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3D tests on overtopping for SSG wave energy converter

by

Lucia Margheritini
Jens Peter Kofoed

March 2007

Preface

This report presents the results of the first study based on laboratory tests of the behaviour of the SSG pilot module in 3D wave conditions. This study was recommended already during Phase 2 of the Co-operation agreement between WEVEnergy AS (Norway) and Aalborg University, Department of Civil Engineering of which the present report is part of Phase 5.
The tests have been realized at the Department of civil Engineering, AAU, in the 3D deep water tank with a scale model 1:60 to prototype and a reproduced bathymetry of the selected location at the time of the experiments. The overtopping rates of the individual reservoirs have been measured and the hydraulic efficiency calculated.
The results are given in terms of overtopping rates for the 3 reservoirs and hydraulic efficiency.

The tests have been performed by Lucia Margheritini with the supervision of Jens Peter Kofoed, AAU. The testing took place in 2 distinct moments with distinct procedures during October 2006 the first and December 2006 the second. The report has been prepared by Lucia Margheritini (e-mail: lm@civil.aau.dk).

Revision History

Version	***Date***	***Author***	***Comment***
0.0	10.07.2006	Lucia Margheritini	Initial draft
0.1	12.03.2007	Lucia Margheritini	Definitive delivery

1 Introduction

The present report describes the work done on 3D physical model tests on overtopping for the SSG wave energy converter. The tests have been performed in the wave tank at Aalborg University, in scale 1:60 compared to the prototype. The bathymetry in the immediate proximity of the pilot plant has been surveyed and the results have been used as the basis for the laboratory model. The SSG caisson model was built respecting the conclusions of the Technical report by Jens Peter Kofoed, 2005 and adapted to the overtopping measurements.
The three overtopping rates corresponding to the three reservoirs have been measured; furthermore, the flow rate over the entire structure was also measured.
The results were obtained during 2 distinct phases: during the first one, tests have been carried out simulating at the same time the direction of the specific wave conditions and the spreading. During the second one we wanted to separate the influence of direction and spreading so that tests have been carried out only with spreading or only with direction. The two set of tests led to different results.

Reasons of why running a second set of tests will be briefly explained; test results and their influence on the efficiency are presented in this report.

2 Objective of the study

Extensive 2D laboratory tests on the SSG have been done in order to evaluate the hydraulic efficiency of the device (Phase 3 of the Cooperation agreement). After those tests the hydraulic efficiency of the SSG design was found to be around 50% for 2D conditions.
The tests described on this report aim to redefine the hydraulic efficiency of the SSG pilot under 3D conditions to have an estimation closer to prototype testing. Going from 2D to 3D conditions, 3 different phenomena are expected to reduce the efficiency:

- Directionality.
- Spreading.
- 3D-ness of the structure (boundary effects, not optimal slope leading to the model…).

The present report proposes to investigate them all in the contest of the SSG pilot.

3 Experimental setup

The model of the SSG used in laboratory is in scale 1:60 to prototype and was fixed rigidly on a 3D concrete model of the cliff located in the middle of the basin at 5 m from the paddles. The cliff is the best reproduction of the scanned bathymetry of the prototype location and the model has been installed on it facing what in reality would be the West direction (270°) (Figure 1).

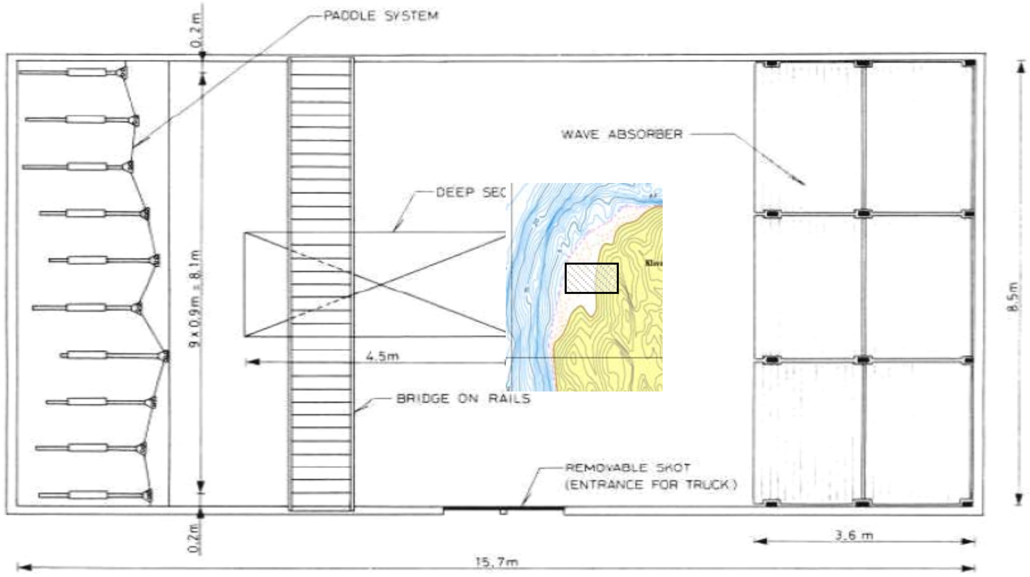


Figure 1. model setup in the wave tank at the hydraulic laboratory at AAU.

The front part of the model of the SSG has been realized according to the conclusions in the Technical report "Experimental Hydraulic Optimization of the wave energy converter Sea Slot-cone Generator", by Jens Peter Kofoed, 2005. The rear part of model was modified and equipped with four slopes leading to different small tank containers: one for each reservoir plus one for the overtopping of the whole structure (Figure 2). The captured overtopping water was then temporally stored and then pumped out again in the basin by small pumps of known capacity; the pumps were automatically activated when the water inside the single containers was reaching a certain pre-established level. By the total utilization of the pumps and the records of water levels inside the rear tanks, the overtopping volumes and flow rates have been derived for the single reservoirs.
The measuring equipment included:

- 4 wave gauges installed to measure time series of water levels in the reservoirs tanks.
- 7 resistive wave probes on a pentangle array placed on the plateau in front of the model, enabling the collection of data for 3D wave analysis.


Figure 2. Uncompleted SSG model during the installation in the tank (left), with back compartments equipped with pumps for the measurement of the overtopping rates (right).

3.1 Tested wave conditions

Table 1. Near shore wave conditions with available power.

Offshore Dir [deg])	Hs [m]	Tp [s]	Dir [deg]	Pwave [kW/m
NW1	1.2	6.1	315	3.8
NW2	1.7	7.9	313	10.0
NW3	2.2	9.3	310	18.7
NW4	2.6	10.6	308	29.8
NW5	3.2	11.7	305	52.7
NW6	4.4	12.7	303	106.1
W1	**1.3**	**6.1**	**270**	**4.4**
W2	**2.3**	**7.9**	**273**	**17.1**
W3	**3.4**	**9.3**	**275**	**44.9**
W4	**4.6**	**10.6**	**278**	**97.3**
W5	**5.9**	**11.7**	**280**	**176.5**
W6	**7.4**	**12.7**	**283**	**298.1**
SW1	0.8	6.1	225	1.6
SW2	1.7	7.9	230	9.8
SW3	2.9	9.3	235	34.4
SW4	4.1	10.6	240	77.7
SW5	5.3	11.7	245	139.4
SW6	6.5	12.7	250	229.4
S1	0.6	6.1	225	0.8
S2	1.0	7.9	228	3.2
S3	1.2	9.3	230	5.3
S4	3.2	10.6	233	47.6
S5	4.2	11.7	235	89.7
S6	5.5	12.7	238	161.8

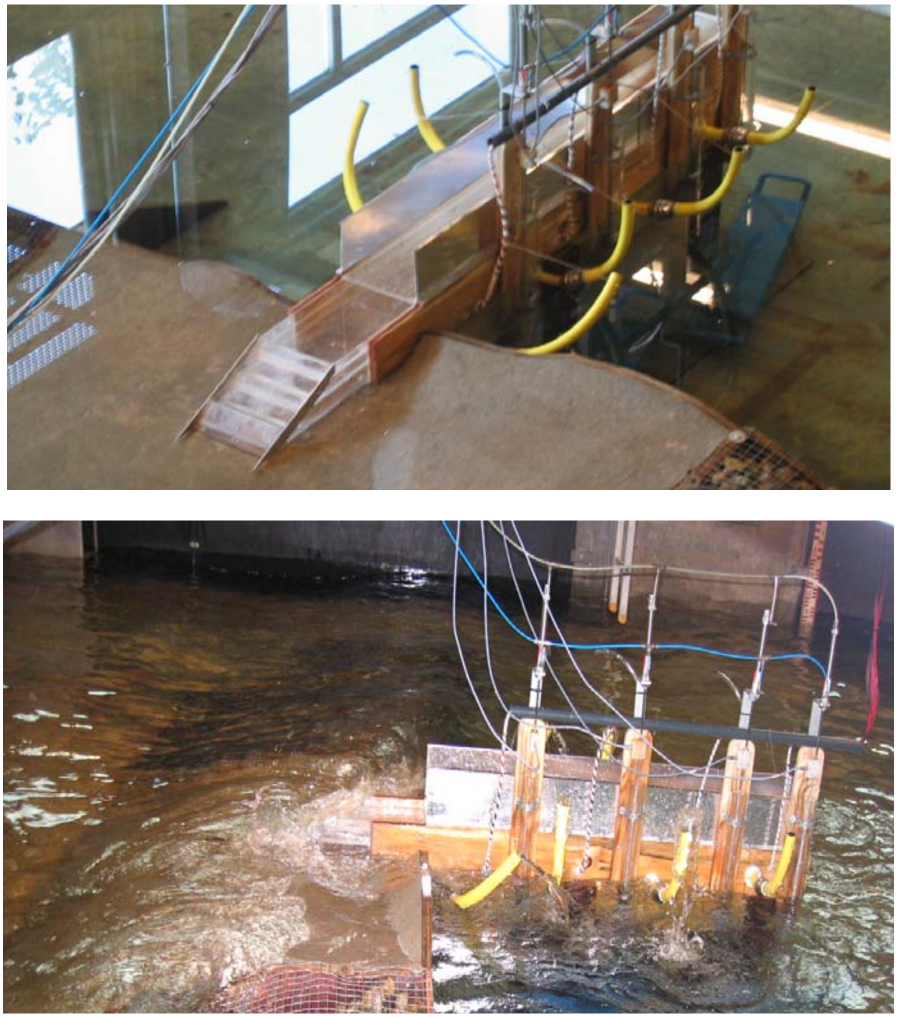


Figure 3. The completed model of the SSG sitting on the reproduction of the cliff at the selected location (above). Under the model during test W3D2S1L0N1.

Tested wave conditions refer to study by Jens Peter Kofoed, Florent Guinot, June 2005 (Phase 2) and do not include storm conditions. Even if the initial intention was to make a study covering all the wave climates at the selected location (Table 1), tests have been carried out focussing on the West direction, the most energetic, and on further investigations with an attack angle varying between -15° and 15° (directions between 255° and 285° at the pilot location), 8 spreading conditions and 3 water levels. The directional spreading (n) function adopted is expressed by the following form:

$$\cos^{2n}\left|(\beta - \beta_0)/2\right|$$

No practical need to investigate the other 3 offshore directions existed as the location for the SSG pilot was not longer certain during the laboratory tests.
Results are strictly dependent on the location as incoming waves are profoundly influenced by the bathymetry and topography of the specific site; therefore, if the final pilot location will be different from the tested one in the contest of these tests, the present results must be taken as a more general guide line. The need of separating the effects of 3D conditions on the efficiency of the SSG and not completely understood laboratory effects made it necessary to run a second set of tests.

First set of tests

On table 2 the test program of the first set of experiments with the full scale parameters is presented. Three different spreading conditions have been tested together with directionality. The tag ID of the tests indicates their main characteristics: W from 1 to 6 indicates the sea state (H_s and T_p and θ); D the offshore wave direction (1= North-West, 2 West, 3 South-West and South); L is the water level (0 = 0.50 m, 1 = 0.51 m and 2 = 0.53 m); N is a counter of the specific test. Information about spreading on the selected pilot location is missing so that three different spreading conditions have been tested: S0 = no spreading (spreading coeff. = 500), S1= low spreading (spreading coeff. = 200), S2 = high spreading (spreading coeff. = 50 and in one case = 20). Each test comprised approximately 1500 waves.

Table 2. First set of tests, where directionality and spreading were tested together.

Tests	Hs [m]	Tp [s]	Water level [m]	Dir [deg]	Lab. Spr [coeff]
W4D2S0L0N1	4.6	10.6	30	278	500
W4D2S0L0N2	4.6	10.6	30	278	500
W4D2S0L2N1	4.6	10.6	31.8	278	500
W4D2S0L2N2	4.6	10.6	31.8	278	500
W4D2S1L0N1	4.6	10.6	30	278	200
W4D2S1L0N2	4.6	10.6	30	278	200
W4D2S2L0N1	4.6	10.6	30	278	50
W4D2S2L0N2	4.6	10.6	30	278	50
W4D2S0L1N1	4.6	10.6	30.6	278	500
W4D2S1L1N1	4.6	10.6	30.6	278	200
W4D2S2L1N1	4.6	10.6	30.6	278	50
W4D2S0L1N2	4.6	10.6	30.6	278	500
W1D2S0L0N1	1.3	6.1	30	270	500
W1D2S0L2N1	1.3	6.1	31.8	270	500
W1D2S1L0N1	1.3	6.1	30	270	200
W1D2S2L0N1	1.3	6.1	30	270	50
W1D2S0L1N1	1.3	6.1	30.6	270	200
W1D2S1L1N1	1.3	6.1	30.6	270	50
W2D2S0L0N1	2.3	7.9	30	273	500
W2D2S0L2N1	2.3	7.9	31.8	273	500
W2D2S1L0N1	2.3	7.9	30	273	200
W2D2S2L0N1	2.3	7.9	30	273	20
W2D2S0L1N1	2.3	7.9	30.6	273	500
W2D2S1L1N1	2.3	7.9	30.6	273	200
W2D2S2L1N1	2.3	7.9	30.6	273	50
W3D2S0L0N1	3.4	9.3	30	275	500
W3D2S0L0N2	3.4	9.3	30	275	500
W3D2S0L2N1	3.4	9.3	31.8	275	500
W3D2S1L0N1	3.4	9.3	30	275	200
W3D2S2L0N1	3.4	9.3	30	275	50
W3D2S2L1N1	3.4	9.3	30.6	275	50
W3D2S0L1N1	3.4	9.3	30	275	500
W3D2S1L1N1	3.4	9.3	30.6	275	200
W5D2S0L0N1	5.9	11.7	30	280	500
W5D2S1L1N1	5.9	11.7	31.6	280	200
W5D2S0L1N1	5.9	11.7	31.6	280	500
W5D2S2L1N1	5.9	11.7	31.6	280	50
W6D2S0L1N1	7.4	12.7	31.6	283	500
W6D2S1L1N1	7.4	12.7	31.6	283	200
W6D2S2L1N1	7.4	12.7	31.6	283	50

Second set of tests

On table 3 the test program of the second set of experiments with the full scale parameters is presented. Eight different spreading conditions have been tested separately from directionality. The tag ID of the tests indicates their main characteristics: W from 1 to 6 indicates the sea state (H_s and T_p); D the offshore wave direction (1= North-West, 2 West, 3 South-West and South) and d the input direction; L is the water level (0 = 0.50 m, 1 = 0.51 m and 2 = 0.53 m); N is a counter of the specific test. In order to better understand the effect of spreading on the overtopping, 5 more different spreading conditions (S) added to the ones of the first set of tests have been tested (total of 8); moreover 2D pure conditions were also simulated in order to separate the effect of the 3D-ness of the structure. The letter I at the beginning of the name of the majority of the tests stays for Investigation on the influence of spreading and directionality. Each test comprised approximately 1500 waves.

Table 3. Second set of tests, where directionality and spreading were tested separately.

Test	Hs [m]	Tp [s]	Water level [m]	Dir [deg]	Lab. Spr [coeff]
IW4D2S0L1N1	4.6	10.6	30.6	270	2D
IW4D2S1000L1N1	4.6	10.6	30.6	270	1000
IW4D2S500L1N1	4.6	10.6	30.6	270	500
IW4D2S350L1N1	4.6	10.6	30.6	270	350
IW4D2S200L1N1	4.6	10.6	30.6	270	200
IW4D2S100L1N1	4.6	10.6	30.6	270	100
IW4D2S50L1N1	4.6	10.6	30.6	270	50
IW4D2S25L1N1	4.6	10.6	30.6	270	25
IW4D2S10L1N1	4.6	10.6	30.6	270	10
IW4D2d5S0L1N1	4.6	10.6	30.6	265	2D
IW4D2d10S0L1N1	4.6	10.6	30.6	260	2D
IW4D2d15S0L1N1	4.6	10.6	30.6	255	2D
IW4D2d-5S0L1N1	4.6	10.6	30.6	275	2D
IW4D2d-15S0L1N1	4.6	10.6	30.6	285	2D
IW2D2d10S0L1N1	2.3	7.9	30.6	260	2D
IW2D2d-10S0L1N1	2.3	7.9	30.6	280	2D
IW2D2S0L1N1	2.3	7.9	30.6	270	2D
IW2D2S10L1N1	2.3	7.9	30.6	270	10
IW2D2S50L1N1	2.3	7.9	30.6	270	50
IW2D2S1000L1N1	2.3	7.9	30.6	270	1000
IW2D2d10S0L1N2	2.3	7.9	30.6	260	2D
IW2D2d-10S0L1N2	2.3	7.9	30.6	280	2D
IW3D2d10S0L1N1	3.4	9.3	30.6	260	2D
IW3D2d-10S0L1N1	3.4	9.3	30.6	280	2D
IW3D2S0L1N1	3.4	9.3	30.6	270	2D
IW3D2S0L1N1	3.4	9.3	30.6	270	2D
IW3D2S10L1N1	3.4	9.3	30.6	270	10
IW3D2S50L1N1	3.4	9.3	30.6	270	50
IW3D2S1000L1N1	3.4	9.3	30.6	270	1000
IW5D2d10S0L1N1	5.9	11.7	30.6	260	2D
IW5D2d-10S0L1N1	5.9	11.7	30.6	280	2D
IW5D2S0L1N1	5.9	11.7	30.6	270	2D
IW5D2S10L1N1	5.9	11.7	30.6	270	10
IW5D2S50L1N1	5.9	11.7	30.6	270	50
IW5D2S1000L1N1	5.9	11.7	30.6	270	1000

4 Results of performed model tests - First set –

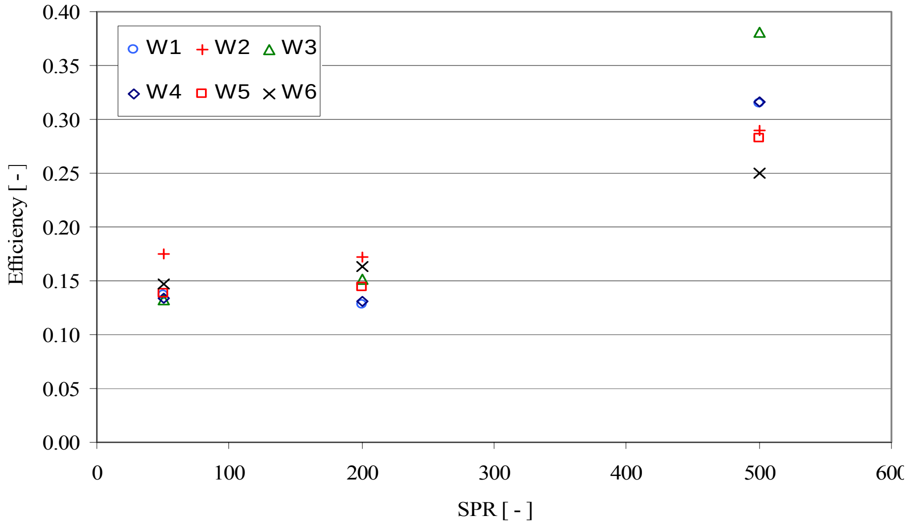
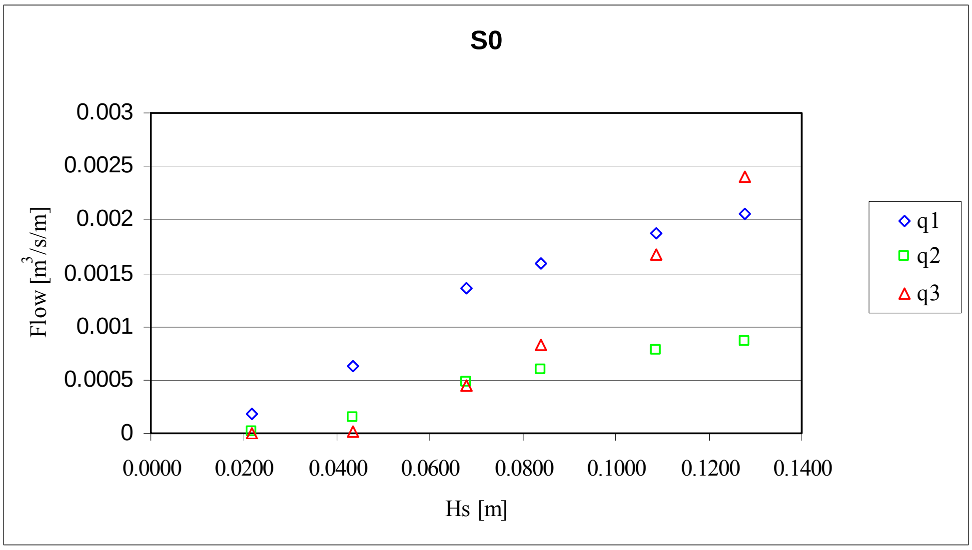
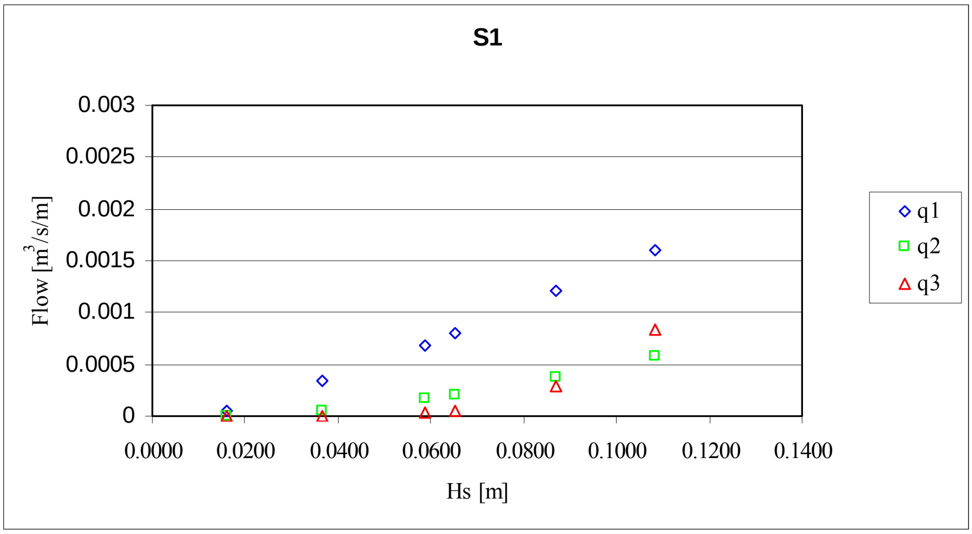


Figure 4. First set of results. The spreading is the target spreading for the tests and the efficiency is the hydraulic efficiency calculated for the specific test.

In Figure 4 the results are plotted in terms of hydraulic efficiency. The very high spreading coefficient 500 corresponds to 2D (no spreading) conditions in a 3D set up, while SPR = 200 and SPR = 50 are indicating respectively a low and high spreading. No relevant difference between low and high spreading has been registered while a dramatic drop on the efficiency must be noticed when passing from a condition with no spreading to a condition with spreading. Moreover no relevant difference exists in between the results from the two distinct conditions.
With regard to single spreading conditions, while for S1 and S2 the efficiency of the single sea states collapses around the same value (16%), for S0 the higher efficiency (38%) is for W3, followed by W1, W4 and W2; lower efficiency corresponds to the higher sea states (W5 and W6). This reflects the fact that the structure has been designed for those sea states that also have the higher probability of occurrence.
A non expected and not reasonable decrease of efficiency from the 2D to 3D tests occurred: from 50% to 15%! Expected was a reduction to 40% (from 50% in 2D conditions) of the hydraulic efficiency, due to the 3D-ness of the structure (boundary effects, not optimal slope leading to the model) but not down to 15% as it resulted.
In figure 5 the flow rates in the 3 different reservoirs for the 3 different spreading conditions. The trend of the overtopping flows for each reservoir compared well with the trends in 2D conditions, converting to a threshold for res. 1 and 2 and exponential for res. 3. The results confirm the above conclusions: the two conditions with spreading (S1 and S2) give almost the same flow rates for the same H_s, while distinct is the 2D condition (S0, with spreading coefficient of 500). This led to the conclusion that something needed to be investigated in cases with spreading and directionality simulated within the same test.


S0
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
Flow [m^3/s/m]
0.0000
0.0200
0.0400
0.0600
0.0800
0.1000
0.1200
0.1400
Hs [m]
q1
q2
q3


S1
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
Flow [m^3/s/m]
0.0000
0.0200
0.0400
0.0600
0.0800
0.1000
0.1200
0.1400
Hs [m]
q1
q2
q3

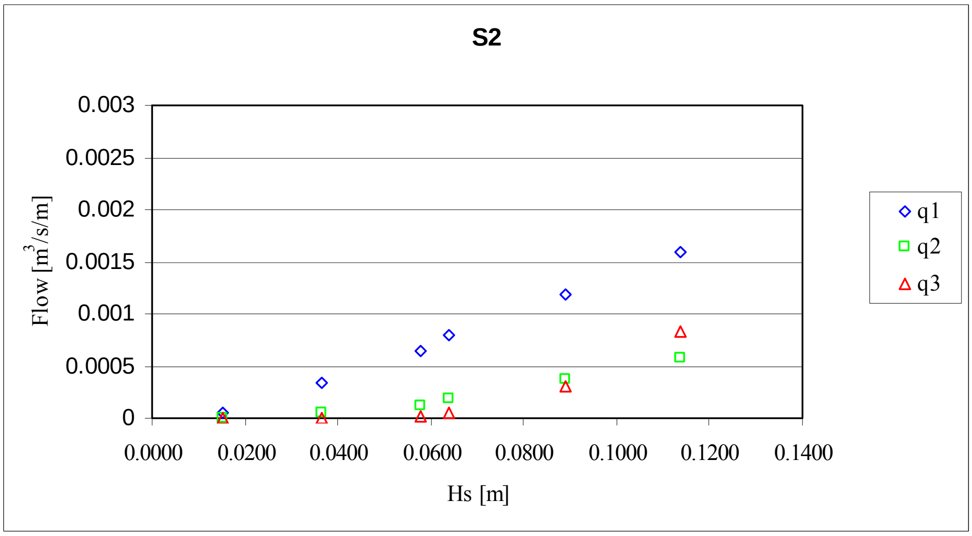
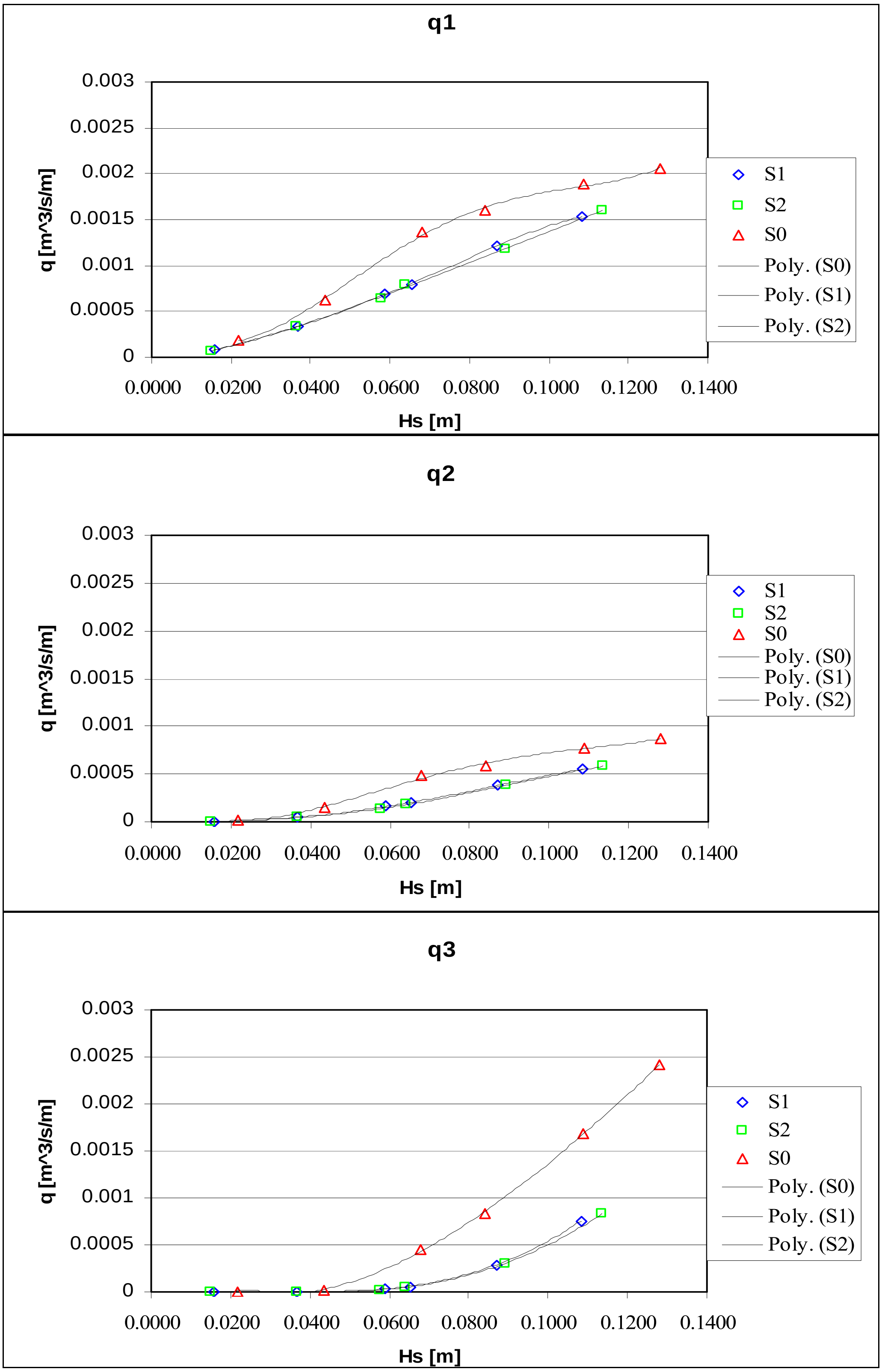

S2
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
Flow [m^3/s/m]
0.0000
0.0200
0.0400
0.0600
0.0800
0.1000
0.1200
0.1400
Hs [m]
q1
q2
q3

Figure 5



q1
q [m^3/s/m]
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
0.0000
0.0200
0.0400
0.0600
0.0800
0.1000
0.1200
0.1400
Hs [m]
S1
S2
S0
Poly. (S0)
Poly. (S1)
Poly. (S2)
q2
q [m^3/s/m]
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
0.0000
0.0200
0.0400
0.0600
0.0800
0.1000
0.1200
0.1400
Hs [m]
S1
S2
S0
Poly. (S0)
Poly. (S1)
Poly. (S2)
q3
q [m^3/s/m]
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
0.0000
0.0200
0.0400
0.0600
0.0800
0.1000
0.1200
0.1400
Hs [m]
S1
S2
S0
Poly. (S0)
Poly. (S1)
Poly. (S2)

Figure 6

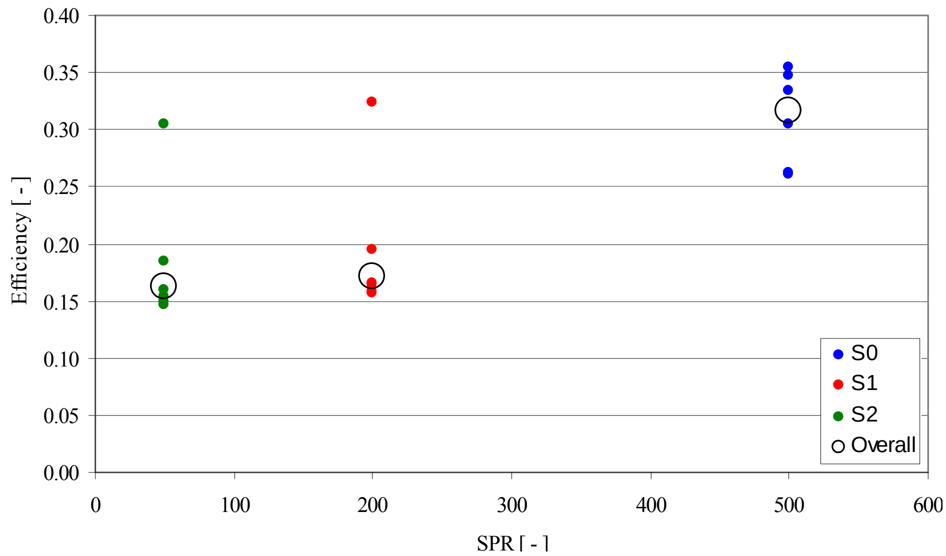


Figure 7. Average results for each spreading condition.

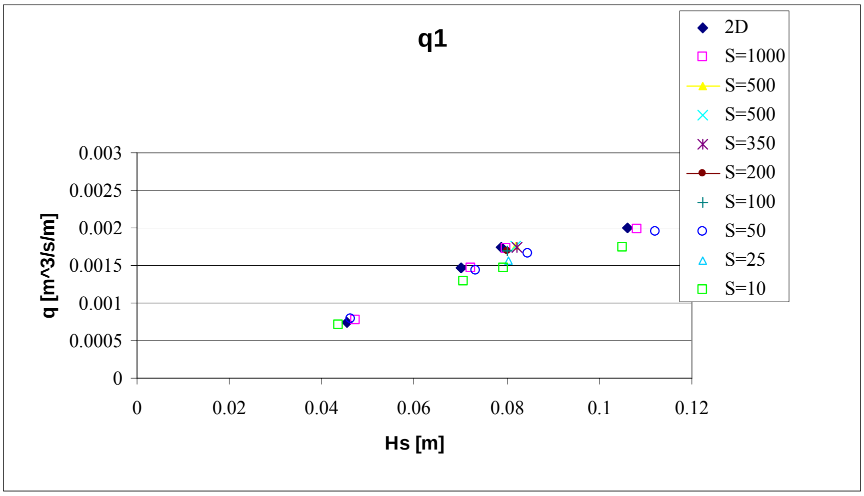
In figure 6 a correlation of the laboratory results has been done for the flow rates in the three reservoirs (q1, q2 and q3).
Two different trends for the flow rates have been distinguished: the first and second reservoir have almost a liner increase of the overtopping while increasing with a dump for the S0 condition; the third reservoir shows an exponential increasing trend with increasing H_s due to the absence of a roof above it.
It is clear that the flow rate for every reservoir is decreasing with the increasing spreading and again that the values of the flow rates for the condition with low spreading and the condition with high spreading are almost the same in the same reservoir, while distinct is the trend in 2D conditions for which the overtopping flow rate is higher.
In conclusion, the results from the first set of tests are an unexpected high reduction of efficiency (figure 7) from the 2D tests:

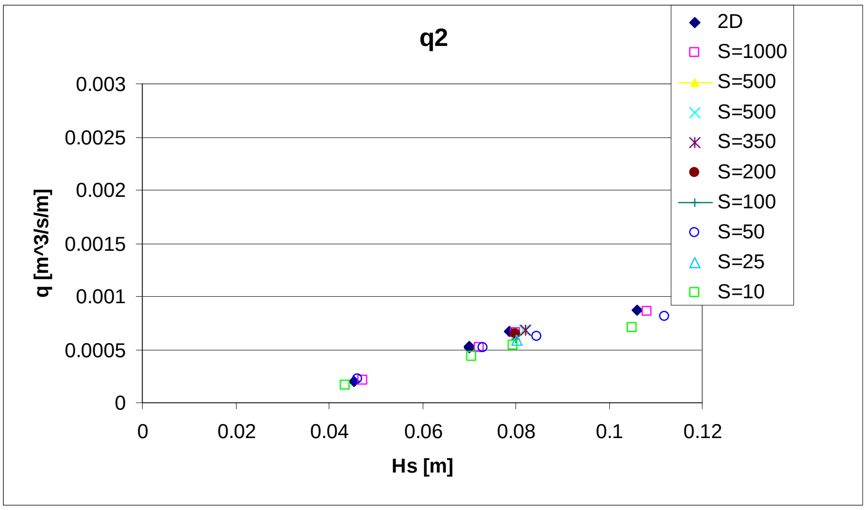
- 3D structure, 2D waves: 31.7 % (blue spots),
- 3D structure, small directional spreading: 17.2 % (red spots),
- 3D structure, large directional spreading: 16.3 % (green spots).

The almost inexistence of differences between the two different spreading conditions is not justified because of the proved decrease of energy reaching the structure in the case with high spreading compared to the low spreading case that is instead more similar to the 2D conditions (see note further).
What made up the conviction of the need of further investigations was:

1. The unexpected reduction of efficiency;
2. the absence of a significant difference in between tests with high spreading and low spreading;
3. the suspect of laboratory effects (see further).

5 Results of performed model tests – Second set –





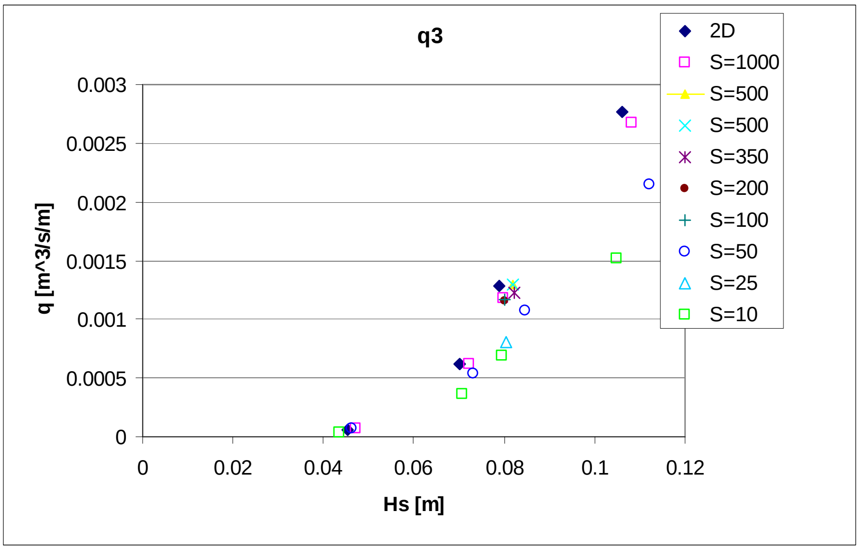


Figure 8. Flow rates into the 1st, 2nd and 3rd reservoir for different wave heights and input spreading coefficients.

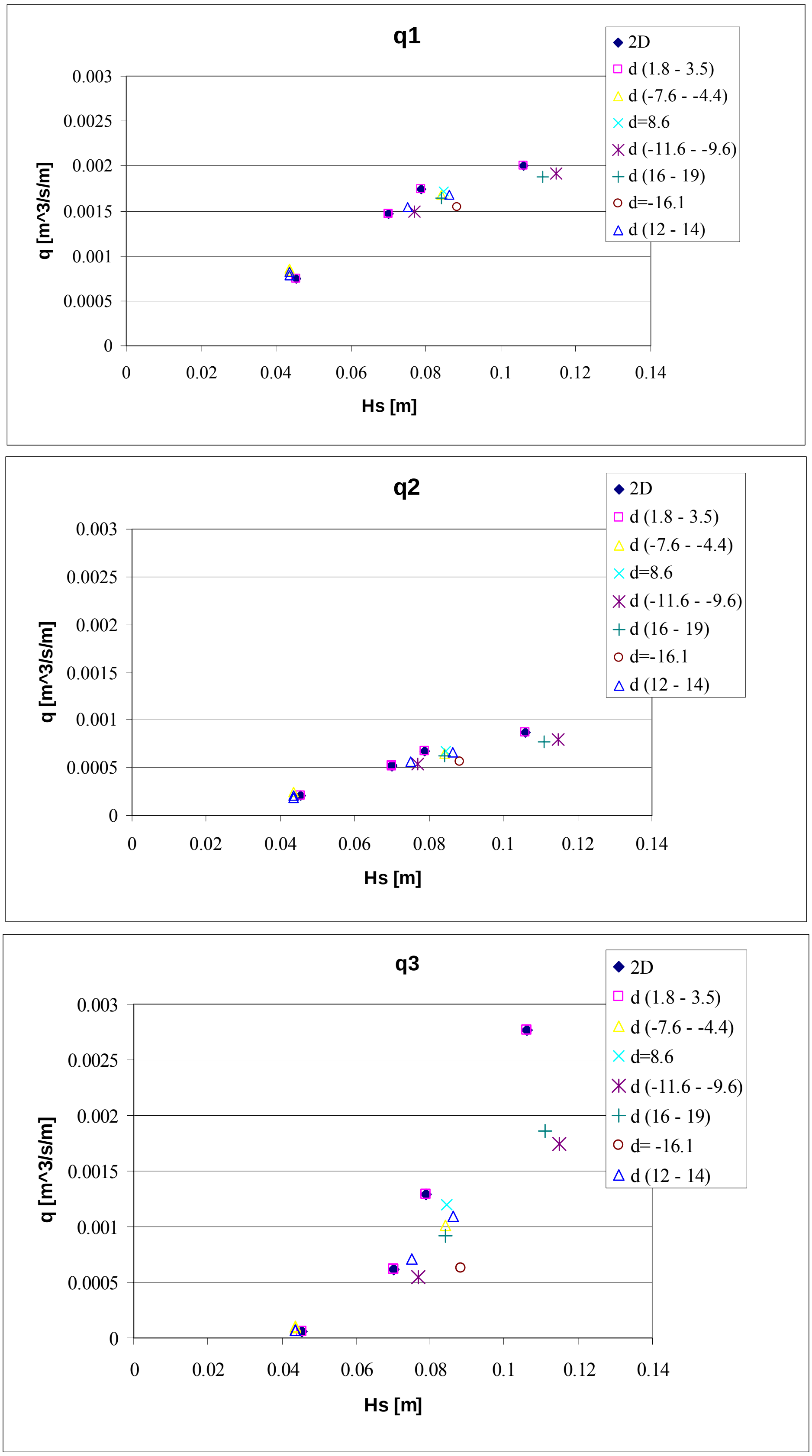


Figure 9. Flow rates into the 1st, 2nd and 3rd reservoir for different wave heights and measured directions.

The first set of tests was carried out simulating each wave condition with its characteristic significant wave height, period and direction (H_s, T_p and θ). Each test was run three times adding three different spreading conditions (S0, S1 and S2). The results showed a non expected and not reasonable decrease of efficiency from the 2D tests to 3D tests. Because of this reason, the influence of direction and spreading wanted to be separated imputing an error in the previous results due to laboratory effects. The new tests were carried out adding to each wave condition, first directionality and after spreading, so that for each wave height we had results from 3 or more tests with direction (d) and separately 3 or more tests with different spreading (S).
In figure 8 flow rates of the tests for the 3 reservoirs (q1, q2 and q3) are plotted for different spreading conditions. The results appear grouped in the graphics depending on the wave high (increasing with H_s). While little difference can be noticed comparing the 2D and the different spreading conditions in reservoir one and two, in reservoir number three for higher H_s the difference between tests with low spreading (≈ 2D conditions) and high spreading are relevant.
In figure 9 the flow rates for the three reservoirs are plotted for different attack angles ($\theta = 0 =$ direct attack). Again little difference can be noticed in reservoir 1 and 2 by increasing θ for the same H_s, while in reservoir number three the flow rates (q3) are very influence by the directionality. A local effect can also be distinguished by a closer look to the graphic: for the same wave highs waves with a positive attack angle ($+\ \theta$) give a bigger flow rate in the 3rd reservoir than the ones with a negative attack angle ($-\ \theta$) and comparable absolute value. This is probably due to the influence of the bathymetry which has a steep slope or focusing characteristics on the left part of the structure (facing the sea).
This asymmetry of results is even more evident when plotting the efficiency.
In Figure 10 (left) the calculated efficiency of laboratory tests with and without spreading is plotted against the efficiency with spreading divided the efficiency without spreading. In black the overall trend of the results depending on spreading. A local effect regards the W2 condition and it could be imputable to the different interaction of the specific short period of the waves with the bathymetry.
In Figure 10 (right) the calculated efficiency of laboratory tests with and without directionality is plotted against the efficiency with directionality divided the efficiency without directionality. Again the W2 condition behaves weirdly when adding an attack angle. What all the tests present is an asymmetry of the graphic; the black line gives a fourth order approximation of the results and proves this statement.

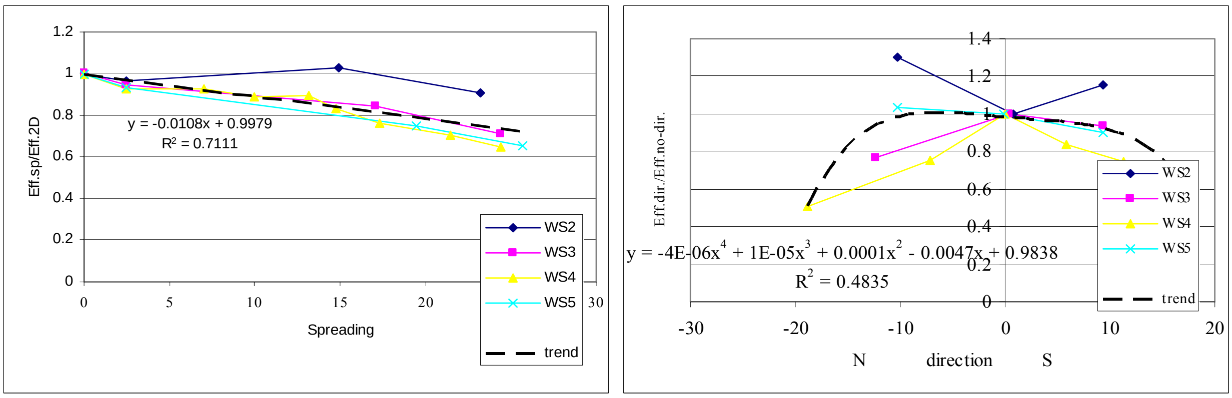


Figure 10. Left. Tests results from laboratory plotted against the efficiency with spreading divided by the efficiency without spreading. The results are plotted for 4 different wave conditions.
Right. Tests results from laboratory plotted against the efficiency with spreading divided by the efficiency without spreading. The results are plotted for 4 different wave conditions.

Not all the range of attack angles has been tested; in reality at the selected SSG pilot location the attack angle can be ±40° while in the laboratory only an attack angles up to±15°have been tested. Despite of this subjective reflections suggested that the efficiency can not decrease to 0 while increasing the attack angle in a range between ±40°. What it is expected to happened in that cases is that local phenomena will convert the waves to the structure and the efficiency will convert to a low threshold. For this reason the trend of the red line in figure 11 is suggested for the location tested in laboratory. The asymmetric effect still present but a limit has been stetted up for the lowest decrease of efficiency from the 2D conditions; the reduction of efficiency has been estimated to be of 0.6 for the NW directions while 0.45 for the SW directions. Nevertheless this is just a guess and when the location for the SSG will be sure, extensive results on directionality are recommended. This kind of investigation is important when the location is defined only, because different bathymetries interact differently with incoming waves.

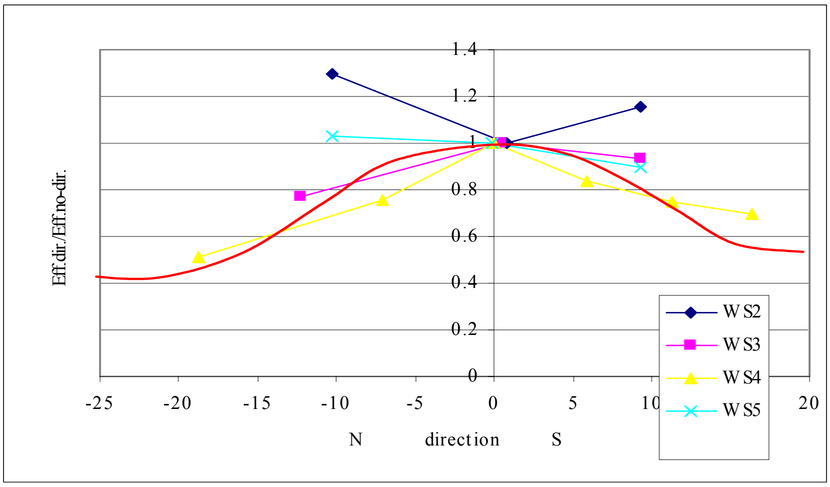


Figure 11. Suggested trend of normalized efficiency depending on attack angle at the SSG structure (selected location).

5.1 Comparison to previous 2D model tests on overtopping

The results from the laboratory tests indicate a decrease of efficiency from 50% in 2D conditions as follow:

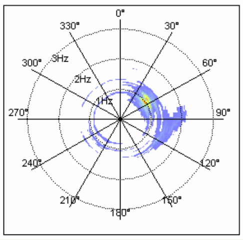
- to 40% due to 3D characteristic of the structure (as expected).
- to 30% (severe spreading). Spreading coming with waves can not be avoided and depending on its magnitude, it can decrease the hydraulic efficiency of the pilot project. In average it can be said that spreading decreases efficiency up to 32%.
- to 25% for unfavourable attack angle on the structure. The influence of directionality is difficult to classify as strictly dependent on the bathymetry of the area and different wave conditions interact differently with the bottom; in average it can be said that directionality decreases efficiency up to 35%.

The combination of 3D-ness, spreading and directionality can not be investigated in laboratory but in the most severe condition the guess is that in overall decrease of efficiency would be from 50% to15%. In average the overall decrease would be from 50% to 25%.

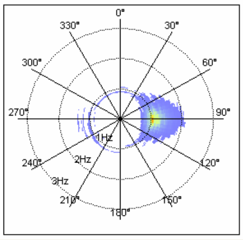
Note

On table 4 the directional spectrum of some of the generated sea states from the 3D analysis are presented; on the left, for the first set of tests where direction and spreading were generated together, conditions with low and height spreading generated a very weird spectrum (laboratory effects). In the middle and on the right, 3D analysis from the second set of tests for the same H_s and T_p but separating the direction from spreading result normal.

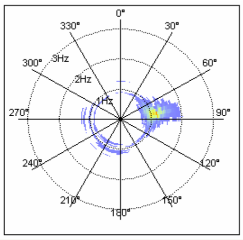
Table 4



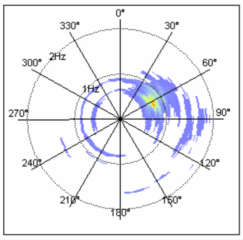
W2D2S2L1N1



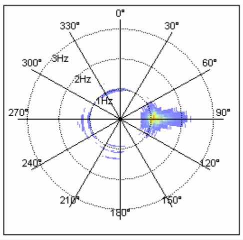
IW2D2S50L1N1



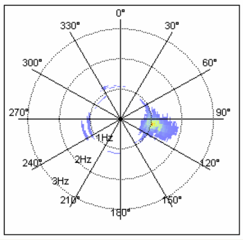
IW2D2d-10S0L1N1



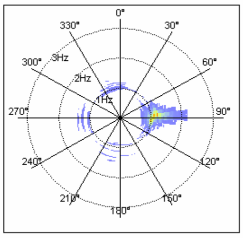
W2D2S1L1N1



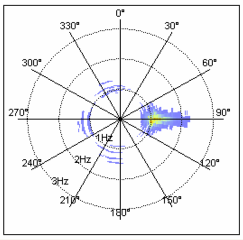
IW2D2S1000L1N1



IW2D2d10S0L1N1



W2D2S0L1N1



IW2D2S0L1N1

6 Conclusions

The first set of tests proved a reduction of the efficiency passing from 2D to 3D conditions and the causes have been investigated by the second set of tests. From these results the following conclusions have been reached:

1. a reduction of efficiency from 50% (2D conditions) to 40% due to the 3D-ness of the structure has been calculated.
2. A reduction of efficiency from 50% (2D conditions) to 32% due to spreading has been calculated.
3. A reduction of efficiency 50% (2D conditions) to 35% due to directionality has been calculated.
4. A reduction of efficiency 50% (2D conditions) to 25% due to the combination of 3d-ness, spreading and directionality has been calculated.
5. The negative spreading effect on the efficiency increases with the increase of the spreading.
6. The negative directionality effect on the efficiency increases with the increase of the attack angle.
7. The spreading effect on the overtopping flow rates is more pronounced for the 3rd reservoir where it can be seen a reduction up to 46% of the incoming flow (for high H_s). The same can be said for the directionality where it can be seen a reduction up to 35% of the incoming flow.
8. Prove of the influence of the bathymetry has been highlighted: waves with a positive attack angle (SW) have less negative influence on the flow rates and on the efficiency than the corresponding waves with a negative attack angle (NW).
9. The decreases on efficiency are strictly related to the pilot plat of the SSG wave energy converter not to the device in general: because the design of the module has a low width-to depth ratio therefore is very sensitive to directionality. Most of the problems would be reduced one that a line of modules one at the side of the others (breakwater set-up) will be realized.

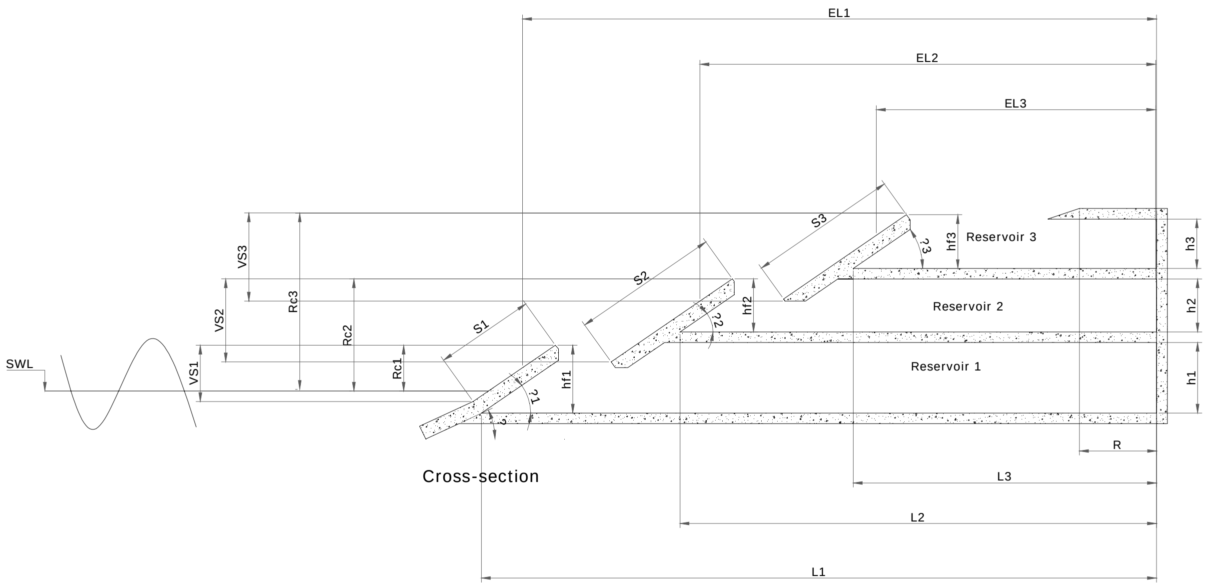
7 Literature

Kofoed, J. P. 2005 : *Model testing of the wave energy converter Seawave Slot-Cone Generator*. Hydraulics and Coastal Engineering No. 18, ISSN: 1603-9874, Dept. of Civil Eng., Aalborg University, April, 2005.

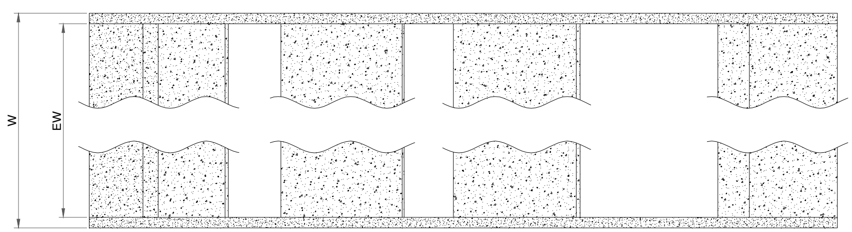
Kofoed, J. P. and Guinot, F. 2005 : *Study of Wave Conditions at Kvitsøy Prototype Location of Seawave Slot-Cone Generator*. Hydraulics and Coastal Engineering No. 25, ISSN: 1603-9874, Dept. of Civil Eng., Aalborg University, June, 2005.

Kofoed J. P. 2002 : *Wave Overtopping of Marine Structures – Utilization of Wave Energy*. Ph. D. Thesis, defended January 17, 2003 at Aalborg University. Hydraulics & Coastal Engineering Laboratory, Department of Civil Engineering, Aalborg University, December, 2002.

7.1.1 Appendix – Definition sketch



Cross-section



Top view

SWL = Still Water Level
EL1 = Effective Length of Reservoir 1
EL2 = Effective Length of Reservoir 2
EL3 = Effective Length of Reservoir 3
EW = Effective Width of the structure (not considering the walls)
h1 = Height of Reservoir 1
h2 = Height of Reservoir 2
h3 = Height of Reservoir 3
hf1 = Height Full (maximum filling) Reservoir number 1
hf2 = Height Full (maximum filling) Reservoir number 2
hf3 = Height Full (maximum filling) Reservoir number 3
L1 = Length of Reservoir 1
L2 = Length of Reservoir 2
L3 = Length of Reservoir 3
Rc1 = Reservoir 1 Crest free board relative to SWL
Rc2 = Reservoir 2 Crest free board relative to SWL
Rc3 = Reservoir 3 Crest free board relative to SWL
S1 = Slope length of Reservoir 1
S2 = Slope length of Reservoir 2
S3 = Slope length of Reservoir 3
VR1 = Volume Reservoir 1 (= EW * EL1 * hf1)
VR2 = Volume Reservoir 2 (= EW * EL2 * hf2)
VR3 = Volume Reservoir 3 (= EW * EL2 * hf3)
VS1 = Vertical size of Reservoir 1 slope
VS2 = Vertical size of Reservoir 2 slope
VS3 = Vertical size of Reservoir 3 slope
W = Width of the structure
? = angle at the toe of the structure
?1 = inclination angle of reservoir 1 front plate
?2 = inclination angle of reservoir 2 front plate
?3 = inclination angle of reservoir 3 front plate