		2.05		0.66		1.13		2.00		0.00		0.00
16		0.00		1.43		2.21		2.49		1.22		2.56		3.14		1.27		0.00	
15	0.81		0.00		0.68		1.06		1.19		2.44		0.94		0.00		1.79		0.83
14		0.00		0.00		2.03		0.87		0.00		0.00		0.78		0.00		0.00	
13	2.17		0.00		2.05		2.51		1.87		0.00		0.00		0.00		0.00		1.89
12		0.00		0.00		3.29		0.00		0.00		0.00		0.00		3.45		0.00	
11	0.00		0.00		0.00		1.74		0.00		0.00		0.00		0.00		2.32		2.85
10		1.12		0.00		0.00		0.00		0.00		2.28		2.14		0.00		0.00	
9	1.12		1.83		0.00		0.00		0.81		2.35		2.64		0.00		2.98		1.39
8		0.00		0.00		2.32		0.00		0.00		0.00		0.00		0.63		0.00	
7	0.00		0.00		0.00		0.00		0.00		0.00		0.00		1.72		1.75		0.00
6		0.00		0.00		0.00		2.23		0.47		2.71		1.74		0.00		0.00	
5	0.00		0.00		0.00		0.63		0.87		0.00		1.12		1.42		0.00		0.00
4		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
3	0.00		0.00		0.00		0.00		2.65		0.00		0.51		0.00		0.00		0.00
2		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.94		0.00	
1	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00

Hs = 11.23 cm, Ns = 3.02

Rows \ Columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
20		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.77		0.77	
19	0.00		0.00		1.32		0.00		0.00		0.00		0.00		0.94		1.12		0.00
18		0.00		0.00		0.00		0.00		0.00		0.00		0.00		2.13		0.00	
17	0.00		2.49		1.79		0.87		1.12		1.12		1.02		2.14		1.17		1.88
16		1.28		0.00		0.00		0.00		0.00		2.05		0.00		0.00		0.00	
15	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		1.41		1.25
14		0.00		0.00		0.00		0.00		0.00		2.86		2.42		1.64		2.37	
13	1.61		2.05		0.00		0.00		1.02		1.19		2.94		1.10		3.04		1.63
12		0.00		0.00		0.00		0.00		2.56		3.59		8.46		3.07		0.51	
11	0.00		0.00		0.00		0.00		0.00		0.00		26.48		6.48		1.45		1.62
10		0.00		0.00		0.00		1.62		1.88		34.04		2.23		3.39		1.12	
9	0.00		2.05		0.00		0.00		2.51		46.10		35.33		1.92		3.47		1.63
8		0.00		0.00		0.00		1.54		2.31		52.27		3.07		0.00		0.26	
7	2.88		1.87		1.19		0.00		2.13		0.00		1.38		0.00		0.00		0.00
6		0.00		0.96		0.62		1.55		0.00		2.43		0.00		0.00		0.00	
5	0.00		1.74		0.00		1.98		1.45		2.61		2.32		0.00		0.00		0.00
4		0.00		0.00		0.00		0.00		0.00		0.00		2.05		0.00		0.00	
3	0.00		0.00		0.00		0.00		1.42		0.87		0.00		0.00		0.00		0.26
2		0.00		0.00		0.00		0.51		2.44		0.00		0.00		0.00		0.00	
1	0.00		0.00		0.00		0.00		3.26		3.65		4.86		2.43		2.45		4.44

Hs = 12.07 cm, Ns = 3.24																			
Rows	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
20		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.77		0.77	
19	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		1.12		0.00
18		0.00		0.00		0.00		0.00		0.00		0.00		0.00		3.33		0.00	
17	0.00		2.49		1.79		0.87		0.00		1.93		1.02		2.14		1.17		1.92
16		1.28		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
15	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		1.41		0.00
14		0.00		0.00		0.00		0.00		0.00		0.77		3.59		0.51		1.54	
13	1.61		2.05		0.00		0.00		1.02		0.00		1.61		2.38		1.77		0.00
12		0.00		0.00		0.00		0.00		2.56		3.33		8.46		3.07		0.00	
11	0.00		0.00		0.00		0.00		0.00		0.00		24.70		4.09		0.00		0.00
10		0.00		0.00		0.00		0.00		0.00		14.09		0.00		4.87		1.79	
9	0.00		2.05		0.00		0.00		0.00		27.97		35.33		0.00		3.47		0.00
8		0.00		0.00		0.00		1.54		2.31		45.87		0.00		0.00		0.00	
7	2.88		3.11		0.00		0.00		0.00		0.00		1.38		0.00		0.00		0.00
6		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
5	0.00		0.00		0.00		0.00		1.45		2.61		2.32		0.00		0.00		0.00
4		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	
3	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00
2		0.00		0.00		0.00		0.51		1.54		0.00		0.00		0.00		0.00	
1	0.00		0.00		0.00		0.00		0.00		0.00		0.00		2.51		0.00		0.00

Overall Distance [mm]																			
	Columns																		
Rows	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
20		0.00		1.25		2.38		2.86		3.73		2.64		1.12		0.77		1.63	
19	3.04		1.87		2.68		3.87		3.30		3.65		3.54		2.68		2.84		0.00
18		0.43		2.51		2.51		3.04		3.06		4.46		2.44		3.34		2.64	
17	1.83		0.96		1.92		2.56		3.97		4.73		5.48		3.14		2.86		1.54
16		2.84		4.06		3.48		3.28		2.68		5.51		4.63		2.05		1.37	
15	2.48		4.01		3.11		4.26		3.28		2.56		3.07		1.76		3.62		1.54
14		3.45		1.88		5.22		2.05		3.04		3.73		4.33		3.90		4.65	
13	1.98		4.10		4.97		4.22		3.57		3.38		7.11		2.08		3.84		4.26
12		1.77		0.63		3.29		2.92		5.55		11.54		10.88		4.34		2.28	
11	1.22		1.26		2.48		3.93		2.88		1.85		29.06		8.69		2.61		3.67
10		3.06		1.30		3.53		3.86		4.69		36.96		5.42		2.23		3.53	
9	1.22		2.34		2.68		2.64		3.50		44.42		32.59		1.28		1.96		1.49
8		1.69		1.23		1.79		3.83		2.49		34.36		1.12		1.63		1.26	
7	2.58		1.87		1.62		2.03		2.13		1.43		1.28		2.84		1.45		1.45
6		0.00		1.39		1.13		1.87		1.65		2.20		2.08		1.37		1.88	
5	1.06		1.64		0.37		1.89		2.28		1.25		1.25		1.12		1.23		0.99
4		4.06		1.83		3.28		1.49		1.23		2.49		1.45		1.45		2.38	
3	1.43		1.65		1.87		0.00		1.26		0.87		2.23		1.37		2.61		3.49
2		2.68		1.23		2.24		1.02		0.37		0.00		1.36		0.94		3.13	
1	0.00		0.00		0.00		0.00		2.24		1.82		4.86		0.20		2.45		4.44

E

Damage

In this appendix, pictures of the resulting displacement and damage from the lab tests are shown as well as the calculated displacement tables.

E.1. Damaged Areas

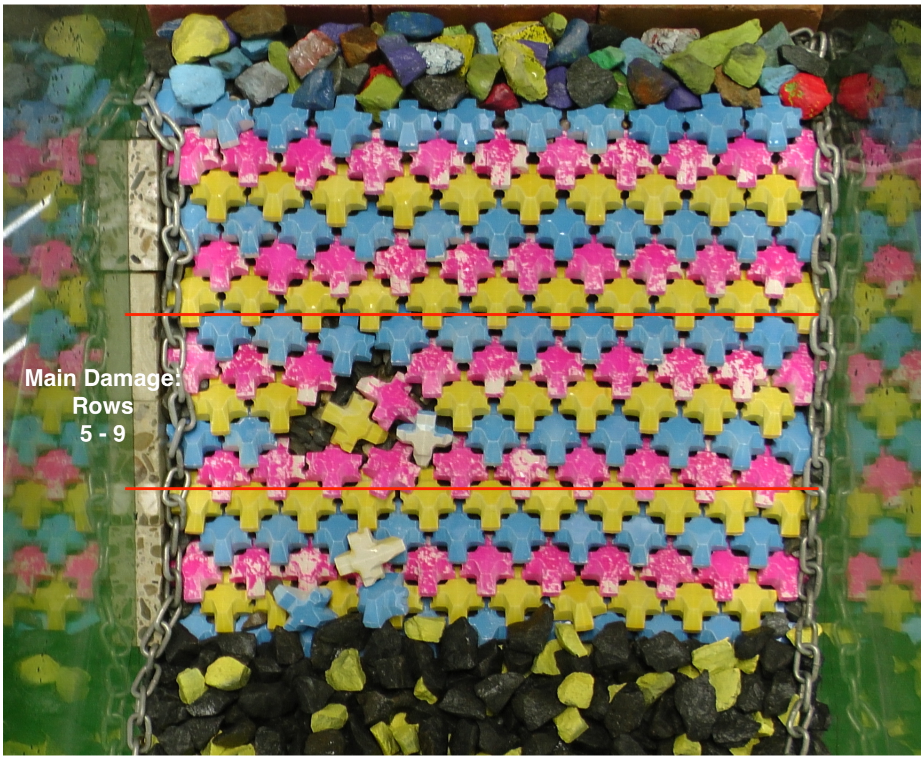


Figure E.1: Damaged area of armor layer units during tests from Series1.

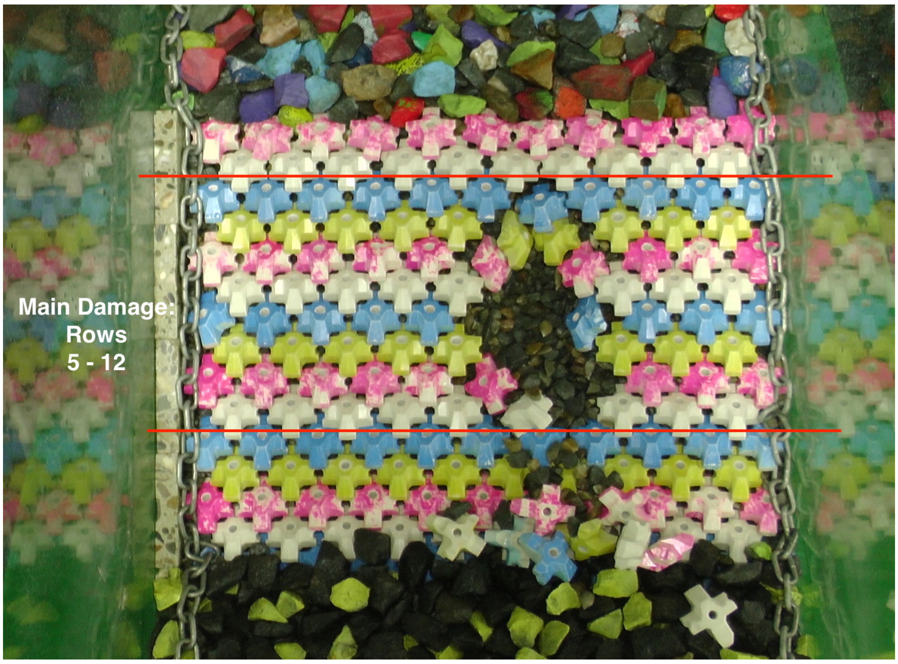


Figure E.2: Damaged area of armor layer units during tests from Series3.

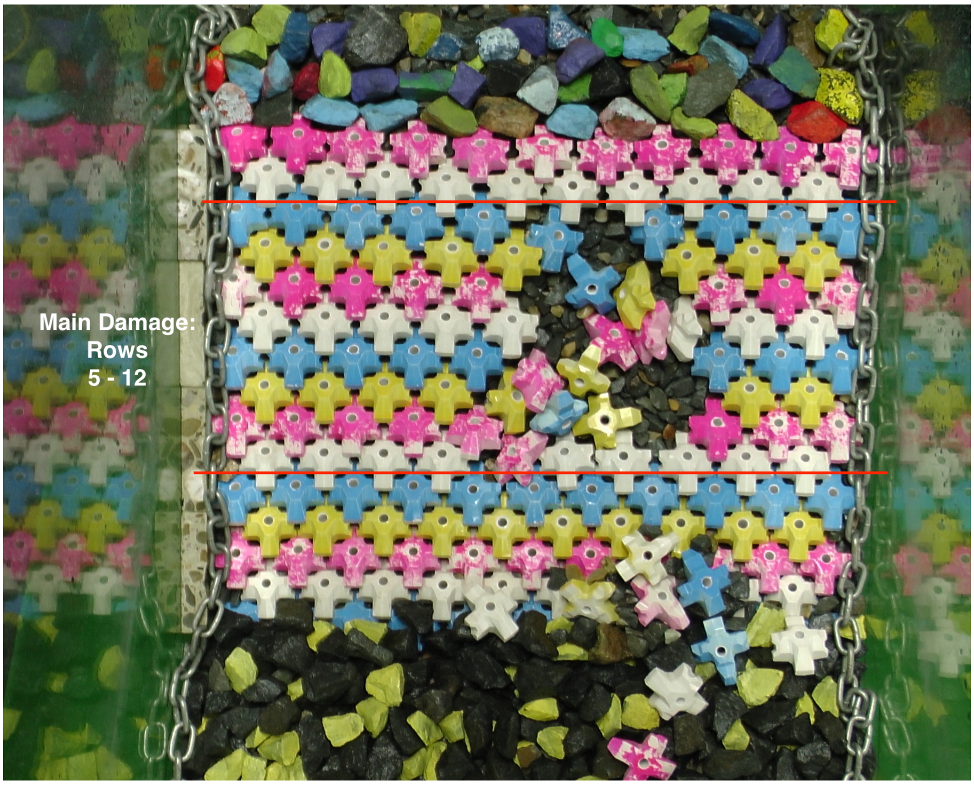


Figure E.3: Damaged area of armor layer units during tests from Series4.

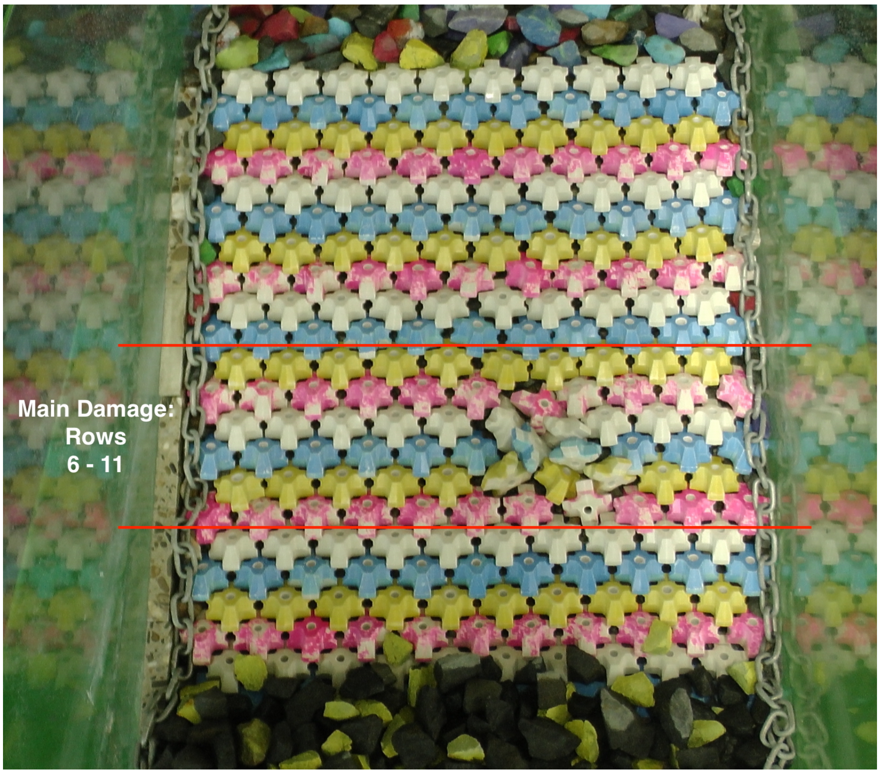


Figure E.4: Damaged area of armor layer units during tests from Series5.

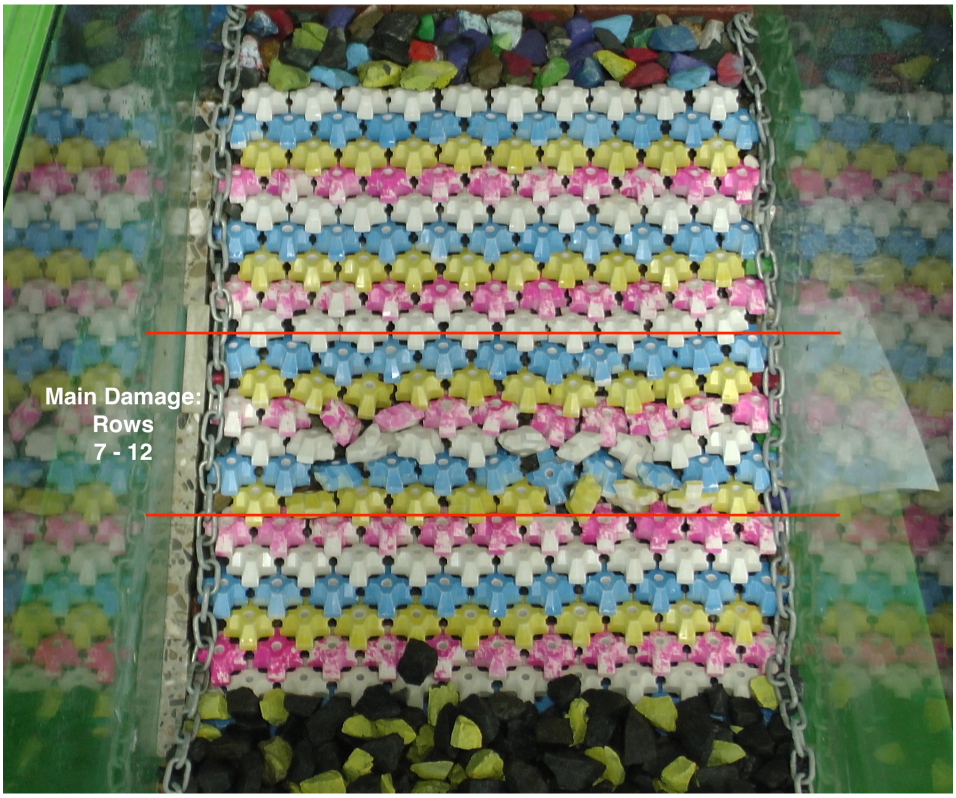


Figure E.5: Damaged area of armor layer units during tests from Series6.

E

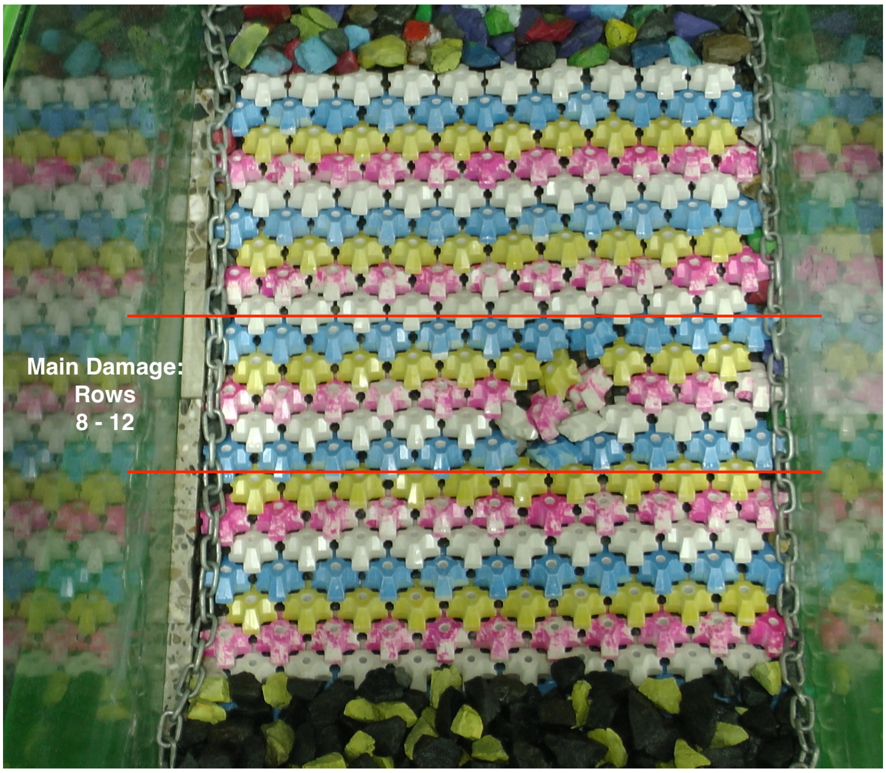


Figure E.6: Damaged area of armor layer units during tests from Series7.