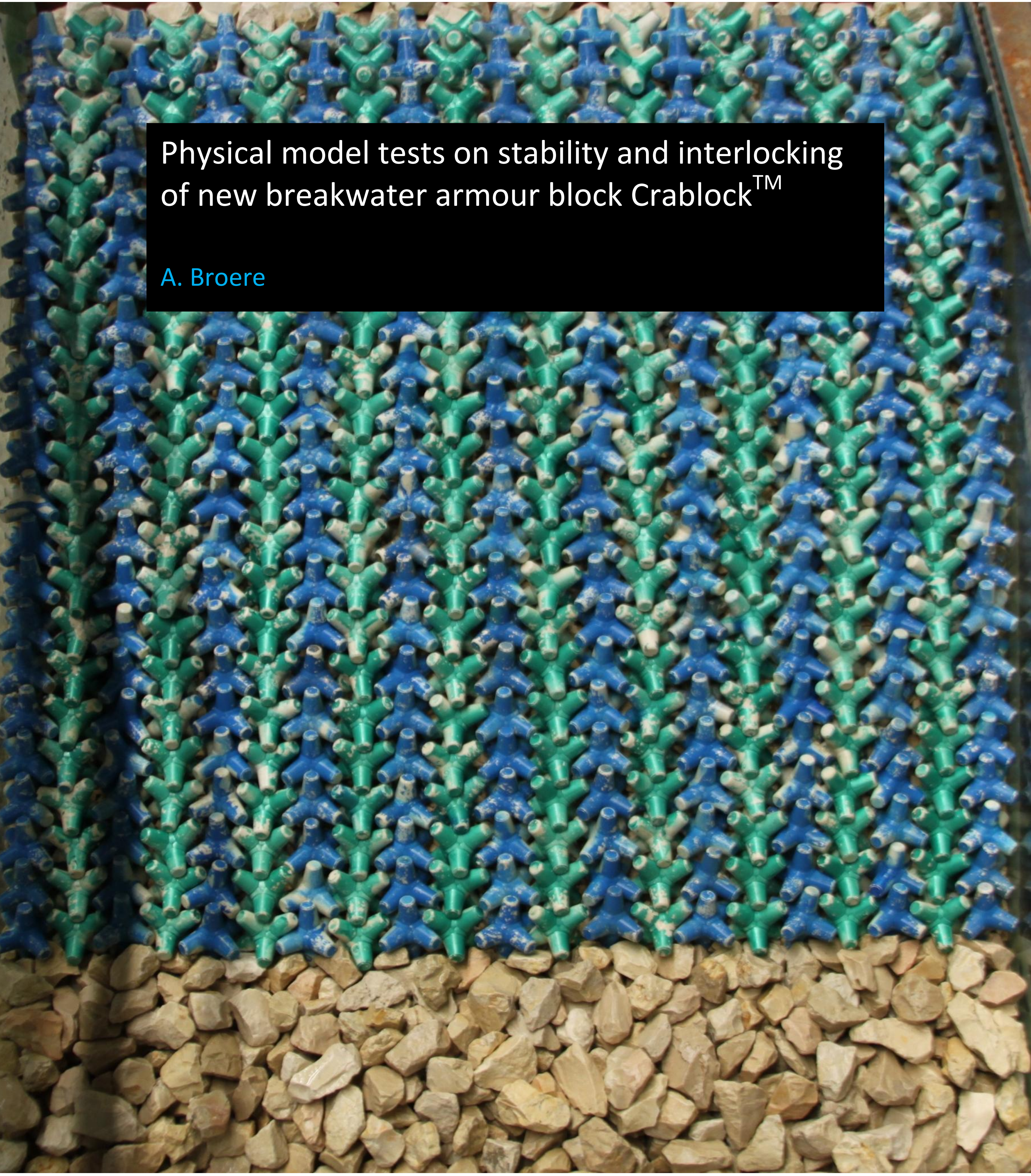

Physical model tests on stability and interlocking of new breakwater armour block Crablock^{TM}

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Challenge the future

Physical model tests on stability and interlocking of new breakwater armour block Crablock^{TM}

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A. Broere

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Summary

Rubble mound concrete armour units can protect new reclamations, beaches or breakwater structures. However, only the protection of breakwater structures is in this research considered. The design of rubble mound concrete armour layers for breakwaters can be divided in a single layer system and a double layer system. The single layer system is nowadays mostly applied because of the high interlocking, high stability of the structure, reduction of concrete use and a decrease of the construction period. There are several types of artificial units which can be placed in a single layer armour. These types all have different shapes and improvement keeps going on by trying to develop a new more effective one. At this moment the development of the new breakwater armour unit Crablock is going on. During the development of the Crablock it was already applied for the repair works of the breakwaters in the harbours of Al Fujeirah, UAE. After applying the Crablock in Al Fujeirah, the shape was optimised by adding fillets between the flukes to reduce the stress levels.

The development of guidance for the preliminary design of the Crablock is going on as well and therefore additional research is necessary. Prof. Van der Meer was asked to perform some of the extra research needed. Support for this research was found by two students of UNESCO-IHE, whereof 1 visiting student from Italy and one student of TU Delft (author). The research was divided in a theoretical study and physical model tests. The theoretical study has been focussed on a comparison of different comparable, already existing armour units. This comparison resulted in recommendations for physical model tests to come to a design guidance for the Crablock armour units (Bofantini, 2014). Dry physical placement tests were performed to verify the recommended patterns and packing densities. After finishing the dry placement tests, the final test program for the physical flume tests could be made together with the small scale model set-up (Salauddin, 2015). The small scale physical flume tests were performed with focus on wave overtopping (Salauddin, 2015) and on hydraulic stability (author). Finally, a physical model test set-up was made to determine the influence of wave attack on the interlocking properties of the units. Some pull tests were therefore conducted after wave exposure in the wave flume and in dry conditions (author).

The cross section of the physical model in the wave flume consisted of a sloping foreshore of 1:30 and an armour slope of 3:4. 10 test series were performed which differed in placement grid, placement orientation, wave steepness, packing density and crest level. Next to the 10 test series, some additional tests were conducted without structure in place to verify the wave conditions found. Each test series consisted of a number of subtests where the wave heights were increased until failure of armour slope took place. The performance of the Crablock armour layer is based on damage patterns for corresponding wave heights. Damage criteria are defined for displacement of units, individual movement and rocking. For the displacement of units, the influence of side effects by the wave flume is eliminated.

For the test series a rectangular grid with uniform placement and diamond grid with random placement were applied. Diamond grid was only applied for packing density $0.63/D_n^2$ and showed very similar results with rectangular grid. This means that the placement pattern did not influence the hydraulic stability. During the physical model tests two different wave steepnesses were tested ($S_{m-1,0}$= 0.04 and $S_{m-1,0}$= 0.02 in deep water). For wave steepness $S_{m-1,0}$= 0.02, considering long waves, damage was observed in an earlier stage so there is a certain influence from the wave steepness. The influence could nevertheless not be quantified because for wave steepness $S_{m-1,0}$= 0.04 was in most cases no damage obtained due to generator limitations. The high crest level showed less displacements than the normal crest level, only the movements observed were larger. So the larger settlements prevented part of the displacement of units. The most vulnerable area on the armour layer was located in the transition zone from the slope to the horizontal part at the crest, settlement resulted in low local packing densities. The impact of highest waves was for the normal crest more focussed on the weakest point which might also be an explanation.

When only considering displacement of units the influence of packing density is not obvious. Individual unit movement and rocking can be more related to packing density. For the lowest packing density applied ($0.63/D_n^2$) the movements were so big that large openings were created at the upper part of the armour layer. The local packing density became so loose that some units were even rolling over the under layer. Rocking of units started for low wave heights. When increasing the initial packing density, the movements became less and rocking started at a later stage.

The hydraulic stability of the Crablock armour unit can be expressed by the stability number like it is done for other artifical interlocking armour units.

$$Stability\ number = \frac{H_s}{\Delta D_n} \qquad \text{With:} \qquad \Delta = \frac{\rho_s - \rho_w}{\rho_w}$$

Based on the damage found for the criteria's movements and rocking, packing density $0.63/D_n^2$ is assumed to be not sufficient and is therefore not taken into account to determine the stability number.

A safety margin is commonly applied for armour units to prevent considerable consequences after under estimating the design wave. This margin is based on the behaviour of the armour layer with respect to individual movement and rocking, but also on the ratio between start of displacements and failure. The lowest point where displacements were observed was for all tests applied with $0.66/D_n^2$ and $0.69/D_n^2$ around stability number 4.6. The design value of the stability number was in this stage assumed as 2.8, comparable to other units. This leads to a large safety factor of 1.6. From this point of view it might be attractive to increase the design stability number, which is a decision to be made by the owners of the Crablock.

To get more insight in how the Crablock units were interlocked with each other some pull tests were performed. The pull tests consisted of unit extractions from three different levels on the slope: Location 1 is situated above SWL, Location 2 around SWL and Location 3 below SWL. To improve the reliability, multiple units have been extracted per level. The interlocking degree is defined as the ratio between the force needed to extract a single unit and the own weight. Some test series were performed in the wave flume after the test series on the hydraulic stability were finished. In this case the settlement after wave attack was included in the interlocking degree. To define the actual influence of settlement, also some dry pull tests have been performed with same placement pattern and packing density.

For Location 2 and 3 (around and below SWL) the ratio between the interlocking degrees with and without wave exposure is in the order of 2 to 3. So for that locations the settlement caused a considerable higher interlocking degree. For the highest extraction at Location 1, the difference is negligible.

It seemed that the interlocking degree was dependant on packing density but also on the extraction level on the slope. An increase in packing density led to a higher interlocking degree. This increase was higher at the location below SWL because the additional weight of the units above became important.

Finally, the performance of Crablock is compared with the units Accropode and Xbloc. It appeared that the hydraulic stability of Crablock is higher than the other two. On the other side, the packing density applied for Crablock was also higher. This is a good reason to reconsider the design stability number, which could be increased, still leading to a safe design, but with a smaller unit (less concrete).

Preface

This report is written as final fulfilment for the completion of my MSc study at the Delft University of Technology, Faculty of Civil Engineering and Geosciences, Section of Coastal Engineering. It reports on the research project I performed on the hydraulic stability and interlocking of the new armour unit Crablock. With this research I hope to have enhanced more insight on the performance of Crablock units and thereby a major step forward is achieved for further development.

The completion of my research would not be possible without the support of the following people. First of all, I like to thank prof. J.W. Van der Meer (UNESCO-IHE/TU Delft) for his dedicated supervision throughout the research. He helped me a lot during the process by sharing his knowledge and experience. My sincere thanks go to the other members of my thesis committee Ir. H.J. Verhagen (TU Delft) and Ing. C. Kuiper (TU Delft) for their helpful feedback, enthusiasm and guidance.

I want to thank Md. Salauddin (MSc student of UNESCO-IHE) for his collaboration during the physical model tests performed in the wave flume and sharing his knowledge he already gathered on this topic. Also, I would like to express my appreciations to the members of the Hydraulics Laboratory at TU Delft for their assistance and advice during the experiments. Further, I want to thank dr. B. Hofland (TU Delft) too for helping me with writing the Matlab script.

Finally, my appreciations also go to AM Marine Works and CDR International BV for sponsoring the laboratory studies at Delft University of Technology.

André Broere
July, 2015

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List of Symbols

Symbol	Definition	Unit
B	Width of the layer	[m]
D_n	Nominal diameter of unit	[m]
$E(f)$	Variance density spectrum	[m^2/H_z]
f	Frequency	[H_z]
g	Gravity	[m/s^2]
H_{m0}	Significant wave height according to spectrum	[m]
H_s	Significant wave height according to time series	[m]
H_{saD}	Assumed design wave height	[m]
$H_{s,inc}$	Incoming significant wave height	[m]
$H_{s,tot}$	Total significant wave height, $H_{s,inc}$ + $H_{s,refl}$	[m]
K_{refl}	Reflection coefficient	[-]
K_D	Hudson stability factor	[-]
M	Mass	[kg]
m_0	Zeroth-order moment of variance density spectrum E(f)	[m^2]
N	Number of waves	[-]
n	Total number of units	[-]
n_d	Number of displaced units	[-]
n_m	Number of moved units	[-]
n_r	Number of rocking units	[-]
N_{od}	Relative number of displacement of units	[-]
N_{om}	Relative number of movement of units	[-]
N_{or}	Relative number of rocking of units	[-]
P	Notional permeability	[-]
$W_{crablock}$	Weight of Crablock unit	[N]
W_{50}	50% weight of unit distribution curve	[N]
S_d	Damage level	[-]
SWL	Still water level	[-]
$S_{m-1.0}$	Spectral wave steepness	[-]
S_{op}	Wave steepness based on peak period	[-]
T_m	Mean period time series	[s]
$T_{m-1.0}$	Spectral wave period	[s]
T_p	Peak period spectrum	[s]
T_z	Mean wave period	[s]
α	Slope angle	[°]
Δ	Relative density	[-]
ρ_s	Density of unit/rock	[kg/m^3]
ρ_w	Density of water	[kg/m^3]
Ψ	Degree of saturation	[-]
ξ_z	Surf similarity parameter ($tan\alpha/\sqrt{2\pi H_s/gT_z^2}$)	[-]

1 Introduction

This section gives a brief introduction on the research subject, it provides the reader some background information about rubble mound breakwaters and the different armour units available. The contribution of this research is described with respect to other research done for the development of the single layer armour unit Crablock. The scope of this research is stated in research objectives and research questions. Finally the outline of this report is presented.

1.1 General introduction

Rubble mound concrete armour layer protections can be used for several purposes. The armour can protect new reclamations, beaches or breakwater structures. This research is focussed on the protection of breakwater structures only. Breakwaters have water at both sides and can be applied for various purposes. The most important applications are: protection against waves to prevent coastal erosion, to provide a safe shipping environment in the harbour area, guiding of currents along shore and protection against silting up of an approach channel by narrowing the cross section.

The wave energy is mainly dissipated by wave breaking and wave reflection back to the sea. Wave energy is in most cases also transmitted to the leeward side by overtopping and penetration through the structure. The composition and shape of the armour layer largely depends on the wave climate, availability of material and execution limitations.

1.2 Development of the artificial armour unit

The history of expanding harbours and larger vessels led to longer breakwaters into deeper water with inherently higher waves. To withstand severe wave attack on the breakwater, the structure has to be protected with a sufficiently stable armour layer. The limited availability of large stone sizes that a quarry can produce plus difficult placing and handling, lead to a restricted construction of breakwaters in wild wave climates. In the second half of the twentieth century a stronger interest in developing artificial units for rubble mound armour layers arose. This armour layer consists of un-reinforced concrete units which can be made in any amount and size needed. The rubble mound breakwater is generally build up with a permeable core, filter layer and armour layer.

The first artificial units were concrete cubes. Later on, various attempts have been made to improve the stability with reducing the concrete demand. This resulted in two basic armouring principles of concrete armour units. The first one is a randomly placed interlocking armour unit with its own weight as a governing stability parameter. The second one is an uniformly placed, friction based type armouring (Muttray & Reedijk, 2008).

1.3 Rubble mound breakwaters

For the armour layer a distinction is made in single layer systems and double layer systems. The behaviour of single layer systems differs from double layer systems (Van der Meer 1999). The single layers settles a little after the first wave attack, preferably within the construction period, and gets a higher packing density. Every unit makes contact with some others in the armour layer, rocking of the units is therefore limited. The stability of the single layer system is provided by the whole armour layer whereas for the double layer it is mainly provided by the individual units only. If damage starts for a high wave height the whole structure may subsequently fail in the single layer system, for just a little increase in wave height. The damage development of the double layer systems is more gradually. Because of the possible brittle failure of single layer units a safety factor is taken into account in the design guidelines.

See Appendix A for an overview of some of the rubble mound armour units with placement pattern, provided stability mechanism, development year and country (Muttray et al., 2003; DMC).

1.4 Background

In June 2007, tropical cyclone Gonu made landfall in United Arab Emirates and caused a lot of damage. Al Masaood harbour is one of the affected areas. This harbour is located near the town of Dibba, Al Fujeirah, and is connected to the Gulf of Oman. The breakwater structures of this harbour were harmed by this storm. This event made the people aware of the vulnerability of the harbour, besides the possibility of even bigger storms in the future. To keep the armour layer sufficient for future demands, the armour needed to be repaired with an armour layer which can withstand higher loads than initially. The owner of the harbour, HE Abdulla Al Masaood, decided to develop a new single layer armour unit for replacing the damaged armour layer. They gave the name Crablock to this new unit, after his shape.

1.5 Problem definition

After the cyclone Gonu, HE Abdulla Al Masaood started with the development of the Crablock. The main objectives of the founder in the development was to establish the following properties (Hendrikse and Heijboer, 2014):

- A single layer concrete unit
- Less chance on rocking and settlement on slope
- To be placed by excavator instead of a wire-crane
- Rapid and simple placement
- No divers for under water placement required
- Good stacking possibility, minimal stockpiling yard
- Easy to cast
- Stability guaranteed by weight and interlocking
- High hydraulic stability and sufficient structural strength
- Excellent porosity performance to reduce wave overtopping

In the first stages of the development, the placement pattern and packing density were examined in several dry tests in Al Masaood harbour. These tests were performed on 1:1 scale before they actually did under water attempts. The Crablock got modified during this experiments to improve the characteristics. At first, the Crablock had two short hubs with four longer and slender legs. The units could lie flat on the slope and only vertical interlocking was possible. To achieve also horizontal interlocking, the two short hubs were extended. The latest major modification is the transformation into a 3D symmetrical shape with 6 same leg lengths. See Figure 1-1 and Figure 1-2. This provides a less slender unit whereby a tighter regular placement as well as random placement is applicable. Later on, they added fillets between the flukes to reduce the stress levels (Phelp et al., 2012).

Figure 1-1: First Crablock shape with 2 short hubs [Hendrikse, 2014]

Figure 1-2: Current 3D symmetrical shape of Crablock with fillets [Hendrikse, 2014]

As owner of the harbour there was a nice opportunity to get experience in constructing the required pattern and to get an insight in how the Crablock behaves in reality. The placement of the Crablock on the breakwaters in Al Fujeirah can therefore be seen as part of the development of the armour unit, Figure 1-3. Although the 3D symmetrical shape that was used for the armour replacement of the breakwater in Al Fujeirah was not yet been applied with fillets, it gave very useful data. Due to a lack of experiments carried out and the little experience by using the Crablock in breakwaters there is not an optimal design guideline yet. At this moment, the advised design parameters are based on the comparison with other already extensively tested and successfully applied armour units. In 2009, CSIR performed roughly some first tests on the stability and placement but for optimising the design guidelines, still additional research on Crablock was needed.

Figure 1-3: Use of Crablock on the breakwater in Al Fujeirah [Hendrikse, 2014]

1.6 Approach research

AM Marine Works in cooperation with CDR International asked prof. Van der Meer to perform some extra research to come closer to a preliminary design guideline. Additional support for this was found by UNESCO-IHE and TU Delft, where the latter can provide a wave flume for physical testing.

This research is divided in a theoretical study and physical model tests. First, a visiting Italian student of UNESCO-IHE elaborated on the theoretical study (Bonfantini, 2014). Hereby a comparison was made with the extensively tested armour units Accropode and Xbloc. The study covered the placing pattern, packing density, height of the crest, slope angle, crest height, influence of wave steepness and finally she did recommendations for the dry placement tests and wave flume tests needed.

The recommended dry placement tests and wave flume tests were reconsidered by a MSc student of UNESCO-IHE (Salauddin, 2015). Salauddin (2015) first tested the suggested placement patterns by Bonfantini (2014) in a dry placement test. After finding a good practical placement method with sufficient packing density, he defined the final cross section for the flume tests. The cross section in the wave flume was constructed by Salauddin (2015) and a student of TU Delft (author).

The physical model tests on Crablock have been performed by Salauddin (2015) and the author. Two placement patterns were tested in the flume with varying packing densities and different crest levels.

When doing the flume tests, Salauddin (2015) measured the wave overtopping and the author determined the damage development of the Crablock to define the hydraulic stability. Finally, the author defined the experimental set up to determine the interlocking between the units before and after wave exposure. The interlocking before wave exposure was found by performing some dry pull tests. The influence of wave attack was determined from pull tests on the armour layer after completing the tests series on hydraulic stability. An overview of the research on Crablock can be found in Figure 1-4.

All of these activities together may lead to more insight in packing densities, placement patterns, wave overtopping and hydraulic stability. Also a comparison of the Crablock unit and other single layer armour units is made. Note: the structural strength was not determined.

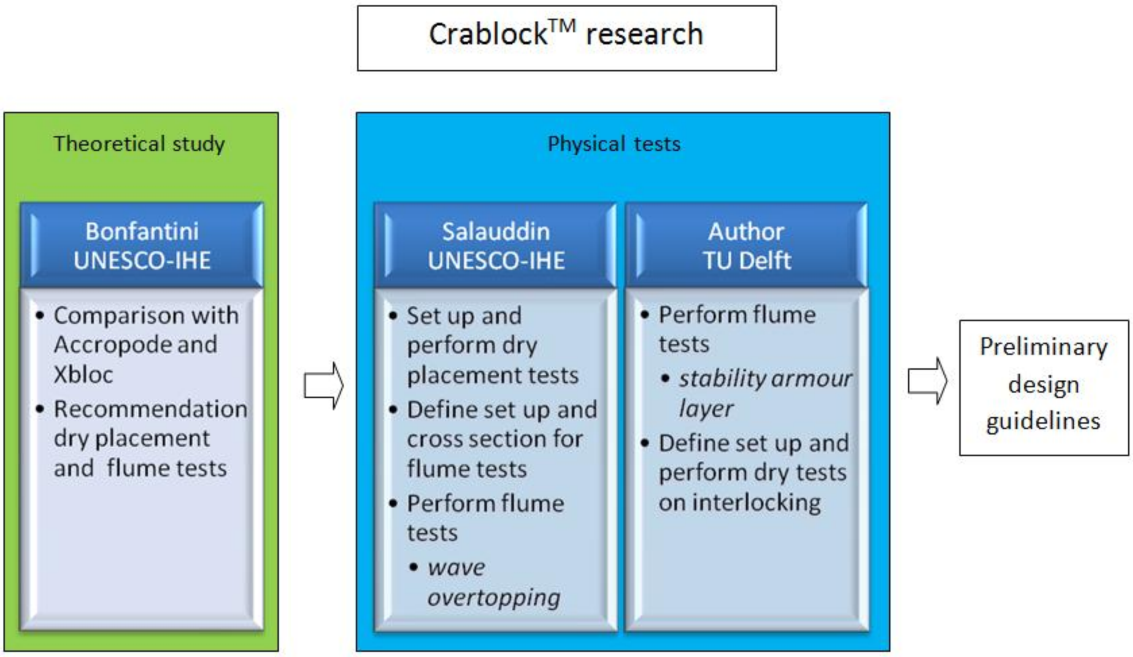


Figure 1-4: Overview research on Crablock

1.7 Research objective

The main objective of the research as a whole, is to provide more insight and to come closer to a preliminary design guidance for the single layer Crablock armour unit. Within this research, the author performed 2D physical flume tests to collect data of the hydraulic stability of the Crablock under wave attack. Additional to this, pull tests were performed to analyse the interlocking degree for the Crablock units in comparison to different placement densities and techniques.

The purpose of this part of the research is to accomplish the following sub-objectives:

- Study the influence of placement pattern and possibly other parameters on the hydraulic stability of the Crablock
- Examine the relation between wave steepness and hydraulic stability of the Crablock
- Determine the interlocking degree of the different placement patterns
- Assess the performance of the Crablock in comparison with other single layer armour units

In order to achieve the sub-objectives from above the following research questions were considered:

- How does the placement pattern influence the hydraulic stability of the Crablock?
- How does the wave steepness influence the stability?
- What is the stability number of the Crablock?
- Which placement pattern has best interlocking properties?
- How does the interlocking degree influence the hydraulic stability?
- How does the Crablock perform in comparison with other single layer armour units?

1.8 Outline of the report

Chapter 2 - Theoretical background
In this section the theoretical background is given for the design of rubble mound breakwater armour layers. The failure mechanisms and damage definitions are presented which were used for this research and the stability number is introduced.

Chapter 3 - Research methodology
The physical model set-ups and test programs of the flume tests and pull tests were elaborated in this chapter. The small scale flume tests were performed to determine the hydraulic stability of the Crablock unit. The pull tests were executed to define the interlocking properties.

Chapter 4 - Results
This chapter describes the method used to evaluate the wave conditions found during the flume tests. Also the Matlab script applied to determine the movement of individual units after wave exposure is presented.

Chapter 5 - Analysis on stability
The visual observations done during the physical model tests are presented here to give the reader more insight in the actual behaviour of the Crablock armour layer.

Chapter 6 - Analysis on stability
This chapter is dedicated to the actual hydraulic stability of the Crablock. The damage pattern is determined for different criteria and the point of failure is defined. The chapter concludes the analysis with a recommended design value for the stability number.

Chapter 7 - Analysis on interlocking degree
The interlocking properties expressed in an interlocking degree is presented in this chapter. Pull tests were performed in the wave flume after exposure of waves and in dry conditions without influence of waves.

Chapter 8 - Comparison with other single layer armour units
The results found for the physical model tests on Crablock are in this chapter compared with the data obtained from the earlier tested units Accropode and Xbloc.

Chapter 9 - Conclusions and recommendations
Here the research questions are answered. The formulated conclusions and recommendations are based on the results of this research.

2 Theoretical background

In chapter 2 the theoretical background is elaborated which is needed for the research project. In paragraph 2.1 the previous studies performed on single layer armour units are described and which are used as reference. The conventional design of rubble mound breakwater armour layers is written in paragraph 2.2. The definition of failure and different damage criteria are presented in paragraph 2.3 and 2.4, which were used for this research. Finally, the stability number is derived in paragraph 2.5.

2.1 Previous studies

The first interlocking armour unit Tetrapod was introduced in 1950, but from the 1980's extensive research has been done on several types of rubble mound breakwater armour units. A distinction can be made in single layer and double layer as written in chapter 1. Since Crablock belongs to single layer armour systems, no further special attention is paid to the double layer systems. Previous studies on Accropode and Xbloc are used as reference for the research on the stability of Crablock.

Since the introduction of the Crablock in 2007, very limited research has been done on the performance. The development of Crablock consisted at first instance on small scale optimising the shape of the unit. When the shape was supposed to be sufficient, it was used for the repairs of the breakwaters in Al Masaood Harbour. After the repairs, CSIR (2009) started with some first physical 2D model tests to check the hydraulic stability of Crablock. They performed the tests with scale 1:60 and applied a slope of 1:1.5. Both regular and random placement grids were tested. The tests showed some hopeful results and they concluded that the Crablock unit was worth further development and research.

2.2 Rubble mound breakwater design

The mound breakwaters are the most applied type of breakwaters and is generally a mound of stones. However, a homogenous structure is not desirable. Only applying large stones to resist the wave forces makes the structure very permeable and may therefore not be sufficient for the dissipation of waves. There is also potential sediment transport through the structure. Therefore the design is based on the principle of a multi-layer system where small stones or quarry run is used as core material that is covered by sufficient large stones to form the armour layer. To prevent fine material from washing out through the voids, sometimes different under layers needs to be applied, Figure 2-1. For the lower support of the armour layer mostly a toe berm is applied, which prevents from sliding down and also consist of stones.

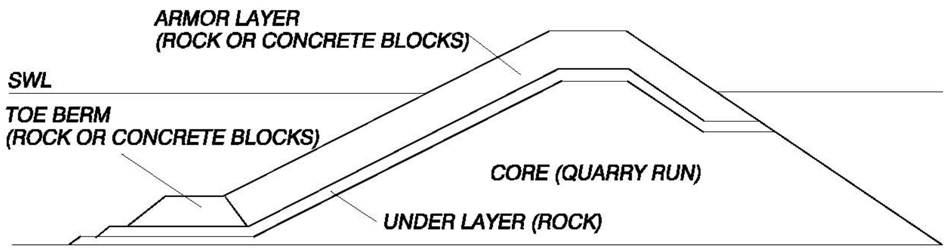


Figure 2-1: Conventional multi-layer rubble mound breakwater [CEM, 2006]

2.3 Failure mechanisms

For many people, the word 'failure' implies a total or partial collapse of a structure, but this definition is limited and not accurate when discussing design and performance of coastal structures (CEM, 2006). In the context of design reliability, it is preferable to define failure as:

Failure: Damage that results in structure performance and functionality below the minimum anticipated by design.

When the structure still serves its original purpose at or above the minimum expected level, partial collapse of the structure be classified as 'damage'. For example, subsidence of a breakwater protecting a harbour would be considered as failure if it resulted in wave heights within the harbour that exceed operational criteria. Conversely, partial collapse of a rubble-mound jetty head might be classified as damage if resulting impacts to navigation and dredging requirements are minimal or within acceptable limits (CEM 2006).

Coastal project elements fail for one or more of the following reasons (CEM 2006):

- Design failure occurs when either the structure as a whole, including its foundation, or individual structure components cannot withstand load conditions within the design criteria. Design failure also occurs when the structure does not perform as anticipated.
- Load exceedance failure occurs because anticipated design load conditions were exceeded.
- Construction failure arises due to incorrect or bad construction or construction materials.
- Deterioration failure is the result of structure deterioration and lack of project maintenance.

The stability of a rubble mound breakwater structure is an interaction between the hydraulic loads, the structural strength and geotechnical capacity. When this interactions are in unbalance the structure can fail on multiple mechanisms. In the design process all possible failure mechanisms, see Figure 2-2, must be identified and evaluated in order to obtain a balanced design.

In this research only the erosion or breakage of the armour layer have been taken into account. The overtopping was investigated by Salauddin (2015). The other failure mechanisms were prevented from happening by for instance over dimensioning the toe and applying a fixed crest wall. The inner slope was not present in the model set up so erosion of the inner slope was not an issue. Furthermore, settling of the subsoil was not relevant in the wave flume. It was tried to achieve the settlement of the core already in advance by pushing and by filling and emptying the flume a few times.

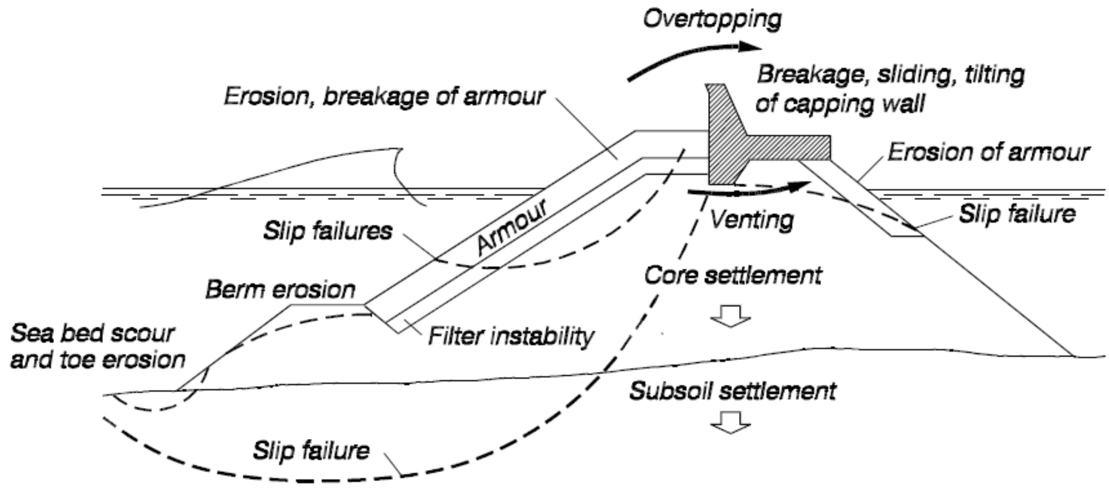


Figure 2-2: Failure modes for a rubble mound breakwater [CEM, 2006]

2.4 Damage definition

To determine the performance by means of the hydraulic stability, research on the behaviour of the armour layer has been done. The stability is directly related to the starting point of damage and the point of failure. To define damage for a rubble mound armour several methods are used.

The most obvious method to define damage is based on the extraction of units from the armour layer. The number of units displaced from the structure can be expressed as a relative strip displacement. The relative strip displacement N_{od}, is in equation (2.1) defined as the number of units displaced within a strip of one D_n width.

$$N_{od} = \frac{n_d\ (number\ of\ displaced\ units)}{\frac{B\ (width\ of\ breakwater\ section\ considered)}{D_n\ (nomial\ diameter)}} \tag{2.1}$$

Next to displacements of units, settlement of the units may also lead to damage of the armour layer. When the movements become too big, the interlocking function between the units can be lost. A damage criteria based on movements is therefore introduced in the form of a relative settlement method. This method gives insight in the settlements within the armour layer. A threshold level of movement needs to be defined to quantify the exceeding number of units N_{om} and is presented in equation (2.2). This number of units is also related to the width of the structure and the nominal diameter.

$$N_{om} = \frac{n_m(number\ of\ moved\ units\ exceeding\ threshold\ level)}{\frac{B\ (width\ of\ breakwater\ section\ considered)}{D_n\ (nomial\ diameter)}} \tag{2.2}$$

Although the structural strength of the units cannot be determined from the physical model test, repeated movements of the units was visually observed and counted. This typical rotational movements are called "rocking". In reality, rocking can harm the individual units and may lead to damage of the armour layer. Therefore also a damage criteria is presented for rocking of Crablock units in equation (2.3).

$$N_{or} = \frac{n_r(number\ of\ rocking\ units)}{\frac{B\ (width\ of\ breakwater\ section\ considered)}{D_n\ (nomial\ diameter)}} \tag{2.3}$$

2.5 Stability

The performance of the structure can be empirically determined by defining the stability according to equation (2.4), described below. The stability is a function between the forcing of the waves and the strength of the structure following from the geometry.

$$Stability = \frac{Load}{Strength} = f(waves, geometry) \tag{2.4}$$

The stability of a breakwater armour layer is provided by an interaction between gravity, interlocking and bottom friction with the under layer. The contribution of these three mechanisms depends on the shape of the unit, the placement method and packing density. The slope angle plays an important role in which interaction is governing. Burcharth 1993, showed in his research on Dolos the interactions between the mechanisms belonging to a certain slope angle.

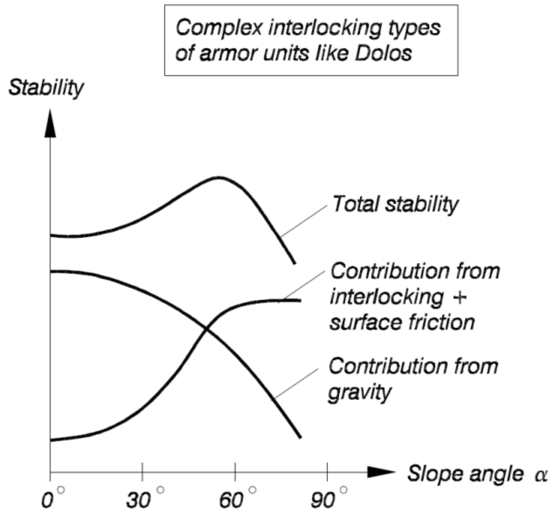


Figure 2-3: Contribution stability mechanisms in relation to slope angle [Burcharth, 1993]

Single layer armour units on breakwaters are commonly constructed in a slope between 1:1.5 and 3:4, which is 33.7 to 36.9 degrees. According to Figure 2-3, this means a major contribution of gravity and an increasing influence of interlocking and surface friction. Note that Figure 2-3 is schematical and not based on measurements. Increasing the slope angle for a better total stability of the armour layer will negatively affect other elements of the structure.

Influence permeability

The permeability of the structure is related to the under layer and the core. The under layer provides the foundation for the armour layer and it functions as filter to prevent the core material of being eroded. A permeable slope allows the waves to penetrate more into the structure and reduce the flow velocities along the slope surface. The internal water pressures also reduces with an increase of the permeability. Figure 2-4 illustrates this principle.

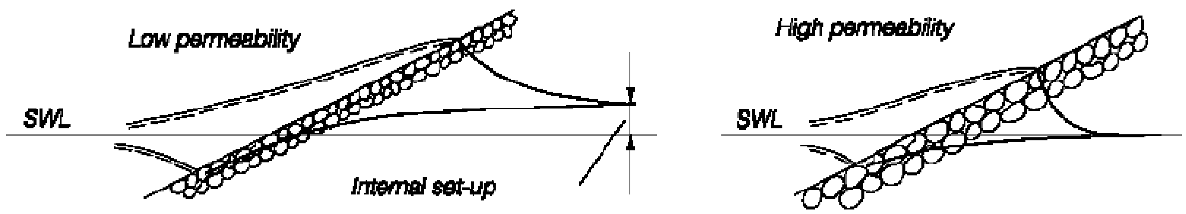


Figure 2-4: Influence permeability on flow velocity and internal set up [CEM, 2006]

The impact of attacking waves on a breakwater is dissipated when intruding the rubble mound material. A more permeable core can dissipate more energy by creating turbulent flows and will give less wave reflection. The attack on the armour is therefore also smaller compared with a less permeable core. In general a higher permeability of the under layer and core allows a lighter armour layer.

Stability formula of Hudson

This formula was proposed after many experiments by the Waterways Experiment Station in Vicksburg Mississippi. Hudson found in these experiments criteria for the design and construction of rubble mound breakwaters and came up with the following equation (2.5) (Hudson, 1959).

$$Hudson\ formula: W_{50} = \frac{\rho_s g {H_s}^3}{K_D \Delta^3 cot\alpha} \tag{2.5}$$

This formula is rewritten by Van der Meer to make it suitable for present use with random waves, equation (2.6).

$$Rewritten: \frac{H_s}{\Delta D_n} = (K_D cot\alpha)^{1/3} \tag{2.6}$$

Where:
D_n = Nominal diameter unit [m]
g= Gravity [m/s^2]
H_s = Significant design wave height [m]
K_D= Stability factor [-]
W_{50} = 50% value of weight distribution curve [N]
α = Slope angle [^{o}]
Δ = Relative density armour unit [-]
ρ_s = Density of armour unit [-]

The recommended values for stability factor K_D differs per types of armour units and per circumstance.

Stability formula Van der Meer
Although the formula of Hudson is widely used, there are some important parameters missing in the equation. Van der Meer (1987) extended this stability formula for rock slopes by including wave period, storm duration and the permeability of the core. Additionally a damage criteria was inserted which allows for a certain damage while stability factor K_D considers start of damage (5%). Finally he came up with a formula for plunging wave conditions and a formula for surging waves, see equation (2.7) and (2.8).

Plunging waves:

$$\frac{H_s}{\Delta D_n} = 6.2P^{0.18}\left(\frac{S_d}{\sqrt{N}}\right)^{0.2} * 1/\sqrt{\xi_z} \tag{2.7}$$

Surging waves:

$$\frac{H_s}{\Delta D_n} = 1.0P^{-0.13}\left(\frac{S_d}{\sqrt{N}}\right)^{0.2} * \sqrt{cot\alpha} * \xi_z^p \tag{2.8}$$

Where:
D_n = Nominal diameter unit [m]
H_s = Significant design wave height [m]
N = Number of waves [-]
P = Notional permeability [-]
S_d= Damage level [-]
T_z= Average wave period [s]
Δ = Relative density armour unit [-]
ξ_z = Surf similarity parameter ($tan\alpha/\sqrt{2\pi H_s/gT_z^2}$) [-]

Stability number

The left hand side of the stability formulas of Hudson (2.6) and Van der Meer (2.7)(2.8) is commonly used to indicate the stability of concrete armour units. This part represents the stability number and is given in equation (2.9).

$$Stability\ number = \frac{H_s}{\Delta D_n} \tag{2.9}$$

The influencing parameters introduced by Van der Meer (1987) are based on rock slopes so the parameters that might influence the stability number needs to be verified for each type of armour unit. For single layer armour units applied on breakwaters, it appeared that the armour slope and permeability are more or less fixed. These parameters are therefore not taken into account in this research on Crablock armour units. The influence of the number of waves, damage level and wave period is examined in the physical model tests.

3 Research methodology

This chapter describes the methods used to determine the hydraulic stability and interlocking properties. In paragraph 3.1 the set-up of the 2D physical model for the wave flume is described. In paragraph 3.2 the test program is elaborated for the hydraulic stability. The model set-up for the pull test is illustrated in paragraph 3.3. The tests performed for determining the interlocking degree can be found in paragraph 3.4.

3.1 Physical model set-up for hydraulic stability

3.1.1 Wave flume

The laboratory tests were carried out in a wave flume located at Delft University of Technology. The flume has a length of approximately 45m and a width of 0.80m. The wave generator is capable of generating regular and irregular waves. For these tests the JONSWAP-spectrum was used. The generator is equipped with an absorption system which eliminates the reflected waves from structures built. At the end of the flume the waves were absorbed by a rough sloping revetment to prevent wave reflection when no structure is constructed.

3.1.2 Scaling

The physical model tests performed on hydraulic stability were not based on a prototype model that needed to be checked before it could be constructed in reality. The parameters applied in these tests were therefore not scaled according to scaling laws to represent real prototype situations. The main objective of these small scale model tests was to obtain the performance by means of hydraulic stability. The dimensions of the breakwater structure applied in the small scale tests were based on the Crablock model units available.

3.1.3 Design wave height

The design of the cross section largely depends on the significant design wave height considered for the testing. The significant design wave height is elaborated from the design stability number where the safety factor already is included. The safety factor can be rather high since the physical model tests on Accropode showed failure short after initial damage (Van der Meer, 1999). The design value of the stability number was at first instance assumed as 2.8, comparable with Core-loc, Xbloc and Accropode II (Van der Meer, 1999: DMC, 2003: CLI,2012). This stability number has been used as starting point for test set-up.

$$stability\ number = \frac{H_s}{\Delta D_n} = 2.8 \tag{3.1}$$

Based on the material properties available for the physical model tests, the following calculation can be made to determine the design value of the significant wave height;

$$M = 0.0637kg$$
$$\rho_s = 2364\ kg/m^3$$
$$\Delta = \frac{\rho_s - \rho_w}{\rho_w} = \frac{2364 - 1000}{1000} = 1.364$$
$$D_n = \sqrt[3]{\frac{M}{\rho_s}} = \sqrt[3]{\frac{0.0637}{2364}} = 0.0299m$$
$$H_{saD} = N_s * \Delta * D_n = 2.8 * 1.364 * 0.0299 = 0.114m$$

The assumed significant design wave height H_{saD} was as calculated 0.114m and was needed for the set-up of the experiments. Safety factors are included in here, so it was not expected that failure would occur with a wave height equal to the assumed design wave.

3.1.4 Placement pattern

The placement pattern is an important parameter for the stability, it influences the packing density and interlocking properties. Bonfantini 2014, investigated possible placement patterns based on theoretical comparison with Accropode and Xbloc. For the placement pattern two different grids were recommended; the rectangular placement grid and the diamond placement grid, Figure 3-1 and Figure 3-2.

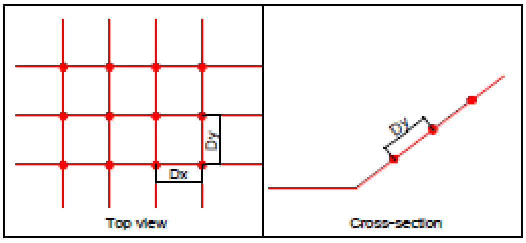


Figure 3-1: Rectangular placement grid [Bonfantini, 2014]

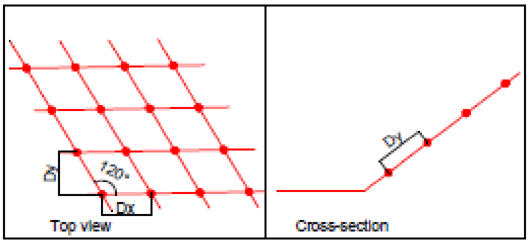


Figure 3-2: Diamond placement grid [Bonfantini, 2014]

Within these placement grids also a distinction was made between an uniform and random orientation of the units. In the uniform placement is the orientation of the units on the slope predefined, while in the random placement the units on the slope are placed in an arbitrary orientation, although they lie on a predefined grid.

The recommended placement methods by Bonfantini, 2014 were verified by Salauddin, 2015 by performing dry placement tests. After the dry placement tests, Salauddin (2015) concluded that the diamond shape grid with a random unit orientation and the rectangular grid with uniform orientation appears to have the best characteristics. These placement methods were therefore used in the wave flume tests. Twenty-two horizontal rows were applied for all flume tests, whereof two rows were located on the horizontal part of the crest.

3.1.5 Cross section

The small scale model consisted of a single layer Crablock armour, under layer, permeable core, stone protection at the toe and a crest wall (Salauddin, 2015). The armour layer had a fixed slope of 3 [vertical] to 4 [horizontal], which is a commonly used slope for single layer armour units.

Sufficient water depth in front of the generator was needed to generate waves. When the waves approaching the breakwater structure, the water depth was reduced by applying a sloping foreshore of 1:30. This reduction was needed to provide the desired water depth in front of the structure and to resemble a sea bathymetry. The length of the sloping foreshore is 10.00m, thus the height of the artificial bottom was 0.33m. To provide a possibility for adequate measuring of the wave heights in front of the breakwater, a 2.00m long horizontal foreshore was added. To prevent the landward slope from erosion by overtopping, the slope was replaced by a vertical wall with holes and a wire mesh so the water could flow through without eroding the core material. The overtopping waves carried water to the other side of the breakwater and to keep the water level equal at both sides of the structure, an open pipe connection at the underside was applied see Figure 3-3 and Figure 3-4.

The crest freeboard has been determined by making a comparison with other single layer unit tests. A crest height of approximately 1.2x the assumed design wave height was chosen to allow for some overtopping (Salauddin, 2015). To investigate the influence of the crest height on hydraulic stability, a crest height of 1.6x the assumed design wave height was also tested. The crest width was set to 3.5 times the nominal diameter of the Crablock model unit. Furthermore, a fixed crest wall was applied to prevent potential crest failure to influence the armour layer.

Finally, after all physical model tests have been performed on the hydraulic stability, the structure was removed to verify the measured wave heights found during the test series with structure. For these test series only the foreshore was maintained, see Figure 3-5.

3.1.6 Material composition

The scale models of the Crablock units were leading in the configuration of the whole structure. The weight of an individual unit was 0.0635kg, had a height of 0.056m and a corresponding nominal diameter of 0.0299m. The physical tests were carried out with fresh water and the density of the units was determined at 2365kg/m^3. The height of the armour layer was chosen as 0.056m, equal to the unit height. The ratio between the height of the unit and the nominal diameter is 1.873.

Based on Salauddin 2015, the under layer of the Crablock tests for the diamond shape pattern was chosen as $W_{crablock}$/10 of the armour layer weight. The weight of the under layer was therefore set as 0.00635kg. By taking a factor 3 in the grading, a gradation of 0.003-0.009kg was needed. This resembles a stone size of 11-16mm. For the rectangular shape pattern a smaller grading was needed due to placing problems (Salauddin, 2015). Therefore 7-11mm was taken.

The stone weight in the permeable core of the breakwater should according to Salauddin, 2015 have a ratio of $W_{crablock}$/50. Therefore a mass of 0.00128kg was needed but when taking the corresponding grading, some stones will become so small that the risk of a laminar flow regime is likely and scale effects may occur. To prevent problems with the permeability of the core, a bigger stone size than 6mm was applied. The core was comprised with a stone grading of 7-11mm (Salauddin, 2015).

The toe was over dimensioned to prevent potential failure influencing the stability of the armour layer (Salauddin, 2015). A stone grading of 25-40mm was therefore used. See Table 3-1 for an overview.

Table 3-1: Overview materials

Element	Weight [g]	Stone size [mm]	Thickness [mm]	Density [kg/m^3]
Armour layer	63.5	29.9	56	2364
Under layer	3-9 / 1-4	11-16 / 7-11	28	2650
Toe	40-160	25-40	42	2650
Core	-	7-11	-	2650

3.1.7 Water depth

Bruce et al 2009 considered a water depth of in front of the structure of 2.5 to 3.0 times the design wave. For the small scale tests on the Xbloc by DMC 2003, a water depth of 0.35m and 0.40m was used. The Accropode small scale test (Delft Hydraulics, 1987) recommended a water depth in front of the structure between 2 to 3 times the design wave and applied a water depth of 0.40m. The small scale test of the Crablock unit was performed with a water depth of 0.35m, which is approximately 3 times the design wave height (Salauddin, 2015). For the cross sections and water depth used see Figure 3-3, Figure 3-4 and Figure 3-5.

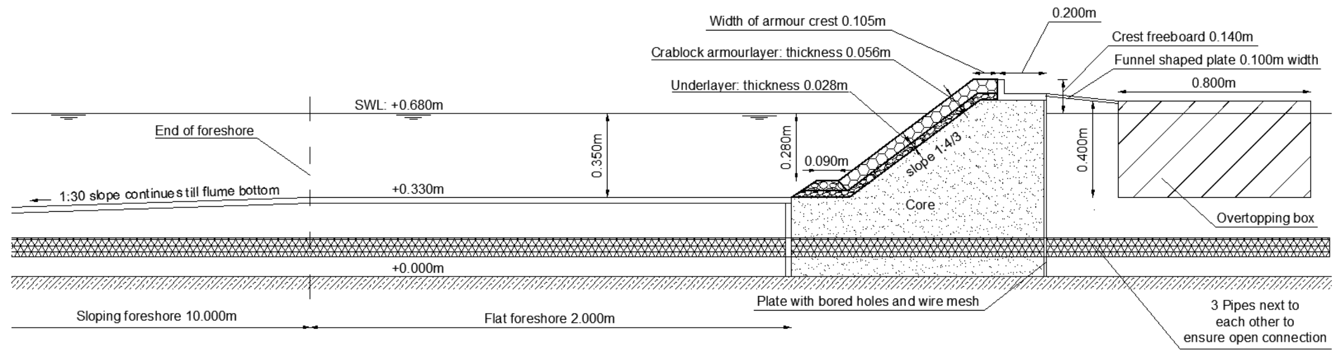


Figure 3-3: Cross section physical model test crest height 1.2H$_{saD}$; test 1-8

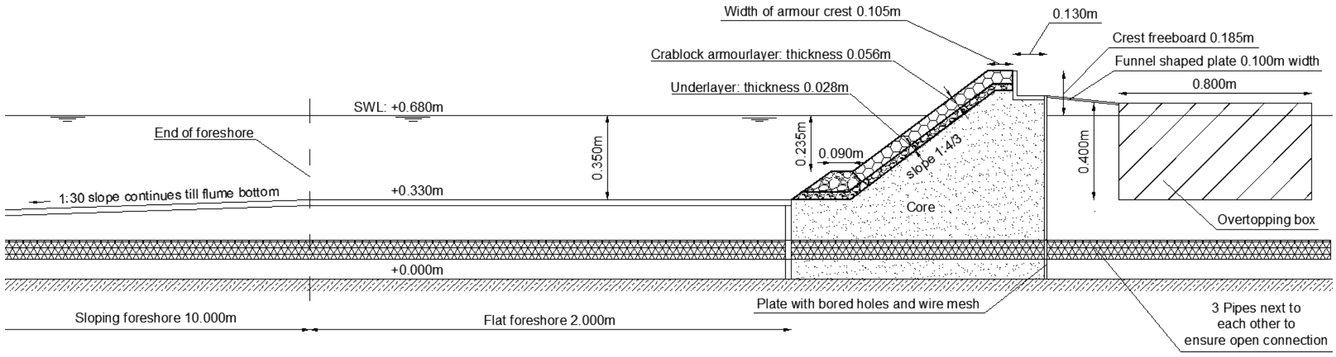


Figure 3-4: Cross section physical model test crest height 1.6H$_{saD}$; test 9-10

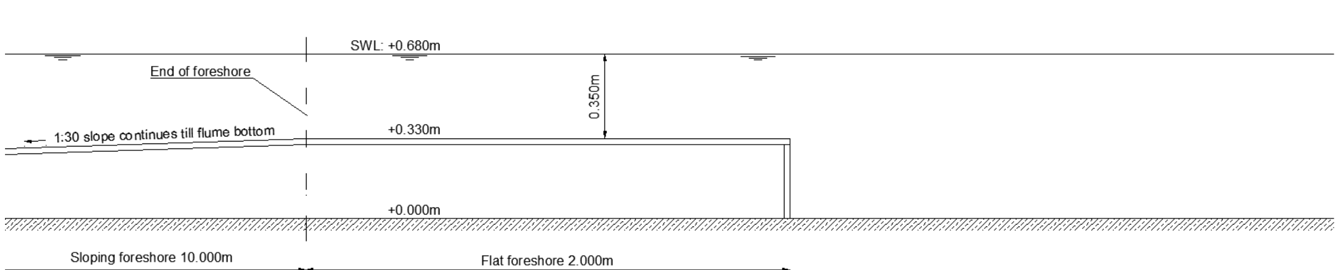


Figure 3-5: Cross section physical model test without structure; test 13-14

3.1.8 Equipment

The physical model tests were performed with irregular waves so it was important to determine the actual wave spectra the armour layer experienced. Therefore the wave spectra needed to be measured at 2 locations in the flume. The first one was located just after the wave generator in deep water to verify the incident wave spectra. After the waves passing the sloping foreshore of 1:30 the waves got modified. To define the actual wave spectra in front of the structure the waves also needed to be measured at this location. According to Mansard and Funke, 1980, a least squares method was used to determine the incoming wave spectra after correcting for the reflected spectra. The 3-point method is supposed to be most accurate (Mansard and Funke, 1980). For both locations 3 wave gauges were used. The horizontal foreshore of 2.000m in front of the structure was included to provide an equal water depth for the 3 wave gauges. The closest wave gauge to the structure on the fore shore is located 1.400m from the armour layer to avoid influence of the structure on the wave heights (Klopman & Van der Meer, 1999). The distance between the fourth and fifth gauge was kept at 0.300m and the distance between the fifth and sixth was kept at 0.400m, see Figure 3-7. The wave gauges were calibrated every test series. Moreover, a wave gauge at the crest wall was used to count the number of overtopping waves. The water that was carried by the overtopping waves was caught in a box behind the structure to determine the volume. Due to the large expected overtopping volume only 0.100m of the total crest width was used to determine the overtopping. The water volume in the overtopping box was defined by measuring the water level differences. In total, 7 wave gauges were used for the model test and 1 water level indicator, see Figure 3-6. Furthermore, a digital photo camera was used to record the mutations of the armour under wave attack. The digital photo camera was located at a fixed location with an angle of 90 degrees on the armour slope. This fixed position made it possible to compare the photos for analysing the actual settlement and damage development by means of position change of the units. Additional, a video camera recorded the wave attack.

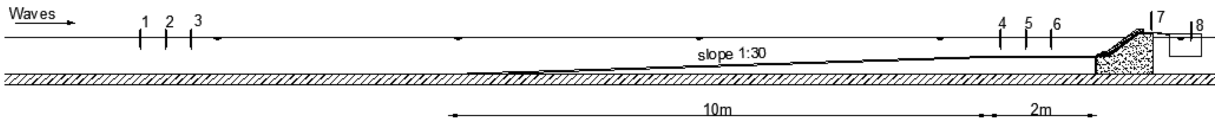


Figure 3-6: Locations of measurement equipment

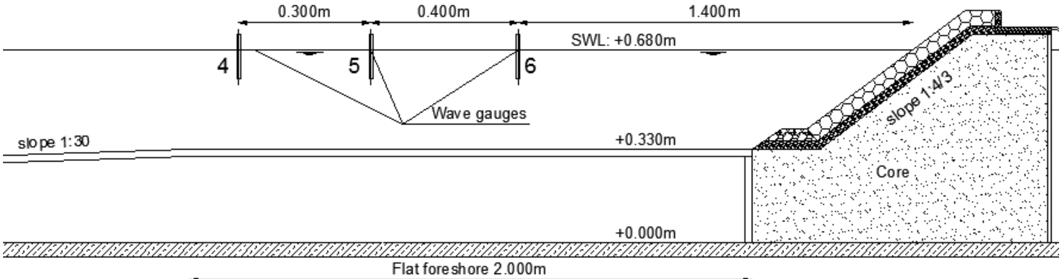


Figure 3-7: Detail of wave gauges in front of structure

3.1.9 Settlements

Initial settlement occurred after exposure to a mild wave climate, this were the first subtests of the test series with low wave heights. Mutations of the armour layer are expected around the still water level because the wave attacks were most severe at that location. The packing density would increase subsequently around the SWL and decrease in the upper part of the armour layer. The settlement should play an important role in the damage development and need to be determined accurately. In order to determine the settlement, photographs from a fixed position needed to be taken before and after each subtest. To provide good photographs for the analysis, the water level in front of the structure was lowered till below the toe. Matlab was used to analyse the photographs on individual unit movements.

3.1.10 Structural strength

The structural strength is not extensively taken into account in this research. The scaled Crablock units does not represent the structural strength like it should have in reality. The flume test was therefore carried out with only counting the number of rocking units.

3.2 Test program for hydraulic stability

The 2D physical model tests were performed in a wave flume to determine the hydraulic stability of the Crablock. In this physical model tests the placement, packing density, wave steepness and crest level was varied.

To resemble the wave conditions in coastal areas, the wave spectrum of JONSWAP was used. In front of the breakwater shallow water conditions occur and there is wave to structure interaction. The spectral period based on the first negative moment of the energy spectrum ($T_{m-1.0}$) is therefore a better descriptor than the peak period (T_p) of the spectrum (Verhagen et al. 2009). This period gives more weight to the longer periods in the spectrum. The peak period, T_p, is in general about 1.1 times $T_{m-1,0}$. Thus the wave steepness $S_{m-1.0}$ is about 1.21 times bigger than wave steepness S_{op}, which is based on T_p.

The wave steepnesses $S_{m-1.0}$ of 0.02 and 0.04 at deep water were used to cover most of the appearing ranges. For higher wave steepnesses, breaking waves became dominant in the flume which influenced the wave spectrum by introducing a lot of non-linear effects. Higher steepnesses were therefore not used in these physical model tests.

All tests started with low wave heights to allow initial settling of the armour layer, the bedding-in test. During the tests the wave height was increased to cause possible damage and failure. The wave height increase happened in separate steps, therefore several subtests were introduced for each test. The wave heights increased each subtest with 0.02m (Salauddin, 2015). See Table 3-2 for the test program. Together with the increase of wave height, the wave period needed also to be enlarged for keeping the wave steepness constant, Table 3-3. The determination of the corresponding wave periods was done by applying the following formula (3.2):

$$T_{m-1.0} = \sqrt{\frac{H_{m0}}{S_{m-1.0}} * \frac{2\pi}{g}} \tag{3.2}$$

At first instance 1000 waves for each subtest were simulated. When no damage occurred during these 1000 waves, the wave heights have been increased by continuing with the succeeding subtest. If damage occurs within the first 1000 waves and the movements of the individual units did not stop (no stable armour layer), the tests proceeded longer than 1000 waves. A longer duration of the test might increase the damage. When the armour layer was stable after occurrence of damage, the test have been stopped.

The test series terminated when the armour layer failed or if the limit of the generated wave heights was reached. After each complete test series, the armour layer was removed and rebuilt, if needed the under layer was also reconstructed.

Table 3-2: Test program

Test	Grid	Unit Orientation	Under layer [mm]	Hor. Vs Upslope distance, D_n [m]	Packing Density [units/m^2]	Wave steepness $S_{m-1.0}$ [-]	Freeboard xH_{saD} [-]
1	Rectangular	Uniform	7-11	1.21 x 1.20	$0.69/D_n^2$	0.04	1.2
2	Rectangular	Uniform	7-11	1.21 x 1.20	$0.69/D_n^2$	0.02	1.2
3	Diamond	Random	11-16	1.40 x 1.14	$0.63/D_n^2$	0.04	1.2
4	Diamond	Random	11-16	1.40 x 1.14	$0.63/D_n^2$	0.02	1.2
5	Rectangular	Uniform	7-11	1.27 x 1.20	$0.66/D_n^2$	0.04	1.2
6	Rectangular	Uniform	7-11	1.27 x 1.20	$0.66/D_n^2$	0.02	1.2
7	Rectangular	Uniform	7-11	1.33 x 1.20	$0.63/D_n^2$	0.04	1.2
8	Rectangular	Uniform	7-11	1.33 x 1.20	$0.63/D_n^2$	0.02	1.2
9	Rectangular	Uniform	7-11	1.27 x 1.20	$0.66/D_n^2$	0.04	1.6
10	Rectangular	Uniform	7-11	1.27 x 1.20	$0.66/D_n^2$	0.02	1.6
*11**	*Not taken into account for the research on hydraulic stability*						
*12**	*Not taken into account for the research on hydraulic stability*						
*13**	-	-	-	-	-	*0.04*	-
*14**	-	-	-	-	-	*0.02*	-

* Test 11 and 12 were performed with a smooth wooden armour plate to verify the overtopping results of the preceding test series by Salauddin (2015), these tests are not taken into account for the research on the hydraulic stability. Test 13 and 14 were conducted without structure to verify the wave heights determined from the tests with structure.

Table 3-3: Test settings at deep water

Wave steepness $S_{m-1.0}$ [-]		Wave height H_{mo} [m]	Wave period T_p [s]	Wave period $T_{m-1.0}$ [s]
0.04	Subtest a	0.07	1.24	1.14
	Subtest b	0.10	1.43	1.31
	Subtest c	0.13	1.60	1.46
	Subtest d	0.16	1.75	1.60
	Subtest e	0.19	1.89	1.73
	Subtest f	0.22	2.02	1.84
	Subtest g	0.25	2.15	1.94
0.02	Subtest a	0.07	1.73	1.58
	Subtest b	0.10	2.07	1.89
	Subtest c	0.13	2.36	2.15
	Subtest d	0.16	2.61	2.35
	Subtest e	0.19	2.85	2.53
	Subtest f	0.22	3.06	2.66
	Subtest g	Not possible due to generator limitation		

3.3 Physical model set-up on interlocking

3.3.1 Pull tests

Based on the theoretical background prescribed in chapter 2, interlocking between units in the armour layer is expected to be an important mechanism for providing the hydraulic stability of the Crablock. The level of interlocking is defined by the interlocking degree and can be found by using equation (3.3).

$$Interlocking\ degree = \frac{Extraction\ force}{Weight\ unit} \tag{3.3}$$

To get insight in the interlocking degree, several pull tests were performed to find the force needed to extract units out of the armour layer. The extraction force was measured just after placement of the armour in dry conditions and after exposure of waves in the flume. The tests after the flume test have been performed to determine the influence of settling on the interlocking degree. The settling was supposed to improve the stability of the armour layer.

3.3.2 Measurements

A fishing line was used for the pull tests to extract the Crablock units out of the armour layer, these ropes do not stretch and can therefore not influence the measurements. In the dry tests, the ropes were already attached to the units before they were placed. This was not possible when performing the flume tests so in this case the ropes were very carefully connected afterwards.

To measure the force development in time and the maximum force that was needed to extract the Crablock unit, a computer controlled gauge was used. Before the measurements started, some calibration tests were carried out with a known weight. With the calibrated strain gauge the force on the rope attached to the unit could be measured. Due to the high sensitivity of the measuring device, a high frequency noise was found in the measurements. By using a low-pass filter the higher frequencies were filtered out in the analysis.

The unit has to be lifted perpendicular from the slope before the unit can drop out the armour layer. To secure the 90 degrees angle between the rope and the slope, a frame was used. This frame was capable of moving the strain gauge to perform the pull tests on any position of the slope wanted, see Figure 3-8.

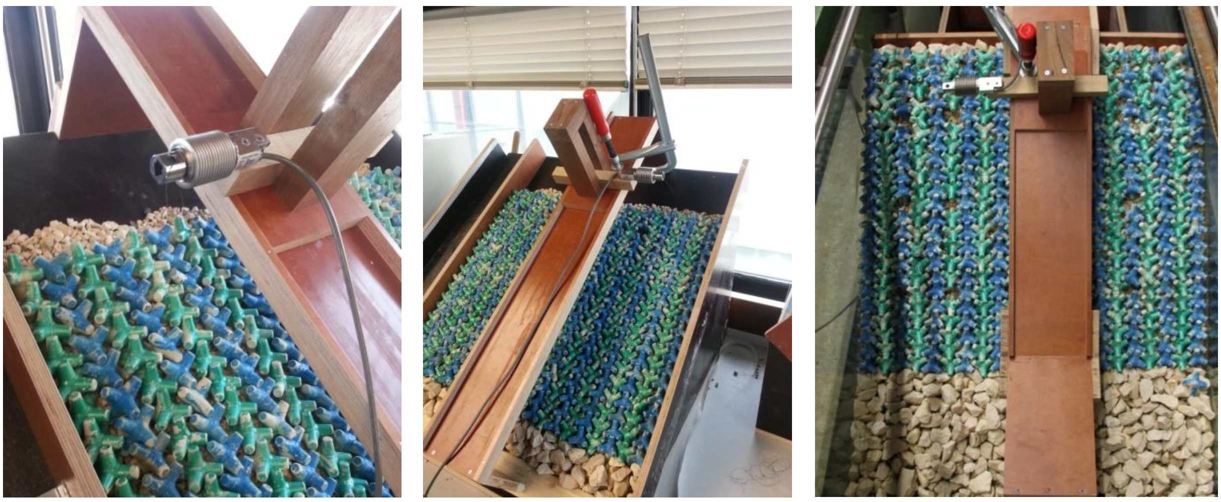


Figure 3-8: Pulling frame and strain gauge

In the photos above show the frame and strain gauge used for the extractions. The frame secured the extraction angle to be perpendicular to the slope.

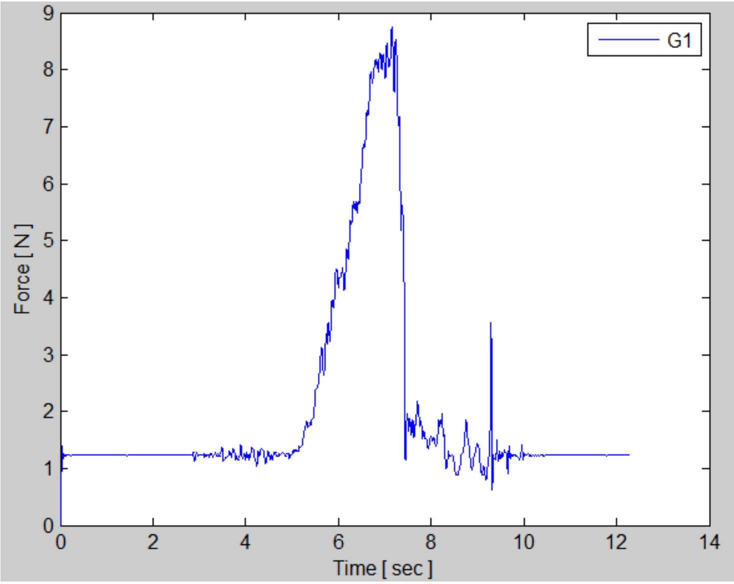


Figure 3-9: Example of filtered strain gauge signal

The units were extracted by operating the strain gauge through the frame by hand, tried with equal velocity. Figure 3-9 shows an example of the data obtained from a pull test. The first seconds a flat signal for the strain gauge in rest without any pulling can be observed. The average value of this flat part is taken as the zero-value. For force needed to extract an unit, the maximum value of the signal was taken. The difference between the maximum pull force and the zero-value was used for further analysis. After the unit was extracted, the weight of each unit separately was determined very accurately. The distorted signal at the end is related to the swinging movements of the still attached unit after it was extracted from the armour.

3.3.3 Cross section and materials

To determine the interlocking degree without influence of wave exposure, a dry test set up was built. A wooden plate with an iron mesh on top to prevent stones sliding off the plate was used for these dry test series, see Figure 3-10 and Figure 3-11. The slope of the plate was 3:4, equal to the armour slope used in the flume tests. The stones of the under layer were placed on a wooden plate of 80x100cm in the gradation 7-11mm for rectangular placement grid and 11-16mm for diamond placement grid. On top the armour layer was placed with the two different placement grids and variable packing densities.

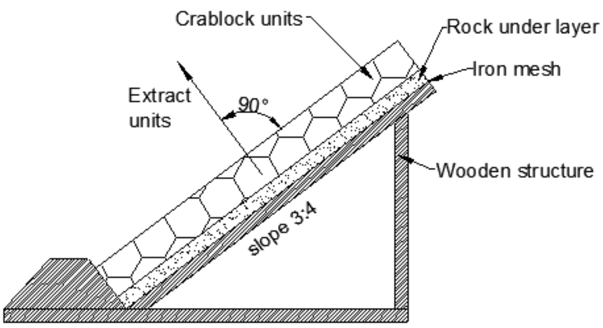


Figure 3-10: Model set-up for dry pull test

The cross section used for the unit extractions after wave exposure was equal to the cross section used for the flume tests on hydraulic stability, see par. 3.1.

Figure 3-11: Iron mesh for dry pull test

3.4 Test program for interlocking degree

3.4.1 Test program

After performing the physical model tests in the wave flume tests, the pull tests provide extra information to clarify the behaviour of the Crablock units. To make a comparison between an armour with and without settling it is important to use the same configurations in the dry tests as used by the flume tests. This means the same placement pattern and packing density. The test program can be found in Table 3-4. For the dry tests the packing was assumed over the whole armour equal and was defined by a measuring tape. To define the actual local packing density after settling due to wave attack, photo analysis has been done.

Unfortunately, the pull tests were not performed on all the test series in the flume. The rectangular grid with uniform placement and a packing density of 0.69/D_n^2 was not tested after exposure of waves just as the diamond grid with random placement and packing density of 0.63/D_n^2.

The Crablock units were extracted from several heights on the slope. This was needed to investigate the influence of the additional weight of the units above on the interlocking. The first height was close to the base of the slope, the fifth to seventh row. The second height was the twelfth to fifteenth and the third height close to the top the seventeenth to nineteenth row. Figure 3-12 shows the extraction locations. All units were extracted with at least two units in between. These two separation units have been chosen to prevent prior extractions influencing the extraction of the following units. Furthermore, no Crablock units have been extracted along the side walls of the slope. These places experience a certain influence from the boundary, they are not fully interlocked.

The interlocking degree was found by the ratio between the maximum extraction force needed to extract the Crablock out of the slope and the unit weight. The weight of each extracted unit was measured very accurate after the extraction was done. At each height on the slope multiple units were extracted to improve the accuracy.

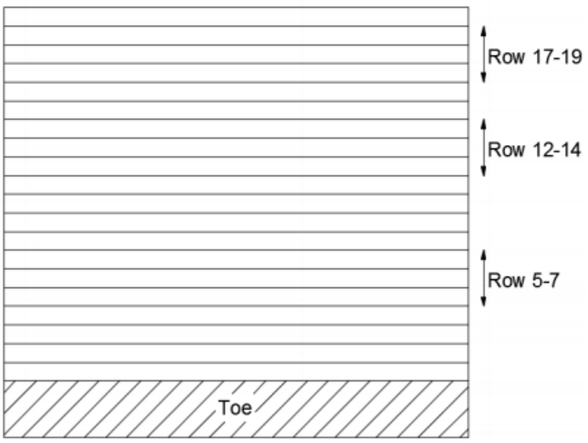


Figure 3-12: Extract locations

Table 3-4: Test program pull tests

Test	Extraction location	Grid	Placement	Packing density [units/m^2]	Under layer [mm]	Wave Steepness $S_{m-1,0}$ [-]	Freeboard xH_{saD} [-]
5	Flume	Rectangular	Uniform	$0.66/D_n^2$	7-11	0.04	1.2
6	Flume	Rectangular	Uniform	$0.66/D_n^2$	7-11	0.02	1.2
7	Flume	Rectangular	Uniform	$0.63/D_n^2$	7-11	0.04	1.2
8	Flume	Rectangular	Uniform	$0.63/D_n^2$	7-11	0.02	1.2
9	Flume	Rectangular	Uniform	$0.66/D_n^2$	7-11	0.04	1.6
10	Flume	Rectangular	Uniform	$0.66/D_n^2$	7-11	0.02	1.6
15	Dry	Rectangular	Uniform	$0.63/D_n^2$	7-11	-	-
16	Dry	Rectangular	Uniform	$0.66/D_n^2$	7-11	-	-
17	Dry	Rectangular	Uniform	$0.69/D_n^2$	7-11	-	-
18	Dry	Diamond	Random	$0.63/D_n^2$	11-16	-	-
19	Dry	Diamond	Random	$0.68/D_n^2$*	11-16	-	-

* This packing density is in practice not feasible due to pushing the units during placement. It is only performed for better understanding of the behaviour with diamond pattern.

4 Results

The methods to come to the actual wave conditions and individual unit movements are elaborated in chapter 4. The determination of the required wave heights is described in paragraph 4.1. Here are the resulting wave heights and the wave periods also checked with literature. In paragraph 4.2 the method of analysing the movement per unit is explained.

4.1 Wave conditions

The determination of the wave conditions of the flume tests can be based on two different methods. The wave spectrum analysis and the time series analysis are both useful for defining the significant wave height. From the spectral analysis the significant wave height H_{m0} can be defined and would be used for overtopping calculations. The time series analysis results in significant wave height H_s and is needed for the stability number.

4.1.1 Determination H_s

The significant wave height H_s is determined by doing a time series analysis. H_s is defined as $H_{1/3}$, being the average of the highest one-third of the wave heights measured in the time domain. The wave heights were measured in deep water at the generator side and in shallow water in front of the structure.

The time series analysis can only be done per individual wave gauge and results in the total significant wave height, this includes the incoming and the reflecting wave. Because the wave gauges in deep and shallow water were placed in groups of three, the average value of the three has been used. Because the wave heights found by this method represent the total significant wave height, it had to be corrected for the reflecting wave to obtain the incoming wave height. The incoming waves are for both deep and shallow water found by using equation (4.1), this is also known as the Mansard and Funke method (Mansard and Funke, 1980). This equation is valid for linear waves.

$$H_{s,inc} = H_{s,tot} * \sqrt{\frac{1}{1 + {K_{refl}}^2}} \tag{4.1}$$

Where:
$H_{s,inc}$= Incoming significant wave height [m]
$H_{s,tot}$= Total significant wave height, $H_{s,inc} + H_{s,refl}$ [m]
K_{refl}= Reflection coefficient [-]

The reflecting wave close to the structure can possibly disturb the measured signal in shallow water conditions due to the presence of non-linear wave patterns. To verify the measured wave heights at shallow water, also some test series were done without a structure in place. Whereby the foreshore was still included. The measurements at shallow water were without structure not influenced by wave reflection anymore since a mild slope revetment at the end of the flume absorbed the wave energy. In deep water conditions the non-linear effects by wave reflection are negligible.

The time series analysis for the tests without structure was also done for deep and shallow water. For both locations, again an average H_s of the three individual wave gauges was used. The wave development of H_s from deep to shallow water as found with and without structure in place is plotted in Figure 4-1 and Figure 4-2.

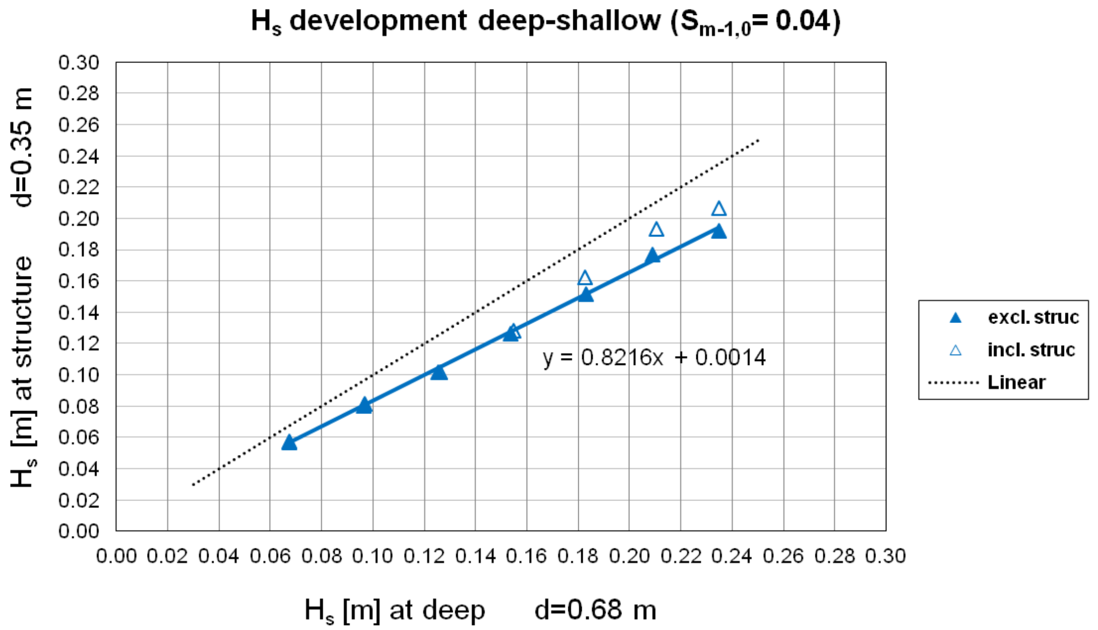


Figure 4-1: H_s development deep-shallow for $S_{m-1,0}$= 0.04

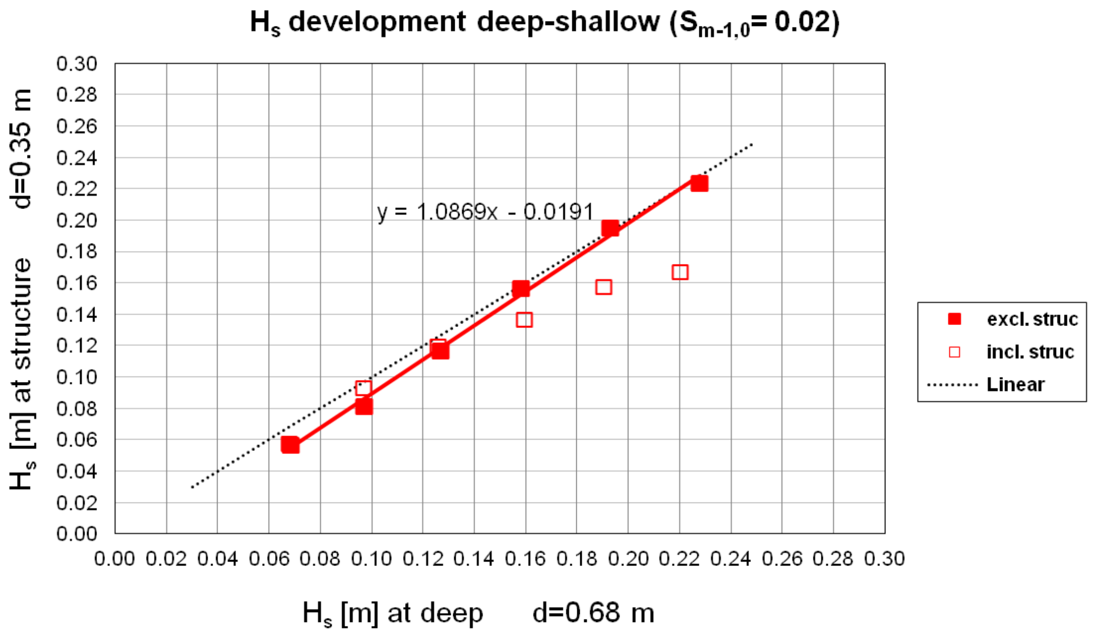


Figure 4-2: H_s development deep-shallow for $S_{m-1,0}$= 0.02

From Figure 4-1 and Figure 4-2 it can be concluded that the presence of the structure especially had influence on the higher wave conditions. The deviation becomes larger with larger wave heights and the incoming wave conditions found with the structure in place were therefore not correct. Since the Mansard and Funke method is only applicable for linear waves, the deviation means that considerable non linearity's were introduced by the long waves ($S_{m-1,0}$= 0.02) and in lesser extent by short waves ($S_{m-1,0}$= 0.04).

In case of short waves ($S_{m-1,0}$= 0.04), a clear decrease in wave height from deep to shallow water was observed without a structure. This can be explained by the occurrence of breaking waves. In the case of long waves ($S_{m-1,0}$= 0.02) there was without structure nearly no shoaling of breaking of waves observed, the deep water wave heights did not get modified when arriving in shallow water.

To find the correct incoming wave conditions in front of the structure, the development of the significant wave height from deep to shallow without structure was used. The trend lines in this figure were used to calculate all the significant wave heights in shallow water by extrapolation.

For the H_s found for each subtest see Appendix B.

4.1.2 Wave spectrum

The wave spectrum of JONSWAP was used for the physical model tests performed in the flume. This spectrum converts from high frequencies to low frequencies and resembles a young sea state where the waves were not fully developed due to limitations in the fetch length. The shape is shown in Figure 4-3 (Holthuizen, 2009). The spectral analysis was used for determining the significant wave height H_{m0} according to equation (4.2) and (4.3).

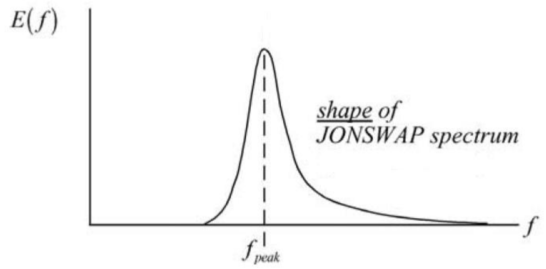


Figure 4-3: Shape of JONSWAP-spectrum

$$m_0 = \int_0^\infty E(f)df \tag{4.2}$$

$$H_{m0} = 4\sqrt{m_0} \tag{4.3}$$

Where:
m_0 = Zeroth-order spectral moment [m^2]
E(f) = Variance density spectrum [m^2/H_z]

Just as the significant wave heights H_s from the time series analysis, the spectral significant wave heights H_{m0} were also elaborated with and without structure.

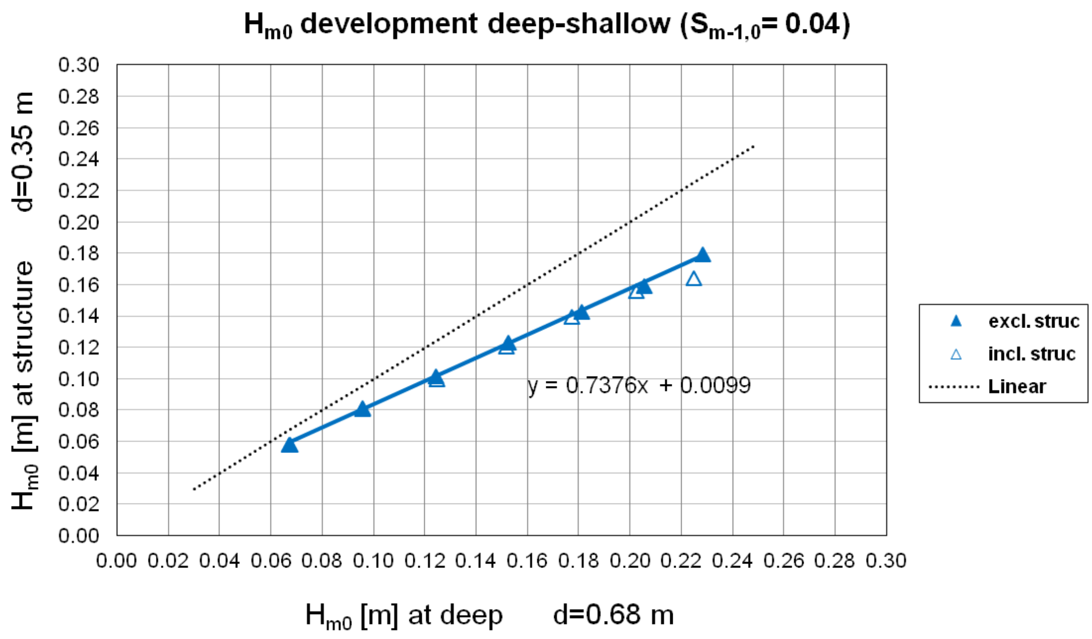


Figure 4-4: H_{m0} development deep-shallow $S_{m-1,0}$= 0.04

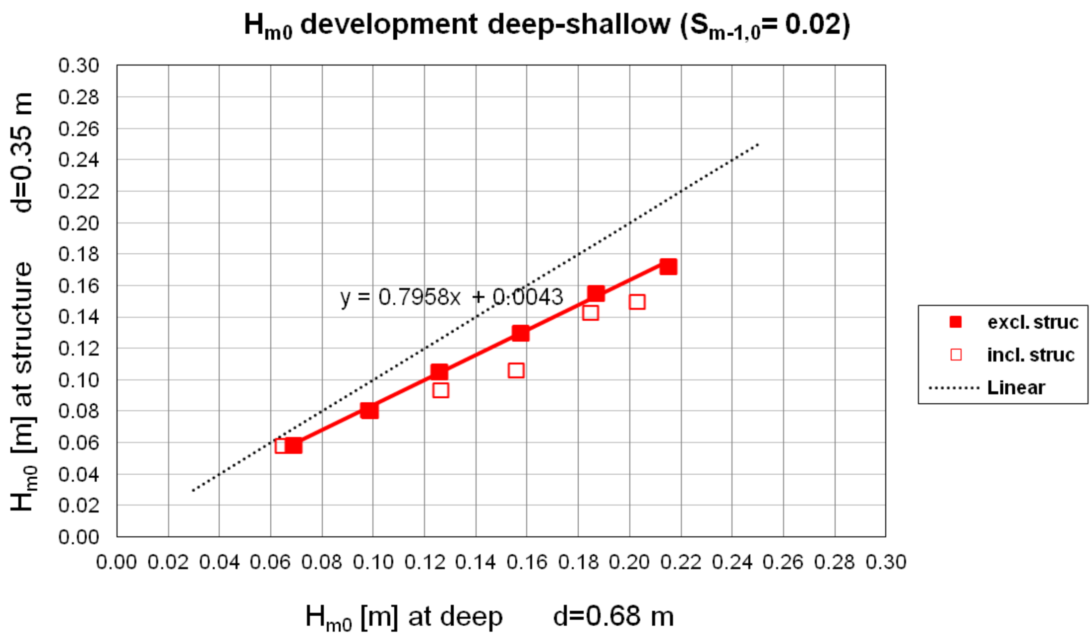


Figure 4-5: H_{m0} development deep-shallow $S_{m-1,0}$= 0.02

From the results, plotted in Figure 4-4 and Figure 4-5, it can be concluded that the disturbance by the structure is mainly present with the long waves. This is also the case for significant wave height H_s. For the short waves ($S_{m-1,0}$= 0.04) only the highest waves were affected by the presence of the structure.

4.1.3 Relation H_s and H_{m0}

Although the wave heights H_s and H_{m0} were determined with different methods, it might be expected that there is a certain relation between these wave heights. To show the relation between H_s and H_{m0}, Figure 4-6 and Figure 4-7 are plotted below for the wave conditions found without a structure in place.

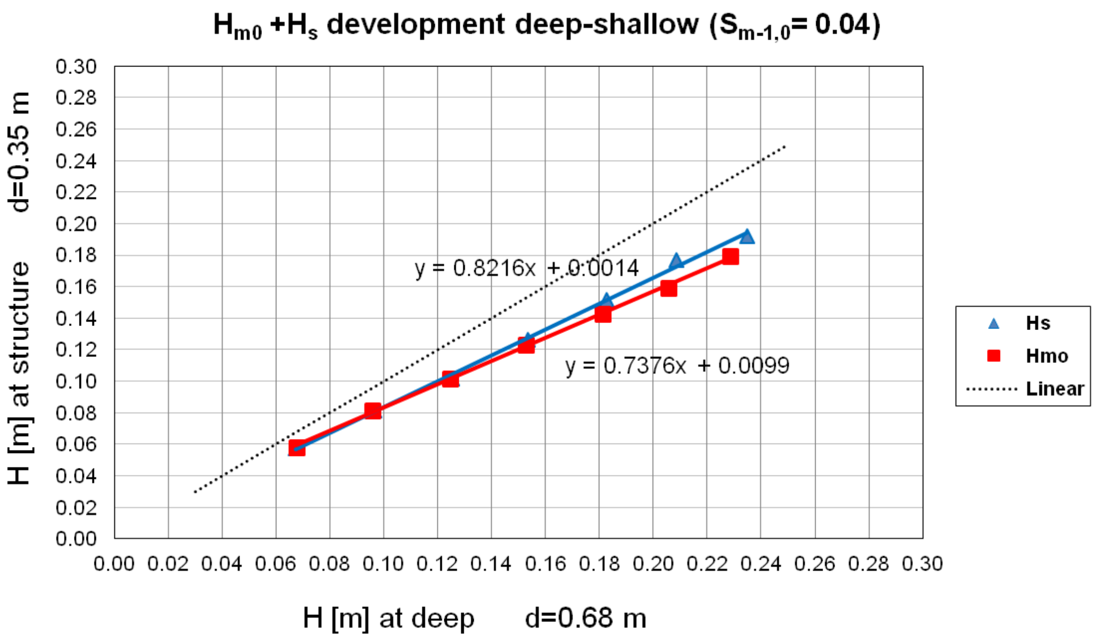


Figure 4-6: Relation H_{m0} + H_s for $S_{m-1,0}$= 0.04

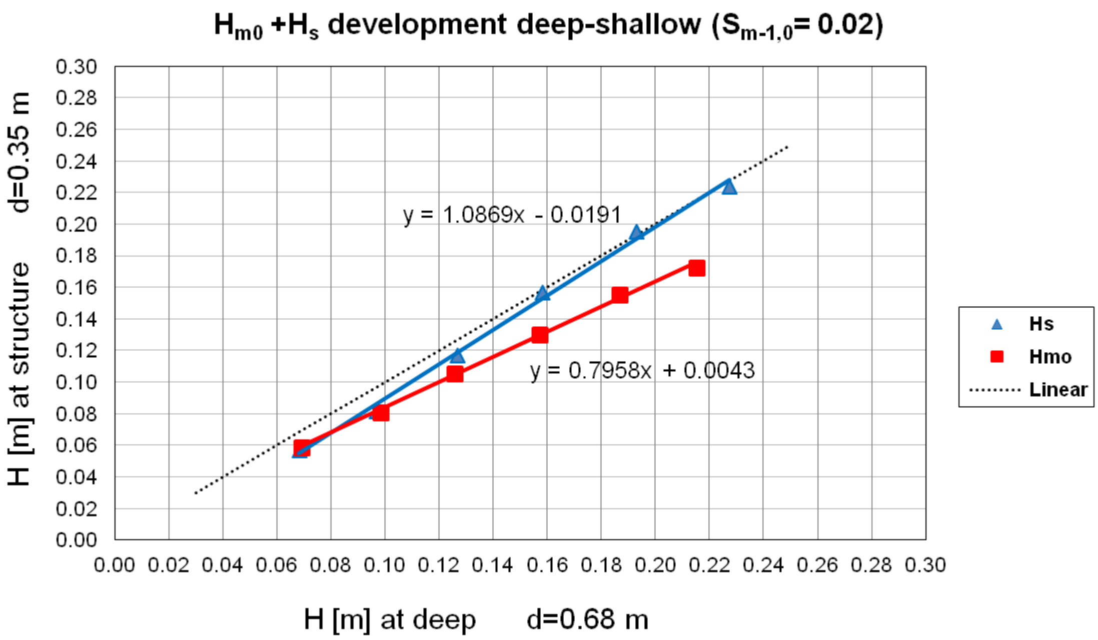


Figure 4-7: Relation H_{m0} + H_s for $S_{m-1,0}$= 0.02

For the short waves ($S_{m-1,0}$= 0.04), plotted in Figure 4-6, the difference between the two significant wave heights is minimal. Figure 4-7 shows a considerable difference between H_{m0} and H_s for the long waves ($S_{m-1,0}$= 0.02). The significant wave height H_s is, especially at shallow water, for the higher waves much higher than the significant wave height H_{m0} found from the spectrum.

Although significant wave height H_s and H_{m0} are often assumed as equal, this is like the tests with $S_{m-1,0}$= 0.02 not always the case and therefore caution is needed.

Battjes & Groenendijk (2000) made prediction models for the relations of H_s compared to H_{m0}, based on the slope of the foreshore and water depth in front of the structure. The prediction of the relation H_s-H_{m0} in shallow water which corresponds to the actual cross section used in the physical model tests, is plotted in Figure 4-8. The wave heights obtained from the test series without a structure in place are also included.

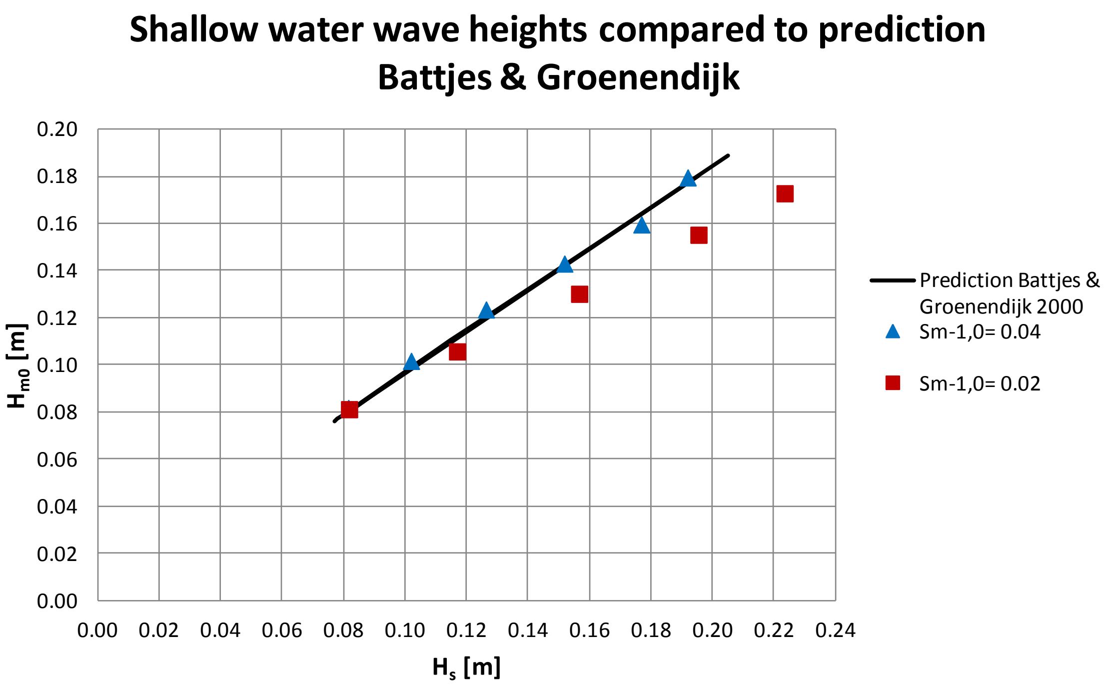


Figure 4-8: Shallow water wave heights compared to prediction Battjes & Groenendijk 2000

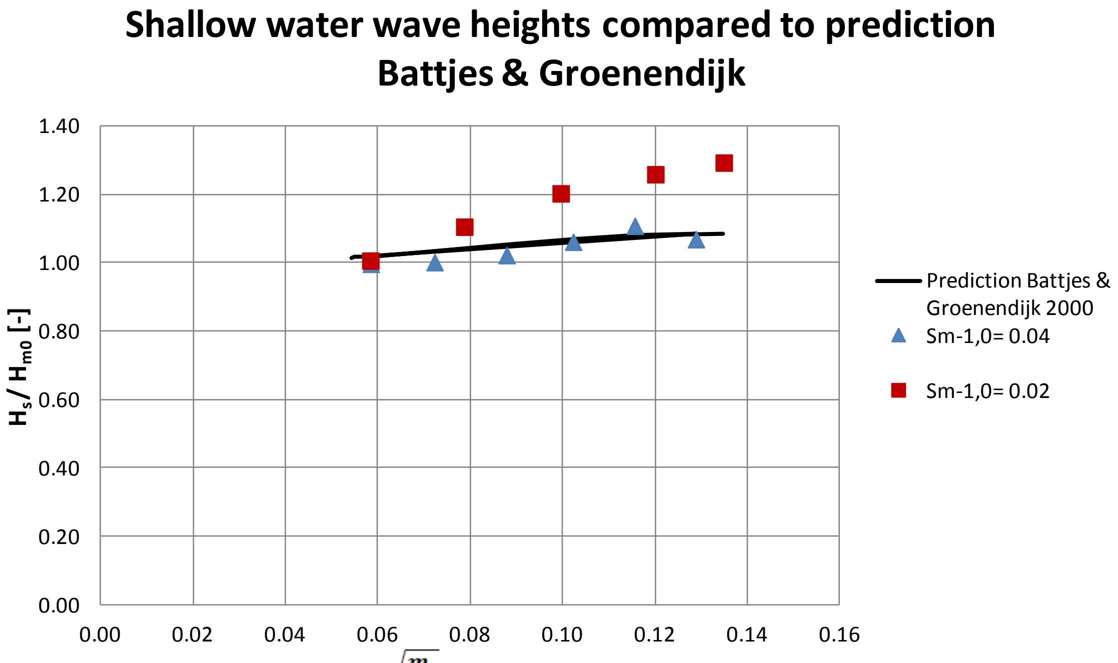
Considering the short waves ($S_{m-1,0}$= 0.04), the relation between H_s and H_{m0} determined from the tests show a very similar relation as predicted by Battjes and Groenendijk, 2000. However, on the other hand the wave heights found for the long wave test series show a very different relation than predicted.

The prediction model of Battjes and Groenendijk does not include wave steepness but the wave conditions found during the physical model tests on Crablock show that this model is not applicable for wave steepness $S_{m-1,0}$= 0.02. The model is therefore not valid for long waves.

Groenendijk, 1998 introduced relative local wave heights to describe the non-dimensional wave height distribution on shallow water foreshores. In shallow water the significant wave height H_s is no longer uniquely related to the spectral wave height H_{m0}. Therefore the degree of saturation according to Equation (4.4) is used to characterise the wave deformation process on shallow foreshores.

$$\Psi = \frac{\sqrt{m_0}}{d} \tag{4.4}$$

Where:
m_0 = Zeroth-order spectral moment [m^2]
d = Local water depth at shallow water [m]



$$\Psi = \frac{\sqrt{m_0}}{d}$$

Figure 4-9: Comparison with prediction Battjes & Groenendijk 2000 based on degree of saturation

Considering the relations found for the degree of saturation in Figure 4-9, it shows again the deviation of the wave heights found for the test series conducted with wave steepness $S_{m-1,0}$=0.02.

4.1.4 Wave period

The peak period (T_p) and spectral period ($T_{m-1,0}$) have been calculated from the spectral analysis and are plotted against each other in Figure 4-10. The periods plotted originates from the physical model tests without a structure in place. According to Eurotop, 2007 the ratio between T_p and $T_{m-1,0}$ is in case of a uniform (single peaked) spectrum a fixed relationship of 1.1.

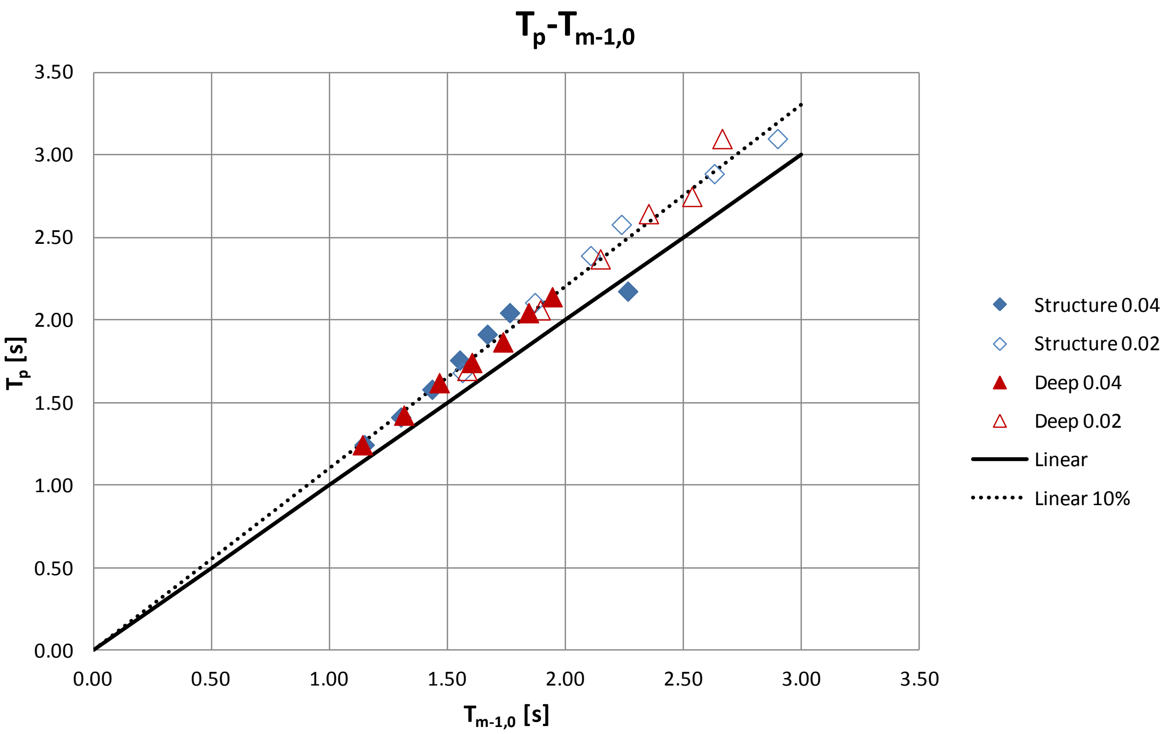


Figure 4-10: Relation T_p and $T_{m-1,0}$

Regarding Figure 4-10, most of the found wave periods (T_p and $T_{m-1,0}$) are close to the dotted line which represents the ratio of 1.1. The wave period $T_{m-1,0}$ found for the last subtest of the test series with corresponding wave steepness $S_{m-1,0}$= 0.04 deviates a lot. The single peaked spectral shape of JONSWAP changed in this specific subtest into a multiple peaked spectrum, see Figure 4-11. Breaking wave conditions at shallow water due to depth limitations caused for subtest 13g the extra peak for frequencies close to zero at the left side, which represents long waves. The small peak around 0.9Hz is caused by broken waves which split up into two smaller waves with half periods.

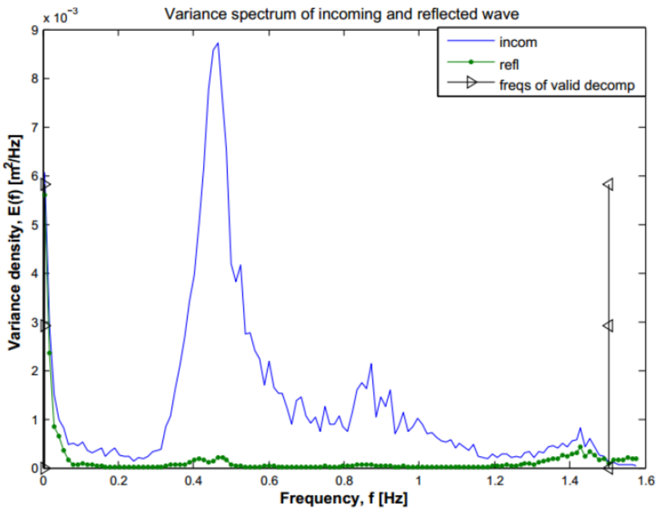


Figure 4-11: Variance spectrum at shallow water subtest 13g

The mean wave period (T_m) needed to be calculated from time series analysis. The time series analysis was performed on all wave gauges separately and the values found for T_m were for the three gauges at deep nearly equal, just as for the three wave gauges at the structure. Although there were very minor differences the average value of the three gauges is plotted in Figure 4-12. According to Eurotop, 2007 the relation T_p/T_m can be expressed in a ratio between 1.1 and 1.25. Based on the results of this research, this relation can be confirmed.

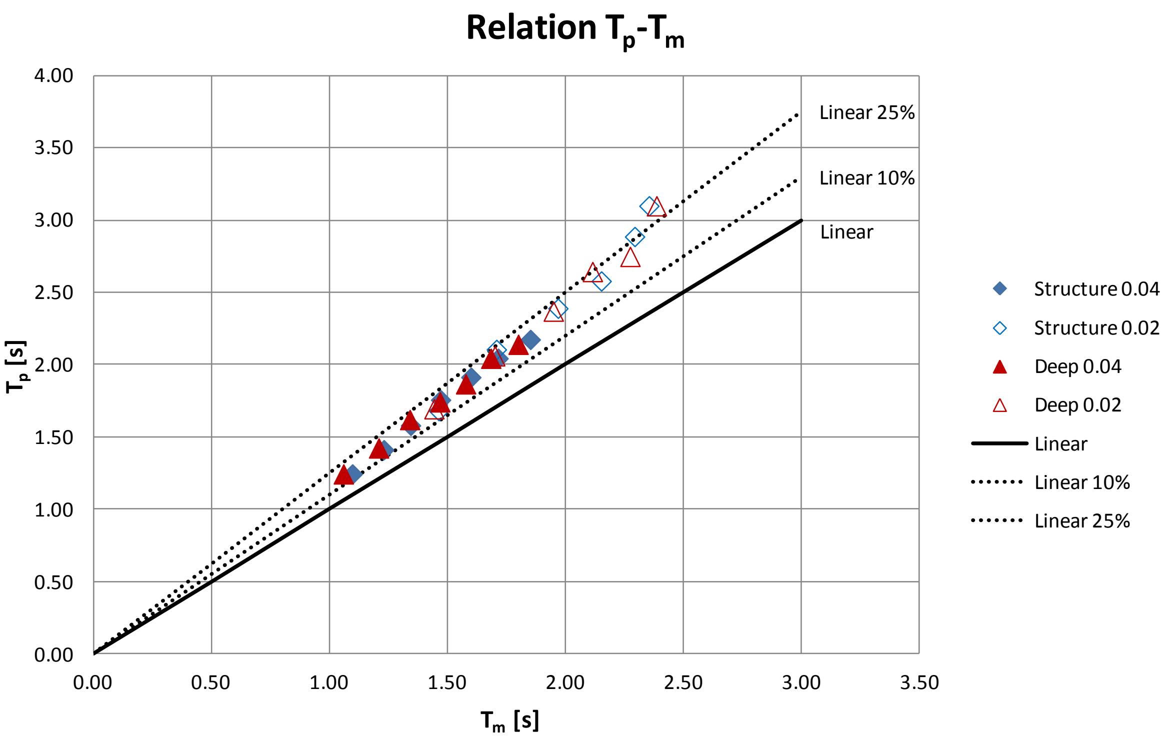


Figure 4-12: Relation T_p and T_m

4.2 Photo analysis unit movement

The stability of the Crablock is based on the damage development of the armour under wave attack. The movement of units was determined by comparing the photographs taken before and after each subtest. It was tried to take the photographs from exactly the same position but because the camera had to be set up again every morning there was a little deviation in camera position and zoom. To correct these small deviations, a Matlab script was made to make a photo overlay possible. After scaling and repositioning of the photographs, the centres of all units were marked to get the coordinates. The coordinates were calibrated with a known distance on the photograph. Based on the comparison in coordinates, the movement per unit could be calculated. Figure 4-13, Figure 4-14 and Figure 4-15 give an example of the photo analysis for subtest 7e.

Figure 4-13: Photograph after subtest 7e

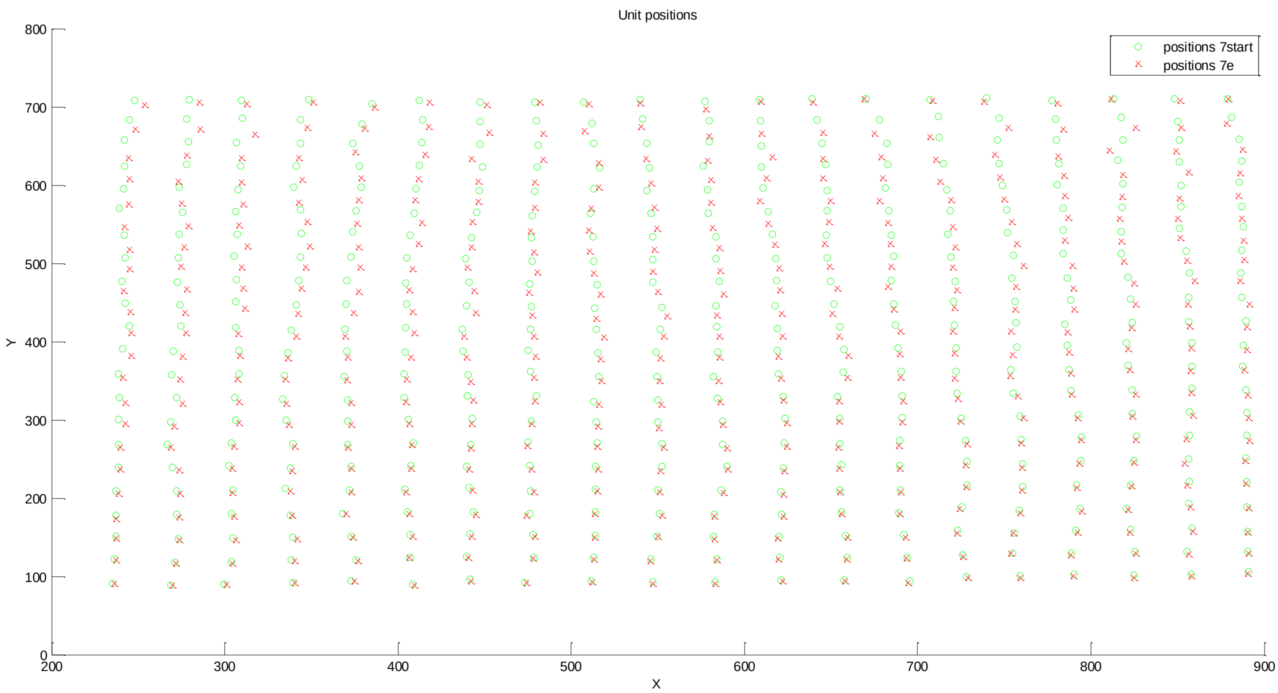


Figure 4-14: Movements after subtest 7e

Threshold: 15 mm   Nr of units exceed: 120

22	8.90	7.95	6.30	5.48	5.67	7.73	6.59	3.62	4.59	4.44	10.98	1.77	5.03	1.32	2.79	5.87	5.18	1.72	4.74	0.58
21	15.42	17.62	25.69	12.87	7.13	9.96	17.46	19.22	12.50	11.16	22.59	18.63	19.76	20.00	30.97	15.09	16.23	18.27	9.20	10.30
20	26.77	20.50	22.92	21.31	13.81	17.13	22.47	22.03	29.60	23.07	28.03	18.11	21.91	20.51	33.27	21.77	24.19	18.47	17.56	15.41
19	20.30	26.05	24.80	20.99	18.18	20.46	21.86	22.87	29.32	23.53	20.63	16.57	19.59	20.09	26.70	21.14	18.21	21.35	16.69	16.98
18	23.21	23.19	21.28	22.98	18.59	16.02	16.26	24.50	28.80	26.39	19.59	19.11	15.74	19.88	16.26	21.30	17.21	19.55	19.13	20.82
17	27.23	20.67	20.29	19.34	19.71	15.72	14.47	23.50	25.83	23.75	21.52	17.45	15.90	17.38	24.32	18.17	14.40	16.71	18.66	17.68
16	21.50	19.27	19.29	20.45	22.93	14.87	14.46	21.30	22.09	19.24	16.92	15.42	12.73	13.82	19.63	17.55	15.96	13.71	14.43	20.04
15	17.08	13.54	16.85	15.63	16.51	17.35	12.10	17.66	18.14	17.06	17.76	14.28	12.68	16.37	15.55	16.40	18.01	12.17	13.25	13.26
14	14.41	12.48	13.16	11.24	17.74	10.64	13.45	12.37	14.66	14.56	18.31	14.22	12.29	9.44	12.67	12.56	16.10	10.20	11.41	12.09
13	13.39	12.23	12.63	13.30	13.87	12.44	12.88	12.64	14.96	13.28	14.04	12.70	14.14	8.32	7.79	11.33	14.06	8.85	9.93	10.72
12	11.25	10.83	8.86	9.02	10.10	9.92	10.48	11.57	12.47	11.26	13.27	12.04	13.70	9.00	8.71	12.64	11.71	8.26	6.69	8.44
11	11.71	9.72	7.49	7.69	9.11	8.53	8.67	11.05	8.84	9.47	8.54	9.21	9.81	8.97	7.80	11.89	10.43	9.42	7.36	7.40
10	6.53	8.51	7.54	5.27	6.12	7.41	9.84	9.14	7.44	6.86	7.72	6.98	8.65	9.28	9.98	8.12	6.07	6.67	6.21	5.92
9	9.26	9.18	7.48	6.71	4.44	5.57	8.10	7.39	5.22	6.57	5.99	4.40	6.90	8.49	7.61	5.18	5.70	6.25	5.75	7.76
8	8.09	6.80	4.78	6.57	5.60	6.76	7.29	4.19	6.58	8.60	5.13	6.07	3.66	6.22	4.48	3.59	4.61	4.98	5.09	7.10
7	4.72	4.81	5.43	3.81	4.84	3.48	4.57	5.19	5.03	6.02	5.87	4.95	4.27	7.67	5.33	5.09	4.27	5.36	5.72	8.56
6	3.39	6.32	3.60	3.66	3.47	3.71	4.10	5.05	3.59	6.13	3.85	3.19	4.48	3.98	5.00	4.69	4.13	3.29	6.51	4.22
5	3.73	4.58	3.31	4.83	3.70	3.18	3.83	2.87	3.50	2.58	3.09	3.70	2.65	2.66	2.35	4.42	3.21	1.72	5.58	2.74
4	4.47	4.20	4.45	1.33	2.41	2.79	3.94	3.05	1.96	2.19	2.79	2.64	3.05	1.42	3.34	3.44	3.71	1.64	5.45	1.54
3	3.18	1.34	3.51	3.36	0.95	2.77	3.67	2.54	1.99	0.98	3.29	3.17	3.56	3.47	3.15	1.22	2.90	3.33	4.86	0.75
2	1.29	1.33	2.35	2.66	1.40	0.39	1.35	1.29	2.36	3.19	1.09	1.96	2.97	2.32	2.36	1.05	2.24	2.21	4.48	1.73
1	1.49	1.62	2.17	1.61	2.28	1.53	1.67	0.88	1.65	2.56	1.67	1.87	1.65	2.46	1.66	2.08	2.48	2.87	2.14	1.80
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**

Movements in mm

Figure 4-15: Movements after subtest 7e per unit

Using the Matlab script for the photo analysis, the above results were found for each subtest. From Figure 4-14 it is clear to see the movement per unit. In subtest 7e large movements at the transition zone between slope and horizontal crest were observed. When using a threshold level the movements can be characterised in several categories as shown in Figure 4-15. Due to manual scaling and marking of the centres of the units there is some deviation in the results. The maximum deviation of the marked centres is 3 mm or $0.1D_n$.

5 Observations

Chapter 5 describes the observations done during the physical model tests performed in the wave flume. The behaviour of the armour layer is described in terms of damage pattern and eventually failure in paragraph 5.1. These observations are important for analysing the stability of Crablock. The overall observation is presented in paragraph 5.2.

5.1 Observation physical model tests

Test 1 $S_{m-1,0}$= 0.04	Packing density: $0.69/D_n^2$	Grid: Rectangular	Placement: Uniform	Freeboard: $1.2H_{saD}$
The armour did not show any settlement during the test series. The packing density is so high that there is nearly any possibility for the units to move within the armour layer. In subtest 1f, 2 units were rocking a few times at the transition zone from the slope to the horizontal part in front of the crest wall. The units stopped with rocking after finding a stable position again. The interlocking of the units in this transition zone was not as good as on the slope, there were larger gaps in between. There were no unit displacements observed in the whole test series.				

Test 2 $S_{m-1,0}$= 0.02	Packing density: $0.69/D_n^2$	Grid: Rectangular	Placement: Uniform	Freeboard: $1.2H_{saD}$
During this test series the units moved a very little within the armour layer. At subtest 2c, 1 unit was rocking at the waterline. The unit was pushed from the underside by the water pressure in the under layer. After some settlements of the units above, the unit became stable again. The first two unit displacements were observed during subtest 2d, located at the transition zone on the left side and on the transition zone against the right side wall. Furthermore, from this subtest also rocking of several units occurred, mostly located at the transition zone. The gaps of the displaced units were filled up with surrounding units. Larger gaps were created at the transition zone because the units on the horizontal part are not settling like the units on the slope. During subtest 2f many displaced units, randomly located in the transition zone, caused failure to the structure.				

Test 3 $S_{m-1,0}$= 0.04	Packing density: $0.63/D_n^2$	Grid: Diamond	Placement: Random	Freeboard: $1.2H_{saD}$
The armour layer encountered large settlements during this test series. The packing density is low and the large porosity made it therefore possible for the units to move. At subtest 3b, large settlement were observed around the waterline. A large settlement happed at once over the whole width. Also 2 units were rocking at the transition zone in this subtest. In subtest 3c, 1 unit was displaced along the left side wall just above the water level. After the settlements the interlocking was not sufficient anymore. In this subtest also large gaps between the units were observed around the transition zone of the armour and many units were rocking at that location. From subtest 3e, the interlocking of the units at the transition zone became so bad that nearly all units at this location were rocking, some units turned completely upside down or were rolling over the under layer. At subtest 3g, again 1 unit was displaced along the left side wall of the flume at the transition zone. Even though a lot of rocking and movement of the units was observed there was in this physical model test no failure of the armour layer achieved. In reality failure could be obtained due to structural strength problems of the units.				

Test 4 $S_{m-1,0}$= 0.02	Packing density: $0.63/D_n^2$	Grid: Diamond	Placement: Random	Freeboard: $1.2H_{saD}$

Large movements of the units were observed in this test series. From subtest 4b, settlements over the whole armour layer were observed. 2 units at the transition zone and 1 unit just above the waterline were rocking. The gaps between the units became larger at the transition zone but also at the horizontal part in front of the crest wall. At subtest 4c, lot of units were rocking at the transition zone and there were also a few units rolling over the horizontal part. At subtest 4d, 3 units were displaced at the horizontal part. The units at the transition zone and horizontal part remained rocking and rolling. The structure failed during subtest 4e, the units at the transition zone were displaced and the under layer was heavily damaged.

Test 5 $S_{m-1,0}$= 0.04	Packing density: $0.66/D_n^2$	Grid: Rectangular	Placement: Uniform	Freeboard: $1.2H_{saD}$

A moderate settlement was observed during the test series of test 5. The armour remained completely stable till subtest 5e, where 1 unit was rocking at the transition zone along the left side wall. At subtest 5f, 1 unit was displaced along the right side wall. The 2 units above settled and filled up the gap, so a new gap was created upslope. The 2 units were not sufficient interlocked anymore and were rocking both whereof 1 unit was also rolling. Furthermore, rocking of units over the whole width was observed at the transition zone. At subtest 5g, 1 unit was lifted along the left side wall but was not displaced. The structure did not fail during the test series.

Test 6 $S_{m-1,0}$= 0.02	Packing density: $0.66/D_n^2$	Grid: Rectangular	Placement: Uniform	Freeboard: $1.2H_{saD}$

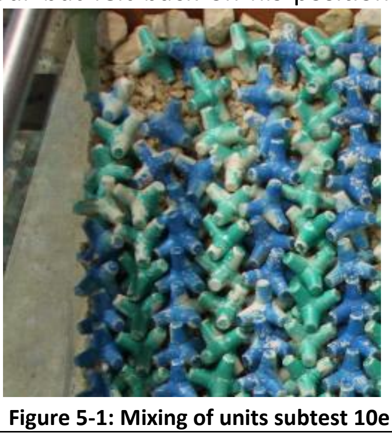
In the test series belonging to test 6, moderate settlements were observed. 1 unit was rocking several times around the waterline due to the upward water pressure from the underside in subtest 6b. The unit became stable after some settling. The settling caused larger gaps around the higher located units upslope. At subtest 6c, 3 units were rocking at the transition zone. 2 units at the transition zone were lifted a little out of the armour layer a few times during subtest 6d, but found a stable position again. Furthermore, 9 units were rocking at the transition zone. The rocking at the transition zone continued and 1 unit along left side wall was lifted a few times without being displaced in subtest 6e. The large openings between the units in the transition zone and horizontal part caused displacements of many units leading to failure of the armour. The sequence of the displaced units was random.

Test 7 $S_{m-1,0}$= 0.04	Packing density: $0.63/D_n^2$	Grid: Rectangular	Placement: Uniform	Freeboard: $1.2H_{saD}$

The armour layer encountered large settlements in this test series. The settlements and movements are comparable with test 3. The different placement grid and pattern did not have influence on the behaviour of the armour layer. 2 units were rocking just above the waterline and 3 units were rocking at the transition zone during subtest 7b. In subtest 7c, 2 units above the waterline were rocking several times till settlements gave them stability. Also 4 units were rocking at the transition zone. During subtest 7d, 3 units above the waterline were rocking just as many units at the transition zone. 1 unit was moving up and down at the horizontal part with each wave attack. From subtest 7e, next to rocking also rolling of 4 units was observed. At subtest 7g, 1 unit was displaced from the transition zone and 1 unit from the horizontal part. No failure was obtained in this physical test, however in practice the structural strength of the units could cause failure.

Test 8 $S_{m-1,0}$= 0.02	Packing density: $0.63/D_n^2$	Grid: Rectangular	Placement: Uniform	Freeboard: $1.2H_{saD}$
Similar to test 4, this test series also had large settlements during the physical tests. Rocking of 4 units started at subtest 8b, at the transition zone and the horizontal part. 10 units were rocking at the transition zone and horizontal part in subtest 8c. Some of these units became stable again after settlement. The settlement caused larger gaps between the units at the transition zone, so 1 unit from there and 1 of the horizontal part were displaced in subtest 8d and 3 units were rolling. At subtest 8e, some units at the horizontal part were lifted and many units were displaced from the transition zone and horizontal part leading to failure of the structure				

Test 9 $S_{m-1,0}$= 0.04	Packing density: $0.66/D_n^2$	Grid: Rectangular	Placement: Uniform	Freeboard: $1.6H_{saD}$
This test series was performed with a larger crest height than the previous ones. A larger settlement was observed than test 5 with equal packing density and wave steepness. The wave energy of the highest waves is now not going over the structure like test 5, but was needed to be absorbed by the armour layer. Some settlement occurred during subtest 9d, so some gaps were created at the transition zone. During subtest 9e, 8 units were rocking whereof 1 unit was located just above the waterline and the others at the transition zone. The number of rocking units increased during subtest 9f and were mainly located in the transition zone, also some units were lifted but kept in position. In subtest 9g, 1 unit above the waterline along the right side wall was displaced. No failure was obtained in this physical test series.				

Test 10 $S_{m-1,0}$= 0.02	Packing density: $0.66/D_n^2$	Grid: Rectangular	Placement: Uniform	Freeboard: $1.6H_{saD}$
A higher crest level was also applied for this last physical model test. This test is based on the packing density comparable with test 6. Although the settlement of the units was larger in this test series. The first unit started to rock at subtest 10b, located along the right side wall above the waterline. During subtest 10c, more units started to rock but became stable after some movements within the armour layer. At the transition zone 1 unit was lifted out the armour but felt back on his position again at subtest 10d. Moreover, there were some units lifted up and down at the transition zone. At subtest 10e, 1 unit was displaced along the left side wall just above the water line which caused also the displacement of the 3 units above. This large gap along the left side wall was filled with units from the column next to it, see Figure 5-1. Furthermore, 3 units were displaced from the transition zone whereof 1 gap along the right side wall was filled up by settlement of the unit above. During subtest 10f, 3 extra units were displaced from the transition zone and some rolling of units was observed. Also horizontal unit movements were observed in the armour layer.  **Figure 5-1: Mixing of units subtest 10e**				

5.2 Overall observations

The wave attack causes settlements of units which makes the packing density around the water level higher and the packing density at the transition zone less. The settlement is larger with lower initial (overall) placing packing densities. The units from the horizontal part do not settle like the units on the slope. The difference in settlement between the units causes large openings in the armour layer at the transition zone from the slope to the horizontal crest. The waves can easily penetrate the armour at that location which makes this the most vulnerable location for the units. The displacement of units is therefore mainly concentrated on the highest part of the armour, the transition from slope to horizontal crest. For a normal crest level the wave attack is also most severe on the upper part of the armour. So the highest attack is focused on the weakest part of the armour layer. The wave attack on the higher crest level is more located on the slope.

In some tests, it was observed that after one or more units have been washed out, the units above the gap would move down and decrease the gap created. The units above the gap took over partially the function of the removed units as a 'self-healing' process. The movement of the units above towards the gap of the displaced unit(s), created new gaps or weak spots on higher locations on the slope.

6 Analysis on stability

In this chapter the results of the physical model tests on hydraulic stability were elaborated. First in paragraph 6.1, the behaviour of the Crablock units is analysed by means of damage development through displacements and the point of failure is introduced. In chapter 6.2 and 6.3 is the damage by movements and respectively rocking described. Chapter 6 is finalised with a discussion on the results found and the thereby belonging stability number is recommended.

For the behaviour of the Crablock armour units, the following criteria have been used:

- Settlement: downward movement of unit(s) along the slope, without loss of interlocking function;
- Damage: quantified on displacements out of grid, movement of units and rocking whereby the function of the armour layer is still intact;
- Failure: Loss of function of the armour layer, start of damage under layer.

See Appendix C for the photographs taken after finishing each subtest.

6.1 Behaviour Crablock under wave attack

To describe the behaviour of Crablock during exposure to waves, the damage development is very important. The damage development was determined through finding the wave heights where damage occurred and quantifying the actual damage. The stage where the first number of units were displaced from the armour layer is defined as 'Start of Damage'. The 'Start of damage' is plotted in Figure 6-1 against the stability number. For some tests the displacement started along the side walls and is assumed as not representative due to the limited interlocking of the units.

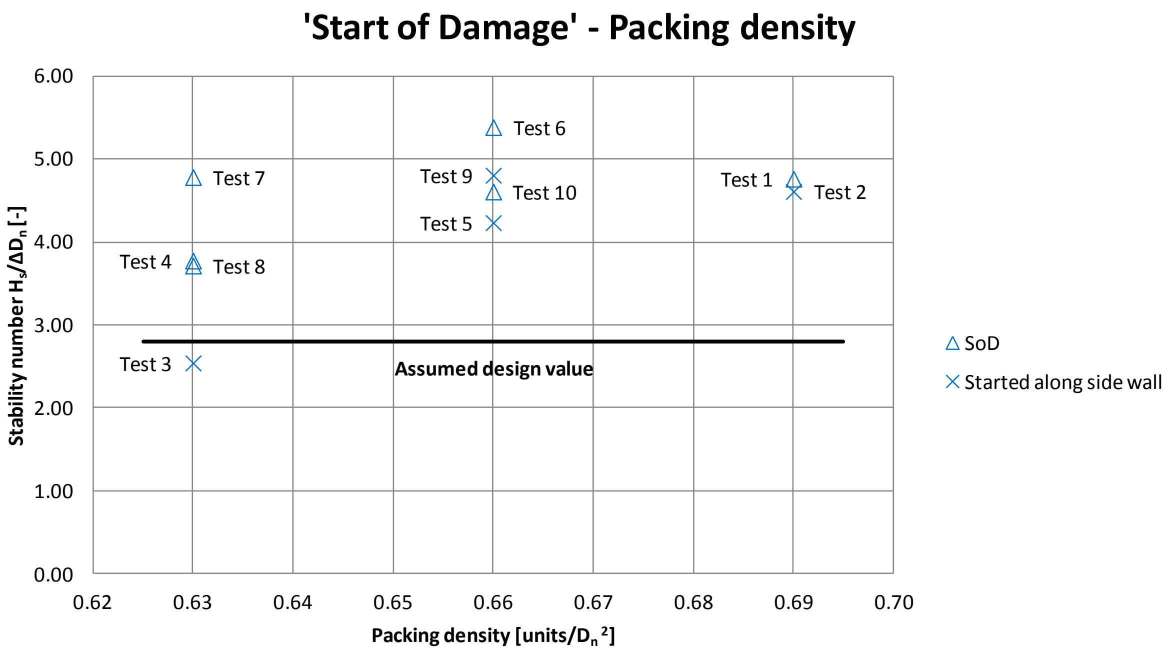


Figure 6-1: Start of damage by displacements

The displacement of units caused in some cases failure of the armour layer, this is the stage where the under layer was damaged because it was directly attacked by waves. In case of test 4, the under layer was eroded and the core was also heavily damaged. This is defined as failure of the structure in this analysis. The cases where no failure was observed, the maximum wave height provided by the generator was not sufficient. Figure 6-2 shows the points of failure related to the stability number.

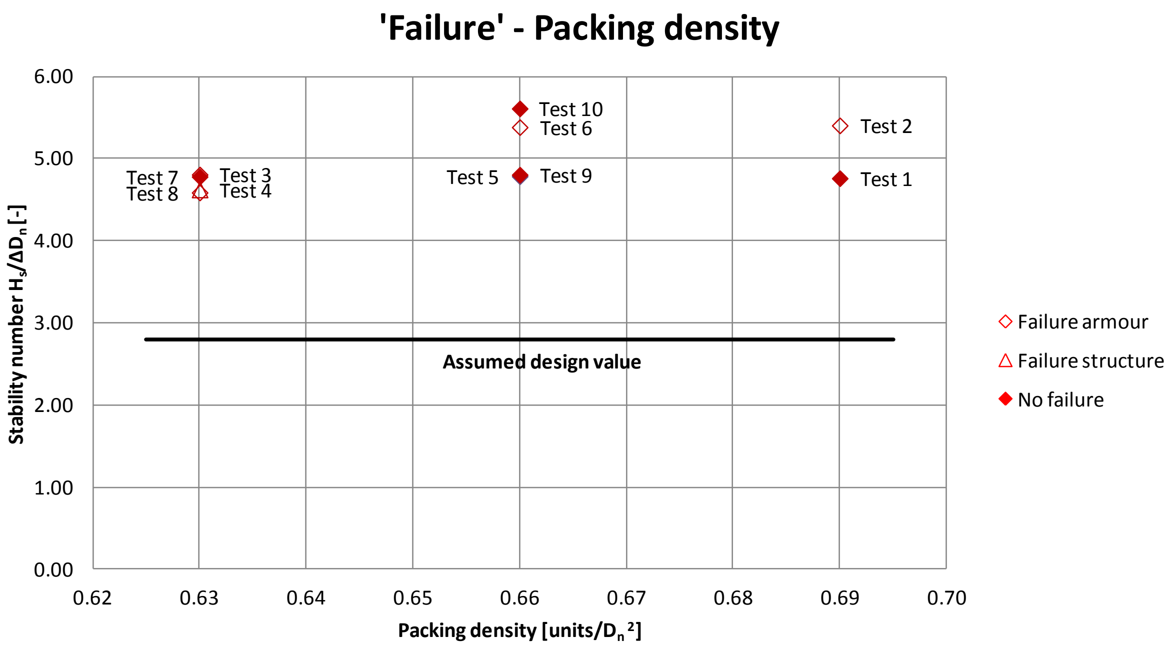


Figure 6-2: Failure based on displacements

The generator was capable of generating higher waves with wave steepness $S_{m-1,0}$= 0.02 than for wave steepness $S_{m-1,0}$= 0.04. The created maximum wave height was for $S_{m-1,0}$= 0.02 in most cases sufficient to cause failure of the structure. However, the highest wave height obtained for $S_{m-1,0}$= 0.04 was often not high enough to obtain failure.

To quantify the damage development, the displacement of individual units can be used. Therefore the relative number of units displaced is introduced in Chapter 2. The results in this analysis are based on the following equation (6.1).

$$N_{od} = \frac{n_d\,(number\ of\ displaced\ units)}{\frac{0.80m}{0.030m}} \tag{6.1}$$

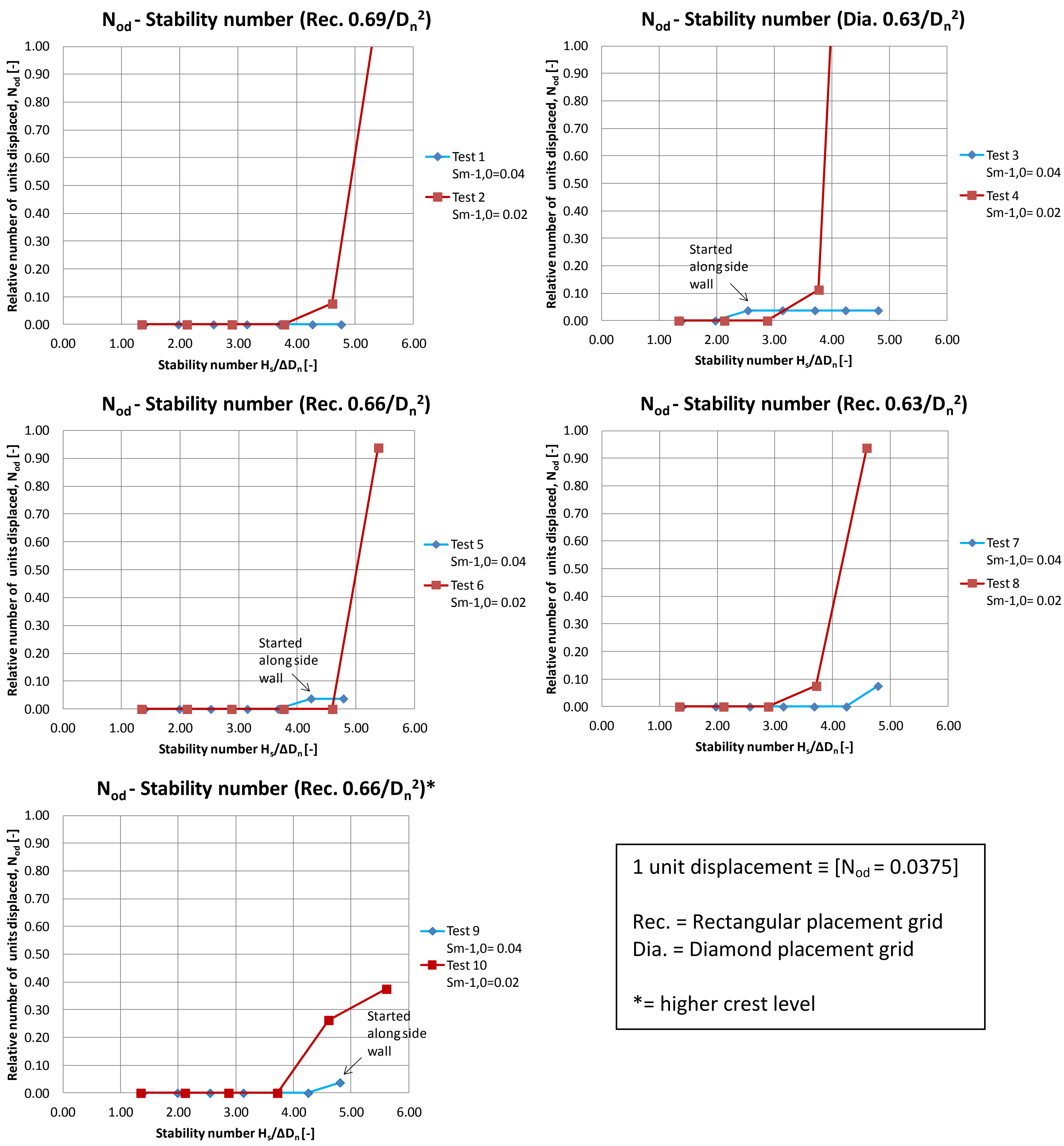


Figure 6-3: Damage curves N_{od} for all tests

Figure 6-3 is not corrected for side effects and shows the influence of the wave steepness on the damage development. The test series with long waves ($S_{m-1,0}$= 0.02) caused damage to the armour layer in an earlier stage than the short waves ($S_{m-1,0}$= 0.04). Next to this, it is also important to mention that the long waves test series were able to reach higher wave heights when needed. In some cases the long waves could therefore cause substantial damage while there was no damage observed for the test series with short waves yet.

See appendix D for an overview of the displacements.

6.2 Damage by movements

Besides looking to the displacement of the individual units, damage can also be expressed by movement of the units. Most common movements of units of breakwater armour layer can be characterised in the form of settlements. When the movements are too big, the decrease in interlocking between the units can lead to a reduction of the stability. To quantify the movements threshold levels of >0.25D_n, >0.5D_n, >0.75D_n and >1.0D_n have been introduced. The following equation (6.2) is thereby used.

$$N_{om} = \frac{n_m(number\ of\ moved\ units\ exceeding\ threshold\ level)}{\frac{0.80m}{0.030m}} \tag{6.2}$$

In some cases the displacement of Crablock units from the armour layer influenced the movement of the remained surrounding units. The movements of the influenced remaining units were therefore corrected according to Table 6-1.

Table 6-1: Corrections on movements of units

Test	Subtest	Stab. Nr.	Correction
2	e	4.610	2 unit movements are not counted which were located at the right top. Due to displacement of 1 unit, large settlements were observed for the 2 units above.
3	g	4.807	From >0.75D_n, 2 unit movements are not counted. Due to displacement of 1 unit, these 2 units obtained large settlements.
5	f	4.234	2 unit movements are not counted which were located at right top. Due to displacement of 1 unit, large settlement of the 2 units above occurred.
	g	4.786	2 unit movements are not counted, located at the right top. Due to the displacement of 1 unit, large settlement of 2 units above was observed.
9	g	4.805	From >0.75D_n, 5 unit movements are not counted. Due to displaced units a part of column settled.
10	e	4.608	8 unit movement are not taken into account. Displacements caused large settlement of 8 units above and next to it.
	f	5.612	*Too mixed to analyse*

For an overview and plot per test see Appendix E.

Example

To visualise the correction needed, the analysis of subtest 2e is presented in Figure 6-4 and Figure 6-5. One unit was displaced along the right side wall. The 2 units above the displaced unit settled into the gap created. These two units are not taken into account for quantifying the number of units that exceeds a certain threshold level. The unit displaced somewhat left from the centre did not influence movement of surrounding units so no correction is applied for that location.

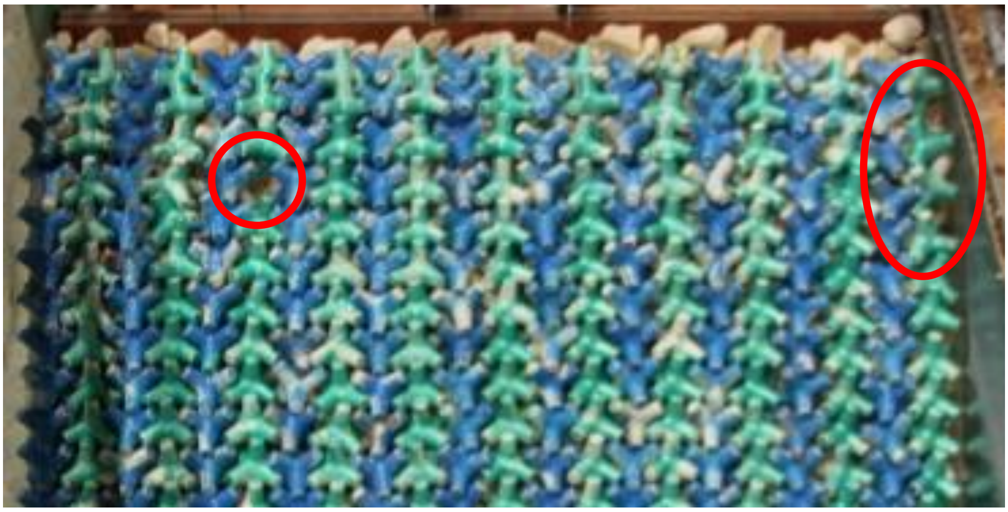


Figure 6-4: Displaced units after subtest 2e

22	3.43	2.82	3.33	2.09	2.38	4.45	3.21	3.09	2.50	0.86	3.77	1.87	2.66	2.23	2.46	4.04	3.77	2.56	0.19	3.71	2.43	4.62
21	2.34	1.22	4.47	2.31	2.61	1.02	0.65	4.26	1.53	0.99	2.39	2.31	1.87	9.30	2.88	0.71	7.08	1.59	3.03	6.12	1.06	27.56
20	1.32	1.22	2.03	6.15	6.99	4.78	2.52	3.69	4.38	3.26	7.15	1.63	2.96	3.48	4.39	3.15	1.92	3.93	3.89	3.76	3.52	25.63
19	10.51	6.80	8.59	11.71	10.86	0.00	7.78	5.35	3.92	4.92	9.98	5.09	3.05	6.44	3.63	1.57	1.31	2.11	6.55	7.58	6.46	0.00
18	9.03	7.27	8.39	4.75	4.22	6.89	6.23	5.07	7.71	7.27	6.81	4.76	4.02	4.16	2.85	3.10	2.38	3.71	4.64	6.90	4.81	8.20
17	9.11	9.45	10.18	8.61	3.77	5.86	5.17	4.44	6.01	5.13	4.34	8.89	6.38	3.75	3.33	4.92	2.39	1.04	3.72	5.79	6.06	9.37
16	8.27	10.14	7.36	8.72	5.44	9.23	6.26	5.19	4.92	3.36	3.89	8.73	9.65	7.51	4.42	4.34	2.93	5.31	4.94	6.65	7.44	1.76
15	8.14	8.56	7.77	6.47	5.68	6.34	4.11	1.84	2.66	2.24	2.08	4.95	7.70	7.24	3.80	2.00	2.74	2.98	4.60	6.16	8.98	7.28
14	6.44	8.58	6.34	7.29	4.93	4.44	2.63	4.23	3.01	5.58	3.90	4.22	6.31	6.99	2.11	3.84	2.77	2.66	4.82	8.78	6.62	6.86
13	4.48	7.86	6.08	6.34	3.98	4.47	1.37	4.18	1.75	5.71	2.33	3.86	3.04	6.56	3.97	3.43	2.73	3.74	2.76	6.50	7.15	7.67
12	3.75	4.63	4.62	5.42	3.83	3.11	2.74	1.75	1.77	2.24	2.31	3.77	2.85	2.03	1.48	1.37	2.56	1.10	2.38	1.76	5.99	7.57
11	2.44	2.89	5.65	3.98	4.48	4.28	2.90	0.84	1.19	1.07	0.62	1.65	1.84	2.39	2.07	1.72	1.44	3.65	3.53	4.23	4.18	8.79
10	3.49	3.13	3.60	2.31	3.41	4.90	1.59	1.32	0.99	2.33	1.16	0.58	0.41	1.27	1.74	1.58	1.30	3.77	2.79	1.05	6.39	7.04
9	3.40	2.67	2.23	3.24	2.92	2.72	1.95	1.71	3.40	0.54	2.20	1.23	3.26	1.39	2.05	1.26	2.12	1.15	1.81	1.80	0.96	3.32
8	3.53	3.60	1.48	3.65	3.89	2.21	2.34	0.35	3.39	2.78	1.59	2.20	1.94	0.35	2.58	3.26	1.99	3.18	2.72	1.03	1.56	5.09
7	4.14	2.52	2.93	1.72	2.59	1.62	1.50	0.90	1.29	1.20	0.44	2.86	2.07	2.12	1.41	1.45	1.71	1.87	0.57	2.76	2.68	4.71
6	1.51	2.40	3.44	2.43	3.10	1.37	1.33	1.53	1.43	0.74	1.63	1.95	2.16	1.52	0.46	2.35	1.85	1.81	0.67	0.72	1.06	5.04
5	1.58	1.00	0.79	1.84	1.27	2.02	2.44	1.88	5.13	1.70	1.12	1.84	2.56	2.21	2.28	3.60	1.07	3.85	1.47	1.10	1.78	4.20
4	1.99	2.63	1.38	1.41	1.27	0.95	0.99	3.10	2.52	1.59	3.08	2.01	1.31	0.85	2.59	5.12	2.14	2.04	1.25	0.82	0.77	4.03
3	2.28	1.54	3.12	0.38	1.94	2.91	1.18	2.37	3.16	1.48	4.45	2.38	2.81	1.56	3.98	3.46	3.40	2.51	3.47	1.69	3.92	2.39
2	0.90	1.40	0.80	1.48	0.49	2.54	2.61	2.00	4.24	2.44	1.86	1.58	1.71	2.15	0.36	4.02	6.47	3.23	3.03	2.49	5.07	3.68
1	0.22	0.72	1.99	1.28	2.84	1.27	2.19	1.23	2.85	2.20	2.75	2.88	1.55	2.48	1.48	1.30	2.51	1.70	1.63	2.09	2.58	1.13
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**

Figure 6-5: Excluded movements at subtest 2e

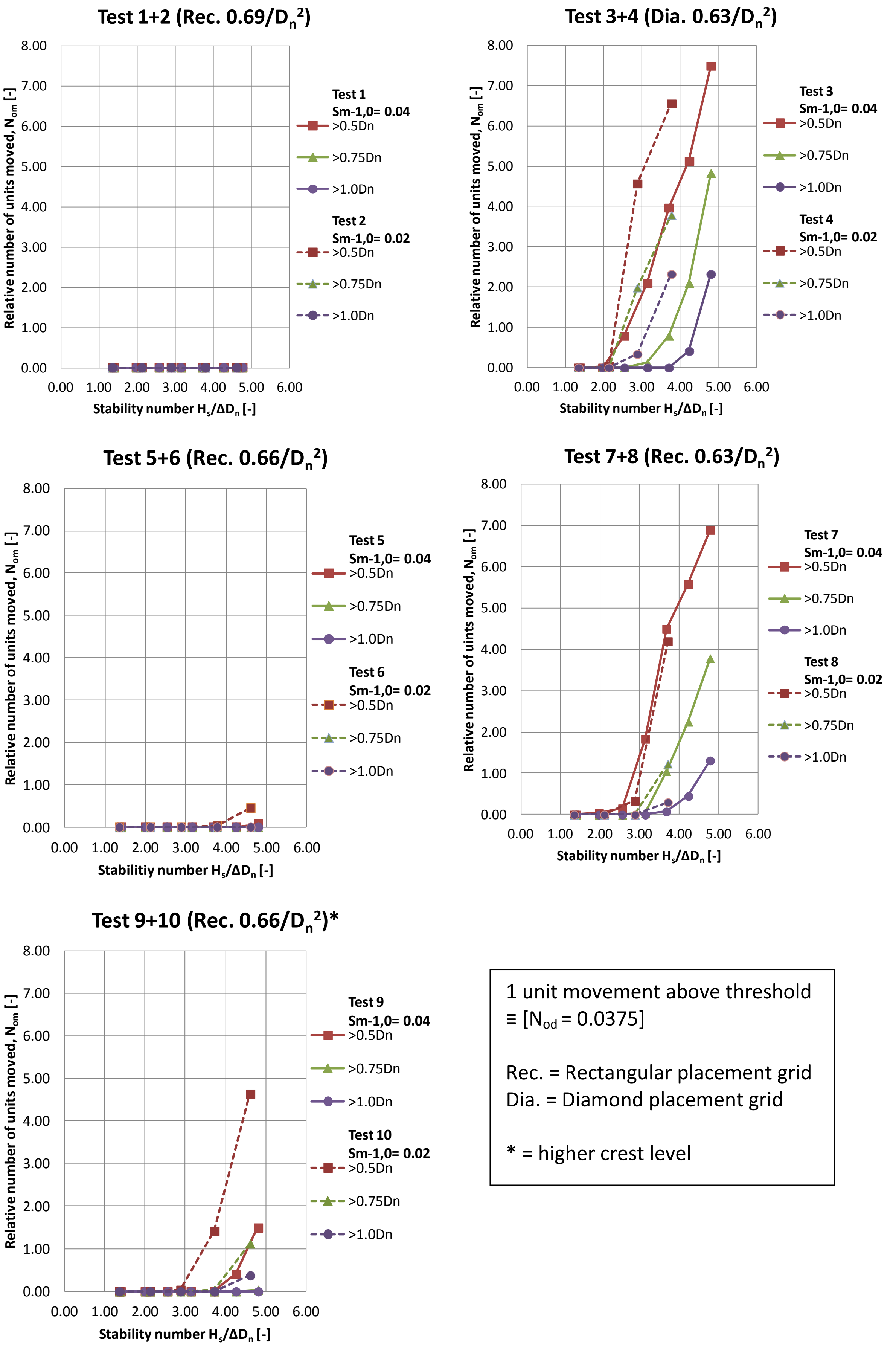


Figure 6-6: Relative number of units moved N_{om} for each test

From Figure 6-6 it can be concluded that wave steepness plays a considerable role in the movement of units. In most cases, the long waves ($S_{m-1,0}$= 0.02) caused more movements compared to the short waves ($S_{m-1,0}$= 0.04). Only the rectangular placement grid with packing density 0.63/D_n^2 showed more movements for short waves.

Furthermore, it is clear to see that a higher packing density experienced less movements of the Crablock units. A higher packing density does not allow for much movement due to the lack of space within the armour. No movements above the threshold levels were observed for packing density 0.69/D_n^2 and the largest movements were found with the lowest packing density 0.63/D_n^2. Hereby it is worth mentioning that a N_{od} value of 4 for example means a movement of more than 100 units, which represents approximately a quarter of all units placed.

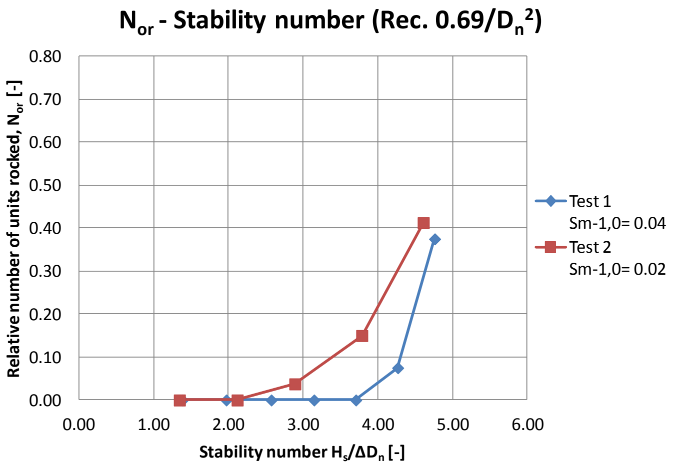
The influence of the crest level is considerable for the packing density of 0.66/D_n^2, the tests with high crest level resulted in larger movements. This can be explained by the exposure to a heavier wave attack since the wave energy of the highest waves was not going over the structure. Although only this packing density was tested for different crest levels it might be expected that there is some influence on other packing densities as well.

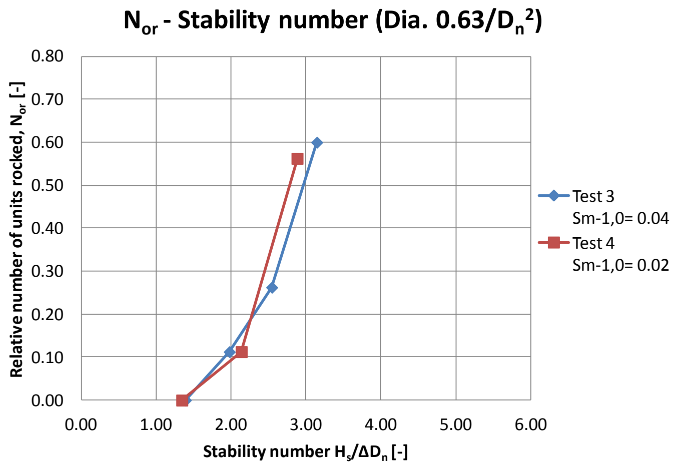
Only minor differences in the movements in the rectangular and diamond placement grid were observed. The diamond placement grid showed slightly larger movements for steepness $S_{m-1,0}$= 0.02 than the rectangular grid. For the short waves there was no difference observed. Since the diamond placement grid was applied with a random unit orientation, the units had more degrees of freedom which may explain the small difference.

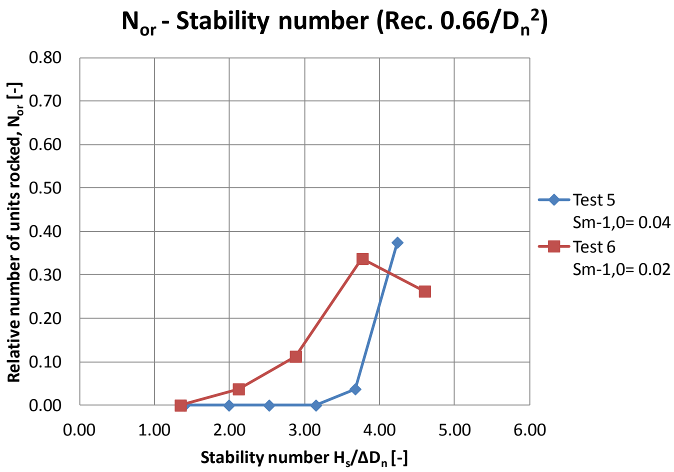
6.3 Damage by rocking

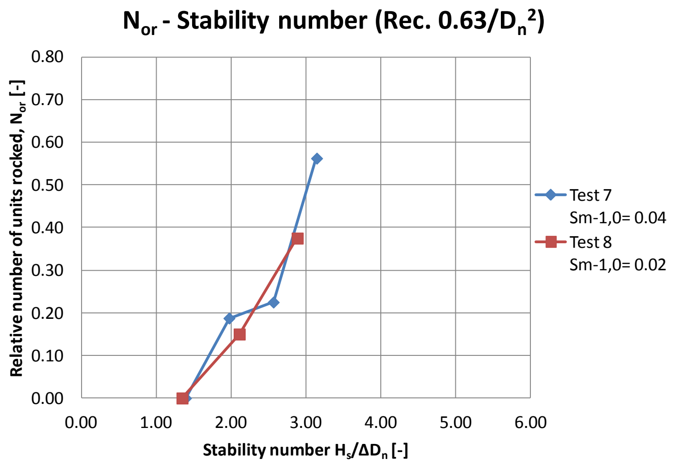
During the physical model tests also rocking of the units was observed. This was quantified by counting the number of units which were rocking during the subtests. The total number of rocking units are expressed in a relative number of units rocked as presented in equation (6.3). The results are plotted below in Figure 6-7.

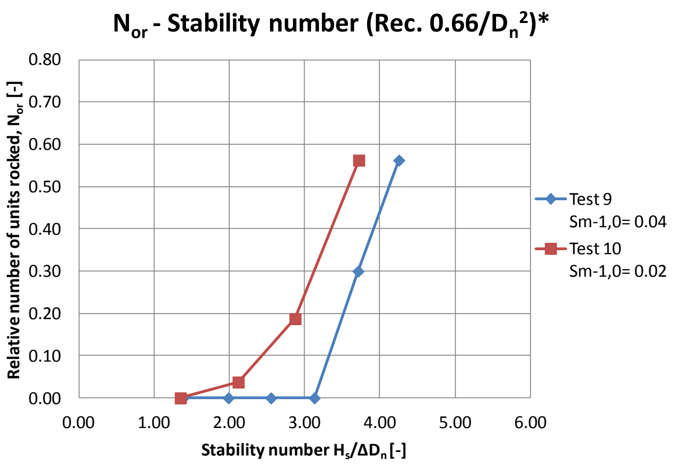
$$N_{or} = \frac{n_r(number\ of\ rocking\ units)}{\frac{0.80\ \text{m}}{0.030\ \text{m}}} \tag{6.3}$$











1 unit rocking ≡ [N_{od} = 0.0375]

Rec. = Rectangular placement grid
Dia. = Diamond placement grid

*= higher crest level

Figure 6-7: Relative number of units rocked N_{or} for all tests

An influence of the crest level on rocking was observed. Looking at packing density $0.66/D_n^2$, test 5 and 6 perform better than test 9 and 10 with higher crest level. The starting point of rocking was equal for both crest levels, but during the higher waves conditions the difference in rocking became considerable. This can be explained by the wave energy that was not going over the structure anymore and needed to be absorbed due to the higher crest level.

The lowest packing density of $0.63/D_n^2$ showed for both the rectangular and diamond placement grid very similar results. This would mean that the influence of placement grid on rocking is negligible.

The influence of the wave steepness was for the rocking criteria not obvious. The long waves ($S_{m-1,0}$= 0.02) caused rocking at an earlier stage than the steep waves ($S_{m-1,0}$= 0.04) for packing densities 0.66-$0.69/D_n^2$. For packing density of $0.63/D_n^2$, it is the other way around.

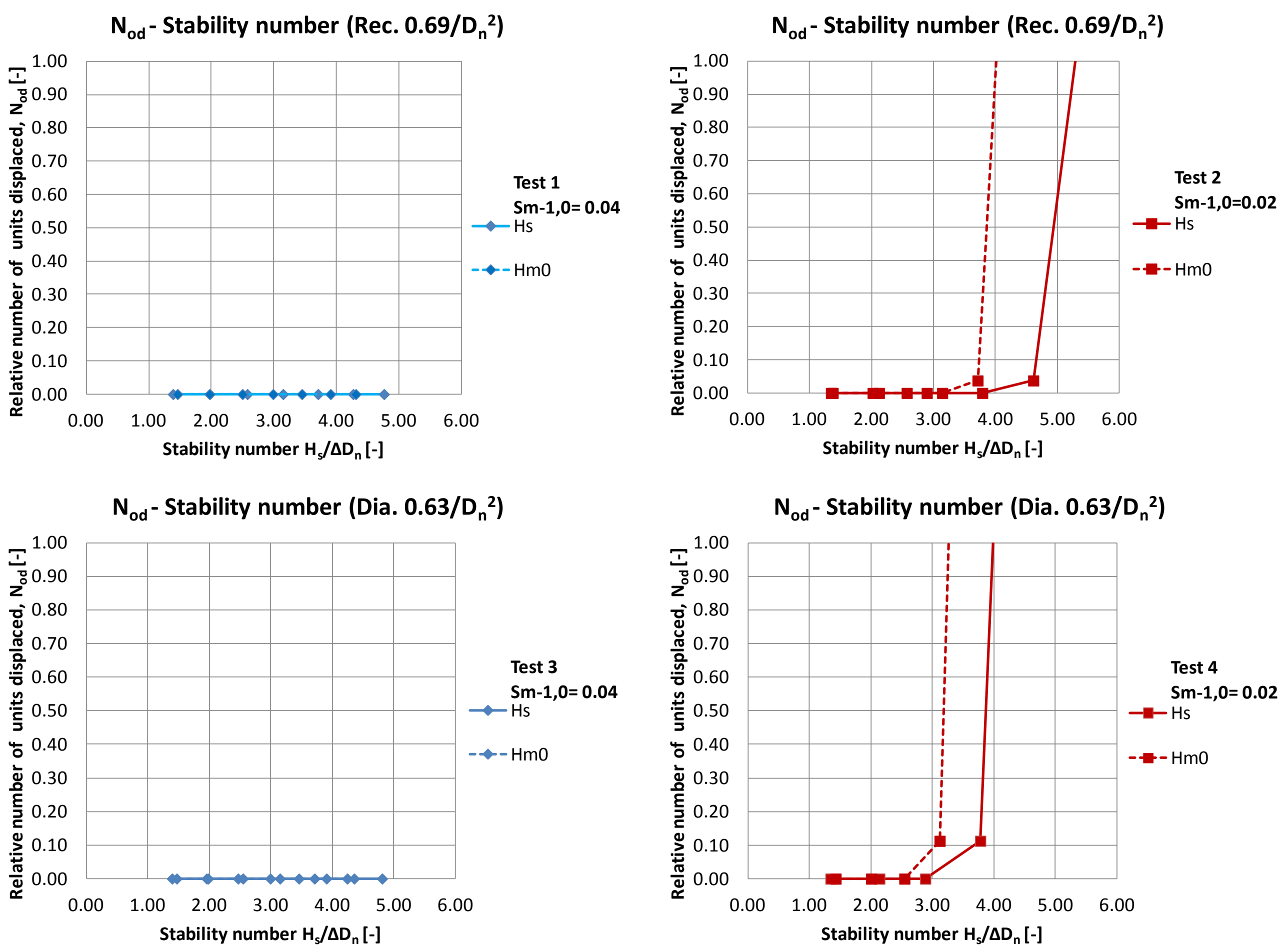
See appendix D for an overview of the rocking development.

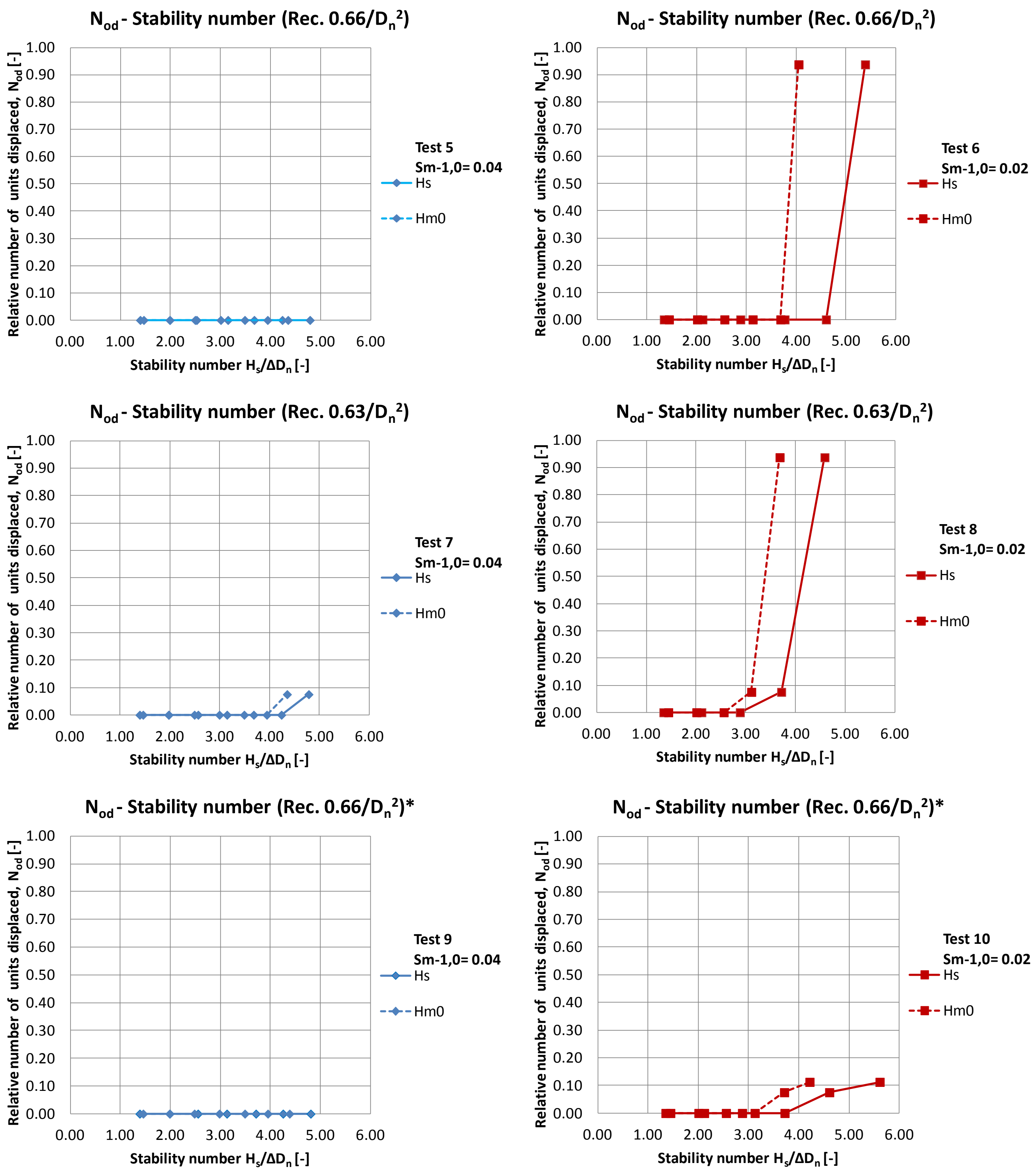
6.4 Discussion results on stability

6.4.1 Damage

Damage by displacements

The corrected damage development by displaced units was used for analysing the stability number. The influence of unit displacements initiated along the side walls was hereby eliminated. Furthermore, the results of this analysis depends largely on which wave heights are used for the stability number. There was a considerable difference between the significant wave height H_s found by time series analysis and significant wave height H_{m0} determined from the spectral analysis. To visualise this difference, the stability numbers plotted in Figure 6-8 are based on both H_s and H_{m0}.





*higher crest level

Figure 6-8: Corrected damage by displacements for stability based on H_s and H_{m0}

For the tests with wave steepness $S_{m-1,0}$= 0.04, the short waves, only a slight damage was obtained during the physical model tests with packing density $0.63/D_n^2$ and rectangular grid. Keep in mind that the maximum wave height reached was not as high as the tests performed with wave steepness $S_{m-1,0}$= 0.02. According to Figure 6-8, the long waves caused damage to the armour layer for all tests. The damage curves found for H_{m0} gave in all cases lower stability numbers, which corresponds to the lower wave heights found for H_{m0} than H_s.

The higher crest level experienced the severe wave attack focussed on the armour slope while for the normal crest level the highest waves attacked the armour at the transition zone from slope to horizontal crest. The heavy attack is therefore focussed on the weakest point of the armour layer.
This might explain the lower number of displacements found for the higher crest level with packing density $0.66/D_n^2$.

In this analysis wave height H_s is used to determine the stability number.

Damage by movements
When concerning a threshold level of $>0.75D_n$, the tests series conducted with packing density $0.63/D_n^2$ show according to Figure 6-9 very large movements in an early stage. The movements larger than $0.75D_n$ started around a stability number of 2 for the diamond grid and around stability number of 3 for rectangular grid.

The movements for packing density $0.66/D_n^2$ started for $S_{m-1,0}$= 0.02 with high crest level for stability numbers larger than 4 as plotted in Figure 6-9. For wave steepness $S_{m-1,0}$= 0.04 only a small exceedance of the threshold level was observed from stability number of 4. For normal crest level, the units did not exceed the threshold level for the whole test series.

The armour layer executed with packing density $0.69/D_n^2$ did not show any movement above the chosen threshold levels at all, so this packing density is not taken into account for this assessment on movement.

Damage by rocking
For analysing the rocking behaviour of Crablock, a criteria of N_{or}= 0.2 is used to eliminate inaccurate placing of the individual armour units. This criteria represents rocking of about 5 units. Looking at Figure 6-9, the armour layer executed with packing density $0.69/D_n^2$ complied this criteria for a stability number of approximately 4. However looking to packing density $0.66/D_n^2$, the rocking criteria was exceeded around a stability number of about 3 for both crest levels.

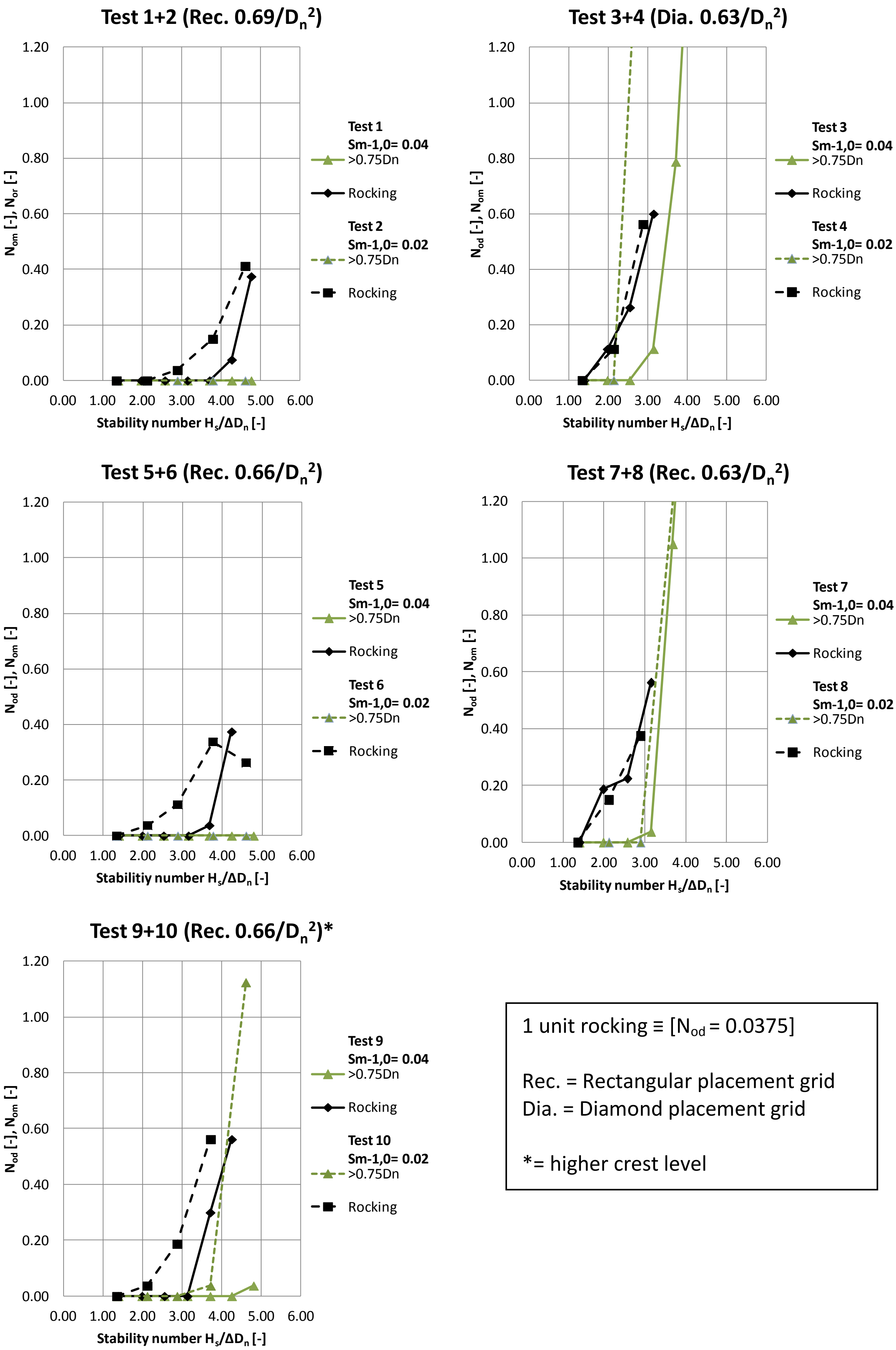


Figure 6-9: Detailed movements >0.75D_n and rocking

6.4.2 Exclude packing density of $0.63/D_n^2$

Although this packing density was by visual observation supposed to be not sufficient in advance but it was nevertheless tested to investigate the behaviour under wave attack. When only considering damage by displacements, the results obtained from packing density $0.63/D_n^2$ were hopeful according to Figure 6-8. For $S_{m-1,0}$= 0.02 the first extraction of units occurred close to a stability number of 4.

Considering the individual movements and rocking of the armour layer, packing density $0.63/D_n^2$ performed very bad. According to Figure 6-9, large movements and considerable rocking started already during low stability numbers. Next to this, the movements resulted in some very loose packed units which rolled over the under layer. This visual observations are more extensively prescribed in chapter 5. Although the units are robust, rolling of units cannot be accepted in order to prevent possible damage to the unit.

Packing density $0.63/D_n^2$ is therefore considered as too loose and not taken into account in further analysis. Since the diamond placement grid is achievable till a packing density of $0.63/D_n^2$, this placement is considered as not applicable for Crablock armour units.

6.4.3 Influence surf similarity parameter

In Figure 6-8 the damage development is plotted for Crablock single layer armour units. The start of damage is based on the corrected displacement of units, the influence of side effects along the walls is thereby eliminated. To visualise the effect of wave steepness, the surf similarity parameter is introduced in equation (6.4). Figure 6-10 includes the stability number on the vertical axis and on the horizontal axis the surf similarity parameter related to the peak wave period, ξ_p, in deep water is plotted. The results belonging to packing density of $0.63/D_n^2$ are not included.

$$\xi_p = \frac{\tan\alpha}{\sqrt{\frac{H_s}{L_p}}}; \text{ Where } \tan\alpha = 3{:}4 \tag{6.4}$$

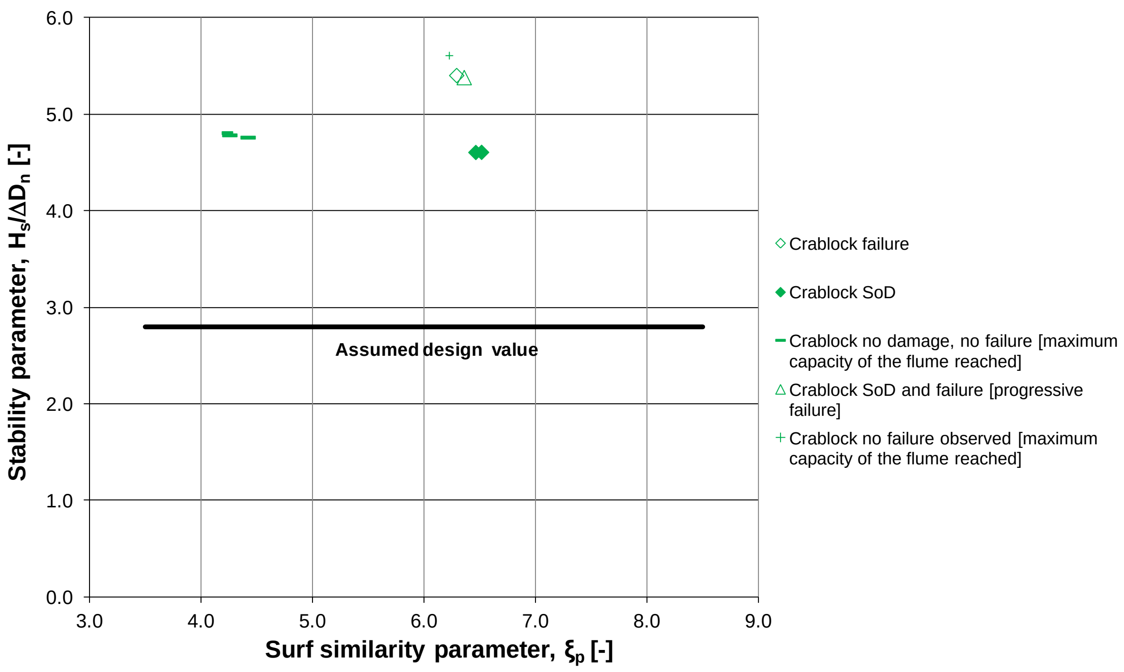


Figure 6-10: Influence surf similarity parameter

Regarding to Figure 6-10, there is no sufficient data available to make conclusions about the influence of the surf similarity parameter. For surf similarity parameters of about 4.5, no damage or failure was obtained before the limit of the generator was reached. Since the stability of the armour layer is already higher without any damage for the lower surf similarity parameters, it might be assumed that damage starts at a higher stage compared to the higher surf similarity parameters. Based on this assumption there is a decrease in the stability of the armour layer with increasing surf similarity parameter.

6.4.4 Design stability number

Breakwaters are designed to withstand extreme wave conditions caused by storm events that occur during the design lifetime of the structure. The determination of the design wave height (in most cases expressed as the significant wave height) is usually based on statistical analysis of long-term extreme wave height measurement. Exceedance of the design wave height might result in damage to a breakwater. However, substantial damage or failure needs to be prevented. The design formula should therefore contain a safety margin to minimise the effects of an underestimated wave height.

Regarding the results of analysis on the hydraulic stability, start of damage by displacements occurred from a stability number of 4.6, see Figure 6-8. This value is only valid for packing densities $0.66/D_n^2$ and $0.69/D_n^2$ and is independent of wave steepness. The results of both wave steepnesses were at least above stability number 4.6.

The movements of the units with the threshold level set on $>0.75D_n$ started for the higher crest level to became considerable from a stability number of 4. Applying a criteria of maximal N_{or}= 0.2 for rocking, the lowest value of the stability number was about 3.

If no damage occurred during the first 1000 waves, more waves were not able to cause damage. The no-damage criterion is therefore independent of the number of waves.

The damage development of the Crablock units under wave attack can for most cases be described as follows: the damage starts at a certain point and after increasing the wave height, the damage continues till failure occurs. Only in case of test series 6 the damage development was progressive. The stage where damage started also led to failure of the armour without increasing the wave height.

Table 6-2: Increase in wave height from Start of Damage to Failure

Test	Packing Density [units/m^2]	Wave height increase from 'Start of Damage' to 'Failure' [%]
1	$0.69/D_n^2$	-
2	$0.69/D_n^2$	17
5	$0.66/D_n^2$	-
6	$0.66/D_n^2$	0
9	$0.66/D_n^2$	-
10	$0.66/D_n^2$	-

Regarding Table 6-2, it is possible that the armour layer may fail immediately after it has experienced first damage. This means a sufficient margin in the design stability number is needed to prevent serious problems after the actual wave height exceed the design wave height. During the physical model tests on Accropode also progressive failure was observed (Delft Hydraulics, 1987). Therefore the required safety factor has to be of the same order as those applied for Accropode.

The movement of units was considerable for stability numbers of about 4, this is assumed as not governing in the determination of the design value because this should be lower anyway. The design value needs to guarantee a complete stable armour. Rocking of units may therefore not occur for wave heights below the design wave corresponding to a certain stability number. The safety margin in the design value of the stability number needs to be sufficient to prevent this.

The safety factor of 1.5 applied on single layer armour unit Accropode resulted in a design value of the stability number of 2.5 (Delft Hydraulics, 1987). For Xbloc, a safety factor of 1.25 resulted in a stability number of 2.8 for design purposes (DMC, 2003). When due to the similar progressive failure an equal safety factor would be applied as for Accropode, the design stability number results in approximately 3. However, a stability number of about 3 is also the point where the criteria on rocking (N_{or}= 0.2) was exceeded. The margin between the design stability number and start of rocking is not known for Accropode but for Xbloc a value of 1.1 is applied (DMC, 2003). This margin of 1.1 is also applied on Crablock with respect to exceedance of the rocking criteria.

Although it might be very conservative, at this stage the design value of the stability number is therefore supposed as 2.8 and is thereby equal as assumed when preparing the model set-up. Nevertheless, the safety factor of 1.6 is considerable and a higher stability factor could be chosen by the owner of Crablock. When taking a higher stability number one should realise that the criteria on rocking has to be less strict.

$$stability\ number = \frac{H_s}{\Delta D_n} = 2.8 \tag{6.5}$$

It should be noticed that the derived formula is based on a limited amount of test series in which several items have been varied. The test series provided with packing density of $0.63/D_n^2$ are not taken into account in this formula so only 6 test series are remaining. To validate the design value additional physical model tests should be performed.

7 Analysis on interlocking degree

The extraction force of the units is expected to be related to the local packing density and the location on the slope. The pull tests were therefore performed with different packing densities and the units were extracted on three different levels on the slope. The influence of wave attack on the extraction force is described in paragraph 7.1, the forces on different crest levels is elaborated in paragraph 7.2. The results obtained from the dry tests only is presented in paragraph 7.3. Finally the actual local packing density is determined for the pull tests after wave attack in paragraph 7.4.

See Appendix F for the data determined from all pull tests.

7.1 Influence wave attack

To determine the influence of wave attack on the interlocking degree of the Crablock units, several pull tests were performed after wave exposure. As described in equation (3.3), the ratio between extraction force and unit weight is defined as the interlocking degree. The test series in the wave flume for analysing the hydraulic stability had to be finished completely before extraction of units could be done. All subtests had to be performed to simulate the settlement of the armour layer during its life time. So the units were extracted on the settled armour layer. After the pull tests had been finished, the units were removed and a new armour layer was built for the following test series.

This pull tests after wave attack were performed on the rectangular grid with uniform placement. For each packing density two tests were performed, one with wave steepness $S_{m-1,0}$= 0.04 and one with wave steepness $S_{m-1,0}$= 0.02. Next to the extraction tests after wave exposure, some dry tests were performed. No settlements within the armour layer were taken into account in the dry tests. The extraction locations applied in the dry tests were based on a fictitious SWL. This makes comparison possible with results obtained after wave exposure. By comparing the interlocking degrees, the influence of the waves on the settling of the units can be defined. Hereby, it is worth mentioning that the maximum wave heights reached for the short and long waves and corresponding stability number were not always equal.

Note: Row 17-19 (above SWL) is mentioned as Location 1 in the analysis below, Row 12-14 (around SWL) as Location 2 and Row 5-7 (below SWL) as Location 3. See Figure 3-12*.*

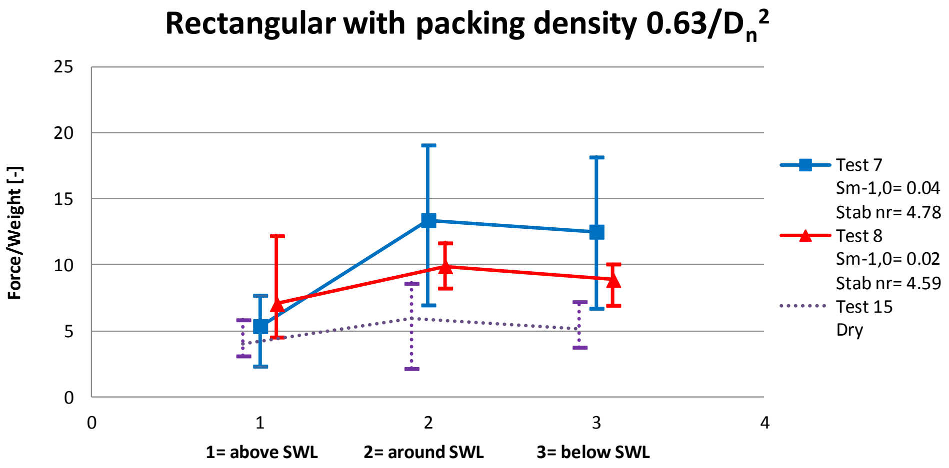


Figure 7-1: Overview average interlocking degree 0.63/D_n^2

Figure 7-1 shows an increase in interlocking degree after exposure of waves. The vertical lines express the deviations found and the horizontal lines resemble the average values. For the dry test the ratio Force/Weight can be characterised in the order of 5 for all three locations, while wave exposure increased this value up to 2-3 times. The short waves ($S_{m-1,0}$= 0.04) caused a deformation of the armour layer which resulted in higher interlocking degrees than the waves with steepness $S_{m-1,0}$= 0.02. The difference in results between the different locations after wave attack can be explained by large settlements around the SWL and thus a higher packing density. A higher packing density is assumed to obtain a higher interlocking degree.

In the dry test no influence of the extraction location was found, the packing was so loose that the units above did not contribute to the interlocking degree by providing some additional weight. The little increase of the average value found around the SWL is just the result of larger deviations.

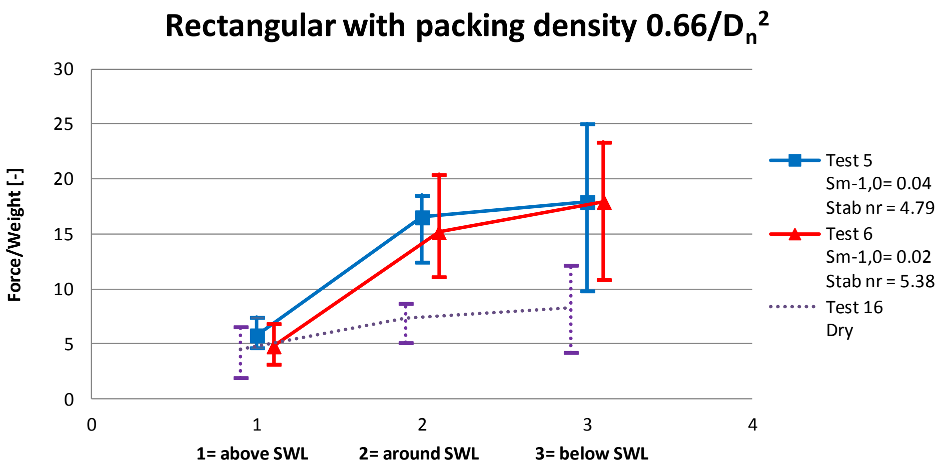


Figure 7-2: Overview average interlocking degree 0.66/D_n^2

A small influence of the wave steepness was in the case of packing density 0.66/D_n^2 observed, see Figure 7-2. The ratio between the interlocking degrees with and without wave exposure is in the order of 3. In this case it can also be assumed that settlement increased the packing density and so the interlocking degree. The interlocking degrees found after wave exposure for Location 2 and 3 were almost equal. However, this comparison is based on armour layers exposed to different wave heights. Due to the increase of interlocking degree from Location 1 to 2, it can be assumed that the packing density of 0.66/D_n^2 provided enough interlocking thus the weight of the units above was affecting the interlocking degree of units located below. The relation between Location 1 and 2 is here presented as linear but this needs some additional research. The linear relation between location 2 and 3 is based on the small difference in interlocking degree supposed as logical.

7.2 Influence crest level

The influence of the crest height on the pulling force is shown in Figure 7-3 and Figure 7-4. The pull tests were performed with different crest levels but with an equal packing density of $0.66/D_n^2$. Because the extraction heights differs for the two crest heights compared to SWL, it is chosen to plot the extraction locations as a ratio of D_n, vertically measured.

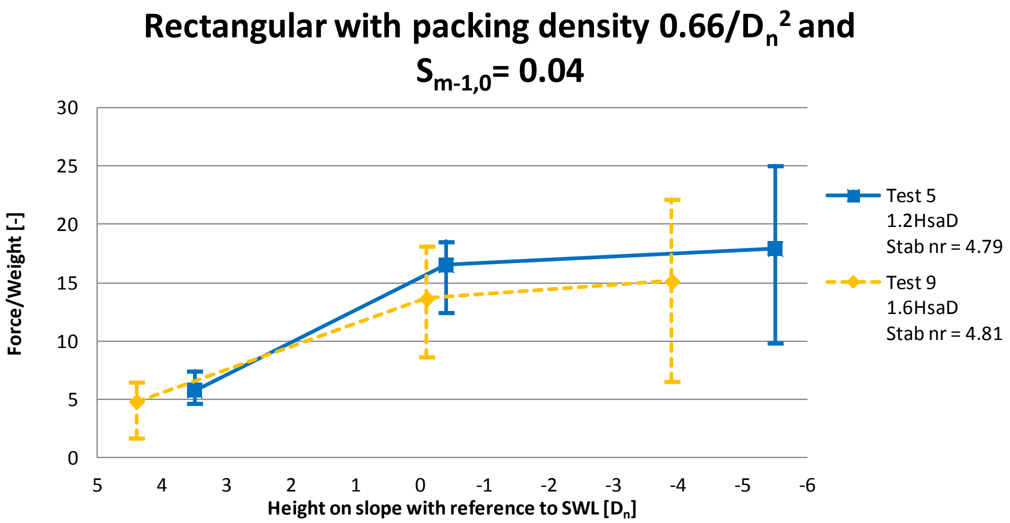


Figure 7-3: Overview interlocking degree $0.66/D_n^2$ and $S_{m-1,0}$= 0.04 with different crest level

Figure 7-3 shows a more or less horizontal relation between the interlocking degrees found around SWL and under the water line. This indicates that for packing density $0.66/D_n^2$ the number of rows above the extraction location is more important than the influence of waves. From a certain number of rows the interlocking degree did not increase any further. The relation between the extraction above SWL and around SWL is here plotted as linear but this is not particularly examined.

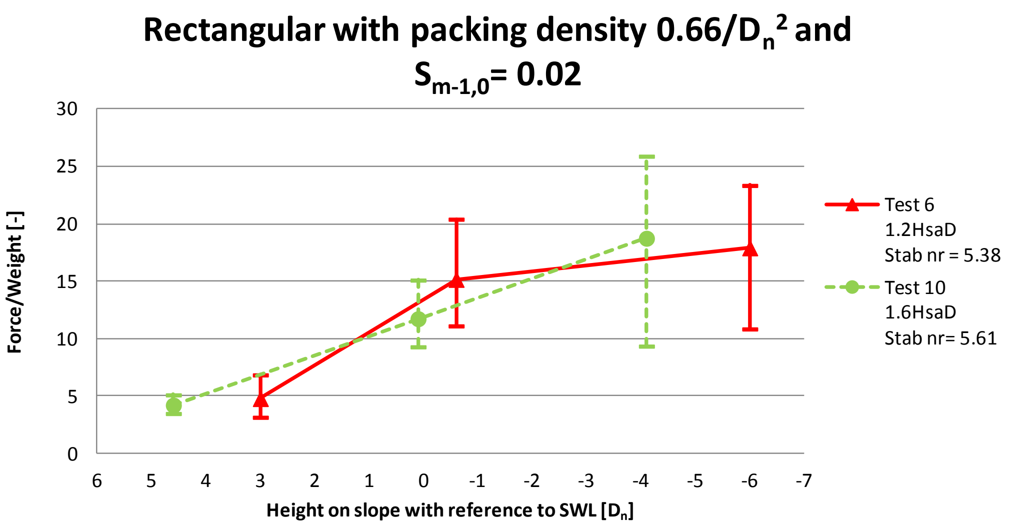


Figure 7-4: Overview interlocking degree $0.66/D_n^2$ and $S_{m-1,0}$= 0.02 with different crest level

The horizontal relation between the interlocking degrees around SWL and below SWL is only observed for the normal crest height, see Figure 7-4. For the high crest level is an increasing interlocking degree found for the different extraction locations.

The movement of individual Crablock units, described in chapter 6.2, showed for the crest level with height $1.6H_{saD}$ bigger values than for a crest level height of $1.2H_{saD}$. The movements were mainly concentrated in the upper part of the armour layer where the waves attack was focussed. This did not result in higher interlocking degrees for locations above and around SWL. The relation between settlement and interlocking degree is therefore not clear for $S_{m-1,0}$= 0.04 as plotted in Figure 7-3.

The larger movements observed for the higher crest level for $S_{m-1,0}$= 0.02 were mainly located between SWL and the upper part of the armour layer. According to Figure 7-4, this resulted in a lower interlocking degree around SWL and an increased interlocking degree for the extractions below SWL. This might be explained by obtaining a lower packing density around SWL and a higher packing density below SWL initiated by settlements.

7.3 Dry tests

The armour layer experienced a considerable influence of the wave attack, as presented in chapter 7.1 and 7.2. The results of all dry tests are therefore combined in Figure 7-5 to provide more insight in the interlocking degree when only considering different packing densities without settlement.

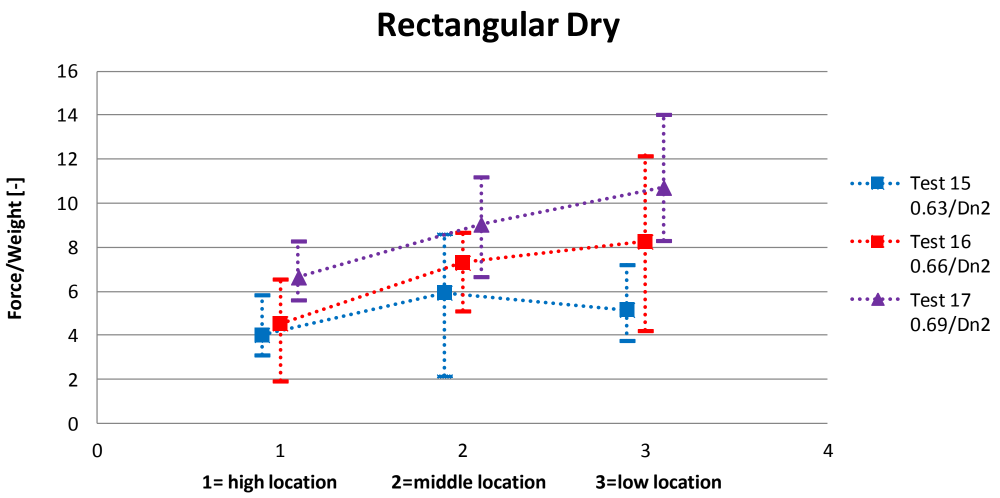


Figure 7-5: Overview averages rectangular dry pull tests

Without settlement, a higher packing density resulted in a higher interlocking degree. From packing density $0.66/D_n^2$, the influence of the additional weight of the units above the extraction was present. This additional weight caused higher interlocking degrees when performing the pull test closer to the base of the armour layer. The almost horizontal relation between Location 2 and 3 is as earlier mentioned, observed for packing density $0.66/D_n^2$ but this is no longer present for packing density $0.69/D_n^2$.

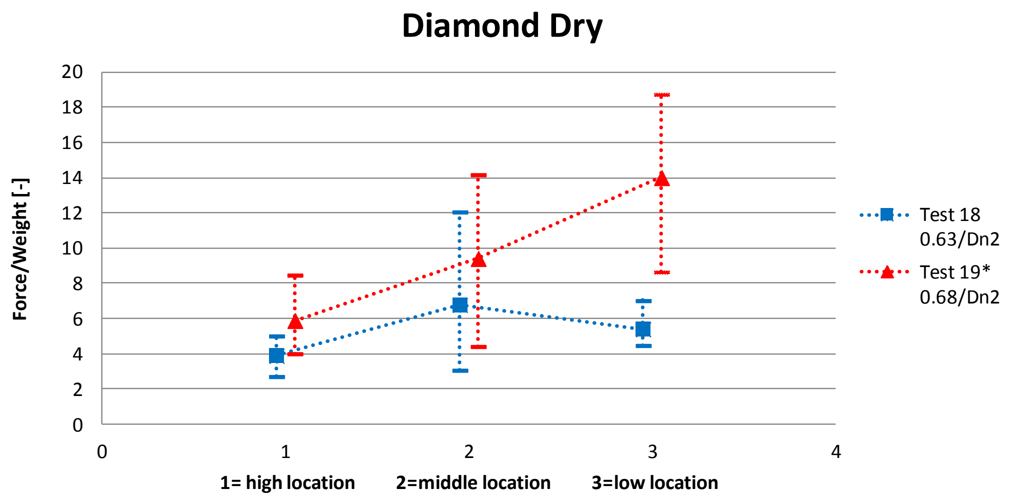


Figure 7-6: Overview averages diamond dry pull tests

** The pull test shown in* Figure 7-6 *with a packing density of 0.68/D_n^2 is not feasible in practice and only performed for better understanding of the interlocking degree of the diamond placing pattern.*

For the diamond placement grid with packing density 0.63/D_n^2, the location of the extraction did not influence the resulting interlocking degrees. The packing density is too low for any influence of the additional weight of the units above. This is also the case with the previously shown rectangular grid with an equal packing density of 0.63/D_n^2. The interlocking degrees belonging to the packing density of 0.68/D_n^2, show a higher value at the bottom of the armour layer. So a considerable influence of the units above was present. The increasing interlocking degree for extractions lower on the armour layer was also observed for packing density 0.69/D_n^2 provided with rectangular pattern, see Figure 7-5. From this is might be concluded that packing density is important for the relation between Location 2 and 3.

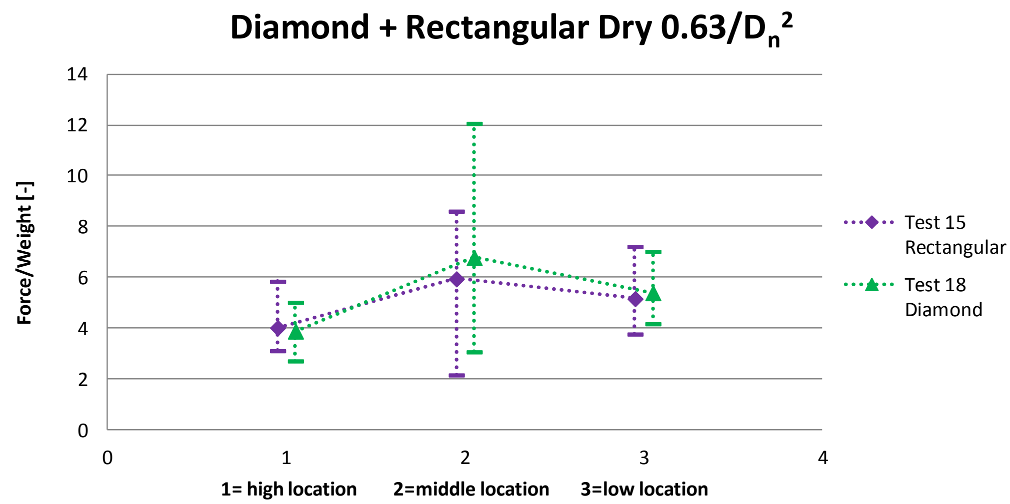


Figure 7-7: Overview average interlocking degree 0.63/D_n^2 with different placement grids

A large deviation was found for both placement patterns in the middle location. This deviation resulted in a higher average interlocking degree in the middle than for the low location.

7.4 Packing density after wave attack

The actual local packing density of the armour layer after exposure to waves is defined afterwards by analysing the photographs. The packing density is determined for each of the three extraction locations. The total area of the extraction location was taken into account by measuring the horizontal length and the vertical length of the three unit rows belonging to the extraction location. This area is divided by the number of units located in the whole extraction location. The resulting packing density is supposed as a representative average value for that extraction location.

Due to the large movements and sometimes damage of the armour layer which is usually concentrated around Location 1, the average packing density found for this location might not be accurate enough. This analysis is only done for initial packing densities $0.63/D_n^2$ and $0.66/D_n^2$ since packing density $0.69/D_n^2$ is not tested after wave attack. In Figure 7-8, the average packing density is plotted on the x axis and the average interlocking degree found for a location on the y axis. The purpose of this figure is to visualise the relation between packing density and interlocking degree.

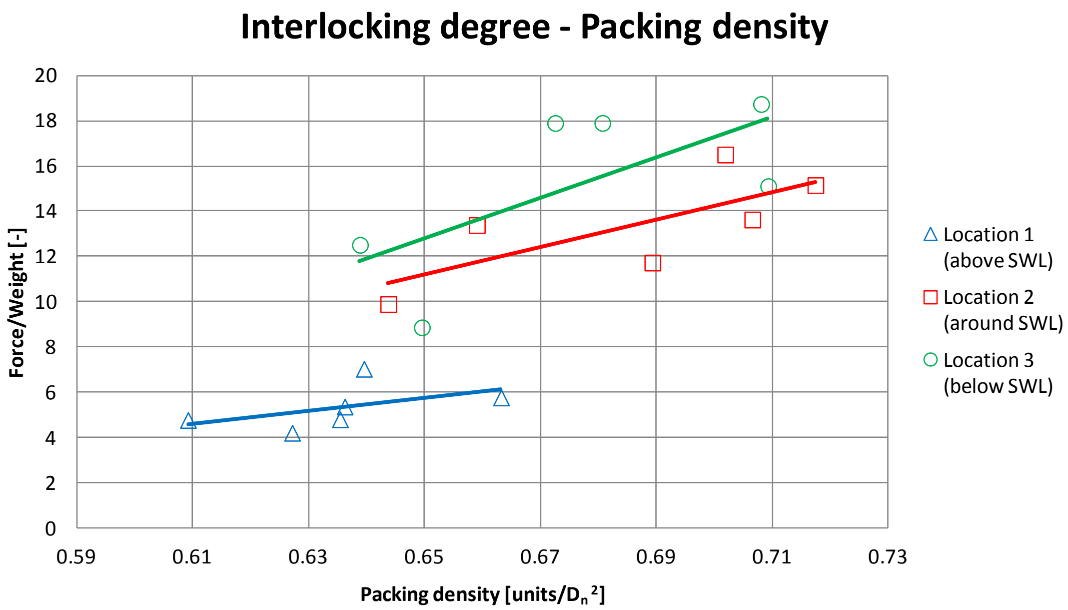


Figure 7-8: Overview interlocking degree corresponding to packing density after wave attack

From Figure 7-8 it is clear to see the interaction between the packing density and the interlocking degree. For all three extraction locations, the interlocking degree becomes higher with an increasing packing density. Furthermore, it is remarkable that not only the packing density plays a role in the interlocking degree but also the extraction location. For the three extraction locations the ratio between the increase of packing density and interlocking degree is different, the slope of the trend lines differ. The more additional rows above the extraction location, the larger the influence on interlocking degree. Furthermore, the local packing density is of importance, this was also shown in the results of the dry placement tests in Figure 7-6.

To analyse the packing densities obtained after wave exposure with respect to the initial packing density is plotted in Figure 7-9 and Figure 7-10.

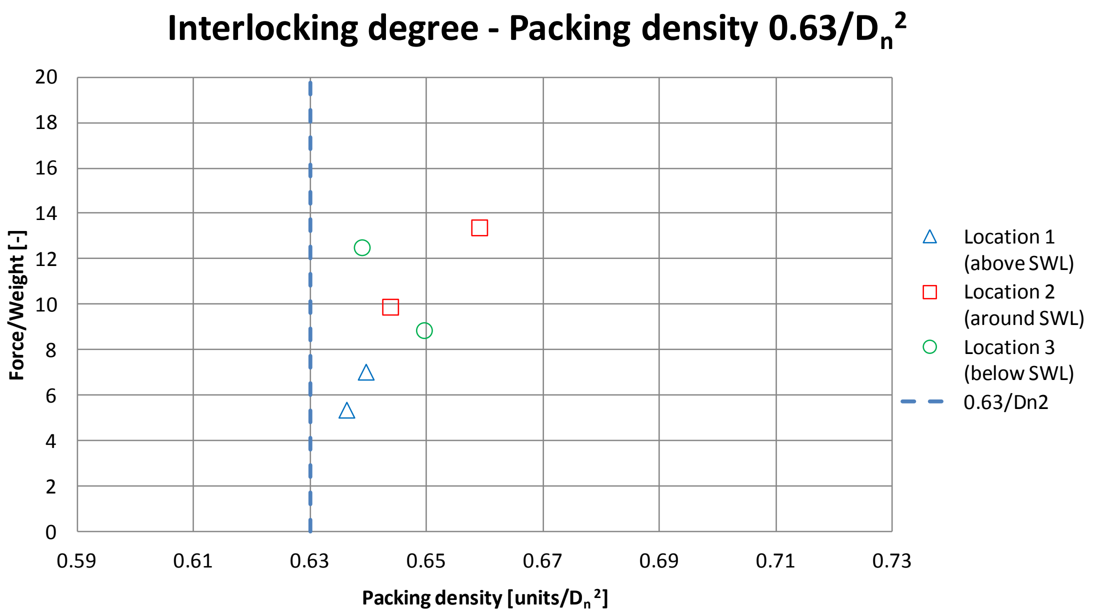
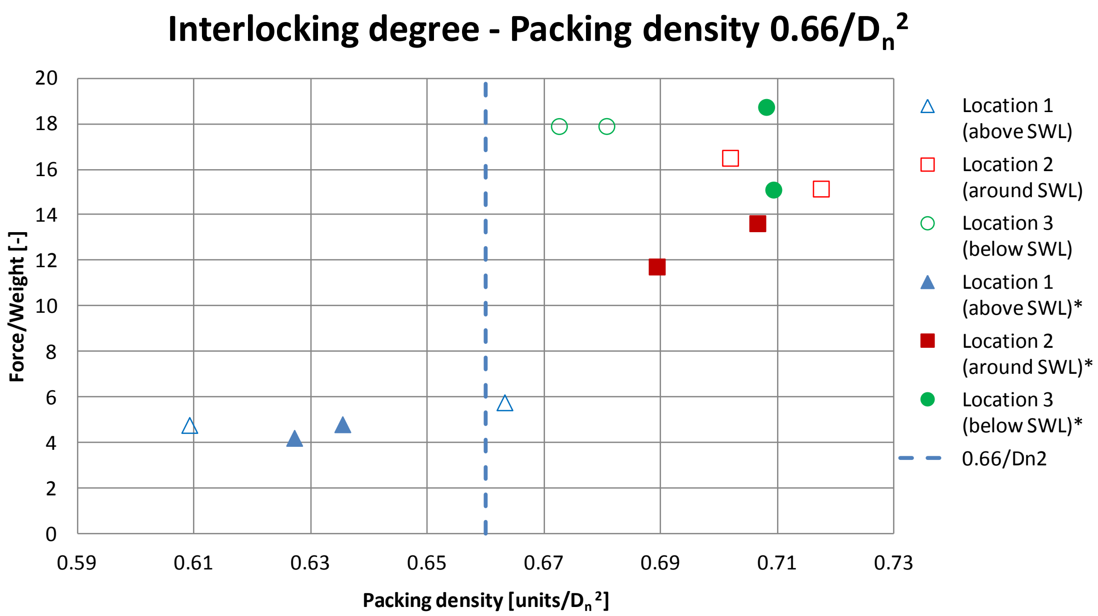


Figure 7-9: Interlocking degree with packing density after wave attack on initial packing density 0.63/D_n^2



*higher crest level

Figure 7-10: Interlocking degree with packing density after wave attack on initial packing density 0.66/D_n^2

Figure 7-9 and Figure 7-10 show that an increase in packing density is obtained for extraction Location 2 and 3. Wave attack caused settlement of Crablock units which resulted in higher packing densities. This settlements resulted in lower packing densities at the upper part of the armour layer. The lower packing densities were sometimes located at extraction Location 1. Occurrence of displacements was concentrated at the upper part of the armour layer so this was also decreasing the packing density of Location 1.

8 Comparison with other single layer armour units

In chapter 8 the results found for hydraulic stability and interlocking degree is compared with other single layer armour units. In paragraph 8.1, the hydraulic stability is compared with Accropode and Xbloc. The interlocking degree of Crablock is compared with Xbloc in paragraph 8.2.

8.1 Stability comparison

In this paragraph the comparison is made between the Crablock and the earlier tested single layer armour units Accropode and Xbloc. These units were extensively tested and therefore the data necessary for comparison is available. The set-up of the physical model tests performed on these three units was almost similar. All had a deep water part where the waves were generated and had a 1:30 sloping foreshore for the transition to shallow water in front of the structure. Although the configurations were comparable, there are some differences in the test conditions. The Crablock and Xbloc have been tested with a JONSWAP wave spectrum (DMC, 2003) and the Accropode have been tested with a Pierson-Moskovitz spectrum (Delft Hydraulics, 1987). For Accropode “constant wave height tests” were performed, while for Xbloc and Crablock “increasing wave height test series” were performed.

The packing density of $0.63/D_n^2$ is according to the analysis done in previous chapters assumed to be not sufficient. The results belonging to this packing density are therefore not included in this comparison with other single layer armour units.

An overview of the packing densities applied in the small scale model tests of the three units is given in Table 8-1.

Table 8-1: Packing densities applied per unit type

Unit	Packing density [units/m^2]
Accropode	$0.64/D_n^2$
Xbloc	$0.55\text{-}0.59/D_n^2$
Crablock	$0.66\text{-}0.69/D_n^2$

More specifications of Crablock with corresponding packing density can be found in appendix G.

The data based on displacement of units for the experiments on hydraulic stability on Accropode, Xbloc and Crablock is plotted in Figure 8-1, Figure 8-2 and Figure 8-3.

There is no data available to quantify the unit movement and rocking for the physical model tests on Accropode and Xbloc. The comparison is therefore not made for these subjects.

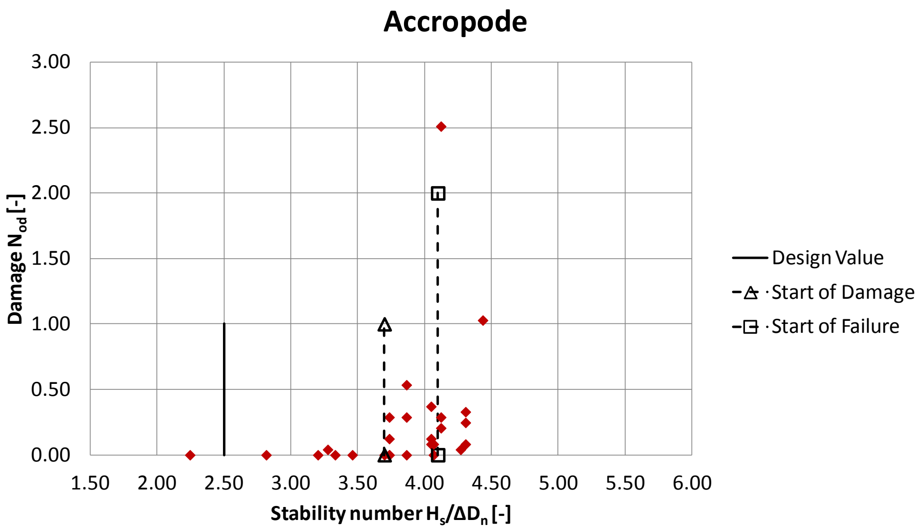
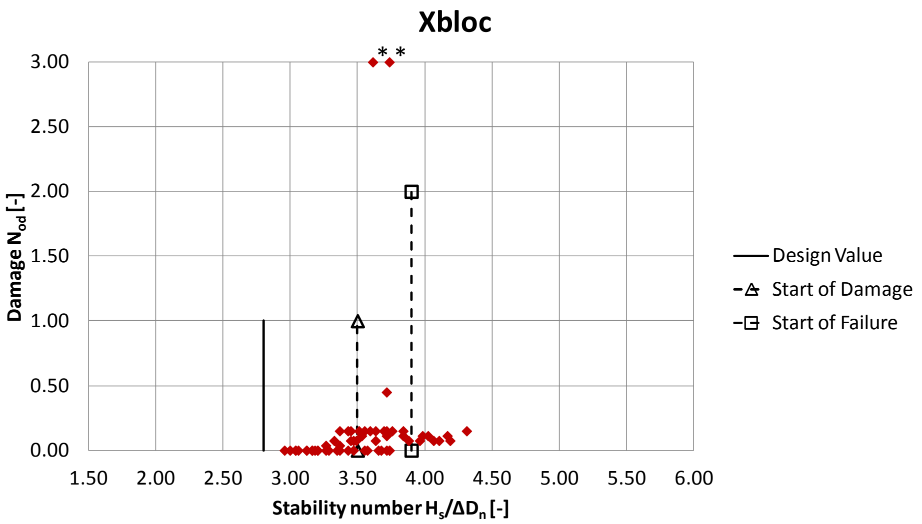


Figure 8-1: Stability of Accropode [Delft Hydraulics, 1987]



* failure presented as N_{od} = 3.0 instead of N_{od} = 15 to keep the graph clear

Figure 8-2: Stability of Xbloc [DMC, 2003]

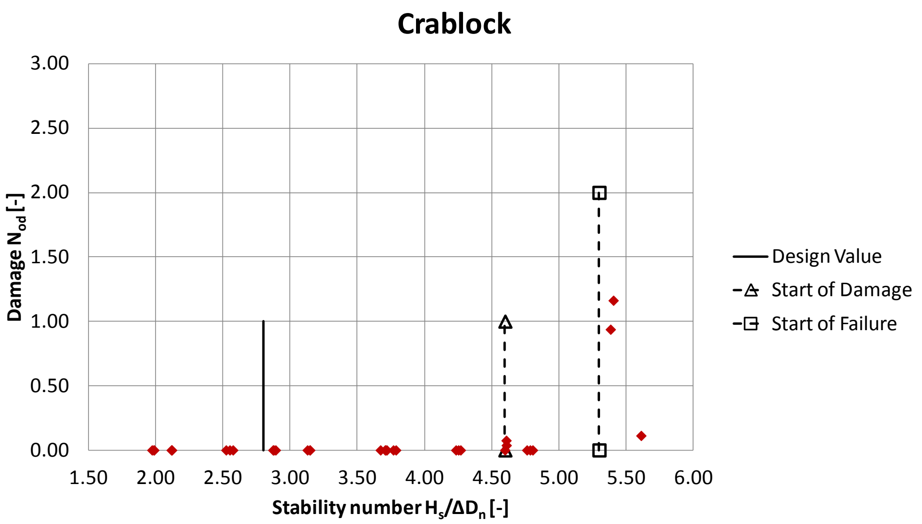


Figure 8-3: Stability of Crablock

Since Xbloc was tested with different packing densities the average start of damage and average start of failure are given in Figure 8-2. For the tests where no failure has been observed, the highest measured stability numbers have been used for the average value (DMC, 2003). In case of the physical tests on Crablock the lowest values are used although also multiple packing densities were applied.

The hydraulic performance of the Crablock units is, based on Figure 8-3, more stable than the single layer armour units Accropode and Xbloc. The stability number where first damage was observed was for the Crablock unit larger than Accropode and Xbloc, respectively 24% (Delft Hydraulics, 1987) and 31% (DMC, 2003). Failure occurred also at a higher stability number than for Accropode (29%) and Xbloc, (36%).

The difference in design value of the stability number largely depends on which safety factor is applied with respect to the start of displacements. In case of Accropode a considerable factor of 1.5 (Delft Hydraulics, 1987) is used due to the chance on progressive failure. For Xbloc a smaller safety factor of 1.25 is used for a minimal packing density of $0.58/D_n^2$ (DMC, 2003). The design value for Crablock is very conservative because a factor of 1.6 is applied. This safety factor is based on a strict criteria on rocking.

8.2 Interlocking degree comparison

The results of the dry extraction tests performed on Crablock armour units can be compared with the extraction tests performed on Xbloc (De Lange, 2010). The extraction tests on Xbloc were performed in dry conditions with packing density $1.20/D^2$ (or $0.58/D_n^2$) and were varied with different under layers, slope angles and unit densities. Only the relevant test is taken into account for this comparison. In Figure 8-4, the results obtained from the research on Xbloc were plotted together with the results found on the research on Crablock.

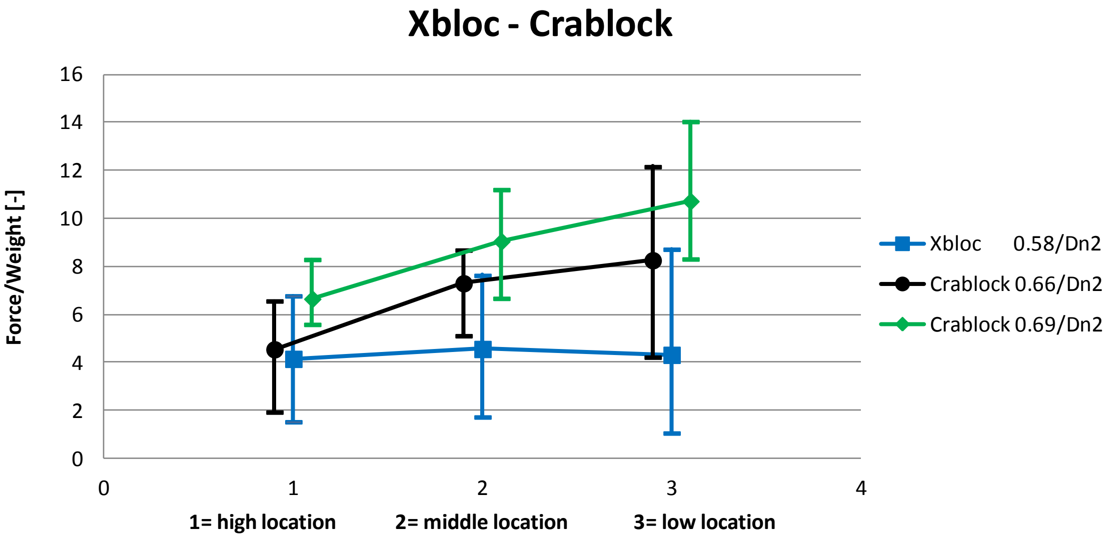


Figure 8-4: Comparison dry extraction tests Xbloc-Crablock

Regarding Figure 8-4 it might be concluded that the interlocking degree of Crablock executed with packing density $0.66/D_n^2$ is for the high located extraction from the same order. On the other hand, for the middle location the interlocking degree is about 75% higher and for the low location even double as high.

For the Crablock armour layer consisting of packing density $0.69/D_n^2$, Figure 8-4 shows an increase of 75% of the interlocking degree for the high extraction location. The middle location gives for Crablock about double the interlocking degree and for the low location an increase of 175% was achieved.

9 Conclusions and recommendations

The results and discussions for the tests on hydraulic stability and interlocking degree are described in chapter 6 and 7. Based on these observations, the conclusions of the physical model tests and tests on the interlocking degree are presented in paragraph 9.1. Finally, this chapter ends up by giving recommendations for future research on the development of the single layer Crablock armour unit in paragraph 9.2.

9.1 Conclusions

Based on the observations and analysis, the research questions are answered in this section for each specific question.

- *How does the placement pattern influence the hydraulic stability of the Crablock?*
  In the small scale physical model tests two different placement methods were applied. Rectangular grid with uniform placement and a diamond grid with random placement. Only packing density $0.63/D_n^2$ was tested with these two placement methods because a higher packing density with diamond grid is considered as not feasible in practice. Looking at 'Start of Damage', there is no distinction between both placement patterns observed. Considering the movement of the individual units, the test series with long waves show an increase in movements for the diamond grid in comparison with rectangular grid. The movements were equal for short waves. The results on rocking showed for both placement methods similar results. The influence of placement pattern on the hydraulic stability is therefore not present. Since packing density $0.63/D_n^2$ is eliminated for design purposes, diamond placement grid is considered as not applicable for Crablock.

- *How does the wave steepness influence the stability?*
  Considering the displacements, wave steepness $S_{m-1,0}$= 0.02 causes more damage than wave steepness $S_{m-1,0}$= 0.04 for equal wave heights. The wave steepness has therefore certainly an influence on the displacements. Long waves could reach higher wave heights which explains the occurrence of damage during these test series where there was not any damage observed for the short waves test series. The stability number reached was just higher. The test series with wave steepness $S_{m-1,0}$= 0.02 resulted also in larger movements. For packing densities $0.66/D_n^2$ and $0.69/D_n^2$ rocking starts at an earlier stage for the long wave test series although this is the other way around with packing density $0.63/D_n^2$. However, packing density $0.63/D_n^2$ is for the analysis not taken into account. It may be concluded that wave steepness $S_{m-1,0}$= 0.02 affected the hydraulic stability more than $S_{m-1,0}$= 0.04. This influence is especially present at higher stability numbers so for design purposes it can be assumed that wave steepness is no parameter of consideration.

- *What is the stability number of the Crablock?*
  The hydraulic stability of Crablock can be expressed in a stability number. This is commonly used to indicate the stability of concrete armour units. Based on the observations for movement and rocking, packing density $0.63/D_n^2$ is assumed as not sufficient for Crablock. To define the hydraulic stability of Crablock only packing density $0.66/D_n^2$ and $0.69/D_n^2$ are therefore considered. First occurrence of displacement was observed at a stability number of

4.6 for both packing densities and crest levels. Movements above threshold level >0.75D_n were for a normal crest level not observed for both packing densities. In case of the higher crest level with packing density 0.66/D_n^2, the movements with wave steepness $S_{m-1,0}$= 0.02 exceed the threshold level from about a stability number of 4. The rocking criteria of N_{or}= 0.2 is exceeded around a stability number of 3. A safety margin of 1.1 is taken between the design value and exceedance of the rocking criteria. This leads to a supposed conservative stability number of 2.8, which corresponds with a safety factor of 1.6 when taking first occurrence of displacement into account. Note that this safety factor is rather high so it could be attractive for the owner of Crablock to choose a higher stability number. When taking a higher stability number, one should allow a less strict rocking criteria.

$$stability\ number = \frac{H_s}{\Delta D_n} = 2.8 \tag{9.1}$$

This stability number is defined for the 'no damage' criterion for packing densities between 0.66/D_n^2 and 0.69/D_n^2, whereof 0.69/D_n^2 is supposed as the maximum achievable in practice. This value is independent of the number of waves and wave steepness. Furthermore, the crest level of 1.2 times the design significant wave height is recommended to prevent large movements. This movements might lead to a complete loss of interlocking which introduces the risk of rolling of units.

- *Which placement pattern has best interlocking properties?*
  Only dry pulling tests were performed on the two different placement patterns based on rectangular and diamond grid. These tests were both executed with a packing density of 0.63/D_n^2. There were no differences observed between the different placement patterns, see also Figure 7-7. The deviation and average values found for the three different extraction locations are very similar. It should be noted that packing density 0.63/D_n^2 is not supposed sufficient and since diamond grid is applicable with a maximum packing density of 0.63/D_n^2, diamond grid is considered as not possible in Crablock armour design. The results of the pull tests showed that the interlocking degree was dependent of the local packing density and the location on the armour layer.

  When only considering the rectangular placement grid the following can be concluded: the relation between the interlocking degrees of the three extraction locations depends, based on dry tests, on the packing density. For packing density 0.63/D_n^2 there is no influence from rows above. Packing density 0.66/D_n^2 got nearly equal results for Location 2 and 3, from a certain number of rows above there was no influence on interlocking anymore. An increase over the three locations was observed for packing density 0.69/D_n^2, the number of rows did matter.

- *How does the interlocking degree influence the hydraulic stability?*
  Only rectangular placement grid with normal crest level is taken into account in this comparison. For the values for the interlocking degree, the average values from the dry pull tests are used.

Table 9-1: Hydraulic stability and interlocking degree

Test	Packing density [units/m^2]	$S_{m-1,0}$ [-]	Stab. nr at first Displacement [-]	Interlocking degree		
				Location 1	Location 2	Location 3
1	$0.69/D_n^2$	0.04	-	6.65	9.05	10.72
2	$0.69/D_n^2$	0.02	4.61	6.65	9.05	10.72
5	$0.66/D_n^2$	0.04	-	4.55	7.30	8.26
6	$0.66/D_n^2$	0.02	5.38	4.55	7.30	8.26
7	$0.63/D_n^2$	0.04	4.78	4.02	5.94	5.16
8	$0.63/D_n^2$	0.02	3.72	4.02	5.94	5.16

Packing density 0.66-$0.69/D_n^2$: an increase of interlocking degree in the order of 2 was over all three extraction locations observed, see Table 9-1. No damage by displacement of units was observed for wave steepness $S_{m-1,0}$= 0.04, for both packing densities. Wave steepness $S_{m-1,0}$= 0.02 caused for packing density $0.69/D_n^2$ earlier displacements than for packing density $0.66/D_n^2$ and failure happened for equal wave heights. From this it might be concluded that there is no clear relation between the interlocking degree and hydraulic stability. Movements and rocking are not taken into account in this comparison.

Packing density 0.63-$0.66/D_n^2$: an increase of interlocking degree up to a value of 3 for Location 3 was observed, see Table 9-1. For short waves ($S_{m-1,0}$=0.04) no damage was observed for packing density $0.66/D_n^2$ while for packing density $0.63/D_n^2$ displacements were observed in the last subtest. Due to the absence of damage for packing density $0.66/D_n^2$, no full comparison can be made for this wave steepness. A big difference between the two packing densities was observed for long waves.

The interlocking degree for packing density $0.63/D_n^2$ is not sufficient and an increase in packing density directly results in a higher hydraulic stability. From packing density $0.66/D_n^2$ and higher the interlocking degree is sufficient and an increase in interlocking does not influence the stability anymore.

- *How does the Crablock perform in comparison with other single layer armour units?*
Considering the displacements of units, the hydraulic performance of Crablock is better than other single layer amour units Accropode and Xbloc. However, the packing density of Crablock is also higher, and so the concrete use. When looking at the actual start of damage by displacement in the model tests, see Table 9-2, Crablock is much more stable.

Table 9-2: Start of damage by displacement of units

Unit	Stability number $H_s/\Delta D_n$ [-]
Accropode	3.7
Xbloc	3.5
Crablock	4.6

Based on the recommended stability number of 2.8 the Crablock unit can be applied with more safety than Accropode and much more than Xbloc. However, when the owner of Crablock chooses to take a higher stability number for design purposes the concrete use can be reduced. For the comparison on movements and rocking no data is available for Accropode and Xbloc.

The interlocking degree can only compared with the pull tests performed on Xbloc. These pull tests were done without influence of wave attack. The armour layer of Xbloc was provided with packing density $0.58/D_n^2$, although the pull tests on Crablock were performed with higher packing densities. The resulting interlocking degree of Crablock is 2 to 3 times higher than determined from the pull tests on Xbloc.

9.2 Recommendations

9.2.1 Hydraulic stability

- Two different crest levels were considered in this research. To determine the influence of crest level, additional physical model tests are advised with more different crest levels.
- Only perpendicular wave attack is considered in the physical model tests performed, to determine the influence of oblique waves additional tests are needed.
- When building the physical model in the wave flume, the placement of Crablock armour units needed special attention. The first row had to be placed very accurately, otherwise placement of succeeding rows above was not possible anymore. In this research the stones belonging to the toe got the right position and orientation so the first row of units could be placed as desired. In practice is this method very complicated and probably unacceptable. A possible solution for this first row might be a modification of the armour unit or the design of a separate base block which can only be used in the first row.
- Displacement of units was observed at high stability numbers around 4.6 but considerable rocking occurred already around stability number of 3. The criteria set for rocking were at this moment limiting the design value of Crablock. Investigation of the structural strength of Crablock is needed so the impact of rocking on the hydraulic stability might be reduced.

9.2.2 Interlocking degree

- The interlocking degree only based on single tests, more test with equal set-up are advised to determine a more reliable average value.
- To investigate the relation between the interlocking degree of Location 1 (above SWL) and Location 2 (around SWL) more research is needed for the rows in between. The relation is in this report presented as linear but this is not particularly examined.

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Appendixes

A. Single and double layer armour systems

Table A-1: Overview single layer armour units

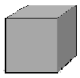
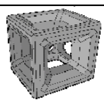
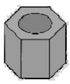
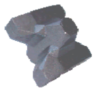
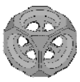
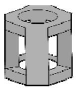
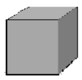
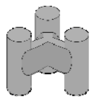
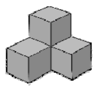
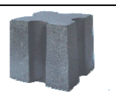
Single layer armour systems					
Unit		Placement pattern	Main stability parameter	Year developed	Country
Cube		Random/uniform	Own weight	-	-
Cob		Uniform	Friction	1969	UK
Seabee		Uniform	Friction	1978	Australia
Accropode™		Random	Interlocking	1980	France
Shed		Uniform	Friction	1982	UK
Core-Loc®		Random	Interlocking	1996	USA
Diahitis		Uniform	Friction	1998	Ireland
A-Jack®		Random	Interlocking	1998	USA
Xbloc®		Random	Interlocking	2003	NL
Accropode II™		Random	Interlocking	2004	France
Core-loc II®		Random	Interlocking	2006	USA
Crablock™		Random/uniform	Interlocking	2007	UAE

Table A-2: Overview double layer armour units

Double layer armour systems					
Unit		Placement pattern	Main stability parameter	Year developed	Country
Cube		Random/uniform	Own weight	-	-
Tetrapod		Random/uniform	Own weight/ interlocking	1950	France
Tribar		Random	Own weight/ interlocking	1958	USA
Modified cube		Random	Own weight	1959	USA
Stabit		Random	Interlocking	1961	UK
Akmon		Random	Own weight/ interlocking	1962	NL
Tripod		Random	Own weight/ interlocking	1962	NL
Dolos		Random	Interlocking	1963	Republic of South Africa
Antifer cube		Random	Own weight	1973	France

B. Wave conditions

Table B-1: Overview wave conditions with structure (1)

	Structure											Deep									
Test No	H_{m0} spectrum analysis [m]	H_{m0} extrapolation [m]	H_s time series [m]	H_s extrapolation [m]	Stability number based on extrapolation H_s [-]	Stability number based on extrapolation H_{m0} [-]	T_p [s]	$T_{m-1,0}$ [s]	Wave Length, L_z [m]	Wave Steepness, S_{op} [-]	Reflection co-efficient [-]	H_{m0} spectrum analysis [m]	H_s time series analysis [m]	T_p [s]	$T_{m-1,0}$ [s]	Wave Length, L_z [m]	Wave Steepness, S_{op} [-]	Surf similarity par ξ_p [-]	Wave Length, $L_{m-1,0}$ [m]	Wave Steepness, $S_{m-1,0}$ [-]	Reflection co-efficient [-]
1a	0.06	0.06	0.06	0.06	1.39	1.46	1.25	1.15	1.96	0.03	0.41	0.07	0.07	1.25	1.15	2.42	0.03	4.50	2.05	0.03	0.31
1b	0.08	0.08	0.08	0.08	1.97	1.97	1.43	1.32	2.38	0.03	0.45	0.10	0.10	1.45	1.32	3.28	0.03	4.39	2.73	0.04	0.31
1c	0.10	0.10	0.10	0.11	2.57	2.50	1.63	1.49	2.71	0.04	0.48	0.12	0.13	1.61	1.47	4.04	0.03	4.27	3.39	0.04	0.32
1d	0.12	0.12	0.13	0.13	3.15	2.99	1.91	1.64	2.98	0.04	0.52	0.15	0.15	1.74	1.61	4.75	0.03	4.20	4.06	0.04	0.32
1e	0.14	0.14	0.16	0.15	3.71	3.45	1.97	1.81	3.17	0.04	0.54	0.18	0.18	1.84	1.73	5.27	0.03	4.09	4.67	0.04	0.31
1f	0.16	0.16	0.19	0.17	4.27	3.91	2.07	1.90	3.51	0.04	0.54	0.20	0.21	2.01	1.86	6.32	0.03	4.19	5.38	0.04	0.30
1g	0.16	0.18	0.21	0.19	4.76	4.31	2.18	1.97	3.95	0.04	0.57	0.22	0.23	2.23	1.95	7.80	0.03	4.42	5.93	0.04	0.28
2a	0.06	0.06	0.06	0.05	1.35	1.37	1.71	1.63	2.97	0.02	0.50	0.07	0.07	1.74	1.59	4.72	0.01	6.39	3.96	0.02	0.35
2b	0.08	0.08	0.09	0.09	2.12	2.02	2.09	1.97	3.51	0.02	0.57	0.10	0.10	2.01	1.90	6.32	0.02	6.02	5.64	0.02	0.36
2c	0.09	0.10	0.12	0.12	2.89	2.57	2.33	2.28	3.99	0.02	0.65	0.13	0.13	2.26	2.16	7.96	0.02	5.96	7.31	0.02	0.35
2d	0.11	0.13	0.14	0.15	3.79	3.14	2.54	2.44	4.57	0.02	0.70	0.16	0.16	2.56	2.37	10.21	0.02	6.08	8.79	0.02	0.33
2e	0.14	0.15	0.16	0.19	4.61	3.71	2.39	2.17	5.39	0.03	0.60	0.18	0.19	2.99	2.56	13.93	0.01	6.51	10.23	0.02	0.32
2f	0.15	0.17	0.17	0.22	5.41	4.06	2.58	2.14	5.46	0.03	0.59	0.20	0.22	3.02	2.70	14.26	0.01	6.29	11.33	0.02	0.31
3a	0.06	0.06	0.06	0.06	1.39	1.47	1.24	1.16	1.96	0.03	0.34	0.07	0.07	1.25	1.15	2.42	0.03	4.49	2.05	0.03	0.26
3b	0.08	0.08	0.08	0.08	1.98	1.95	1.44	1.32	2.38	0.03	0.39	0.09	0.10	1.45	1.32	3.28	0.03	4.42	2.72	0.03	0.27
3c	0.10	0.10	0.10	0.10	2.54	2.46	1.52	1.49	2.71	0.04	0.42	0.12	0.12	1.61	1.47	4.04	0.03	4.30	3.38	0.04	0.28
3d	0.12	0.12	0.13	0.13	3.15	2.99	1.74	1.64	2.98	0.04	0.46	0.15	0.15	1.74	1.61	4.75	0.03	4.20	4.06	0.04	0.29
3e	0.14	0.14	0.16	0.15	3.71	3.45	1.97	1.79	3.29	0.04	0.49	0.18	0.18	1.90	1.75	5.64	0.03	4.23	4.77	0.04	0.29
3f	0.16	0.16	0.19	0.17	4.24	3.90	2.05	1.91	3.51	0.04	0.50	0.20	0.21	2.01	1.86	6.32	0.03	4.19	5.37	0.04	0.28
3g	0.17	0.18	0.21	0.20	4.81	4.35	2.16	1.97	3.80	0.04	0.51	0.23	0.24	2.16	1.96	7.29	0.03	4.25	5.99	0.04	0.26
4a	0.06	0.06	0.06	0.05	1.34	1.42	1.72	1.63	2.88	0.02	0.46	0.07	0.07	1.70	1.59	4.49	0.02	6.11	3.96	0.02	0.31
4b	0.08	0.08	0.09	0.09	2.14	2.00	2.08	1.97	3.51	0.02	0.52	0.10	0.10	2.01	1.90	6.32	0.02	6.04	5.65	0.02	0.33
4c	0.11	0.10	0.12	0.12	2.88	2.54	2.37	2.13	4.18	0.03	0.56	0.12	0.13	2.36	2.17	8.66	0.01	6.25	7.32	0.02	0.32
4d	0.13	0.13	0.14	0.15	3.78	3.12	2.54	2.18	4.57	0.03	0.58	0.15	0.16	2.56	2.37	10.21	0.02	6.10	8.79	0.02	0.31
4e	0.15	0.15	0.16	0.19	4.62	3.70	2.38	2.16	5.34	0.03	0.55	0.18	0.19	2.96	2.57	13.70	0.01	6.47	10.29	0.02	0.30
5a	0.06	0.06	0.06	0.06	1.40	1.47	1.25	1.14	1.92	0.03	0.38	0.07	0.07	1.23	1.15	2.35	0.03	4.42	2.05	0.03	0.29
5b	0.08	0.08	0.08	0.08	1.99	1.99	1.44	1.32	2.31	0.03	0.43	0.10	0.10	1.41	1.32	3.12	0.03	4.26	2.72	0.04	0.29
5c	0.10	0.10	0.10	0.10	2.52	2.49	1.68	1.49	2.71	0.04	0.46	0.12	0.12	1.61	1.47	4.04	0.03	4.27	3.39	0.04	0.30
5d	0.12	0.12	0.13	0.13	3.15	3.00	1.74	1.75	3.07	0.04	0.49	0.15	0.15	1.79	1.61	4.99	0.03	4.29	4.05	0.04	0.30
5e	0.14	0.14	0.16	0.15	3.67	3.48	1.95	1.80	3.17	0.04	0.51	0.18	0.18	1.84	1.75	5.27	0.03	4.07	4.77	0.04	0.30
5f	0.15	0.16	0.19	0.17	4.23	3.94	2.05	1.91	3.51	0.04	0.52	0.20	0.21	2.01	1.86	6.32	0.03	4.17	5.38	0.04	0.29
5g	0.16	0.18	0.21	0.20	4.79	4.35	2.16	1.97	3.80	0.04	0.54	0.23	0.24	2.16	1.96	7.29	0.03	4.25	5.98	0.04	0.27

Table B-2: Overview wave conditions with structure (2)

	Structure											Deep									
Test No	H_{m0} spectrum analysis [m]	H_{m0} extrapolation [m]	H_s time series [m]	H_s extrapolation [m]	Stability number based on extrapolation H_s [-]	Stability number based on extrapolation H_{m0} [-]	T_p [s]	$T_{m-1,0}$ [s]	Wave Length, L_z [m]	Wave Steepness, S_{op} [-]	Reflection co-efficient [-]	H_{m0} spectrum analysis [m]	H_s time series analysis [m]	T_p [s]	$T_{m-1,0}$ [s]	Wave Length, L_z [m]	Wave Steepness, S_{op} [-]	Surf similarity par ξ_p [-]	Wave Length, $L_{m-1,0}$ [m]	Wave Steepness, $S_{m-1,0}$ [-]	Reflection co-efficient [-]
6a	0.06	0.06	0.06	0.05	1.34	1.44	1.72	1.63	2.97	0.02	0.50	0.07	0.07	1.74	1.59	4.72	0.01	6.22	3.96	0.02	0.34
6b	0.08	0.08	0.09	0.09	2.12	2.01	2.11	1.97	3.54	0.03	0.56	0.10	0.10	2.03	1.90	6.42	0.02	6.08	5.63	0.02	0.35
6c	0.09	0.10	0.12	0.12	2.88	2.56	2.33	2.28	3.99	0.03	0.65	0.13	0.13	2.26	2.16	7.96	0.02	5.97	7.31	0.02	0.34
6d	0.13	0.13	0.14	0.15	3.77	3.13	2.54	2.56	4.57	0.03	0.61	0.15	0.16	2.56	2.37	10.21	0.02	6.09	8.78	0.02	0.33
6e	0.14	0.15	0.16	0.19	4.60	3.68	2.38	2.17	5.39	0.03	0.59	0.18	0.19	2.99	2.56	13.93	0.01	6.54	10.23	0.02	0.32
6f	0.15	0.17	0.17	0.22	5.38	4.05	2.58	2.13	5.51	0.03	0.58	0.20	0.22	3.05	2.70	14.51	0.01	6.36	11.35	0.02	0.31
7a	0.06	0.06	0.06	0.06	1.39	1.46	1.25	1.15	1.92	0.03	0.36	0.07	0.07	1.23	1.15	2.34	0.03	4.43	2.06	0.03	0.27
7b	0.08	0.08	0.08	0.08	1.97	1.97	1.42	1.32	2.31	0.03	0.41	0.10	0.10	1.41	1.32	3.12	0.03	4.28	2.71	0.04	0.28
7c	0.10	0.10	0.10	0.10	2.56	2.49	1.66	1.49	2.63	0.04	0.44	0.12	0.13	1.57	1.47	3.84	0.03	4.17	3.37	0.04	0.29
7d	0.12	0.12	0.13	0.13	3.14	2.99	1.74	1.65	3.07	0.04	0.47	0.15	0.15	1.79	1.61	4.99	0.03	4.30	4.06	0.04	0.29
7e	0.14	0.14	0.16	0.15	3.68	3.49	1.95	1.80	3.17	0.04	0.50	0.18	0.18	1.84	1.74	5.27	0.03	4.07	4.72	0.04	0.29
7f	0.16	0.16	0.19	0.17	4.24	3.94	2.06	1.90	3.51	0.04	0.51	0.20	0.21	2.01	1.86	6.32	0.03	4.17	5.38	0.04	0.28
7g	0.17	0.18	0.21	0.20	4.78	4.35	2.16	1.97	3.80	0.04	0.53	0.23	0.24	2.16	1.96	7.29	0.03	4.25	5.99	0.04	0.26
8a	0.06	0.06	0.06	0.05	1.35	1.44	1.72	1.63	2.85	0.02	0.48	0.07	0.07	1.68	1.59	4.41	0.02	6.02	3.96	0.02	0.33
8b	0.08	0.08	0.09	0.09	2.11	2.01	2.08	1.97	3.49	0.02	0.54	0.10	0.10	2.00	1.90	6.27	0.02	6.01	5.63	0.02	0.34
8c	0.10	0.10	0.12	0.12	2.88	2.56	2.35	2.17	4.18	0.02	0.58	0.13	0.13	2.36	2.17	8.67	0.01	6.23	7.31	0.02	0.33
8d	0.12	0.13	0.14	0.15	3.72	3.11	2.60	2.22	4.61	0.03	0.60	0.15	0.16	2.58	2.39	10.39	0.01	6.16	8.88	0.02	0.32
8e	0.14	0.15	0.16	0.19	4.59	3.68	2.38	2.18	5.34	0.03	0.58	0.18	0.19	2.96	2.56	13.67	0.01	6.48	10.25	0.02	0.31
9a	0.06	0.06	0.06	0.06	1.38	1.45	1.25	1.15	1.96	0.03	0.37	0.07	0.07	1.25	1.15	2.42	0.03	4.51	2.06	0.03	0.28
9b	0.08	0.08	0.08	0.08	1.99	1.98	1.44	1.32	2.38	0.03	0.42	0.10	0.10	1.45	1.32	3.28	0.03	4.38	2.71	0.04	0.29
9c	0.10	0.10	0.10	0.10	2.55	2.48	1.51	1.47	2.71	0.04	0.46	0.12	0.12	1.61	1.47	4.04	0.03	4.28	3.38	0.04	0.30
9d	0.12	0.12	0.13	0.13	3.13	2.98	1.74	1.64	2.98	0.04	0.48	0.15	0.15	1.74	1.61	4.75	0.03	4.20	4.06	0.04	0.31
9e	0.14	0.14	0.16	0.15	3.71	3.49	1.95	1.79	3.17	0.04	0.51	0.18	0.18	1.84	1.74	5.27	0.03	4.06	4.70	0.04	0.30
9f	0.16	0.16	0.19	0.17	4.25	3.95	2.08	1.89	3.55	0.04	0.53	0.20	0.21	2.03	1.86	6.43	0.03	4.20	5.37	0.04	0.30
9g	0.17	0.18	0.21	0.20	4.81	4.38	2.16	1.99	3.80	0.04	0.55	0.23	0.24	2.16	1.96	7.29	0.03	4.23	5.99	0.04	0.28
10a	0.06	0.06	0.06	0.05	1.35	1.44	1.72	1.62	2.88	0.02	0.48	0.07	0.07	1.70	1.59	4.49	0.02	6.07	3.95	0.02	0.32
10b	0.08	0.08	0.09	0.09	2.12	2.01	2.08	1.97	3.54	0.02	0.55	0.10	0.10	2.03	1.90	6.43	0.02	6.09	5.64	0.02	0.33
10c	0.10	0.10	0.12	0.12	2.87	2.55	2.37	2.17	4.18	0.02	0.60	0.13	0.13	2.36	2.17	8.67	0.01	6.24	7.31	0.02	0.34
10d	0.13	0.13	0.14	0.15	3.72	3.12	2.54	2.21	4.61	0.03	0.62	0.15	0.16	2.58	2.39	10.39	0.01	6.15	8.89	0.02	0.33
10e	0.15	0.15	0.16	0.19	4.61	3.71	2.50	2.18	5.34	0.03	0.61	0.18	0.19	2.96	2.57	13.71	0.01	6.46	10.27	0.02	0.32
10f	0.16	0.17	0.17	0.23	5.61	4.22	2.53	2.14	5.50	0.03	0.60	0.21	0.23	3.05	2.71	14.50	0.01	6.22	11.42	0.02	0.32

Table B-3: Overview wave conditions without structure

	Structure							Deep									
Test No	H_{m0} spectrum analysis [m]	H_s time series [m]	T_p [s]	$T_{m-1,0}$ [s]	Wave Length, L_z [m]	Wave Steepness, S_{op} [-]	Reflection co-efficient [-]	H_{m0} spectrum analysis [m]	H_s time series analysis [m]	T_p [s]	$T_{m-1,0}$ [s]	Wave Length, L_z [m]	Wave Steepness, S_{op} [-]	Surf similarity par ξ_p [-]	Wave Length, $L_{m-1,0}$ [m]	Wave Steepness, $S_{m-1,0}$ [-]	Reflection co-efficient [-]
13a	0.06	0.06	1.25	1.15	1.96	0.03	0.12	0.07	0.07	1.25	1.14	2.42	0.03	4.50	2.02	0.03	0.10
13b	0.08	0.08	1.41	1.30	2.33	0.04	0.15	0.10	0.10	1.42	1.31	3.17	0.03	4.31	2.70	0.04	0.10
13c	0.10	0.10	1.58	1.43	2.73	0.04	0.16	0.12	0.13	1.62	1.46	4.10	0.03	4.31	3.35	0.04	0.11
13d	0.12	0.13	1.76	1.55	2.98	0.04	0.18	0.15	0.15	1.74	1.60	4.74	0.03	4.18	4.01	0.04	0.10
13e	0.14	0.15	1.91	1.67	3.23	0.04	0.19	0.18	0.18	1.87	1.73	5.45	0.03	4.11	4.69	0.04	0.09
13f	0.16	0.18	2.04	1.76	3.58	0.04	0.21	0.21	0.21	2.04	1.84	6.53	0.03	4.23	5.30	0.04	0.10
13g	0.18	0.19	2.17	2.26	3.76	0.05	0.30	0.23	0.23	2.14	1.94	7.16	0.03	4.20	5.89	0.04	0.10
14a	0.06	0.06	1.68	1.56	2.88	0.02	0.12	0.07	0.07	1.70	1.58	4.49	0.02	6.05	3.90	0.02	0.09
14b	0.08	0.08	2.11	1.87	3.61	0.02	0.13	0.10	0.10	2.06	1.89	6.64	0.01	6.16	5.59	0.02	0.10
14c	0.11	0.12	2.39	2.11	4.21	0.03	0.15	0.13	0.13	2.37	2.15	8.77	0.01	6.27	7.19	0.02	0.10
14d	0.13	0.16	2.58	2.24	4.73	0.03	0.16	0.16	0.16	2.64	2.35	10.92	0.01	6.25	8.62	0.02	0.10
14e	0.16	0.20	2.89	2.63	4.93	0.03	0.19	0.19	0.19	2.75	2.53	11.80	0.02	5.96	10.02	0.02	0.10
14f	0.17	0.22	3.10	2.90	5.60	0.03	0.20	0.22	0.23	3.10	2.66	14.99	0.01	6.26	11.06	0.02	0.10

Note: Test 11+12 were performed with a smooth wooden plate on top of the armour to verify the found overtopping discharge by Salauddin (2015). These tests are not relevant for the research on the stability of the armour layer and therefore not taken into account.

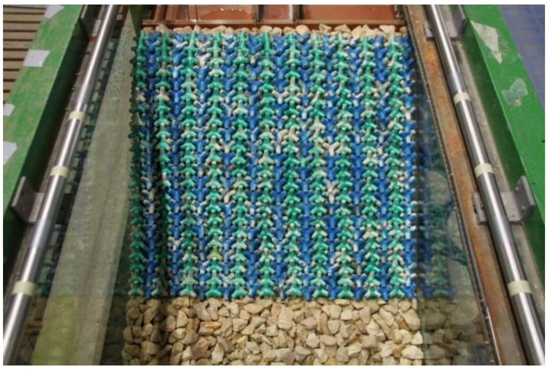
C. Photographs armour layer after each subtest

Photo's test 1

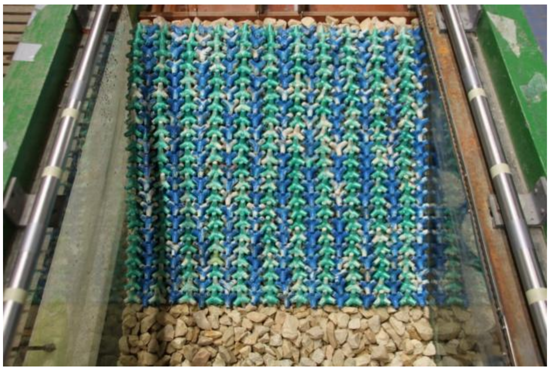
1 start

1a

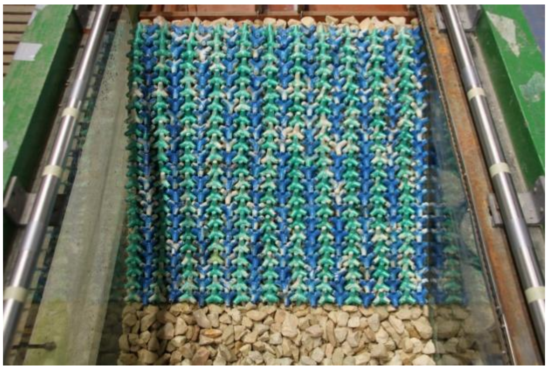
1b



1c

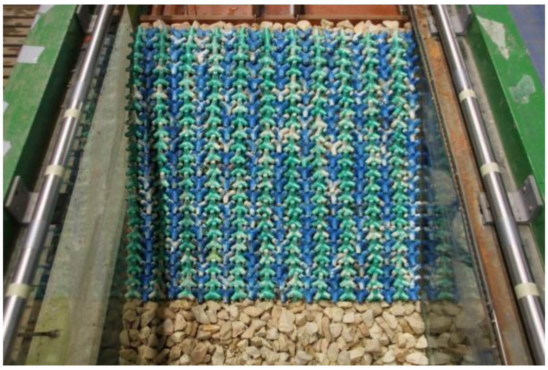


1d



1e

1f



1g

Figure C-1: Photographs after each subtest test 1

Photo's test 2

2 start

2a

2b

2c

2d

2e

2f

Figure C-2: Photographs after each subtest test 2

Photo's test 3

3 start

3a

3b

3c

3d

3e

3f

3g

Figure C-3: Photographs after each subtest test 3

Photo's test 4

4 start

4a

4b

4c

4d

4e

Figure C-4: Photographs after each subtest test 4

Photo's test 5

5 start

5a

5b

5c

5d

5e

5f

5g

Figure C-5: Photographs after each subtest test 5

Photo's test 6

6 start

6a

6b

6c

6d

6e

6f

Figure C-6: Photographs after each subtest test 6

Photo's test 7

7 start

7a

7b

7c

7d

7e

7f

7g

Figure C-7: Photographs after each subtest test 7

Photo's test 8

8 start

8a

8b

8c

8d

8e

Figure C-8: Photographs after each subtest test 8

Photo's test 9

9 start

9a

9b

9c

9d

9e

9f

9g

Figure C-9: Photographs after each subtest test 9

Photo's test 10

10 start

10a

10b

10c

10d

10e

10f

Figure C-10: Photographs after each subtest test 10

D. Damage by displacement and rocking

Table D-1: Overview damage by displacements N_{od} and rocking N_{or}

	Test No	H_{m0} at Structure extrapolation [m]	H_s at Structure Extrapolation [m]	Stability number based on extrapolation H_s [-]	Stability number based on extrapolation H_{m0} [-]	Nr of units displaced [-]	N_{od} [-]	Nr of units displaced, corrected for side effects [-]	N_{od} corrected for side effects [-]	Nr of units rocking [-]	N_{or} [-]
$S_{m-1,0}$= 0.04	1a	0.06	0.06	1.39	1.46	0	0	0	0	0	0.000
0.69/D_n^2	1b	0.08	0.08	1.97	1.97	0	0	0	0	0	0.000
Rectangular	1c	0.10	0.11	2.57	2.50	0	0	0	0	0	0.000
Uniform	1d	0.12	0.13	3.15	2.99	0	0	0	0	0	0.000
Freeboard: 1.2H_{saD}	1e	0.14	0.15	3.71	3.45	0	0	0	0	0	0.000
	1f	0.16	0.17	4.27	3.91	0	0	0	0	2	0.075
	1g	0.18	0.19	4.76	4.31	0	0	0	0	10	0.375
$S_{m-1,0}$= 0.02	2a	0.06	0.05	1.35	1.37	0	0	0	0	0	0.000
0.69/D_n^2	2b	0.08	0.09	2.12	2.02	0	0	0	0	0	0.000
Rectangular	2c	0.10	0.12	2.89	2.57	0	0	0	0	1	0.038
Uniform	2d	0.13	0.15	3.79	3.14	0	0	0	0	4	0.150
Freeboard: 1.2H_{saD}	2e	0.15	0.19	4.61	3.71	2	0.075	1	0.0375	11	0.413
	2f	0.17	0.22	5.41	4.06	31	1.1625	31	1.1625	-	-
$S_{m-1,0}$= 0.04	3a	0.06	0.06	1.39	1.47	0	0	0	0	0	0.000
0.63/D_n^2	3b	0.08	0.08	1.98	1.95	0	0	0	0	3	0.113
Diamond	3c	0.10	0.10	2.54	2.46	1	0.0375	0	0	7	0.263
Random	3d	0.12	0.13	3.15	2.99	1	0.0375	0	0	16	0.600
Freeboard: 1.2H_{saD}	3e	0.14	0.15	3.71	3.45	1	0.0375	0	0	-	-
	3f	0.16	0.17	4.24	3.90	1	0.0375	0	0	-	-
	3g	0.18	0.20	4.81	4.35	1	0.0375	0	0	-	-
$S_{m-1,0}$= 0.02	4a	0.06	0.05	1.34	1.42	0	0	0	0	0	0.000
0.63/D_n^2	4b	0.08	0.09	2.14	2.00	0	0	0	0	3	0.113
Diamond	4c	0.10	0.12	2.88	2.54	0	0	0	0	15	0.563
Random	4d	0.13	0.15	3.78	3.12	3	0.1125	3	0.1125	-	-
Freeboard: 1.2H_{saD}	4e	0.15	0.19	4.62	3.70	100	3.75	100	3.75	-	-
$S_{m-1,0}$= 0.04	5a	0.06	0.06	1.40	1.47	0	0	0	0	0	0.000
0.66/D_n^2	5b	0.08	0.08	1.99	1.99	0	0	0	0	0	0.000
Rectangular	5c	0.10	0.10	2.52	2.49	0	0	0	0	0	0.000
Uniform	5d	0.12	0.13	3.15	3.00	0	0	0	0	0	0.000
Freeboard: 1.2H_{saD}	5e	0.14	0.15	3.67	3.48	0	0	0	0	1	0.038
	5f	0.16	0.17	4.23	3.94	1	0.0375	0	0	10	0.375
	5g	0.18	0.20	4.79	4.35	1	0.0375	0	0	-	-
$S_{m-1,0}$= 0.02	6a	0.06	0.05	1.34	1.44	0	0	0	0	0	0.000
0.66/D_n^2	6b	0.08	0.09	2.12	2.01	0	0	0	0	1	0.038
Rectangular	6c	0.10	0.12	2.88	2.56	0	0	0	0	3	0.113
Uniform	6d	0.13	0.15	3.77	3.13	0	0	0	0	9	0.338
Freeboard: 1.2H_{saD}	6e	0.15	0.19	4.60	3.68	0	0	0	0	7	0.263
	6f	0.17	0.22	5.38	4.05	25	0.9375	25	0.9375	-	-
$S_{m-1,0}$= 0.04	7a	0.06	0.06	1.39	1.46	0	0	0	0	0	0.000
0.63/D_n^2	7b	0.08	0.08	1.97	1.97	0	0	0	0	5	0.188
Rectangular	7c	0.10	0.10	2.56	2.49	0	0	0	0	6	0.225
Uniform	7d	0.12	0.13	3.14	2.99	0	0	0	0	15	0.563
Freeboard: 1.2H_{saD}	7e	0.14	0.15	3.68	3.49	0	0	0	0	-	-
	7f	0.16	0.17	4.24	3.94	0	0	0	0	-	-
	7g	0.18	0.20	4.78	4.35	2	0.075	2	0.075	-	-
$S_{m-1,0}$= 0.02	8a	0.06	0.05	1.35	1.44	0	0	0	0	0	0.000
0.63/D_n^2	8b	0.08	0.09	2.11	2.01	0	0	0	0	4	0.150
Rectangular	8c	0.10	0.12	2.88	2.56	0	0	0	0	10	0.375
Uniform	8d	0.13	0.15	3.72	3.11	2	0.075	2	0.075	-	-
Freeboard: 1.2H_{saD}	8e	0.15	0.19	4.59	3.68	25	0.9375	25	0.9375	-	-
$S_{m-1,0}$= 0.02	9a	0.06	0.06	1.38	1.45	0	0	0	0	0	0.000
0.66/D_n^2	9b	0.08	0.08	1.99	1.98	0	0	0	0	0	0.000
Rectangular	9c	0.10	0.10	2.55	2.48	0	0	0	0	0	0.000
Uniform	9d	0.12	0.13	3.13	2.98	0	0	0	0	0	0.000
Freeboard: 1.6H_{saD}	9e	0.14	0.15	3.71	3.49	0	0	0	0	8	0.300
	9f	0.16	0.17	4.25	3.95	0	0	0	0	15	0.563
	9g	0.18	0.20	4.81	4.38	1	0.0375	0	0	-	-
$S_{m-1,0}$= 0.04	10a	0.06	0.05	1.35	1.44	0	0	0	0	0	0.000
0.63/D_n^2	10b	0.08	0.09	2.12	2.01	0	0	0	0	1	0.038
Rectangular	10c	0.10	0.12	2.87	2.55	0	0	0	0	5	0.188
Uniform	10d	0.13	0.15	3.72	3.12	0	0	0	0	15	0.563
Freeboard: 1.6H_{saD}	10e	0.15	0.19	4.61	3.71	7	0.2625	2	0.075	-	-
	10f	0.17	0.23	5.61	4.22	10	0.375	3	0.1125	-	-

E. Damage by unit movement

Table E-1: Number of exceeding units for all subtests

		Nr of units				N_{om}			
		>7.5mm	>15mm	>22.5mm	>30mm	>7.5mm	>15mm	>22.5mm	>30mm
Test	Stab. Nr.	>0.25D_n	>0.5D_n	>0.75D_n	>1.0D_n	>0.25D_n	>0.5D_n	>0.75D_n	>1.0D_n
1a	1.39	0	0	0	0	0.00	0.00	0.00	0.00
1b	1.97	0	0	0	0	0.00	0.00	0.00	0.00
1c	2.57	0	0	0	0	0.00	0.00	0.00	0.00
1d	3.15	0	0	0	0	0.00	0.00	0.00	0.00
1e	3.71	0	0	0	0	0.00	0.00	0.00	0.00
1f	4.27	0	0	0	0	0.00	0.00	0.00	0.00
1g	4.76	5	0	0	0	0.19	0.00	0.00	0.00
2a	1.35	0	0	0	0	0.00	0.00	0.00	0.00
2b	2.12	0	0	0	0	0.00	0.00	0.00	0.00
2c	2.89	0	0	0	0	0.00	0.00	0.00	0.00
2d	3.79	4	0	0	0	0.15	0.00	0.00	0.00
2e	4.61	36	0	0	0	1.35	0.00	0.00	0.00
2f	5.41	Failure				Failure			
3a	1.39	1	0	0	0	0.04	0.00	0.00	0.00
3b	1.98	55	0	0	0	2.06	0.00	0.00	0.00
3c	2.54	124	21	0	0	4.65	0.79	0.00	0.00
3d	3.15	179	56	3	0	6.71	2.10	0.11	0.00
3e	3.71	212	106	21	0	7.95	3.98	0.79	0.00
3f	4.24	233	137	56	11	8.74	5.14	2.10	0.41
3g	4.81	274	200	129	62	10.28	7.50	4.84	2.33
4a	1.34	0	0	0	0	0.00	0.00	0.00	0.00
4b	2.14	88	1	0	0	3.30	0.04	0.00	0.00
4c	2.88	233	122	53	9	8.74	4.58	1.99	0.34
4d	3.78	257	175	101	62	9.64	6.56	3.79	2.33
4e	4.62	Failure				Failure			
5a	1.40	0	0	0	0	0.00	0.00	0.00	0.00
5b	1.99	0	0	0	0	0.00	0.00	0.00	0.00
5c	2.52	0	0	0	0	0.00	0.00	0.00	0.00
5d	3.15	0	0	0	0	0.00	0.00	0.00	0.00
5e	3.67	5	0	0	0	0.19	0.00	0.00	0.00
5f	4.23	18	0	0	0	0.68	0.00	0.00	0.00
5g	4.79	18	2	0	0	0.68	0.08	0.00	0.00
6a	1.34	0	0	0	0	0.00	0.00	0.00	0.00
6b	2.12	0	0	0	0	0.00	0.00	0.00	0.00
6c	2.88	3	0	0	0	0.11	0.00	0.00	0.00
6d	3.77	50	1	0	0	1.88	0.04	0.00	0.00
6e	4.60	145	12	0	0	5.44	0.45	0.00	0.00
6f	5.38	Failure				Failure			
7a	1.39	0	0	0	0	0.00	0.00	0.00	0.00
7b	1.97	53	1	0	0	1.99	0.04	0.00	0.00
7c	2.56	80	4	0	0	3.00	0.15	0.00	0.00
7d	3.14	182	49	1	0	6.83	1.84	0.04	0.00
7e	3.68	238	120	28	2	8.93	4.50	1.05	0.08
7f	4.24	270	149	60	12	10.13	5.59	2.25	0.45
7g	4.78	282	184	101	35	10.58	6.90	3.79	1.31
8a	1.35	0	0	0	0	0.00	0.00	0.00	0.00
8b	2.11	11	0	0	0	0.41	0.00	0.00	0.00
8c	2.88	119	9	0	0	4.46	0.34	0.00	0.00
8d	3.72	232	112	33	8	8.70	4.20	1.24	0.30
8e	4.59	Failure				Failure			
9a	1.38	0	0	0	0	0.00	0.00	0.00	0.00
9b	1.99	0	0	0	0	0.00	0.00	0.00	0.00
9c	2.55	4	0	0	0	0.15	0.00	0.00	0.00
9d	3.13	26	0	0	0	0.98	0.00	0.00	0.00
9e	3.71	51	0	0	0	1.91	0.00	0.00	0.00
9f	4.25	98	11	0	0	3.68	0.41	0.00	0.00
9g	4.81	154	40	1	0	5.78	1.50	0.04	0.00
10a	1.35	1	0	0	0	0.04	0.00	0.00	0.00
10b	2.12	19	0	0	0	0.71	0.00	0.00	0.00
10c	2.87	72	1	0	0	2.70	0.04	0.00	0.00
10d	3.72	222	38	1	0	8.33	1.43	0.04	0.00
10e	4.61	268	124	30	10	10.05	4.65	1.13	0.38
10f	5.61	Too mixed to analyse				Too mixed to analyse			

Movements per threshold level per test series

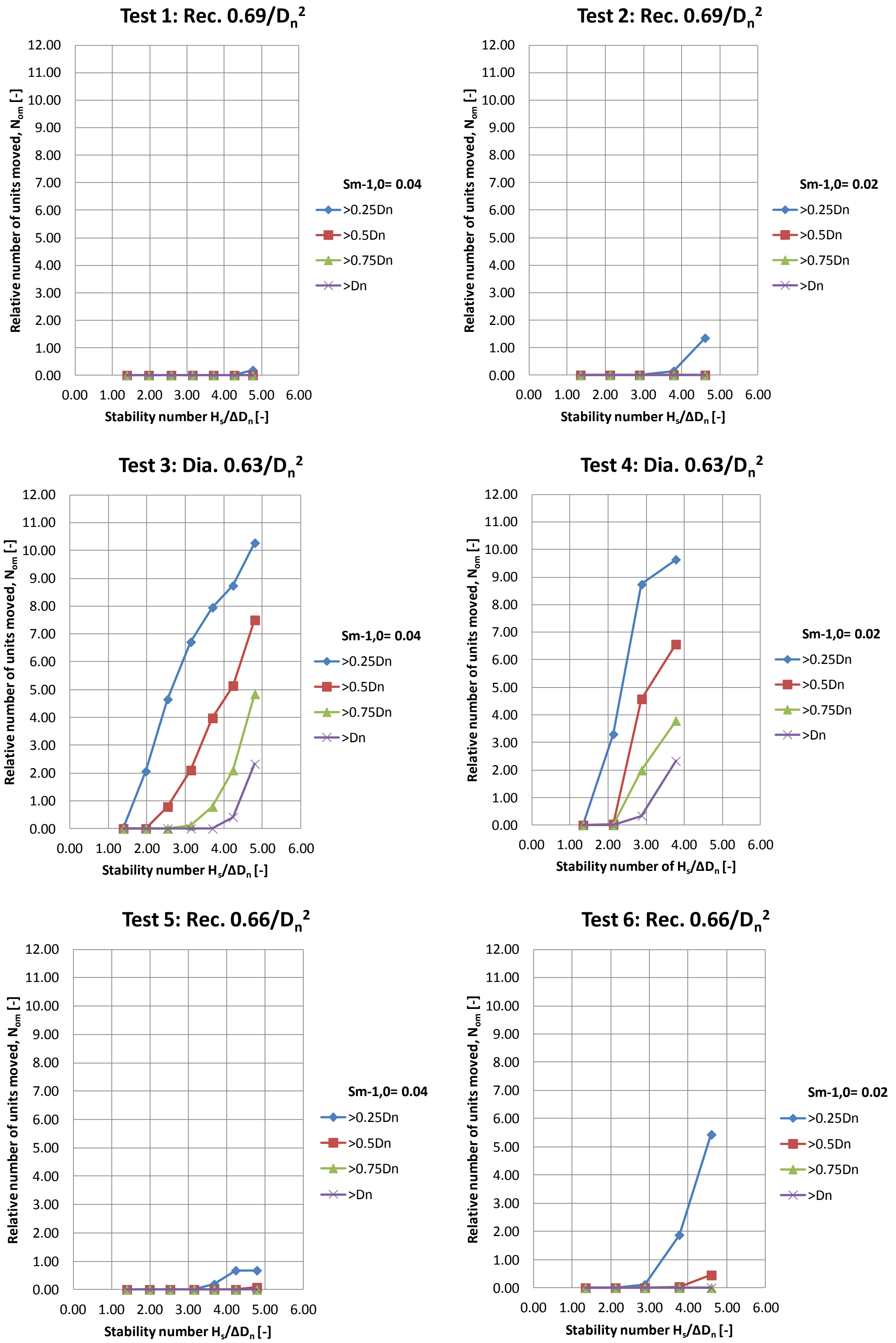


Figure E-1: Movements per threshold level (1)

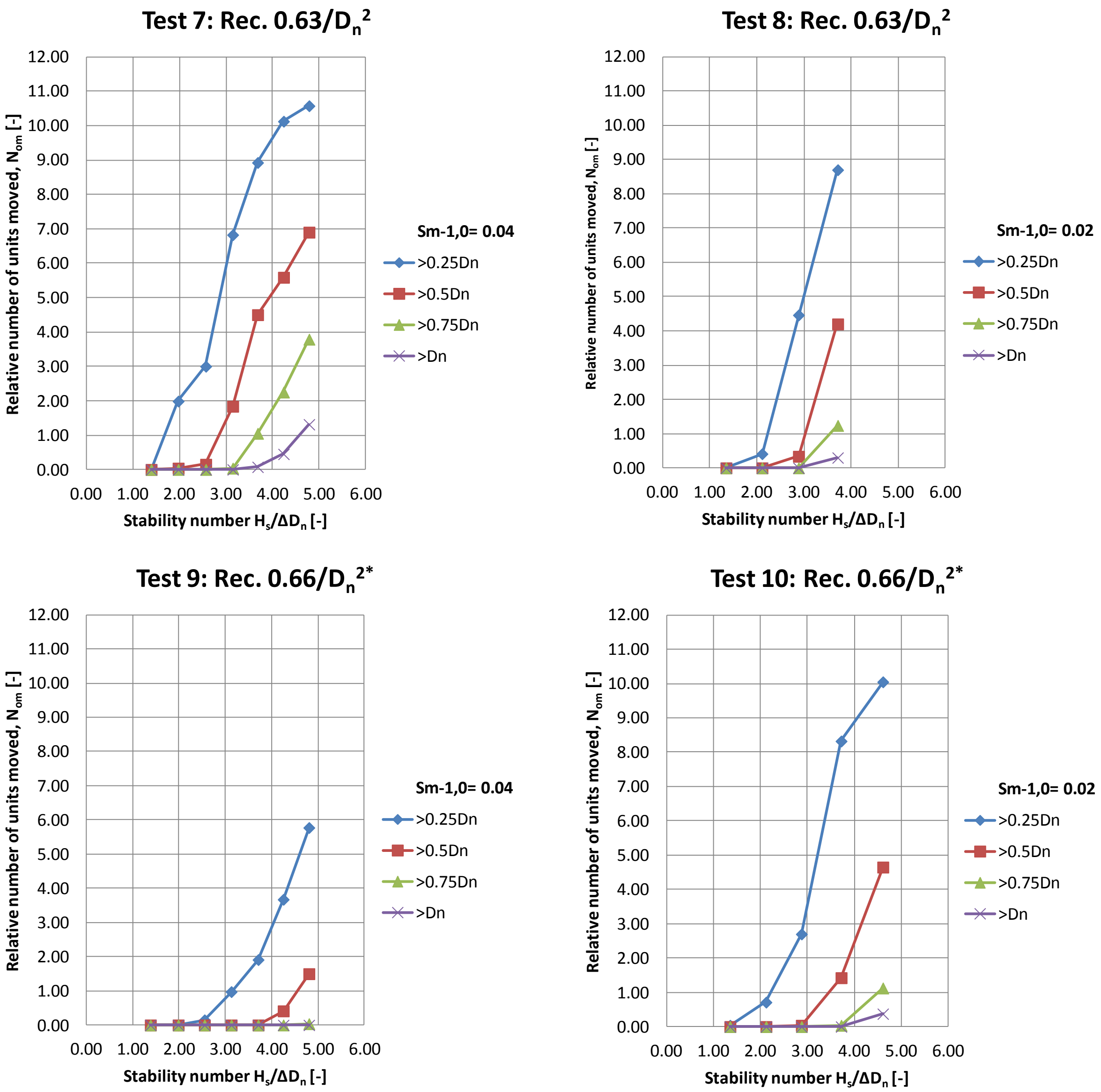


Figure E-2: Movements per threshold level (2)

Some results of the found during the subtests to give insight in how the movements took place

Test 1

Test 1g >0.25Dn Stab. Nr = 4.76

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
22	1.13	2.18	1.27	1.45	1.46	1.88	0.96	3.01	1.45	1.67	1.35	1.16	1.41	1.80	1.28	0.66	1.28	1.53	0.65	0.62	1.15	1.09
21	8.14	2.15	2.66	0.08	0.77	0.94	2.01	0.77	3.09	2.35	2.16	2.43	1.86	1.54	1.38	2.19	1.90	0.45	2.47	1.51	1.99	1.46
20	3.14	3.23	6.30	3.95	3.49	3.72	5.57	5.02	7.75	4.34	4.91	0.86	1.48	4.43	3.26	1.42	2.27	2.50	1.76	1.35	4.95	2.70
19	1.80	3.25	3.85	1.83	5.85	3.58	4.04	6.43	6.03	4.98	3.24	0.99	1.89	3.06	2.95	1.48	0.73	4.84	2.50	2.85	3.47	3.49
18	3.37	7.05	8.36	4.58	3.52	2.95	5.65	4.29	3.36	4.84	2.67	2.70	3.20	1.35	3.33	2.91	2.87	4.07	2.64	4.06	2.54	9.98
17	1.05	7.59	5.39	4.14	4.32	4.29	5.75	5.59	5.33	6.60	2.53	3.32	2.43	3.71	0.72	3.59	4.48	3.55	3.46	3.05	5.36	2.80
16	6.42	5.02	3.41	4.13	3.04	0.93	5.60	5.08	4.18	2.48	5.02	2.88	1.16	2.61	0.55	3.42	2.88	1.58	1.70	0.29	2.60	3.68
15	6.15	5.95	6.54	4.12	4.11	3.24	5.51	5.87	6.32	6.45	2.46	2.98	2.69	2.24	3.73	1.06	1.35	1.67	2.04	2.15	2.45	2.38
14	5.69	5.45	4.93	5.09	4.25	2.28	5.39	5.28	3.82	4.25	2.51	2.29	1.02	1.94	1.60	3.04	1.06	1.39	1.88	4.28	2.53	3.12
13	1.72	5.34	6.55	1.49	4.55	2.24	2.57	1.80	2.31	3.15	2.04	0.95	3.21	1.79	1.98	1.49	2.40	0.78	2.46	0.95	2.70	3.79
12	2.67	2.27	2.24	3.42	1.19	3.29	2.17	3.50	1.82	4.48	3.50	2.03	1.82	2.51	2.00	2.45	0.99	0.86	1.65	3.38	1.25	2.00
11	1.34	6.22	2.76	2.97	3.02	4.26	3.01	2.67	3.50	3.51	2.57	3.54	1.53	2.21	1.91	1.71	1.70	1.07	1.72	4.29	3.41	2.70
10	4.00	2.43	3.65	2.16	2.81	2.44	2.87	1.11	0.94	1.40	1.86	1.30	1.64	1.41	0.54	0.93	0.82	1.17	1.47	2.98	1.69	1.60
9	2.30	0.96	1.61	1.72	2.04	2.34	2.22	2.50	1.77	0.80	1.22	1.55	1.16	2.39	1.03	1.32	1.08	0.73	1.24	1.34	1.43	2.76
8	2.62	2.24	1.91	2.39	2.76	1.94	1.10	1.46	1.41	1.71	0.84	0.69	0.87	0.86	2.35	0.93	0.20	2.41	2.09	2.27	1.06	2.92
7	1.11	2.23	2.08	2.10	0.21	1.11	1.85	2.54	0.50	1.85	2.37	1.29	0.43	2.31	0.37	1.77	0.73	0.63	1.19	4.01	0.48	1.76
6	1.28	0.41	1.10	0.89	0.47	0.09	0.32	1.33	0.27	1.19	2.77	2.06	0.50	0.97	1.62	1.19	0.81	0.90	1.64	2.41	2.31	1.75
5	1.54	0.44	1.02	1.72	0.89	2.46	1.71	2.29	1.64	0.28	0.79	3.36	0.63	1.40	0.51	1.12	2.23	1.15	0.96	1.97	1.69	1.35
4	1.58	1.71	1.34	0.63	1.86	0.27	0.67	0.84	0.92	1.43	1.34	1.47	0.86	1.28	1.31	2.22	0.63	1.39	1.00	1.90	1.03	2.47
3	1.28	1.39	1.21	1.27	1.53	1.16	0.45	1.09	2.09	1.77	0.37	2.19	0.92	0.57	1.06	1.12	1.89	0.85	0.12	0.69	2.40	1.84
2	1.20	1.04	1.55	1.94	2.72	0.19	0.92	1.83	1.96	1.33	0.74	0.95	0.37	0.27	2.32	1.11	0.81	1.59	0.55	1.67	0.44	1.81
1	1.24	0.85	1.04	0.58	1.07	1.13	1.56	1.14	0.93	0.68	1.19	1.46	1.33	0.91	1.33	1.10	1.72	0.73	1.84	1.11	0.21	1.41

Test 2

Test 2d >0.25Dn Stab. Nr = 3.79

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
22	2.95	0.54	0.63	2.31	1.83	2.11	3.03	2.77	3.78	1.00	1.85	2.56	2.22	2.16	1.19	2.09	5.46	1.66	1.65	1.53	3.49	2.42
21	2.86	1.28	2.20	2.79	1.09	2.87	0.67	2.39	2.11	0.70	3.04	2.81	1.85	1.03	1.64	1.44	3.94	3.07	1.95	1.91	3.17	0.68
20	1.42	1.52	0.68	3.55	2.13	3.82	5.00	3.41	5.30	3.48	2.35	2.81	2.06	2.97	3.00	2.48	3.01	1.62	3.34	4.61	2.59	0.44
19	6.13	5.02	6.64	3.95	2.52	7.53	5.33	5.27	4.01	4.55	0.85	3.23	2.55	1.22	3.37	2.46	2.14	3.10	2.42	4.94	3.01	0.63
18	8.51	6.69	6.26	4.94	5.35	5.37	4.49	3.54	4.46	4.93	2.01	3.09	0.76	2.74	1.57	1.95	2.27	1.64	1.57	3.72	2.93	3.96
17	6.63	7.61	7.85	3.55	5.38	6.41	3.02	3.13	3.79	3.05	1.90	2.32	2.27	2.25	0.80	3.10	3.30	1.57	2.26	2.84	2.88	4.77
16	5.20	7.24	5.30	6.05	3.98	4.89	3.59	4.34	2.85	2.19	2.36	1.92	3.11	3.28	2.44	2.04	1.71	3.14	2.70	3.79	1.84	2.55
15	5.10	4.80	4.38	5.63	5.88	6.50	4.30	2.29	2.42	2.00	1.19	3.12	4.20	2.72	3.60	1.95	0.89	0.96	2.20	3.50	3.03	3.01
14	4.26	7.27	4.80	7.33	3.84	4.08	2.64	3.30	2.14	1.75	1.74	2.27	3.15	6.32	1.67	2.05	2.01	1.10	4.42	1.28	3.66	3.40
13	4.13	3.63	2.15	5.92	3.46	2.83	1.67	2.61	1.89	2.25	1.74	2.09	3.37	3.23	3.44	2.42	0.73	2.87	0.73	2.22	4.57	4.56
12	2.95	2.28	3.45	4.83	4.54	3.24	3.00	1.77	2.07	2.14	3.37	4.15	3.19	1.99	1.57	3.29	3.17	1.09	1.41	1.89	1.93	2.34
11	1.12	3.88	3.82	3.63	3.49	3.26	3.37	1.79	1.74	1.56	0.92	0.80	0.85	1.73	2.77	3.52	2.35	2.41	1.87	2.25	1.77	3.56
10	2.33	2.48	3.20	2.37	3.53	3.96	1.87	1.38	1.95	3.13	1.90	1.54	0.70	1.89	3.22	1.76	1.68	3.73	1.34	2.92	2.24	3.34
9	1.71	3.03	2.58	3.12	2.93	1.61	1.41	0.73	1.50	2.20	1.96	1.16	2.29	3.42	2.61	1.71	2.04	0.93	0.64	1.64	1.93	1.69
8	2.22	3.12	2.92	2.18	3.32	2.75	2.15	1.73	5.91	2.02	2.31	1.75	2.76	1.28	3.34	3.33	2.16	3.10	2.21	1.64	1.03	1.18
7	3.52	2.12	3.26	1.66	3.13	1.57	1.43	0.85	1.83	1.29	0.52	3.21	3.12	2.36	0.82	2.14	3.98	2.63	1.22	2.99	0.78	2.89
6	2.30	1.23	4.45	2.10	2.78	2.25	2.76	1.42	1.47	0.93	2.11	2.58	3.15	1.13	0.11	3.17	2.50	3.75	1.53	0.74	2.38	3.69
5	2.31	1.67	2.51	1.33	2.12	2.47	1.60	1.73	3.39	2.07	1.10	2.58	2.94	2.17	1.93	3.61	1.62	4.70	2.27	1.82	1.89	0.75
4	0.64	2.07	1.95	1.90	1.56	1.64	1.44	3.67	2.79	1.05	2.52	2.49	0.90	0.88	2.23	4.48	2.25	2.81	0.96	0.12	1.99	6.28
3	2.12	1.00	2.50	1.03	2.32	2.43	1.81	1.24	2.03	1.69	2.42	2.56	2.11	1.31	1.30	2.44	3.03	2.01	2.62	2.84	3.24	3.25
2	1.21	0.42	0.30	0.67	1.01	2.27	2.25	1.14	3.18	2.82	1.79	2.48	1.25	2.45	0.99	2.26	4.12	3.62	5.60	2.02	4.64	4.15
1	0.29	0.33	0.68	1.81	2.22	0.92	1.74	1.50	2.45	2.44	1.64	1.19	0.52	1.75	2.41	2.73	1.14	1.30	2.26	1.48	0.82	2.85

Test 2e >0.25Dn Stab. Nr = 4.61

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
22	3.43	2.82	3.33	2.09	2.38	4.45	3.21	3.09	2.50	0.86	3.77	1.87	2.66	2.23	2.46	4.04	3.77	2.56	0.19	3.71	2.43	4.62
21	2.34	1.22	4.47	2.31	2.61	1.02	0.65	4.26	1.53	0.99	2.39	2.31	1.87	9.30	2.88	0.71	7.08	1.59	3.03	6.12	1.06	27.56
20	1.32	1.22	2.03	6.15	6.99	4.78	2.52	3.69	4.38	3.26	7.15	1.63	2.96	3.48	4.39	3.15	1.92	3.93	3.89	3.76	3.52	25.63
19	10.51	6.80	8.59	11.71	10.86	0.00	7.78	5.35	3.92	4.92	9.98	5.09	3.05	6.44	3.63	1.57	1.31	2.11	6.55	7.58	6.46	0.00
18	9.03	7.27	8.39	4.75	4.22	6.89	6.23	5.07	7.71	7.27	6.81	4.76	4.02	4.16	2.85	3.10	2.38	3.71	4.64	6.90	4.81	8.20
17	9.11	9.45	10.18	8.61	3.77	5.86	5.17	4.44	6.01	5.13	4.34	8.89	6.38	3.75	3.33	4.92	2.39	1.04	3.72	5.79	6.06	9.37
16	8.27	10.14	7.36	8.72	5.44	9.23	6.26	5.19	4.92	3.36	3.89	8.73	9.65	7.51	4.42	4.34	2.93	5.31	4.94	6.65	7.44	1.76
15	8.14	8.56	7.77	6.47	5.68	6.34	4.11	1.84	2.66	2.24	2.08	4.95	7.70	7.24	3.80	2.00	2.74	2.98	4.60	6.16	8.98	7.28
14	6.44	8.58	6.34	7.29	4.93	4.44	2.63	4.23	3.01	5.58	3.90	4.22	6.31	6.99	2.11	3.84	2.77	2.66	4.82	8.78	6.62	6.86
13	4.48	7.86	6.08	6.34	3.98	4.47	1.37	4.18	1.75	5.71	2.33	3.86	3.04	6.56	3.97	3.43	2.73	3.74	2.76	6.50	7.15	7.67
12	3.75	4.63	4.62	5.42	3.83	3.11	2.74	1.75	1.77	2.24	2.31	3.77	2.85	2.03	1.48	1.37	2.56	1.10	2.38	1.76	5.99	7.57
11	2.44	2.89	5.65	3.98	4.48	4.28	2.90	0.84	1.19	1.07	0.62	1.65	1.84	2.39	2.07	1.72	1.44	3.65	3.53	4.23	4.18	8.79
10	3.49	3.13	3.60	2.31	3.41	4.90	1.59	1.32	0.99	2.33	1.16	0.58	0.41	1.27	1.74	1.58	1.30	3.77	2.79	1.05	6.39	7.04
9	3.40	2.67	2.23	3.24	2.92	2.72	1.95	1.71	3.40	0.54	2.20	1.23	3.26	1.39	2.05	1.26	2.12	1.15	1.81	1.80	0.96	3.32
8	3.53	3.60	1.48	3.65	3.89	2.21	2.34	0.35	3.39	2.78	1.59	2.20	1.94	0.35	2.58	3.26	1.99	3.18	2.72	1.03	1.56	5.09
7	4.14	2.52	2.93	1.72	2.59	1.62	1.50	0.90	1.29	1.20	0.44	2.86	2.07	2.12	1.41	1.45	1.71	1.87	0.57	2.76	2.68	4.71
6	1.51	2.40	3.44	2.43	3.10	1.37	1.33	1.53	1.43	0.74	1.63	1.95	2.16	1.52	0.46	2.35	1.85	1.81	0.67	0.72	1.06	5.04
5	1.58	1.00	0.79	1.84	1.27	2.02	2.44	1.88	5.13	1.70	1.12	1.84	2.56	2.21	2.28	3.60	1.07	3.85	1.47	1.10	1.78	4.20
4	1.99	2.63	1.38	1.41	1.27	0.95	0.99	3.10	2.52	1.59	3.08	2.01	1.31	0.85	2.59	5.12	2.14	2.04	1.25	0.82	0.77	4.03
3	2.28	1.54	3.12	0.38	1.94	2.91	1.18	2.37	3.16	1.48	4.45	2.38	2.81	1.56	3.98	3.46	3.40	2.51	3.47	1.69	3.92	2.39
2	0.90	1.40	0.80	1.48	0.49	2.54	2.61	2.00	4.24	2.44	1.86	1.58	1.71	2.15	0.36	4.02	6.47	3.23	3.03	2.49	5.07	3.68
1	0.22	0.72	1.99	1.28	2.84	1.27	2.19	1.23	2.85	2.20	2.75	2.88	1.55	2.48	1.48	1.30	2.51	1.70	1.63	2.09	2.58	1.13

Test 3

Test 3c >0.5Dn Stab. Nr = 2.54

22	1.71	2.88	2.27	2.16	2.76	2.86	3.97	2.23	4.09	3.38	2.84	3.52	1.01	2.86	2.56	0.54	0.57	2.05	
21	1.71	1.57	1.73	4.26	4.26	0.74	4.42	3.37	1.99	5.55	3.94	2.09	1.12	1.41	2.25	1.24	0.39	1.98	2.67
20	0.88	5.23	5.20	4.23	4.10	3.39	4.31	3.49	6.51	5.94	1.57	4.04	2.37	1.79	2.39	3.74	1.97	3.00	
19	3.90	6.90	6.86	5.18	7.88	7.18	7.82	12.01	8.19	6.08	5.25	4.02	3.60	3.98	5.35	1.22	3.71	4.14	7.98
18	6.87	12.89	6.17	8.76	7.26	11.00	11.98	5.85	8.29	8.02	4.27	3.03	7.85	7.40	5.18	4.10	4.19	6.40	
17	7.82	10.36	11.38	5.38	7.37	10.59	16.03	8.22	5.27	8.56	11.32	10.12	8.24	7.30	9.11	2.15	7.97	7.04	6.52
16	13.60	16.04	1.86	10.98	8.01	7.47	11.29	6.57	5.74	10.22	14.44	15.21	12.97	9.46	7.13	6.56	8.06	10.07	
15	0.00	16.87	9.70	4.82	9.72	14.28	17.22	15.30	14.09	10.16	12.66	16.31	19.36	9.36	7.45	5.19	4.40	5.81	6.91
14	15.40	6.30	7.44	9.05	9.48	12.61	13.05	10.99	13.74	12.00	17.22	18.08	20.68	12.48	8.15	6.12	5.15	6.40	
13	6.35	8.75	9.12	9.48	18.26	11.20	13.03	13.01	10.69	14.91	15.41	14.50	19.89	16.24	6.00	4.79	5.97	2.08	2.47
12	5.14	5.42	5.38	8.42	12.73	11.37	8.73	9.43	10.79	11.49	15.15	18.17	21.98	15.42	6.13	4.51	4.36	4.34	
11	7.59	5.74	8.07	5.73	14.46	9.64	8.73	9.39	8.34	9.47	10.65	15.30	12.94	12.93	9.38	6.87	3.32	4.28	4.58
10	4.14	4.13	5.19	14.57	9.62	9.84	10.01	7.80	9.43	10.06	13.15	12.64	10.72	9.54	5.61	4.21	2.49	4.63	
9	2.35	2.23	3.11	5.90	6.44	9.17	10.82	5.79	6.76	8.39	8.96	11.46	11.61	9.84	3.42	3.31	4.16	7.47	5.28
8	3.18	1.99	5.17	3.28	3.50	7.03	3.87	9.46	7.67	9.21	8.58	5.63	11.03	6.82	4.88	2.17	4.37	2.45	
7	3.29	1.78	3.84	6.48	4.94	5.92	9.05	6.23	10.04	4.57	6.21	3.58	6.09	3.43	3.07	1.99	2.93	3.91	3.21
6	3.18	3.24	5.34	4.89	5.86	6.41	8.42	5.69	6.41	3.18	4.42	4.88	5.35	3.53	3.61	4.76	4.47	1.83	
5	1.02	0.97	2.21	2.15	2.06	2.89	4.71	4.42	4.50	3.82	1.11	0.73	1.20	2.68	1.66	1.76	5.65	0.41	3.66
4	3.38	1.69	2.17	4.17	2.14	2.39	3.16	1.18	3.28	0.82	2.89	2.89	2.19	3.14	3.94	0.39	2.39	3.30	
3	2.02	0.79	0.96	2.01	4.42	1.33	3.98	2.21	2.14	1.28	1.37	0.88	1.87	2.87	3.30	1.20	0.91	2.42	1.53
2	1.39	0.68	1.50	1.98	0.51	2.53	1.60	3.42	2.48	3.97	2.78	2.21	2.17	2.49	3.64	4.95	2.63	1.58	
1	2.01	0.79	1.52	1.70	1.78	2.21	0.62	1.58	1.47	1.51	0.17	2.03	1.02	1.55	1.02	1.15	0.56	4.33	2.26

Figure E-3: Schematical movements per subtest (1)

Test 3d >0.5Dn Stab. Nr = 3.15

22	1.71	4.67	0.74	3.03	3.02	4.19	2.12	2.35	5.89	1.86	3.94	1.97	2.12	2.63	3.92	2.10	3.99	3.25	
21	1.84	4.28	3.40	2.83	20.99	8.35	9.84	3.84	3.71	10.58	4.55	6.88	1.09	4.10	5.62	1.17	1.30	3.42	2.83
20	3.15	5.33	4.84	6.74	23.16	11.76	14.48	17.34	10.86	12.76	3.14	4.30	6.62	4.57	5.74	4.91	2.96	7.26	
19	5.17	5.46	7.11	8.23	13.40	18.23	18.29	25.85	17.44	10.16	9.02	8.93	2.35	6.90	7.90	3.04	7.82	6.08	12.28
18	8.84	15.16	7.15	11.86	12.75	16.57	18.78	10.24	18.19	17.53	12.44	7.78	12.13	11.17	9.49	7.10	6.73	10.92	
17	8.71	12.87	14.67	6.94	11.95	13.81	18.10	15.91	13.06	17.76	17.03	14.46	11.91	13.89	12.89	6.31	9.90	9.61	13.02
16	15.68	17.94	5.02	13.02	14.29	15.66	17.93	15.62	17.26	14.10	17.65	17.92	14.32	13.14	11.43	8.55	9.58	14.03	
15	0.00	17.87	8.24	7.07	13.81	18.36	18.64	16.04	14.52	21.14	16.92	19.47	16.65	11.12	12.29	7.51	9.08	7.95	10.56
14	15.70	8.12	8.25	13.52	14.79	18.09	14.80	13.31	16.59	13.34	20.43	19.49	23.09	16.14	10.41	10.25	6.50	6.50	
13	6.44	10.52	9.74	10.40	20.57	13.29	14.27	15.44	11.69	15.50	19.74	14.74	21.14	16.95	7.95	7.03	9.07	2.73	6.08
12	8.94	5.93	7.30	10.84	15.35	11.36	11.36	11.13	11.25	13.53	15.98	18.36	22.46	15.93	8.95	5.32	4.58	6.95	
11	9.91	6.20	6.95	8.40	14.84	12.98	11.03	9.73	9.47	8.91	9.17	15.33	15.45	11.54	10.94	10.12	5.18	6.62	7.31
10	4.15	4.47	5.66	15.87	10.52	11.48	13.81	11.43	12.08	13.34	16.90	15.78	13.71	11.23	8.25	4.15	4.91	6.95	
9	2.93	5.32	1.99	9.18	6.78	12.27	11.58	7.54	9.27	9.65	8.29	13.63	15.03	10.22	4.43	5.70	3.74	6.15	6.56
8	2.99	3.43	6.30	3.65	4.58	8.71	4.05	10.66	8.74	10.28	8.13	7.19	14.90	6.94	5.64	3.02	6.43	4.83	
7	2.04	2.63	4.04	6.32	5.86	8.01	6.99	6.51	10.16	7.70	7.10	3.91	9.58	4.14	2.17	1.34	2.60	1.42	3.78
6	1.09	2.45	6.35	5.42	5.73	6.26	7.07	6.68	7.24	1.89	4.87	5.16	7.58	4.26	5.11	4.26	5.10	3.51	
5	2.84	0.87	3.80	3.58	3.58	3.46	4.76	4.70	5.66	6.35	0.55	0.87	3.41	3.23	4.21	1.09	5.34	2.93	1.62
4	3.30	2.25	3.16	5.53	2.79	2.04	3.37	2.54	3.27	2.25	2.14	2.72	3.34	2.05	3.99	0.11	3.01	5.90	
3	1.47	1.17	2.24	3.62	6.28	3.67	4.18	4.67	3.12	3.76	0.38	0.19	2.35	2.66	4.25	5.22	3.58	2.09	1.92
2	0.40	2.82	2.32	3.43	1.01	4.48	1.21	2.20	1.49	3.25	1.98	2.68	2.30	1.61	2.83	5.51	3.20	2.22	
1	1.81	0.44	1.29	2.20	2.22	1.12	1.01	0.05	1.75	1.25	0.49	1.19	0.89	1.51	2.13	2.99	1.38	2.09	2.13

Test 3e >0.5Dn Stab. Nr = 3.71

22	1.41	2.08	5.46	4.91	8.14	3.54	2.91	4.49	14.00	5.28	3.64	4.11	4.39	5.41	5.95	2.81	2.67	4.32	
21	2.88	6.78	4.20	13.32	22.15	12.26	11.27	5.73	6.81	16.87	8.23	5.95	3.97	7.82	6.98	3.98	2.98	6.21	6.20
20	6.38	11.06	15.06	22.11	27.93	15.17	18.39	19.70	14.39	19.69	5.51	6.09	11.08	7.16	7.46	6.15	5.05	10.42	
19	7.96	12.37	16.89	19.09	20.39	23.58	21.54	29.05	27.02	15.83	15.73	14.15	5.33	10.72	9.72	5.07	5.57	8.13	13.56
18	12.57	22.72	18.25	24.00	14.60	22.87	22.12	16.94	24.61	20.45	17.68	12.51	20.37	16.73	8.86	10.81	8.78	12.19	
17	12.75	17.52	18.07	15.40	17.71	18.36	22.92	18.60	21.31	25.47	20.85	22.04	18.83	16.59	17.96	7.86	9.40	10.21	13.14
16	15.22	18.50	7.69	15.18	17.61	15.84	16.94	15.38	22.45	22.87	24.06	21.91	21.22	17.00	15.82	8.64	8.47	11.52	
15	0.00	18.30	9.56	10.61	18.39	20.42	21.00	20.35	17.64	24.58	20.38	21.88	25.01	13.13	13.56	8.28	7.94	10.99	10.23
14	20.15	8.29	10.86	13.56	18.16	18.83	17.46	15.42	18.71	16.89	23.90	22.89	26.66	17.13	11.47	10.24	5.24	9.84	
13	8.57	12.25	10.37	13.58	21.13	16.22	16.41	16.79	15.13	19.24	19.58	20.11	23.46	20.04	9.80	8.34	8.58	4.57	5.88
12	9.78	7.19	6.98	13.91	17.60	11.96	14.47	12.51	14.07	17.59	23.50	23.33	28.22	21.48	10.43	7.43	7.16	7.63	
11	9.66	7.10	7.01	7.28	13.58	14.56	14.56	15.31	12.68	12.62	15.64	21.85	18.21	15.58	13.16	9.88	6.20	7.18	6.60
10	6.68	5.95	7.42	15.62	11.40	13.68	13.62	11.97	12.78	15.28	17.55	17.91	14.08	11.94	8.02	4.51	5.64	6.44	
9	4.20	7.11	1.54	5.16	9.92	13.22	15.04	7.66	11.01	9.72	10.26	13.90	15.41	12.48	5.30	3.30	3.25	7.97	7.64
8	4.90	1.47	5.41	3.57	6.27	8.38	5.69	12.14	10.22	11.93	12.64	11.71	16.19	8.84	8.55	5.58	6.24	4.68	
7	3.83	3.66	4.94	6.69	7.78	8.75	10.20	8.10	13.12	8.93	9.22	6.06	7.76	5.93	3.75	5.02	2.03	2.66	3.72
6	1.22	1.55	4.65	4.64	4.74	5.28	5.82	7.45	6.42	3.43	5.94	7.08	8.44	4.01	4.46	3.80	5.65	5.77	
5	1.50	3.08	3.07	3.33	2.33	1.95	4.48	4.19	3.89	6.32	3.00	1.95	5.45	5.61	6.31	1.75	4.95	3.23	3.86
4	1.44	1.00	1.75	4.00	0.99	2.09	0.84	2.06	2.57	5.13	3.42	1.10	4.10	2.84	1.43	2.03	0.68	2.08	
3	2.45	0.45	1.40	3.10	4.20	1.21	1.14	3.47	2.54	1.62	1.59	0.25	0.99	0.99	3.87	4.43	2.50	0.87	2.19
2	3.14	0.33	3.33	2.92	1.38	4.14	1.74	2.41	2.36	2.11	2.78	0.62	1.02	1.22	2.79	4.91	3.08	3.00	
1	1.23	0.98	1.23	1.82	1.61	1.60	1.44	0.15	0.66	1.12	0.98	1.19	0.59	0.53	0.54	1.32	0.15	1.07	1.21

Test 3f >0.5Dn Stab. Nr = 4.24

22	3.10	11.17	3.40	8.17	16.05	5.89	6.04	6.65	13.31	4.12	5.13	5.39	4.42	4.17	4.69	1.83	3.79	4.82	
21	4.32	4.86	10.83	14.05	12.75	11.37	9.94	7.67	7.23	20.86	7.54	3.47	5.00	7.82	8.70	6.41	2.65	6.08	5.60
20	14.80	14.38	17.47	4.09	11.39	20.50	16.20	19.91	19.14	22.44	5.07	9.73	16.48	11.78	10.15	6.67	5.64	9.15	
19	26.43	18.47	24.72	23.38	21.13	30.72	21.33	26.71	28.37	19.73	22.81	22.55	16.62	20.93	19.44	11.26	8.61	10.79	16.37
18	14.13	28.43	22.53	28.00	16.52	22.28	25.10	20.96	29.50	24.21	29.49	29.87	24.89	13.56	13.69	13.87	11.41	17.02	
17	17.50	23.21	28.59	22.25	21.55	18.55	22.52	20.08	22.34	30.71	25.04	34.75	23.60	22.20	20.45	10.65	14.79	11.06	15.59
16	20.46	27.04	13.58	22.90	23.12	19.37	19.65	18.47	28.96	28.38	29.38	31.20	25.28	23.82	20.89	16.45	12.43	13.51	
15	0.00	25.00	13.43	12.90	24.74	23.90	23.46	21.31	18.62	26.74	26.65	31.66	31.82	23.34	21.26	19.00	12.26	12.05	11.23
14	24.52	10.68	12.14	18.12	22.44	23.37	21.65	19.75	21.41	19.83	26.64	30.52	31.59	24.24	18.76	15.81	7.71	11.41	
13	11.31	13.80	13.79	12.80	20.75	18.45	21.10	18.68	16.53	22.07	23.83	27.56	30.22	27.28	17.59	15.03	11.48	4.24	7.29
12	13.76	9.72	9.14	15.08	18.19	16.18	16.03	15.87	13.88	19.82	25.17	31.99	30.16	21.72	15.33	4.92	7.40	9.00	
11	13.65	10.90	9.88	13.32	14.78	16.18	17.65	14.39	13.00	13.41	18.99	25.39	22.06	21.80	13.78	12.86	7.83	5.99	7.25
10	6.39	7.64	6.14	18.33	14.19	16.63	14.81	13.84	13.04	17.72	20.86	21.20	20.30	15.12	8.83	5.16	5.37	9.21	
9	5.82	7.94	4.02	7.36	9.41	13.75	15.73	7.87	12.56	10.44	13.80	15.32	19.47	17.43	6.44	6.30	6.17	6.67	6.54
8	5.71	3.67	7.54	5.97	6.15	9.30	7.65	13.83	12.31	11.04	12.80	11.39	17.40	10.38	7.25	5.08	5.61	5.35	
7	3.69	1.90	3.59	7.45	6.42	8.33	5.87	7.18	12.97	9.46	9.19	7.70	11.05	9.44	5.82	2.12	3.26	3.11	5.18
6	2.14	1.93	5.99	5.97	6.21	6.09	8.55	5.64	9.18	2.11	5.97	6.90	10.86	4.59	3.07	3.97	6.28	5.92	
5	2.03	1.38	4.15	3.04	1.87	2.06	3.69	4.87	3.28	6.32	2.65	2.10	4.92	4.41	3.83	2.64	4.71	4.04	3.62
4	1.96	1.50	1.70	4.10	2.87	0.84	3.29	2.17	3.49	0.66	1.14	3.07	3.17	3.47	3.79	1.26	2.06	3.84	
3	3.31	0.68	0.54	2.71	5.12	0.56	1.58	1.05	0.66	2.26	1.63	2.56	0.69	0.75	5.64	3.20	3.39	2.25	2.92
2	2.01	1.79	2.70	4.13	2.92	2.83	1.02	0.59	1.38	1.54	1.35	1.86	2.26	1.25	2.38	3.61	2.98	2.28	
1	0.78	1.74	1.71	2.07	1.72	1.90	1.73	1.47	0.53	2.21	0.24	1.47	1.30	1.77	1.54	1.14	2.30	1.20	3.70

Test 3g >0.5Dn Stab. Nr = 4.81

22	32.15	26.69	11.50	17.10	24.44	5.29	3.61	6.25	18.88	4.46	6.90	6.42	7.41	9.07	5.80	2.97	3.61	5.75	
21	46.39	46.52	23.50	12.07	36.79	20.62	14.09	20.54	13.17	25.41	7.33	13.03	13.46	17.46	18.32	7.17	1.24	8.23	7.39
20	56.60	32.56	31.24	24.82	36.51	27.99	21.11	32.80	22.16	34.21	7.99	12.67	27.86	29.16	20.72	12.27	11.31	20.31	
19	0.00	31.82	47.59	31.83	28.34	17.24	23.97	37.55	33.84	25.07	33.20	27.26	20.09	30.46	29.03	12.97	13.63	21.81	25.05
18	35.60	40.69	39.66	26.60	17.18	24.61	34.27	28.30	37.96	30.53	38.28	29.22	30.20	30.75	22.63	15.59	15.06	29.60	
17	34.49	38.10	43.09	25.49	34.72	29.52	31.47	23.81	27.83	35.34	31.31	42.44	27.54	27.41	32.57	23.80	19.80	29.01	31.21
16	40.13	40.43	17.69	29.11	30.32	22.29	24.82	23.85	33.52	34.46	37.36	39.55	30.79	34.14	27.86	23.85	24.75	25.99	
15	0.00	36.51	24.13	21.79	33.52	29.79	27.13	27.28	25.03	30.47	32.78	37.06	37.81	27.11	26.02	23.99	19.61	25.08	25.01
14	32.28	19.79	18.37	26.65	26.93	25.87	24.41	23.89	25.53	23.88	32.51	38.35	36.10	32.42	23.35	22.49	16.82	24.92	
13	22.42	25.65	21.06	18.69	24.57	20.94	21.43	23.44	21.09	24.74	30.11	32.41	35.04	31.54	23.90	18.80	15.00	11.99	14.77
12	19.63	15.40	15.19	23.09	21.87	16.91	17.25	18.45	20.78	20.95	30.14	35.85	37.92	27.51	22.18	8.81	12.66	14.81	
11	21.45	15.96	14.78	19.71	19.93	16.75	19.43	18.17	17.03	16.68	22.68	31.31	25.22	27.27	21.36	19.76	9.33	12.36	11.01
10	8.98	12.70	7.90	20.32	14.01	21.74	17.96	16.69	16.26	18.41	23.70	22.90	23.50	19.51	13.95	8.90	11.80	13.71	
9	9.85	11.06	9.26	9.71	11.04	16.17	16.13	9.78	15.24	13.98	16.59	18.70	21.56	18.49	12.25	9.65	7.35	9.28	12.42
8	9.44	7.37	7.00	7.93	8.63	10.85	8.44	14.70	13.83	14.26	14.49	13.50	19.86	12.89	10.92	6.19	7.42	9.55	
7	6.24	4.20	6.49	10.13	5.95	8.89	7.64	9.54	14.89	12.35	10.23	10.24	18.99	9.86	7.71	4.75	3.53	4.28	6.80
6	4.43	3.13	7.43	6.83	6.34	8.33	7.93	6.52	8.09	4.45	8.95	9.24	12.54	6.45	6.39	5.16	8.81	7.33	
5	4.64	4.46	3.48	5.25	2.79	3.41	4.57	6.63	5.70	8.06	3.87	5.97	5.66	7.24	3.60	3.93	5.17	5.86	5.52
4	2.91	3.15	3.98	3.44	1.99	2.66	3.74	3.19	3.97	1.18	2.56	1.51	2.63	3.30	3.58	1.03	4.05	5.63	
3	6.69	1.53	1.29	2.70	5.25	3.44	2.32	3.92	2.49	1.26	2.38	1.43	2.28	0.96	6.19	4.42	5.53	3.07	3.77
2	1.22	1.55	1.69	3.28	2.17	2.95	1.60	2.61	2.80	3.00	3.06	3.13	0.60	1.57	2.63	5.18	4.29	3.27	
1	1.17	1.12	1.40	1.75	2.25	2.06	1.43	0.40	1.14	0.70	1.57	2.08	2.62	1.17	0.50	1.27	1.10	1.94	1.67

Figure E-4: Schematical movements per subtest (2)

Test 4

Test 4c >0.5Dn Stab. Nr = 2.88

22	9.67	24.02	3.72	2.18	3.71	2.91	5.76	2.98	2.25	3.88	4.04	3.97	1.79	3.91	2.28	2.98	4.28	1.57	
21	0.00	14.59	12.95	2.51	8.48	5.40	5.19	3.39	5.22	3.94	3.68	5.73	6.16	8.31	7.25	5.01	3.54	2.92	3.03
20	19.21	33.09	30.27	26.70	13.74	15.03	7.61	4.57	8.25	15.95	8.81	7.48	9.10	7.77	9.27	2.08	3.86	5.04	
19	22.52	36.29	25.69	32.31	20.48	9.93	14.57	4.72	10.75	19.07	16.54	10.01	9.13	10.68	11.76	4.74	6.07	9.28	4.34
18	39.32	26.41	26.63	19.30	17.31	21.12	16.67	8.77	25.16	14.80	15.47	9.79	14.29	7.65	11.56	7.27	5.03	0.00	
17	22.68	34.70	25.83	22.30	16.21	20.56	22.61	23.62	25.42	19.54	15.09	10.92	13.00	14.52	11.07	14.55	9.31	7.97	5.21
16	28.00	25.24	24.56	19.98	18.34	28.55	23.20	23.04	15.89	18.06	13.59	13.95	11.10	13.69	11.37	8.88	8.52	2.67	
15	29.79	31.22	37.03	21.99	19.95	23.11	24.02	23.52	14.37	17.50	22.50	14.14	12.40	12.59	8.56	11.20	7.75	3.89	9.69
14	27.01	28.46	26.29	22.98	21.02	17.03	26.93	18.78	11.48	19.92	21.05	21.27	17.63	7.98	9.63	9.46	5.54	9.57	
13	24.86	33.07	26.62	24.12	19.66	27.32	26.12	19.73	14.13	13.65	16.01	22.13	22.32	15.21	9.84	9.93	5.45	4.47	4.98
12	24.08	25.66	22.47	25.00	22.73	24.91	21.11	12.80	14.14	12.19	20.51	16.51	16.37	8.65	9.44	6.96	7.02	3.97	
11	18.93	26.34	20.06	21.78	19.41	25.20	28.66	17.64	12.69	13.70	20.76	14.94	15.43	10.47	9.28	6.68	5.50	5.69	5.87
10	15.22	24.46	24.80	21.03	20.35	24.24	18.36	12.15	12.89	19.27	14.59	9.64	17.72	7.04	7.33	3.69	2.83	4.46	
9	17.66	16.19	17.60	17.57	15.85	15.40	21.90	10.78	11.46	10.67	12.15	9.83	12.58	8.61	5.22	8.28	3.03	2.34	2.54
8	15.69	13.92	19.64	22.82	16.31	14.27	12.27	9.25	14.50	11.94	6.80	5.38	9.13	3.72	4.90	4.77	3.06	2.47	
7	12.39	11.08	12.96	17.14	18.20	14.75	12.19	10.83	14.11	8.00	10.12	8.21	4.24	1.32	4.27	1.27	3.01	1.65	4.00
6	11.31	10.51	13.53	17.20	13.74	15.41	5.89	12.01	4.85	6.10	6.03	4.79	4.50	2.50	1.55	1.21	4.54	2.43	
5	6.89	5.03	6.32	12.17	14.22	10.51	7.73	7.34	7.70	6.29	3.46	4.99	5.28	1.77	2.06	2.88	0.77	3.40	0.66
4	5.48	6.67	10.55	11.22	7.97	9.10	5.57	2.29	4.05	6.70	2.72	3.91	2.74	1.24	1.90	0.76	3.72	3.08	
3	2.63	2.95	0.37	6.01	10.49	3.14	3.57	4.22	2.93	3.16	1.25	1.49	3.95	1.33	1.65	0.38	1.36	1.24	0.90
2	2.60	2.40	1.14	3.38	5.27	3.11	1.60	1.30	1.32	3.13	5.63	2.97	1.83	0.91	1.41	2.26	2.94	1.81	
1	1.18	1.37	1.13	1.12	0.29	2.27	1.05	1.40	1.35	0.41	1.23	1.84	1.32	1.31	1.57	0.83	1.24	0.64	0.29

Test 4d >0.5Dn Stab. Nr =3.78

22	0.00	0.00	30.75	7.78	7.85	1.39	8.33	6.27	4.87	3.20	3.59	5.20	3.19	3.25	0.42	2.63	4.38	2.64	
21	0.00	0.00	45.41	32.01	16.75	17.27	12.02	8.73	6.30	15.94	5.70	7.17	6.50	12.60	1.49	5.64	4.18	2.73	4.48
20	18.06	51.38	31.16	36.56	26.20	36.04	34.45	21.99	9.43	22.26	3.44	14.53	9.21	14.31	14.71	3.59	7.46	2.53	
19	9.41	49.90	40.12	33.67	23.97	20.96	38.46	22.83	16.11	28.39	15.42	11.11	17.28	15.26	14.22	9.88	10.30	7.87	7.18
18	43.91	36.34	36.84	39.53	31.29	37.44	31.21	21.04	31.52	19.84	11.66	11.03	16.12	15.73	15.70	12.22	11.99	0.00	
17	38.06	37.34	38.54	34.80	32.71	37.70	40.77	31.18	29.58	26.47	17.65	16.08	18.07	17.97	18.39	15.70	16.97	11.22	5.43
16	36.43	32.95	37.72	31.97	36.58	43.25	33.81	23.68	25.09	24.46	15.07	17.07	13.96	19.23	15.61	13.20	11.25	6.57	
15	34.00	35.38	44.76	32.81	30.73	37.97	36.18	28.07	18.69	24.52	26.65	19.75	19.88	17.46	9.46	15.52	14.40	11.62	11.09
14	32.28	41.23	35.27	32.56	34.87	29.43	33.98	22.68	18.73	22.86	25.94	27.70	20.55	15.17	15.03	13.89	6.00	15.23	
13	25.48	35.77	33.37	31.74	30.89	36.42	32.13	22.93	22.08	20.76	20.15	27.99	23.16	15.29	12.95	12.89	8.10	8.77	12.80
12	30.31	32.71	30.69	29.96	30.02	33.56	24.98	17.75	19.30	18.50	24.22	20.99	16.52	12.18	14.96	7.30	7.88	3.99	
11	23.97	28.27	28.78	29.39	28.35	35.08	32.70	18.04	14.33	16.40	22.54	15.67	18.37	12.87	11.04	7.57	8.00	5.12	5.96
10	21.81	28.29	29.47	27.59	27.82	30.54	20.93	15.63	16.31	22.80	16.53	15.35	20.16	8.96	9.38	5.68	2.81	7.77	
9	15.39	16.54	24.62	23.76	21.86	20.17	24.37	13.00	14.17	14.27	14.50	10.79	12.79	11.25	7.01	9.28	5.24	5.27	3.31
8	17.59	18.53	22.25	24.61	16.15	15.54	13.81	12.43	14.78	9.80	7.82	7.08	10.06	1.50	3.73	4.21	5.30	4.75	
7	12.56	12.45	15.11	20.68	17.91	17.19	12.75	13.57	14.20	9.99	10.90	6.13	4.88	3.35	6.09	0.68	4.04	1.95	3.12
6	11.64	12.23	14.97	19.05	15.20	16.85	7.76	11.57	5.47	5.79	6.15	4.74	3.40	1.43	2.69	4.19	0.11	1.96	
5	9.04	5.50	6.67	15.19	13.71	12.09	9.07	7.43	7.64	7.71	6.13	4.13	2.53	1.46	0.39	3.35	1.13	2.54	3.14
4	6.13	3.73	10.93	10.05	8.68	4.46	5.44	0.78	1.74	3.89	3.24	1.08	2.72	0.78	1.25	1.55	4.23	2.85	
3	2.03	3.24	0.78	6.31	8.18	6.52	6.10	6.46	3.64	3.37	2.50	1.70	1.50	2.34	1.05	0.78	1.20	2.22	2.21
2	1.72	0.88	2.28	2.92	5.57	4.09	2.75	1.03	1.18	1.95	1.42	0.67	2.32	0.08	1.53	1.98	0.55	2.02	
1	1.14	1.56	0.43	1.37	0.81	1.75	1.66	2.00	2.27	0.87	0.36	1.04	1.96	0.92	1.18	1.47	1.08	0.65	2.28

Test 5

Test 5g >0.25Dn Stab. Nr = 4.79

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
22	6.28	2.67	5.79	6.53	2.26	3.18	0.46	0.52	3.43	0.61	0.99	1.43	1.12	1.81	2.14	2.59	0.96	0.94	1.59	1.24	1.73
21	2.99	2.37	6.41	4.37	3.72	5.52	2.74	3.30	6.09	2.57	1.53	2.83	0.23	1.54	5.31	1.92	5.30	0.96	0.65	3.07	17.05
20	0.66	5.47	5.91	4.01	8.68	5.44	2.20	3.28	3.48	2.59	4.01	6.30	5.04	2.32	3.45	5.34	4.02	4.10	1.62	4.35	19.39
19	5.08	12.10	11.92	6.82	6.76	3.29	1.68	3.00	4.35	4.29	4.46	6.27	4.89	2.94	2.12	1.80	3.12	5.41	3.08	4.11	0.00
18	18.31	10.29	10.80	6.16	7.76	4.24	2.39	4.90	3.82	4.94	5.69	2.04	4.21	4.32	3.78	3.86	2.03	6.11	5.20	6.44	3.38
17	16.33	11.16	7.21	7.42	6.55	4.81	4.59	3.55	5.36	7.28	6.44	5.20	5.39	4.48	6.28	3.57	4.14	5.21	5.37	4.40	4.83
16	13.57	9.22	9.23	8.27	6.63	5.96	4.34	5.45	5.74	6.53	5.90	5.54	3.24	1.86	7.46	3.58	4.52	2.77	6.39	5.89	3.19
15	9.36	5.94	10.18	6.34	2.82	4.93	2.18	2.17	3.29	4.51	4.08	3.78	1.68	6.15	3.31	2.19	3.95	2.55	4.09	3.93	5.03
14	9.12	5.72	7.18	2.42	5.12	4.19	3.81	2.58	1.94	4.73	4.73	1.95	3.16	2.40	3.47	2.85	2.98	3.98	3.26	1.81	6.51
13	8.89	4.51	4.32	2.49	3.89	3.69	3.99	3.00	1.78	1.69	4.22	1.18	0.65	4.22	3.88	1.06	1.84	3.95	3.52	3.65	4.72
12	10.33	5.70	4.71	3.84	4.17	2.93	4.71	2.01	1.95	2.20	4.04	2.22	2.94	5.92	2.71	2.02	1.55	1.92	3.40	1.94	3.20
11	3.60	3.83	1.93	2.34	1.55	1.24	2.26	1.24	1.10	0.64	2.13	3.42	2.93	1.91	4.39	2.75	4.05	1.21	2.61	1.97	3.18
10	4.39	3.95	3.37	2.69	1.08	2.40	1.88	0.90	1.39	3.16	1.84	2.15	1.68	2.19	2.87	3.88	2.97	1.47	1.56	1.42	0.54
9	4.25	1.56	2.61	2.73	2.94	1.86	2.96	2.85	1.05	0.59	0.96	2.61	0.98	2.36	2.88	1.27	1.56	1.44	0.58	2.93	2.19
8	2.88	2.73	1.05	1.33	1.96	0.40	3.07	1.53	1.22	0.71	1.38	1.95	0.23	0.75	1.26	2.24	1.29	2.04	0.31	1.08	0.98
7	1.96	1.74	2.41	2.00	1.68	1.31	1.07	1.11	1.65	2.48	1.70	0.72	1.58	1.85	0.64	0.45	1.20	0.30	2.00	1.07	2.37
6	3.30	2.42	1.63	2.62	1.30	0.52	1.50	0.47	1.84	1.09	1.76	2.68	1.05	2.67	2.07	1.87	1.93	1.93	1.16	2.16	2.28
5	0.46	2.39	0.38	1.56	0.60	1.83	1.40	1.53	2.15	1.42	1.69	2.60	1.78	1.56	0.53	2.22	1.85	1.29	0.91	1.79	0.68
4	0.88	1.98	1.82	1.14	0.86	0.82	0.60	1.97	2.09	1.13	0.70	2.57	2.39	2.57	0.73	0.86	0.59	1.03	1.22	2.13	0.19
3	0.24	1.09	1.31	2.64	0.89	1.43	2.14	1.86	1.55	1.69	1.95	1.07	1.23	1.46	1.45	0.67	2.10	2.79	0.50	0.60	1.66
2	1.19	2.40	1.82	1.69	0.89	0.68	1.31	2.21	1.51	0.81	1.56	0.33	0.76	0.66	0.76	0.77	1.50	0.89	0.28	1.63	1.95
1	1.14	1.48	2.12	0.92	1.14	0.76	0.66	0.44	2.82	0.64	1.06	0.37	1.29	2.23	2.00	1.58	1.98	1.77	0.67	0.52	1.59

Test 5g >0.5Dn Stab. Nr = 4.79

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
22	6.28	2.67	5.79	6.53	2.26	3.18	0.46	0.52	3.43	0.61	0.99	1.43	1.12	1.81	2.14	2.59	0.96	0.94	1.59	1.24	1.73
21	2.99	2.37	6.41	4.37	3.72	5.52	2.74	3.30	6.09	2.57	1.53	2.83	0.23	1.54	5.31	1.92	5.30	0.96	0.65	3.07	17.05
20	0.66	5.47	5.91	4.01	8.68	5.44	2.20	3.28	3.48	2.59	4.01	6.30	5.04	2.32	3.45	5.34	4.02	4.10	1.62	4.35	19.39
19	5.08	12.10	11.92	6.82	6.76	3.29	1.68	3.00	4.35	4.29	4.46	6.27	4.89	2.94	2.12	1.80	3.12	5.41	3.08	4.11	0.00
18	18.31	10.29	10.80	6.16	7.76	4.24	2.39	4.90	3.82	4.94	5.69	2.04	4.21	4.32	3.78	3.86	2.03	6.11	5.20	6.44	3.38
17	16.33	11.16	7.21	7.42	6.55	4.81	4.59	3.55	5.36	7.28	6.44	5.20	5.39	4.48	6.28	3.57	4.14	5.21	5.37	4.40	4.83
16	13.57	9.22	9.23	8.27	6.63	5.96	4.34	5.45	5.74	6.53	5.90	5.54	3.24	1.86	7.46	3.58	4.52	2.77	6.39	5.89	3.19
15	9.36	5.94	10.18	6.34	2.82	4.93	2.18	2.17	3.29	4.51	4.08	3.78	1.68	6.15	3.31	2.19	3.95	2.55	4.09	3.93	5.03
14	9.12	5.72	7.18	2.42	5.12	4.19	3.81	2.58	1.94	4.73	4.73	1.95	3.16	2.40	3.47	2.85	2.98	3.98	3.26	1.81	6.51
13	8.89	4.51	4.32	2.49	3.89	3.69	3.99	3.00	1.78	1.69	4.22	1.18	0.65	4.22	3.88	1.06	1.84	3.95	3.52	3.65	4.72
12	10.33	5.70	4.71	3.84	4.17	2.93	4.71	2.01	1.95	2.20	4.04	2.22	2.94	5.92	2.71	2.02	1.55	1.92	3.40	1.94	3.20
11	3.60	3.83	1.93	2.34	1.55	1.24	2.26	1.24	1.10	0.64	2.13	3.42	2.93	1.91	4.39	2.75	4.05	1.21	2.61	1.97	3.18
10	4.39	3.95	3.37	2.69	1.08	2.40	1.88	0.90	1.39	3.16	1.84	2.15	1.68	2.19	2.87	3.88	2.97	1.47	1.56	1.42	0.54
9	4.25	1.56	2.61	2.73	2.94	1.86	2.96	2.85	1.05	0.59	0.96	2.61	0.98	2.36	2.88	1.27	1.56	1.44	0.58	2.93	2.19
8	2.88	2.73	1.05	1.33	1.96	0.40	3.07	1.53	1.22	0.71	1.38	1.95	0.23	0.75	1.26	2.24	1.29	2.04	0.31	1.08	0.98
7	1.96	1.74	2.41	2.00	1.68	1.31	1.07	1.11	1.65	2.48	1.70	0.72	1.58	1.85	0.64	0.45	1.20	0.30	2.00	1.07	2.37
6	3.30	2.42	1.63	2.62	1.30	0.52	1.50	0.47	1.84	1.09	1.76	2.68	1.05	2.67	2.07	1.87	1.93	1.93	1.16	2.16	2.28
5	0.46	2.39	0.38	1.56	0.60	1.83	1.40	1.53	2.15	1.42	1.69	2.60	1.78	1.56	0.53	2.22	1.85	1.29	0.91	1.79	0.68
4	0.88	1.98	1.82	1.14	0.86	0.82	0.60	1.97	2.09	1.13	0.70	2.57	2.39	2.57	0.73	0.86	0.59	1.03	1.22	2.13	0.19
3	0.24	1.09	1.31	2.64	0.89	1.43	2.14	1.86	1.55	1.69	1.95	1.07	1.23	1.46	1.45	0.67	2.10	2.79	0.50	0.60	1.66
2	1.19	2.40	1.82	1.69	0.89	0.68	1.31	2.21	1.51	0.81	1.56	0.33	0.76	0.66	0.76	0.77	1.50	0.89	0.28	1.63	1.95
1	1.14	1.48	2.12	0.92	1.14	0.76	0.66	0.44	2.82	0.64	1.06	0.37	1.29	2.23	2.00	1.58	1.98	1.77	0.67	0.52	1.59

Test 6

Test 6d >0.25Dn Stab. Nr = 3.77

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
22	2.39	1.28	5.03	2.33	4.52	2.94	1.85	2.31	1.65	0.82	3.32	5.35	3.58	3.50	2.06	6.04	4.02	4.26	2.66	4.67	1.56
21	4.41	2.40	5.55	5.61	5.81	2.27	3.33	1.93	0.92	3.55	2.04	5.74	6.73	5.27	6.99	7.90	2.17	2.88	2.05	9.68	6.06
20	7.73	10.38	15.88	7.27	2.75	4.99	2.83	3.38	9.49	3.28	3.99	5.15	4.09	6.71	7.57	4.03	3.71	3.92	8.15	5.58	8.81
19	11.85	13.69	9.05	6.39	6.20	8.47	4.51	5.76	7.80	3.24	2.40	7.80	4.12	4.34	6.46	7.20	3.33	8.41	6.24	8.60	6.30
18	13.18	11.62	11.02	6.10	8.46	9.29	5.35	6.53	4.98	5.67	6.96	6.11	4.80	6.58	5.32	7.14	8.07	6.34	6.59	6.17	5.01
17	7.14	8.72	6.31	8.63	10.23	8.07	6.35	5.55	6.05	4.42	6.85	8.00	5.38	5.92	3.81	5.00	5.67	7.10	4.98	4.49	6.06
16	11.66	7.57	9.20	9.49	8.64	6.12	7.02	7.58	7.68	5.83	5.43	4.88	5.98	6.17	3.58	4.90	4.97	6.20	5.16	6.33	3.96
15	12.35	8.42	8.21	9.20	12.58	5.61	5.19	8.77	6.25	4.14	7.13	5.66	8.18	6.34	4.58	5.05	4.75	5.50	6.96	4.29	6.12
14	8.06	10.30	7.93	8.55	7.52	4.84	3.78	2.54	5.25	4.91	4.35	5.28	3.55	4.39	3.03	4.97	4.76	5.41	4.34	3.78	3.80
13	12.18	6.00	7.25	5.75	5.39	4.00	4.82	4.87	4.43	5.37	3.93	2.99	2.00	1.92	3.94	4.24	3.44	2.35	3.30	3.33	3.80
12	6.23	5.16	7.94	4.20	4.39	5.42	4.18	2.39	3.20	2.36	3.38	2.46	3.44	2.15	2.33	1.70	1.91	1.25	2.54	2.23	2.56
11	7.30	7.34	7.18	3.48	6.46	6.88	4.46	3.72	4.84	6.05	3.31	2.13	2.22	1.36	1.23	2.36	0.95	2.20	3.71	3.43	1.66
10	6.98	8.03	6.65	3.43	2.60	1.69	3.74	3.55	4.47	0.76	3.52	2.22	1.54	1.28	1.15	0.84	1.47	1.55	4.45	3.76	3.34
9	3.82	4.78	5.92	3.02	4.03	4.72	2.23	5.77	2.96	2.96	3.50	1.08	0.63	3.38	1.40	2.62	1.15	1.04	1.83	3.02	3.36
8	5.16	3.38	3.35	4.95	3.13	2.09	3.24	3.29	2.56	1.74	2.68	2.28	1.89	0.88	1.58	1.43	0.81	1.39	1.14	2.98	2.77
7	5.66	4.84	2.38	2.29	1.86	2.65	3.70	2.25	2.70	2.74	1.42	2.26	0.82	0.82	0.45	1.57	0.29	0.82	1.66	1.82	0.13
6	1.03	2.39	2.33	1.55	2.48	3.40	1.60	2.44	1.81	1.57	0.89	0.93	1.00	1.00	0.40	1.47	1.54	1.41	1.06	1.22	1.92
5	5.14	2.30	3.53	2.22	2.23	1.95	3.03	1.75	0.93	0.70	1.49	2.05	1.03	2.45	1.27	0.81	0.41	2.68	1.60	1.99	2.30
4	3.73	4.36	2.59	2.67	3.83	1.76	2.33	1.45	0.77	0.44	1.49	1.48	0.50	0.94	0.09	0.60	1.59	1.17	1.52	0.53	0.98
3	3.51	2.52	3.59	2.39	2.32	0.46	0.89	2.63	0.66	1.53	1.03	1.79	1.35	1.70	0.77	2.28	1.26	1.55	1.16	2.01	1.57
2	4.19	4.25	2.69	0.64	1.88	1.12	1.15	2.01	0.72	1.89	2.53	2.25	0.77	1.33	0.90	2.29	1.63	1.48	2.32	0.32	1.93
1	1.02	0.38	1.89	1.10	0.16	0.87	1.31	1.33	1.33	2.36	1.97	1.40	1.12	1.78	1.45	1.48	0.95	1.40	2.30	2.17	2.75

Test 6d >0.5Dn Stab. Nr = 3.77

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
22	2.39	1.28	5.03	2.33	4.52	2.94	1.85	2.31	1.65	0.82	3.32	5.35	3.58	3.50	2.06	6.04	4.02	4.26	2.66	4.67	1.56
21	4.41	2.40	5.55	5.61	5.81	2.27	3.33	1.93	0.92	3.55	2.04	5.74	6.73	5.27	6.99	7.90	2.17	2.88	2.05	9.68	6.06
20	7.73	10.38	15.88	7.27	2.75	4.99	2.83	3.38	9.49	3.28	3.99	5.15	4.09	6.71	7.57	4.03	3.71	3.92	8.15	5.58	8.81
19	11.85	13.69	9.05	6.39	6.20	8.47	4.51	5.76	7.80	3.24	2.40	7.80	4.12	4.34	6.46	7.20	3.33	8.41	6.24	8.60	6.30
18	13.18	11.62	11.02	6.10	8.46	9.29	5.35	6.53	4.98	5.67	6.96	6.11	4.80	6.58	5.32	7.14	8.07	6.34	6.59	6.17	5.01
17	7.14	8.72	6.31	8.63	10.23	8.07	6.35	5.55	6.05	4.42	6.85	8.00	5.38	5.92	3.81	5.00	5.67	7.10	4.98	4.49	6.06
16	11.66	7.57	9.20	9.49	8.64	6.12	7.02	7.58	7.68	5.83	5.43	4.88	5.98	6.17	3.58	4.90	4.97	6.20	5.16	6.33	3.96
15	12.35	8.42	8.21	9.20	12.58	5.61	5.19	8.77	6.25	4.14	7.13	5.66	8.18	6.34	4.58	5.05	4.75	5.50	6.96	4.29	6.12
14	8.06	10.30	7.93	8.55	7.52	4.84	3.78	2.54	5.25	4.91	4.35	5.28	3.55	4.39	3.03	4.97	4.76	5.41	4.34	3.78	3.80
13	12.18	6.00	7.25	5.75	5.39	4.00	4.82	4.87	4.43	5.37	3.93	2.99	2.00	1.92	3.94	4.24	3.44	2.35	3.30	3.33	3.80
12	6.23	5.16	7.94	4.20	4.39	5.42	4.18	2.39	3.20	2.36	3.38	2.46	3.44	2.15	2.33	1.70	1.91	1.25	2.54	2.23	2.56
11	7.30	7.34	7.18	3.48	6.46	6.88	4.46	3.72	4.84	6.05	3.31	2.13	2.22	1.36	1.23	2.36	0.95	2.20	3.71	3.43	1.66
10	6.98	8.03	6.65	3.43	2.60	1.69	3.74	3.55	4.47	0.76	3.52	2.22	1.54	1.28	1.15	0.84	1.47	1.55	4.45	3.76	3.34
9	3.82	4.78	5.92	3.02	4.03	4.72	2.23	5.77	2.96	2.96	3.50	1.08	0.63	3.38	1.40	2.62	1.15	1.04	1.83	3.02	3.36
8	5.16	3.38	3.35	4.95	3.13	2.09	3.24	3.29	2.56	1.74	2.68	2.28	1.89	0.88	1.58	1.43	0.81	1.39	1.14	2.98	2.77
7	5.66	4.84	2.38	2.29	1.86	2.65	3.70	2.25	2.70	2.74	1.42	2.26	0.82	0.82	0.45	1.57	0.29	0.82	1.66	1.82	0.13
6	1.03	2.39	2.33	1.55	2.48	3.40	1.60	2.44	1.81	1.57	0.89	0.93	1.00	1.00	0.40	1.47	1.54	1.41	1.06	1.22	1.92
5	5.14	2.30	3.53	2.22	2.23	1.95	3.03	1.75	0.93	0.70	1.49	2.05	1.03	2.45	1.27	0.81	0.41	2.68	1.60	1.99	2.30
4	3.73	4.36	2.59	2.67	3.83	1.76	2.33	1.45	0.77	0.44	1.49	1.48	0.50	0.94	0.09	0.60	1.59	1.17	1.52	0.53	0.98
3	3.51	2.52	3.59	2.39	2.32	0.46	0.89	2.63	0.66	1.53	1.03	1.79	1.35	1.70	0.77	2.28	1.26	1.55	1.16	2.01	1.57
2	4.19	4.25	2.69	0.64	1.88	1.12	1.15	2.01	0.72	1.89	2.53	2.25	0.77	1.33	0.90	2.29	1.63	1.48	2.32	0.32	1.93
1	1.02	0.38	1.89	1.10	0.16	0.87	1.31	1.33	1.33	2.36	1.97	1.40	1.12	1.78	1.45	1.48	0.95	1.40	2.30	2.17	2.75

Figure E-5: Schematical movements per subtest (3)

Test 6e >0.25Dn Stab. Nr = 4.60

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
22	1.88	4.62	5.02	5.56	2.68	7.07	4.50	2.76	4.08	2.49	5.76	7.94	7.99	5.44	4.78	3.13	1.63	2.17	5.32	5.88	4.58
21	1.18	5.72	0.89	1.34	2.39	5.14	4.41	3.70	4.74	5.92	6.36	8.07	7.06	11.71	9.98	7.01	4.59	4.25	6.65	2.70	3.95
20	17.30	7.36	9.01	7.61	6.95	8.04	8.63	11.23	15.07	2.97	4.81	9.11	10.54	10.08	13.45	7.48	3.26	6.02	8.70	2.96	6.22
19	21.79	15.63	14.09	10.59	9.53	12.34	11.16	10.09	12.96	6.69	3.48	10.49	9.20	6.74	8.81	7.56	8.12	7.14	7.95	11.53	8.24
18	18.42	16.38	15.09	10.11	15.41	12.56	8.57	9.65	9.33	10.31	11.30	9.24	10.18	6.07	9.11	10.73	12.39	7.02	8.85	9.52	9.67
17	19.71	12.93	10.42	11.21	17.99	11.87	9.52	8.96	10.68	9.56	11.82	10.35	6.93	7.26	8.64	9.37	8.40	10.15	6.66	8.94	14.90
16	18.34	10.15	14.49	13.13	13.85	7.48	10.12	9.55	11.84	9.22	9.60	9.63	9.09	7.49	5.79	7.52	8.77	7.17	7.19	9.33	10.10
15	15.28	12.94	12.45	12.86	11.98	10.93	8.54	10.42	9.73	8.04	11.74	9.09	11.95	8.89	8.39	7.66	6.29	8.98	8.89	7.37	8.84
14	13.51	14.88	10.85	12.59	13.01	8.45	10.03	7.85	9.27	9.95	7.83	8.20	7.56	7.18	7.41	7.67	7.41	7.38	7.64	7.20	7.19
13	13.40	11.39	8.94	7.47	8.73	8.10	7.54	7.68	7.56	7.89	7.35	6.67	5.76	7.65	5.11	6.65	4.71	3.36	5.79	6.66	5.28
12	11.93	7.53	10.51	6.68	5.72	6.44	7.95	6.30	6.46	5.71	5.48	4.43	6.98	7.50	5.66	4.39	4.01	3.78	6.42	6.44	5.62
11	9.25	10.90	10.38	7.89	9.04	9.98	7.27	6.38	6.65	8.10	5.39	4.92	4.15	3.90	4.51	5.16	2.62	3.20	4.51	4.29	3.07
10	9.18	7.22	7.94	6.19	4.33	5.11	5.89	5.03	6.93	5.58	4.33	3.77	5.47	5.06	4.17	2.67	1.29	3.59	5.16	3.57	3.62
9	7.41	5.91	6.48	4.24	3.32	6.27	4.62	7.04	5.72	3.07	5.87	2.28	3.99	5.15	4.15	3.45	1.50	0.66	2.46	4.63	4.45
8	7.79	4.48	6.14	6.02	5.89	3.52	5.18	6.74	4.69	2.72	4.74	3.71	4.64	1.86	3.84	2.85	1.35	1.01	2.75	4.14	5.17
7	5.34	3.87	3.26	4.17	4.42	3.56	6.34	4.91	4.10	4.11	5.56	4.61	3.57	3.13	2.23	1.70	2.30	0.59	2.17	3.84	3.54
6	4.07	4.31	1.99	4.73	5.06	3.37	6.07	1.09	4.10	0.74	2.67	2.55	2.32	1.43	2.39	4.37	0.67	3.56	2.58	1.13	2.57
5	4.55	2.37	3.66	3.29	3.31	2.74	4.36	3.24	1.49	2.06	1.16	1.51	0.91	2.99	1.37	1.85	1.79	1.52	1.31	0.94	3.35
4	5.03	4.69	3.13	4.59	4.45	1.75	2.10	2.05	3.23	1.82	1.95	2.41	3.26	2.40	2.48	2.57	1.32	1.09	1.28	0.86	1.35
3	2.26	2.54	3.54	2.05	1.97	1.28	1.14	2.21	1.45	1.98	3.21	3.22	2.14	3.01	1.55	2.03	3.14	1.81	2.39	1.58	1.76
2	1.23	1.72	3.45	2.08	2.46	2.09	1.87	3.99	2.11	2.65	3.29	2.27	2.10	2.23	3.04	3.03	2.33	2.33	1.00	1.48	1.77
1	1.46	2.56	2.35	2.26	2.39	1.85	2.13	0.50	2.20	2.02	1.18	2.75	2.60	2.04	2.43	2.02	2.01	2.59	1.01	1.91	1.25

Test 6e >0.5Dn Stab. Nr = 4.60

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
22	1.88	4.62	5.02	5.56	2.68	7.07	4.50	2.76	4.08	2.49	5.76	7.94	7.99	5.44	4.78	3.13	1.63	2.17	5.32	5.88	4.58
21	1.18	5.72	0.89	1.34	2.39	5.14	4.41	3.70	4.74	5.92	6.36	8.07	7.06	11.71	9.98	7.01	4.59	4.25	6.65	2.70	3.95
20	17.30	7.36	9.01	7.61	6.95	8.04	8.63	11.23	15.07	2.97	4.81	9.11	10.54	10.08	13.45	7.48	3.26	6.02	8.70	2.96	6.22
19	21.79	15.63	14.09	10.59	9.53	12.34	11.16	10.09	12.96	6.69	3.48	10.49	9.20	6.74	8.81	7.56	8.12	7.14	7.95	11.53	8.24
18	18.42	16.38	15.09	10.11	15.41	12.56	8.57	9.65	9.33	10.31	11.30	9.24	10.18	6.07	9.11	10.73	12.39	7.02	8.85	9.52	9.67
17	19.71	12.93	10.42	11.21	17.99	11.87	9.52	8.96	10.68	9.56	11.82	10.35	6.93	7.26	8.64	9.37	8.40	10.15	6.66	8.94	14.90
16	18.34	10.15	14.49	13.13	13.85	7.48	10.12	9.55	11.84	9.22	9.60	9.63	9.09	7.49	5.79	7.52	8.77	7.17	7.19	9.33	10.10
15	15.28	12.94	12.45	12.86	11.98	10.93	8.54	10.42	9.73	8.04	11.74	9.09	11.95	8.89	8.39	7.66	6.29	8.98	8.89	7.37	8.84
14	13.51	14.88	10.85	12.59	13.01	8.45	10.03	7.85	9.27	9.95	7.83	8.20	7.56	7.18	7.41	7.67	7.41	7.38	7.64	7.20	7.19
13	13.40	11.39	8.94	7.47	8.73	8.10	7.54	7.68	7.56	7.89	7.35	6.67	5.76	7.65	5.11	6.65	4.71	3.36	5.79	6.66	5.28
12	11.93	7.53	10.51	6.68	5.72	6.44	7.95	6.30	6.46	5.71	5.48	4.43	6.98	7.50	5.66	4.39	4.01	3.78	6.42	6.44	5.62
11	9.25	10.90	10.38	7.89	9.04	9.98	7.27	6.38	6.65	8.10	5.39	4.92	4.15	3.90	4.51	5.16	2.62	3.20	4.51	4.29	3.07
10	9.18	7.22	7.94	6.19	4.33	5.11	5.89	5.03	6.93	5.58	4.33	3.77	5.47	5.06	4.17	2.67	1.29	3.59	5.16	3.57	3.62
9	7.41	5.91	6.48	4.24	3.32	6.27	4.62	7.04	5.72	3.07	5.87	2.28	3.99	5.15	4.15	3.45	1.50	0.66	2.46	4.63	4.45
8	7.79	4.48	6.14	6.02	5.89	3.52	5.18	6.74	4.69	2.72	4.74	3.71	4.64	1.86	3.84	2.85	1.35	1.01	2.75	4.14	5.17
7	5.34	3.87	3.26	4.17	4.42	3.56	6.34	4.91	4.10	4.11	5.56	4.61	3.57	3.13	2.23	1.70	2.30	0.59	2.17	3.84	3.54
6	4.07	4.31	1.99	4.73	5.06	3.37	6.07	1.09	4.10	0.74	2.67	2.55	2.32	1.43	2.39	4.37	0.67	3.56	2.58	1.13	2.57
5	4.55	2.37	3.66	3.29	3.31	2.74	4.36	3.24	1.49	2.06	1.16	1.51	0.91	2.99	1.37	1.85	1.79	1.52	1.31	0.94	3.35
4	5.03	4.69	3.13	4.59	4.45	1.75	2.10	2.05	3.23	1.82	1.95	2.41	3.26	2.40	2.48	2.57	1.32	1.09	1.28	0.86	1.35
3	2.26	2.54	3.54	2.05	1.97	1.28	1.14	2.21	1.45	1.98	3.21	3.22	2.14	3.01	1.55	2.03	3.14	1.81	2.39	1.58	1.76
2	1.23	1.72	3.45	2.08	2.46	2.09	1.87	3.99	2.11	2.65	3.29	2.27	2.10	2.23	3.04	3.03	2.33	2.33	1.00	1.48	1.77
1	1.46	2.56	2.35	2.26	2.39	1.85	2.13	0.50	2.20	2.02	1.18	2.75	2.60	2.04	2.43	2.02	2.01	2.59	1.01	1.91	1.25

Test 7

Test 7d >0.5Dn Stab. Nr = 3.14

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
22	6.49	4.63	5.30	2.41	4.34	3.88	4.97	4.04	5.69	1.34	5.93	2.62	3.54	2.83	4.37	4.30	3.85	3.97	1.33	2.23
21	9.41	2.80	12.02	5.47	4.36	7.82	13.58	17.15	7.63	5.83	7.95	9.63	7.21	14.45	15.28	3.69	6.84	3.99	2.17	3.20
20	23.97	12.61	15.96	15.44	0.66	7.68	15.89	13.59	20.89	17.01	11.64	10.78	17.95	15.64	20.58	7.50	14.16	11.48	1.50	6.50
19	17.85	20.21	19.77	15.09	11.28	14.82	17.28	16.14	19.66	16.60	14.07	12.27	16.88	15.37	18.58	9.19	13.52	14.03	6.91	8.50
18	19.19	18.82	16.18	16.98	10.38	13.66	13.19	19.70	17.59	19.61	14.01	14.25	10.81	14.45	8.19	14.62	8.26	14.52	9.81	10.27
17	17.11	17.39	15.86	12.97	13.50	12.35	13.31	17.73	18.37	17.51	17.51	12.15	9.64	15.14	18.92	11.64	10.01	10.78	13.05	11.58
16	16.88	13.64	16.93	15.33	22.08	11.08	12.03	15.77	20.04	14.43	13.80	11.21	9.11	9.88	14.96	10.80	12.05	7.55	11.18	15.56
15	14.72	14.85	15.92	13.38	14.18	14.59	11.05	12.44	17.07	14.49	11.97	9.86	8.37	11.81	10.27	11.17	11.96	7.71	8.34	10.98
14	15.99	11.45	12.10	10.49	13.63	8.09	10.27	10.40	15.83	13.01	13.57	10.13	9.28	6.51	8.11	8.66	9.88	6.97	7.60	11.87
13	12.48	9.52	11.98	9.89	11.94	9.09	9.47	9.20	11.55	11.05	9.70	10.24	13.02	6.35	4.53	7.39	9.92	5.77	6.85	8.95
12	8.56	9.07	7.31	6.11	8.40	9.07	9.30	7.85	9.37	9.99	8.87	9.24	10.86	5.80	6.06	9.05	8.01	5.93	3.56	5.52
11	8.77	7.71	6.79	7.32	6.88	7.82	7.84	8.79	6.86	8.24	7.82	7.41	5.72	6.30	5.77	12.02	7.94	6.97	6.97	6.72
10	6.20	4.72	6.18	4.44	2.43	5.20	7.73	7.48	6.63	5.45	5.94	4.84	7.45	5.87	9.18	6.61	5.18	5.08	5.79	6.28
9	6.83	6.38	6.03	5.09	3.91	4.49	6.82	4.39	3.17	6.64	5.78	3.83	4.68	5.14	4.92	4.25	4.23	6.26	4.98	5.97
8	5.38	4.38	4.71	5.04	3.91	5.36	5.33	4.65	3.92	5.89	5.50	4.44	4.73	5.16	5.14	2.50	3.81	4.55	4.24	6.08
7	3.88	3.43	4.18	5.00	3.84	3.12	4.56	3.13	4.43	5.21	4.26	5.01	3.03	6.51	4.64	2.63	4.85	4.17	5.43	6.72
6	3.29	3.93	4.33	3.97	2.73	3.85	3.07	3.27	3.97	6.33	4.35	3.25	4.97	3.56	4.09	5.06	5.04	4.23	4.78	3.96
5	5.13	3.27	2.37	3.24	3.51	2.64	3.59	1.22	4.10	2.80	2.63	2.58	3.43	3.26	3.89	4.86	3.38	3.31	5.46	3.41
4	3.47	3.66	1.94	1.11	2.06	2.71	2.13	2.12	2.71	2.39	3.80	3.30	4.11	2.93	3.32	3.44	1.96	3.55	4.78	2.36
3	2.61	1.77	2.08	1.18	0.57	1.65	4.23	1.89	1.33	1.77	2.15	2.90	2.98	3.15	2.47	2.57	2.69	2.81	4.09	1.75
2	2.09	1.50	1.92	2.32	1.22	1.27	1.91	1.37	1.76	3.04	1.84	2.14	4.22	3.03	3.18	1.28	3.13	2.14	3.05	1.94
1	0.90	1.63	2.05	1.24	1.45	1.40	2.62	0.56	1.60	1.93	2.08	2.14	2.39	2.24	2.25	2.22	0.67	1.31	2.66	2.15

Test 7e >0.5Dn Stab. Nr = 3.68

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
22	8.90	7.95	6.30	5.48	5.67	7.73	6.59	3.62	4.59	4.44	10.98	1.77	5.03	1.32	2.79	5.87	5.18	1.72	4.74	0.58
21	15.42	17.62	25.69	12.87	7.13	9.96	17.46	19.22	12.50	11.16	22.59	18.63	19.76	20.00	30.97	15.09	16.23	18.27	9.20	10.30
20	26.77	20.50	22.92	21.31	13.81	17.13	22.47	22.03	29.60	23.07	28.03	18.11	21.91	20.51	33.27	21.77	24.19	18.47	17.56	15.41
19	20.30	26.05	24.80	20.99	18.18	20.46	21.86	22.87	29.32	23.53	20.63	16.57	19.59	20.09	26.70	21.14	18.21	21.35	16.69	16.98
18	23.21	23.19	21.28	22.98	18.59	16.02	16.26	24.50	28.80	26.39	19.59	19.11	15.74	19.88	16.26	21.30	17.21	19.55	19.13	20.82
17	27.23	20.67	20.29	19.34	19.71	15.72	14.47	23.50	25.83	23.75	21.52	17.45	15.90	17.38	24.32	18.17	14.40	16.71	18.66	17.68
16	21.50	19.27	19.29	20.45	22.93	14.87	14.46	21.30	22.09	19.24	16.92	15.42	12.73	13.82	19.63	17.55	15.96	13.71	14.43	20.04
15	17.08	13.54	16.85	15.63	16.51	17.35	12.10	17.66	18.14	17.06	17.76	14.28	12.68	16.37	15.55	16.40	18.01	12.17	13.25	13.26
14	14.41	12.48	13.16	11.24	17.74	10.64	13.45	12.37	14.66	14.56	18.31	14.22	12.29	9.44	12.67	12.56	16.10	10.20	11.41	12.09
13	13.39	12.23	12.63	13.30	13.87	12.44	12.88	12.64	14.96	13.28	14.04	12.70	14.14	8.32	7.79	11.33	14.06	8.85	9.93	10.72
12	11.25	10.83	8.86	9.02	10.10	9.92	10.48	11.57	12.47	11.26	13.27	12.04	13.70	9.00	8.71	12.64	11.71	8.26	6.69	8.44
11	11.71	9.72	7.49	7.69	9.11	8.53	8.67	11.05	8.84	9.47	8.54	9.21	9.81	8.97	7.80	11.89	10.43	9.42	7.36	7.40
10	6.53	8.51	7.54	5.27	6.12	7.41	9.84	9.14	7.44	6.86	7.72	6.98	8.65	9.28	9.98	8.12	6.07	6.67	6.21	5.92
9	9.26	9.18	7.48	6.71	4.44	5.57	8.10	7.39	5.22	6.57	5.99	4.40	6.90	8.49	7.61	5.18	5.70	6.25	5.75	7.76
8	8.09	6.80	4.78	6.57	5.60	6.76	7.29	4.19	6.58	8.60	5.13	6.07	3.66	6.22	4.48	3.59	4.61	4.98	5.09	7.10
7	4.72	4.81	5.43	3.81	4.84	3.48	4.57	5.19	5.03	6.02	5.87	4.95	4.27	7.67	5.33	5.09	4.27	5.36	5.72	8.56
6	3.39	6.32	3.60	3.66	3.47	3.71	4.10	5.05	3.59	6.13	3.85	3.19	4.48	3.98	5.00	4.69	4.13	3.29	6.51	4.22
5	3.73	4.58	3.31	4.83	3.70	3.18	3.83	2.87	3.50	2.58	3.09	3.70	2.65	2.66	2.35	4.42	3.21	1.72	5.58	2.74
4	4.47	4.20	4.45	1.33	2.41	2.79	3.94	3.05	1.96	2.19	2.79	2.64	3.05	1.42	3.34	3.44	3.71	1.64	5.45	1.54
3	3.18	1.34	3.51	3.36	0.95	2.77	3.67	2.54	1.99	0.98	3.29	3.17	3.56	3.47	3.15	1.22	2.90	3.33	4.86	0.75
2	1.29	1.33	2.35	2.66	1.40	0.39	1.35	1.29	2.36	3.19	1.09	1.96	2.97	2.32	2.36	1.05	2.24	2.21	4.48	1.73
1	1.49	1.62	2.17	1.61	2.28	1.53	1.67	0.88	1.65	2.56	1.67	1.87	1.65	2.46	1.66	2.08	2.48	2.87	2.14	1.80

Test 7f >0.5Dn Stab. Nr = 4.24

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
22	7.65	2.70	4.95	0.52	8.66	5.39	5.88	4.70	5.80	7.75	13.05	9.97	2.63	3.29	6.29	4.03	3.17	2.94	3.07	2.75
21	27.33	8.67	16.90	22.89	12.21	25.65	30.08	18.53	9.93	33.25	21.52	17.46	16.99	29.12	36.07	14.33	23.03	21.38	8.06	28.87
20	33.32	18.07	9.92	26.46	8.51	21.91	23.93	29.62	39.15	26.67	17.74	22.46	25.07	23.79	38.19	22.55	26.35	22.59	10.08	27.61
19	28.50	23.89	26.92	25.99	21.39	22.85	25.50	30.65	34.78	29.25	25.93	23.15	26.16	22.26	31.23	19.28	22.88	22.18	10.96	20.32
18	29.55	21.09	22.64	24.67	22.63	16.56	21.39	27.72	36.13	30.91	25.93	24.68	19.98	21.50	22.27	23.91	19.89	21.20	18.15	25.70
17	28.73	19.76	22.91	23.23	20.65	18.11	18.80	25.57	32.04	25.90	24.84	19.02	18.89	21.56	26.64	20.04	16.11	20.01	22.09	18.73
16	21.80	18.94	17.18	22.43	23.06	17.15	18.13	23.31	28.18	23.73	18.89	20.12	17.35	17.36	24.05	18.46	18.31	16.63	17.73	18.19
15	20.93	16.30	17.61	16.83	19.34	17.61	14.68	18.92	21.77	18.50	21.12	18.23	14.84	18.04	21.53	17.03	17.22	15.52	15.24	14.39
14	18.46	13.58	12.22	12.37	17.12	13.51	14.44	14.21	17.99	20.96	20.98	16.80	12.98	13.14	16.00	15.27	18.08	10.18	13.97	13.89
13	15.72	13.55	12.10	14.75	16.98	11.95	14.30	16.35	15.23	15.45	17.68	15.25	17.33	10.99	9.89	13.23	15.64	10.26	11.70	10.42
12	14.97	13.94	7.94	6.82	12.74	9.81	10.55	13.93	11.85	12.29	14.52	13.31	16.68	8.51	12.12	13.54	12.01	10.28	8.93	10.60
11	15.38	13.31	7.82	8.41	11.42	8.28	10.96	14.50	8.91	10.56	12.25	11.78	11.73	10.75	10.90	15.40	12.87	11.51	10.80	9.03
10	9.24	12.01	7.82	7.25	6.90	7.49	10.93	11.41	8.39	8.15	8.71	8.48	10.32	11.08	13.16	10.01	9.64	10.28	10.16	8.46
9	8.86	9.13	8.04	5.48	4.18	6.06	10.04	10.32	4.72	6.32	6.58	5.47	6.98	10.79	9.33	6.43	7.58	9.49	9.15	9.25
8	8.03	6.01	6.09	6.75	6.45	6.14	8.41	4.86	6.17	7.90	7.19	7.93	5.88	9.44	6.62	3.59	8.59	7.42	8.47	9.23
7	5.24	5.55	4.45	4.75	5.23	3.27	6.22	3.94	4.42	6.35	5.51	5.94	6.62	10.16	8.02	5.59	8.46	8.81	9.24	11.41
6	6.27	5.44	3.90	4.73	4.21	4.66	4.42	4.14	3.91	7.62	5.11	4.15	7.19	5.40	6.88	7.22	7.25	6.48	9.51	6.50
5	5.37	4.78	5.54	4.41	3.61	3.31	3.22	1.53	4.15	2.63	3.36	3.40	5.10	2.45	6.13	5.71	4.91	5.68	8.85	4.97
4	5.16	3.10	4.81	2.12	1.37	1.35	3.00	3.30	3.89	2.63	4.51	4.21	5.42	1.44	7.07	5.76	5.42	4.23	7.75	4.78
3	3.03	0.11	2.46	0.55	1.04	0.47	3.53	2.46	2.78	3.04	4.38	5.04	4.20	1.47	6.17	4.85	4.14	4.41	7.22	3.00
2	0.76	1.32	2.34	1.55	1.65	2.75	2.11	3.28	2.94	3.21	2.79	2.51	4.05	4.72	4.32	4.14	5.43	3.70	3.88	3.91
1	2.93	0.66	1.41	0.40	1.72	1.39	1.20	2.04	2.46	2.48	3.01	2.22	3.07	2.03	3.11	2.05	1.66	3.01	2.42	2.45

Test 7g >0.5Dn Stab. Nr = 4.78

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
22	9.77	9.94	0.00	8.17	34.03	11.06	11.25	7.50	10.37	12.64	12.42	15.52	10.19	3.47	1.77	7.60	9.73	4.36	5.50	1.48
21	35.84	12.82	25.62	31.99	41.61	31.79	25.89	18.42	13.02	29.93	26.86	26.79	38.19	36.11	43.83	15.22	26.84	23.56	12.85	18.82
20	41.73	19.23	18.40	28.91	36.44	26.77	30.76	36.83	48.24	18.89	20.68	37.40	26.51	10.25	47.63	23.97	27.06	29.11	23.00	20.26
19	36.40	13.02	18.15	29.06	31.37	31.73	0.00	35.83	41.80	39.97	23.25	31.27	36.11	13.16	40.61	27.85	24.19	29.63	19.14	24.77
18	35.56	13.05	26.85	29.19	19.28	22.72	28.00	33.48	39.14	38.75	22.18	26.60	25.59	3.59	31.40	28.93	21.95	28.66	13.69	29.15
17	36.43	25.04	27.34	28.84	28.92	23.80	24.11	27.92	36.06	32.60	29.70	24.62	28.74	15.29	34.90	25.02	20.57	22.24	24.88	22.08
16	29.58	25.72	19.78	26.86	28.41	24.44	21.78	26.38	31.65	27.21	25.28	23.14	19.82	17.71	31.12	22.49	21.64	20.29	20.70	19.04
15	24.75	23.07	22.92	22.35	24.64	22.31	21.22	23.75	25.78	21.06	26.54	22.61	18.44	18.72	28.23	18.83	22.54	18.42	17.50	17.86
14	25.32	16.91	16.09	15.63	21.91	17.61	18.92	19.46	24.24	22.70	25.49	22.29	16.93	14.85	17.59	20.47	19.50	15.41	17.78	18.23
13	22.62	19.27	15.19	15.98	19.33	16.81	17.44	20.16	17.61	18.24	17.73	19.41	19.53	13.61	15.61	15.29	21.44	16.39	14.60	14.30
12	23.89	16.33	11.40	9.23	14.10	14.35	15.33	19.25	16.59	12.80	16.97	15.12	17.45	11.10	12.87	17.48	16.62	12.17	11.86	11.23
11	19.95	17.22	10.24	9.61	11.97	12.86	15.68	17.82	12.86	11.08	13.45	13.00	14.72	11.24	11.20	15.58	14.53	13.99	10.70	10.26
10	9.98	16.96	8.87	7.02	7.53	7.48	14.78	14.39	10.66	9.48	9.98	8.27	13.14	12.86	13.09	9.52	11.96	11.20	10.01	9.39
9	11.15	10.92	8.46	6.75	5.80	7.31	11.86	10.08	5.97	7.42	8.25	7.87	8.61	12.17	10.58	7.34	11.23	11.84	9.01	9.83
8	9.45	6.85	6.62	7.74	6.09	5.64	8.56	8.55	5.75	7.61	6.93	8.14	4.73	9.77	8.76	5.95	7.97	9.15	9.77	8.96
7	7.93	7.44	5.48	5.29	4.96	2.69	5.33	5.19	5.29	6.24	6.41	7.36	5.54	10.79	7.53	5.60	6.26	8.50	8.20	10.05
6	6.02	6.51	5.42	4.02	3.29	5.21	5.15	4.77	4.21	5.34	6.10	3.92	5.65	4.55	6.43	6.44	5.20	5.75	7.04	4.69
5	7.03	4.23	4.30	5.63	4.10	2.19	4.31	2.04	4.52	2.80	4.35	4.97	4.97	3.46	5.10	5.27	3.05	4.75	9.05	2.68
4	5.94	6.02	5.95	2.31	2.32	1.47	3.64	1.03	2.33	2.47	4.04	3.86	4.66	3.00	4.59	3.55	4.89	3.77	6.88	3.42
3	4.62	3.09	4.07	3.72	1.33	3.01	3.07	1.22	0.85	1.41	3.16	1.34	3.29	3.89	3.46	1.38	2.92	3.24	5.36	3.01
2	1.12	0.89	2.20	3.69	2.32	2.97	2.36	0.81	1.34	1.46	1.75	0.90	1.87	2.17	2.28	0.52	1.52	2.37	4.08	1.42
1	1.71	1.71	2.98	2.29	1.33	2.37	2.70	1.90	1.66	0.56	2.04	2.32	1.98	0.96	2.39	1.38	0.68	2.85	1.02	1.58

Test 8

Test 8c >0.5Dn Stab. Nr = 2.88

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
22	2.85	1.40	4.51	2.84	1.71	1.49	3.51	1.87	4.48	1.26	1.86	3.40	4.71	3.69	2.71	0.55	2.93	2.22	2.16	1.68
21	1.66	0.90	8.45	10.04	7.54	6.81	10.04	13.94	9.26	7.61	1.28	9.24	12.77	4.33	5.42	6.06	6.34	18.73	8.93	7.10
20	6.14	11.21	14.78	14.97	5.52	8.21	14.79	12.79	10.79	10.58	8.90	11.92	11.43	3.89	7.30	6.66	8.13	18.44	9.35	13.99
19	7.90	8.53	13.33	12.84	8.32	14.55	17.99	12.36	9.88	12.05	17.57	13.55	15.69	9.06	8.56	6.90	7.20	8.29	8.17	12.33
18	12.76	7.18	9.68	11.91	11.24	14.29	17.24	11.67	13.64	12.72	13.03	11.55	12.32	9.50	9.91	10.32	4.83	7.66	11.37	11.48
17	13.40	7.97	7.68	11.33	11.45	14.88	20.30	11.60	10.57	15.06	14.40	9.54	12.21	9.82	10.98	7.56	10.26	5.13	7.50	6.78
16	11.47	7.32	10.00	10.12	9.88	12.60	15.75	11.74	10.36	9.55	10.20	6.22	8.34	4.63	6.95	8.46	4.82	3.88	5.03	4.27
15	9.73	8.35	11.04	9.80	12.99	10.41	14.36	13.28	9.05	7.88	8.37	5.66	8.47	5.40	5.26	5.69	3.96	2.54	4.96	3.81
14	6.67	6.33	9.92	5.75	10.33	6.99	13.82	11.15	9.07	7.73	8.12	7.27	7.11	5.75	4.69	4.68	3.63	1.84	4.81	1.51
13	4.88	6.37	7.91	7.31	6.64	8.02	10.12	10.30	7.97	5.43	5.38	4.71	5.06	6.09	3.75	2.80	4.79	1.69	1.95	4.68
12	4.55	7.29	6.92	7.91	4.57	6.32	9.66	7.89	12.15	5.04	4.73	5.02	5.51	4.32	3.80	2.97	2.69	2.90	2.53	2.16
11	6.48	4.89	6.46	3.67	3.36	3.43	4.02	6.20	6.96	5.42	4.92	3.77	3.52	2.38	3.50	3.43	1.95	2.42	1.94	3.11
10	4.21	6.28	3.80	5.57	3.70	4.08	5.49	6.48	5.90	5.77	3.97	4.52	3.08	2.23	2.31	1.08	2.33	2.15	2.69	2.32
9	5.80	4.96	5.21	3.65	4.21	2.47	2.93	2.24	5.49	5.99	4.79	2.44	3.83	2.36	2.55	0.41	2.45	0.59	2.36	2.77
8	6.25	4.46	4.71	1.79	2.19	1.72	3.60	3.08	2.96	4.38	3.12	1.98	1.80	2.11	0.62	1.32	2.55	1.44	0.34	2.00
7	4.74	3.54	2.33	1.75	1.72	2.04	2.47	2.49	4.37	1.20	1.92	0.48	0.61	1.82	1.63	1.82	1.10	0.85	3.14	2.52
6	5.90	3.33	3.16	1.38	2.38	1.12	1.29	2.09	2.50	1.90	2.23	3.28	0.79	2.15	1.05	1.98	0.89	1.81	2.33	1.21
5	4.54	2.01	1.98	1.30	2.21	1.54	3.22	1.55	2.09	2.46	2.55	3.90	2.77	2.50	2.67	1.50	1.68	2.33	1.90	2.03
4	1.70	1.86	1.83	2.21	2.51	0.91	2.61	1.57	0.80	2.09	3.62	1.77	2.29	2.16	2.83	2.41	2.55	3.11	1.51	2.92
3	2.93	0.91	1.62	1.84	1.25	2.23	1.68	1.52	2.34	1.34	1.68	3.05	3.08	3.81	1.93	2.79	2.20	2.57	2.05	3.33
2	0.85	0.31	2.16	2.47	2.12	1.71	2.08	1.85	2.23	3.23	2.40	2.74	2.74	2.48	2.26	4.22	1.75	1.20	2.31	2.58
1	0.83	1.09	2.20	1.53	2.22	2.63	2.39	2.58	2.78	2.57	2.39	1.76	2.76	2.31	2.68	2.38	3.42	2.43	1.54	1.66

Test 8d >0.5Dn Stab. Nr = 3.72

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
22	3.19	3.70	6.06	2.74	6.00	9.25	19.32	8.94	11.13	8.47	19.95	3.96	9.83	14.00	14.32	10.24	7.18	5.11	0.31	1.11
21	5.71	8.31	16.00	16.66	21.30	16.46	22.24	19.46	9.46	39.48	25.17	27.11	17.71	16.19	16.66	17.36	15.97	33.46	10.03	3.05
20	28.63	19.06	25.61	23.58	14.53	19.60	18.43	17.09	18.11	49.74	29.52	23.49	24.20	23.69	31.37	26.70	24.82	26.18	13.44	8.38
19	23.52	23.62	24.80	19.52	17.02	22.62	27.57	22.10	22.36	30.54	34.78	21.72	19.74	19.96	18.61	34.11	0.00	11.90	8.91	10.33
18	20.37	19.55	24.92	18.83	21.96	22.14	27.50	24.59	21.29	21.34	0.00	18.24	18.09	20.17	17.97	23.07	13.60	16.28	14.49	14.96
17	30.20	17.97	20.76	20.28	20.30	21.24	27.86	18.36	18.24	19.86	16.20	14.60	18.28	17.38	18.81	15.43	16.73	10.14	13.43	12.61
16	24.56	19.44	19.37	18.45	21.31	19.68	25.95	17.74	15.05	16.36	16.32	13.29	13.98	12.97	13.71	13.80	8.67	8.74	8.47	10.06
15	23.84	15.39	21.09	19.92	20.67	16.80	19.84	19.57	12.82	12.79	12.66	13.38	14.41	12.16	12.86	10.54	10.05	6.79	8.08	9.24
14	15.60	14.38	15.78	14.13	19.99	12.66	17.52	16.44	14.37	12.62	11.31	11.77	11.95	9.94	12.37	7.13	7.21	6.25	8.66	4.76
13	13.00	13.15	15.37	14.84	13.77	11.72	16.21	15.06	12.30	10.74	10.27	9.65	9.17	10.05	8.32	6.22	6.05	5.22	7.42	7.32
12	13.29	15.01	14.22	15.24	11.10	10.06	14.34	11.24	15.60	10.78	10.42	9.52	11.41	8.24	8.82	6.09	5.55	6.53	6.32	4.37
11	12.07	12.83	13.10	10.68	8.45	7.76	9.01	9.99	11.02	9.07	10.19	8.75	10.22	5.26	7.79	6.64	6.91	6.69	5.34	5.44
10	10.49	11.18	9.08	10.56	7.91	6.58	9.21	7.78	9.82	10.53	10.23	8.10	8.05	5.42	6.25	5.64	4.98	3.64	7.47	5.73
9	12.46	9.92	9.63	5.48	8.43	6.77	5.82	6.73	9.92	8.24	8.17	8.57	8.14	4.23	6.76	4.52	6.05	4.43	6.07	3.87
8	12.22	8.76	9.58	5.99	6.17	4.31	4.24	6.86	6.50	6.42	7.32	5.04	7.23	5.95	5.24	4.34	5.44	3.60	2.67	2.17
7	10.17	9.33	7.38	4.79	6.08	3.64	4.82	5.43	3.37	5.14	3.93	2.78	6.24	2.67	3.00	3.46	3.41	2.45	2.05	3.44
6	10.84	6.17	3.92	5.14	4.77	3.26	3.76	4.95	1.76	2.58	3.95	3.98	4.78	1.36	3.25	2.43	2.95	3.23	6.77	2.44
5	6.41	2.70	5.60	3.16	5.01	4.21	3.72	2.31	2.86	2.73	2.54	1.76	2.10	1.40	2.70	3.92	3.63	3.10	3.73	2.43
4	5.37	2.14	3.45	1.42	4.17	3.23	4.06	1.48	3.63	2.31	1.81	1.96	1.51	2.44	1.60	2.75	1.96	1.26	1.64	2.60
3	2.44	0.60	1.62	0.19	1.70	1.28	2.22	2.31	1.72	2.37	2.23	1.46	1.87	1.19	1.71	1.21	1.76	2.46	1.31	1.22
2	1.15	1.72	0.52	2.89	0.93	2.14	2.92	1.30	1.63	1.27	2.83	2.20	2.86	1.60	1.55	1.80	2.80	2.79	2.28	2.21
1	1.66	1.01	2.33	0.73	1.60	1.23	1.40	2.19	0.82	0.13	2.19	1.94	1.23	1.22	1.79	0.65	0.70	2.00	3.33	1.93

Figure E-6: Schematical movements per subtest (4)

Test 9

Test 9f >0.5Dn Stab. Nr = 4.25

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
22	3.30	3.00	1.60	2.71	3.16	2.49	1.93	2.09	3.83	1.56	3.02	3.73	2.79	4.98	3.08	5.73	3.85	4.89	2.30	4.52	2.26
21	5.69	8.74	1.34	0.53	1.87	0.55	3.56	1.25	6.77	4.57	1.76	4.32	3.86	7.61	10.28	5.65	9.30	7.97	1.58	8.48	14.52
20	17.87	14.54	10.36	8.99	7.16	4.15	11.63	3.28	2.21	4.58	9.04	12.49	10.17	4.78	14.48	8.98	14.26	13.83	12.83	12.88	11.63
19	9.95	14.57	11.05	15.38	6.17	4.78	7.45	8.74	7.39	4.45	7.25	12.47	8.29	9.11	8.98	8.25	14.68	13.93	14.62	15.35	11.64
18	18.42	15.88	14.51	10.03	10.09	4.87	7.34	9.19	8.29	7.04	5.75	7.64	12.48	8.99	7.19	9.09	10.12	12.90	14.48	13.96	13.45
17	14.86	14.33	13.29	9.14	7.73	7.67	6.45	8.90	7.57	7.23	10.68	4.03	9.67	10.37	11.67	9.94	7.16	7.11	12.89	12.98	16.63
16	16.13	15.89	15.27	9.90	6.10	6.85	7.37	8.64	6.42	8.98	7.07	6.78	5.07	4.30	12.23	11.76	7.46	5.51	13.74	13.69	10.18
15	15.92	11.81	9.40	9.74	4.47	4.73	4.06	5.38	8.24	8.97	7.19	7.07	4.99	6.58	8.84	6.23	7.40	4.66	7.70	8.50	12.92
14	14.94	10.49	7.71	8.51	3.42	3.03	7.73	7.47	4.91	6.27	6.41	4.97	6.19	5.33	6.19	5.32	5.26	5.86	5.03	5.47	9.13
13	16.23	6.04	4.10	4.81	4.00	1.75	1.84	2.85	6.26	6.70	6.17	3.92	3.53	2.72	3.05	4.87	3.94	7.35	6.39	2.74	0.69
12	11.57	5.29	4.10	5.32	4.57	2.12	1.02	3.72	7.50	5.80	4.86	2.07	2.47	3.66	4.00	4.76	2.99	5.34	1.60	5.99	5.58
11	6.94	4.85	6.91	4.11	5.44	1.91	1.51	1.75	6.18	3.11	1.94	3.21	3.05	2.84	2.32	1.82	3.60	4.63	3.21	2.93	7.37
10	5.32	2.05	4.18	2.25	1.86	2.10	2.19	2.21	3.88	2.44	4.47	2.03	1.52	2.34	1.39	3.11	2.33	3.17	2.39	0.58	1.16
9	3.77	3.88	3.06	2.78	1.57	3.02	2.43	2.74	2.38	2.80	3.09	2.92	2.04	4.19	1.83	2.98	3.10	4.54	1.27	1.90	2.58
8	2.14	1.25	0.79	2.53	1.41	1.33	2.46	1.47	2.46	4.59	3.30	1.83	3.66	1.60	2.75	1.48	4.28	2.06	1.00	2.57	1.89
7	3.44	1.36	1.73	0.35	1.55	2.75	2.15	0.70	0.72	4.88	2.02	3.79	2.98	3.86	3.11	3.79	2.85	4.30	3.14	2.63	2.71
6	1.03	2.19	1.05	1.50	1.47	1.30	1.05	1.75	2.38	3.16	1.99	2.85	3.59	2.03	2.92	2.74	2.91	3.72	2.43	2.60	3.12
5	2.27	0.40	1.76	1.59	1.51	1.07	0.24	2.27	1.58	2.01	2.42	3.59	3.51	3.20	2.44	2.81	3.24	3.37	3.15	3.89	3.75
4	0.79	1.64	2.25	1.46	0.62	0.89	1.09	2.87	3.25	1.19	1.61	2.96	3.21	2.87	3.41	1.83	2.94	2.77	3.74	1.98	2.13
3	0.94	1.92	1.33	1.58	0.68	0.59	2.71	1.89	2.85	3.01	0.91	2.69	5.28	4.75	2.45	2.67	2.59	3.49	3.92	2.81	4.24
2	2.94	1.58	0.73	1.51	0.56	1.22	2.03	1.78	1.82	2.96	1.04	4.31	3.64	4.26	4.22	3.48	2.15	3.30	2.85	3.51	4.50
1	0.29	0.40	0.71	0.71	0.31	0.44	2.13	0.84	2.08	1.84	2.77	2.58	2.38	1.65	2.41	1.99	2.09	2.89	1.56	2.69	2.02

Test 9g >0.5Dn Stab. Nr = 4.81

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
22	7.10	0.95	2.56	2.49	0.73	2.23	2.38	2.79	3.59	2.67	2.81	2.88	6.01	4.66	5.99	8.37	3.88	7.96	3.24	11.97	2.39
21	4.14	11.92	8.40	8.52	12.38	6.89	3.59	5.45	9.49	8.35	7.03	7.07	9.54	7.26	7.60	8.67	17.72	18.36	9.32	19.35	26.29
20	12.80	12.15	13.12	12.31	13.04	6.68	8.30	7.90	6.07	8.43	11.30	18.17	14.68	9.89	17.54	14.09	20.71	15.84	19.33	20.06	29.91
19	2.07	14.64	13.90	16.13	8.63	8.67	11.11	13.16	9.96	7.46	15.84	21.42	13.76	10.61	10.85	13.19	21.48	14.11	8.38	23.96	34.98
18	21.78	16.42	17.68	10.94	11.79	8.61	11.35	12.24	12.57	10.97	9.25	13.16	15.97	11.89	8.91	12.28	15.67	15.28	19.12	20.28	32.65
17	16.69	19.97	16.28	9.86	10.07	10.27	10.51	11.93	9.91	11.43	11.37	9.96	13.20	14.03	14.08	11.25	10.69	10.05	14.21	16.13	30.51
16	22.02	19.84	17.50	11.22	6.67	9.28	9.88	10.35	7.96	11.29	11.22	8.71	9.82	6.29	13.98	13.07	12.02	7.05	15.36	19.69	0.00
15	19.03	13.71	9.46	10.39	4.75	5.10	7.12	6.87	8.46	9.79	7.74	9.23	3.46	5.45	10.56	8.66	10.49	7.77	9.36	11.53	15.84
14	17.25	12.30	8.31	9.00	4.48	3.44	7.15	7.89	6.31	7.80	8.18	6.71	6.72	4.80	8.60	7.75	7.05	7.56	8.50	8.89	12.89
13	17.50	7.56	5.68	6.05	6.33	2.47	2.80	5.28	8.08	6.77	6.33	5.18	3.50	2.54	6.53	5.42	6.35	7.33	8.16	6.69	7.37
12	13.67	7.02	4.87	4.05	6.52	3.47	1.48	4.01	7.58	6.98	6.92	2.88	3.96	4.71	4.43	3.83	4.39	5.74	3.56	7.80	6.47
11	8.88	5.94	8.01	3.11	7.53	2.29	2.23	2.63	6.25	2.67	2.88	3.13	3.02	3.61	3.76	2.70	4.87	4.50	4.55	4.19	9.76
10	7.86	2.69	3.83	2.77	3.54	1.38	3.77	2.85	5.45	4.03	5.23	2.67	1.74	3.44	1.49	2.34	2.15	1.44	1.71	1.92	3.93
9	5.74	4.48	5.76	2.80	1.96	2.83	2.11	2.55	4.06	2.12	4.16	2.74	1.83	3.39	2.55	2.06	2.90	3.08	3.06	2.46	2.61
8	1.72	0.46	0.99	4.63	0.94	2.51	2.01	2.90	3.17	4.92	4.57	3.04	3.41	2.35	1.84	2.62	3.87	1.22	1.45	1.41	1.18
7	3.06	1.05	2.64	0.83	1.76	1.72	0.77	1.65	2.00	5.01	3.62	3.11	3.68	3.04	2.82	4.19	2.07	2.64	3.24	2.90	1.24
6	1.42	0.76	1.16	0.29	1.36	1.49	1.94	0.54	2.28	2.18	1.83	3.04	3.54	3.12	3.23	3.10	2.39	2.78	2.29	1.18	1.85
5	0.78	2.51	2.01	1.14	0.84	1.60	1.70	2.58	1.85	1.09	2.41	3.49	3.36	2.78	3.08	2.38	2.53	3.27	2.81	2.97	1.59
4	1.35	1.99	0.08	0.86	0.62	1.47	2.74	1.93	3.35	1.08	3.24	1.48	3.66	2.54	2.53	1.92	2.06	1.65	2.02	1.98	2.00
3	0.19	0.89	1.81	1.80	0.79	1.18	2.16	1.94	1.82	2.16	0.59	2.22	4.81	3.45	0.87	1.99	2.05	2.12	3.66	1.66	3.78
2	4.14	0.59	0.91	1.14	0.16	1.32	1.48	1.03	1.69	2.54	1.24	3.96	4.74	4.26	3.23	2.53	1.34	2.84	3.28	2.79	2.63
1	2.76	0.66	1.85	1.02	0.63	1.38	1.59	0.37	2.65	1.63	2.56	3.51	3.81	3.56	3.86	3.73	3.60	3.43	3.38	3.17	3.94

Test 10

Test 10d >0.5Dn Stab. Nr = 3.72

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
22	5.02	2.52	3.53	2.56	1.44	2.94	3.66	2.80	2.75	5.36	0.54	1.92	3.54	2.44	1.06	2.40	0.38	3.51	3.85	0.65	2.03
21	16.55	6.83	2.69	2.44	3.67	5.93	7.12	2.64	5.38	4.75	2.77	2.06	2.41	5.15	5.95	3.78	4.48	15.54	5.86	3.70	13.96
20	15.22	8.34	8.11	10.58	8.77	9.84	10.20	6.84	9.71	6.92	10.77	9.08	11.16	12.47	14.05	9.96	10.99	18.57	10.72	16.92	17.97
19	13.83	15.21	8.53	12.39	12.47	8.09	11.59	7.67	10.60	11.06	11.21	11.08	12.31	15.07	14.05	14.82	15.44	21.91	21.23	18.19	20.42
18	11.06	13.30	10.25	13.32	9.24	9.16	15.80	10.79	11.74	8.89	10.41	10.26	11.70	12.12	12.50	11.62	16.46	22.23	17.92	18.60	20.16
17	10.30	11.85	8.40	9.61	14.64	11.87	12.22	10.94	9.18	11.04	9.17	9.80	6.11	9.50	12.29	13.01	22.68	17.33	15.25	14.95	21.85
16	12.01	10.57	13.88	9.32	11.55	10.14	7.98	7.81	9.30	11.54	8.57	12.12	7.68	10.26	13.63	15.54	12.24	14.91	13.57	15.37	15.15
15	15.51	13.98	10.46	12.43	9.51	9.13	9.11	8.67	12.10	10.49	10.33	9.75	9.53	10.87	13.16	13.00	7.40	10.09	14.11	15.37	17.16
14	13.46	12.02	11.66	11.31	10.09	8.47	8.37	11.10	9.25	10.46	11.23	10.20	10.06	10.70	9.62	12.42	12.25	10.94	13.44	16.43	15.12
13	15.20	11.95	9.76	10.49	6.70	7.52	8.10	6.82	11.55	10.55	10.92	12.05	10.25	8.92	11.77	8.83	12.03	11.56	12.72	17.61	13.78
12	10.18	10.43	12.00	5.09	7.84	5.49	5.88	7.59	6.51	8.51	9.53	12.43	6.70	9.61	10.13	10.28	9.35	11.91	11.19	13.40	16.69
11	10.18	10.29	8.18	4.81	6.11	5.13	6.01	6.20	7.10	6.40	9.56	7.81	9.68	7.37	8.59	9.23	8.11	9.60	13.01	10.85	21.39
10	15.24	10.22	6.34	4.69	3.00	6.10	3.97	6.13	8.48	5.02	8.20	7.59	8.08	9.62	5.70	7.59	6.86	11.03	8.81	12.72	17.97
9	12.08	12.07	6.71	7.50	2.97	4.91	2.61	3.55	4.24	5.87	6.16	4.99	7.71	7.33	4.48	6.91	4.99	7.20	7.56	13.25	17.73
8	7.33	7.84	6.13	5.51	3.73	4.92	2.71	3.77	3.02	4.14	4.87	4.91	6.20	7.52	4.53	4.61	3.93	3.96	5.56	9.94	14.45
7	5.49	8.07	3.59	6.38	4.03	2.16	0.98	3.52	3.59	3.18	3.68	3.18	4.49	6.20	3.57	5.34	3.72	4.93	4.32	8.51	10.61
6	0.41	3.79	5.47	2.32	2.87	1.76	1.14	3.08	2.21	2.18	2.18	3.70	5.32	3.89	2.39	3.85	3.72	4.27	4.59	9.51	7.82
5	0.71	1.37	4.80	3.01	0.64	2.71	1.73	3.17	1.23	0.58	3.80	2.04	3.17	5.60	1.37	2.76	1.66	3.58	0.73	1.32	3.53
4	0.83	1.10	1.90	2.26	2.90	1.66	2.10	1.89	0.76	0.43	0.67	1.69	1.73	3.36	2.47	1.38	0.81	2.03	2.07	3.06	2.80
3	0.46	0.80	0.77	2.03	1.35	2.52	1.06	2.20	2.78	1.53	0.94	2.17	2.98	2.21	1.85	2.46	1.85	1.99	1.30	2.53	1.48
2	1.42	1.01	0.76	0.99	1.25	0.61	1.90	0.90	0.97	0.58	3.23	1.69	1.60	1.27	1.61	1.45	1.66	1.74	1.34	2.18	2.21
1	2.87	1.59	2.36	0.68	3.20	1.49	1.74	1.60	1.83	1.35	1.39	0.38	2.87	0.86	0.09	1.28	2.77	2.46	1.13	1.78	2.82

Test 10e >0.5Dn Stab. Nr = 4.61

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
22	48.21	4.08	7.19	2.51	8.03	5.06	5.40	3.93	3.89	6.49	3.94	2.56	5.37	3.68	0.93	5.74	1.62	4.47	6.98	12.43	25.07
21	0.00	70.83	56.47	29.24	19.25	6.99	8.44	5.48	6.41	13.84	10.28	7.39	2.66	4.46	5.77	7.03	8.31	31.19	0.00	44.06	0.00
20	0.00	78.47	64.84	29.92	19.86	14.58	5.33	6.16	11.71	16.33	11.50	18.56	12.40	35.80	0.00	15.15	12.72	34.63	13.04	25.07	32.84
19	0.00	70.42	31.45	19.80	21.94	10.64	7.16	13.33	14.50	15.63	12.21	15.92	17.40	13.26	18.43	15.67	15.10	30.08	14.12	35.63	40.24
18	0.00	19.23	27.49	21.47	27.22	14.27	3.25	15.13	18.26	14.53	15.28	13.29	16.96	15.34	17.74	15.46	21.30	29.36	7.59	32.15	37.06
17	21.99	22.58	20.03	19.30	23.20	14.75	8.18	14.83	14.09	16.20	13.52	14.50	12.99	14.60	15.16	17.89	26.63	23.39	2.63	28.06	34.70
16	21.75	21.28	23.11	14.69	21.43	14.61	13.87	11.51	13.07	15.27	15.05	15.40	14.37	13.47	17.18	21.35	20.10	20.20	14.40	23.82	26.44
15	22.74	19.41	16.65	15.15	16.92	15.81	11.90	12.62	16.64	12.98	15.47	13.81	11.95	13.88	17.73	18.33	12.30	15.74	17.44	24.77	24.70
14	18.66	18.76	19.90	13.17	18.12	16.91	11.67	15.95	13.54	14.04	15.94	14.81	13.69	16.84	15.01	16.72	18.21	16.58	18.35	22.59	22.19
13	20.55	16.70	16.39	17.43	12.93	14.06	11.47	10.88	14.74	12.15	19.08	17.39	13.49	13.38	17.47	13.08	16.61	17.12	17.05	20.99	20.66
12	15.50	16.30	18.01	11.06	12.27	10.99	8.96	13.38	9.97	10.35	16.62	17.77	9.69	14.19	15.80	14.05	13.80	16.34	15.94	14.62	18.54
11	15.12	14.93	12.30	8.45	10.32	9.42	10.86	8.10	11.98	10.76	12.09	12.00	13.63	10.96	9.98	13.41	11.00	13.02	15.59	13.13	22.69
10	16.52	15.32	10.73	8.67	8.42	7.90	6.23	10.35	12.78	9.06	11.28	10.60	10.37	11.28	9.63	10.03	11.80	12.64	12.47	14.15	21.37
9	16.84	14.93	10.10	11.34	9.14	7.86	5.56	7.49	7.55	8.87	8.09	9.31	11.22	9.34	7.97	8.77	8.58	10.23	9.84	15.57	19.57
8	11.57	11.81	13.75	8.35	4.98	7.87	5.37	6.08	5.65	6.22	7.21	7.11	10.41	9.32	6.42	7.49	8.04	5.35	7.22	12.47	16.37
7	8.11	8.79	7.70	9.96	5.88	5.69	2.89	5.45	5.04	5.18	5.90	3.60	6.25	8.24	4.67	8.37	6.32	5.38	5.89	10.62	12.98
6	3.42	3.81	8.65	4.88	5.84	3.09	4.05	5.46	4.93	3.16	3.90	4.28	6.96	7.00	4.87	5.44	5.37	5.00	5.71	10.12	10.04
5	2.09	2.07	7.91	5.92	2.97	5.63	2.99	5.79	2.82	1.92	4.35	2.47	3.23	7.06	3.62	4.63	2.05	4.69	2.35	3.88	5.35
4	2.46	1.08	4.29	5.74	3.47	4.18	3.98	3.62	2.10	2.00	0.50	1.96	1.89	3.67	4.50	4.07	2.14	4.32	3.31	4.66	3.19
3	1.96	1.89	1.82	2.56	2.75	3.46	4.09	3.35	2.01	2.90	1.84	2.62	1.93	3.89	3.01	2.40	1.72	2.29	3.07	2.72	2.85
2	0.99	1.35	0.40	0.95	1.08	1.16	0.97	0.75	0.76	0.67	2.91	0.65	2.12	2.17	2.04	1.35	2.92	2.18	1.05	1.72	2.80
1	2.64	1.00	1.89	0.53	2.99	0.97	1.98	0.66	2.79	2.57	2.18	0.57	1.71	0.73	3.26	2.09	2.64	2.88	2.41	1.37	2.43

Figure E-7: Schematical movements per subtest (5)

F. Data pull tests

Table F-1: Data pull tests (1)

Testnr	Location	Grid [-]	Under layer [mm]	Packing density [units/D_n^2]	Wave steepness $S_{m-1,0}$ [-]	Freeboard [H_{saD}]	Weight [N]	Force [N]	Ratio [-]	Average ratio [-]
5.1	1	Rectangular	7-11	0.66	0.04	1.2	0.622	3.318	5.335	
5.2	1	Rectangular	7-11	0.66	0.04	1.2	0.625	3.554	5.688	5.773
5.3	1	Rectangular	7-11	0.66	0.04	1.2	0.625	4.635	7.418	
5.4	1	Rectangular	7-11	0.66	0.04	1.2	0.625	2.906	4.653	
5.5	2	Rectangular	7-11	0.66	0.04	1.2	0.628	7.812	12.439	
5.6	2	Rectangular	7-11	0.66	0.04	1.2	0.624	11.552	18.507	16.506
5.7	2	Rectangular	7-11	0.66	0.04	1.2	0.623	10.979	17.617	
5.8	2	Rectangular	7-11	0.66	0.04	1.2	0.630	10.993	17.463	
5.9	3	Rectangular	7-11	0.66	0.04	1.2	0.625	6.143	9.828	
5.10	3	Rectangular	7-11	0.66	0.04	1.2	0.628	11.149	17.757	17.900
5.11	3	Rectangular	7-11	0.66	0.04	1.2	0.627	15.697	25.026	
5.12	3	Rectangular	7-11	0.66	0.04	1.2	0.621	11.790	18.989	
6.1	1	Rectangular	7-11	0.66	0.02	1.2	0.620	4.242	6.842	
6.2	1	Rectangular	7-11	0.66	0.02	1.2	0.622	2.703	4.344	4.779
6.3	1	Rectangular	7-11	0.66	0.02	1.2	0.626	1.974	3.152	
6.4	2	Rectangular	7-11	0.66	0.02	1.2	0.619	8.645	13.961	
6.5	2	Rectangular	7-11	0.66	0.02	1.2	0.631	7.007	11.108	15.156
6.6	2	Rectangular	7-11	0.66	0.02	1.2	0.630	12.844	20.400	
6.7	3	Rectangular	7-11	0.66	0.02	1.2	0.626	6.792	10.844	
6.8	3	Rectangular	7-11	0.66	0.02	1.2	0.623	12.171	19.527	17.903
6.9	3	Rectangular	7-11	0.66	0.02	1.2	0.625	14.578	23.339	
7.1	1	Rectangular	7-11	0.63	0.04	1.2	0.623	1.460	2.343	
7.2	1	Rectangular	7-11	0.63	0.04	1.2	0.623	4.799	7.705	5.369
7.3	1	Rectangular	7-11	0.63	0.04	1.2	0.622	3.631	5.833	
7.4	1	Rectangular	7-11	0.63	0.04	1.2	0.621	3.475	5.597	
7.5	2	Rectangular	7-11	0.63	0.04	1.2	0.620	11.833	19.073	
7.6	2	Rectangular	7-11	0.63	0.04	1.2	0.624	8.404	13.468	13.392
7.7	2	Rectangular	7-11	0.63	0.04	1.2	0.626	4.365	6.974	
7.8	2	Rectangular	7-11	0.63	0.04	1.2	0.624	8.769	14.052	
7.9	3	Rectangular	7-11	0.63	0.04	1.2	0.624	8.762	14.043	
7.10	3	Rectangular	7-11	0.63	0.04	1.2	0.622	4.182	6.720	
7.11	3	Rectangular	7-11	0.63	0.04	1.2	0.624	7.370	11.818	12.517
7.12	3	Rectangular	7-11	0.63	0.04	1.2	0.627	7.423	11.840	
7.13	3	Rectangular	7-11	0.63	0.04	1.2	0.620	11.260	18.164	
8.1	1	Rectangular	7-11	0.63	0.02	1.2	0.623	4.135	6.636	
8.2	1	Rectangular	7-11	0.63	0.02	1.2	0.623	7.600	12.204	7.041
8.3	1	Rectangular	7-11	0.63	0.02	1.2	0.627	2.848	4.545	
8.4	1	Rectangular	7-11	0.63	0.02	1.2	0.625	2.984	4.777	
8.5	2	Rectangular	7-11	0.63	0.02	1.2	0.631	7.356	11.666	
8.6	2	Rectangular	7-11	0.63	0.02	1.2	0.624	5.147	8.247	9.900
8.7	2	Rectangular	7-11	0.63	0.02	1.2	0.624	6.309	10.117	
8.8	2	Rectangular	7-11	0.63	0.02	1.2	0.624	5.974	9.571	
8.9	3	Rectangular	7-11	0.63	0.02	1.2	0.622	6.261	10.072	
8.10	3	Rectangular	7-11	0.63	0.02	1.2	0.624	5.951	9.532	8.870
8.11	3	Rectangular	7-11	0.63	0.02	1.2	0.626	5.592	8.926	
8.12	3	Rectangular	7-11	0.63	0.02	1.2	0.569	3.954	6.951	

Table F-2: Data pull tests (2)

Testnr	Location	Grid [-]	Under layer [mm]	Packing density [units/D_n^2]	Wave steepness $S_{m-1,0}$ [-]	Freeboard [H_{saD}]	Weight [N]	Force [N]	Ratio [-]	Average ratio [-]
9.1	1	Rectangular	7-11	0.66	0.04	1.6	0.624	3.382	5.421	
9.2	1	Rectangular	7-11	0.66	0.04	1.6	0.621	1.044	1.682	
9.3	1	Rectangular	7-11	0.66	0.04	1.6	0.626	3.064	4.898	4.811
9.4	1	Rectangular	7-11	0.66	0.04	1.6	0.622	3.471	5.581	
9.5	1	Rectangular	7-11	0.66	0.04	1.6	0.627	4.056	6.472	
9.6	2	Rectangular	7-11	0.66	0.04	1.6	0.628	7.909	12.595	
9.7	2	Rectangular	7-11	0.66	0.04	1.6	0.622	6.947	11.172	
9.8	2	Rectangular	7-11	0.66	0.04	1.6	0.627	11.369	18.125	13.635
9.9	2	Rectangular	7-11	0.66	0.04	1.6	0.620	5.356	8.639	
9.10	2	Rectangular	7-11	0.66	0.04	1.6	0.627	11.068	17.646	
9.11	3	Rectangular	7-11	0.66	0.04	1.6	0.623	5.492	8.814	
9.12	3	Rectangular	7-11	0.66	0.04	1.6	0.627	13.883	22.139	
9.13	3	Rectangular	7-11	0.66	0.04	1.6	0.625	11.384	18.209	15.110
9.14	3	Rectangular	7-11	0.66	0.04	1.6	0.623	4.069	6.529	
9.15	3	Rectangular	7-11	0.66	0.04	1.6	0.626	12.442	19.861	
10.1	1	Rectangular	7-11	0.66	0.02	1.6	0.626	2.441	3.902	
10.2	1	Rectangular	7-11	0.66	0.02	1.6	0.626	2.736	4.368	
10.3	1	Rectangular	7-11	0.66	0.02	1.6	0.625	3.189	5.102	4.213
10.4	1	Rectangular	7-11	0.66	0.02	1.6	0.629	2.190	3.479	
10.5	2	Rectangular	7-11	0.66	0.02	1.6	0.623	9.403	15.097	
10.6	2	Rectangular	7-11	0.66	0.02	1.6	0.622	5.777	9.287	
10.7	2	Rectangular	7-11	0.66	0.02	1.6	0.621	6.482	10.439	11.735
10.8	2	Rectangular	7-11	0.66	0.02	1.6	0.621	8.678	13.977	
10.9	2	Rectangular	7-11	0.66	0.02	1.6	0.622	6.141	9.873	
10.10	3	Rectangular	7-11	0.66	0.02	1.6	0.624	14.968	23.979	
10.11	3	Rectangular	7-11	0.66	0.02	1.6	0.622	16.112	25.886	
10.12	3	Rectangular	7-11	0.66	0.02	1.6	0.623	5.820	9.348	18.740
10.13	3	Rectangular	7-11	0.66	0.02	1.6	0.622	8.178	13.143	
10.14	3	Rectangular	7-11	0.66	0.02	1.6	0.624	13.313	21.345	
15.1	1	Rectangular	7-11	0.63	-	-	0.627	1.954	3.117	
15.2	1	Rectangular	7-11	0.63	-	-	0.624	1.995	3.196	
15.3	1	Rectangular	7-11	0.63	-	-	0.624	2.987	4.789	4.022
15.4	1	Rectangular	7-11	0.63	-	-	0.624	3.651	5.848	
15.5	1	Rectangular	7-11	0.63	-	-	0.622	1.965	3.159	
15.6	2	Rectangular	7-11	0.63	-	-	0.626	4.301	6.867	
15.7	2	Rectangular	7-11	0.63	-	-	0.619	1.340	2.163	
15.8	2	Rectangular	7-11	0.63	-	-	0.619	5.331	8.606	5.943
15.9	2	Rectangular	7-11	0.63	-	-	0.636	4.699	7.391	
15.10	2	Rectangular	7-11	0.63	-	-	0.623	2.921	4.687	
15.11	3	Rectangular	7-11	0.63	-	-	0.623	2.350	3.773	
15.12	3	Rectangular	7-11	0.63	-	-	0.623	4.493	7.216	
15.13	3	Rectangular	7-11	0.63	-	-	0.630	3.356	5.325	5.164
15.14	3	Rectangular	7-11	0.63	-	-	0.628	3.561	5.673	
15.15	3	Rectangular	7-11	0.63	-	-	0.623	2.387	3.833	

Table F-3: Data pull tests (3)

Testnr	Location	Grid [-]	Under layer [mm]	Packing density [units/D_n^2]	Wave steepness $S_{m-1,0}$ [-]	Freeboard [H_{saD}]	Weight [N]	Force [N]	Ratio [-]	Average ratio [-]
16.1	1	Rectangular	7-11	0.66	-	-	0.622	3.053	4.906	
16.2	1	Rectangular	7-11	0.66	-	-	0.624	3.022	4.841	
16.3	1	Rectangular	7-11	0.66	-	-	0.630	1.219	1.934	4.548
16.4	1	Rectangular	7-11	0.66	-	-	0.620	4.069	6.563	
16.5	1	Rectangular	7-11	0.66	-	-	0.620	2.790	4.498	
16.6	2	Rectangular	7-11	0.66	-	-	0.622	5.099	8.201	
16.7	2	Rectangular	7-11	0.66	-	-	0.623	4.144	6.653	
16.8	2	Rectangular	7-11	0.66	-	-	0.622	3.183	5.115	7.300
16.9	2	Rectangular	7-11	0.66	-	-	0.629	5.462	8.683	
16.10	2	Rectangular	7-11	0.66	-	-	0.623	4.892	7.849	
16.11	3	Rectangular	7-11	0.66	-	-	0.624	5.823	9.338	
16.12	3	Rectangular	7-11	0.66	-	-	0.624	5.812	9.314	
16.13	3	Rectangular	7-11	0.66	-	-	0.631	2.663	4.223	8.260
16.14	3	Rectangular	7-11	0.66	-	-	0.622	3.898	6.265	
16.15	3	Rectangular	7-11	0.66	-	-	0.622	7.567	12.159	
17.1	1	Rectangular	7-11	0.69	-	-	0.623	5.163	8.291	
17.2	1	Rectangular	7-11	0.69	-	-	0.627	3.524	5.616	
17.3	1	Rectangular	7-11	0.69	-	-	0.625	4.475	7.164	6.654
17.4	1	Rectangular	7-11	0.69	-	-	0.626	3.498	5.587	
17.5	1	Rectangular	7-11	0.69	-	-	0.621	4.105	6.610	
17.6	2	Rectangular	7-11	0.69	-	-	0.631	6.855	10.862	
17.7	2	Rectangular	7-11	0.69	-	-	0.622	4.149	6.673	
17.8	2	Rectangular	7-11	0.69	-	-	0.621	6.952	11.203	9.051
17.9	2	Rectangular	7-11	0.69	-	-	0.622	5.192	8.346	
17.10	2	Rectangular	7-11	0.69	-	-	0.621	5.077	8.170	
17.11	3	Rectangular	7-11	0.69	-	-	0.624	8.763	14.039	
17.12	3	Rectangular	7-11	0.69	-	-	0.625	7.507	12.002	
17.13	3	Rectangular	7-11	0.69	-	-	0.624	5.593	8.958	10.723
17.14	3	Rectangular	7-11	0.69	-	-	0.624	5.183	8.312	
17.15	3	Rectangular	7-11	0.69	-	-	0.623	6.424	10.305	
18.1	1	Diamond	11-16	0.63	-	-	0.623	2.408	3.866	
18.2	1	Diamond	11-16	0.63	-	-	0.622	2.637	4.238	
18.3	1	Diamond	11-16	0.63	-	-	0.624	1.693	2.715	3.889
18.4	1	Diamond	11-16	0.63	-	-	0.624	3.131	5.019	
18.5	1	Diamond	11-16	0.63	-	-	0.630	2.271	3.606	
18.6	2	Diamond	11-16	0.63	-	-	0.635	2.621	4.125	
18.7	2	Diamond	11-16	0.63	-	-	0.620	1.906	3.072	
18.8	2	Diamond	11-16	0.63	-	-	0.625	2.083	3.331	6.782
18.9	2	Diamond	11-16	0.63	-	-	0.624	7.068	11.326	
18.10	2	Diamond	11-16	0.63	-	-	0.622	7.499	12.059	
18.11	3	Diamond	11-16	0.63	-	-	0.624	3.428	5.497	
18.12	3	Diamond	11-16	0.63	-	-	0.622	2.785	4.479	
18.13	3	Diamond	11-16	0.63	-	-	0.628	3.656	5.821	5.399
18.14	3	Diamond	11-16	0.63	-	-	0.623	2.601	4.177	
18.15	3	Diamond	11-16	0.63	-	-	0.622	4.370	7.024	

Table F-4: Data pull tests (4)

Testnr	Location	Grid [-]	Under layer [mm]	Packing density [units/D_n^2]	Wave steepness $S_{m-1,0}$ [-]	Freeboard [H_{saD}]	Weight [N]	Force [N]	Ratio [-]	Average ratio [-]
19.1	1	Diamond	11-16	0.68	-	-	0.623	5.282	8.472	
19.2	1	Diamond	11-16	0.68	-	-	0.622	2.495	4.010	
19.3	1	Diamond	11-16	0.68	-	-	0.621	3.408	5.485	5.893
19.4	1	Diamond	11-16	0.68	-	-	0.630	4.510	7.163	
19.5	1	Diamond	11-16	0.68	-	-	0.627	2.720	4.337	
19.6	2	Diamond	11-16	0.68	-	-	0.624	8.105	12.991	
19.7	2	Diamond	11-16	0.68	-	-	0.626	2.770	4.421	
19.8	2	Diamond	11-16	0.68	-	-	0.629	8.918	14.173	9.414
19.9	2	Diamond	11-16	0.68	-	-	0.621	5.536	8.916	
19.10	2	Diamond	11-16	0.68	-	-	0.620	4.074	6.569	
19.11	3	Diamond	11-16	0.68	-	-	0.624	6.832	10.948	
19.12	3	Diamond	11-16	0.68	-	-	0.622	8.218	13.215	
19.13	3	Diamond	11-16	0.68	-	-	0.630	11.649	18.485	14.006
19.14	3	Diamond	11-16	0.68	-	-	0.624	11.696	18.734	
19.15	3	Diamond	11-16	0.68	-	-	0.630	5.444	8.649	

G. Crablock specifications

Table G-1: Crablock™ specifications

Packing density [units/D_n^2]	D/D_n [-]	Packing density [units/D^2]	Unit height D [m]	Unit volume [m^3]	Armour height h [m]	Area [m^2]	Number of armour units [-]	Total concrete [m^3]	Total volume armour [m^3]	Porosity [%]
0.69	1.873	2.421	1.88	1.011	1.410	100	68.5	69.3	141.0	0.509
0.69	1.873	2.421	2.366	2.016	1.775	100	43.2	87.2	177.5	0.509
0.69	1.873	2.421	2.712	3.036	2.034	100	32.9	99.9	203.4	0.509
0.69	1.873	2.421	2.98	4.027	2.235	100	27.3	109.8	223.5	0.509
0.69	1.873	2.421	3.211	5.039	2.408	100	23.5	118.3	240.8	0.509
0.69	1.873	2.421	3.413	6.051	2.560	100	20.8	125.7	256.0	0.509
0.69	1.873	2.421	3.595	7.071	2.696	100	18.7	132.4	269.6	0.509
0.69	1.873	2.421	3.756	8.064	2.817	100	17.2	138.4	281.7	0.509
0.69	1.873	2.421	3.907	9.076	2.930	100	15.9	143.9	293.0	0.509
0.69	1.873	2.421	4.049	10.103	3.037	100	14.8	149.2	303.7	0.509
0.66	1.873	2.315	1.88	1.011	1.410	100	65.5	66.2	141.0	0.530
0.66	1.873	2.315	2.366	2.016	1.775	100	41.4	83.4	177.5	0.530
0.66	1.873	2.315	2.712	3.036	2.034	100	31.5	95.6	203.4	0.530
0.66	1.873	2.315	2.98	4.027	2.235	100	26.1	105.0	223.5	0.530
0.66	1.873	2.315	3.211	5.039	2.408	100	22.5	113.1	240.8	0.530
0.66	1.873	2.315	3.413	6.051	2.560	100	19.9	120.3	256.0	0.530
0.66	1.873	2.315	3.595	7.071	2.696	100	17.9	126.7	269.6	0.530
0.66	1.873	2.315	3.756	8.064	2.817	100	16.4	132.4	281.7	0.530
0.66	1.873	2.315	3.907	9.076	2.930	100	15.2	137.7	293.0	0.530
0.66	1.873	2.315	4.049	10.103	3.037	100	14.1	142.7	303.7	0.530
0.63	1.873	2.210	1.88	1.011	1.410	100	62.5	63.2	141.0	0.552
0.63	1.873	2.210	2.366	2.016	1.775	100	39.5	79.6	177.5	0.552
0.63	1.873	2.210	2.712	3.036	2.034	100	30.0	91.2	203.4	0.552
0.63	1.873	2.210	2.98	4.027	2.235	100	24.9	100.2	223.5	0.552
0.63	1.873	2.210	3.211	5.039	2.408	100	21.4	108.0	240.8	0.552
0.63	1.873	2.210	3.413	6.051	2.560	100	19.0	114.8	256.0	0.552
0.63	1.873	2.210	3.595	7.071	2.696	100	17.1	120.9	269.6	0.552
0.63	1.873	2.210	3.756	8.064	2.817	100	15.7	126.3	281.7	0.552
0.63	1.873	2.210	3.907	9.076	2.930	100	14.5	131.4	293.0	0.552
0.63	1.873	2.210	4.049	10.103	3.037	100	13.5	136.2	303.7	0.552