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AmWaj Island development, Bahrain

Physical modelling of submerged breakwaters

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WL | delft hydraulics

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ABSTRACT:

The AmWaj Islands Project involves the development of a new island off the north coast of Muharraq Island in Bahrain (see Figure 1). To protect this new island from wave attack, a scheme of submerged breakwaters has been planned, which should also function as the anchor for a sandy beach, preventing the sand from being washed out into the sea. Two of the technical aspects to be considered in the design process is the amount of wave transmission over the breakwaters (important for the beach stability analysis) and the stability of the armour layer on the breakwater. The present test programme was designed to investigate these aspects for a number of different breakwater configurations.

REFERENCES: Fax MLS/1063/CON, dd. 6 March 2002 Commissioning of work
Fax MLS/1114/OBW, dd. 4 April 2002 Commissioning of additional test series

VER.	ORIGINATOR		DATE	REMARKS	REVIEW		APPROVED BY	
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Contents

List of Symbols

D_{nXX}	diameter $D_{nXX}=(M_{XX} / \rho_s)^{1/3}$	(m)
Fr	number of Froude, defined as $Fr=V^2 / gL$	(-)
g	gravitational acceleration	(m/s^2)
h	water depth at the toe of the structure	(m)
H_{m0}	measured wave height based on the energy density spectrum, defined as $H_{m0}=4\sqrt{m_0}$	(m)
H_s	significant wave height (time domain)	(m)
$H_{s,t}$	significant transmitted wave height	(m)
m_{0i}	area under the incident energy density spectrum	(m^2)
L	characteristic length	(m)
M_{XX}	mass of stones given by XX% on weight exceedance curve	(kg)
n_L	length scale	(-)
N_s	stability number	(-)
Re	Reynolds number	(-)
s_{op}	wave steepness based on peak wave period	(-)
T_p	peak wave period	(s)
V	velocity	(m/s)
Δ	relative density of stone, defined as $\Delta=(\rho_s-\rho_w)/\rho_w$	(-)
ρ_s	density of stone	(kg/m^3)
ρ_w	density of water	(kg/m^3)

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1 Introduction

1.1 Background

The AmWaj Islands Project involves the development of a new island off the north coast of Muharraq Island in Bahrain (see Figure 1). To protect this new island from wave attack, a scheme of submerged breakwaters has been planned, which should also function as the anchor for a sandy beach, preventing the sand from being washed out into the sea. The report by Pilarczyk (2002) describes the conceptual design of these breakwater structures.

Two of the technical aspects to be considered in the design process is the amount of wave transmission over the breakwaters (important for the beach stability analysis) and the stability of the armour layer on the breakwater. The present test programme was designed to investigate these aspects for a number of different breakwater configurations.

In their fax (MLS/1063/CON, dd. 6 March 2002) OSSIS Property Developers commissioned WL | Delft Hydraulics to perform 2-dimensional physical model testing on 8 breakwater cross-sections. An additional test series was commissioned on 4 April, 2002 (Fax MLS/1114/OBW) from OSSIS to WL | Delft Hydraulics.

The tests were performed in March and April 2002 by Mr. P. A. Pasterkamp and Mr. J. Ouderling in a wave flume created in the Vinje Basin at the de Voorst location of WL | Delft Hydraulics. The project leader was Mr. G.M. Smith, who also prepared this report. Technical guidance on behalf of OSSIS was provided for this study by Mr. P. de Bruin.

1.2 Objective of the study

The objective of the 2D model was to evaluate the performance of 8 different cross-sections of the breakwater with respect to wave transmission and the stability of the rock armour. Two different crest elevations were tested, 4 crest widths and 2 sizes of rock armour were tested for 2 different water levels.

It is noted that the stability or the behaviour of the beach behind the breakwater has not been evaluated in this study.

2 Boundary conditions

The hydraulic and structural design conditions for the tests were provided by OSSIS.

2.1 Hydraulic boundary conditions

The hydraulic boundary conditions applied for the tests were:

Wave height:	H_s	= 2.5 m
Wave period:	T_p	= 8.0 s
High water level	HWL	= CD + 3.5 m
Low water level	LWL	= CD + 2.4 m

A foreshore of uniform slope of 1:50 was applied from the toe of the breakwater to a depth of about CD -6m.

2.2 Structural design conditions

Eight cross sections have been tested. Four of these sections had a crest elevation of CD + 0.8 m and four with a crest elevation of CD + 1.5m. Four crest widths were tested, 50m, 40m, 30m and 20m, for each of the 2 elevations.

The design cross-section consisted of a core of geotubes overlain with a granular filter and an armour layer. The geotubes had a width of about 10 m. The height of the geotubes varied, depending on the crest elevation of the section. For the section with the crest at CD + 0.8m, the height of the geotube was 1.5 m (See Figure 2). For the section with the crest at CD + 1.5m, the height of the geotube was 2.2 m (See Figure 3). These cross-sections, along with the rock gradations named “Armour 1” and ”Filter 1” in the table below have been specified by OSSIS at the start of the project.

Two armour layer gradations and 2 filter layer gradations have been tested. The properties of these rock gradations are listed in Table 2.1 below and shown graphically in Figure 4.

	Gradation	M_{50} (kg)	D_{n50} (m)
Armour 1	300 - 1000	612	0.61
Filter 1	60 - 300	188	0.41
Armour 2	100-500	341	0.50
Filter 2	10 - 60	26	0.21

Table 2.1 Tested armour and filter gradations

The filter layer “Filter 2” is relatively fine compared to “Filter 1”. The gradation for Filter 2 is based on general design practice, that the filter gradation is about 1/10 of the armour gradation, by weight. For filter gradations larger than 10-60 kg it may be required to first place a finer gravel layer over the geotubes for protection purposes.

3 Facility and model set-up

3.1 Vinjé Basin

The physical model tests were performed in the Multi-directional wave basin of WL | DELFT HYDRAULICS ('De Voorst'). This wave basin has a width of 26.4 m and a length of 30 meters. In this basin a flume with a width of one meter was constructed (Photograph 2).

The facility is equipped with a wave board with 80 paddles for generating regular/monochromatic and irregular/random waves in relatively shallow water by a translatory wave board. The on-line computer facilities for wave board control, data-acquisition and data-processing allow for direct control and computation of relevant wave characteristics. The wave board has active wave absorption which means that waves propagating towards the wave board are measured and that the motion of the wave board compensates for these reflected waves so that these waves do not re-reflect towards the model. Active wave absorption is essential for the present tests since the breaking waves on the foreshore result in reflected energy, especially in the low-frequencies. In these tests second-order wave generation is used.

3.2 Model set-up

3.2.1 Model scale

The scale of the 2D model was determined based on the design wave and water level conditions. The length scale factor chosen was n_L=20.

For the water motion in free surface waves gravitational and inertial forces are the dominant factors. Consequently the ratio of these forces in prototype and model should be equal. Therefore the Froude number Fr (defined as the ratio of gravitational to inertial forces) should be reproduced in the model on a scale $n_{Fr} = 1$. From the so-called Froude scaling law the following relationships, expressed in terms of the length scale factor n_L, are derived:

Wave height H(m)	$n_H = n_L$
Wave period T(s)	$n_T = n_L^{0.5}$
Velocity V(m/s)	$n_H = n_L^{0.5}$
Mass M (kg)	$n_H = n_\rho \cdot n_L^3$

Turbulent flow in the armour layer (as in nature under design conditions) will be ensured if the Reynolds criterion has been met:

$$\mathrm{Re} = \frac{\sqrt{gH_s} \cdot D_n}{\nu} > 3 \cdot 10^4 \tag{3.1}$$

For the present design conditions (with a scale of 20) the Re-number equals $3.3*10^4$. This criterion was thus fulfilled.

The scaling of stability was achieved by ensuring that the stability number N_s was the same in model and nature. The differences in water density (salt and fresh) and in the armour density are accounted for in this parameter. The stability number is defined as

$$N_s = \frac{H_s}{\Delta D_n} \tag{3.2}$$

where H_s is the significant wave height, Δ is the relative weight of the armour and D_n is the nominal diameter of the armour units. With this relation (Eq. 3.2) the model scale is determined by the ratio of wave height in prototype to wave height in the model.

$$n_L = \frac{H_{s,p}}{H_{s,m}} = \frac{\Delta_p}{\Delta_m} \cdot \left(\frac{M_p}{M_m}\right)^{1/3} \cdot \left(\frac{\rho_p}{\rho_m}\right)^{1/3} \tag{3.3}$$

Subscript p refers to the prototype, m to the model.

3.3 Measurements

Six wave height meters (WHM) were used to measure the waves in the model. The incoming and reflected waves were determined by means of arrays of three wave gauges. In the first series of tests one array was placed in front of the wave generator and a second array was placed behind the breakwater to measure the transmitted wave height. The same wave conditions were used in the 2nd series of tests. So, in that series the array of WHM's at the wave generator was moved to the toe of the breakwater. In this way information was also obtained over the influence of the foreshore on the waves. In the 3rd series of tests, different wave conditions were applied and the waves were therefore measured using an array at the wave generator and a new array at the toe.

The assessment of armour layer stability was made by placing the armour layer in coloured bands and taking photographs before and after each test. In this way the movement of individual armour stones could be easily detected. After each stability test, the number of displaced stones from each band was counted and related to the number of stones originally in the band, so that the damage percentage could be determined.

4 Model construction and test programme

4.1 Model construction

The submerged breakwater consisted of a core, constructed from geotubes filled with sand, overlain by a filter layer and a cover layer. The geotubes had a width of about 10 m and were placed across the width of the flume. A number of geotubes were placed one directly behind the other to complete the core (see example on Photo page 1).

The geotubes were modelled by cotton bags fitted with a zipper. These bags were placed in the appropriate position in the flume and were filled with dry sand to about the desired dimensions (width and height). Water was then poured into the bags in order to compact the sand; due to the permeable nature of the bags the water could drain freely. When needed additional sand was placed in the bags and this procedure was repeated until the correct height was achieved. The purpose of the geotubes is to retain the sand so that it cannot be washed out through the rock armour layers. They must therefore be permeable enough to allow drainage of water but not the sand. This was achieved in the model. No other measurements of the actual properties of the applied fabric, or the geotubes in general, were made, as this was not considered to be relevant to the process of transmission or armour stability and was not included in the scope of the present study.

For Series 1 and 2, the 50 m wide crest was constructed and tested first. The narrower crest widths were achieved by removing the landward most section of the breakwater to the desired crest width and then reconstructing the filter and armour layers.

Cross-sections of the different structures are tested are shown in the following figures:

Cross section 1, tested in Series 1 is shown in Figure 2.
Cross section 2, tested in Series 2 and 3 are shown in Figure 3.

4.2 Test programme

The 1st and 2nd test series were performed with the following water level and wave conditions (at the location of the wave generator):

Test number	Water Level (m wrt CD)	H_s (m)	T_p (s)
1,3,5,7	+3.5	2.5	8.0
2,4,6,8	+2.4	2.5	8.0

Table 4.1 Tested wave and water level conditions for Series 1 and 2

For each water level the 4 tests were performed for different crest widths, 50 m, 40 m, 30 m and 20 m, respectively. For all of these tests the transmitted wave height behind the breakwater was measured. For the tests with the 50 m and 20 m wide crest the stability of the armour layer was also determined.

The 3rd test series was performed with slightly lower waves, to examine the behaviour of a lighter rock gradation, which could be applied in sections where the breakwater is located in shallower water. The applied conditions were:

Test Number	Water Level (m wrt CD)	H_s (m)	T_p (s)
1	+3.5	2.0	7.3
2	+3.5	2.5	8.0
3	+2.4	2.0	7.3
4	+2.4	2.5	8.0

Table 4.2 Tested wave and water level conditions for Series 3

For all of these tests the transmission and stability were determined.

All tests were performed with about 1000 waves, which was sufficient to determine the statistical and spectral properties of the incoming waves. All tests were performed with a JONSWAP spectrum, with a peak enhancement factor of $\gamma = 3.3$.

The tests for Series 1 are numbered 101,102 etc. Similarly the tests for Series 2 and 3 are numbered 201, 202,... and 301, 302... etc.

5 Results

The results of the transmission and stability tests are presented in the following sections. For the transmission results of the measured transmission coefficients are presented in table form and in graphical form (Figure 5). In Figure 6 the measured results are compared with some recent design formulae. Results of the stability tests are presented in table form in the following sections, in terms of the percentage of displaced stones on the breakwater. For this purpose the damage percentages are presented for the front slope, 0-10 m on the crest, 10-20 m , 20-30 m 30-40 m, 40-50 m and the rear slope.

5.1 Transmission tests

In Table 5.1 the results of the measured wave conditions for the tests in Series 1, for the breakwater crest elevation of CD +0.8 m.

Test nr.	Crest Length (m)	Water level (m, CD)	Before structure Hs (m)	Before structure Tp (m)	Behind structure Hs,t (m)	Transmission C_T (-)
101	50	+3.5	2.37	7.98	1.32	0.56
102	50	+2.4	2.50	7.98	0.89	0.36
103	40	+3.5	2.49	7.97	1.44	0.58
104	40	+2.4	2.54	8.02	0.95	0.37
105	30	+3.5	2.48	7.91	1.54	0.62
106	30	+2.4	2.34	8.01	1.07	0.46
107	20	+3.5	2.45	8.01	1.67	0.68
108	20	+2.4	2.33	8.00	1.24	0.53

Table 5.1 Measured wave conditions for Series 1

Test nr.	Crest Length (m)	Water level (m, CD)	Before structure Hs (m)	Before structure Tp (m)	Behind structure Hs,t (m)	Transmission C_T (-)
201	50	+3.5	2.51	7.95	1.05	0.42
202	50	+2.4	2.50	8.03	0.61	0.24
203	40	+3.5	2.49	8.01	1.15	0.46
204	40	+2.4	2.54	8.02	0.70	0.28
205	30	+3.5	2.48	7.91	1.22	0.49
206	30	+2.4	2.34	8.01	0.76	0.33
207	20	+3.5	2.45	8.01	1.36	0.56
208	20	+2.4	2.33	8.00	0.93	0.40

Table 5.2 Measured wave conditions for Series 2

Test nr.	Crest Length (m)	Water level (m, CD)	Before structure Hs (m)	Before structure Tp (m)	Behind structure Hs,t (m)	Transmission C_T (-)
301	40	+3.5	1.84	7.19	0.98	0.53
302	40	+3.5	2.43	8.03	1.14	0.47
303	40	+2.4	1.85	7.23	0.54	0.29
304	40	+2.4	2.32	7.97	0.71	0.31

Table 5.3 Measured wave conditions for Series 3

These results are presented graphically in Figures 5 and 6. In Figure 5 the transmission coefficient is plotted against the relative freeboard (R_c/H_{si}) in the upper panel and against the relative crest length (B/L) in the lower panel. The wave length L is the local wave length at the depth of the crest, computed using the linear wave theory. The data points are presented for both the HWL and LWL, for each series. From the panels in Figure 5 the influence of the water level, crest elevation and crest length can be determined. For a given criterion on the transmission coefficient, say $c_T = 0.4$, the conditions satisfying this criterion can be determined. For instance it is seen that for the HWL condition, none of the test results fall below the 0.4 level of c_T. The selection of the relevant criterion must be determined by the acceptable wave conditions behind the breakwater, with regards to the stability of the beach. This, however, can only be assessed in a detailed study of the beach behaviour for the given conditions such as sand type and size, slope angle and length, etc.

The measured results have also been compared to recent design formulae presented by d'Angremond et. al. (1996) and Seabrook and Hall (1998) in Figure 6. For the formula from d'Angremond et. al. a "structure coefficient" (A_{str}) needs to be defined. Suggested values range from 0.64 for rock slopes to 0.80 for a smooth, impermeable dam. No specific value is given for a submerged structure. The results in Figure 6 (upper panel) are based on a value of $A_{str} = 0.8$, which gives a good agreement between the measured and computed results. The deviations from the line are seen to be due mainly to the crest length.

The comparison to the formula from Seabrook and Hall (1988) are shown in Figure 6, lower panel. With this formula no separate coefficient needs to be defined. The results are very similar to those for the formula from d'Angremond et. al., with the deviations resulting primarily from the crest length.

5.2 Stability tests

The results of the damage measurements for the 12 test conditions where the amount of displaced armour was determined, are listed in Table 5.4 below. Damage is listed in terms of percentages for different sections of the breakwater, related to the number of stones initially present in each section. For this purpose the damage percentages are presented for the front slope, 0-10 m on the crest, 10-20 m , 20-30 m 30-40 m, 40-50 m and the rear slope.

Test	WL (m)	Crest elev (m)	Crest width (m)	Hsi (m)	Tp (s)	Damage in % per section of breakwater						
						Front slope	0-10 (m)	10-20 (m)	20-30 (m)	30-40 (m)	40-50 (m)	Rear slope
	300-1000 kg armour											
101	3.5	0.8	50	2.37	7.98	0.2	0.2	0	0	0	0.2	0
102	2.4	0.8	50	2.50	7.98	0.2	0	0	0	0	0	0
107	3.5	0.8	20	2.52	8.01	0	0	0				0
108	2.4	0.8	20	2.51	8.00	0	0	0.7				0
	300-1000 kg armour											
201	3.5	1.5	50	2.51	7.95	0.2	0.3	0.3	0.2	0.2	0	0
202	2.4	1.5	50	2.50	8.03	0.2	1.6	0.5	0.5	0	0	0
207	3.5	1.5	20	2.45	8.01	0	0.2	0.3				1.0
208	2.4	1.5	20	2.33	8.00	0.2	0.3	1.1				0.4
	100-500 kg armour											
301	3.5	1.5	40	1.84	7.19	0	0.7	0	0	0		0
302	3.5	1.5	40	2.43	8.03	0.3	0.7	1.3	0.9	0.1		0
303	2.4	1.5	40	1.85	7.23	0.4	0.8	0.1	0	0		0
304	2.4	1.5	40	2.32	7.97	0.5	1.2	0.9	0.4	0.1		0

Table 5.4 Measured damage conditions for all series

For all tests it is seen that less than 2% damage has occurred in all sections, for the wave conditions tested. Comparing the results from Series 1 and Series 2, it is seen that more damage occurred in Series 2, which was to be expected as the crest elevation was higher and therefore more susceptible to wave attack. This is also true when comparing Series 2 and Series 3, for the similar wave and water level conditions more damage occurred in Series 3, having the lighter armour layer. Even still, the damage recorded can be classified as "no damage" level. It is, however, noted that some sections of the breakwater will be located in deeper water where higher wave conditions may apply than have been tested in this investigation.

6 Conclusions and recommendations

The physical model testing of the breakwater has led to the following conclusions:

Stability

- The 300-1000 kg rock gradation exhibited less than 2% damage for all sections of the breakwater for all tests with the 2.5 m wave height.
- The 100-500 kg exhibited also less than 2% damage for all sections, for the tests with the 2.0 m wave height and also for the 2.5 m wave height.
- The stability of the tested rock gradations for sections of the breakwater that are located in deeper water, where higher wave heights could occur, has not been assessed.

Transmission

- For Series 1, with crest elevation at CD +0.8 m and the HWL, the transmission coefficient varied from 0.56 for the 50 m wide crest to 0.66 for the 20 m wide crest.
- For Series 1, with crest elevation at CD +0.8 m, and the LWL, the transmission coefficient varied from 0.36 for the 50 m wide crest to 0.49 for the 20 m wide crest.
- For Series 2, with crest elevation at CD +1.5 m and the HWL, the transmission coefficient varied from 0.42 for the 50 m wide crest to 0.56 for the 20 m wide crest.
- For Series 2, with crest elevation at CD +1.5 m, and the LWL, the transmission coefficient varied from 0.24 for the 50 m wide crest to 0.40 for the 20 m wide crest.
- The results of Series 3 were comparable to those for Series 2, for the tests having the same wave, water level and crest widths.
- The measured results compared well to the valued predicted by the design formula of de d'Angremond et. al. (1996) when a value of $A_{str} = 0.8$ is applied and also to the formula of Seabrook and Hall (1998). The deviations from the predicted values can be attributed primarily to the crest length.

Recommendations

- It is recommended to perform a detailed study of the behaviour of the beach behind the breakwater to better ensure its stability. In particular, the influence of a possible water level setup behind the breakwaters, the influence of diffracted wave energy through the gaps in the segmented breakwaters and the effect of waves approaching at an angle to breakwater on the beach stability should be investigated.

References

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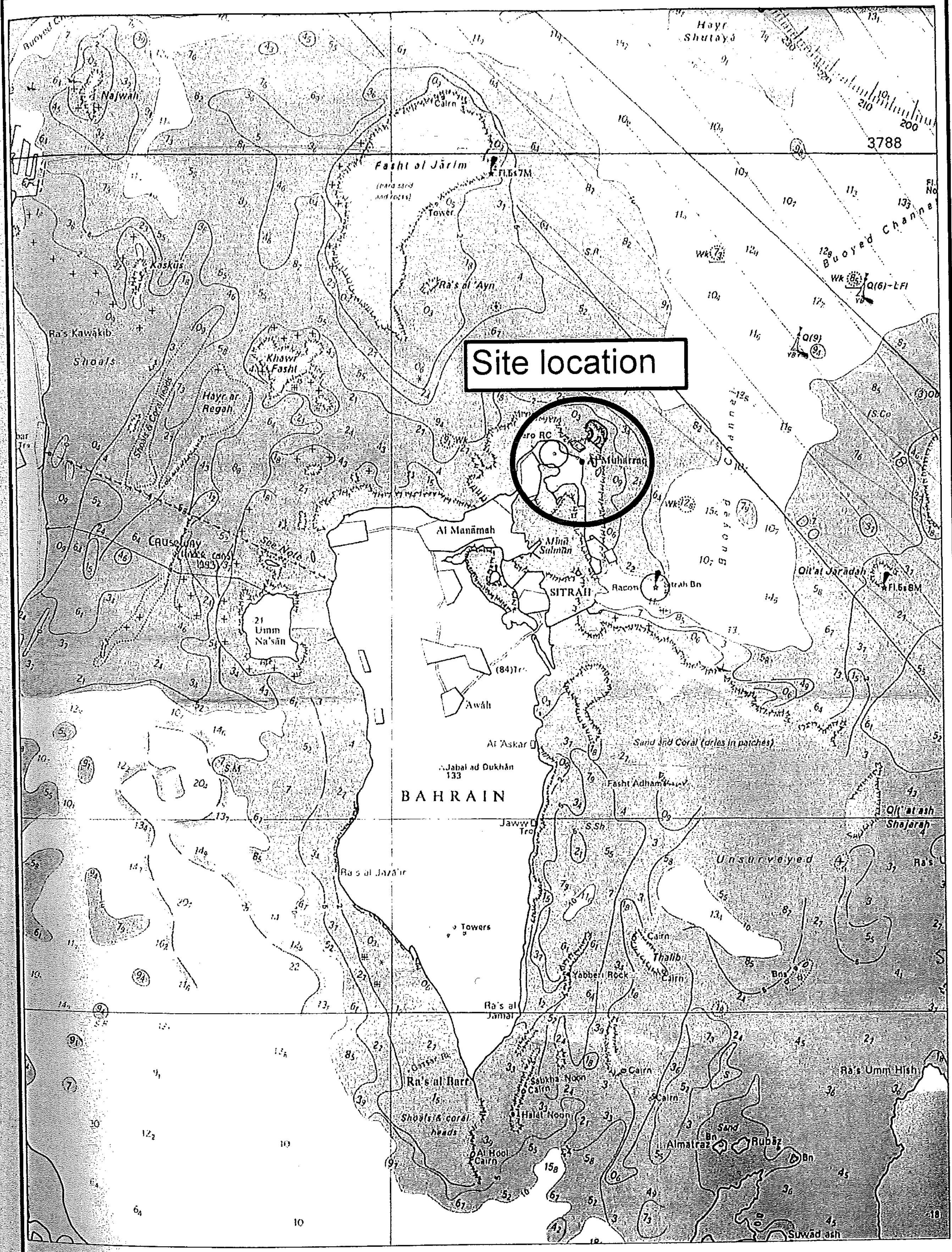
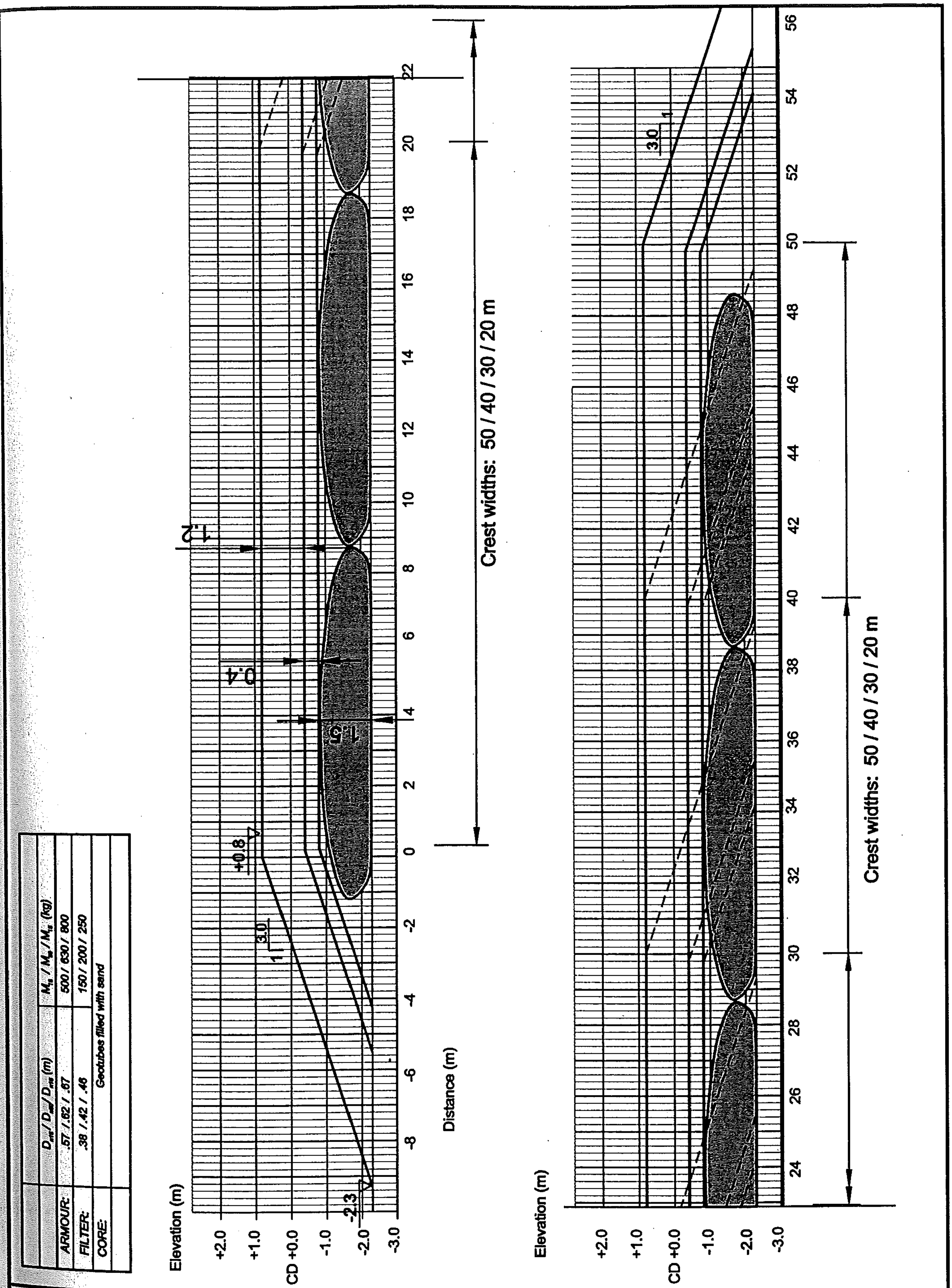
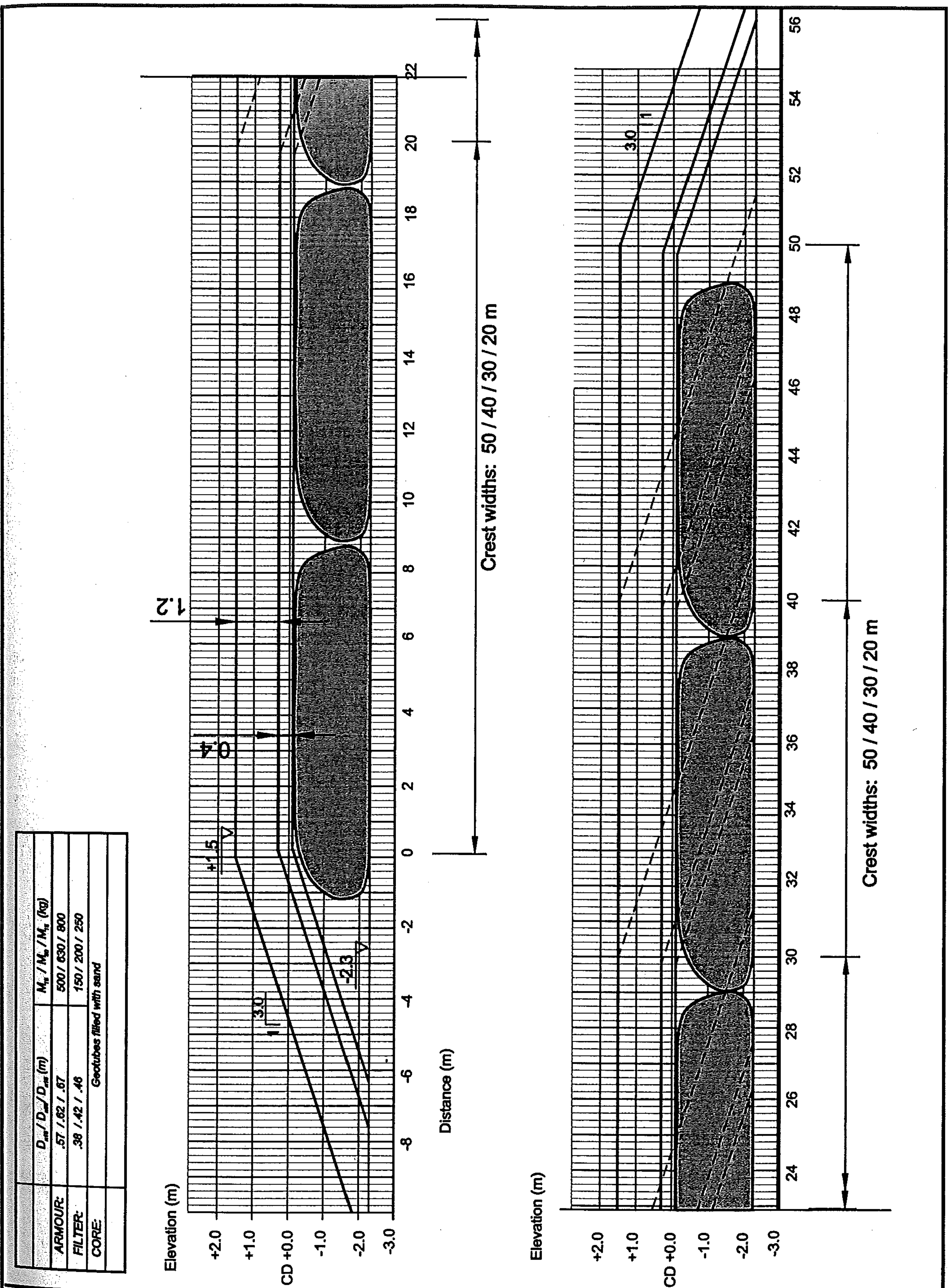


Site location	File: H4087-Fig_1.XLS	By: GMS Date:17-04-02
WL | Delft Hydraulics	H4087	FIG. 1



	D_{n15} / D_{n50} / D_{n85} (m)	M_{15} / M_{50} / M_{85} (kg)
ARMOUR:	.57 / .62 / .67	500 / 630 / 800
FILTER:	.38 / .42 / .46	150 / 200 / 250
CORE:	Geotubes filled with sand	

Cross-sections of structures tested in present investigation Test Series 1	file: H4087-Fig_2.Dwg	BY: GMS Date: 15-04-2002
	Scale: 1:7.5 to model	
WL| delft hydraulics	H4087	FIG. 2



Cross-sections of structures tested
Test Series 2 and 3

file: H4087-Fig_3.Dwg

BY: GMS

Date: 13-03-2002

Scale: 1:7.5 to model

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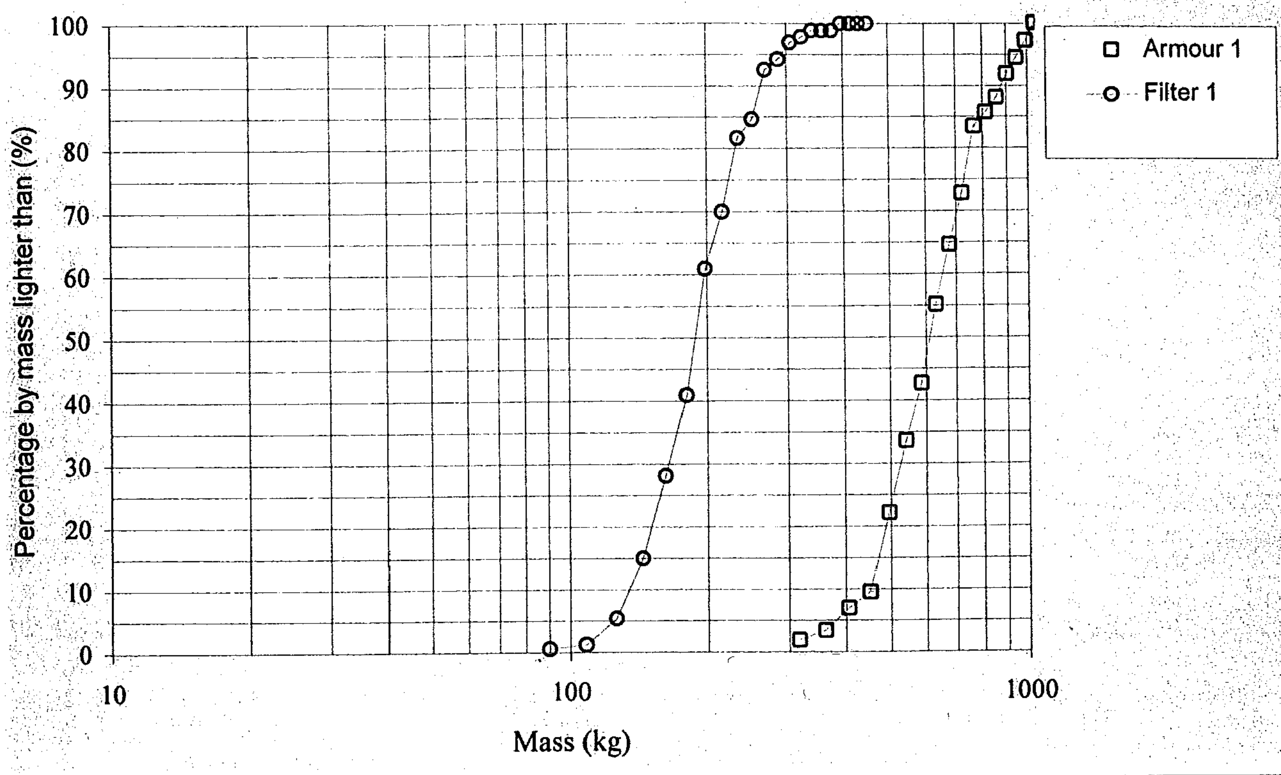
H4087

FIG. 3

SERIES 1 and 2



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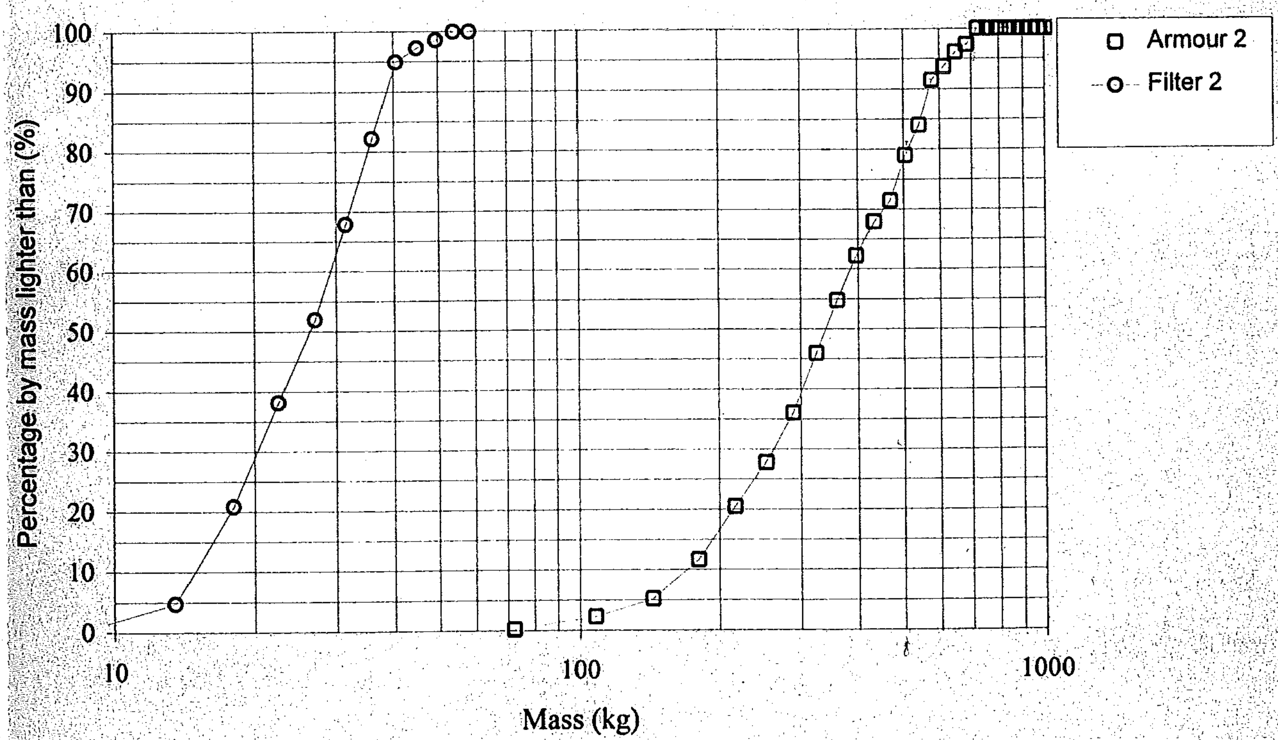
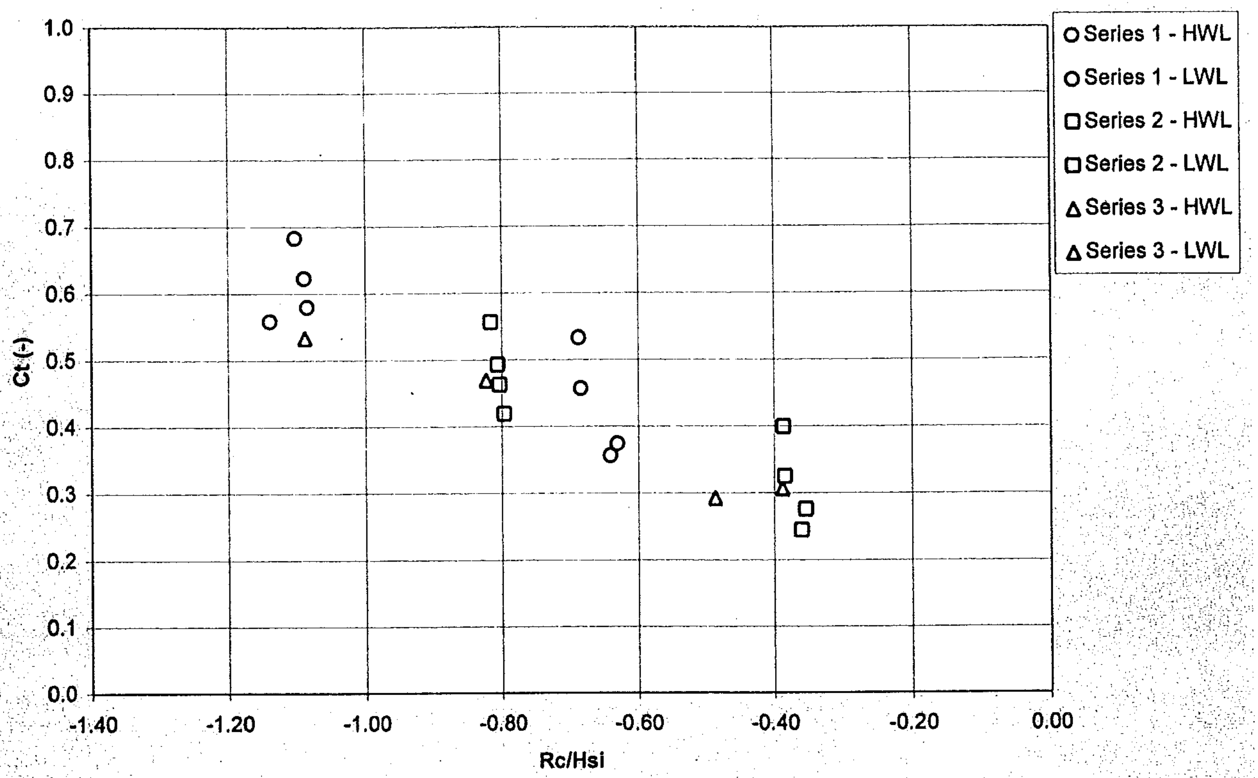
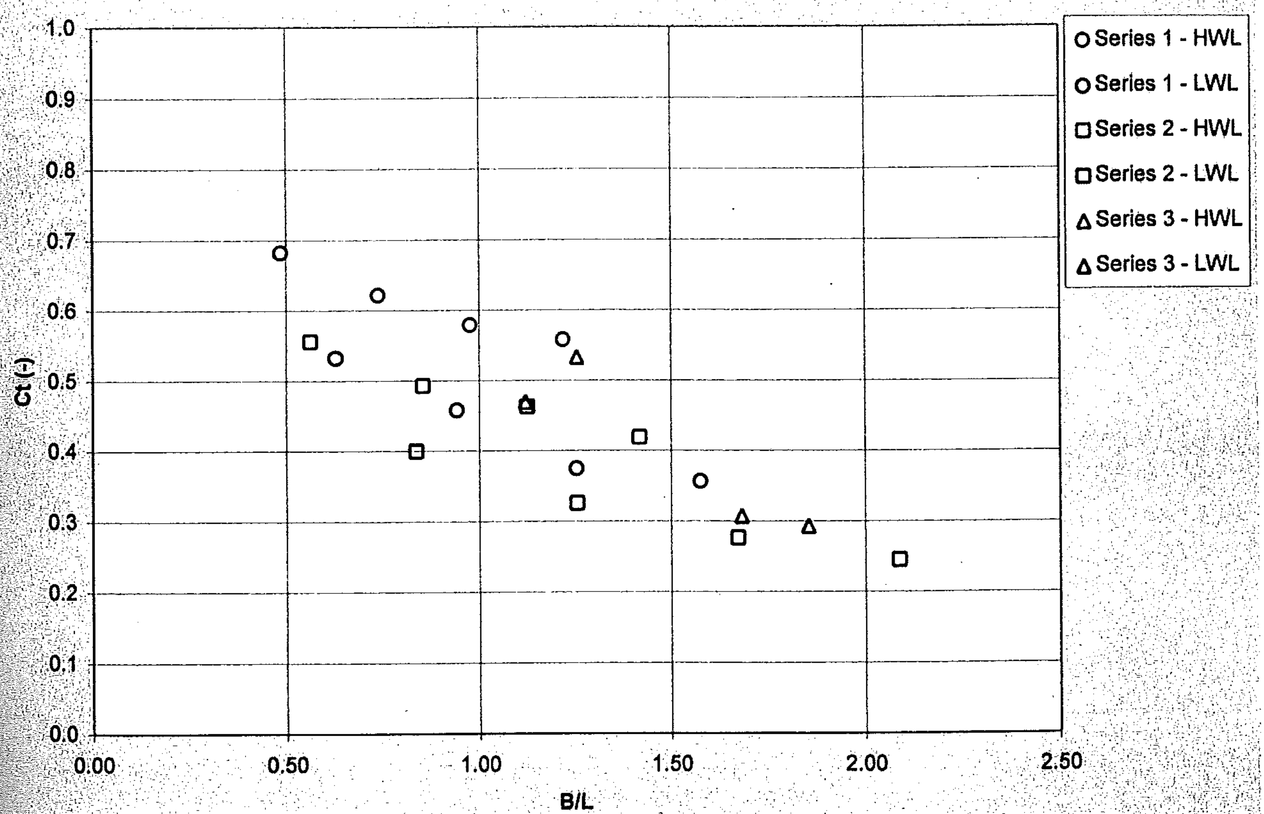
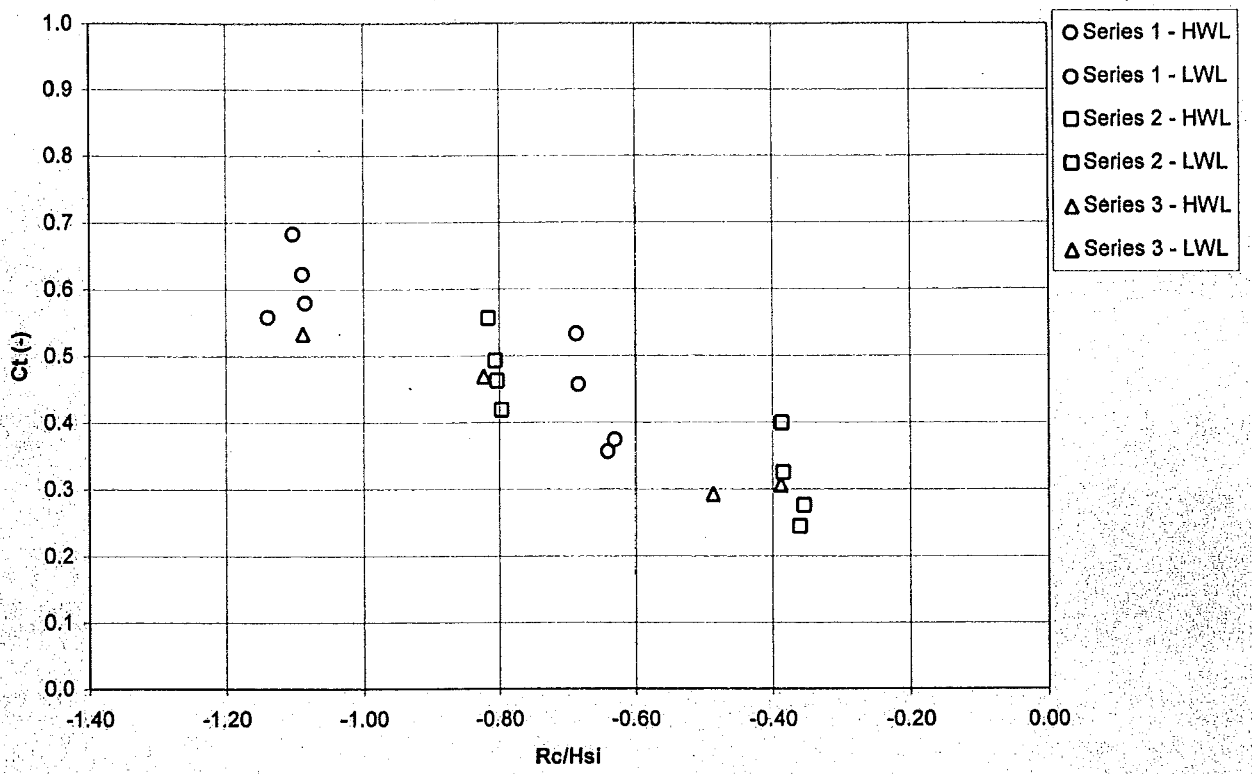


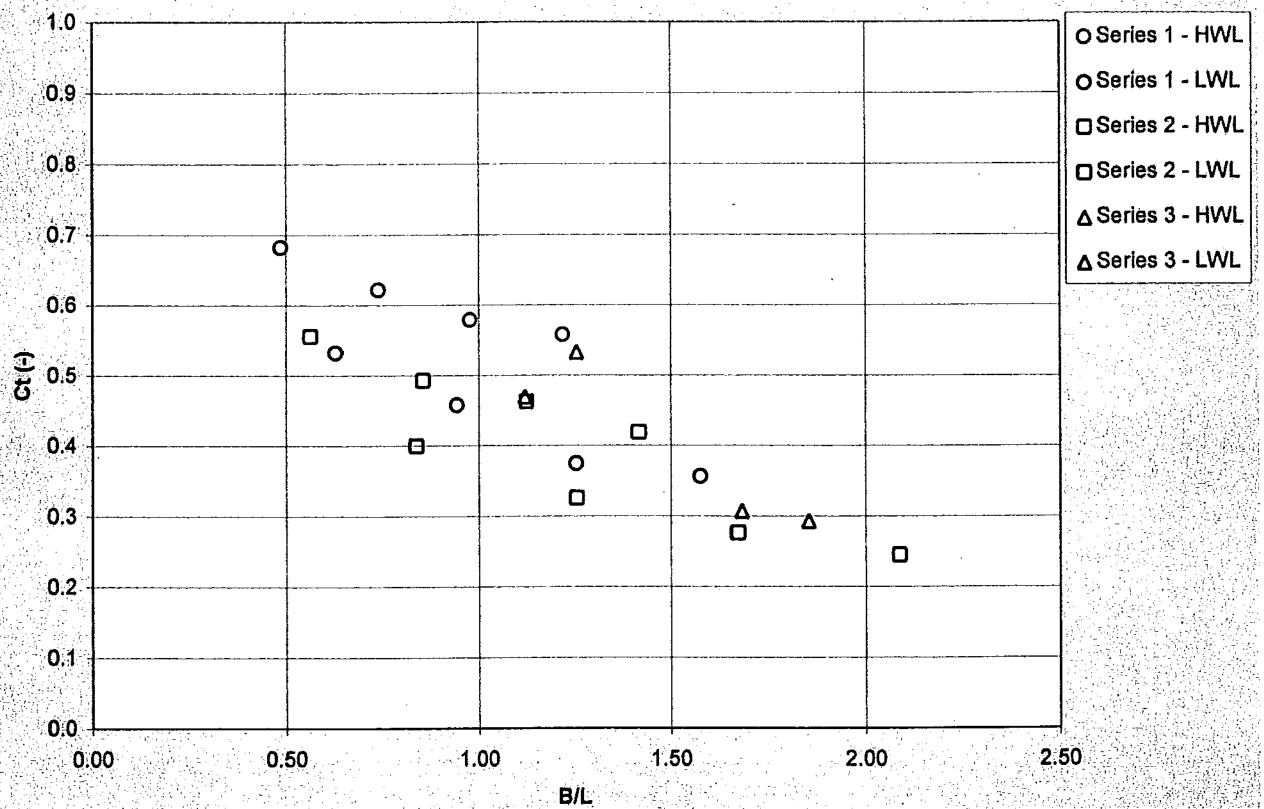
Armour and filter gradations	File: H4087_Fig_4-.XLS	By: GMS Date:15-04-02
WL | Delft Hydraulics	H4087	FIG. 4



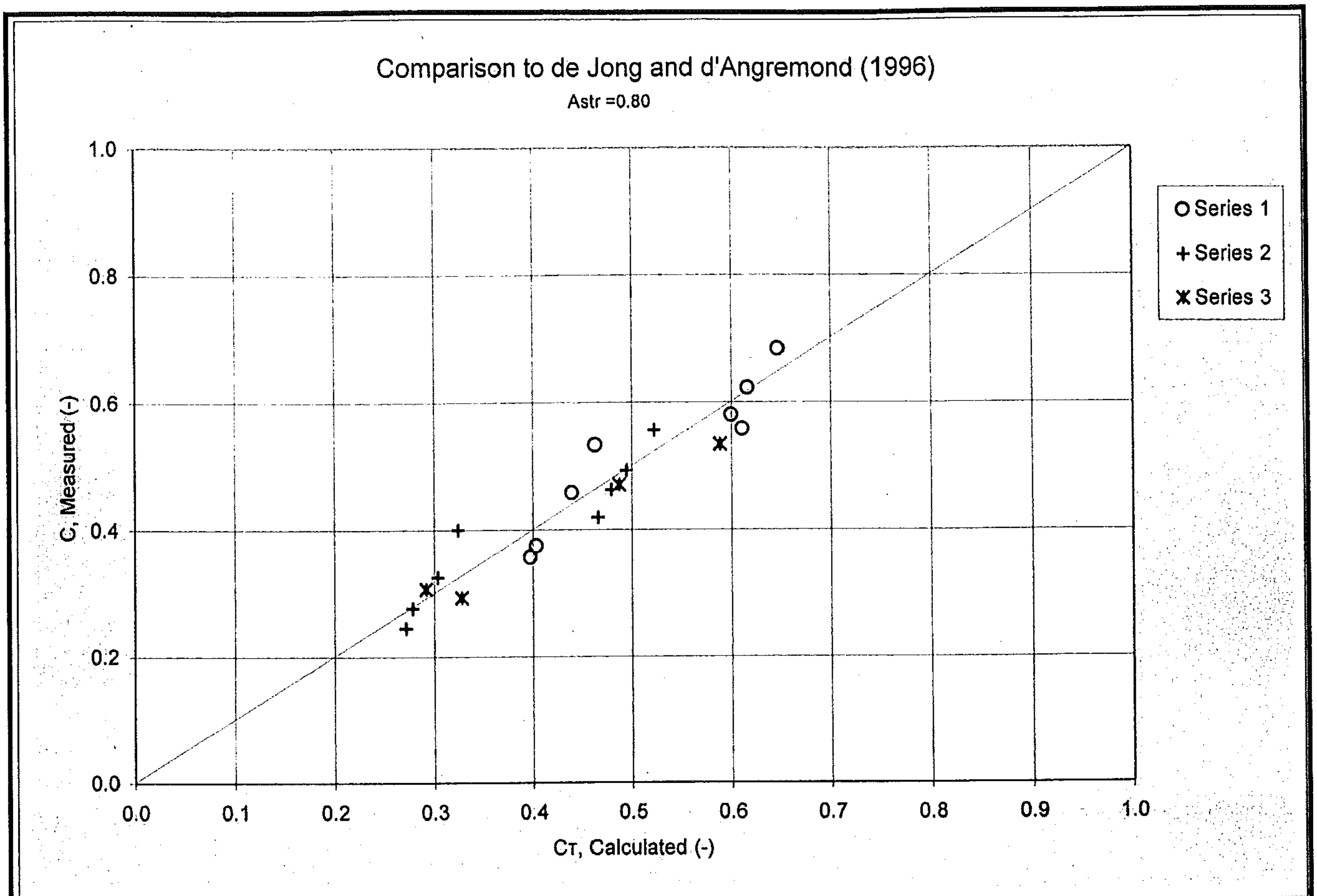


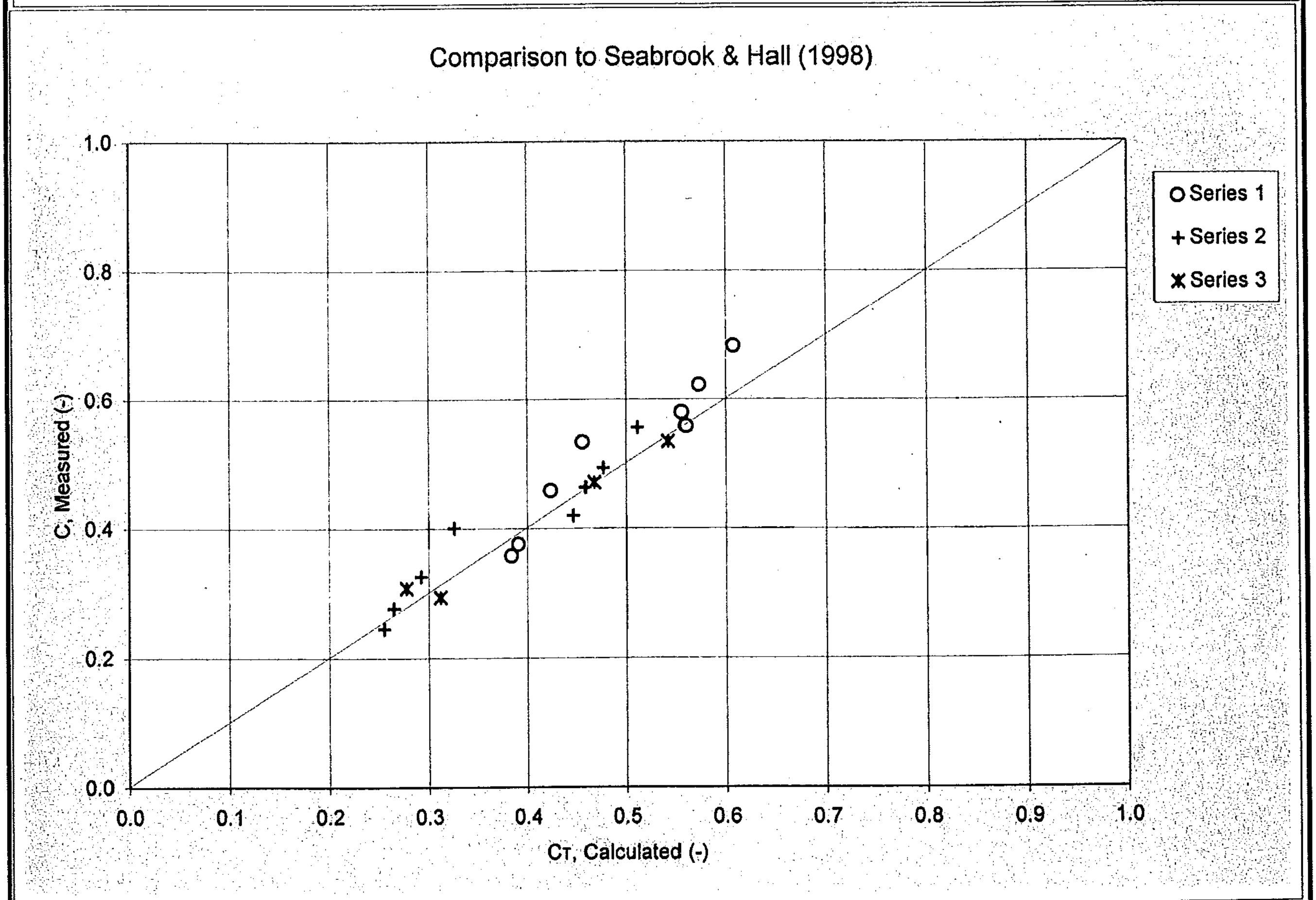
Transmission coefficient as function of Rc/Hsi and B/L all tests	File: H4087-Fig_5.XLS	By: GMS Date:17-04-02
WL | Delft Hydraulics	H4087	FIG. 5



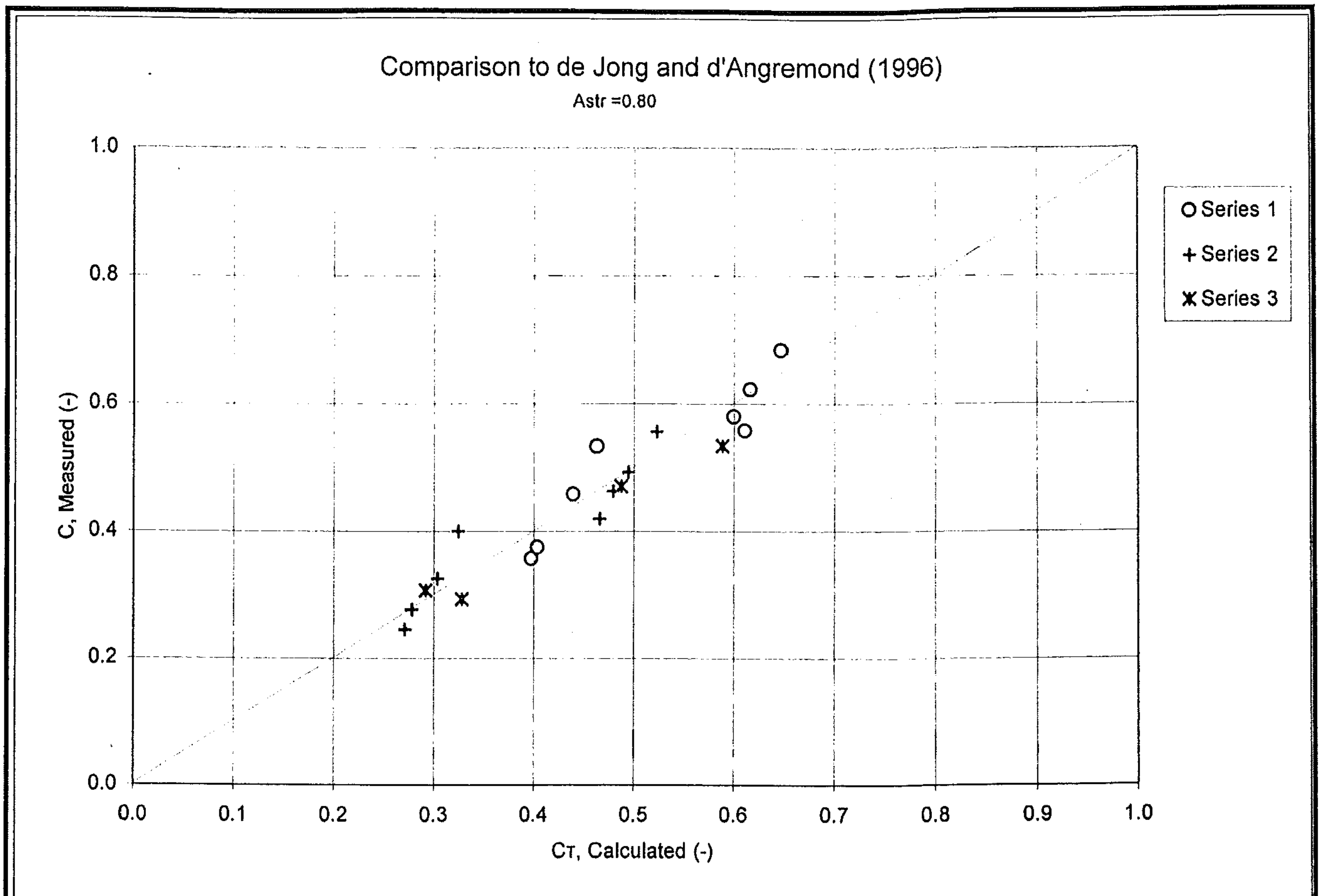


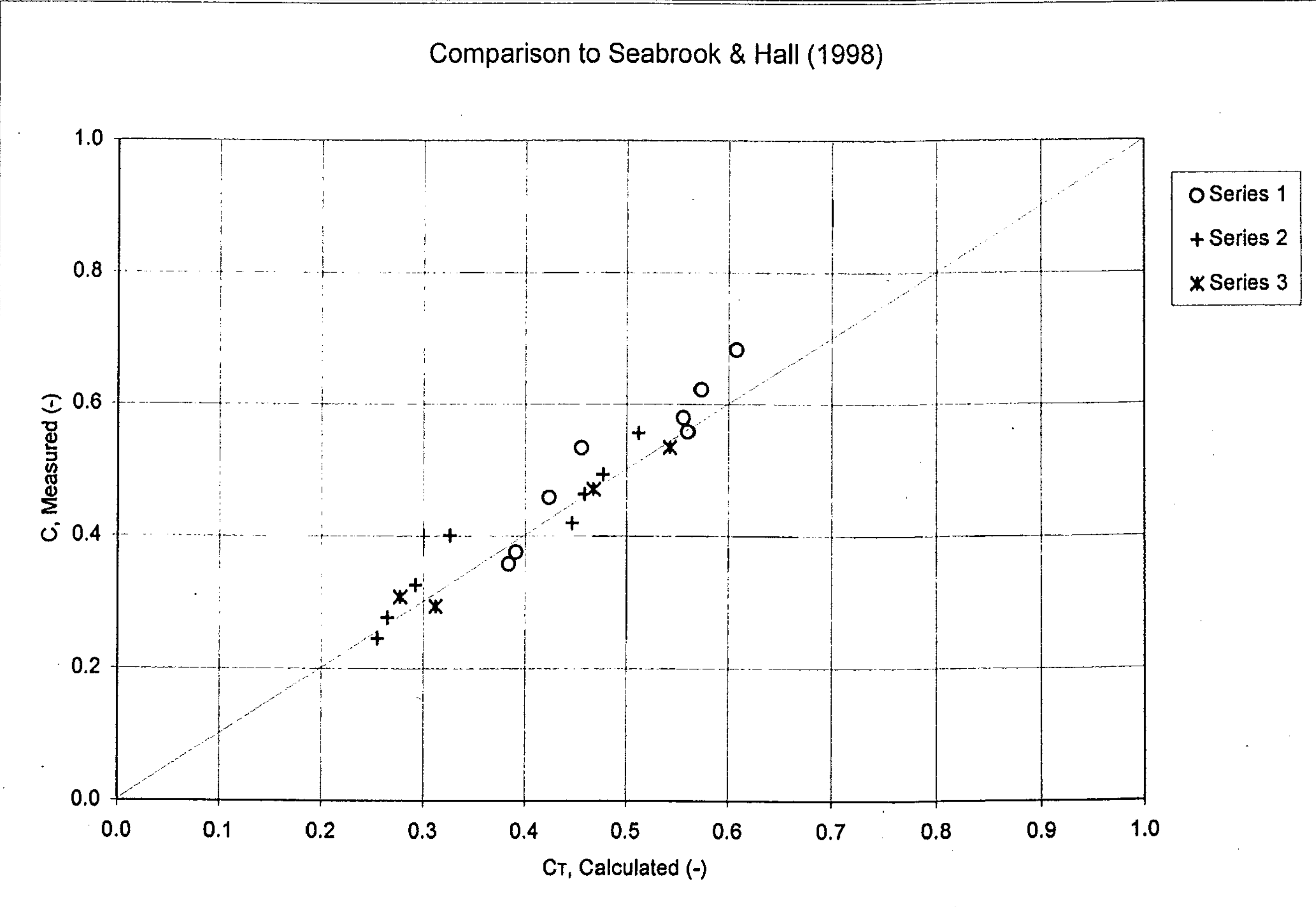
Transmission coefficient as function of Rc/Hsi and B/L all tests	File: H4087-Fig_5.XLS	By: GMS Date:17-04-02
WL | Delft Hydraulics	H4087	FIG. 5





Measured CT values, compared to design formulae from de Jong & d'Angremond (1996) and Seabrook & Hall (1998)	File: H4087-Fig_6.XLS	By: GMS Date:17-04-02
WL | Delft Hydraulics	H4087	FIG. 6





Measured CT values, compared to design formulae from de Jong & d'Angremond (1996) and Seabrook & Hall (1998)	File: H4087-Fig_6.XLS	By: GMS Date:17-04-02
WL | Delft Hydraulics	H4087	FIG. 6

Photo 1 Geotubes in the flume during Construction for Series 1

Photo 2 Geotubes with partial filter during Construction for Series 1

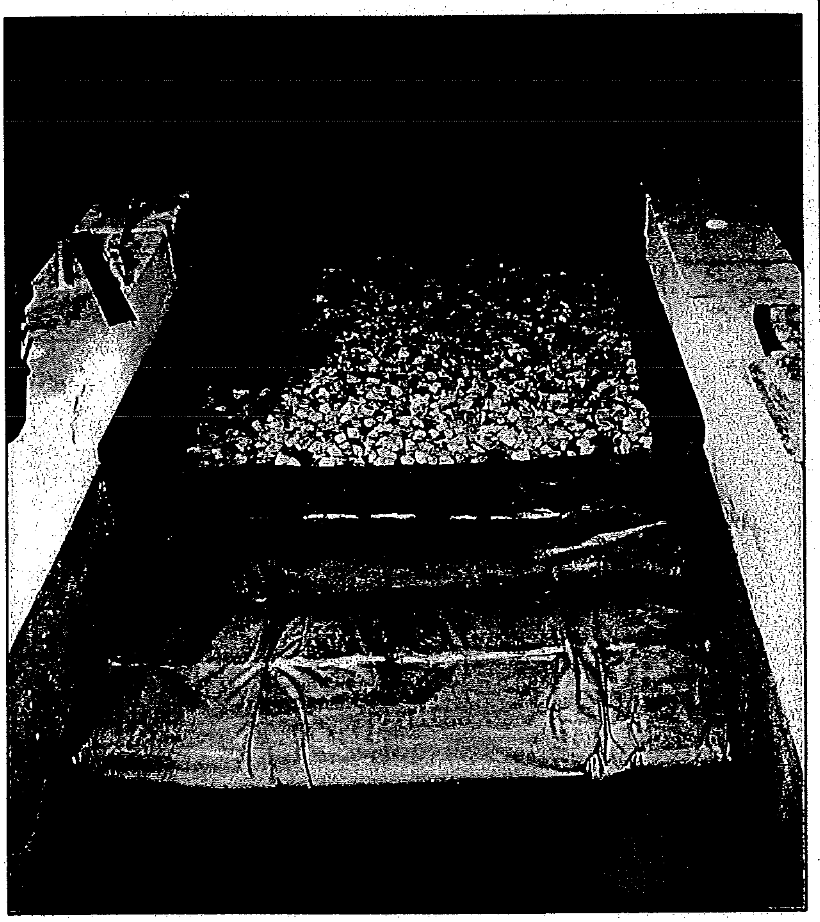


Photo 11 40 m breakwater after T302

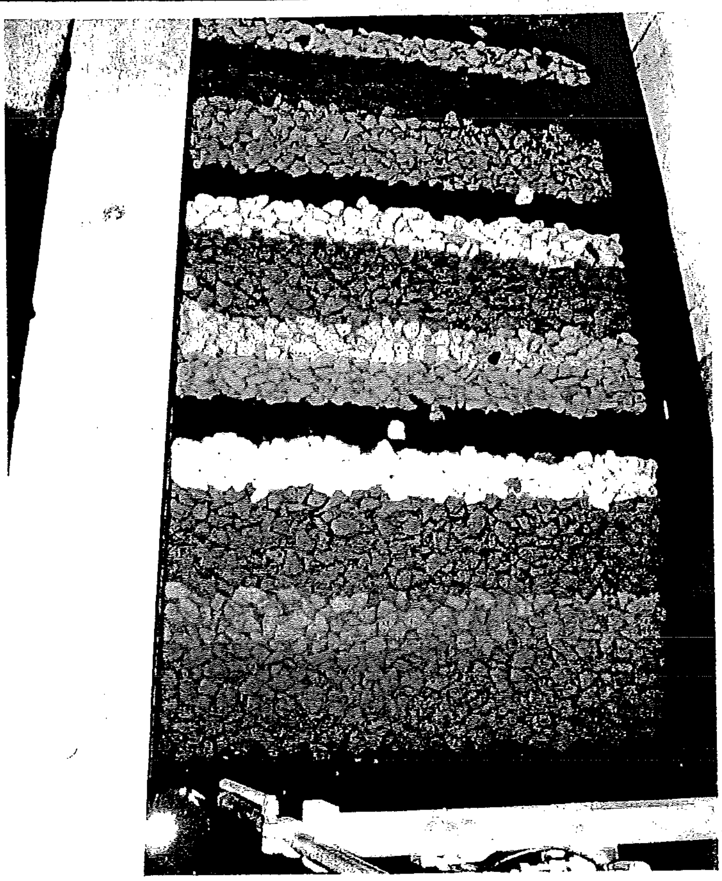
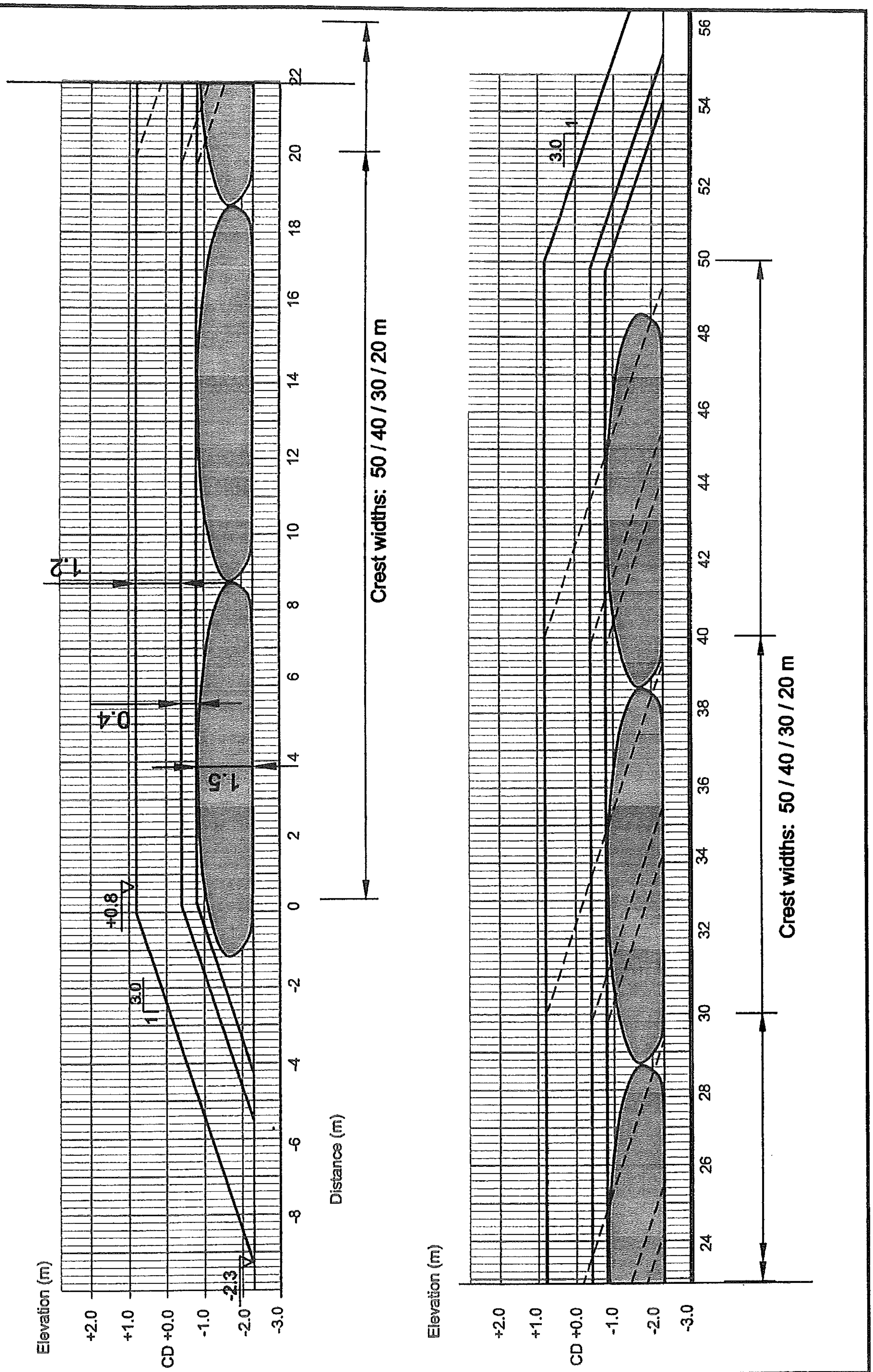


Photo 12 40 m breakwater after T304



	D_{n15} / D_{n50} / D_{n85} (m)	M_{15} / M_{50} / M_{85} (kg)
ARMOUR:	.57 / .62 / .67	500 / 630 / 800
FILTER:	.38 / .42 / .46	150 / 200 / 250
CORE:	Geotubes filled with sand	

Cross-sections of structures tested in present investigation
Test Series 1

file: H4087-Fig_2.Dwg

BY: GMS

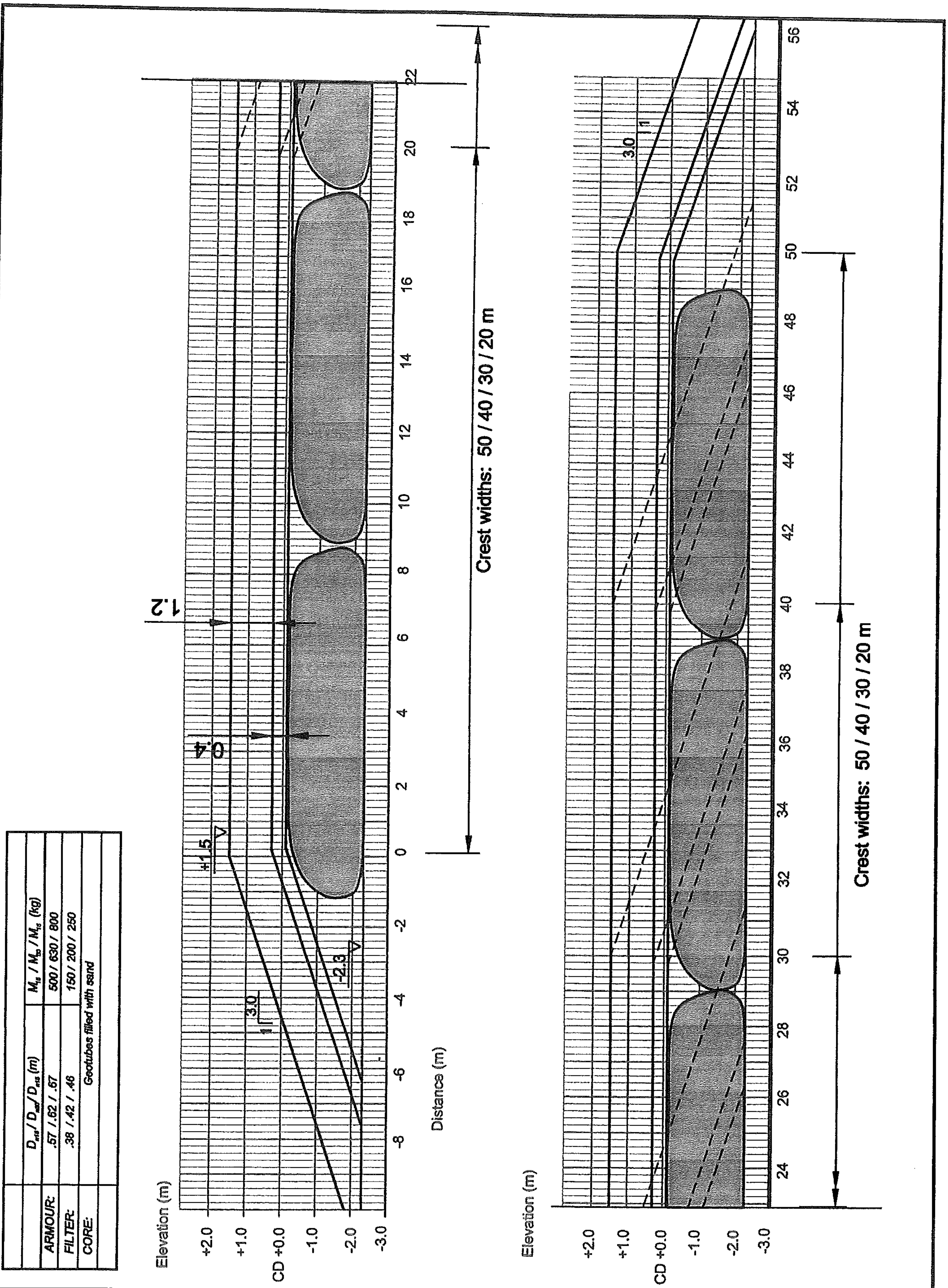
Date: 15-04-2002

Scale: 1:7.5 to model

WL| delft hydraulics

H4087

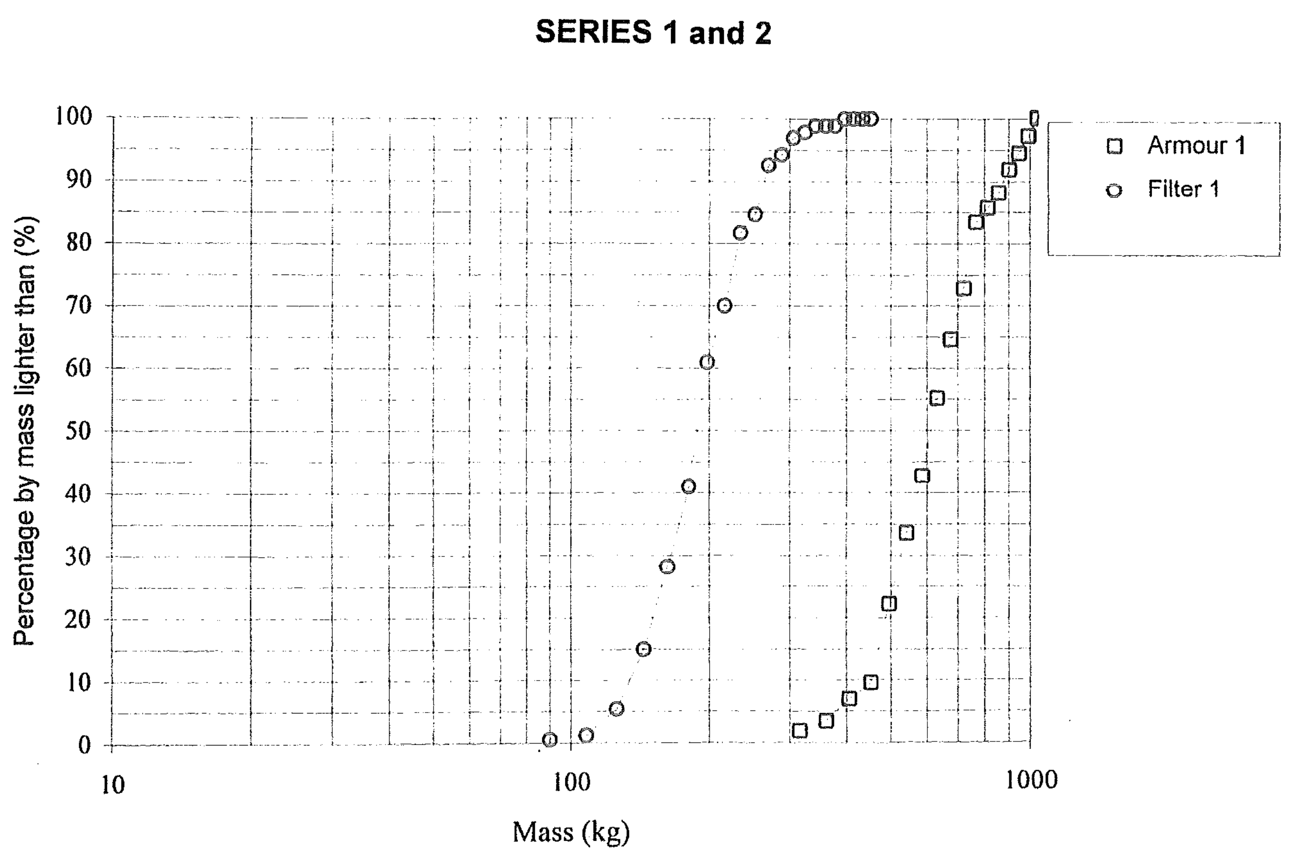
FIG. 2

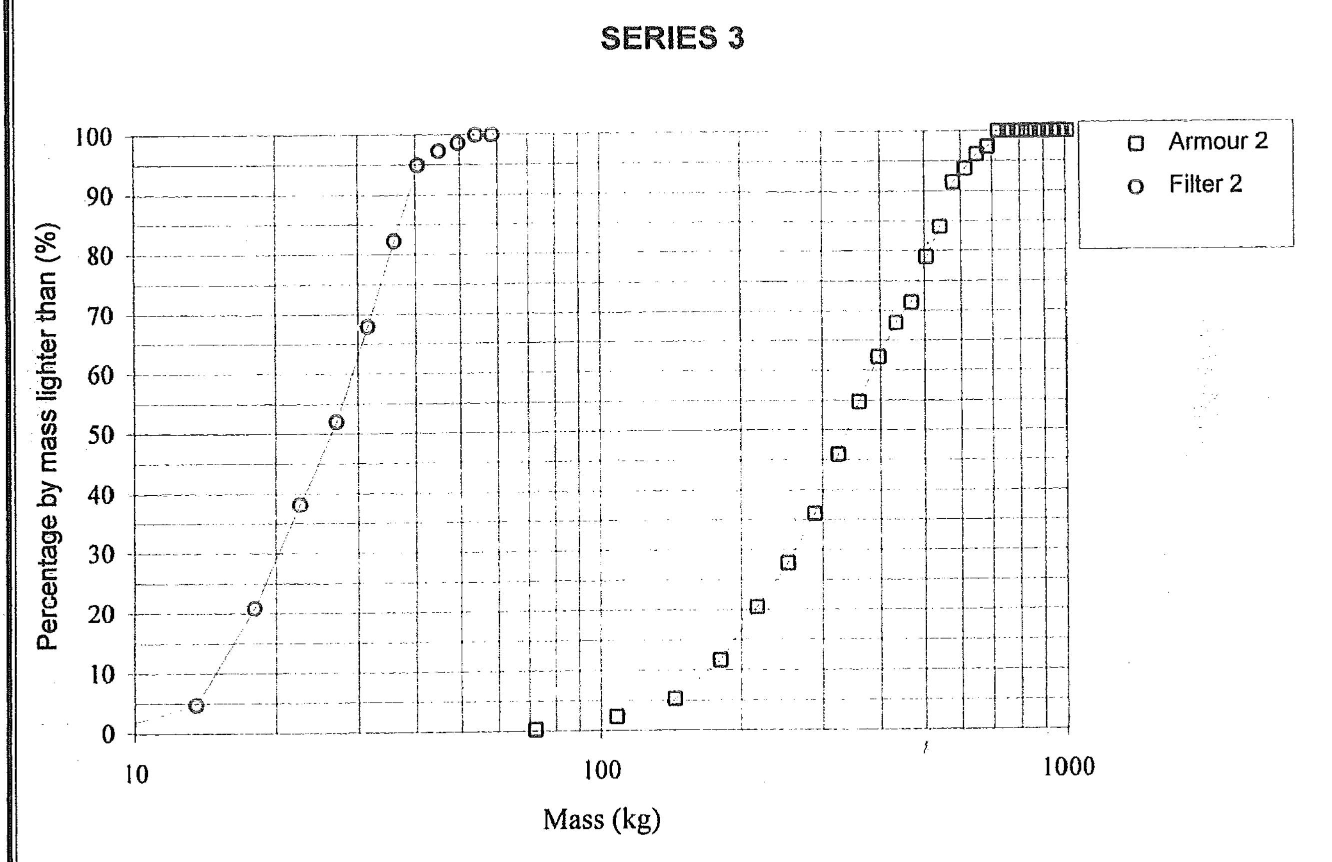


Cross-sections of structures tested
Test Series 2 and 3

file: H4087-Fig_3.Dwg	BY: GMS Date: 13-03-2002	
Scale: 1:7.5 to model		

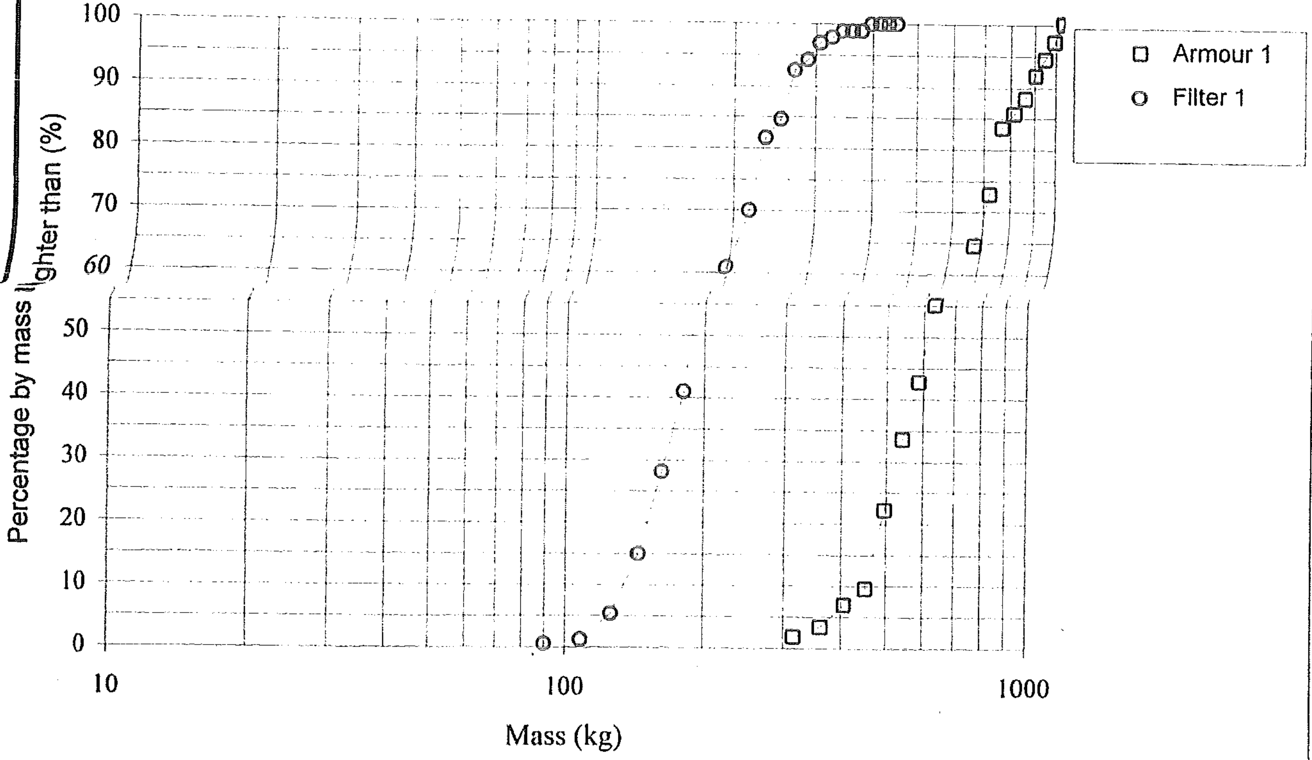
WL| Delft Hydraulics | H4087 | FIG. 3



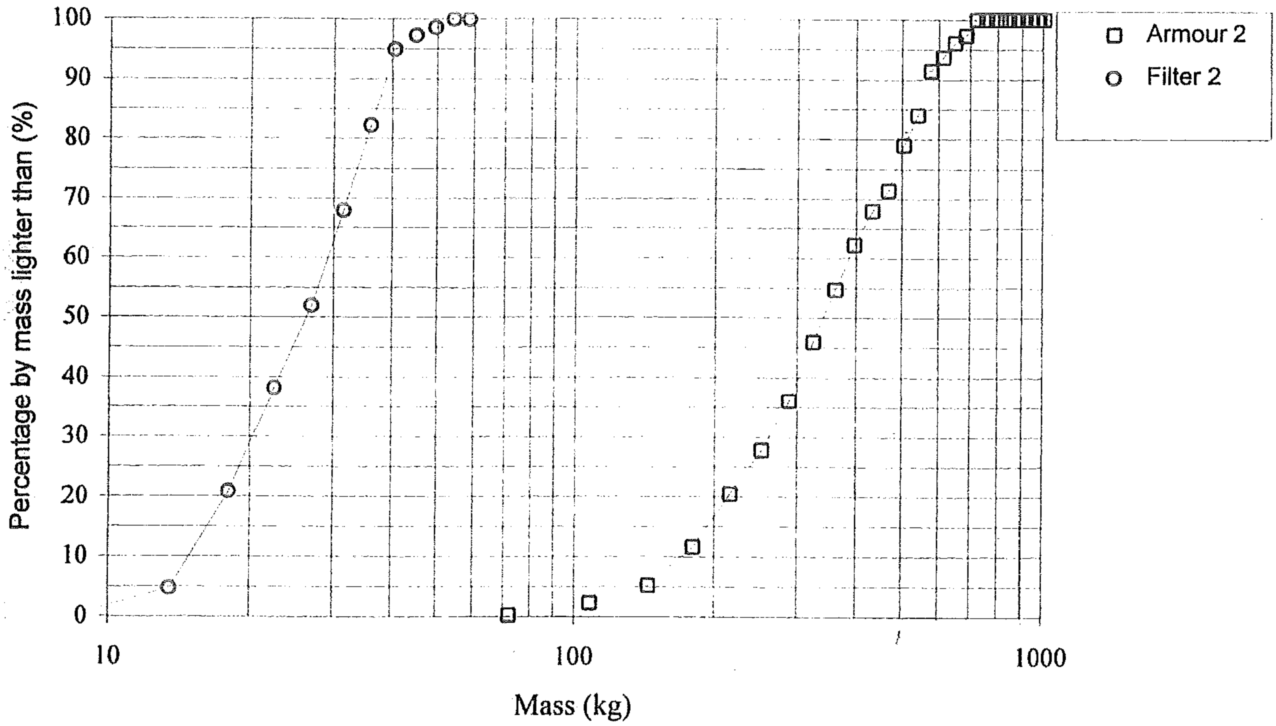


Armour and filter gradations	File: H4087_Fig_4-.XLS	By: GMS Date:15-04-02
WL | Delft Hydraulics	H4087	FIG. 4

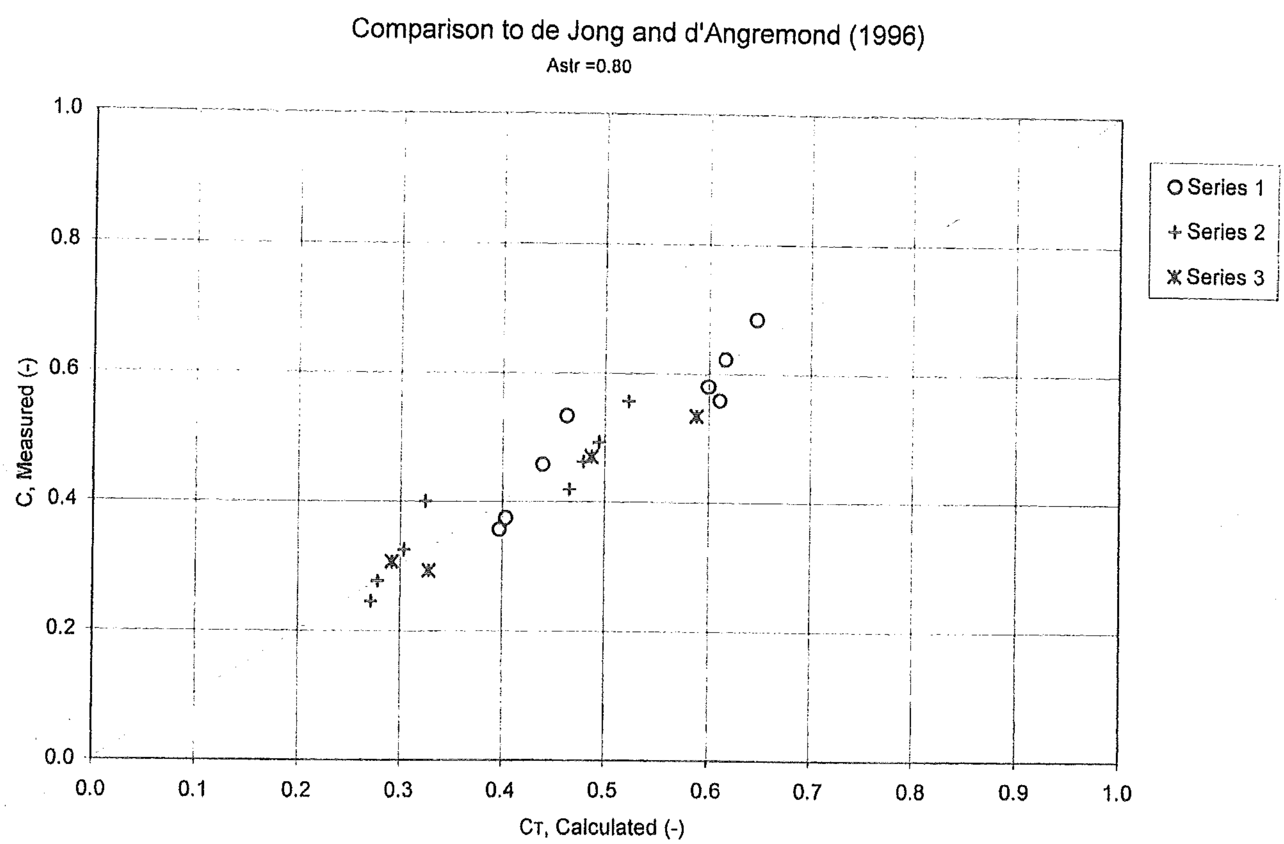
SERIES 1 and 2

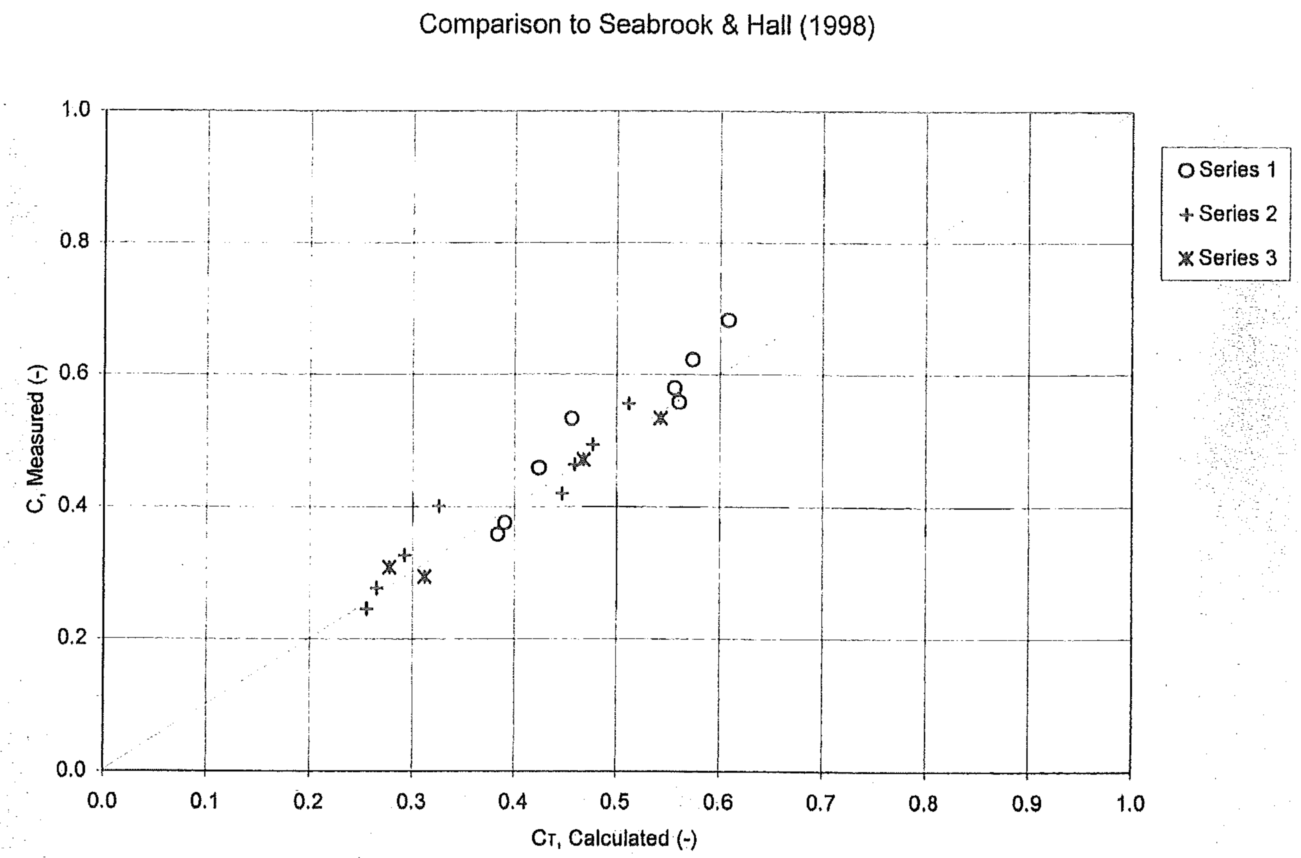


SERIES 3

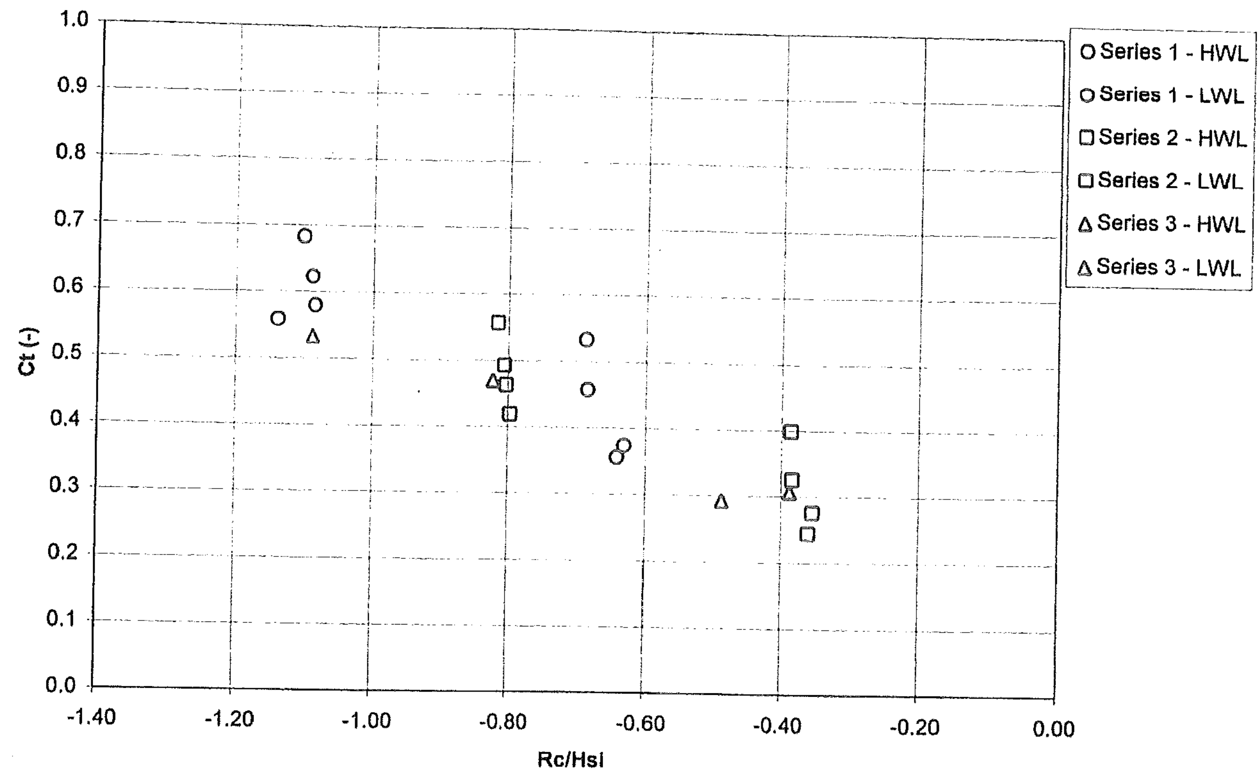


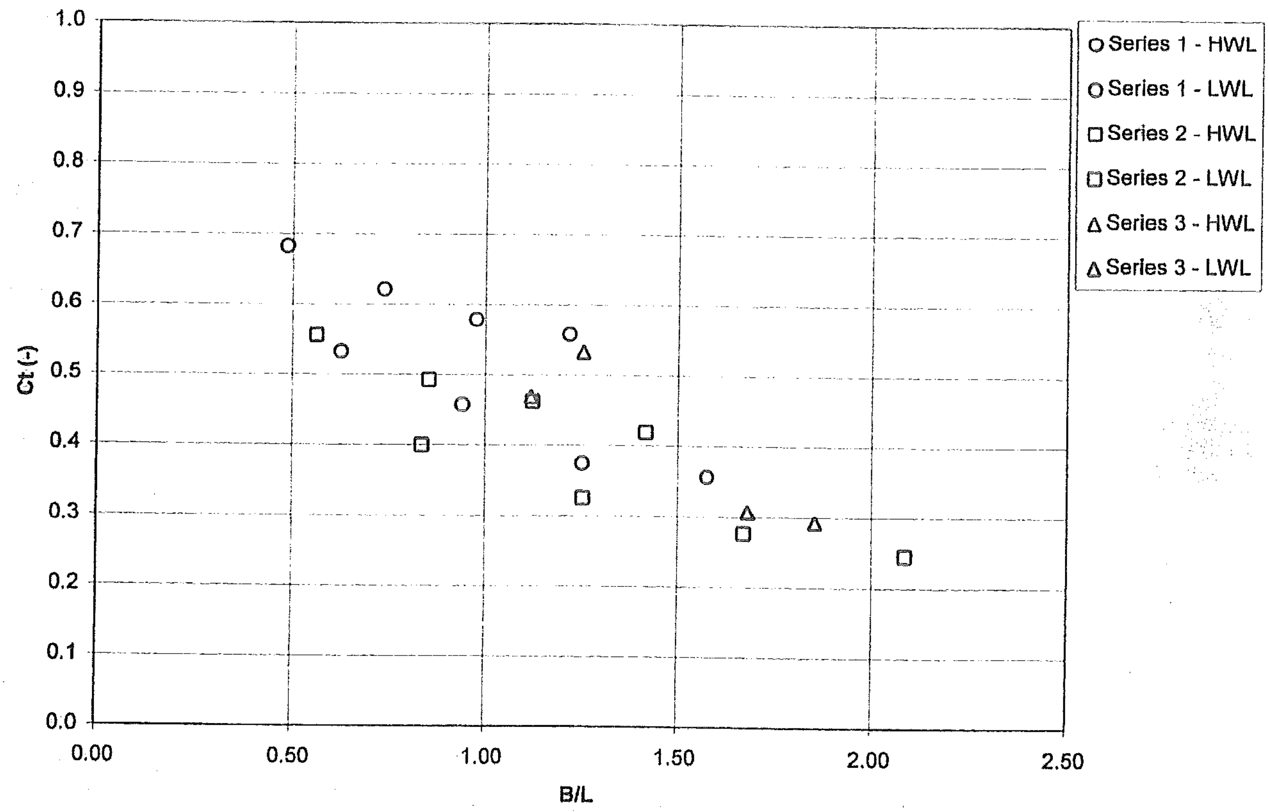
Armour and filter gradations	File: H4087_Fig_4-.XLS	By: GMS Date:15-04-02
WL | Delft Hydraulics	H4087	FIG. 4



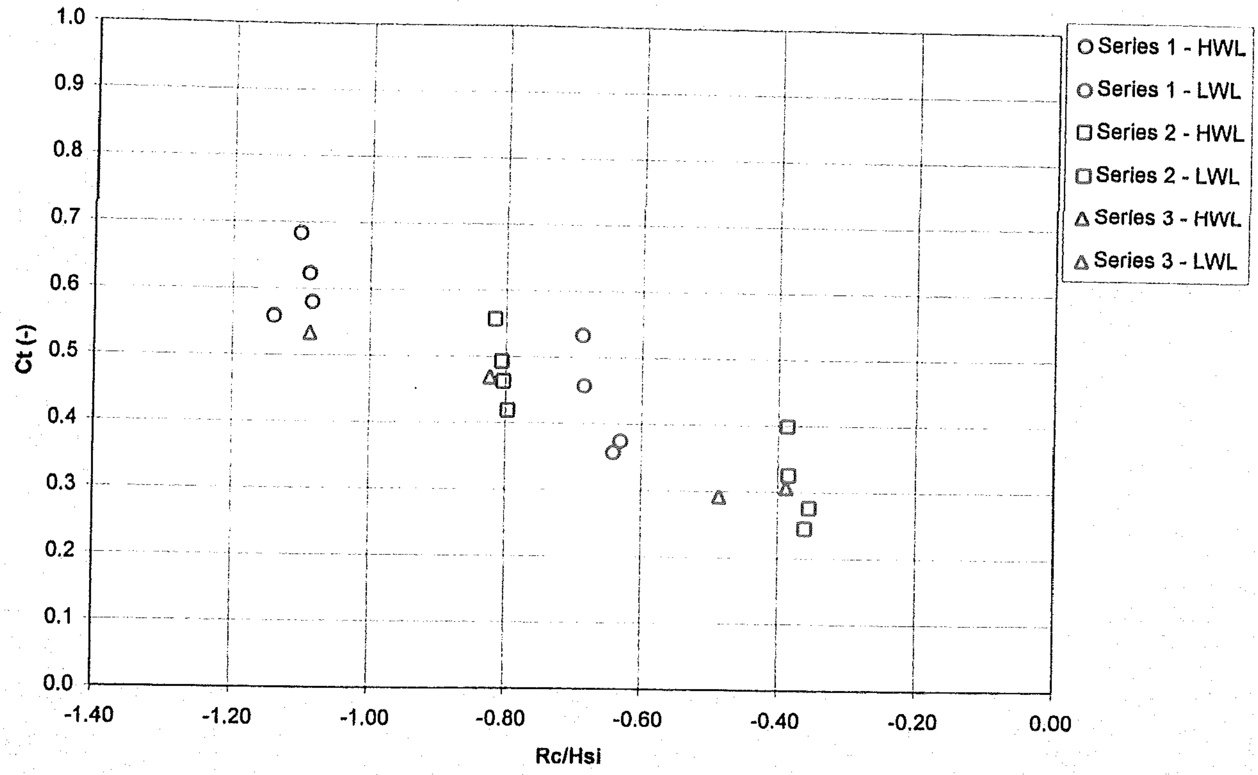


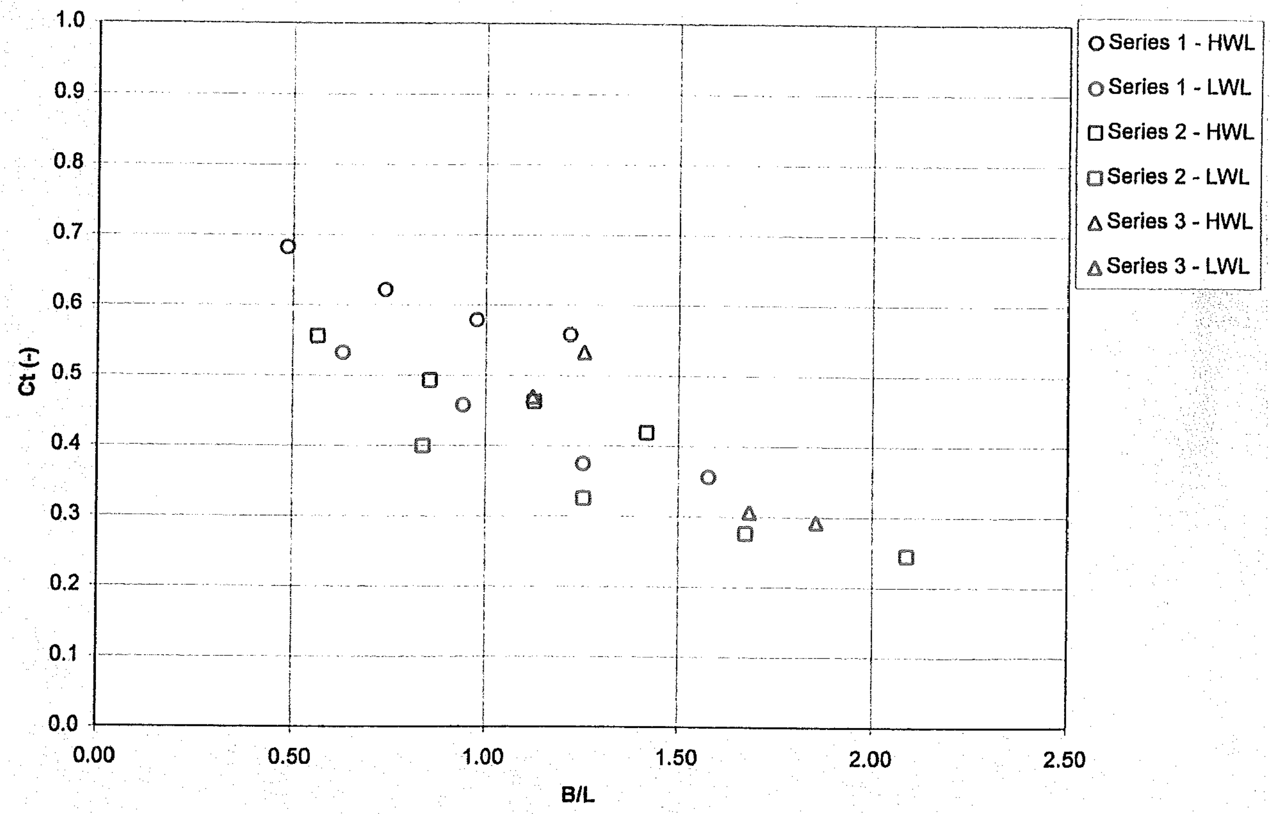
Measured CT values, compared to design formulae from de Jong & d'Angremond (1996) and Seabrook & Hall (1998)	File: H4087-Fig_6.XLS	By: GMS Date:17-04-02
WL | Delft Hydraulics	H4087	FIG. 6





Transmission coefficient as function of Rc/Hsi and B/L all tests	File: H4087-Fig_5.XLS	By: GMS Date:17-04-02
WL | Delft Hydraulics	H4087	FIG. 5





Transmission coefficient as function of Rc/Hsi and B/L all tests	File: H4087-Fig_5.XLS	By: GMS Date:17-04-02
WL | Delft Hydraulics	H4087	FIG. 5