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FP5- EESD

CREST LEVEL ASSESSMENT OF
COASTAL STRUCTURES BY
FULL-SCALE MONITORING,
NEURAL NETWORK PREDICTION
AND HAZARD ANALYSIS
ON PERMISSIBLE WAVE OVERTOPPING

CLASH

EVK3-CT-2001-00058

REPORT

D24 Report on additional tests

Part B

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J. Pearson
T. Bruce
L. Franco
J. Van der Meer
M. Falzacappa
R. Molino

University of Edinburgh

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1. Introduction

This report details the results of the second phase of the additional white spot tests undertaken by the University of Edinburgh. Part A was undertaken by Aalborg University who investigated the effect of wave obliquity. Edinburgh were commissioned to undertake a series experiments to determine the relative difference in overtopping characteristics for various types of armour units. Following discussions within the CLASH partners and actual availability of the model units, it was decided that the following armour units/cross-sections should be preferably tested:

1. Smooth slope (reference)
2. Rock slope (reference) - grading around D_{85}/D_{15} = 1.25 –1.5 required
3. Cubes
4. Antifer cubes
5. Tetrapods
6. Dolosse
7. One layer of cubes (porosity 25%)
8. Accropode
9. Core-Loc®s
10. Xbloc®'s
11. Haro
12. Sheds or Seabees

It was originally anticipated that the model tests would include Dolosse and Sheds or Seabees, unfortunately at the time of testing these units were unavailable, hence for the CLASH database estimates of γ_f were made.

Mean overtopping discharges were required behind the crest unit and also at the transition from slope to crest (excluding the crest). The sea state was a standard Jonswap spectrum (γ = 3.3) and the overtopping for approximately 1000 waves was to be recorded. The standard test programme gave three wave heights, two water levels and three wave steepnesses (s_{op} = 0.02, 0.035 & 0.05).

Chapter 2 (Van der Meer) describes the background and objectives of the proposed experiments. Chapter 3 reports the experimental set-up, Chapter 4 details the results and finally Chapter 5 gives conclusions. A small study to investigate the effect of crest berm width is given in Appendix I.

2. Background and experimental objectives

2.1 Objectives.

The main objective of the white spot tests is to determine the *relative* difference in overtopping behaviour for various types of armour units. Finally, this should lead to roughness factors γ_f for the database.

2.2 Relative Overtopping.

What is a good definition of relative overtopping? Overtopping over a complete smooth structure could be considered as a structure giving maximum overtopping (no friction, no porosity). If this situation is considered as a reference with γ_f =1, which till now is the case in the database, roughness factors will always be equal or smaller than 1. Although we are interested in overtopping, it is also possible to determine the roughness factor by comparing wave run-up. Figure 1 gives the results for the 2% run-up level for smooth slopes (using T_p, not for very shallow foreshores). The graph shows a large influence of the surf similarity parameter, Iribarren number, or breaker parameter for smaller values and no influence for larger breaker parameters. This behaviour is very typical for smooth slopes.

In the same figure results of run-up tests on rock slopes have been given. Rock slopes with slopes of 1:2, 1:3 and 1:4 for impermeable structures (such as dike revetments with an impermeable core) and 1:1.5, 1:2 and 1:3 slopes with a permeable core, comparable to breakwaters are given. Based on the structures with an impermeable core, a roughness factor was determined for the Dutch TAW guidelines for wave run-up and wave overtopping at dikes. For ξ_{op} < 2 the roughness factor was γ_f = 0.55. Figure 2.1 clearly shows that for large breaker parameters the run-up comes closer to the values for smooth structures. Probably, long waves on steep slopes (large breaker parameters) do not feel any roughness, as long the core is impermeable. On the basis of this conclusion it was decided for the mentioned guideline to linearly increase the roughness factor from 0.55 to 1.0 between ξ_{op} = 2 and 8. The relationship is shown in Figure one and covers well the data for rock on an impermeable core. This method leads to the conclusion that the influence of roughness decreases for larger breaker parameters.

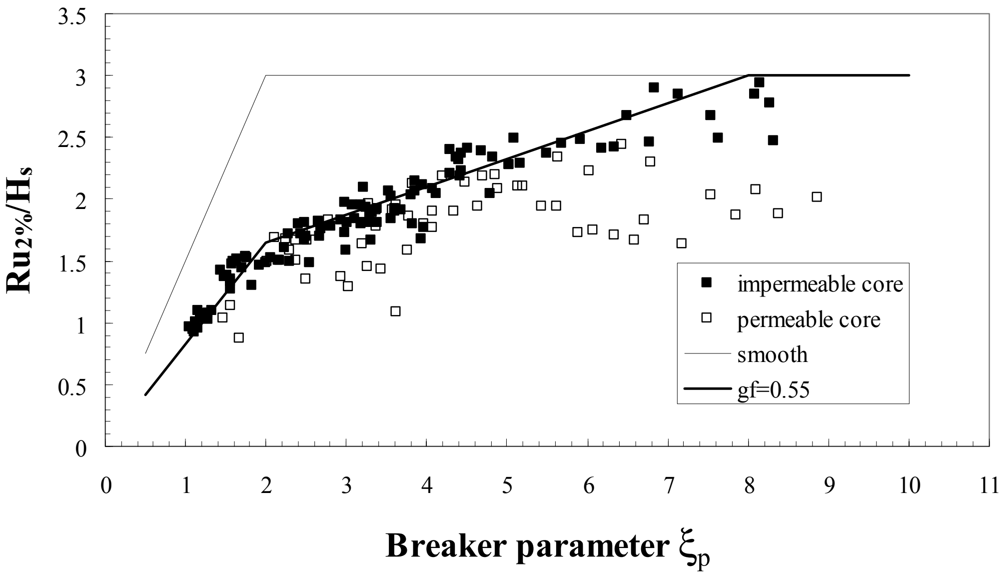


Figure 2.1. Wave run-up for smooth and rock slopes

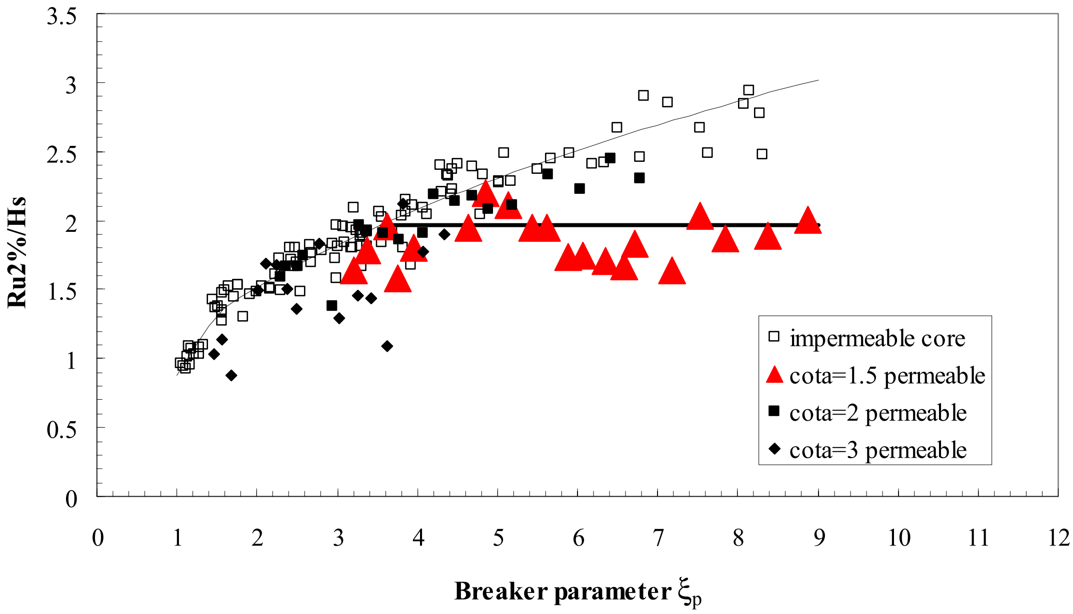


Figure 2.2. Wave run-up on rock slopes

Another way to look at the influence of roughness and permeability is to take the results for rock structures as a reference. Figure 2.2 shows the run-up results in more detail. Run-up formulae for rock are (Van der Meer, 1998):

$R_{u2\%} = 0.88\ \xi_{op}$ for $\xi_{op} < 1.5$

$R_{u2\%} = 1.1\ \xi_{op}^{0.46}$ for $\xi_{op} > 1.5$

with a maximum of $R_{u2\%} = 1.97\ \xi_{op}$ for permeable structures

These formulae are also given in Figure 2.2. In this graph the impermeable core structures are given as one group. Distinction has been made for the structures with a permeable core, comparable to breakwaters. A slope of 1:1.5 is very common for rubble mound breakwaters and this slope for a rock structure is given more attention in Figure 2. The maximum run-up was clearly based on the results for this slope. Although there is quite some scatter, for breaker parameters larger than 5 there is no other clear trend than a horizontal line. For ξ_{op} values between 3 and 5 there still could be an influence of increasing run-up with increasing breaker parameter. This range is very important as it includes a slope of 1:1.5 with wave steepnessess between 0.02 and 0.04.

Comparing wave run-up is easier than comparing wave overtopping. The main reason is that for measuring wave overtopping also a small horizontal crest is present, behind which the overtopping is caught. This is not the case for wave run-up, where only a high straight slope is present. For overtopping the horizontal crest has influence on the results, certainly if overtopping results are compared with a smooth impermeable structure. For such a smooth structure the horizontal crest has no influence on overtopping, where the width of the crest has influence on rough and permeable structures.

It might be concluded that in order to define a good roughness factor the comparison with a rock structure could lead to better results than comparison with a smooth structure. The results of the actual tests should show what is the best way.

2.3 Standard test situation

Important wave overtopping is often related to situations quite close to the design values for structure stability. The stability of the structure itself is not an issue. In order to compare different units of different sizes, a standard test situation and standard cross-section is required. Such a standard test situation can best be based on design conditions for the structures.

Very often breakwaters with a steep slope are designed for a fixed stability number $H_s/\Delta D_n$. The actual value is different for various units. But if a stability number is defined for each unit, this is the basis for both the test set-up and the cross-section. Table 2.1 gives various units with their stability number for design, proposed to be used for setting up and scaling of the experiments.

Table 2.1. Proposed stability numbers for different armour units to be used to scale the experiments

Type of armour	$H_s/\Delta D_n$	**Layer thickness coefficient** k_t	**Porosity (%)**	**Packing density** φ
Rock	1.5	1.15	± 40	1.38
Cube	2.2	1.1	47	1.17
Antifer	2.2	(1.1)	(47)	(1.17)
Tetrapod	2.2	1.04	50	1.04
Dolos	2.8	0.94	56	0.83
Accropode	2.5	1.51	59	0.62
Core-Loc®	2.8	1.51	63	0.56
Xbloc®	2.8	1.49	61	0.58
One layer of cubes	2.2	1.0	30	0.70
Sheds, etc	2.8 (D instead of D_n)			

The layer thickness of an armour layer can be determined by:

$r = n\, k_t\, D_n$

where: n is the number of layers (1 or 2), k_t is the layer thickness coefficient.

The coefficients are given in Table 1. For rock a layer thickness of 2 D_{50} is specified (where D_{50} is the sieve diameter) according to the tests on rock slopes as in Figures 1 and 2. The sieve size is larger than the nominal diameter, which means that the layer thickness is about 2.3 D_{n50}, giving a layer thickness coefficient of 1.15. With the porosity and the layer thickness it is possible to determine the number of units per square meter:

$N_a = n\, k_t\, (1 - \text{porosity}/100)/D_n^2$

Actually, in the model and certainly in reality it is difficult to determine k_t and the porosity. It is much easier to count or specify the number of units on a certain area and use the packing density φ as a parameter. The packing density is defined as the number of units per square D_n, or:

$\varphi/D_n^2 = N_a/A$

where: φ = packing density, D_n = nominal diameter, N_a = number of units on a surface A

The layer coefficients, the porosities and the packing density are given in Table 2.1. Still some values are missing. During testing it is proposed to report at least the packing density.

The main basis for a standard test situation is the stability number. Given the stability number, the wave height under design conditions can be calculated. This should be a wave height which can be generated in the flume. This design wave height is given as H_o:

H_o = stability number $*$ ΔD_n

Tests with H_o should be the maximum significant wave height for testing. Other situations could be testing with $0.5H_o$ and $0.75H_o$. Each wave height could be repeated for two wave steepnessess, s_{op}=0.02 and 0.04, where the steepness is defined as: $s_{op} = 2\pi H_s/(gT_p^2)$. And two water levels could be tested, R_c/H_o = 1.0 and 0.5. This leads to a total of 12 tests for one structure, covering small to large overtopping.

Standard tests

Wave heights:	H = 1.0 H_o; 0.75 H_o and 0.5 H_o
Wave steepness	s_{op} = 0.02 and 0.04
Water levels:	R_c/H_o = 1.0 and 0.5

Fortunately the time schedule allowed additional tests to be undertaken, hence it was decided to use three wave periods of s_{op} = 0.02 and 0.035 & 0.05.

2.4 Standard cross-section

Most structures are built in fairly shallow water. But in order to make the comparison between tests for the roughness factor easier, it is better not to include a foreshore. On the other hand, the water depth should not be too large, because the structure becomes much larger with a larger water depth. A water depth of $2.5H_o$ is chosen for the tests. For such a water depth the waves do not break and they can be generated without a foreshore. Also a horizontal foreshore is acceptable, as long as the water depth above this foreshore is $2.5H_o$.

The crest freeboard under design conditions could be $1.0H_o$. The structure height becomes then $3.5H_o$. Figure 2.3 gives the proposed standard cross-section. For the actual layer thickness the values in Table 1 have to be used.

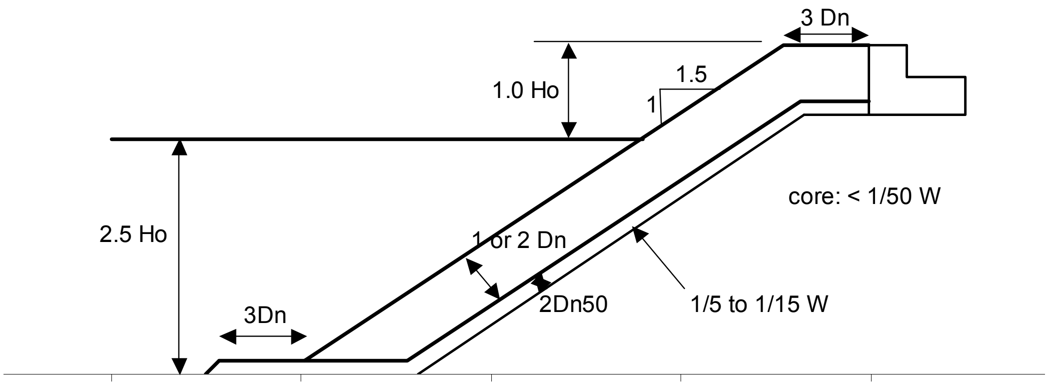


Figure 2.3. Proposal for a standard cross-section

The slope of the structure is 1:1.5. All dimensions are related to H_o or to the nominal diameter of the unit. The toe is $3D_n$ wide, as well as the crest. The under layer could be 1/5 to 1/15 of the weight of the armour unit. For the second test condition with a higher water level the water depth becomes $3H_o$ and the crest freeboard $0.5H_o$. The crest element should have the same height as the structure.

2.5 Work method

The set-up in the flume depends on two items: the maximum significant wave height that can be generated in the flume and the available size of the unit. In any case $H_{s\ max} > H_o$. This gives a maximum size of unit that can be used:

$D_{n\ max} < H_{s\ max} / (\Delta * \text{stability number Table 1})$

Suppose a wave flume with $H_{s\ max} = 0.11$ m and the testing of Accropode ($H_s/\Delta D_n = 2.5$). This gives $D_{n\ max} = 0.0326$ m and $W_{max} = 0.081$ kg, using 2350 kg/m^3 as mass density for the model units.

In the list of available Accropode from Sogreah the largest unit which can be chosen has a weight of 0.0742 kg with a mass density of 2361 kg/m^3. This gives $D_n = 0.0315$ m and $\Delta = 1.36$ and finally $H_o = 0.107$ m. The total structure height becomes 0.375 m, the water depth for the first series of test 0.268 m.

2.6 Suggested analysis

Based on the results in Figures 2.1 and 2.2, a wave period influence may be expected for rough structures, as the test results will be between $3 < \xi_{op} < 5$. Figure 4 gives a similar graph as Figures 2.1 and 2.2, but now for wave overtopping. Note that the vertical axis is on a logarithmic scale. A smooth impermeable slope for a certain relative crest height would give the solid line: large influence of the breaker parameter for small values, no influence for values larger than about 2. The data points in Figure 2.4 are artificial points for Accropode. A first check could be to make a graph like Figure 2.4 and conclude whether the breaker parameter or wave period has an influence on the overtopping.

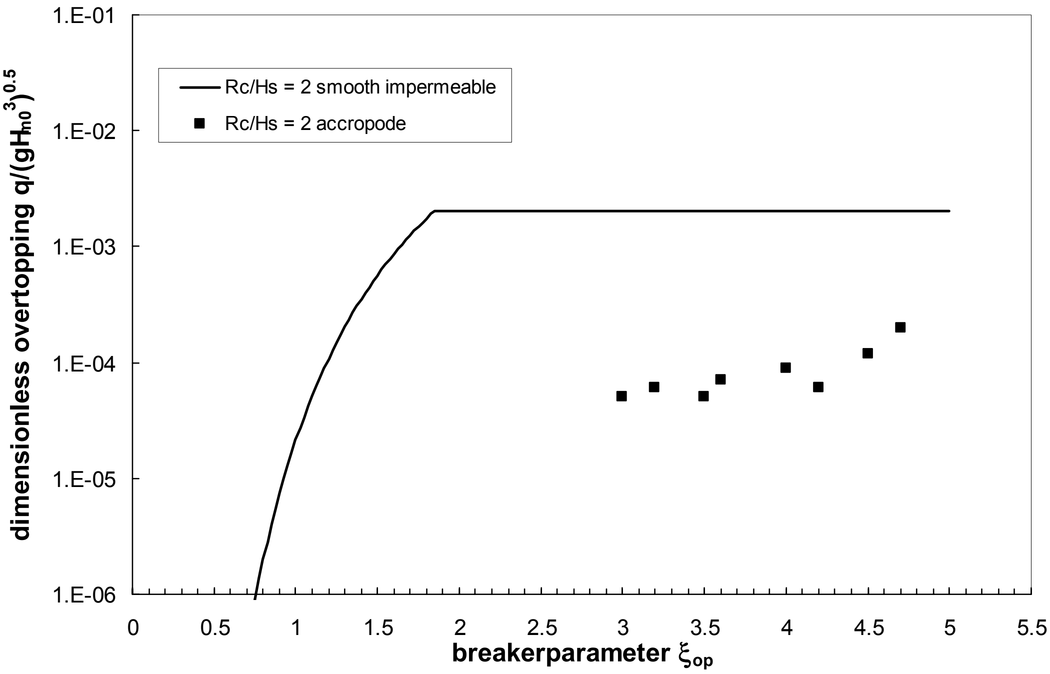


Figure 2.4. Wave overtopping versus the breaker parameter. Check on influence of wave period.

An other graph to show the results is the traditional one with $q/(gH_s^3)^{0.5}$ versus the relative freeboard R_s/H_s. If the breaker parameter or wave period has no influence on overtopping, this would be sufficient. But if there is an influence, dimensionless parameters like those by Van der Meer for breaking waves or those by Owen could be used.

3. Experimental set-up and procedure

3.1 Objectives

The main objectives of the "white spot" tests is to determine the *relative* difference in overtopping behaviour for various types of armour units. The armour units that were to be investigated are given below:

Type of structure	Porosity (%)	Layer thickness coefficient k_t	Packing Density φ
Smooth structure			
Rock	± 40	1.15	1.38
Cube	47	1.10	1.17
Antifer	47	1.10	1.17
Haro			
Tetrapods	50	1.04	1.04
One layer of cubes	30	1.00	0.70
Accropode	59	1.51	0.62
Core-Loc®	63	1.51	0.56
Xbloc®	61	1.49	0.58

Table 3.1. Geometrical parameters of different armour blocks

It was originally anticipated that the model tests would include Dolosse and sheds or Seabees, unfortunately at the time of testing these units were unavailable, hence for the CLASH database estimates were made.

3.2 Laboratory Description

The 2-d experimental investigations at small-scale were all completed in the wave channel in the School of Engineering and Electronics at University of Edinburgh, UK. The channel is 20 m long, 0.4 m wide and has an operating water depth of 0.7 m (Figure 3.1). The sidewalls and the bottom of the flume are made of glass. Waves are generated by a flap type wave paddle that is capable to produce regular and irregular waves with significant wave heights up to 0.11 m and wave periods up to 2.0 s for a fixed water depth of 0.70m at the paddle. The paddle is equipped with a non-user controllable active absorption system which significantly reduces reflected waves returning from the structure.

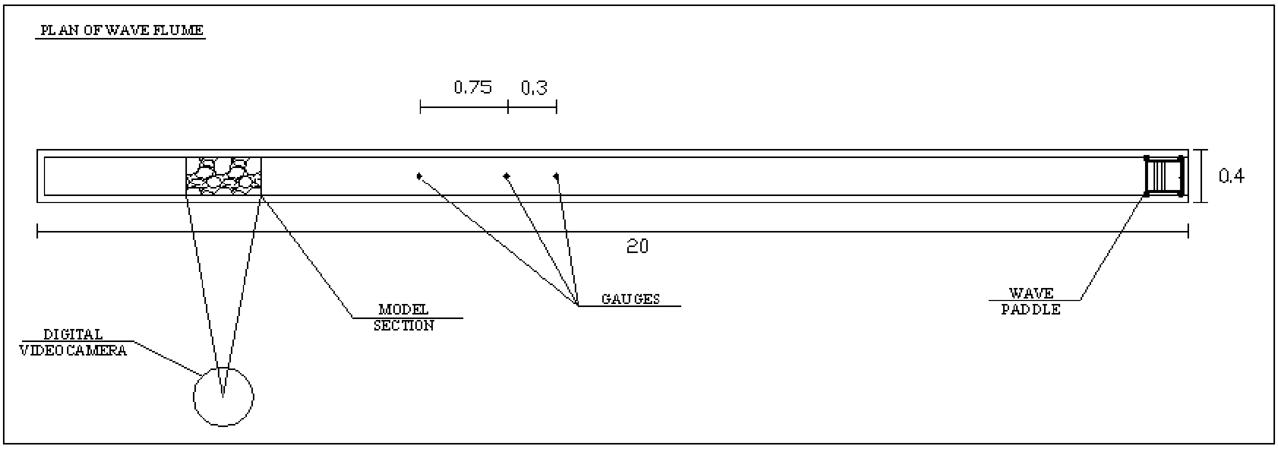


Figure 3.1 Plan of wave flume

Figure 3.2 Side view of wave flume

Overtopping discharges were directed via a centrally placed chute (width either 0.1 or 0.2m), which discharged into a measuring container suspended from a load cell. Individual overtopping events were detected by two parallel strips of metal tape run along the structure crest which acted as a switch closed by the water. For higher discharge conditions, water was removed from the collection container using an electric pump during data collection periods. At the end of the test the loadcell voltage trace was passed through an algorithm which determined that total volume of water which overtopped the structure during the test. Similarly wave-by-wave overtopping volumes were measured by determining the increment in the mass of water in the collection tank after each overtopping event following the general approach first used by Franco et al (1994), and subsequently applied at other laboratories in UK / Europe.

All tests were recorded on video tape for later analysis as necessary. The camera was positioned to the side of the flume to record the wave breaking regime and the overtopping characteristics. In addition still photographs were taken of the armour slope to investigate the stability of the armour layer as a record of unit placements.

To determine the wave characteristics, three resistance type wave gauges were used. A quoted precision of ±2% can be achieved with these wave gauges. The gauges consist of a pair of resistance wire which are placed vertically in the water and fixed in position above the tank. The resistance from the gauge is converted to a voltage. By moving the gauge up and down known amounts in still water allows the voltage water elevation relationship to be determined. The gauges relationship between water level and voltage is linear.

The electronics allow the gain and offset of each gauge to be tuned / adjusted. For this study the electronics of the gauges were tuned such that the calibration on each gauge were set each morning to 1volt = 20 mm. This was done by zeroing the gauge at still water level, then moving the gauge a fixed distance (usually 50mm) and then adjusting the gain of the gauge until the required voltage was achieved (usually 2.5 volts). The gauge was then returned to its initial position and the voltage recorded. If the voltage was within 0.02 volts of zero (0.4mm), then the calibration was deemed to be acceptable. If not, then the voltage was re-zeroed and the calibration procedure repeated again until the required voltage acceptability was achieved. The recorded voltages of the gauges during measurements were converted to water surface elevations during later analysis.

The gauges were positioned shoreward of the toe of the structure at distances of 0.75 & 0.3m and incident and reflected conditions were separated using the methodology described by Mansard and Funke.

3.3 Core Material

Figure 3.3 Installation of filter layer

The core and filter material was graded into the correct size by sieving the material through the appropriate mesh size. For the core layer, the requirement was that the weight was less than 1/50W, where W is the weight of the armour unit. As all the armour units differed in weight, careful consideration was given such that the filter layer fitted all criteria. Figure 3.2 shows the installation of the core layer.

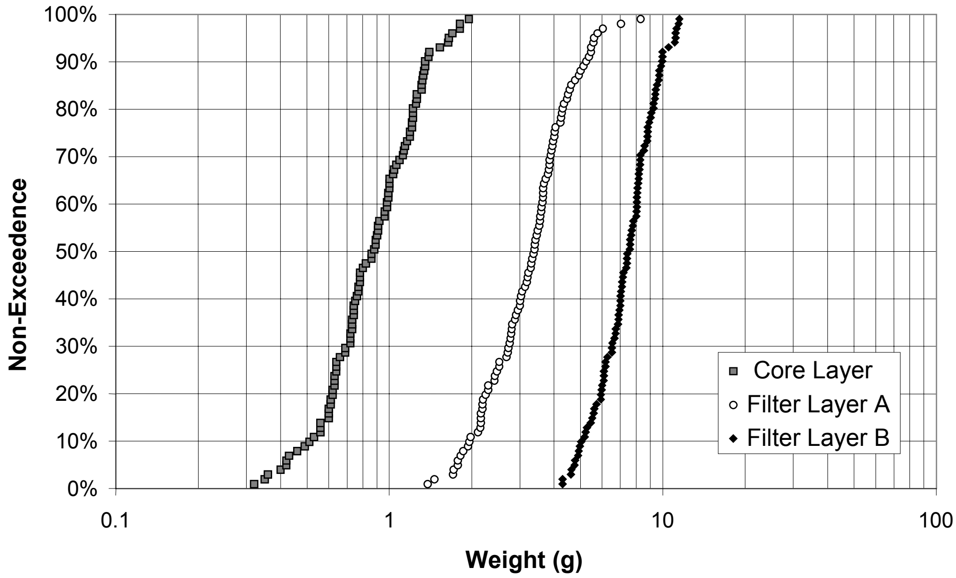


Figure 3.4 Filter & Core layer grading curves

Grading	Core	Filter A	Filter B
W_{85}/W_{15}	2.18	2.12	1.70
W_{50} (g)	0.86	3.37	7.42

Table 3.2 Filter & Core layer characteristics

The weight difference between the different types of armour units was too large to allow a single grading of filter layer, hence two filter layer gradings were made, the smaller grading (Filter Layer A) was used for the Haro, whilst the larger grading (Filter layer B) was used for the Cubes, Antifer, Tetrapod, Rock, Core-Loc®, Accropode, and Xbloc®. Figure 3.4 and Table 3.2 shows the core and filter layer characteristics.

3.4 Testing procedure

Prior to undertaking the tests, the water level was adjusted to the required freeboard (R_c). For each armour unit type, two freeboards were investigated. The size of armour unit determined the design offshore significant wave height, H_{mo}. As the units were of different size, H_{mo} also varied accordingly.

For the smooth structure R_c/H_{mo} = 1.0 and 1.7. For the natural rock R_c/H_{mo} = 0.9 and 1.3, and for all the other armour units R_c/H_{mo} = 0.8 and 1.3. Overtopping measurements were made at a single location, a distance of $3D_n$ behind the crest for this study, however additional tests were undertaken whereby measurements were also taken at the intersection of the sloping section and the horizontal (named 'Corner' in this study). Although the results from these tests have been included for completeness in this report, these results are not used in the conclusions. The wave gauges were calibrated each morning. The unit properties of the armour units are summarised in Table 3.2.

	stability no Hs / D Dn [-]	mass density [kg/m3]	relative mass density D [-]	layer thickness coeff kt [-]	porosity [%]	packing density phi [-]	largest flume waves Hs, max [m]	largest poss nom dia Dn, max [m]	armour unit max weight W max [kg]	no. units per sq m per layer Na [-]	approx no. units required N [-]	max nominal diameter Dn [m]
Rock - large	1.5	2650	1.65	1.15	40	1.38	0.11	0.044	0.233			0.044
Rock - Small	1.5	2650	1.65	1.15	40	1.38	0.11	0.044	0.233			0.044
Cube	2.2	2350	1.35	1.1	47	1.17	0.11	0.037	0.119	425	238	0.037
Antifer	2.2	2350	1.35	1.1	47	1.17	0.11	0.037	0.119	425	170	0.037
Tetrapod	2.2	2350	1.35	1.04	50	1.04	0.11	0.037	0.119	379	152	0.037
Dolosse	2.8	2350	1.35	0.94	56	0.83	0.11	0.029	0.058	488	195	0.029
Accropod	2.5	2350	1.35	1.51	59	0.62	0.11	0.033	0.081	583	233	0.033
Coreloc	2.8	2350	1.35	1.51	63	0.56	0.11	0.029	0.058	660	264	0.029
Xbloc	2.8	2350	1.35	1.4	61	0.58	0.11	0.029	0.058	645	258	0.029
single layer cubes	2.2	2350	1.35	1	30	0.7	0.11	0.037	0.119	510	204	0.037
Haro	2.6											

	actual unit weight W [kg]	actual nominal diameter Dn [m]	actual mass density rho [kg/m3]	no. of units per sq m per layer Na [-]	approx no. units required N [-]	actual relative mass density D [-]	actual wave height Hs [m]	water depth h [m]	crest freeboard Rc [m]	toe width = crest width [m]	underlayer weight, max [kg]	underlayer weight, min [kg]	core material weight, max [kg]
Rock - large	0.1910	0.042	2650	398	159	1.65	0.103	0.258	0.103	0.125	0.038	0.013	0.0038
Rock - Small	0.0720	0.030	2650	763	305	1.65	0.074	0.186	0.074	0.090	0.014	0.005	0.0014
Cube	0.0620	0.030	2361	660	264	1.36	0.089	0.222	0.089	0.089	0.012	0.004	0.0012
Antifer	0.0850	0.033	2361	535	214	1.36	0.099	0.247	0.099	0.099	0.017	0.006	0.0017
Tetrapod	0.1000	0.035	2350	427	171	1.35	0.104	0.259	0.104	0.105	0.020	0.007	0.0020
Dolosse													
Accropod	0.0742	0.032	2361	622	249	1.36	0.107	0.268	0.107	0.095	0.015	0.005	0.0015
Coreloc	0.0605	0.030	2300	632	253	1.30	0.108	0.271	0.108	0.089	0.012	0.004	0.0012
Xbloc	0.0620	0.030	2300	607	243	1.30	0.109	0.273	0.109	0.090	0.012	0.004	0.0012
single layer cubes	0.0620	0.030	2361	792	317	1.36	0.089	0.222	0.089	0.089	0.012	0.004	0.0012
Haro	0.0420	0.026	2361	0	0	1.36	0.092	0.231	0.092	0.078	0.008	0.003	0.0008

Table 3.2 Unit properties

The tests had a fixed duration of 1024s, hence depending upon the period gave between 700 and 1300 waves. For all conditions a JONSWAP (γ=3.3) pseudo-random wave spectrum was used. A summary of each set of tests undertaken for each armour unit is given on the following pages. Photographs show the condition of the structure (a) before testing began; and (b) at the end of the 20 tests for each structure.

For the cubes, it was decided to investigate if the orientation of the cube influenced the overtopping characteristics, hence the cubes were tested in a 'flat' orientation whereby the cubes were placed relatively flat to each other and the second case was when the cubes were placed in a more roigh random pattern.

"Case A" – Cubes Flat

30 tests - Cubes arranged with the faces in flat manner. Rc/Hmo = 1.3 and 0.8, where Rc = 118mm and Rc = 71mm. Packing density = 1.19

Start of Tests

End of Tests

"Case B" – Cubes Rough

31 tests - Cubes arranged with the faces in an irregular "random" manner. Rc/Hmo = 1.3 and 0.8, where Rc = 118mm and Rc = 71mm. Packing density = 1.17 . Towards the end of the tests it was noted that the cubes moved slightly from a "random" pattern to a more regular "flat" pattern , no readjustment of the units was made during the testing.

Start of Tests

End of Tests

“Case C” - Antifer

31 tests - Antifer arranged with the faces in flat manner. Rc/Hmo = 1.3 and 0.8, where Rc = 128.7mm and Rc = 79mm. Packing density = 1.17

Start of Tests

End of Tests

“Case D” - Haro

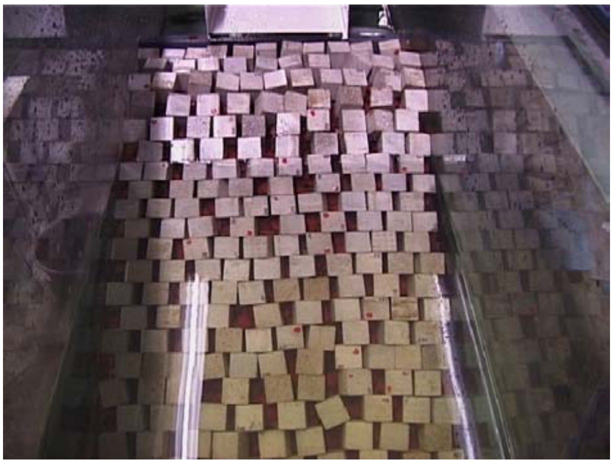
30 tests - Haro arranged with the faces in flat manner. Rc/Hmo = 1.3 and 0.8, where Rc = 118mm and Rc = 74mm.

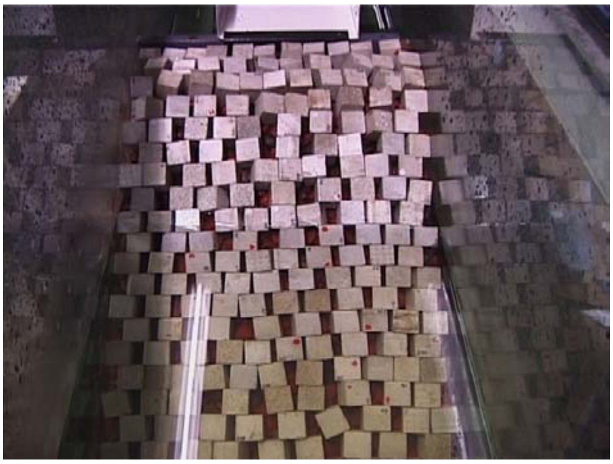
Start of Tests

End of Tests

“Case E” – Single layer cubes Flat

29 tests - Cubes arranged with the faces in flat manner on an alone layer. Rc/Hmo = 1.3 and 0.8, where Rc = 116mm and Rc = 71mm. Packing density = 0.65


Start of Tests


End of Tests

“Case F” - Tetrapod

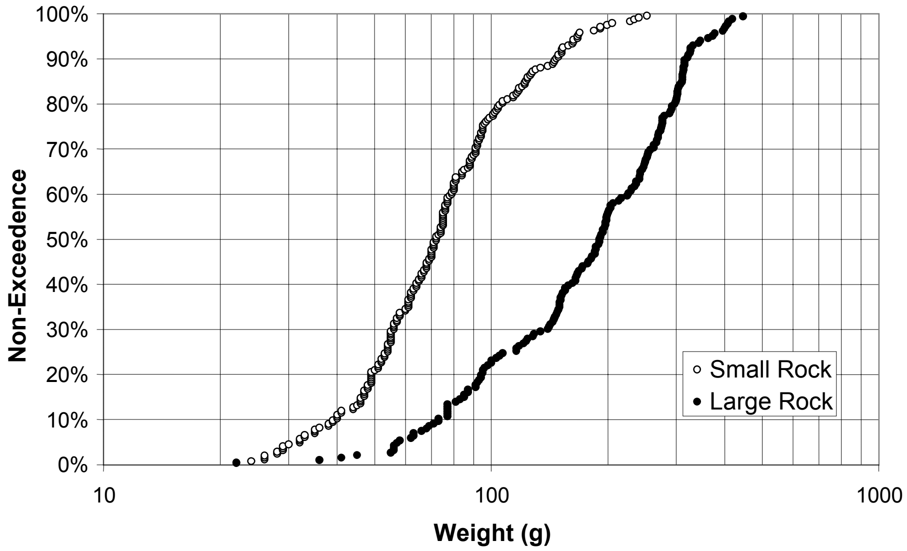
29 tests - Tetrapod arranged according to “T” (SOTRAMER). Rc/Hmo = 1.3 and 0.8, where Rc = 135mm and Rc = 83mm. Packing density = 0.99


Start of Tests


End of Tests

“Case H” – Rock

For the rock test, two stone sizes were used, initially a larger rock was used, however later analysis of the grading curve showed that the rock was larger than the maximum weight (233g), consequently a smaller rock was used for the remainder of the tests, however the results of the large rock are shown within this report.



Small and large Rock grading curve

Grading	Small Rock	Large Rock
W_{85}/W_{15}	2.62	3.64
W_{50} (g)	72	190

Small and large Rock characteristics

“Case H1” – Rock (“large”)

20 tests - natural rock. R_c/H_{mo} = 1.3 and 0.9, where R_c = 134mm and R_c = 95mm. Packing density = 1.38.


Start of Tests


End of Tests

“Case H2” – Rock (“Small”)

20 tests - natural rock. R_c/H_{mo} = 1.3 and 0.9, where R_c = 134mm and R_c = 95mm. Packing density = 1.38.


Start of Tests


End of Tests

"Case G" – Smooth Slope

18 tests – smooth Slope. R_c/H_{mo} = 1.0 and 1.7, where R_c = 110mm and R_c = 187mm.

"Case I" – Core-Loc®

23 tests – Core-Loc®. R_c/H_{mo} = 1.3 and 0.8, where R_c = 86.4mm and R_c = 140mm. Packing density = 0.56 .

Start of Tests

End of Tests

“Case L” - Accropode

23 tests – Accropode. R_c/H_{mo} = 1.3 and 0.8, where R_c = 139mm and R_c = 86mm. Packing density = 0.62.


Start of Tests


End of Tests

“Case M” - Xbloc®

23 tests – Xbloc®. R_c/H_{mo} = 1.3 and 0.8, where R_c = 142mm and R_c = 90mm. Packing density = 0.58.


Start of Tests


End of Tests

4. Summary of results

This section presents the results of the tests both in tabular form and graphically, a summary of results is shown in Table 4.1

	SUMMARY OF RESULTS		
	Clash data		Reduction factor due to 3Dn berm width
	B/Dn = 3	B/Dn = 0	
	γ_{f1}	γ_{f2}	$\gamma_b=\gamma_{f1}/\gamma_{f2}$
Smooth		1.054	
Large rock	0.416	0.470	0.89
Rock	0.420	0.418	1.00
Rock (1:2)	0.343	0.431	0.80
Cubes flat	0.492	0.530	0.93
Cubes (1:2)	0.459	0.503	0.91
Cubes rough	0.491	0.497	0.99
Antifer	0.523	0.527	0.99
Haro	0.491	0.466	1.05
Tetrapod	0.406	0.403	1.01
1 Layer cube	0.516	0.515	1.00
Accropod	0.481	0.493	0.98
CoreLoc	0.459	0.467	0.98
Xbloc	0.467	0.492	0.95

Table 4.1 : Summary of results and reduction factor due to 3Dn berm width

SMOOTH

N° Test	Case [%]	Test [%]	Refl. coef.	Hm0 [m]	Tp [s]	T-1,0 [s]	Sop	Som	ξ	Rc [m]	Rc/Hm0	Now	O/T [litres]	Chute [m]	Logtime [s]	q [$m^3/m*s$]	q/sqrt(gh^3)
1	2	75	0.70	0.11	1.74	1.60	0.024	0.028	4.261	0.11	0.97	307	145.82	0.1	916.5	1.59E-03	1.32E-02
2	3.5	50	0.69	0.11	1.37	1.26	0.036	0.043	3.462	0.11	1.04	306	112.94	0.1	942.25	1.20E-03	1.11E-02
3	5	75	0.60	0.11	1.21	1.10	0.048	0.058	3.003	0.11	1.00	293	116.03	0.1	934	1.24E-03	1.09E-02
4	2	50	0.75	0.10	1.58	1.43	0.025	0.031	4.136	0.11	1.12	235	69.50	0.1	968.5	7.18E-04	7.40E-03
5	3.5	50	0.74	0.07	1.09	1.03	0.038	0.042	3.406	0.11	1.57	146	21.59	0.1	1000.25	2.16E-04	3.73E-03
6	5	75	0.63	0.08	0.96	0.95	0.056	0.058	2.798	0.11	1.36	225	43.96	0.1	986.5	4.46E-04	6.21E-03
7	2	100	0.84	0.06	1.32	1.15	0.022	0.029	4.466	0.11	1.85	86	7.49	0.1	1010	7.42E-05	1.63E-03
8	3.5	100	0.73	0.05	0.93	0.89	0.040	0.044	3.302	0.11	2.03	69	4.24	0.1	1010	4.20E-05	1.07E-03
9	5	100	0.64	0.05	0.84	0.79	0.049	0.056	2.977	0.11	2.01	97	6.21	0.1	1005.75	6.18E-05	1.54E-03
10	2	75	0.76	0.11	1.74	1.59	0.023	0.028	4.330	0.187	1.70	130	30.79	0.1	991.5	3.11E-04	2.71E-03
11	3.5	50	0.75	0.10	1.44	1.28	0.032	0.040	3.700	0.187	1.82	126	25.95	0.1	995.5	2.61E-04	2.53E-03
12	5	75	0.67	0.10	1.15	1.09	0.050	0.055	2.961	0.187	1.81	166	35.21	0.1	991.75	3.55E-04	3.41E-03
13	2	50	0.81	0.09	1.58	1.42	0.024	0.029	4.298	0.187	2.05	49	6.99	0.1	1010	6.92E-05	8.01E-04
14	3.5	50	0.78	0.08	1.21	1.09	0.034	0.041	3.606	0.187	2.46	55	5.46	0.1	1005.25	5.43E-05	8.29E-04
15	5	75	0.67	0.08	0.99	0.94	0.050	0.055	2.945	0.187	2.45	58	4.44	0.1	1005.25	4.42E-05	6.68E-04
16	2	100	0.86	0.06	1.26	1.15	0.023	0.027	4.388	0.187	3.34	4	0.06	0.1	1010	6.31E-07	1.52E-05
17	3.5	100	0.76	0.05	0.99	0.89	0.033	0.041	3.621	0.187	3.70	3	0.08	0.1	1010	8.35E-07	2.35E-05
18	5	100	0.65	0.05	0.84	0.79	0.046	0.053	3.082	0.187	3.66	9	0.31	0.1	1010	3.08E-06	8.52E-05

Table 4.2 : Overtopping tests results measured at 3Dn - Smooth

ROCK

N° Test	Case [%]	Test [%]	Refl. coef.	Hm0 [m]	Tp [s]	T-1,0 [s]	Sop	Som	ξ	Rc [m]	Rc/Hm0	Now	O/T [litres]	Chute [m]	Logtime [s]	q [$m^3/m*s$]	q/sqrt(gh^3)
1	3.5	75	0.26	0.072	1.09	1.04	0.039	0.043	3.35	0.095	1.32	7	0.78	0.2	1010	3.88E-06	6.40E-05
2	5	75	0.25	0.051	0.90	0.85	0.040	0.045	3.29	0.095	1.87	0	0.00	0.2	1010	0.00E+00	0.00E+00
3	2	75	0.23	0.067	0.93	0.90	0.050	0.054	2.96	0.095	1.41	3	0.26	0.2	1010	1.30E-06	2.37E-05
4	5	50	0.29	0.055	1.19	1.09	0.025	0.030	4.18	0.095	1.73	0	0.00	0.2	1010	0.00E+00	0.00E+00
5	3.5	100	0.34	0.079	1.44	1.35	0.024	0.028	4.22	0.095	1.21	38	8.01	0.2	1004.75	3.99E-05	5.77E-04
6	2	100	0.23	0.092	1.04	1.03	0.055	0.056	2.83	0.095	1.04	53	10.77	0.2	1006	5.35E-05	6.16E-04
7	3.5	100	0.28	0.093	1.32	1.19	0.034	0.042	3.56	0.095	1.02	58	17.90	0.2	1001.5	8.94E-05	9.99E-04
8	5	100	0.25	0.069	1.09	1.04	0.037	0.041	3.43	0.062	0.90	41	7.84	0.2	1005.75	3.90E-05	6.86E-04
9	5	75	0.25	0.051	0.90	0.86	0.040	0.044	3.30	0.062	1.22	1	0.19	0.2	1010	9.38E-07	2.63E-05
10	2	50	0.23	0.068	0.93	0.90	0.050	0.054	2.94	0.062	0.91	29	4.37	0.2	1010	2.16E-05	3.87E-04
11	2	75	0.24	0.055	0.84	0.80	0.049	0.055	2.98	0.062	1.14	4	0.71	0.2	1010	3.54E-06	8.87E-05
12	5	75	0.28	0.056	1.19	1.09	0.026	0.031	4.12	0.062	1.10	9	1.36	0.2	1010	6.74E-06	1.61E-04
13	5	100	0.32	0.079	1.44	1.34	0.024	0.028	4.22	0.062	0.79	98	35.13	0.2	990.25	1.77E-04	2.55E-03
14	3.5	100	0.23	0.094	1.04	1.03	0.056	0.057	2.78	0.062	0.66	128	43.82	0.2	986.75	2.22E-04	2.44E-03
15	2	100	0.27	0.096	1.32	1.19	0.035	0.044	3.51	0.062	0.64	159	62.10	0.2	971	3.20E-04	3.42E-03

Table 4.3 : Overtopping tests results measured at 3Dn - Rock

N° Test	Case [%]	Test [%]	Refl. coef.	Hm0 [m]	Tp [s]	T-1,0 [s]	Sop	Som	ξ	Rc [m]	Rc/Hm0	Now	O/T [litres]	Chute [m]	Logtime [s]	q [$m^3/m*s$]	q/sqrt(gh^3)
16	3.5	75	0.24	0.055	0.84	0.80	0.049	0.055	2.97	0.062	1.13	2	0.58	0.2	1010	2.85E-06	7.07E-05
17	5	75	0.28	0.057	1.21	1.09	0.025	0.030	4.18	0.062	1.10	11	1.58	0.2	1010	7.83E-06	1.86E-04
18	2	75	0.25	0.052	0.91	0.86	0.040	0.045	3.31	0.062	1.20	1	0.16	0.2	1010	7.95E-07	2.17E-05
19	3.5	100	0.25	0.072	1.09	1.04	0.039	0.043	3.36	0.062	0.86	43	8.55	0.2	1006.25	4.25E-05	7.04E-04
20	5	100	0.32	0.081	1.44	1.34	0.025	0.029	4.16	0.062	0.77	100	43.36	0.2	981.75	2.21E-04	3.06E-03
21	3.5	75	0.25	0.070	1.09	1.04	0.038	0.042	3.39	0.095	1.35	4	0.67	0.2	1010	3.32E-06	5.67E-05
22	5	75	0.23	0.068	0.93	0.90	0.051	0.055	2.93	0.095	1.39	0	0.00	0.2	1010	0.00E+00	0.00E+00
23	2	75	0.33	0.082	1.49	1.35	0.024	0.029	4.30	0.095	1.16	32	10.01	0.2	1006	4.97E-05	6.81E-04
24	2	100	0.23	0.096	1.09	1.03	0.052	0.058	2.91	0.095	0.99	40	9.67	0.2	1005.75	4.81E-05	5.16E-04
25	3.5	100	0.28	0.098	1.32	1.19	0.036	0.044	3.48	0.095	0.97	43	20.73	0.2	997.25	0.00E+00	0.00E+00

Table 4.4 : Overtopping results tests measured at corner - Rock

LARGE ROCK

N°	Refl. coef.	Hm0	Tp	T-1,0	Sop	Som	ξ	Rc	Rc/Hm0	Now	O/T	Chute	Logtime	q	q/sqrt(gh^3)
Test		[m]	[s]	[s]				[m]			[litres]	[m]	[s]	[m³/s]	
1	0.22	0.07	1.09	1.04	0.038	0.042	3.40	0.095	1.36	2	0.299	0.2	1010	1.48E-06	2.54E-05
2	0.21	0.08	1.09	1.04	0.042	0.046	3.22	0.095	1.21	3	0.782	0.2	1010	3.87E-06	5.65E-05
3	0.19	0.08	1.04	0.95	0.049	0.058	2.97	0.095	1.15	13	1.570	0.2	1010	7.77E-06	1.04E-04
4	0.26	0.10	1.58	1.43	0.025	0.031	4.14	0.095	0.96	54	19.806	0.2	1010	9.91E-05	1.02E-03
5	0.25	0.06	1.32	1.16	0.021	0.028	4.51	0.095	1.63	1	0.009	0.2	1010	4.65E-08	1.05E-06
6	0.23	0.12	1.37	1.28	0.041	0.047	3.24	0.095	0.79	109	42.074	0.2	1010	2.14E-04	1.63E-03
7	0.20	0.11	1.14	1.10	0.055	0.059	2.81	0.095	0.85	77	17.646	0.2	1010	8.82E-05	7.55E-04
8	0.29	0.09	1.82	1.63	0.018	0.023	4.91	0.095	1.02	76	43.835	0.2	1010	2.23E-04	2.49E-03
9	0.23	0.08	1.09	1.04	0.042	0.046	3.23	0.134	1.73	0	0.000	0.2	1010	0.00E+00	0.00E+00
10	0.21	0.08	1.04	0.95	0.048	0.057	3.00	0.134	1.65	0	0.000	0.2	1010	0.00E+00	0.00E+00
11	0.27	0.09	1.58	1.43	0.024	0.029	4.25	0.134	1.44	6	1.180	0.2	1010	5.84E-06	6.54E-05
12	0.24	0.12	1.37	1.28	0.042	0.048	3.21	0.134	1.09	36	11.315	0.2	1010	5.63E-05	4.16E-04
13	0.22	0.11	1.14	1.10	0.056	0.060	2.80	0.134	1.19	14	1.755	0.2	1010	8.73E-06	7.37E-05
14	0.30	0.11	1.74	1.63	0.023	0.027	4.31	0.134	1.21	20	6.207	0.2	1010	3.09E-05	2.67E-04

Table 4.5 : Overtopping tests results measured at 3Dn – Large Rock

N°	Refl. coef.	Hm0	Tp	T-1,0	Sop	Som	ξ	Rc	Rc/Hm0	Now	O/T	Chute	Logtime	q	q/sqrt(gh^3)
Test		[m]	[s]	[s]				[m]			[litres]	[m]	[s]	[m³/s]	
15	0.23	0.07	1.09	1.04	0.040	0.044	3.30	0.134	1.80	2	0.222	0.2	1010	1.10E-06	1.73E-05
16	0.21	0.08	1.04	0.95	0.047	0.055	3.05	0.134	1.71	6	0.361	0.2	1010	1.79E-06	2.60E-05
17	0.27	0.09	1.58	1.43	0.022	0.027	4.41	0.134	1.54	14	1.267	0.2	1010	6.27E-06	7.81E-05
18	0.23	0.11	1.37	1.28	0.039	0.045	3.33	0.134	1.17	52	9.813	0.2	1010	4.88E-05	4.05E-04
19	0.21	0.10	1.14	1.10	0.051	0.055	2.92	0.134	1.30	46	3.844	0.2	1010	1.90E-05	1.84E-04
20	0.25	0.09	1.58	1.43	0.023	0.028	4.36	0.095	1.07	46	8.755	0.2	1010	4.33E-05	5.23E-04
21	0.21	0.08	1.09	1.04	0.041	0.045	3.27	0.095	1.25	12	1.177	0.2	1010	5.83E-06	8.90E-05
22	0.20	0.08	1.04	0.95	0.048	0.057	3.02	0.095	1.18	15	1.069	0.2	1010	5.29E-06	7.40E-05
23	0.23	0.12	1.37	1.28	0.040	0.046	3.28	0.095	0.81	160	38.956	0.2	1010	1.97E-04	1.56E-03
24	0.21	0.11	1.14	1.10	0.054	0.058	2.85	0.095	0.88	160	18.451	0.2	1010	9.18E-05	8.22E-04

Table 4.6 : Overtopping results tests measured at corner – Large Rock

ROCK (1:2)

N°	Refl. coef.	Hm0	Tp	T-1,0	Sop	Som	ξ	Rc	Rc/Hm0	Now	O/T	Chute	Logtime	q	q/sqrt(gh^3)
Test		[m]	[s]	[s]				[m]			[litres]	[m]	[s]	[m³/s]	
1	0.21	0.07	1.09	1.04	0.037	0.041	3.44	0.095	1.39	4	0.115	0.2	1010	5.68E-07	1.01E-05
2	0.21	0.05	0.90	0.85	0.038	0.042	3.40	0.095	2.00	0	0.000	0.2	1010	0.00E+00	0.00E+00
3	0.20	0.07	0.93	0.89	0.049	0.054	2.97	0.095	1.42	1	0.020	0.2	1010	1.00E-07	1.85E-06
4	0.28	0.08	1.49	1.35	0.023	0.028	4.32	0.095	1.18	15	2.827	0.2	1010	1.40E-05	1.95E-04
5	0.19	0.10	1.04	1.03	0.057	0.058	2.77	0.095	1.00	20	2.594	0.2	1010	1.28E-05	1.39E-04
6	0.23	0.10	1.32	1.19	0.035	0.044	3.50	0.095	0.98	30	7.531	0.2	1010	3.74E-05	3.97E-04
7	0.20	0.07	1.09	1.04	0.039	0.043	3.35	0.062	0.86	18	2.814	0.2	1010	1.40E-05	2.29E-04
8	0.18	0.05	0.91	0.86	0.040	0.045	3.31	0.062	1.20	3	0.036	0.2	1010	1.78E-07	4.87E-06
9	0.19	0.07	0.93	0.90	0.052	0.056	2.90	0.062	0.89	11	1.443	0.2	1010	7.14E-06	1.23E-04
10	0.20	0.06	0.84	0.80	0.050	0.055	2.96	0.062	1.12	1	0.148	0.2	1010	7.34E-07	1.80E-05
11	0.23	0.06	1.19	1.09	0.026	0.031	4.10	0.062	1.09	5	0.418	0.2	1010	2.07E-06	4.85E-05
12	0.25	0.08	1.49	1.35	0.024	0.029	4.29	0.062	0.76	63	19.007	0.2	1010	9.51E-05	1.29E-03
13	0.16	0.10	1.04	1.03	0.059	0.060	2.72	0.062	0.63	97	10.365	0.1	1010	1.03E-04	1.06E-03
14	0.18	0.10	1.32	1.19	0.037	0.045	3.44	0.062	0.62	128	19.368	0.1	1010	1.94E-04	1.95E-03

Table 4.7 : Overtopping tests results measured at 3Dn – Rock (1:2)

N°	Refl. coef.	Hm0	Tp	T-1,0	Sop	Som	ξ	Rc	Rc/Hm0	Now	O/T	Chute	Logtime	q	q/sqrt(gh^3)
Test		[m]	[s]	[s]				[m]			[litres]	[m]	[s]	[m³/s]	
15	0.19	0.10	1.32	1.19	0.036	0.044	3.48	0.062	0.63	135	19.765	0.1	1010	1.97E-04	2.05E-03
16	0.16	0.10	1.04	1.03	0.058	0.059	2.73	0.062	0.63	102	10.790	0.1	1010	1.07E-04	1.11E-03
17	0.19	0.06	1.19	1.09	0.027	0.032	4.03	0.062	1.05	60	1.413	0.2	1010	7.00E-06	1.56E-04
18	0.16	0.05	0.91	0.86	0.041	0.046	3.28	0.062	1.18	18	0.473	0.2	1010	2.34E-06	6.21E-05
19	0.18	0.06	0.84	0.80	0.051	0.056	2.93	0.062	1.10	16	1.243	0.2	1010	6.16E-06	1.47E-04
20	0.22	0.10	1.32	1.20	0.037	0.045	3.43	0.095	0.94	98	22.926	0.2	1010	1.15E-04	1.15E-03
21	0.19	0.10	1.04	1.03	0.059	0.060	2.71	0.095	0.95	95	17.966	0.2	1010	8.94E-05	9.06E-04
22	0.27	0.11	1.74	1.54	0.023	0.029	4.39	0.095	0.89	121	51.089	0.2	1010	2.61E-04	2.37E-03
23	0.26	0.09	1.49	1.35	0.025	0.030	4.19	0.095	1.11	65	14.132	0.2	1010	7.03E-05	8.90E-04
24	0.20	0.08	1.12	1.04	0.038	0.045	3.37	0.095	1.26	22	3.036	0.2	1010	1.50E-05	2.31E-04

Table 4.8 : Overtopping results tests measured at corner – Rock (1:2)

CUBES FLAT

N° Test	Case [%]	Test [%]	Refl. coef.	Hm0 [m]	Tp [s]	T-1,0 [s]	Sop	Som	ξ	Rc [m]	Rc/Hm0	Now	O/T [litres]	Chute [m]	Logtime [s]	q [m^3/s]	q/sqrt(gh^3)
1	3.5	75	0.35	0.06	1.09	1.03	0.035	0.039	3.55	0.118	1.83	10	0.29	0.2	1010	1.46E-06	2.84E-05
2	3.5	100	0.38	0.09	1.32	1.19	0.034	0.042	3.56	0.118	1.26	87	11.54	0.2	1010	5.75E-05	6.38E-04
3	3.5	50	0.32	0.05	0.90	0.84	0.036	0.042	3.46	0.118	2.56	0	0.00	0.2	1010	0.00E+00	0.00E+00
4	5	100	0.33	0.09	1.09	1.02	0.049	0.056	2.99	0.118	1.30	92	8.83	0.2	1010	4.40E-05	5.12E-04
5	5	75	0.31	0.06	0.90	0.89	0.050	0.051	2.96	0.118	1.87	10	0.05	0.2	1010	2.26E-07	4.55E-06
6	5	85	0.36	0.07	1.19	1.08	0.032	0.038	3.71	0.118	1.70	17	0.56	0.2	1010	2.77E-06	4.82E-05
7	2	75	0.41	0.08	1.44	1.35	0.025	0.028	4.21	0.118	1.49	49	3.08	0.2	1010	1.52E-05	2.18E-04
8	2	100	0.41	0.10	1.74	1.54	0.021	0.027	4.55	0.118	1.18	105	27.76	0.2	1010	1.39E-04	1.41E-03
9	2	50	0.37	0.05	1.19	1.09	0.025	0.030	4.20	0.118	2.17	1	0.00	0.2	1010	0.00E+00	0.00E+00
10	3.5	75	0.34	0.06	1.09	1.03	0.034	0.038	3.58	0.071	1.12	33	1.85	0.2	1010	9.15E-06	1.84E-04
11	3.5	50	0.31	0.04	0.91	0.85	0.034	0.040	3.55	0.071	1.59	0	0.00	0.2	1010	0.00E+00	0.00E+00
12	5	75	0.30	0.06	0.91	0.89	0.049	0.051	2.99	0.071	1.13	44	1.84	0.2	1010	9.09E-06	1.83E-04
13	2	50	0.37	0.05	1.21	1.09	0.024	0.029	4.26	0.071	1.31	12	0.19	0.2	1010	9.20E-07	2.32E-05
14	5	50	0.30	0.04	0.78	0.75	0.047	0.050	3.06	0.071	1.61	10	0.20	0.2	1010	9.67E-07	3.32E-05
15	2	75	0.39	0.08	1.44	1.35	0.025	0.028	4.18	0.071	0.88	90	24.78	0.2	1010	1.25E-04	1.74E-03
16	5	100	0.31	0.09	1.09	1.03	0.050	0.056	2.96	0.071	0.77	129	16.62	0.1	1010	1.66E-04	1.89E-03
17	3.5	100	0.35	0.09	1.32	1.19	0.035	0.043	3.54	0.071	0.75	157	23.62	0.1	1010	2.37E-04	2.60E-03
18	2	100	0.38	0.10	1.74	1.54	0.021	0.028	4.51	0.071	0.70	185	51.92	0.1	1010	5.29E-04	5.24E-03

Table 4.9 : Overtopping tests results measured at 3Dn – Cubes Flat

N° Test	Case [%]	Test [%]	Refl. coef.	Hm0 [m]	Tp [s]	T-1,0 [s]	Sop	Som	ξ	Rc [m]	Rc/Hm0	Now	O/T [litres]	Chute [m]	Logtime [s]	q [m^3/s]	q/sqrt(gh^3)
19	2	100	0.36	0.11	1.78	1.63	0.022	0.026	4.47	0.071	0.66	241	78.59	0.1	1010	8.17E-04	7.36E-03
20	3.5	100	0.35	0.09	1.32	1.19	0.035	0.042	3.55	0.071	0.75	205	35.69	0.1	1010	3.61E-04	3.98E-03
21	5	100	0.30	0.09	1.09	1.02	0.050	0.056	2.97	0.071	0.77	177	24.25	0.1	1010	2.44E-04	2.78E-03
22	2	50	0.36	0.05	1.21	1.09	0.024	0.030	4.24	0.071	1.29	27	1.41	0.2	1010	7.00E-06	1.74E-04
23	3.5	50	0.32	0.05	0.91	0.85	0.035	0.041	3.52	0.071	1.56	8	0.21	0.2	1010	1.06E-06	3.48E-05
24	5	50	0.30	0.05	0.78	0.75	0.048	0.052	3.03	0.071	1.57	28	0.47	0.2	1010	2.34E-06	7.77E-05
25	2	100	0.41	0.10	1.74	1.54	0.021	0.027	4.55	0.118	1.18	105	42.49	0.2	1010	2.15E-04	2.17E-03
26	3.5	100	0.37	0.09	1.32	1.19	0.034	0.042	3.59	0.118	1.28	84	16.07	0.2	1010	8.03E-05	9.17E-04
27	5	100	0.32	0.09	1.09	1.02	0.048	0.055	3.02	0.118	1.33	75	9.60	0.2	1010	4.77E-05	5.74E-04
28	2	50	0.38	0.05	1.19	1.09	0.023	0.028	4.33	0.118	2.31	1	0.01	0.2	1010	4.33E-08	1.20E-06
29	3.5	75	0.35	0.06	1.09	1.03	0.032	0.037	3.67	0.118	1.96	12	0.30	0.2	1010	1.47E-06	3.17E-05
30	5	75	0.31	0.06	0.93	0.88	0.044	0.049	3.13	0.118	1.97	14	0.11	0.2	1010	5.26E-07	1.14E-05

Table 4.10 : Overtopping results tests measured at corner – Cubes Flat

CUBES FLAT (1:2)

N° Test	Refl. coef.	Hm0 [m]	Tp [s]	T-1,0 [s]	Sop	Som	ξ	Rc [m]	Rc/Hm0	Now	O/T [litres]	Chute [m]	Logtime [s]	q [m^3/s]	q/sqrt(gh^3)
1	0.22	0.07	1.14	1.04	0.035	0.043	3.50	0.116	1.62	2	0.270	0.2	1010	1.34E-06	2.22E-05
2	0.19	0.07	0.90	0.90	0.053	0.053	2.87	0.116	1.74	0	0.000	0.2	1010	0.00E+00	0.00E+00
3	0.30	0.08	1.44	1.35	0.025	0.028	4.19	0.116	1.45	20	3.259	0.2	1010	1.62E-05	2.28E-04
4	0.20	0.09	1.09	1.03	0.050	0.056	2.96	0.116	1.25	36	4.590	0.2	1010	2.27E-05	2.57E-04
5	0.25	0.09	1.32	1.20	0.034	0.042	3.56	0.116	1.24	38	10.406	0.2	1010	5.17E-05	5.74E-04
6	0.31	0.10	1.74	1.54	0.021	0.027	4.53	0.116	1.15	65	28.052	0.2	1010	1.41E-04	1.41E-03
7	0.23	0.07	1.14	1.04	0.035	0.042	3.54	0.071	1.01	29	4.442	0.2	1010	2.20E-05	3.78E-04
8	0.21	0.07	0.93	0.90	0.051	0.055	2.91	0.071	1.02	19	2.293	0.2	1010	1.13E-05	1.98E-04
9	0.23	0.06	0.84	0.80	0.050	0.056	2.95	0.071	1.28	2	0.226	0.2	1010	1.12E-06	2.73E-05
10	0.25	0.06	1.21	1.09	0.025	0.031	4.14	0.071	1.23	5	0.473	0.2	1010	2.34E-06	5.40E-05
11	0.30	0.08	1.46	1.34	0.024	0.029	4.24	0.071	0.88	72	24.057	0.2	1010	1.20E-04	1.66E-03
12	0.20	0.10	1.04	1.03	0.057	0.058	2.76	0.071	0.74	110	30.093	0.2	1010	1.51E-04	1.62E-03
13	0.23	0.05	0.91	0.86	0.040	0.046	3.28	0.071	1.36	0	0.000	0.2	1010	0.00E+00	0.00E+00
14	0.23	0.10	1.32	1.19	0.036	0.044	3.50	0.071	0.73	127	20.470	0.1	1010	2.04E-04	2.16E-03
15	0.29	0.10	1.74	1.53	0.021	0.028	4.51	0.071	0.70	164	45.832	0.1	1010	4.68E-04	4.61E-03

Table 4.11 : Overtopping tests results measured at 3Dn – Cubes Flat (1:2)

N° Test	Refl. coef.	Hm0 [m]	Tp [s]	T-1,0 [s]	Sop	Som	ξ	Rc [m]	Rc/Hm0	Now	O/T [litres]	Chute [m]	Logtime [s]	q [m^3/s]	q/sqrt(gh^3)
16	0.24	0.10	1.32	1.19	0.036	0.044	3.50	0.071	0.73	179	30.900	0.1	1010	3.12E-04	3.30E-03
17	0.21	0.10	1.04	1.03	0.058	0.059	2.75	0.071	0.73	155	20.578	0.1	1010	2.06E-04	2.19E-03
18	0.26	0.06	1.19	1.09	0.026	0.032	4.06	0.071	1.22	18	2.160	0.2	1010	1.07E-05	2.43E-04
19	0.24	0.05	0.91	0.86	0.041	0.046	3.27	0.071	1.35	2	0.380	0.2	1010	1.88E-06	4.97E-05
20	0.24	0.06	0.84	0.80	0.050	0.056	2.94	0.071	1.26	6	0.910	0.2	1010	4.50E-06	1.08E-04
21	0.25	0.09	1.32	1.19	0.035	0.043	3.54	0.116	1.22	54	12.940	0.2	1010	6.44E-05	7.05E-04
22	0.20	0.09	1.09	1.03	0.051	0.057	2.93	0.116	1.23	52	7.371	0.2	1010	3.66E-05	4.04E-04
23	0.32	0.10	1.74	1.54	0.021	0.027	4.52	0.116	1.15	84	34.058	0.2	1010	1.72E-04	1.71E-03
24	0.31	0.08	1.44	1.35	0.025	0.028	4.19	0.116	1.45	28	5.495	0.2	1010	2.73E-05	3.85E-04
25	0.22	0.07	1.09	1.03	0.037	0.042	3.42	0.116	1.67	5	0.460	0.2	1010	2.28E-06	3.98E-05

Table 4.12 : Overtopping results tests measured at corner – Cubes Flat (1:2)

CUBES ROUGH

N° Test	Case [%]	Test [%]	Refl. coef.	Hm0 [m]	Tp [s]	T-1,0 [s]	Sop	Som	ξ	Rc [m]	Rc/Hm0	Now	O/T [litres]	Chute [m]	Logtime [s]	q [m^3/m*s]	q/sqrt(gh^3)
1	3.5	75	0.30	0.06	1.09	1.03	0.033	0.037	3.65	0.118	1.94	18	0.080	0.2	1010	3.94E-07	8.36E-06
2	3.5	100	0.34	0.09	1.32	1.19	0.033	0.041	3.62	0.118	1.30	53	7.191	0.2	1010	3.58E-05	4.18E-04
3	3.5	50	0.28	0.04	0.90	0.84	0.033	0.038	3.64	0.118	2.83	0	0.000	0.2	1010	0.00E+00	0.00E+00
4	5	100	0.29	0.09	1.09	1.02	0.047	0.054	3.03	0.118	1.34	61	4.351	0.2	1010	2.15E-05	2.62E-04
5	5	75	0.27	0.06	0.90	0.89	0.047	0.049	3.04	0.118	1.98	6	0.017	0.2	1010	8.50E-08	1.86E-06
6	5	85	0.28	0.07	1.04	0.96	0.043	0.050	3.19	0.118	1.64	23	0.546	0.2	1010	2.70E-06	4.46E-05
7	2	75	0.36	0.08	1.44	1.35	0.024	0.027	4.28	0.118	1.54	21	1.836	0.2	1010	9.09E-06	1.36E-04
8	2	100	0.38	0.10	1.74	1.54	0.020	0.026	4.62	0.118	1.22	71	25.436	0.2	1010	1.28E-04	1.35E-03
9	2	50	0.32	0.05	1.19	1.08	0.024	0.028	4.30	0.118	2.28	1	0.000	0.2	1010	0.00E+00	0.00E+00
10	3.5	75	0.28	0.06	1.09	1.03	0.032	0.037	3.67	0.074	1.23	28	1.318	0.2	1010	6.53E-06	1.41E-04
11	3.5	50	0.27	0.04	0.91	0.85	0.032	0.037	3.70	0.074	1.79	1	0.000	0.2	1010	0.00E+00	0.00E+00
12	3.5	75	0.25	0.06	0.91	0.89	0.047	0.049	3.05	0.074	1.22	28	1.182	0.2	1010	5.85E-06	1.26E-04
13	2	50	0.31	0.05	1.19	1.09	0.023	0.027	4.35	0.074	1.46	7	0.173	0.2	1010	8.55E-07	2.40E-05
14	5	50	0.27	0.04	0.78	0.75	0.043	0.047	3.17	0.074	1.80	11	0.070	0.2	1010	3.46E-07	1.33E-05
15	2	75	0.33	0.08	1.44	1.35	0.023	0.027	4.31	0.074	0.98	78	21.303	0.2	1010	1.07E-04	1.64E-03
16	5	100	0.25	0.09	1.09	1.02	0.047	0.053	3.05	0.074	0.85	121	15.557	0.1	1010	1.55E-04	1.92E-03
17	3.5	100	0.29	0.09	1.32	1.19	0.033	0.040	3.65	0.074	0.83	145	25.891	0.1	1010	2.59E-04	3.10E-03
18	2	100	0.33	0.10	1.74	1.54	0.020	0.026	4.64	0.074	0.77	191	60.783	0.1	1010	6.26E-04	6.74E-03

Table 4.13 : Overtopping tests results measured at 3Dn – Cubes Rough

N° Test	Case [%]	Test [%]	Refl. coef.	Hm0 [m]	Tp [s]	T-1,0 [s]	Sop	Som	ξ	Rc [m]	Rc/Hm0	Now	O/T [litres]	Chute [m]	Logtime [s]	q [m^3/m*s]	q/sqrt(gh^3)
19	2	100	0.32	0.10	1.74	1.54	0.020	0.026	4.63	0.074	0.77	181	54.927	0.1	1010	5.62E-04	6.01E-03
20	3.5	100	0.28	0.09	1.32	1.19	0.033	0.040	3.65	0.074	0.83	179	22.204	0.1	1010	2.22E-04	2.67E-03
21	5	100	0.24	0.09	1.09	1.02	0.047	0.054	3.04	0.074	0.84	180	13.558	0.1	1010	1.35E-04	1.65E-03
22	2	50	0.28	0.05	1.19	1.09	0.023	0.028	4.32	0.074	1.44	32	0.406	0.2	1010	2.01E-06	5.53E-05
23	3.5	50	0.23	0.04	0.90	0.84	0.033	0.037	3.64	0.074	1.78	11	0.034	0.2	1010	1.68E-07	6.31E-06
24	5	50	0.23	0.04	0.78	0.75	0.044	0.048	3.15	0.074	1.77	29	0.156	0.2	1010	7.75E-07	2.90E-05
25	2	100	0.37	0.10	1.74	1.54	0.021	0.026	4.60	0.118	1.21	79	25.604	0.2	1010	1.29E-04	1.35E-03
26	3.5	100	0.32	0.09	1.32	1.19	0.033	0.040	3.66	0.118	1.33	60	6.400	0.2	1010	3.18E-05	3.85E-04
27	5	100	0.27	0.09	1.09	1.02	0.046	0.053	3.07	0.118	1.37	69	3.287	0.2	1010	1.63E-05	2.05E-04
28	3.5	75	0.29	0.06	1.09	1.03	0.032	0.036	3.72	0.118	2.01	6	0.068	0.2	1010	3.37E-07	7.57E-06
29	5	75	0.26	0.06	0.90	0.88	0.046	0.048	3.08	0.118	2.03	5	0.020	0.2	1010	9.78E-08	2.23E-06

Table 4.14 : Overtopping results tests measured at corner – Cubes Rough

ANTIFER CUBES

N° Test	Case [%]	Test [%]	Refl. coef.	Hm0 [m]	Tp [s]	T-1,0 [s]	Sop	Som	ξ	Rc [m]	Rc/Hm0	Now	O/T [litres]	Chute [m]	Logtime [s]	q [m^3/m*s]	q/sqrt(gh^3)
1	3.5	75	0.32	0.072	1.19	1.09	0.033	0.039	3.64	0.128	1.77	12	0.257	0.2	1010	1.27E-06	2.10E-05
2	3.5	100	0.34	0.105	1.37	1.28	0.037	0.041	3.44	0.128	1.22	71	14.867	0.2	1010	7.36E-05	6.96E-04
3	3.5	50	0.29	0.045	0.95	0.89	0.033	0.037	3.61	0.128	2.82	0	0.000	0.2	1010	0.00E+00	0.00E+00
4	5	100	0.32	0.115	1.22	1.17	0.050	0.054	2.94	0.128	1.11	103	27.219	0.2	1010	1.35E-04	1.10E-03
5	5	75	0.28	0.067	0.99	0.94	0.042	0.049	3.22	0.128	1.91	18	0.134	0.2	1010	6.64E-07	1.22E-05
6	5	50	0.37	0.090	1.58	1.43	0.043	0.028	3.17	0.128	1.42	48	8.821	0.2	1010	4.37E-05	5.17E-04
7	2	75	0.40	0.107	1.74	1.63	0.023	0.026	4.35	0.128	1.19	78	39.603	0.2	1010	1.96E-04	1.78E-03
8	2	100	0.35	0.055	1.32	1.15	0.020	0.027	4.62	0.128	2.32	0	0.000	0.2	1010	0.00E+00	0.00E+00
9	2	50	0.30	0.076	1.19	1.10	0.023	0.040	4.38	0.128	1.69	53	5.403	0.2	1010	0.00E+00	0.00E+00
10	3.5	75	0.30	0.075	1.19	1.09	0.033	0.040	3.65	0.079	1.06	50	6.094	0.2	1010	3.02E-05	4.73E-04
11	3.5	100	0.32	0.102	1.37	1.27	0.036	0.040	3.48	0.079	0.78	135	66.863	0.2	1010	3.31E-04	3.25E-03
12	3.5	50	0.29	0.047	0.95	0.89	0.035	0.038	3.54	0.079	1.68	1	0.000	0.2	1010	0.00E+00	0.00E+00
13	5	75	0.27	0.074	1.04	0.95	0.046	0.053	3.06	0.079	1.06	36	4.107	0.2	1010	2.03E-05	3.21E-04
14	5	50	0.28	0.048	0.84	0.79	0.044	0.050	3.16	0.079	1.63	7	0.080	0.2	1010	3.94E-07	1.18E-05
15	2	50	0.34	0.054	1.32	1.16	0.022	0.026	4.42	0.079	1.45	11	0.197	0.2	1010	9.77E-07	2.46E-05
16	5	100	0.28	0.102	1.14	1.10	0.055	0.055	2.82	0.079	0.77	167	25.479	0.1	1010	2.52E-04	2.46E-03
17	2	75	0.34	0.093	1.58	1.43	0.025	0.029	4.19	0.079	0.85	124	26.603	0.1	1010	2.63E-04	2.95E-03
18	2	100	0.36	0.087	1.78	1.62	0.016	0.021	5.23	0.079	0.91	122	38.507	0.1	630	6.11E-04	7.66E-03

Table 4.15 : Overtopping tests results measured at 3Dn – Antifer Cubes

N° Test	Case [%]	Test [%]	Refl. coef.	Hm0 [m]	Tp [s]	T-1,0 [s]	Sop	Som	ξ	Rc [m]	Rc/Hm0	Now	O/T [litres]	Chute [m]	Logtime [s]	q [m^3/m*s]	q/sqrt(gh^3)
19	2	75	0.35	0.092	1.58	1.42	0.024	0.029	4.28	0.079	0.86	175	45.993	0.1	1010	4.55E-04	5.19E-03
20	5	100	0.28	0.100	1.14	1.09	0.050	0.054	2.96	0.079	0.79	222	44.047	0.1	1010	4.36E-04	4.39E-03
21	3.5	100	0.32	0.099	1.37	1.27	0.034	0.040	3.57	0.079	0.80	232	56.606	0.1	1010	5.60E-04	5.73E-03
22	2	50	0.34	0.054	1.32	1.15	0.020	0.026	4.69	0.079	1.46	19	0.591	0.2	1010	2.92E-06	7.44E-05
23	3.5	50	0.29	0.047	0.95	0.89	0.033	0.038	3.62	0.079	1.67	15	0.076	0.2	1010	3.76E-07	1.17E-05
24	5	50	0.27	0.047	0.84	0.79	0.042	0.048	3.21	0.079	1.68	33	0.133	0.2	1010	6.61E-07	2.08E-05
25	2	75	0.37	0.087	1.58	1.43	0.022	0.027	4.41	0.1287	1.48	43	7.502	0.2	1010	3.71E-05	4.64E-04
26	5	100	0.30	0.096	1.14	1.09	0.047	0.051	3.04	0.1287	1.35	61	8.618	0.2	1010	4.27E-05	4.61E-04
27	3.5	100	0.34	0.095	1.37	1.28	0.033	0.037	3.65	0.1287	1.35	59	12.622	0.2	1010	6.25E-05	6.80E-04
28	3.5	75	0.32	0.073	1.19	1.09	0.033	0.039	3.62	0.1287	1.76	15	0.584	0.2	1010	2.89E-06	4.68E-05
29	5	75	0.28	0.073	1.04	0.95	0.044	0.052	3.16	0.1287	1.76	16	0.407	0.2	1010	2.02E-06	3.25E-05

Table 4.16 : Overtopping results tests measured at corner – Antifer Cubes

HARO

N° Test	Case [%]	Test [%]	Refl. coef.	Hm0 [m]	Tp [s]	T-1,0 [s]	Sop	Som	ξ	Rc [m]	Rc/Hm0	Now	O/T [litres]	Chute [m]	Logtime [s]	q [m^3/m*s]	q/sqrt(gh^3)
1	3.5	75	0.29	0.062	1.09	1.03	0.034	0.038	3.61	0.118	1.89	2	0.117	0.2	1010	5.79E-07	1.19E-05
2	3.5	100	0.33	0.089	1.32	1.19	0.033	0.040	3.66	0.118	1.33	30	7.549	0.2	1010	3.74E-05	4.52E-04
3	3.5	50	0.25	0.039	0.90	0.84	0.031	0.035	3.78	0.118	3.05	0	0.000	0.2	1010	0.00E+00	0.00E+00
4	5	100	0.28	0.086	1.09	1.02	0.046	0.053	3.06	0.118	1.37	29	4.201	0.2	1010	2.08E-05	2.62E-04
5	5	75	0.25	0.058	0.91	0.88	0.045	0.047	3.12	0.118	2.05	0	0.000	0.2	1010	0.00E+00	0.00E+00
6	5	85	0.26	0.071	1.04	0.96	0.042	0.050	3.21	0.118	1.66	4	0.402	0.2	1010	1.99E-06	3.36E-05
7	2	75	0.36	0.076	1.44	1.35	0.024	0.027	4.29	0.118	1.54	15	2.881	0.2	1010	1.43E-05	2.15E-04
8	2	100	0.37	0.098	1.74	1.54	0.021	0.026	4.59	0.118	1.20	61	28.458	0.2	993.5	1.43E-04	1.49E-03
9	2	50	0.30	0.050	1.21	1.09	0.022	0.027	4.43	0.118	2.34	0	0.000	0.2	1010	0.00E+00	0.00E+00
10	3.5	50	0.24	0.044	0.90	0.85	0.035	0.039	3.55	0.118	2.70	0	0.000	0.2	1010	0.00E+00	0.00E+00
11	3.5	75	0.28	0.068	1.09	1.03	0.036	0.041	3.46	0.074	1.09	25	4.281	0.2	1010	2.12E-05	3.84E-04
12	3.5	50	0.26	0.046	0.91	0.85	0.036	0.041	3.49	0.074	1.60	2	0.055	0.2	1010	2.74E-07	8.82E-06
13	5	75	0.25	0.065	0.91	0.89	0.050	0.052	2.95	0.074	1.14	16	1.947	0.2	1004.75	9.69E-06	1.88E-04
14	5	50	0.25	0.050	0.84	0.79	0.045	0.051	3.10	0.074	1.47	2	0.160	0.2	1010	7.91E-07	2.24E-05
15	2	50	0.31	0.054	1.21	1.09	0.024	0.029	4.29	0.074	1.38	5	0.331	0.2	1010	1.64E-06	4.22E-05
16	2	75	0.35	0.079	1.44	1.35	0.025	0.028	4.21	0.074	0.93	72	33.612	0.2	994	1.69E-04	2.42E-03
17	5	100	0.27	0.091	1.09	1.03	0.049	0.055	2.98	0.074	0.81	107	19.554	0.1	999	1.96E-04	2.28E-03
18	3.5	100	0.31	0.096	1.32	1.19	0.035	0.043	3.51	0.074	0.77	163	35.329	0.1	989.25	3.57E-04	3.83E-03
19	2	100	0.35	0.101	1.74	1.54	0.021	0.027	4.53	0.074	0.73	181	73.285	0.1	968	7.57E-04	7.56E-03

Table 4.17 : Overtopping tests results measured at 3Dn – Haro

N° Test	Case [%]	Test [%]	Refl. coef.	Hm0 [m]	Tp [s]	T-1,0 [s]	Sop	Som	ξ	Rc [m]	Rc/Hm0	Now	O/T [litres]	Chute [m]	Logtime [s]	q [m^3/m*s]	q/sqrt(gh^3)
20	2	75	0.35	0.082	1.44	1.35	0.025	0.029	4.14	0.074	0.90	113	25.445	0.1	998.75	2.55E-04	3.46E-03
21	3.5	100	0.31	0.099	1.32	1.19	0.036	0.045	3.46	0.074	0.75	184	45.618	0.1	984.75	4.63E-04	4.73E-03
22	5	100	0.27	0.093	1.09	1.03	0.050	0.056	2.96	0.074	0.80	117	24.195	0.1	998.5	2.42E-04	2.73E-03
23	2	50	0.31	0.056	1.21	1.09	0.025	0.030	4.20	0.074	1.32	3	0.328	0.2	1010	1.62E-06	3.92E-05
24	3.5	50	0.26	0.049	0.91	0.85	0.038	0.043	3.40	0.074	1.52	0	0.000	0.2	1010	0.00E+00	0.00E+00
25	5	50	0.25	0.052	0.84	0.79	0.047	0.053	3.06	0.074	1.42	1	0.077	0.2	1010	3.80E-07	1.03E-05
26	2	75	0.34	0.079	1.44	1.35	0.024	0.028	4.22	0.118	1.50	16	2.663	0.2	1010	1.32E-05	1.91E-04
27	5	100	0.27	0.090	1.09	1.02	0.049	0.055	3.00	0.118	1.31	37	3.604	0.2	1010	1.78E-05	2.10E-04
28	3.5	100	0.31	0.095	1.32	1.19	0.035	0.043	3.53	0.118	1.24	36	9.813	0.2	1004.25	4.89E-05	5.31E-04
29	3.5	75	0.28	0.066	1.09	1.03	0.036	0.040	3.49	0.118	1.78	2	0.133	0.2	1010	6.57E-07	1.22E-05
30	5	75	0.24	0.064	0.90	0.89	0.050	0.052	2.94	0.118	1.85	1	0.034	0.2	1010	1.68E-07	3.33E-06

Table 4.18 : Overtopping results tests measured at corner – Haro

TETRAPOD

N° Test	Case [%]	Test [%]	Refl. coef.	Hm0 [m]	Tp [s]	T-1,0 [s]	Sop	Som	ξ	Rc [m]	Rc/Hm0	Now	O/T [litres]	Chute [m]	Logtime [s]	q [m^3/m*s]	q/sqrt(gh^3)
1	3.5	75	0.27	0.079	1.19	1.10	0.036	0.042	3.477	0.083	1.05	7	1.243	0.2	1010	6.15E-06	8.80E-05
2	3.5	50	0.24	0.052	0.95	0.90	0.037	0.041	3.452	0.083	1.60	0	0.000	0.2	1010	0.00E+00	0.00E+00
3	5	75	0.24	0.080	1.04	0.95	0.048	0.057	3.023	0.083	1.04	5	0.536	0.2	1010	2.66E-06	3.74E-05
4	5	50	0.23	0.053	0.84	0.79	0.047	0.053	3.040	0.083	1.58	0	0.000	0.2	1010	0.00E+00	0.00E+00
5	2	50	0.29	0.060	1.32	1.16	0.022	0.029	4.433	0.083	1.37	1	0.000	0.2	1010	0.00E+00	0.00E+00
6	3.5	100	0.28	0.111	1.37	1.27	0.038	0.044	3.386	0.083	0.75	68	13.202	0.1	1003.5	1.32E-04	1.14E-03
7	5	100	0.25	0.108	1.14	1.10	0.053	0.057	2.857	0.083	0.77	63	8.276	0.1	1004.25	8.24E-05	7.42E-04
8	2	75	0.29	0.098	1.58	1.42	0.025	0.031	4.157	0.083	0.85	65	12.222	0.1	1004.25	1.22E-04	1.27E-03
9	2	100	0.31	0.112	1.74	1.63	0.024	0.027	4.299	0.083	0.74	131	43.173	0.1	985.5	4.38E-04	3.74E-03
10	3.5	75	0.26	0.067	1.09	1.04	0.036	0.040	3.480	0.135	2.02	0	0.000	0.2	1010	0.00E+00	0.00E+00
11	3.5	50	0.24	0.050	0.95	0.89	0.035	0.040	3.531	0.135	2.73	0	0.000	0.2	1010	0.00E+00	0.00E+00
12	5	75	0.24	0.050	0.95	0.89	0.035	0.040	3.530	0.135	2.73	0	0.000	0.2	1010	0.00E+00	0.00E+00
13	3.5	100	0.29	0.103	1.37	1.27	0.035	0.041	3.504	0.135	1.31	11	1.578	0.2	1010	7.81E-06	7.53E-05
14	5	100	0.26	0.102	1.14	1.09	0.051	0.055	2.936	0.135	1.32	6	0.815	0.2	1010	4.03E-06	3.94E-05
15	2	75	0.31	0.087	1.58	1.43	0.022	0.027	4.403	0.135	1.55	2	0.222	0.2	1010	1.10E-06	1.37E-05
16	2	100	0.35	0.113	1.74	1.63	0.024	0.027	4.274	0.135	1.19	27	11.267	0.2	1004	5.61E-05	4.71E-04
17	5	85	11.00	0.071	0.93	0.91	0.053	0.055	2.878	0.135	1.90	0	0.000	0.2	1010	0.00E+00	0.00E+00
18	3.5	85	0.24	0.032	0.77	0.73	0.034	0.038	3.554	0.135	4.20	0	0.000	0.2	1010	0.00E+00	0.00E+00

Table 4.19 : Overtopping tests results measured at 3Dn – Tetrapod

N° Test	Case [%]	Test [%]	Refl. coef.	Hm0 [m]	Tp [s]	T-1,0 [s]	Sop	Som	ξ	Rc [m]	Rc/Hm0	Now	O/T [litres]	Chute [m]	Logtime [s]	q [m^3/m*s]	q/sqrt(gh^3)
19	3.5	75	0.26	0.068	1.09	1.04	0.037	0.041	3.448	0.135	1.98	1	0.005	0.2	1010	2.27E-08	4.07E-07
20	3.5	100	0.30	0.105	1.37	1.27	0.036	0.042	3.469	0.135	1.28	19	2.876	0.2	1010	1.42E-05	1.33E-04
21	5	100	0.26	0.106	1.14	1.09	0.053	0.057	2.880	0.135	1.27	11	1.394	0.2	1010	6.90E-06	6.37E-05
22	2	100	0.35	0.117	1.74	1.63	0.025	0.028	4.211	0.135	1.16	41	12.296	0.2	1004.5	6.12E-05	4.91E-04
23	2	75	0.32	0.094	1.58	1.43	0.024	0.030	4.228	0.135	1.43	6	0.833	0.2	1010	4.12E-06	4.54E-05
24	3.5	85	0.29	0.092	1.32	1.18	0.034	0.043	3.583	0.135	1.46	5	0.420	0.2	1010	2.08E-06	2.36E-05
25	2	75	0.31	0.094	1.58	1.42	0.024	0.030	4.230	0.083	0.88	50	14.066	0.2	1004.75	7.00E-05	7.72E-04
26	3.5	100	0.29	0.112	1.37	1.27	0.039	0.045	3.362	0.083	0.74	84	29.639	0.2	996	1.49E-04	1.27E-03
27	5	100	0.25	0.112	1.14	1.10	0.055	0.059	2.809	0.083	0.74	79	17.363	0.2	1000.5	8.68E-05	7.43E-04
28	5	75	0.25	0.083	1.04	0.95	0.049	0.058	2.976	0.083	1.01	6	0.808	0.2	1010	4.00E-06	5.38E-05
29	3.5	75	0.26	0.074	1.09	1.04	0.040	0.044	3.317	0.083	1.13	1	0.380	0.2	1010	0.00E+00	0.00E+00

Table 4.20 : Overtopping results tests measured at corner – Tetrapod

CUBE ONE OF LAYER

N° Test	Case [%]	Test [%]	Refl. coef.	Hm0 [m]	Tp [s]	T-1,0 [s]	Sop	Som	ξ	Rc [m]	Rc/Hm0	Now	O/T [litres]	Chute [m]	Logtime [s]	q [$m^3/m*s$]	q/sqrt(gh^3)
1	3.5	75	0.32	0.070	1.09	1.04	0.037	0.042	3.42	0.071	1.02	56	10.404	0.2	1004	5.18E-05	9.02E-04
2	3.5	50	0.30	0.049	0.91	0.85	0.038	0.043	3.41	0.071	1.46	3	0.175	0.2	1010	8.67E-07	2.59E-05
3	5	75	0.28	0.067	0.91	0.89	0.052	0.053	2.91	0.071	1.07	35	5.401	0.2	1010	2.67E-05	4.96E-04
4	5	50	0.28	0.052	0.84	0.80	0.047	0.053	3.05	0.071	1.36	7	0.554	0.2	1010	2.74E-06	7.37E-05
5	2	50	0.36	0.054	1.21	1.09	0.024	0.029	4.30	0.071	1.33	7	1.109	0.2	1010	5.49E-06	1.42E-04
6	2	75	0.39	0.079	1.44	1.35	0.024	0.028	4.23	0.071	0.90	110	21.355	0.1	999.75	2.14E-04	3.09E-03
7	5	100	0.30	0.092	1.09	1.03	0.049	0.056	2.97	0.071	0.77	160	27.580	0.1	996.25	2.77E-04	3.16E-03
8	3.5	100	0.35	0.092	1.32	1.19	0.034	0.042	3.58	0.071	0.77	185	36.437	0.1	988.5	3.69E-04	4.18E-03
9	2	100	0.38	0.097	1.74	1.54	0.021	0.026	4.60	0.071	0.73	222	77.969	0.1	963.5	8.09E-04	8.49E-03
10	3.5	75	0.34	0.066	1.09	1.04	0.035	0.039	3.52	0.116	1.77	3	0.332	0.2	1010	1.64E-06	3.12E-05
11	3.5	50	0.31	0.045	0.90	0.85	0.036	0.040	3.50	0.116	2.58	1	0.009	0.2	1010	4.43E-08	1.48E-06
12	5	75	0.30	0.062	0.91	0.89	0.048	0.050	3.02	0.116	1.88	6	0.030	0.2	1010	1.50E-07	3.10E-06
13	5	50	0.30	0.048	0.84	0.79	0.043	0.049	3.20	0.116	2.44	1	0.005	0.2	1010	2.48E-08	7.66E-07
14	2	50	0.37	0.049	1.19	1.09	0.022	0.027	4.41	0.116	2.35	0	0.000	0.2	1010	0.00E+00	0.00E+00
15	2	75	0.40	0.074	1.44	1.35	0.023	0.026	4.36	0.116	1.57	20	2.908	0.2	1010	1.44E-05	2.29E-04
16	5	100	0.32	0.087	1.09	1.02	0.047	0.053	3.06	0.116	1.34	37	5.977	0.2	1005.5	2.97E-05	3.72E-04
17	3.5	100	0.37	0.088	1.32	1.19	0.032	0.040	3.67	0.116	1.32	33	9.788	0.2	1003	4.88E-05	5.97E-04
18	2	100	0.41	0.095	1.74	1.54	0.020	0.026	4.67	0.116	1.23	63	32.031	0.2	992.75	1.61E-04	1.77E-03

Table 4.21 : Overtopping tests results measured at 3Dn – One layer of Cubes

N° Test	Case [%]	Test [%]	Refl. coef.	Hm0 [m]	Tp [s]	T-1,0 [s]	Sop	Som	ξ	Rc [m]	Rc/Hm0	Now	O/T [litres]	Chute [m]	Logtime [s]	q [$m^3/m*s$]	q/sqrt(gh^3)
19	2	75	0.40	0.078	1.44	1.35	0.024	0.027	4.24	0.116	1.49	35	6.299	0.2	1010	3.12E-05	4.56E-04
20	5	100	0.32	0.091	1.09	1.03	0.049	0.055	2.98	0.116	1.27	61	9.709	0.2	1010	4.81E-05	5.56E-04
21	3.5	100	0.37	0.094	1.32	1.19	0.034	0.042	3.56	0.116	1.24	64	16.327	0.2	1001.25	8.15E-05	9.10E-04
22	3.5	75	0.33	0.067	1.09	1.03	0.036	0.041	3.47	0.116	1.72	5	0.504	0.2	1010	2.50E-06	4.55E-05
23	5	75	0.30	0.065	0.93	0.89	0.048	0.052	3.02	0.116	1.79	6	0.308	0.2	1010	1.52E-06	2.95E-05
24	2	75	0.37	0.055	1.21	1.09	0.024	0.030	4.25	0.071	1.30	11	1.506	0.1	1010	1.49E-05	3.71E-04
25	3.5	100	0.31	0.049	0.91	0.85	0.038	0.043	3.39	0.071	1.45	3	0.158	0.1	1010	1.57E-06	4.63E-05
26	5	100	0.30	0.053	0.84	0.79	0.047	0.054	3.03	0.071	1.35	3	0.493	0.1	1010	4.88E-06	1.29E-04
27	2	50	0.39	0.079	1.44	1.35	0.025	0.028	4.22	0.071	0.90	116	22.444	0.2	997.5	1.13E-04	1.62E-03
28	3.5	50	0.35	0.094	1.32	1.19	0.034	0.042	3.55	0.071	0.76	179	37.206	0.2	992	0.00E+00	0.00E+00
29	5	50	0.31	0.094	1.09	1.03	0.050	0.057	2.94	0.071	0.76	149	25.151	0.2	999.25	1.26E-04	1.40E-03

Table 4.22 : Overtopping results tests measured at corner – One layer of Cubes

ACCROPODE

N° Test	Case [%]	Test [%]	Refl. coef.	Hm0 [m]	Tp [s]	T-1,0 [s]	Sop	Som	ξ	Rc [m]	Rc/Hm0	Now	O/T [litres]	Chute [m]	Logtime [s]	q [$m^3/m*s$]	q/sqrt(gh^3)
1	3.5	75	0.29	0.073	1.09	1.04	0.039	0.043	3.33	0.086	1.18	5	1.139	0.2	1010	5.64E-06	9.10E-05
2	5	75	0.26	0.078	1.04	0.95	0.047	0.056	3.06	0.086	1.10	10	1.956	0.2	1010	9.68E-06	1.41E-04
3	2	75	0.39	0.091	1.58	1.43	0.024	0.029	4.30	0.086	0.94	54	21.598	0.2	998.25	1.08E-04	1.25E-03
4	5	100	0.29	0.106	1.12	1.10	0.054	0.056	2.84	0.086	0.81	91	30.414	0.2	995.25	1.53E-04	1.41E-03
5	3.5	100	0.35	0.107	1.37	1.27	0.037	0.042	3.44	0.086	0.81	87	40.216	0.2	985	2.04E-04	1.87E-03
6	2	100	0.39	0.111	1.82	1.64	0.022	0.027	4.50	0.086	0.77	109	73.375	0.2	827.5	4.43E-04	3.82E-03
7	2	50	0.34	0.059	1.32	1.16	0.021	0.028	4.50	0.086	1.47	0	0.000	0.2	1010	0.00E+00	0.00E+00
8	3.5	75	0.29	0.069	1.09	1.04	0.037	0.041	3.44	0.139	2.03	1	0.035	0.2	1010	1.74E-07	3.09E-06
9	5	75	0.25	0.074	1.04	0.95	0.044	0.053	3.14	0.139	1.88	1	0.091	0.2	1010	4.49E-07	7.12E-06
10	2	75	0.39	0.088	1.58	1.43	0.023	0.027	4.39	0.139	1.59	10	2.648	0.2	1010	1.31E-05	1.62E-04
11	5	100	0.29	0.103	1.14	1.10	0.051	0.055	2.93	0.139	1.35	25	4.872	0.2	1005.5	2.42E-05	2.35E-04
12	3.5	100	0.29	0.103	1.14	1.10	0.051	0.055	2.93	0.139	1.35	23	5.545	0.2	1010	2.74E-05	2.67E-04
13	2	100	0.40	0.118	1.74	1.64	0.025	0.028	4.19	0.139	1.18	35	15.369	0.2	1005	7.65E-05	6.04E-04
14	5	85	0.27	0.095	1.09	1.02	0.051	0.058	2.93	0.139	1.47	5	0.726	0.2	1010	3.60E-06	3.95E-05
15	3.5	85	0.34	0.095	1.32	1.19	0.035	0.043	3.53	0.139	1.46	8	1.446	0.2	1010	7.16E-06	7.77E-05

Table 4.23 : Overtopping tests results measured at 3Dn – Accropode

N° Test	Case [%]	Test [%]	Refl. coef.	Hm0 [m]	Tp [s]	T-1,0 [s]	Sop	Som	ξ	Rc [m]	Rc/Hm0	Now	O/T [litres]	Chute [m]	Logtime [s]	q [$m^3/m*s$]	q/sqrt(gh^3)
16	5	100	0.29	0.111	1.14	1.10	0.055	0.059	2.81	0.139	1.25	45	7.946	0.2	1005.75	3.95E-05	3.39E-04
17	3.5	100	0.36	0.111	1.37	1.27	0.038	0.044	3.38	0.139	1.26	41	9.631	0.2	1007	4.78E-05	4.15E-04
18	2	75	0.39	0.093	1.58	1.43	0.024	0.029	4.25	0.139	1.49	12	3.571	0.2	1010	1.77E-05	1.98E-04
19	3.5	75	0.29	0.076	1.09	1.04	0.041	0.045	3.26	0.139	1.82	2	0.229	0.2	1010	1.13E-06	1.71E-05
20	5	75	0.27	0.094	1.09	1.02	0.050	0.057	2.94	0.139	1.48	6	1.723	0.2	1010	8.53E-06	9.45E-05
21	2	100	0.40	0.121	1.74	1.64	0.026	0.029	4.13	0.139	1.15	52	26.864	0.2	996	1.35E-04	1.02E-03
22	3.5	75	0.29	0.079	1.09	1.04	0.042	0.047	3.21	0.086	1.09	4	2.721	0.2	1010	1.35E-05	1.94E-04
23	5	75	0.26	0.085	1.04	0.95	0.050	0.060	2.94	0.086	1.02	8	3.743	0.2	1010	1.85E-05	2.40E-04
24	2	75	0.38	0.099	1.58	1.42	0.025	0.031	4.14	0.086	0.87	63	33.882	0.2	991.75	1.71E-04	1.76E-03
25	5	100	0.28	0.115	1.14	1.10	0.057	0.062	2.76	0.086	0.75	75	39.445	0.2	930.25	2.12E-04	1.73E-03
26	3.5	100	0.35	0.116	1.37	1.27	0.040	0.046	3.31	0.086	0.74	101	60.329	0.2	974.5	0.00E+00	0.00E+00

Table 4.24 : Overtopping results tests measured at corner – Accropode

Core-Loc®

N° Test	Case [%]	Test [%]	Refl. coef.	Hm0 [m]	Tp [s]	T-1,0 [s]	Sop	Som	ξ	Rc [m]	Rc/Hm0	Now	O/T [litres]	Chute [m]	Logtime [s]	q [m^3/m*s]	q/sqrt(gh^3)
1	3.5	75	0.26	0.071	1.09	1.04	0.038	0.042	2.55	0.086	1.20	3	0.510	0.2	1010	2.53E-06	4.22E-05
2	5	75	0.23	0.078	1.04	0.95	0.047	0.055	2.32	0.086	1.10	7	1.181	0.2	1010	5.84E-06	8.54E-05
3	2	75	0.37	0.089	1.58	1.43	0.023	0.028	3.30	0.086	0.96	56	25.218	0.2	999	1.26E-04	1.51E-03
4	5	100	0.26	0.105	1.14	1.10	0.052	0.056	2.20	0.086	0.82	74	31.040	0.2	993	1.56E-04	1.47E-03
5	3.5	100	0.32	0.106	1.37	1.27	0.036	0.042	2.62	0.086	0.81	95	54.049	0.2	981.75	2.75E-04	2.55E-03
6	2	100	0.37	0.113	1.74	1.63	0.024	0.027	3.24	0.086	0.76	161	117.565	0.1	935.5	1.26E-03	1.05E-02
7	2	50	0.30	0.060	1.32	1.16	0.022	0.029	3.36	0.086	1.42	1	0.083	0.1	1010	8.20E-07	1.76E-05
8	5	100	0.28	0.103	1.14	1.10	0.051	0.055	2.22	0.14	1.37	14	2.205	0.2	1010	1.09E-05	1.06E-04
9	3.5	100	0.35	0.102	1.37	1.27	0.035	0.040	2.67	0.14	1.38	18	4.520	0.2	1010	2.24E-05	2.20E-04
10	2	75	0.38	0.090	1.58	1.43	0.023	0.028	3.29	0.14	1.56	9	2.247	0.2	1010	1.11E-05	1.32E-04
11	3.5	75	0.28	0.076	1.09	1.05	0.041	0.044	2.48	0.14	1.85	1	0.053	0.2	1010	2.61E-07	4.01E-06
12	5	75	0.23	0.076	1.04	0.95	0.045	0.054	2.35	0.14	1.84	0	0.000	0.2	1010	0.00E+00	0.00E+00
13	2	100	0.39	0.110	1.74	1.64	0.023	0.026	3.28	0.14	1.27	35	17.002	0.2	1000.75	8.49E-05	7.39E-04
14	5	85	0.25	0.090	1.09	1.03	0.048	0.054	2.28	0.14	1.56	1	0.258	0.2	1010	1.28E-06	1.52E-05
15	5	85	0.32	0.090	1.32	1.18	0.033	0.041	2.75	0.14	1.55	7	0.978	0.2	1010	4.84E-06	5.71E-05

Table 4.25 : Overtopping tests results measured at 3Dn – Core-Loc®

N° Test	Case [%]	Test [%]	Refl. coef.	Hm0 [m]	Tp [s]	T-1,0 [s]	Sop	Som	ξ	Rc [m]	Rc/Hm0	Now	O/T [litres]	Chute [m]	Logtime [s]	q [m^3/m*s]	q/sqrt(gh^3)
16	5	100	0.27	0.106	1.14	1.10	0.052	0.056	2.19	0.14	1.33	5	2.476	0.2	1010	1.23E-05	1.14E-04
17	3.5	100	0.34	0.107	1.37	1.28	0.037	0.042	2.61	0.14	1.31	19	5.497	0.2	1005.25	2.73E-05	2.49E-04
18	2	75	0.38	0.091	1.58	1.43	0.023	0.028	3.26	0.14	1.54	6	2.275	0.2	1010	1.13E-05	1.31E-04
19	3.5	75	0.27	0.076	1.09	1.05	0.041	0.044	2.48	0.14	1.85	1	0.092	0.2	1010	4.53E-07	6.96E-06
20	3.5	85	0.25	0.091	1.09	1.03	0.049	0.055	2.26	0.14	1.54	1	0.356	0.2	1010	1.76E-06	2.06E-05
21	2	100	0.38	0.113	1.74	1.64	0.024	0.027	3.25	0.14	1.24	35	17.609	0.2	1002.5	8.78E-05	7.43E-04
22	3.5	75	0.24	0.074	1.09	1.04	0.040	0.044	2.51	0.086	1.16	1	0.916	0.2	1010	4.53E-06	7.21E-05
23	5	100	0.22	0.080	1.04	0.95	0.048	0.057	2.29	0.086	1.08	5	1.473	0.2	1010	7.29E-06	1.03E-04

Table 4.26 : Overtopping results tests measured at corner – Core-Loc®

XBLOC®

N° Test	Case [%]	Test [%]	Refl. coef.	Hm0 [m]	Tp [s]	T-1,0 [s]	Sop	Som	ξ	Rc [m]	Rc/Hm0	Now	O/T [litres]	Chute [m]	Logtime [s]	q [m^3/m*s]	q/sqrt(gh^3)
1	3.5	75	0.26	0.0748	1.092	1.042	0.040	0.044	3.293	0.09	1.20	4	0.451	0.2	1010	2.234E-06	3.486E-05
2	5	75	0.23	0.08046	1.037	0.9516	0.048	0.057	3.015	0.09	1.12	1	0.669	0.2	1010	3.313E-06	4.634E-05
3	2	75	0.37	0.09313	1.575	1.424	0.024	0.029	4.256	0.09	0.97	47	17.145	0.2	1000.5	8.568E-05	9.625E-04
4	5	100	0.26	0.107	1.138	1.095	0.053	0.057	2.869	0.09	0.84	77	24.368	0.2	994.75	1.225E-04	1.117E-03
5	3.5	100	0.33	0.1079	1.365	1.269	0.037	0.043	3.427	0.09	0.83	75	33.843	0.2	991	1.708E-04	1.538E-03
6	2	100	0.37	0.115	1.781	1.642	0.023	0.027	4.331	0.09	0.78	73	48.282	0.1	479.5	1.007E-03	8.244E-03
7	2	50	0.32	0.06105	1.321	1.158	0.022	0.029	4.409	0.09	1.47	0	0.000	0.1	1010	0.000E+00	0.000E+00
8	5	100	0.38	0.08876	1.575	1.432	0.023	0.028	4.360	0.142	1.60	10	1.738	0.2	1010	8.602E-06	1.039E-04
9	3.5	100	0.28	0.1041	1.138	1.096	0.051	0.056	2.909	0.142	1.36	27	3.368	0.2	1010	1.667E-05	1.585E-04
10	2	75	0.35	0.1068	1.365	1.274	0.037	0.042	3.445	0.142	1.33	28	5.077	0.2	1010	2.513E-05	2.299E-04
11	3.5	75	0.27	0.07131	1.092	1.04	0.038	0.042	3.372	0.142	1.99	0	0.000	0.2	1010	0.000E+00	0.000E+00
12	5	75	0.26	0.09158	1.092	1.027	0.049	0.056	2.976	0.142	1.55	3	0.491	0.2	1010	2.429E-06	2.799E-05
13	2	100	0.32	0.09295	1.321	1.184	0.034	0.042	3.573	0.142	1.53	8	0.953	0.2	1010	4.719E-06	5.316E-05
14	5	85	0.39	0.1145	1.743	1.641	0.024	0.027	4.248	0.142	1.24	35	14.312	0.2	1005.5	7.117E-05	5.865E-04

Table 4.27 : Overtopping tests results measured at 3Dn - XBloc®

N° Test	Case [%]	Test [%]	Refl. coef.	Hm0 [m]	Tp [s]	T-1,0 [s]	Sop	Som	ξ	Rc [m]	Rc/Hm0	Now	O/T [litres]	Chute [m]	Logtime [s]	q [m^3/m*s]	q/sqrt(gh^3)
15	5	100	0.28	0.1076	1.138	1.095	0.053	0.057	2.861	0.142	1.32	44	6.424	0.2	1005.75	3.194E-05	2.889E-04
16	3.5	100	0.35	0.1094	1.365	1.274	0.038	0.043	3.403	0.142	1.30	42	8.765	0.2	1010	4.339E-05	3.828E-04
17	2	75	0.38	0.09405	1.575	1.432	0.024	0.029	4.235	0.142	1.51	18	3.390	0.2	1010	1.678E-05	1.858E-04
18	3.5	75	0.27	0.07794	1.092	1.045	0.042	0.046	3.226	0.142	1.82	2	0.258	0.2	1010	1.275E-06	1.871E-05
19	3.5	85	0.26	0.09309	1.092	1.026	0.050	0.057	2.952	0.142	1.53	12	1.513	0.2	1010	7.491E-06	8.421E-05
20	2	100	0.39	0.1185	1.743	1.639	0.025	0.028	4.176	0.142	1.20	56	21.104	0.2	1000	1.055E-04	8.259E-04
21	3.5	75	0.26	0.07851	1.092	1.037	0.042	0.047	3.214	0.09	1.15	12	1.537	0.2	1010	7.607E-06	1.104E-04
22	5	75	0.23	0.08433	1.037	0.9516	0.050	0.060	2.945	0.09	1.07	22	2.678	0.2	1010	1.326E-05	1.728E-04
23	2	75	0.36	0.09788	1.575	1.423	0.025	0.031	4.152	0.09	0.92	69	28.393	0.2	996.5	1.425E-04	1.485E-03
24	5	100	0.26	0.1149	1.138	1.095	0.057	0.061	2.769	0.09	0.78	108	34.713	0.2	991.5	1.751E-04	1.435E-03
25	3.5	100	0.33	0.1162	1.365	1.27	0.040	0.046	3.302	0.09	0.77	121	44.556	0.2	982.25	2.268E-04	1.828E-03

Table 4.28 : Overtopping results tests measured at corner - XBloc®

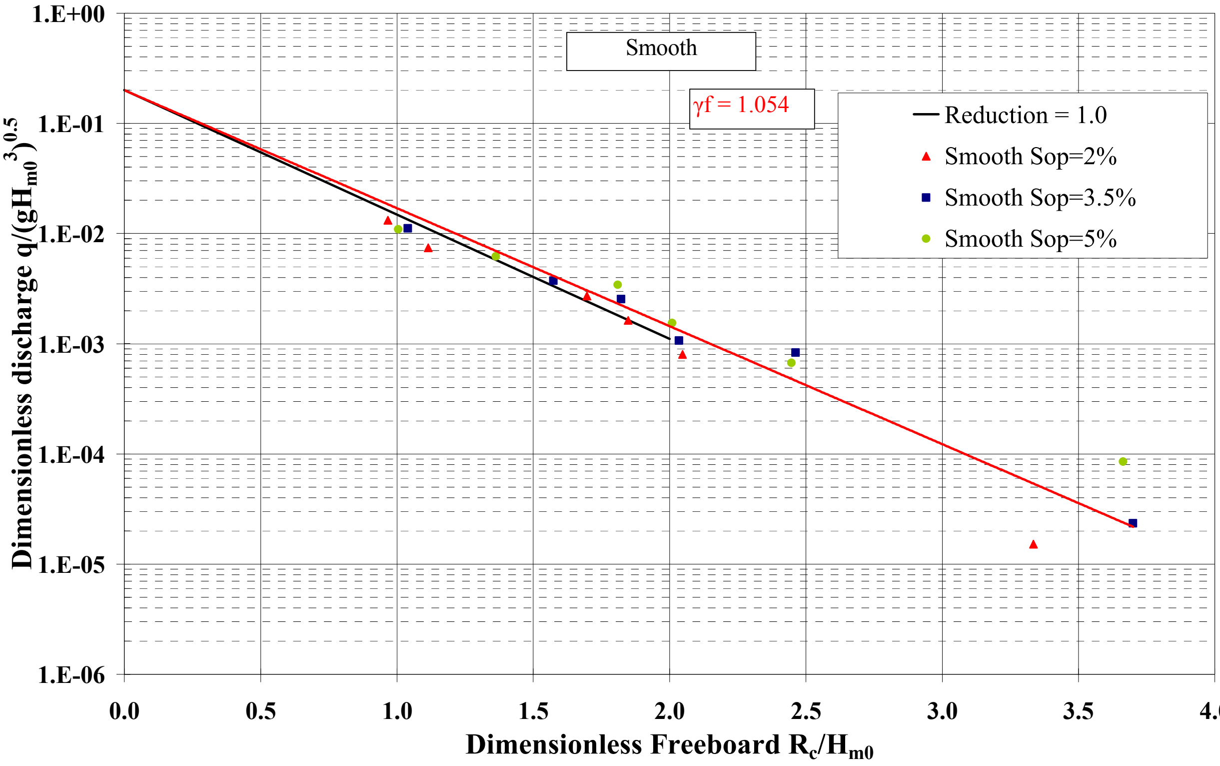


Figure 4.1: A graph of dimensionless overtopping discharge v's dimensionless freeboard for the smooth structure (discharge measured at corner)

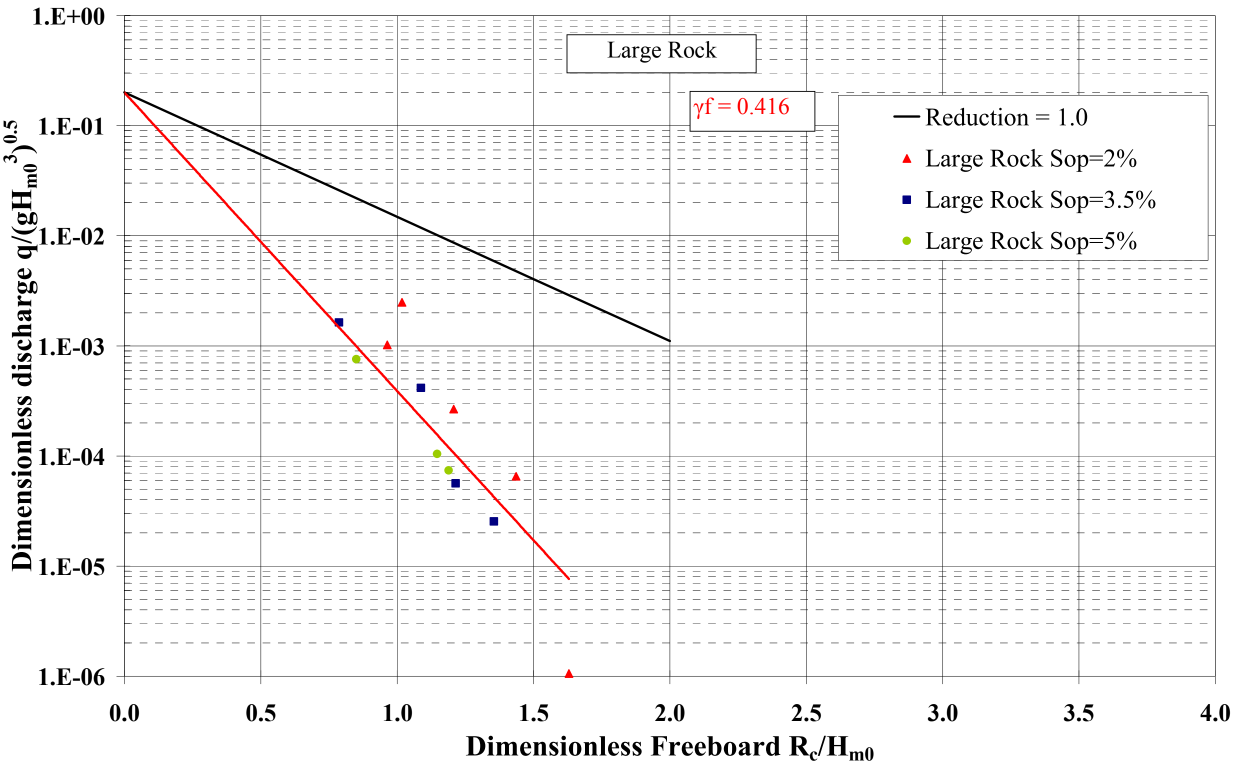


Figure 4.2: A graph of dimensionless overtopping discharge v's dimensionless freeboard for the large rock structure (discharge measured at 3Dn)

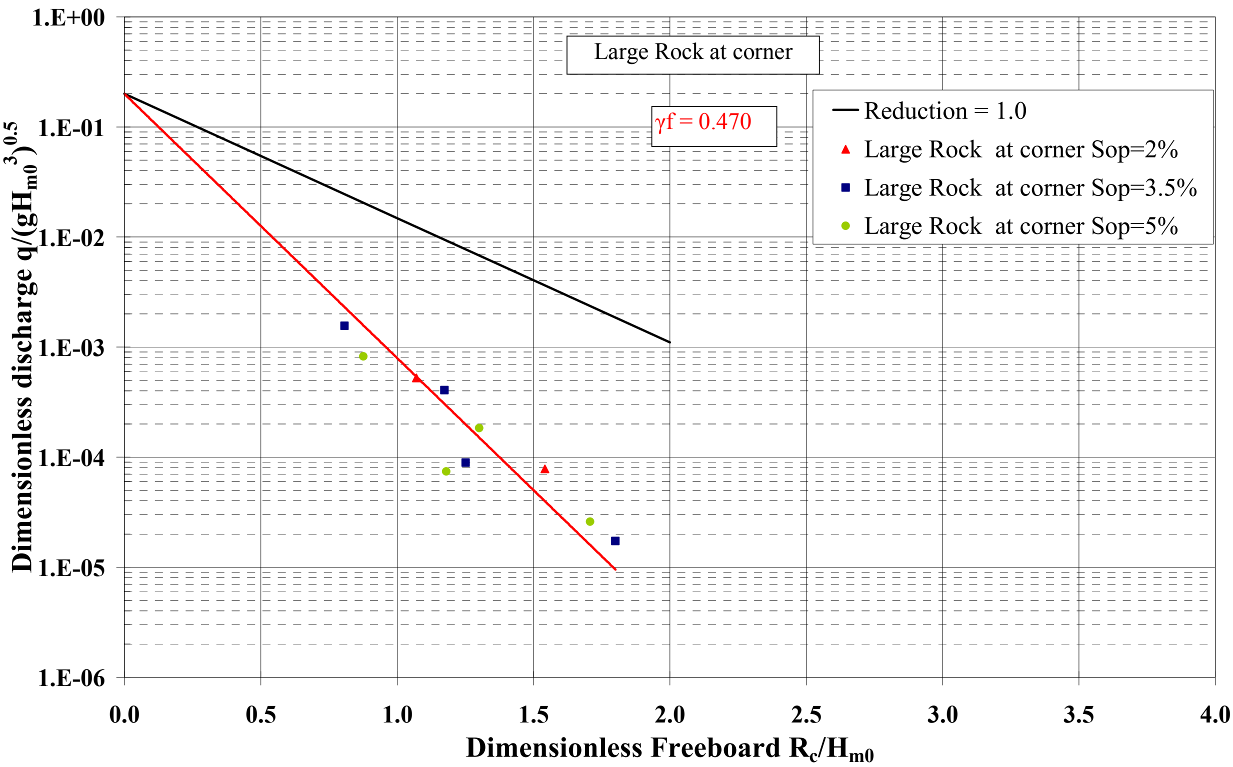


Figure 4.3: A graph of dimensionless overtopping discharge v's dimensionless freeboard for the large rock structure (discharge measured at corner)

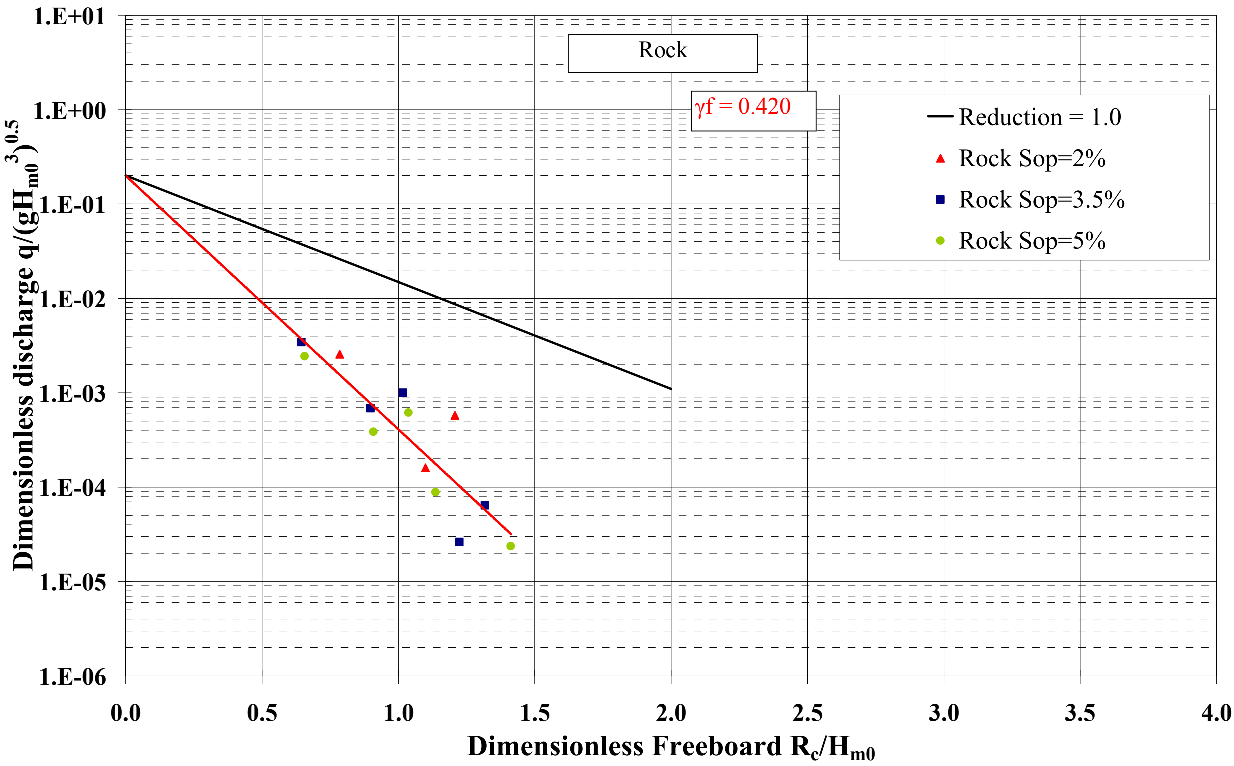


Figure 4.4: A graph of dimensionless overtopping discharge v's dimensionless freeboard for the rock structure (discharge measured at 3Dn)

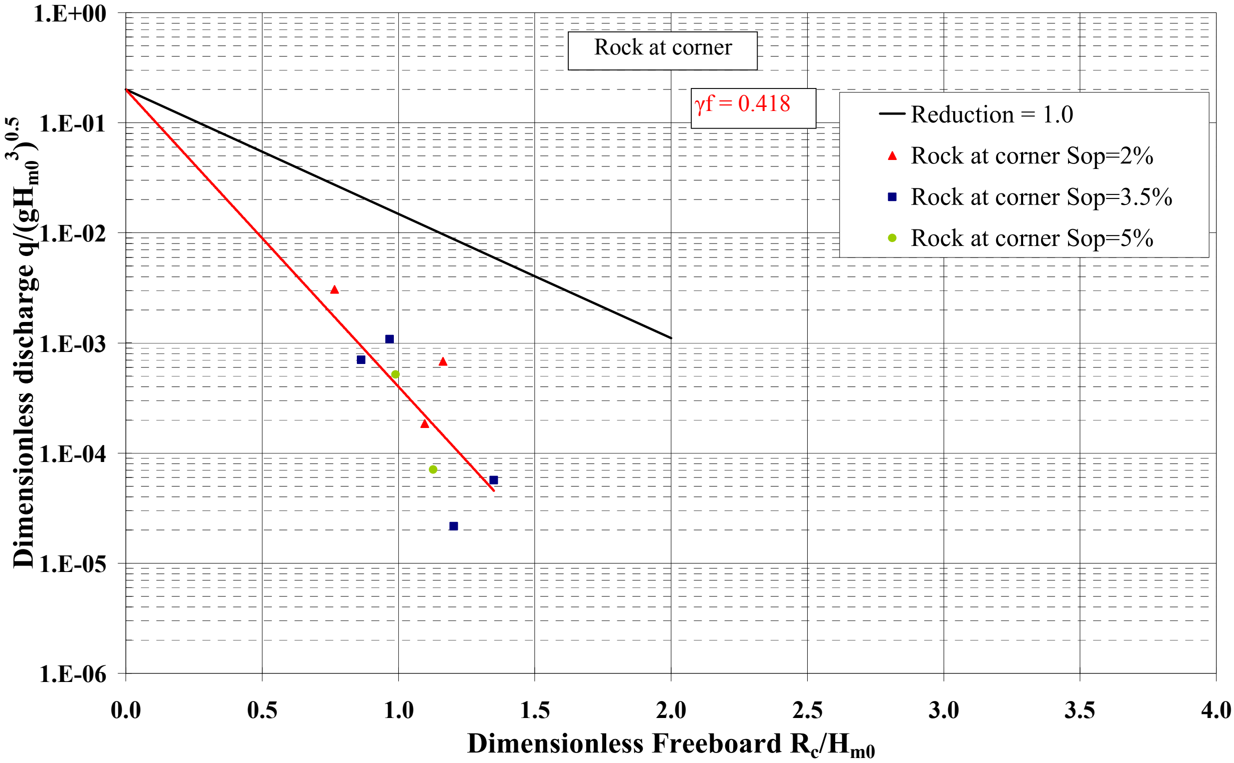


Figure 4.5: A graph of dimensionless overtopping discharge v's dimensionless freeboard for the rock structure (discharge measured at corner)

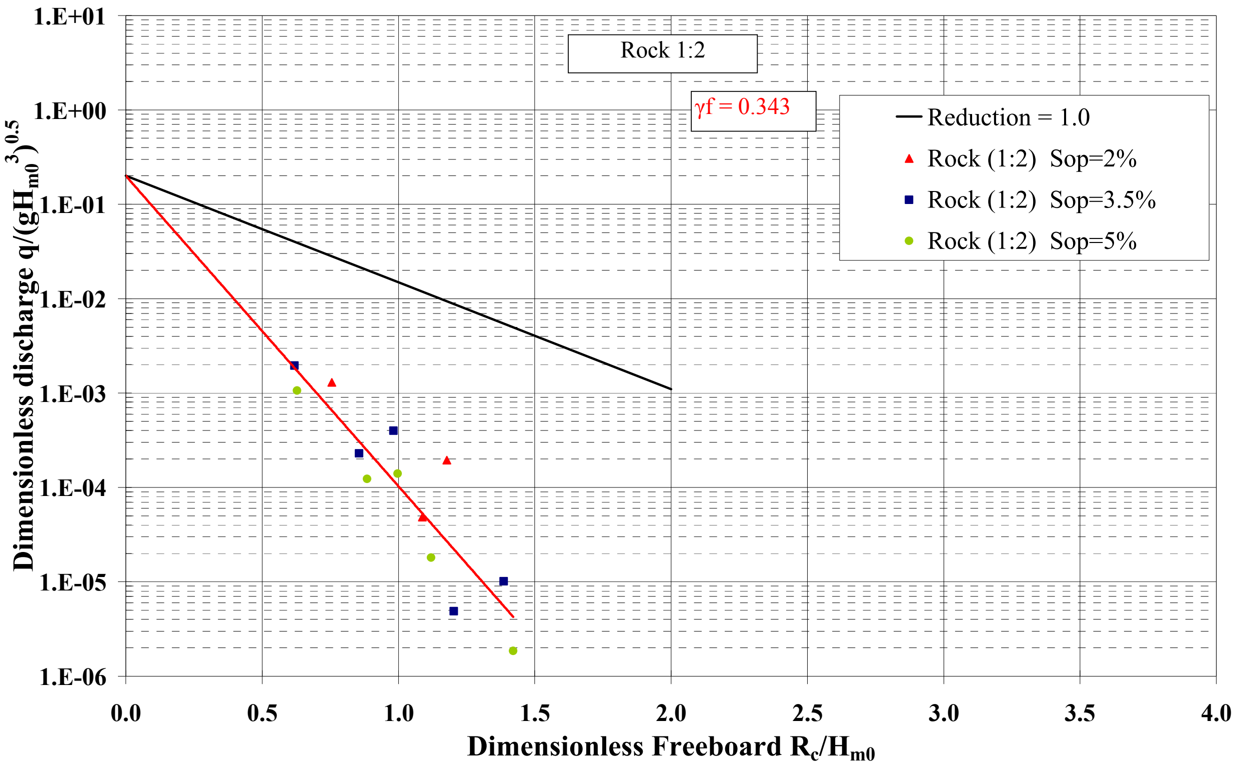


Figure 4.6: A graph of dimensionless overtopping discharge v's dimensionless freeboard for the rock structure with slope 1:2 (discharge measured at 3Dn)

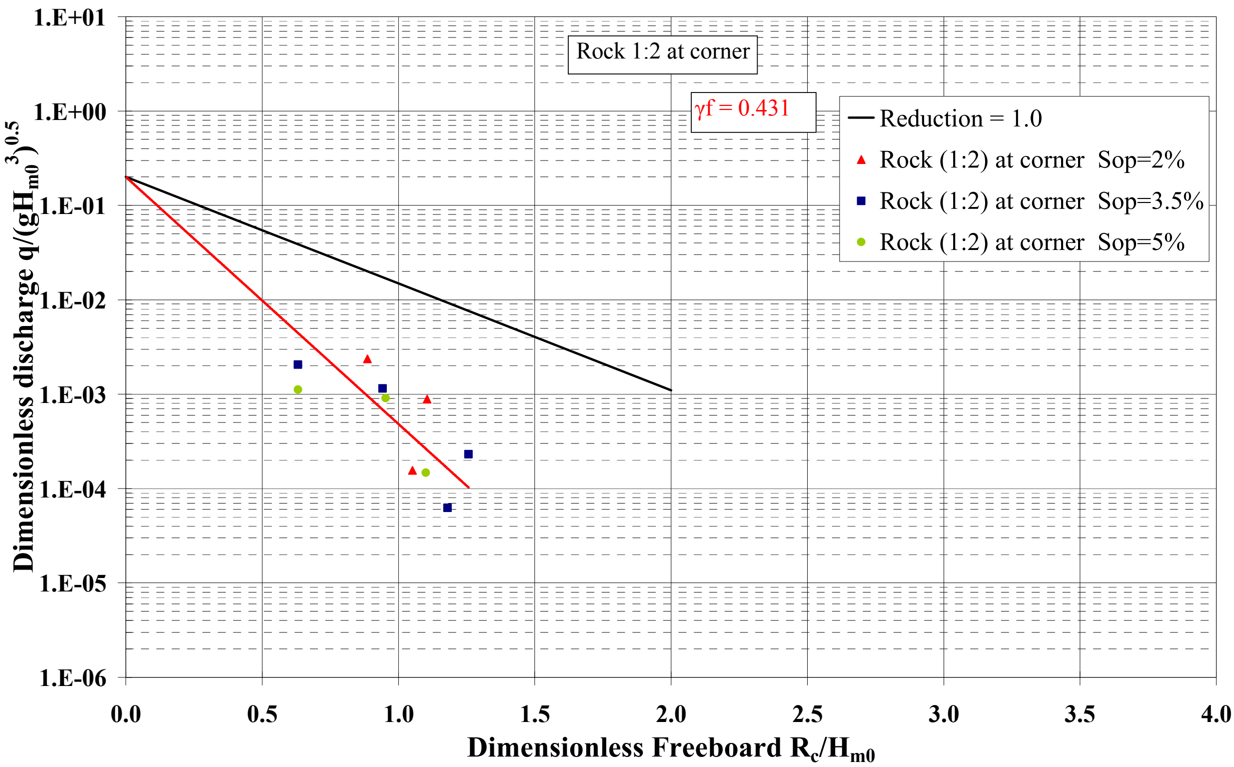


Figure 4.7: A graph of dimensionless overtopping discharge v's dimensionless freeboard for the rock structure with slope 1:2 (discharge measured at corner)

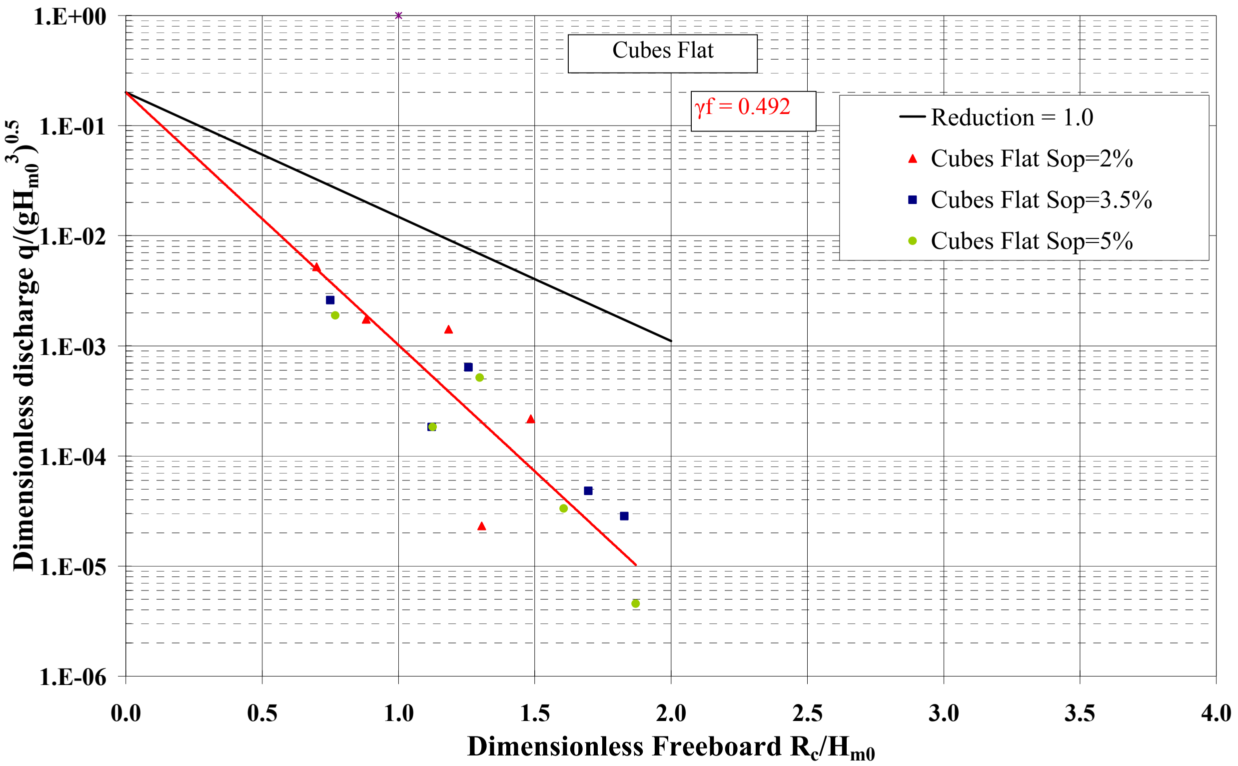


Figure 4.8: A graph of dimensionless overtopping discharge v's dimensionless freeboard for the cube (flat) structure (discharge measured at 3Dn)

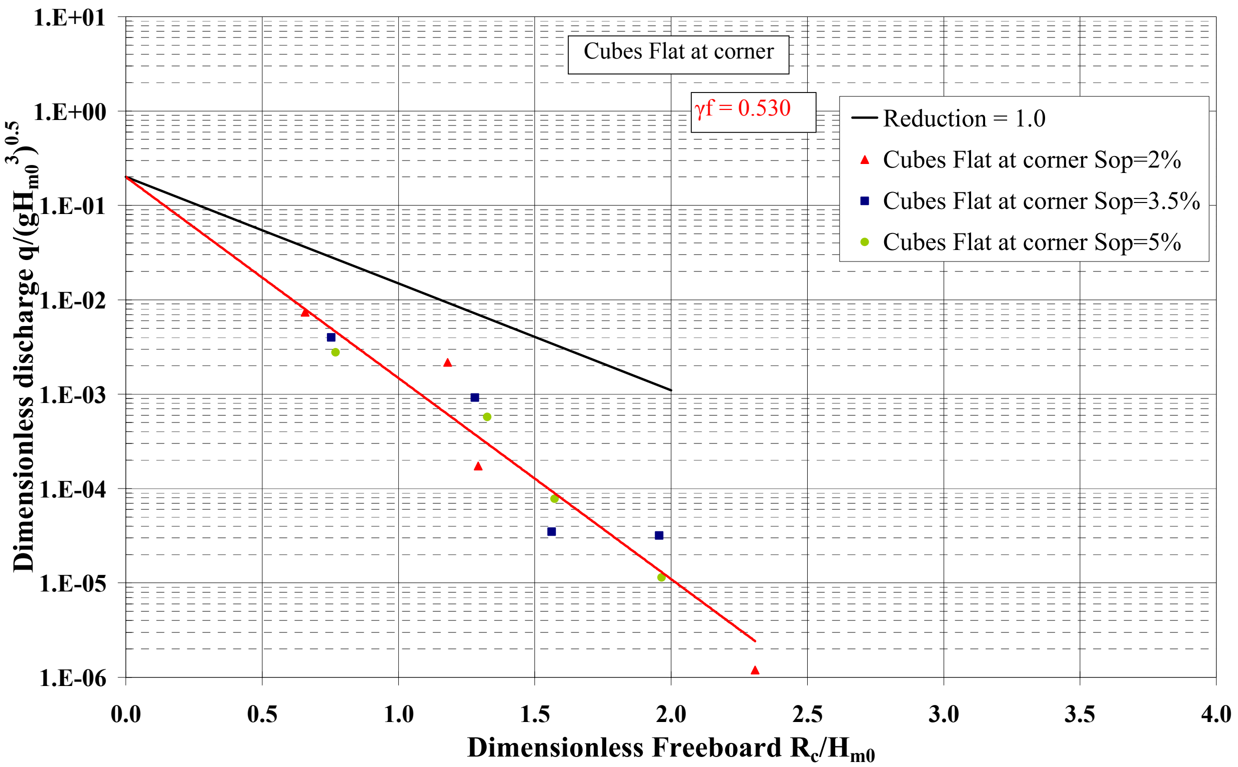


Figure 4.9: A graph of dimensionless overtopping discharge v's dimensionless freeboard for the cube (flat) structure (discharge measured at corner)

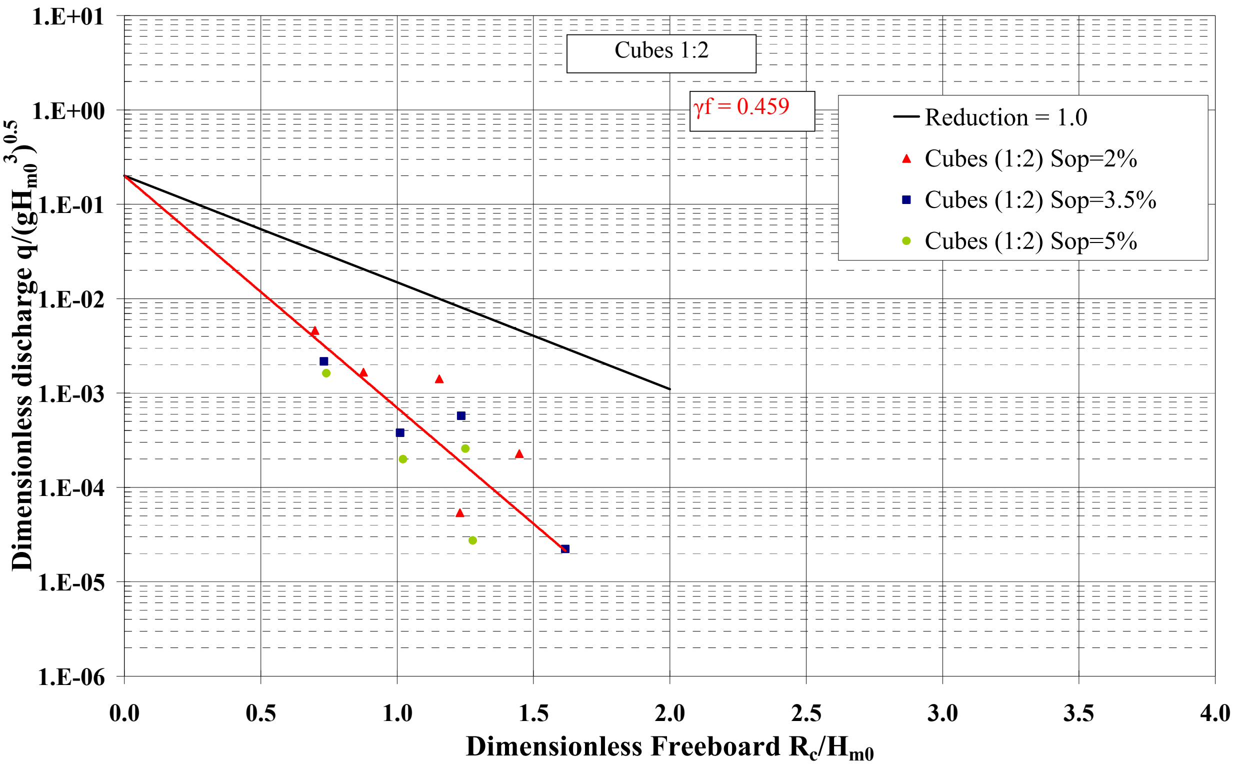


Figure 4.10: A graph of dimensionless overtopping discharge v's dimensionless freeboard for the cube structure with 1:2 slope (discharge measured at 3Dn)

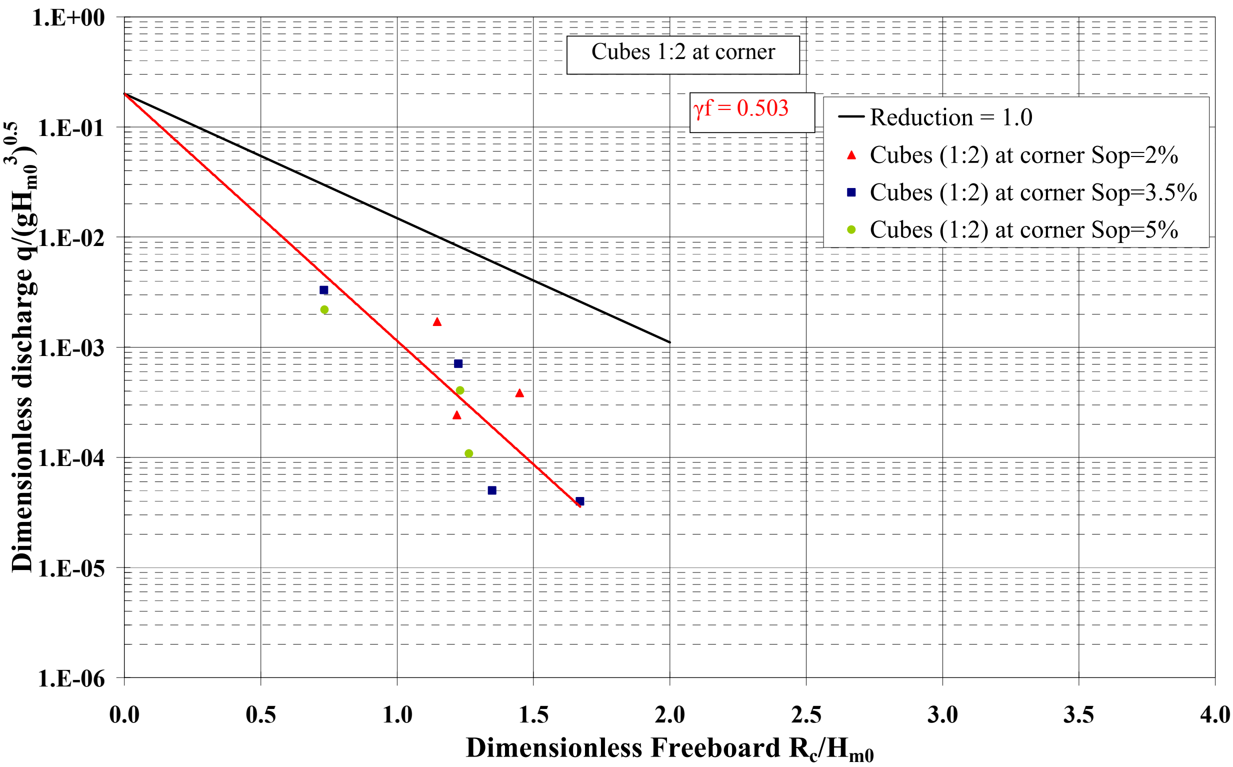


Figure 4.11: A graph of dimensionless overtopping discharge v's dimensionless freeboard for the cube structure with 1:2 slope (discharge measured at corner)

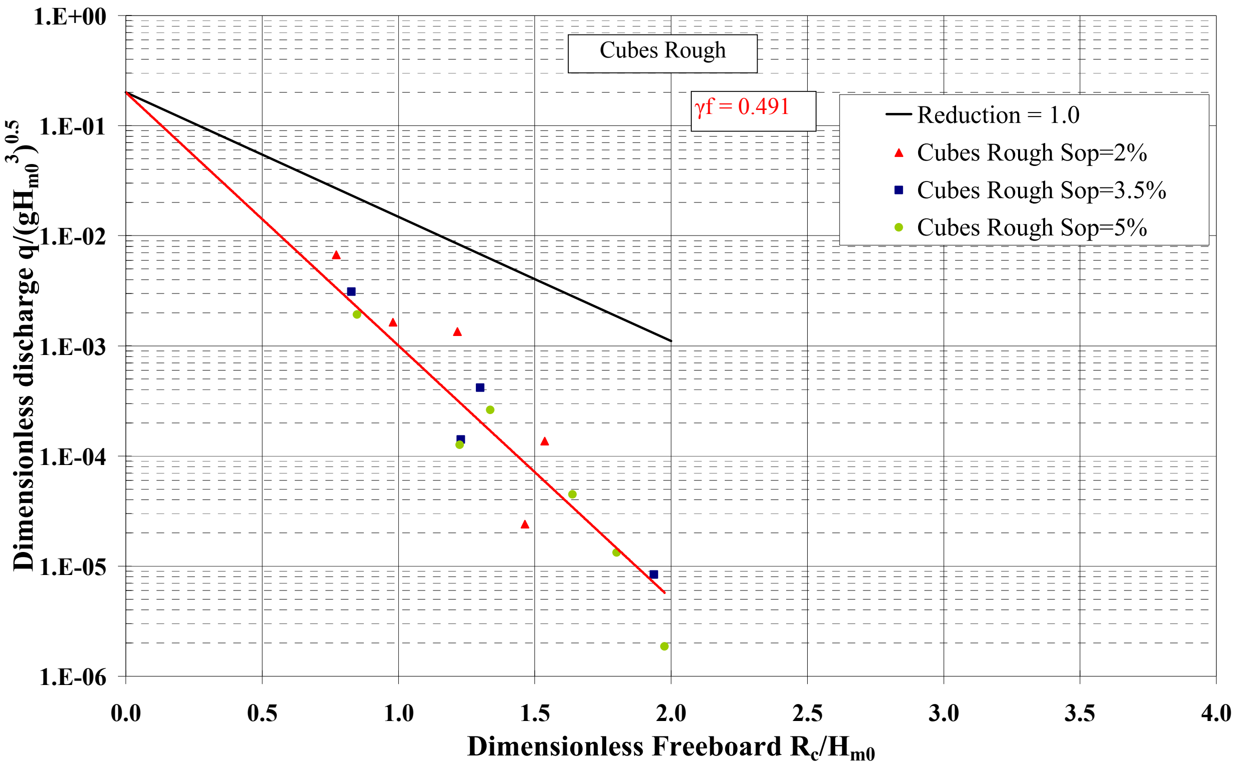


Figure 4.12: A graph of dimensionless overtopping discharge v's dimensionless freeboard for the cube (rough) structure (discharge measured at 3Dn)

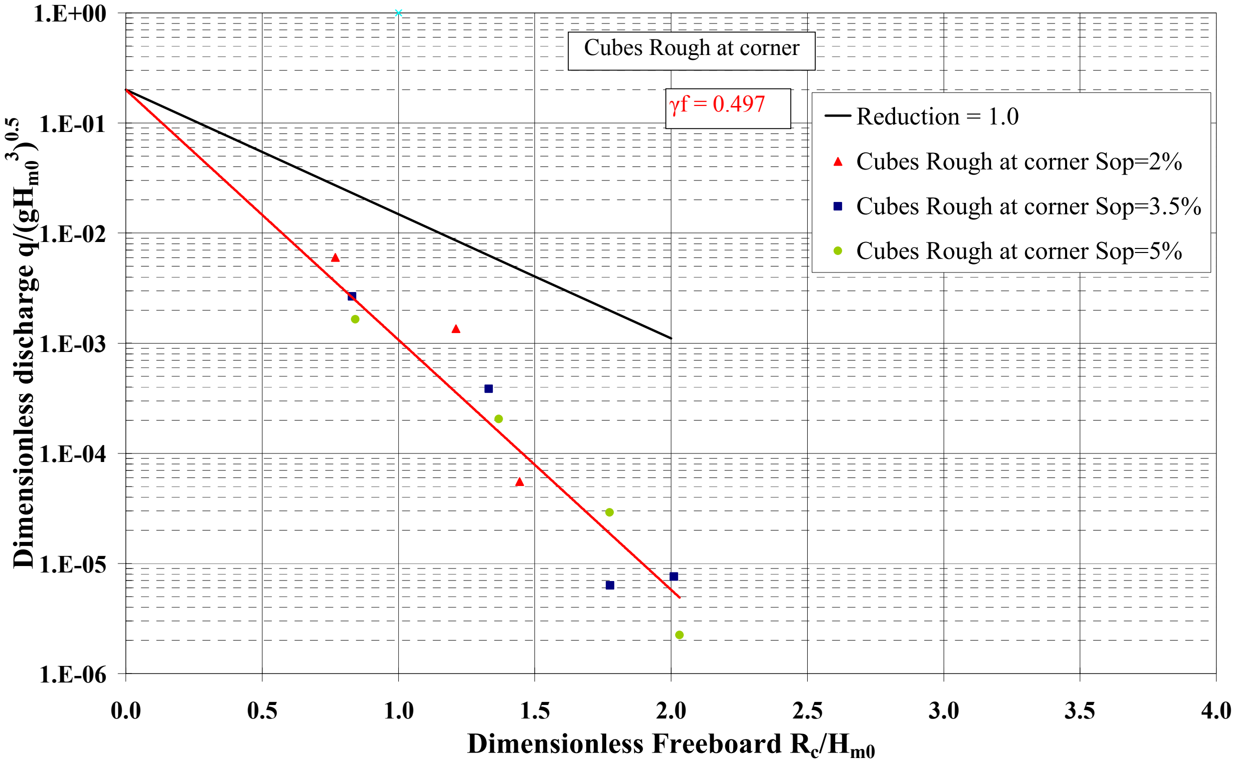


Figure 4.13: A graph of dimensionless overtopping discharge v's dimensionless freeboard for the cube (rough) structure (discharge measured at corner)

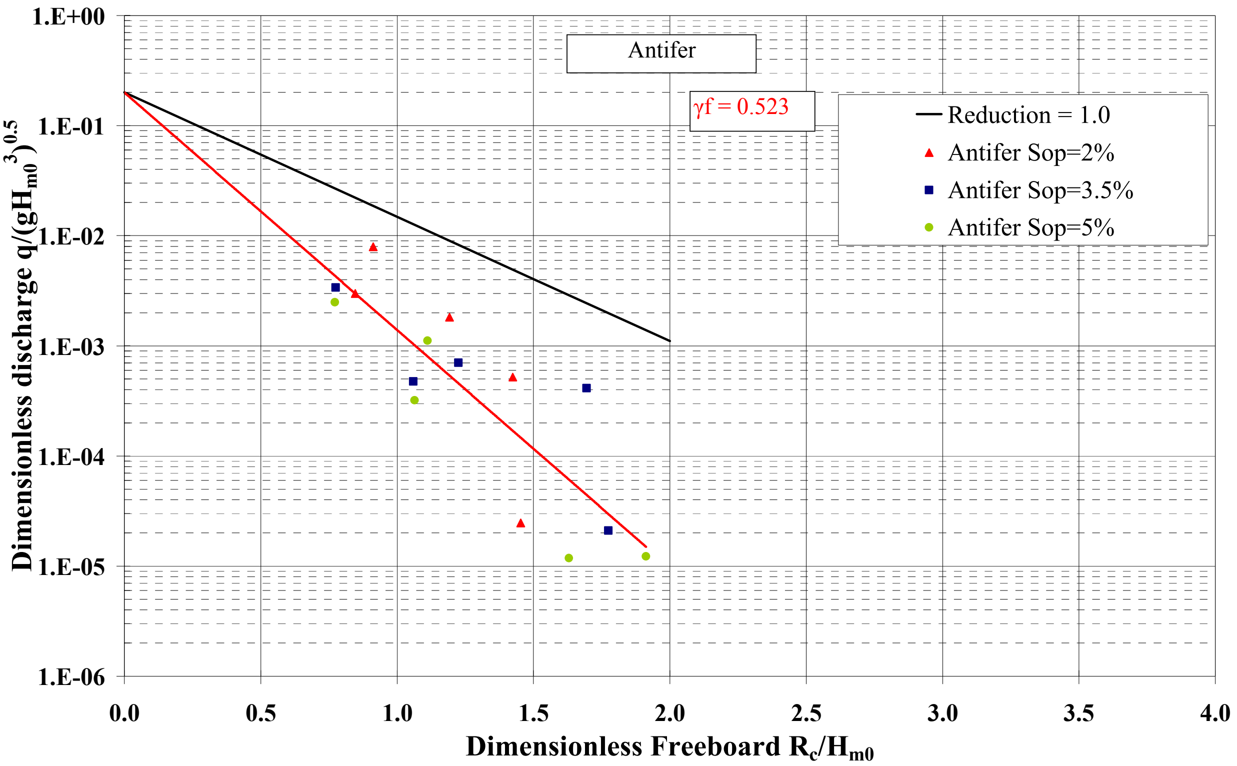


Figure 4.14: A graph of dimensionless overtopping discharge v's dimensionless freeboard for the antifer structure (discharge measured at 3Dn)

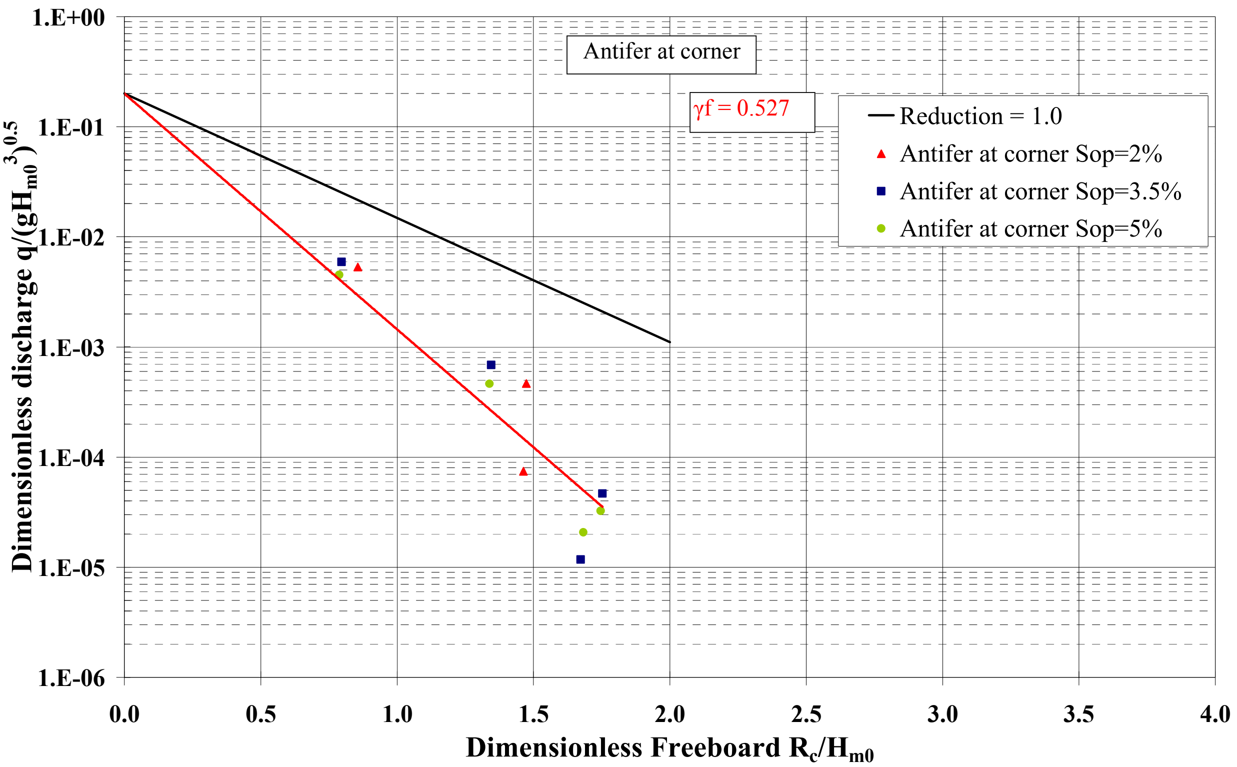


Figure 4.15: A graph of dimensionless overtopping discharge v's dimensionless freeboard for the antifer structure (discharge measured at corner)

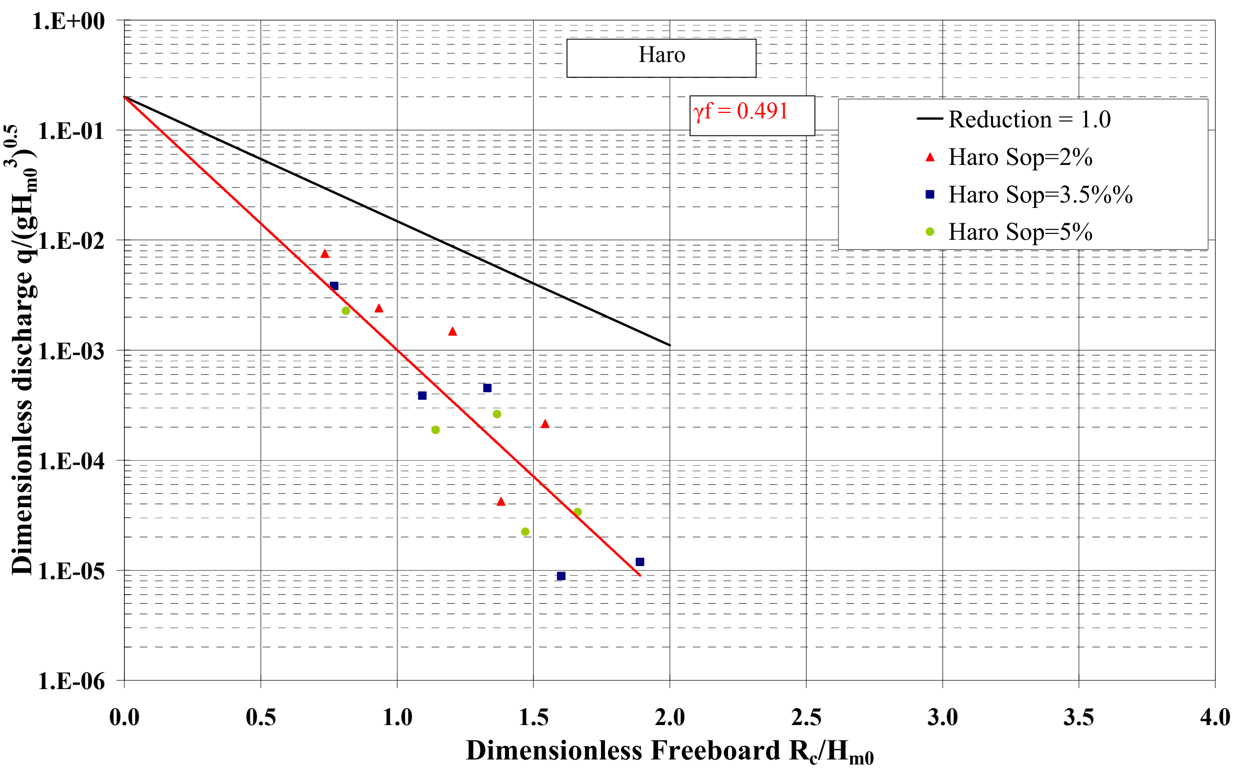


Figure 4.16: A graph of dimensionless overtopping discharge v's dimensionless freeboard for the Haro structure (discharge measured at 3Dn)

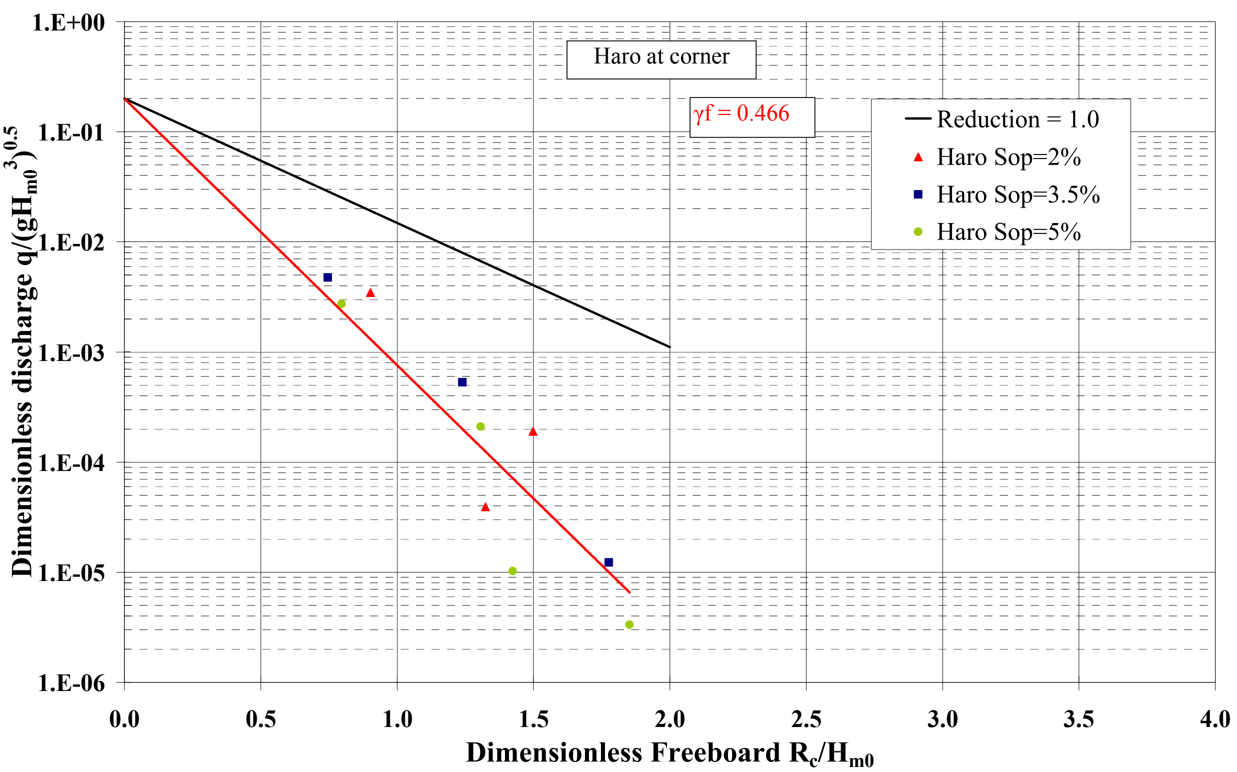


Figure 4.17: A graph of dimensionless overtopping discharge v's dimensionless freeboard for the Haro structure (discharge measured at corner)

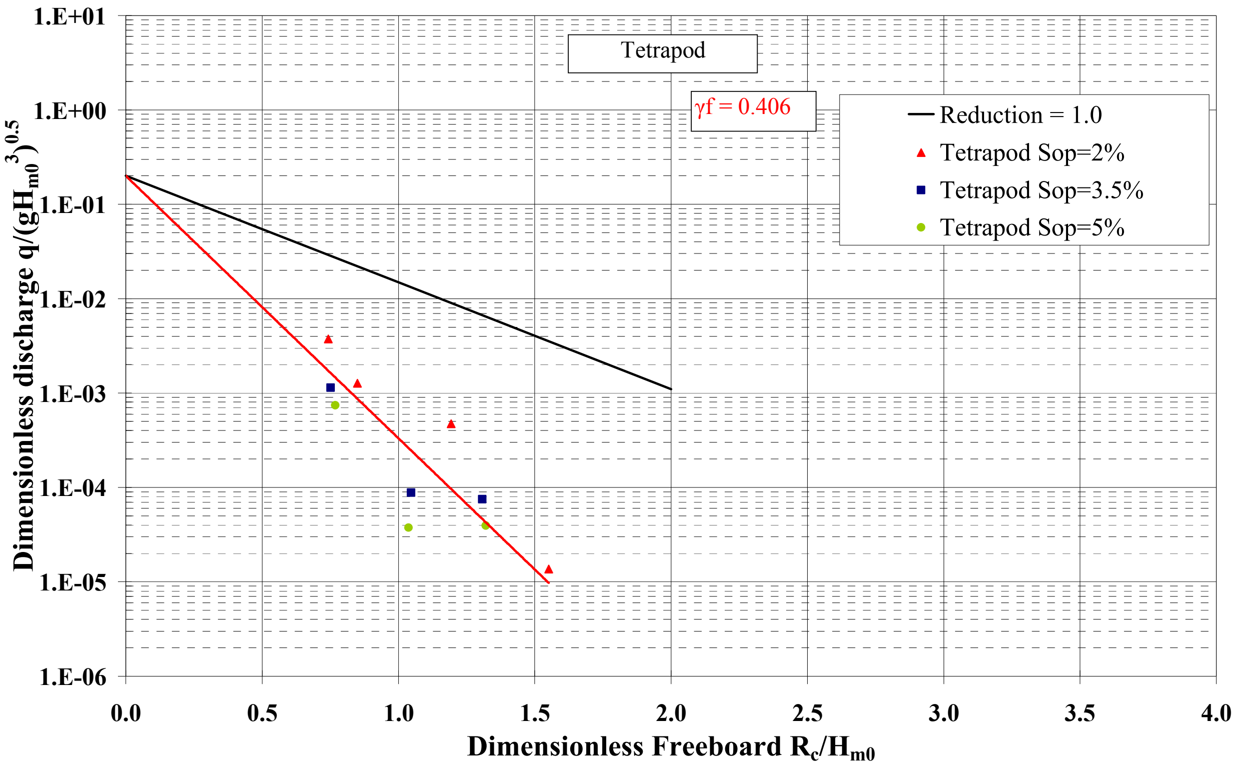


Figure 4.18: A graph of dimensionless overtopping discharge v's dimensionless freeboard for the Tetrapod structure (discharge measured at 3Dn)

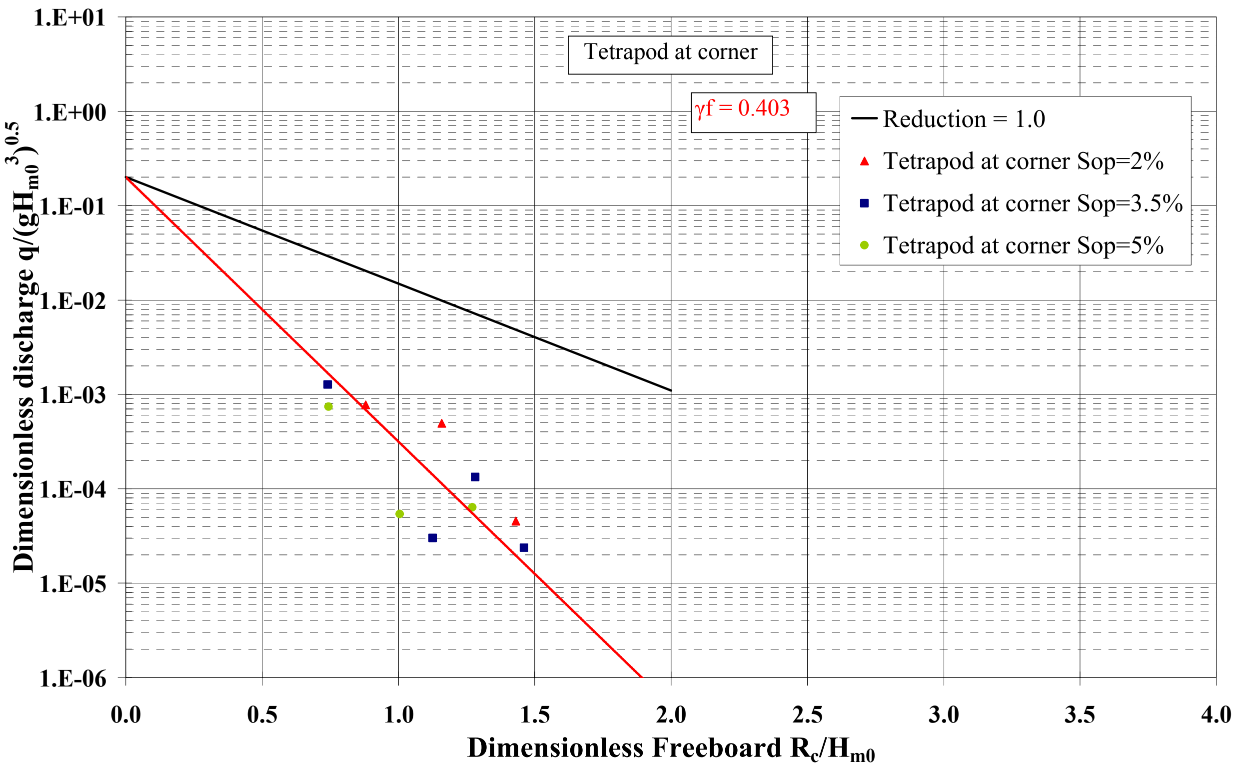


Figure 4.19: A graph of dimensionless overtopping discharge v's dimensionless freeboard for the Tetrapod structure (discharge measured at corner)

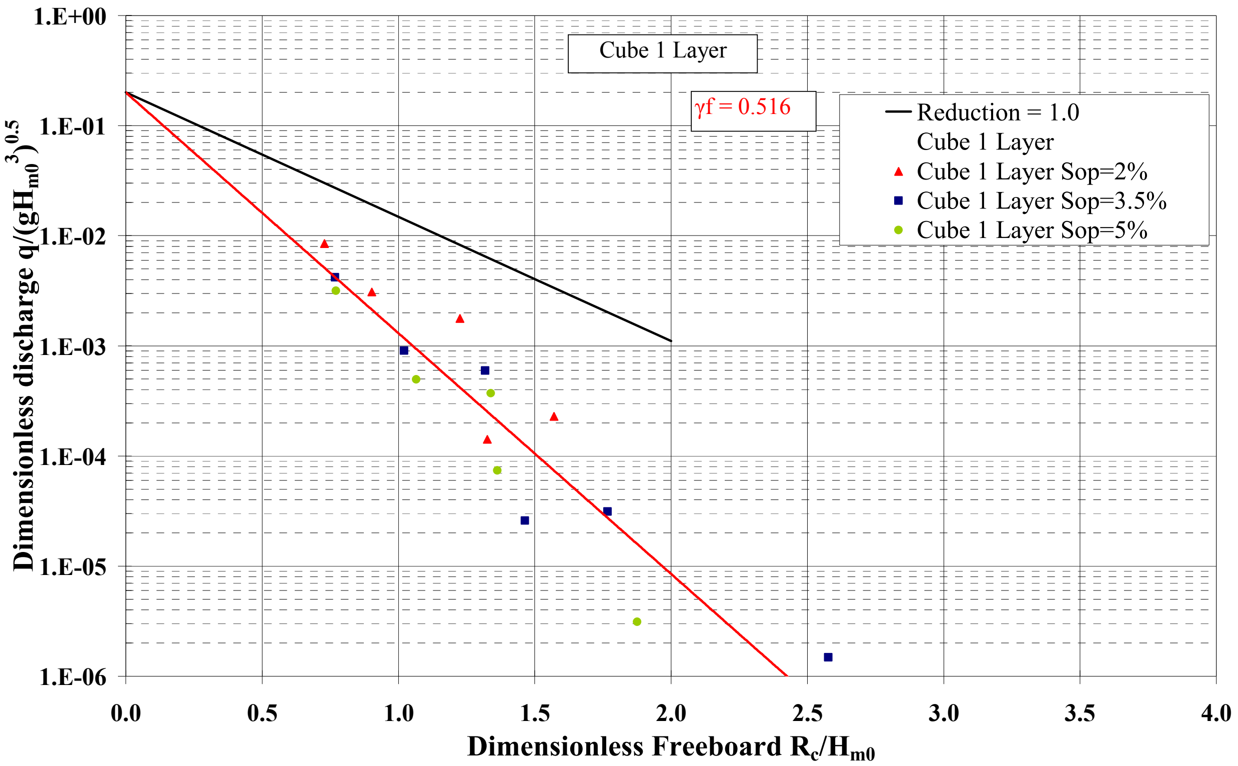


Figure 4.20: A graph of dimensionless overtopping discharge v's dimensionless freeboard for the Cube (single layer) structure (discharge measured at 3Dn)

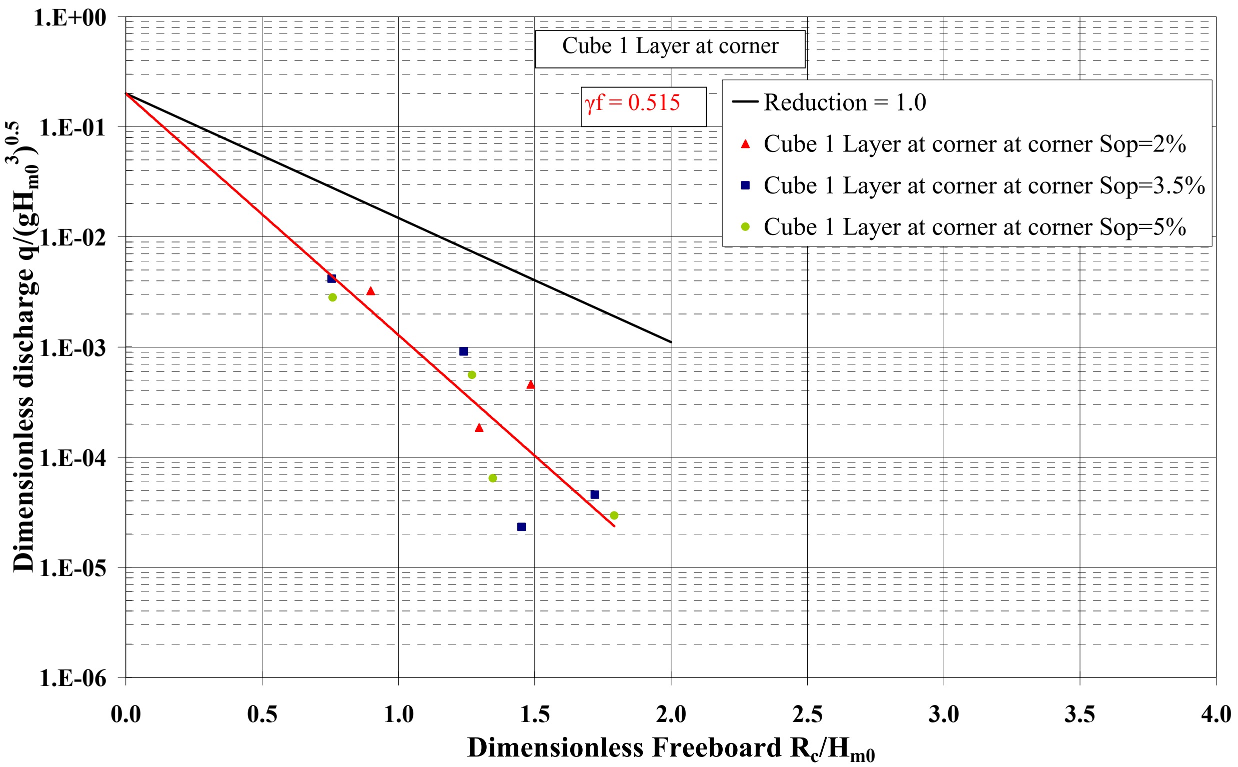


Figure 4.21: A graph of dimensionless overtopping discharge v's dimensionless freeboard for the Cube (single layer) structure (discharge measured at corner)

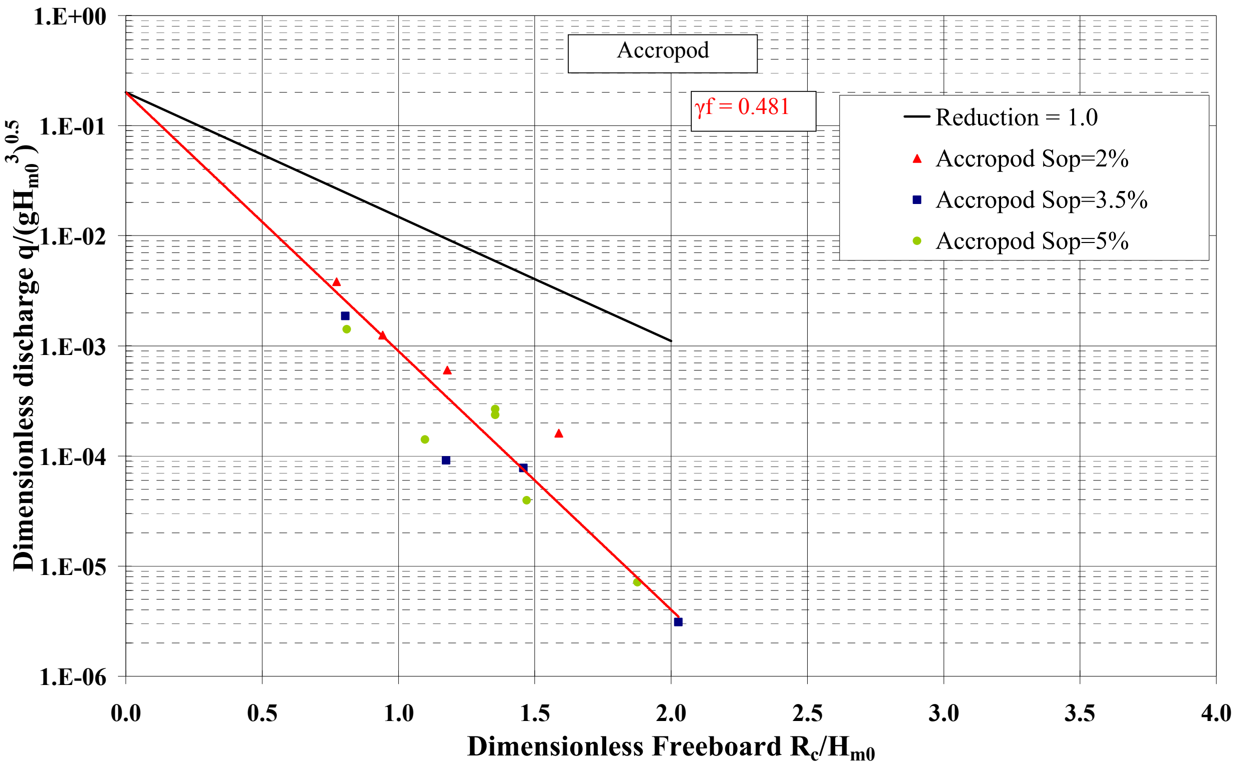


Figure 4.22: A graph of dimensionless overtopping discharge v's dimensionless freeboard for the Accropode structure (discharge measured at 3Dn)

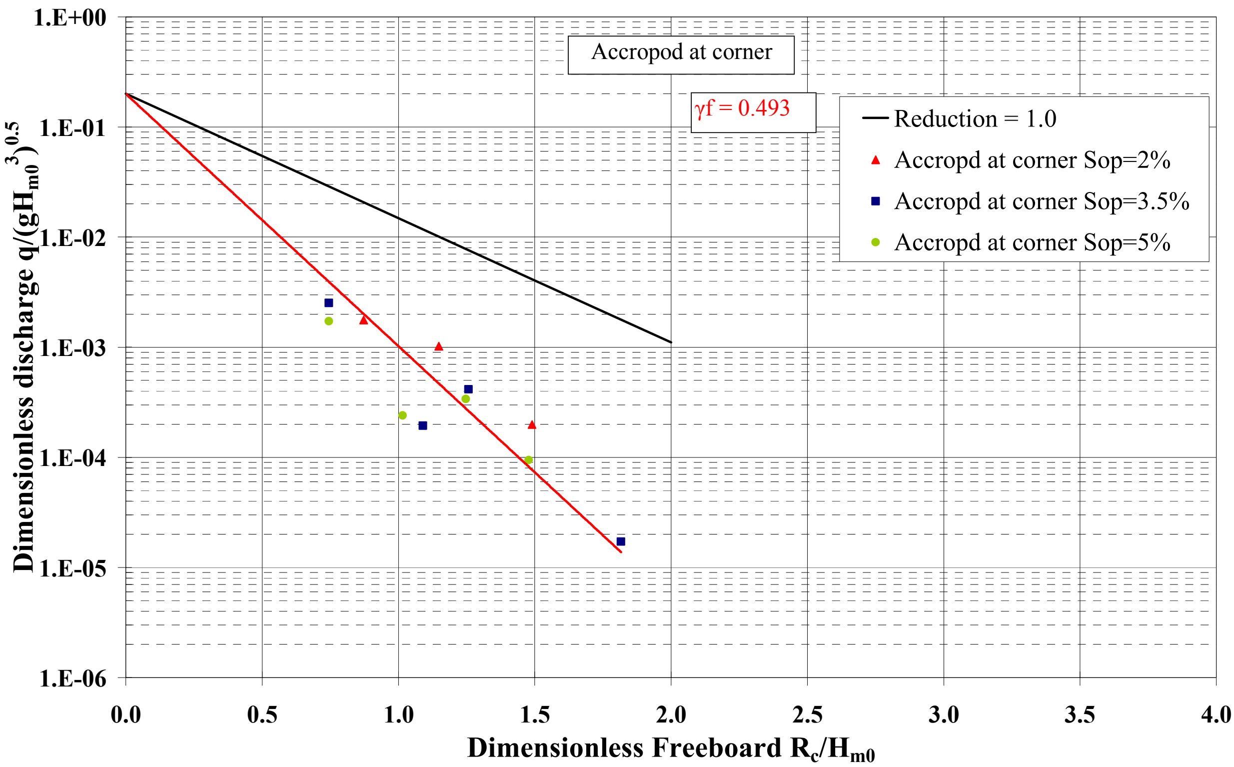


Figure 4.23: A graph of dimensionless overtopping discharge v's dimensionless freeboard for the Accropode structure (discharge measured at corner)

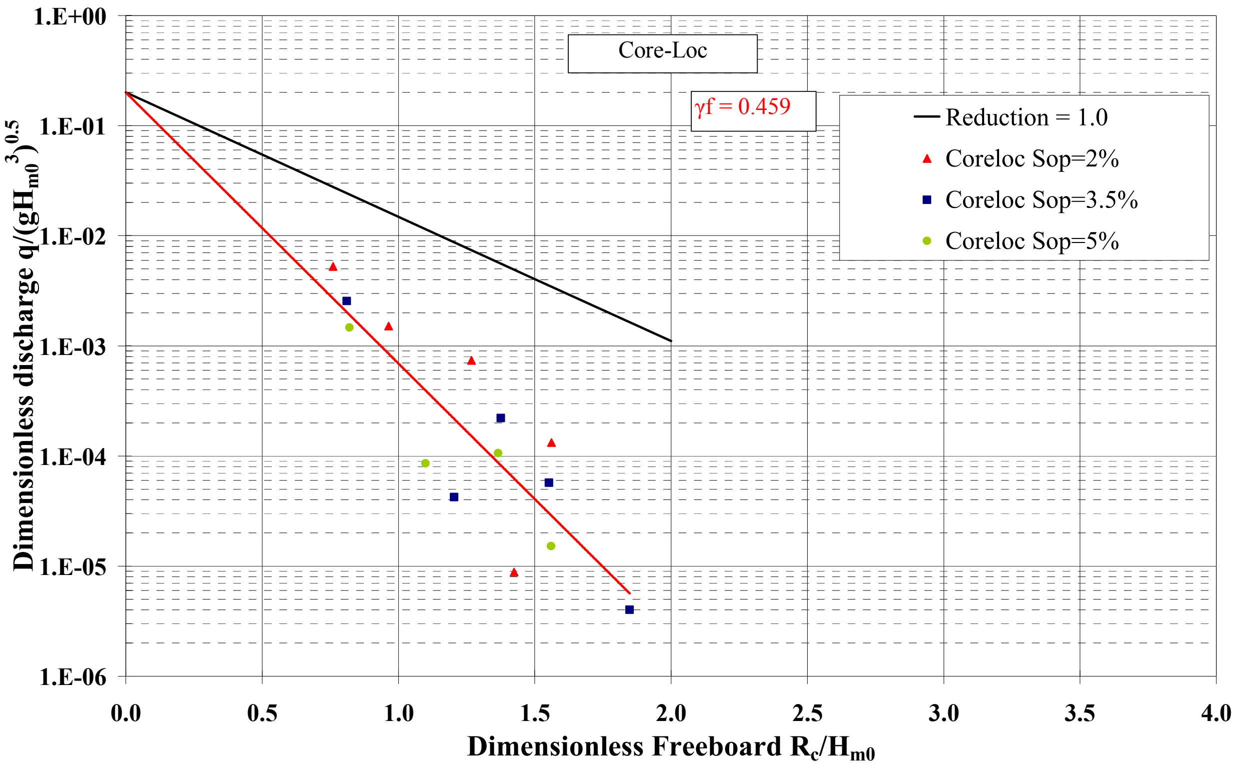


Figure 4.24: A graph of dimensionless overtopping discharge v's dimensionless freeboard for the Core-Loc® structure (discharge measured at 3Dn)

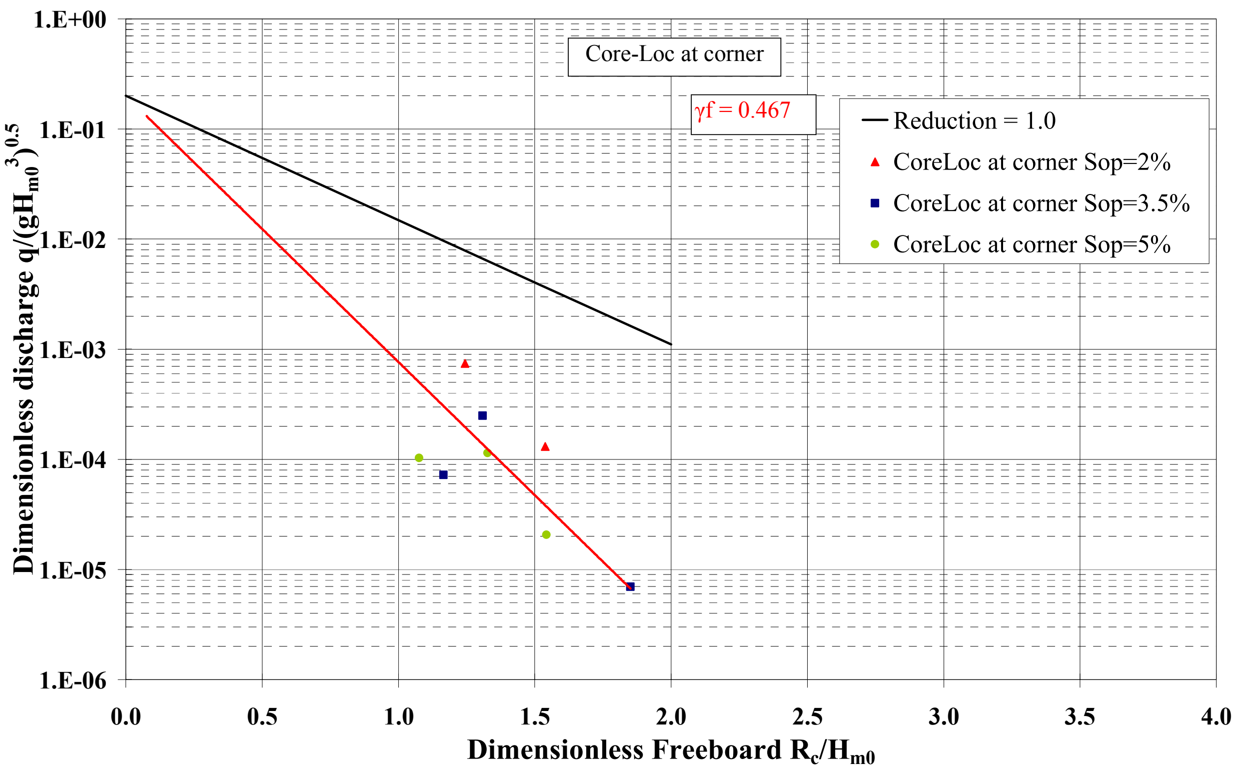


Figure 4.25: A graph of dimensionless overtopping discharge v's dimensionless freeboard for the Core-Loc® structure (discharge measured at corner)

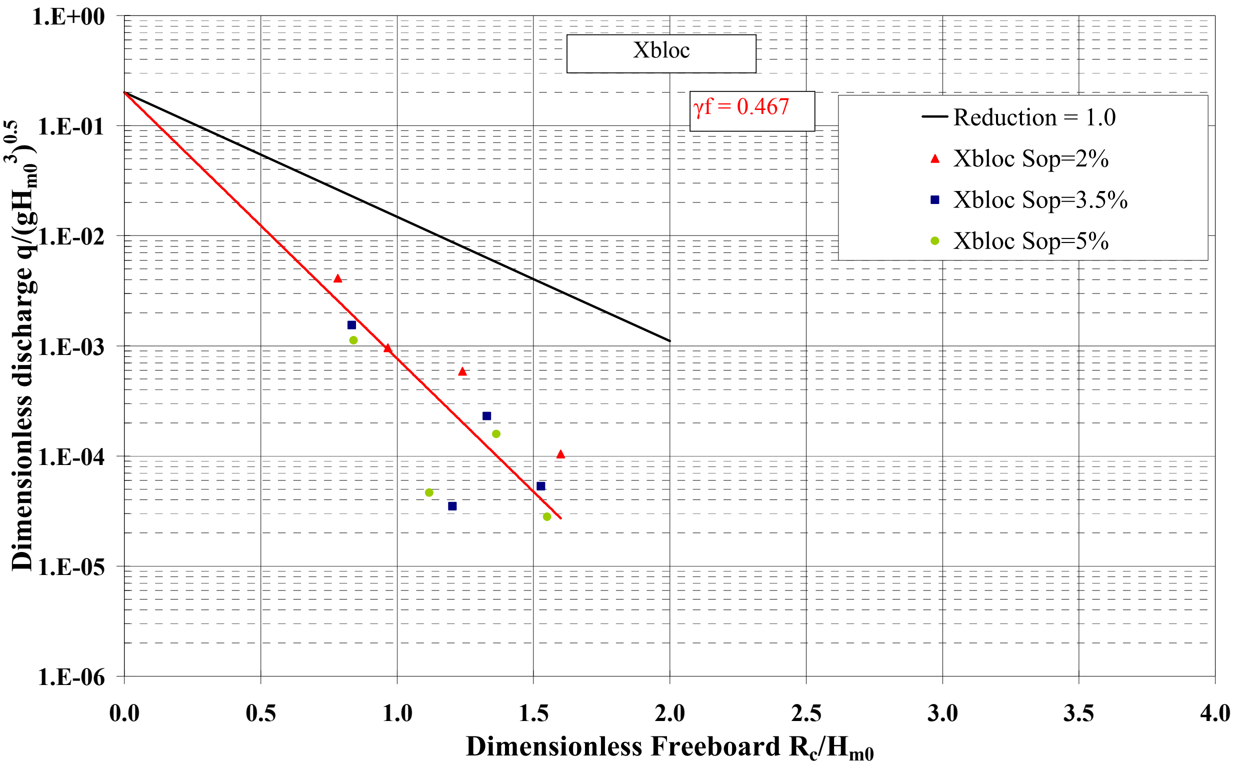


Figure 4.26: A graph of dimensionless overtopping discharge v's dimensionless freeboard for the Xbloc® structure (discharge measured at 3Dn)

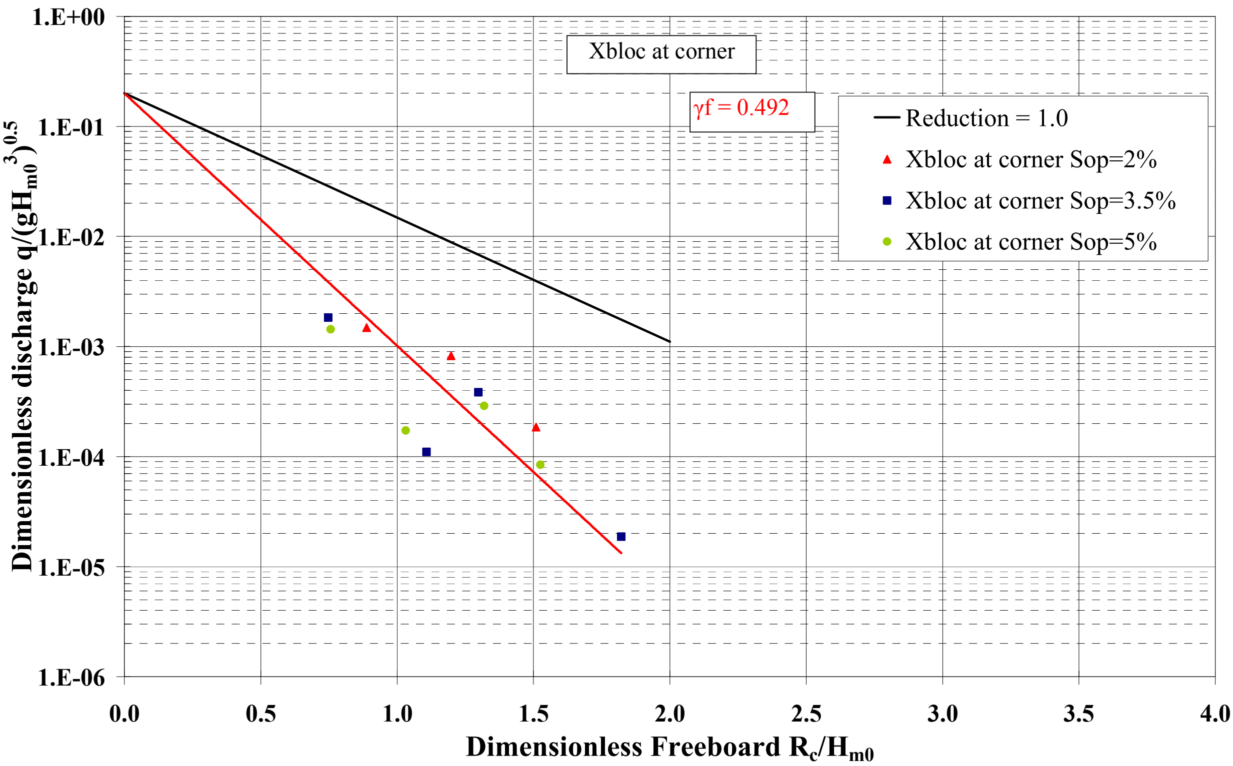


Figure 4.27: A graph of dimensionless overtopping discharge v's dimensionless freeboard for the Xbloc® structure (discharge measured at corner)

5 Conclusions

Detailed measurements have been made in experimental facilities to parameterise the mean overtopping rates for a range of different armour units on a 1:1.5 sloping structure. Additional investigations have been carried out on a 1:2 slope for Rock and Cube armour units.

Within experimental limitations, the results demonstrate that the overtopping characteristics follow the general trend of van der Meer formula. It is noticeable that in almost all cases the wave period has an influence on the overtopping, a larger period gives more overtopping.

A review of similar previous studies (Aminti-Franco 1988, Franco-Cavani 1999) and parallel tests undertaken at AAU (report D24, Pt I) and UGhent (report D24, Pt III) was undertaken. The results from this study and the above studies were discussed amongst the CLASH partners. This allowed the following values of γ_f to be finally selected for a sloping structure with slope 1:1.5, with crest berm width of 3Dn with a permeable core / underlayer, which is valid for breakwaters only (not for revetments)

Discharge measurements at the 'corner' (intersection between horizontal/slope) were considered to be unrealistic, therefore γ_f on measurements were based on the results for $3D_n$ only. The partners felt that the measurements at the 'corner' were not wrong, but in fact give a situation which does not exist in nature. Actually, a vertical wall should be present at Gc=0, but this is impossible as elements have a dimension. Therefore it was decided to take Gc=3Dn as the reference point for all rough structures.

The partners also felt that the γ_f values should also be 'factored' according to the results of the base condition (smooth slope $\gamma_f = 1.05$), i.e. further 5% reduction for all values.

Comparison with previous / parallel studies showed that for the Rock case (permeable core), γ_f varies with slope angle

1:1.3 $\gamma_f = 0.52$
1:1.5 $\gamma_f = 0.42$
1:2.0 $\gamma_f = 0.38$
1:3.5 $\gamma_f = 0.33$

The results of this study also showed a dependency of γ_f with the slope angle for rock. In the database, and also for use of the Neural Network, only one value for γ_f is given. Thus it was noted that the Neural Network must be able to include the slope influence in its prediction. Therefore, in the database only structures with cotα=1.5 and Gc=3Dn should use γ_f from the table below be given. For rock with impermeable underlayer/core, it was felt that the γ_f was too low and should be increased to $\gamma_f = 0.55$.

Type of armour	No Layers	Final γ_f
Smooth		1.00
Rock	2	0.40
Cube	2	0.47
One layer of cubes	1	0.50
Antifer	2	0.47
Haro	2	0.47
Tetrapod	2	0.38
Dolosse (est.)	*2*	*0.43*
Accropode	1	0.46
Core-Loc®	1	0.44
Xbloc®	1	0.45
Berm Breakwater (est.)	*2*	*0.40*
Icelandic Bermbreakwater (est.)	*2*	*0.35*
Seabeas & Sheds (est.)		*0.50*

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Delta Marine, The Netherlands - Xbloc®
Protecuo, Italy - Tetrapods
Flanders Hydraulics, The Netherlands - Antifer

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Appendix I

The effect of armour crest berm width on wave overtopping

note by:

L.Franco
M.Falzacappa
R.Molino

Rome, October 2004

1. Analysis of CLASH tests at UEdin

The model tests performed at UEdin in June 2004 for the assessment of the roughness factor of different armour units included measurements at the seaward sharp corner (q_0) and at the parapet wall, i.e. behind the crest berm composed by 3 units (q_3).

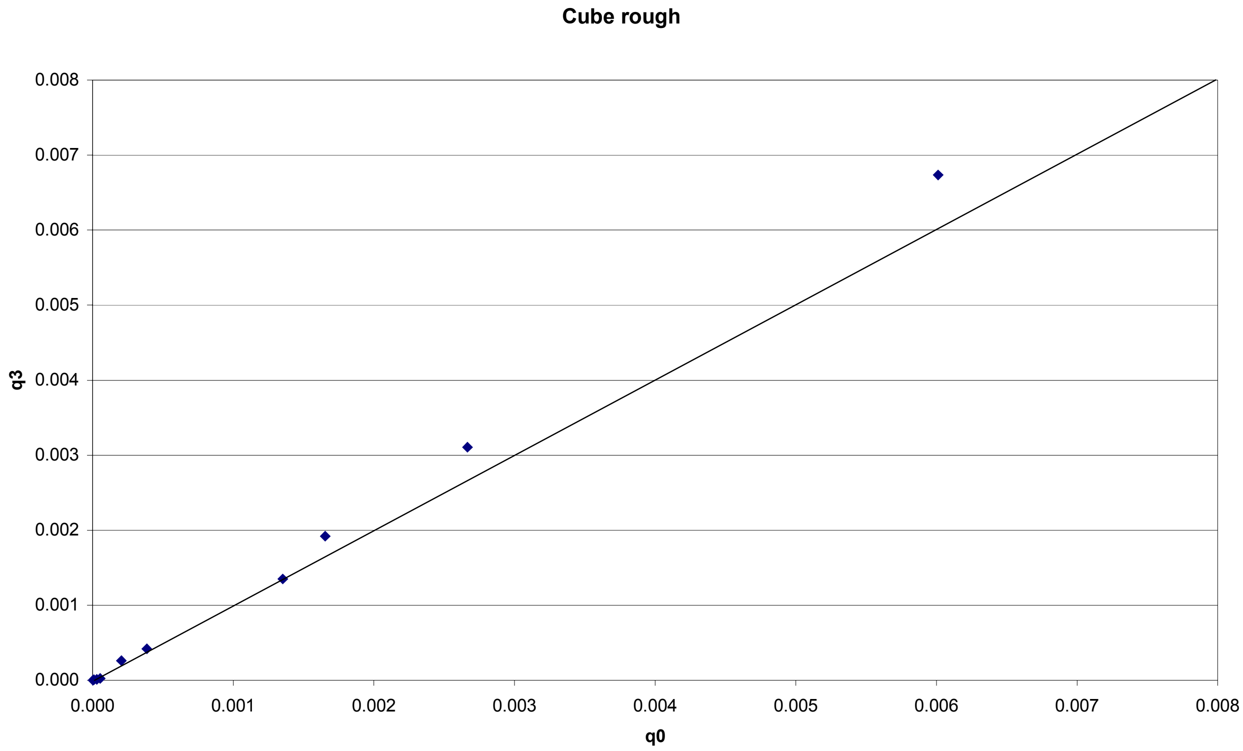
It was envisaged that the comparison of the two sets of data should give an estimate of the expected reduction of overtopping rate due to the friction and percolation of the water running over the porous and rough crest berm (through of constant width = 3 units).

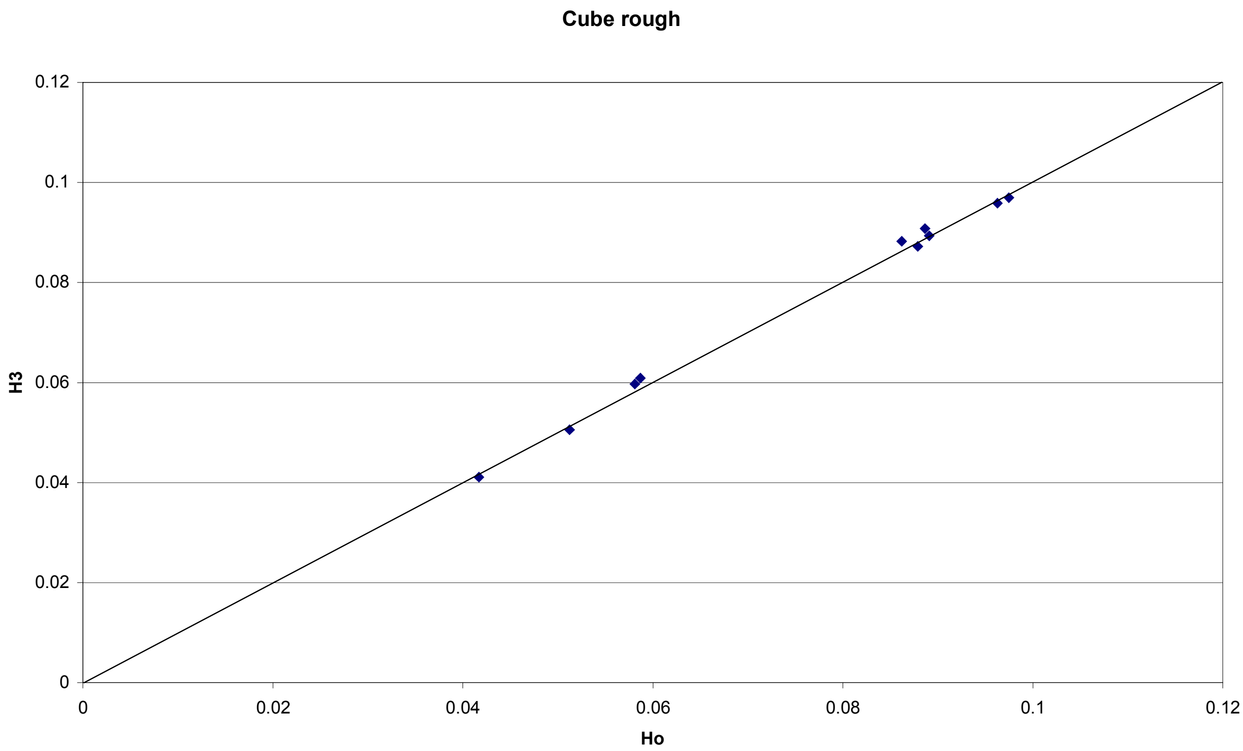
The gammaf values obtained for different units in the two positions (see MOD report of july 2004, tab.1 below) show quite surprisingly that in some cases (eg. Haro, tetrapods) the overtopping was larger at the landward location (i.e. with 3Dn berm) than at the seaward one (i.e. zero berm), i.e gammab=gammaf3/gammaf0 > 1.0 !).

A direct comparison between tests is not possible because the incident wave conditions were not exactly repeated (i.e. Hs for 3D berm labelled H3 could differ from Hs for zero berm width labelled H0. The graphs in figures 1-6 show the correspondence of q3/q0 and H3/H0 for three most typical armour types (cubes, rock, tetrapods) . Scatter and overestimates are particularly evident for the tetrapods.

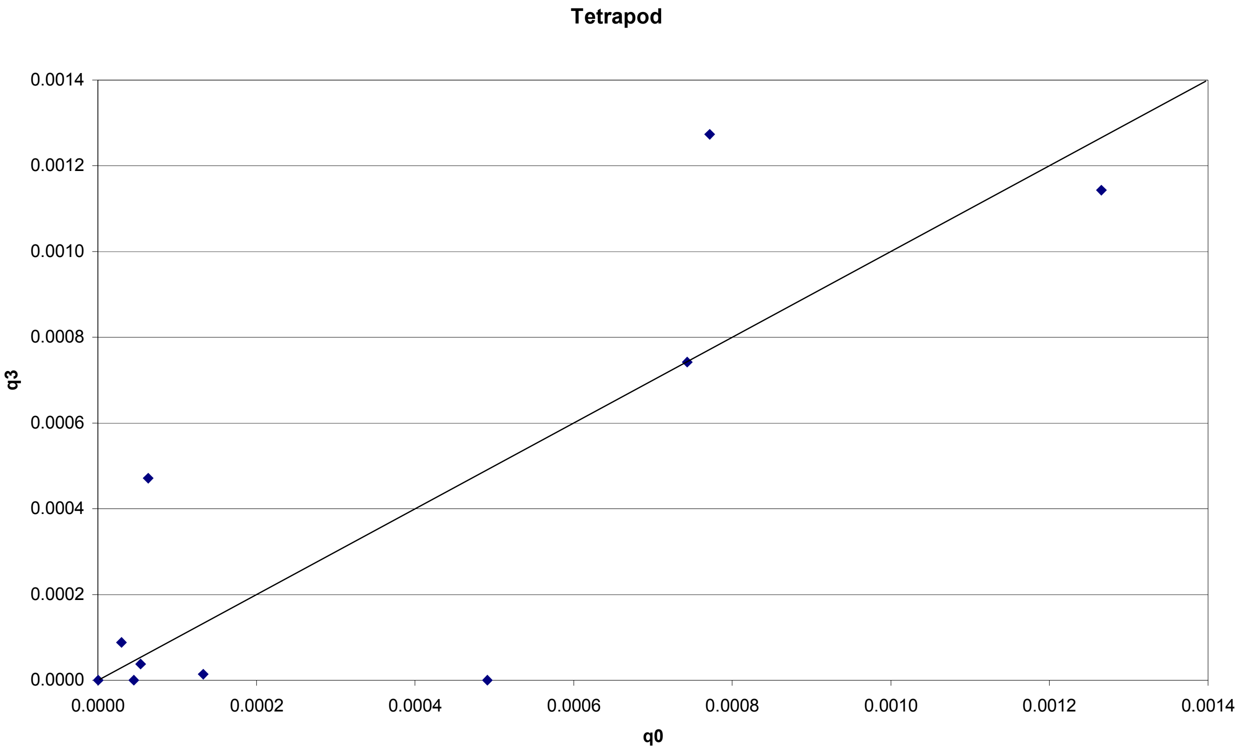
	SUMMARY OF RESULTS		
	Clash data		Reduction factor due to 3Dn berm width
	B/Dn = 3	B/Dn = 0	
	γ_{f1}	γ_{f2}	$\gamma_b=\gamma_{f1}/\gamma_{f2}$
Smooth		1.054	
Large rock	0.416	0.470	0.89
Rock	0.420	0.418	1.00
Rock (1:2)	0.343	0.431	0.80
Cubes flat	0.492	0.530	0.93
Cubes (1:2)	0.459	0.503	0.91
Cubes rough	0.491	0.497	0.99
Antifer	0.523	0.527	0.99
Haro	0.491	0.466	1.05
Tetrapod	0.406	0.403	1.01
1 Layer cube	0.516	0.515	1.00
Accropod	0.481	0.493	0.98
CoreLoc	0.459	0.467	0.98
Xbloc	0.467	0.492	0.95

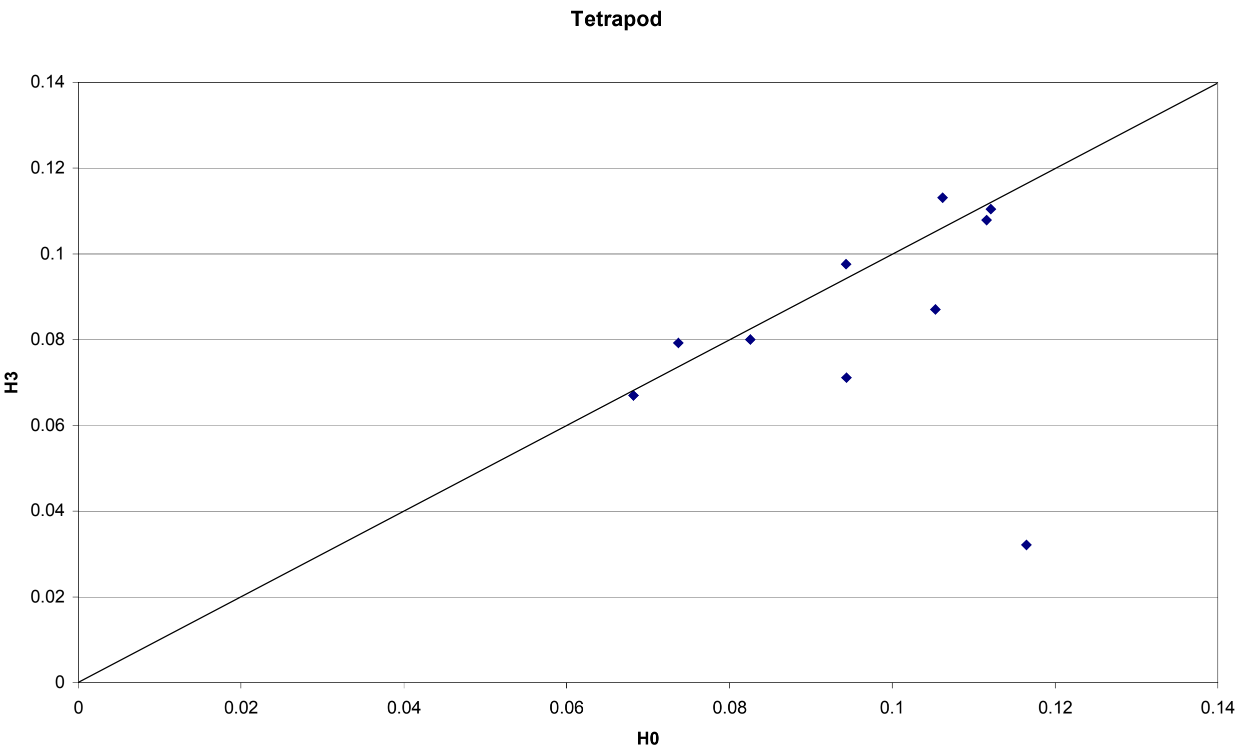
Table 1 : *Summary of results and reduction factor due to 3Dn berm width(CLASH tests at Uedin2004)*



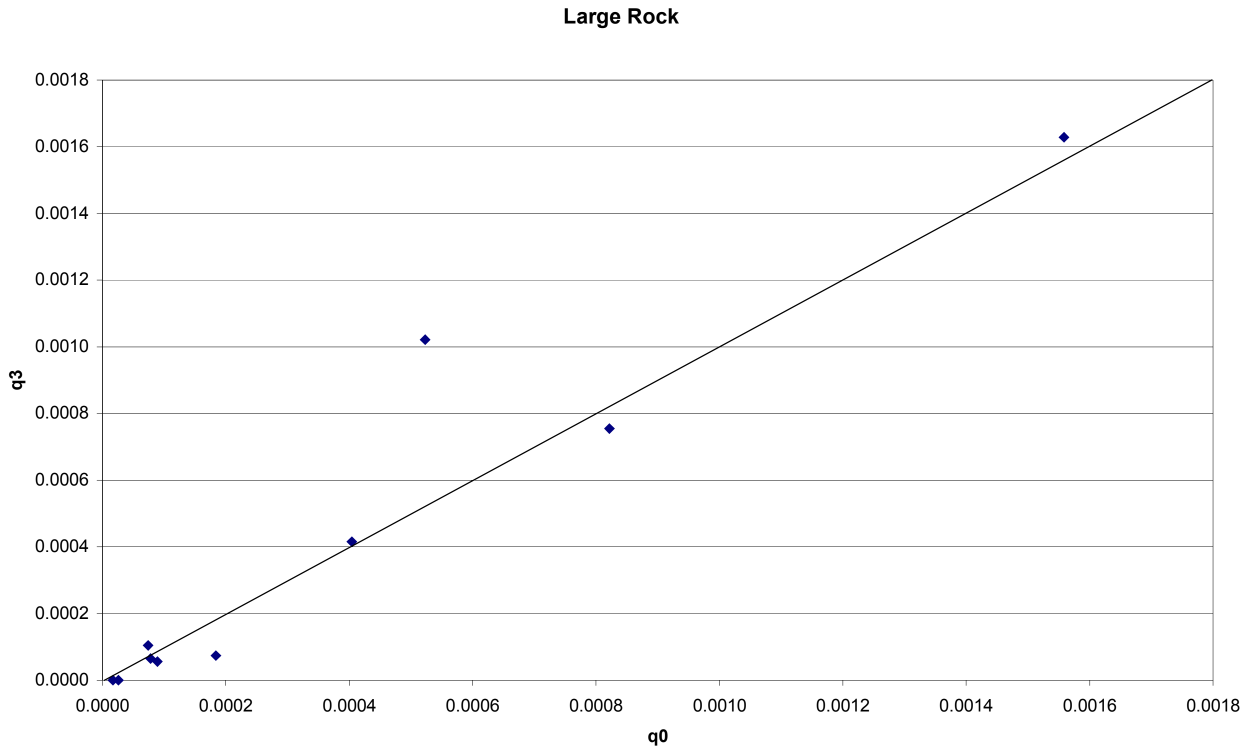


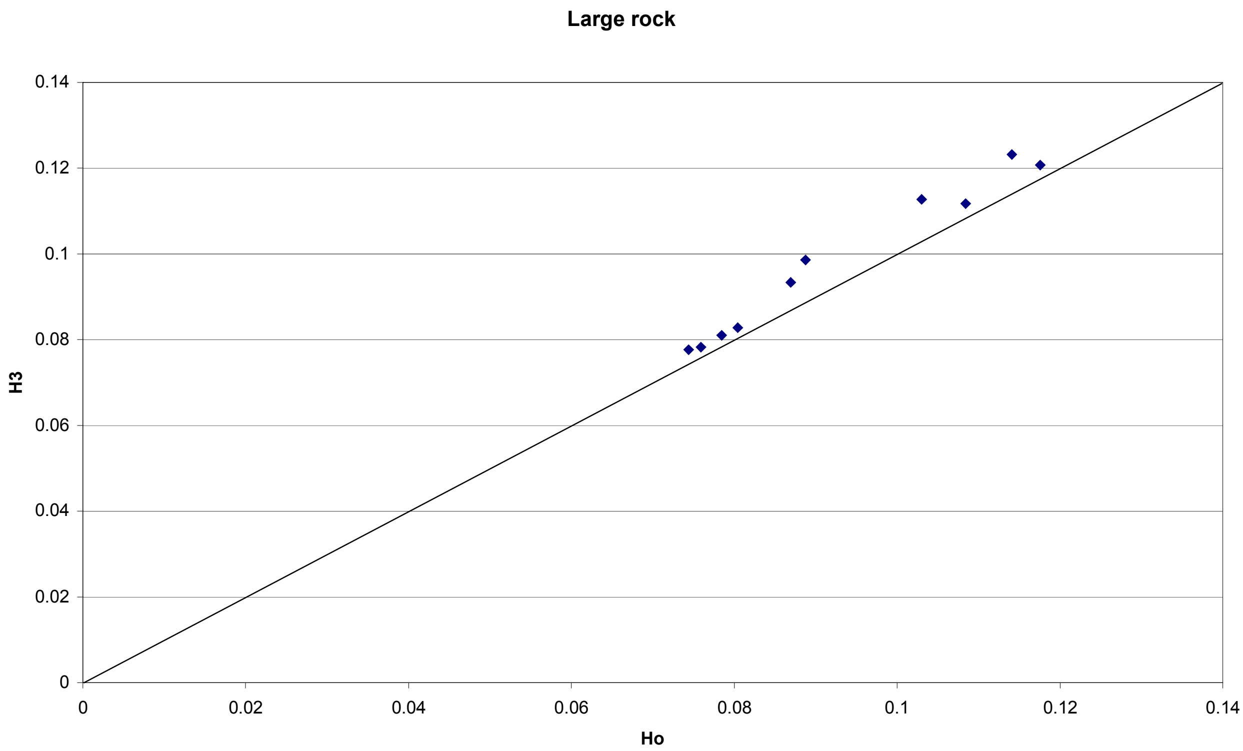
Figures 1 & 2: Comparison of discharge and wave conditions for the same generated waves condition at ‘corner’ and 3Dn – on Rough Cubes





Figures 3 & 4: Comparison of discharge and wave conditions for the same generated waves condition at 'corner' and 3Dn – on Tetrapod





Figures 5 & 6: Comparison of discharge and wave conditions for the same generated waves condition at ‘corner’ and 3Dn – on Large Rock

2. Comparisons with Besley's formula

Besley (1999) gives a reduction factor Cr (of the discharge q) to account for the influence of the width of the crest on wave overtopping for ROCK structures as a function of the relative berm width B/Hs:

$$Cr = 3.06 \cdot EXP(-1.5 \cdot B/Hs) \qquad (1)$$

The new CLASH data (blue dots) have been plotted in figures 7-8-9 (including tetrapods and cubes) against the Besley's formula (eq.1) computed for the same values of B/Hs (violet dots). Cr is assumed as the ratio q3/q0 or q3Dn/q0.

The scatter is rather large despite the limited tested range of B/Hs, and the bias for cubes quite evident. Data are also given in table 2

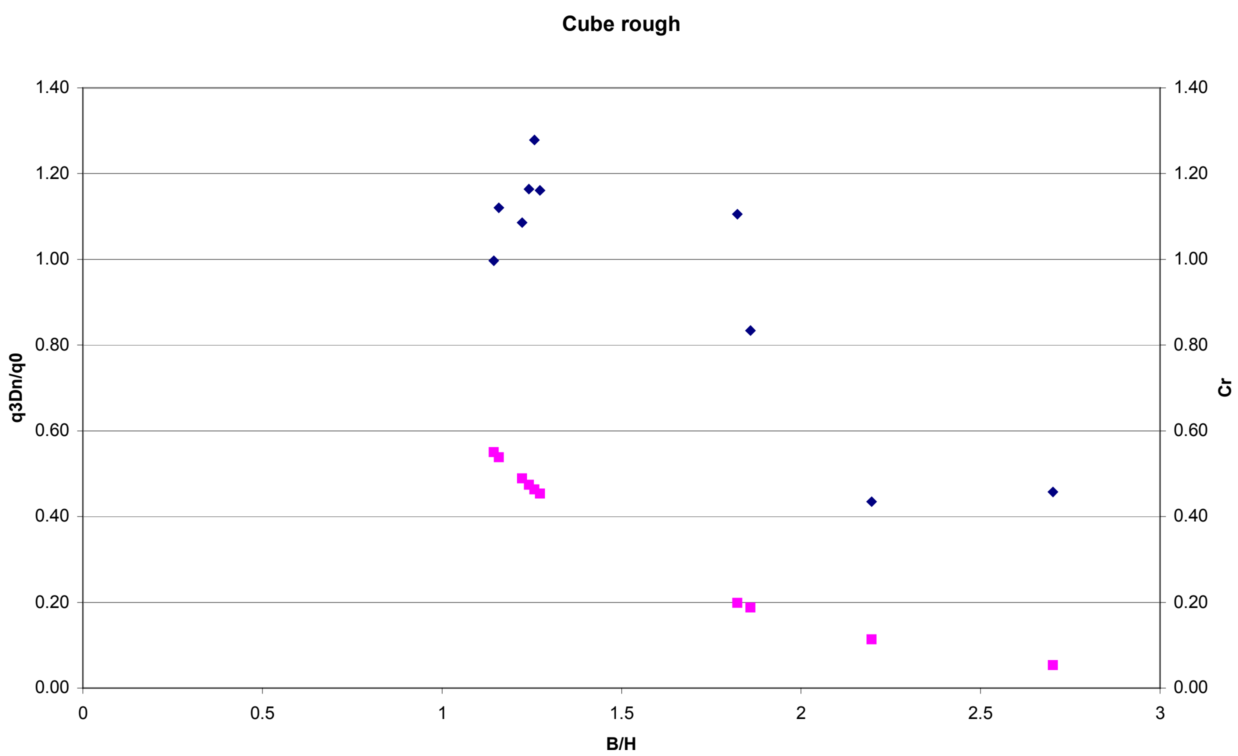


Figure 7: Rough Cubes – Comparison with Besley (1999)

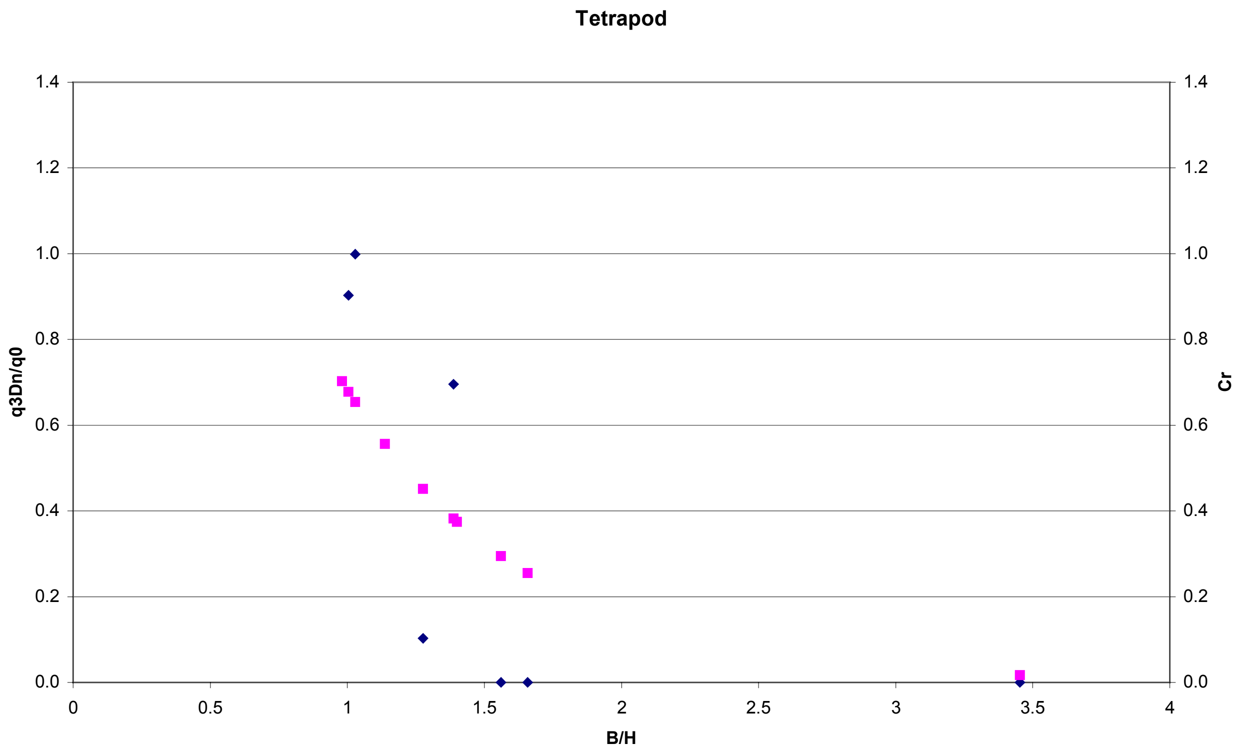


Figure 8: Tetrapod – Comparison with Besley (1999)

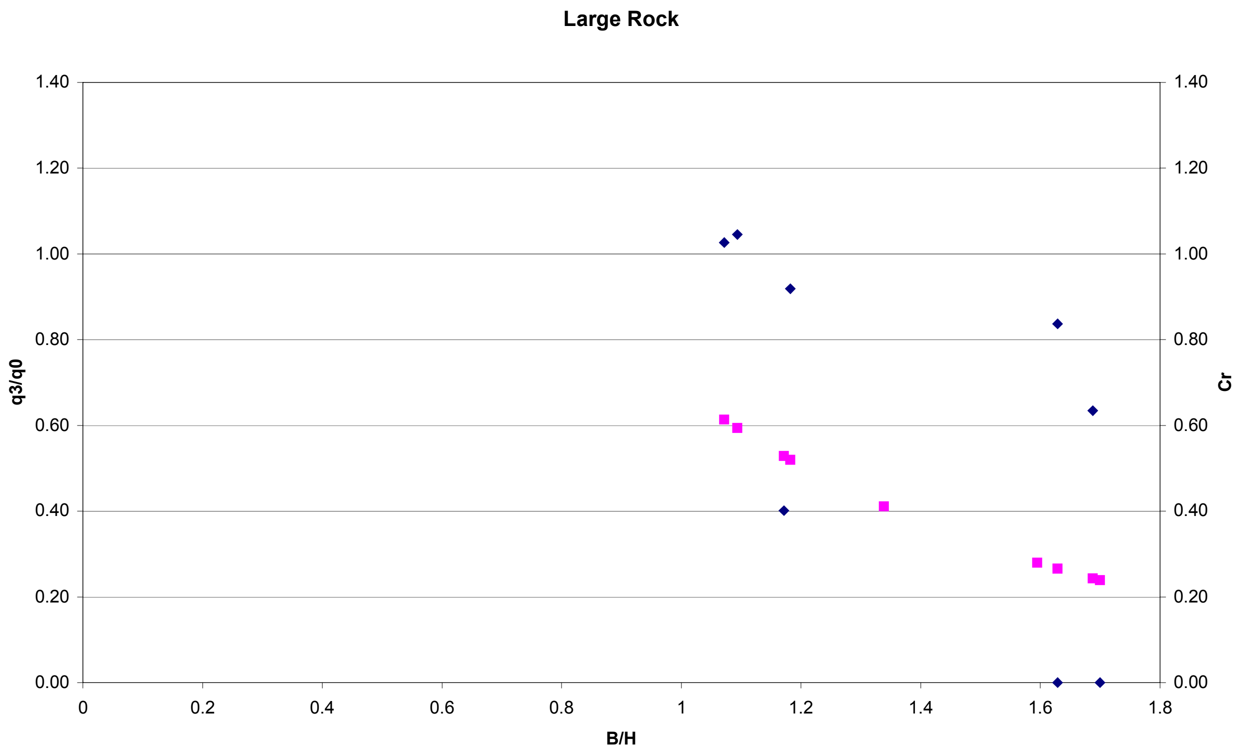


Figure 9: Large Rock – Comparison with Besley (1999)

Cube	Rc	q0	q 3Dn	H0	H3	q3Dn/q0	B/H	Cr
250	0.118							
275	0.118							
2100	0.118	1.35E-03	1.35E-03	0.09746	0.097	9.97E-01	1.14433	0.549866
350	0.118							
375	0.118	7.57E-06	8.36E-06	0.05869	0.06092	1.11E+00	1.822062	0.198955
3100	0.118	3.85E-04	4.18E-04	0.08865	0.09076	1.09E+00	1.223006	0.488657
550	0.118							
575	0.118	2.23E-06	1.86E-06	0.05809	0.0597	8.34E-01	1.859296	0.188147
5100	0.118	2.05E-04	2.62E-04	0.08622	0.08825	1.28E+00	1.25779	0.463814
250	0.074	5.53E-05	2.40E-05	0.05123	0.05053	4.34E-01	2.196715	0.11342
275	0.074							
2100	0.074	6.01E-03	6.74E-03	0.09627	0.09585	1.12E+00	1.158059	0.538658
350	0.074							
375	0.074							
3100	0.074	2.67E-03	3.10E-03	0.08909	0.08932	1.16E+00	1.242723	0.474417
550	0.074	2.90E-05	1.33E-05	0.0417	0.04109	4.57E-01	2.701387	0.053202
575	0.074							
5100	0.074	1.65E-03	1.92E-03	0.08788	0.08724	1.16E+00	1.272352	0.453793

Tetrapod	Rc	q0	q 3Dn	H0	H3	q3Dn/q0	B/H	Cr
250	0.083							
275	0.083	7.72E-04	1.27E-03	0.0943	0.09765	1.65E+00	1.136713	0.556185
2100	0.083							
350	0.083							
375	0.083	3.00E-05	8.80E-05	0.07373	0.07926	2.94E+00	1.400454	0.374461
3100	0.083	1.27E-03	1.14E-03	0.1121	0.1105	9.03E-01	1.004525	0.67816
550	0.083							
575	0.083	5.38E-05	3.74E-05	0.08256	0.08004	6.96E-01	1.386807	0.382206
5100	0.083	7.43E-04	7.42E-04	0.1116	0.1079	9.99E-01	1.02873	0.653979
250	0.135							
275	0.135	4.54E-05	0.00E+00	0.09439	0.07116	0.00E+00	1.559865	0.294822
2100	0.135	4.91E-04	0.00E+00	0.1165	0.03215	0.00E+00	3.452566	0.017242
350	0.135							
375	0.135	4.07E-07	0.00E+00	0.0682	0.06698	0.00E+00	1.657211	0.254768
3100	0.135	1.33E-04	1.37E-05	0.1053	0.08702	1.03E-01	1.275569	0.451609
550	0.135							
575	0.135							
5100	0.135	6.37E-05	4.71E-04	0.1062	0.1131	7.40E+00	0.981432	0.702062

Rock	Rc	q0	q 3Dn	H0	H3	q3Dn/q0	B/H	Cr
250	0.095							
275	0.095	5.23E-04	1.02E-03	0.08877	0.0986	1.95E+00	1.338742	0.41078
2100	0.095							
350	0.095							
375	0.095	8.90E-05	5.65E-05	0.0759	0.07821	6.35E-01	1.687764	0.243356
3100	0.095	1.56E-03	1.63E-03	0.1176	0.1207	1.05E+00	1.093621	0.593323
550	0.095							
575	0.095	7.40E-05	1.04E-04	0.08045	0.08279	1.41E+00	1.594395	0.27994
5100	0.095	8.22E-04	7.55E-04	0.1084	0.1117	9.19E-01	1.181737	0.519863
250	0.134							
275	0.134	7.81E-05	6.54E-05	0.08692	0.09334	8.37E-01	1.628423	0.26601
2100	0.134							
350	0.134							
375	0.134	1.73E-05	0.00E+00	0.07441	0.07768	0.00E+00	1.699279	0.239188
3100	0.134	4.05E-04	4.16E-04	0.1141	0.1232	1.03E+00	1.071429	0.613406
550	0.134							
575	0.134	2.60E-05	0.00E+00	0.07848	0.08106	0.00E+00	1.628423	0.26601
5100	0.134	1.84E-04	7.37E-05	0.103	0.1127	4.01E-01	1.171251	0.528104

Table 2: Reduction factors for Rough Cubes, Tetrapods & Large Rock

3. Reanalysis of data by Aminti & Franco 1988

Since the influence of the berm width can be better assessed for variable widths, it was believed more useful to retrieve the old data by Aminti and Franco (A&F) who tested a similar structure armoured with two-layer rock, tetrapods and cubes with three different crest berm widths: B/Dn= 3–5–7 (though with just one Hs).

The aim was to derive a gammab reduction factor (<=1) to be included in Van der Meer formula. Since tests by A&F were carried out for slopes 1:1.33 and 1:2 the resulting gammaf values were interpolated to achieve the value for a representative slope of 1:1.5.

Then the ratio of gammaf (B=0) / gammaf (B=3Dn) obtained in CLASH for these 3 units was applied to the gammaf values obtained from the A&F data to obtain the corresponding “virtual” coefficients for the untested B=0 case.

Then the A&F gamma factors for B=3-5-7 Dn were normalized to the virtual B=0 case (assuming gammab equal to 1) to obtained the requested gammab values as a function of B/Dn.

Finally, since the gammab values for B=0 and B= 3 Dn were very close to 1 (or even with an unrealistic negative trend), it was assumed gammab = constant = 1.0 for B < 3 Dn.

Then an exponential law was fitted to the three data sets and results are shown in figure 10 for the three types of units, assuming that gammab goes to zero when B goes to infinity (the very wide porous structure would significantly reduce overtopping).

The results show that narrow crest berms have negligible influence on wave overtopping; moreover the berms made with cubes seem to have the greatest effect on overtopping reduction.

Further datasets with extended berm widths and further unit types should be included in the analysis to confirm these results.

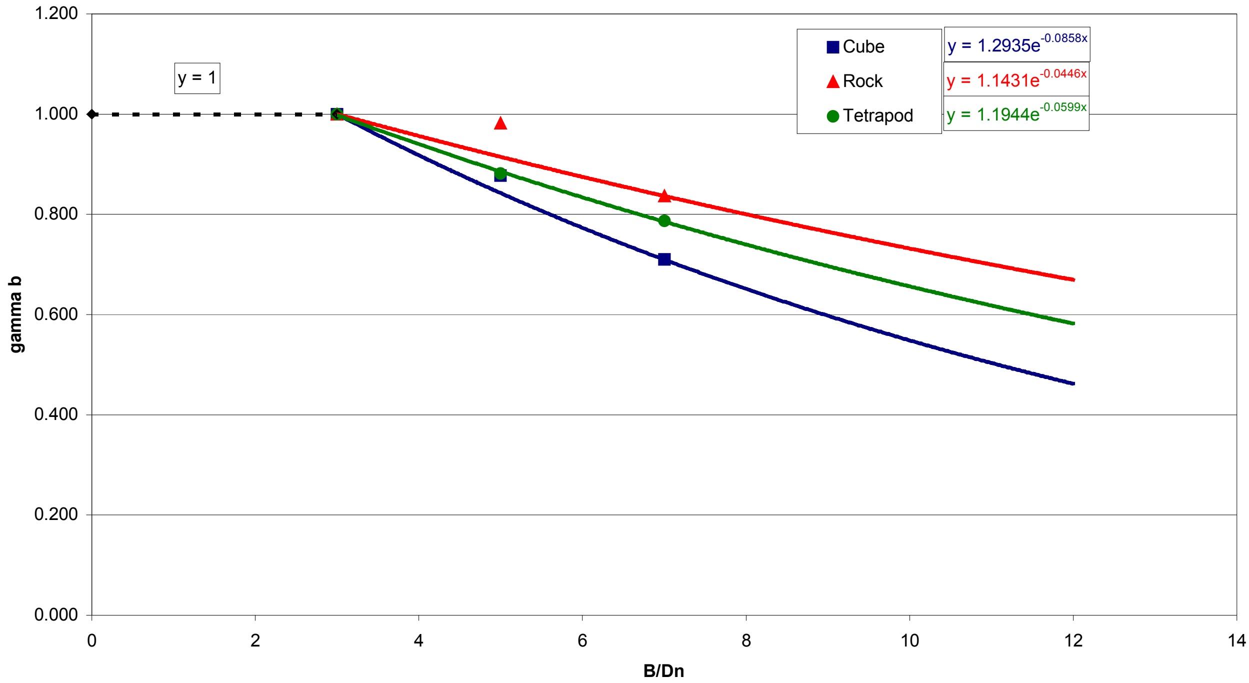


Figure10: Overtopping reduction factor due to armour crest berm width (based on Aminti-Franco 1988 data with B/Dn = 3-5-7)

Notation:

Dn = nominal armour unit diameter (m)

Ho = Wave height measured at seaward corner (m)

H3 = Wave height measured at the parapet wall (m)

qo = Overtopping discharge measured at corner (-)

q3 = Overtopping discharge measured at the parapet wall (-)

Cr = Reduction factor (Besley 1999- EA report W178) (-)

$Cr = 3.06\exp(-1.5B/H_s)$, where B is the berm crest width