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PORTO DI VADO LIGURE

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Working with water

EX 6223

Vado Ligure, Italy

2D Physical modelling of wave loads on a multi-purpose platform



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Summary

Vado Ligure, Italy

2D Physical Modelling of wave loads on a multi-purpose platform

Report EX6223
February 2010

In 2006, the Port of Savona promoted the development of a Multi-Purpose Platform at Vado Ligure to handle container and bulk cargos, replacing current bulk and oil terminal facilities.

Approximately 100,000m^2 of the platform will be formed as a reclamation bounded by concrete caissons or revetments. The outer 100,000m^2 (approx.) will be formed as an elevated deck on beams (longitudinal and transverse), suspended on vertical piles, themselves founded from submerged rectangular caissons. At the sea bed, the caissons will be founded on and surrounded by rock bed protection.

This report describes two-dimensional (2D) physical model tests to quantify wave transformation over the structure, wave loading on the platform and scour protection stability and observe overtopping.

Wave heights were found to reduce dramatically over the first two caissons due to depth-limited breaking and destructive interference over the top face of the caissons.

Wave loads measured on submerged structural elements were characterised by quasi-static oscillations following closely the local wave-induced variation in water surface elevation. Wave-in-deck load time-histories recorded on the deck and beam elements exhibit the characteristic pattern with short duration peaks followed by a quasi-static oscillation.

No noticeable displacement of the scour armour was observed in any of the tests up to the 1:100 year conditions, with the scour protection material showing only moderate cumulative damage after testing the 1:100 year condition.

Overall, the structure performed well under the tested design conditions, and wave loads on the deck were generally below initial expectations. It is recommended that appropriate dynamic analysis of the structure and its structural elements is performed to assess the relative importance of short duration impulsive loads. Selected rock of 100-300 kg should be used to protect the most exposed top layer of the scour protection.

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Appendix A Wave calibration
Appendix B Wave spectra transformation along the structure
Appendix C Load Time Histories

1. Introduction

In 2006, the Port of Savona promoted the development of a Multi-Purpose Platform at Vado Ligure to handle container and bulk cargos, replacing current bulk and oil terminal facilities.

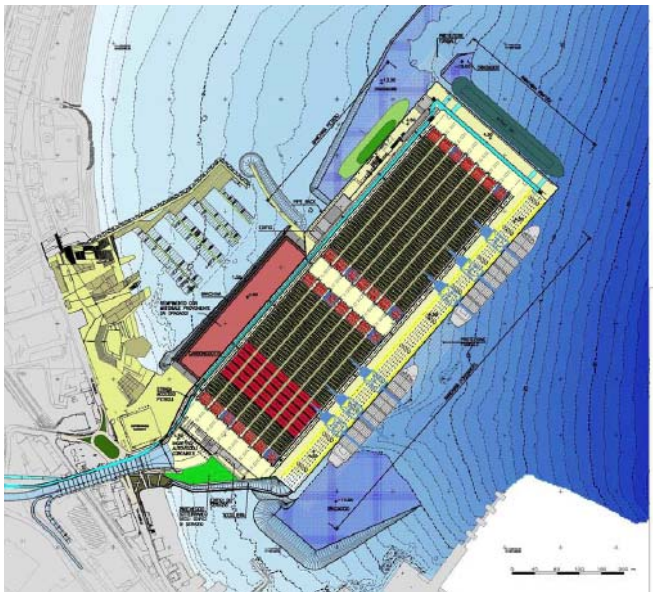


Figure 1 Overview of planned development

Approximately 100,000m^2 of the platform will be formed as reclamation bounded by concrete caissons or revetments. The outer 100,000m^2 (approx.) will be formed as an elevated deck on beams (longitudinal and transverse), suspended on vertical piles, themselves founded from submerged rectangular caissons. At the sea bed, the caissons will be founded on and surrounded by rock bed protection. An overall plan view of the platform foundation is given in Figure 2.

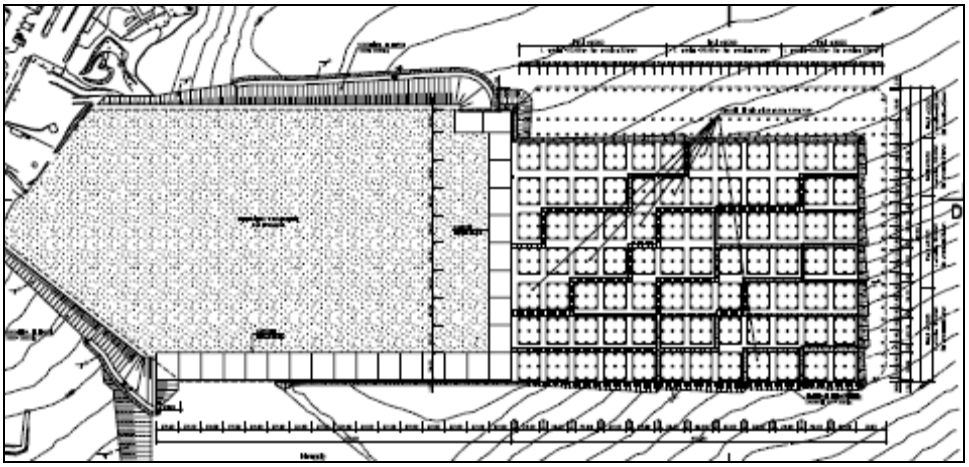


Figure 2 Plan view of the platform foundations, with indication of tested longitudinal sections

1.1. SCOPE

This model study has been carried out for Technital at a scale of 1:60 to measure pulsating and impulsive wave pressures acting on the platform deck / beams, and on the submerged caissons using pressure and force transducers.

Two longitudinal section of the platform were reproduced and tested in the model:
- Test Series A: Section B-B (Figure 2);
- Test Series B: Section D-D (Figure 2).

Wave overtopping onto the top deck was also observed visually during testing, and scour of the foundation was monitored using photographic stills.

1.2. DATA

The following data have been provided by the client:
- Bathymetry;
- Plan view and cross section of the platform;
- Wave condition at the toe of the structure;
- Size of scour protection material.

Technital also defined return periods for use in assessing wave conditions at the site, that is: 1:5 years, 1:25 years, 1:100 years and 1:500 years (overload).

2. Methodology

2.1 FROUDE SCALING LAWS

The Froude scaling law is applied to physical models where gravity is the predominant factor in the fluid motion. Wave models, since wave motion is essentially a gravitational phenomenon, are therefore designed according to this law. The Froude law states that the Froude number, Fr, should be the same in model and prototype, where Fr is defined as:

$$F_r = \frac{u}{\sqrt{gD}} \qquad (1)$$

where u is a characteristic velocity (m/s), g is the acceleration due to gravity (m/s^2) and D is a characteristic length (m).

Wave models are not distorted, having the same horizontal and vertical scales. The linear scale of the model, to which the bathymetry and structures were constructed, is known as the geometric scale, λ. Froudian scaling relationships for other parameters are outlined below:

Length	λ	Time	$\lambda^{½}$
Velocity	$\lambda^{½}$	Force	λ^3
Volume	λ^3	Acceleration	1

In the design of a physical model of this type, the principal concern is to ensure that the main aspects of the wave structure interaction are reproduced faithfully at a scale that avoids significant scale effects. The test sections must also be of a practical size to be handled in the facility selected and with the resources available. The breakwater was modelled to a scale of

1:60, selected to match the particular model armour units available. All dimensions referred to in this report are in prototype units / dimensions unless otherwise stated.

2.2 TEST FACILITIES

The modelling was carried out in Wave Flume 1 at HR Wallingford. The flume is 45m long by 1.2m wide and can operate with water depths of up to 1.6m. The bathymetry constructed for this model during Test Series A and B is shown in Figures 3 and 4 respectively. Waves were produced by an absorbing random wave generator driven by an electric motor system. The floor of the model was set at -42.5mCD for Test Series A and -48.0mCD for Test Series B.

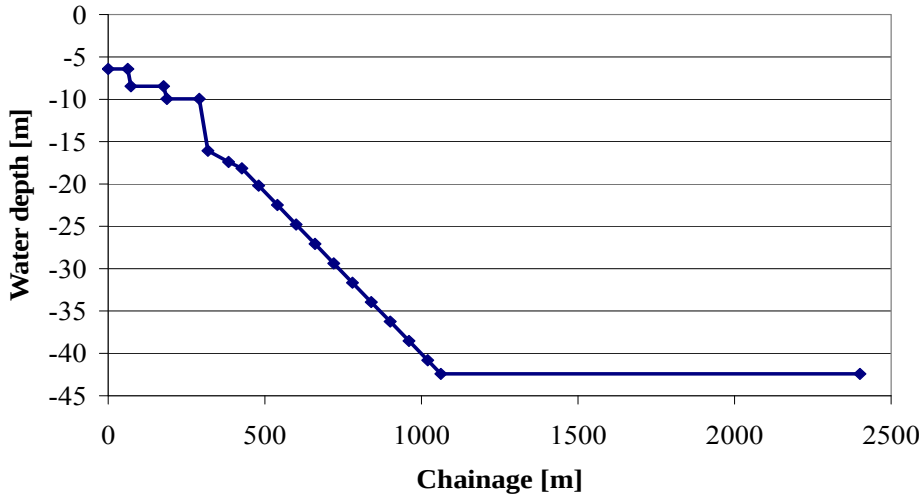


Figure 3 Model bathymetry for Test Series A

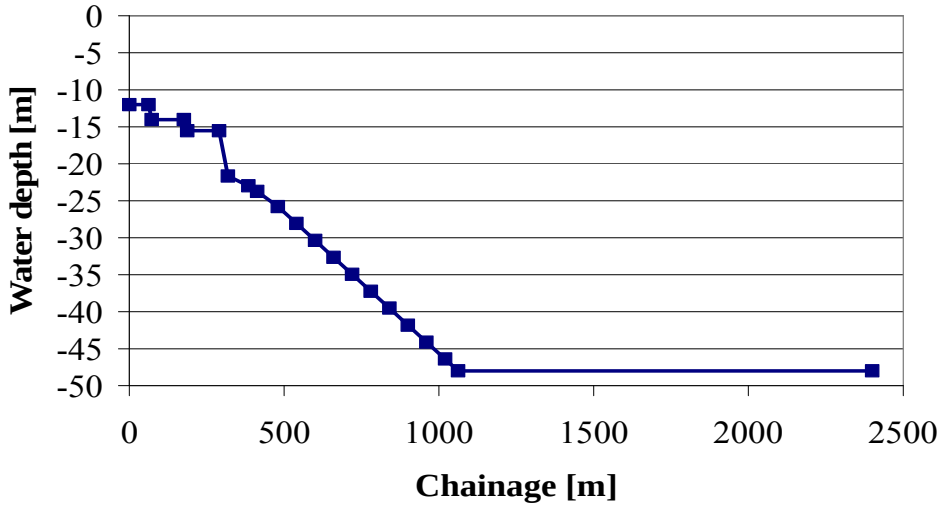


Figure 4 Model bathymetry for Test Series B

The input signal to the wave generator is produced by a random wave synthesiser, which uses HRW's HRWavemaker software. HRWavemaker is capable of producing random sea states to any required spectral shape. For this study JONSWAP spectra with $\gamma = 3.3$ were used.

Model wave measurements were acquired and analysed by HRW's HRDaq software, which contains spectral and statistical analysis routines. Waves were measured using twin-wire resistance gauges, with a resolution of less than 0.1mm at model scale.

The bathymetry was formed by a cement mortar mix placed on top of a compacted fill. The main shape of the bathymetry is modelled by creating bars that run the length of the model in the form of the bathymetry and then screeding between them. The detail of the main model section was then modelled on top. The bathymetry extended upwards from the -42.5mCD and -48.0mCD contour respectively for Test Series A and B.

2.3 WAVE CALIBRATIONS

The four wave conditions used in the study are summarised in Table 1. These have joint return periods ranging from 1:5 to 1:500 years and were provided by Technital at a water depth of -16mCD. Wave conditions were then propagated backwards offshore to a water depth of -42.5mCD (Test Series A) and -48.0mCD (Test Series B) The results are summarised in Table 1 and 2 for Test Series A0-A1 and B0-B1 respectively and were used as input for calibration.

Table 1 Wave conditions used in Test Series A0-A1

Test Series	Return period (years)	Nearshore				Offshore			
		H_s (m)	T_m (s)	T_p (s)	SWL (mCD)	H_s (m)	T_m (s)	T_p (s)	SWL (mCD)
A0	5	2.5	5.8	7.3	+0.0	2.7	5.8	7.3	+0.0
A0	25	3.3	6.6	8.4	+0.0	3.5	6.6	8.4	+0.0
A0	100	4.0	7.2	9.2	+0.0	4.2	7.2	9.2	+0.0
A0	500	5.0	8.0	10.2	+0.0	5.0	8.0	10.2	+0.0
A1	5	2.5	5.8	7.3	+0.0	2.7	5.8	7.3	+0.0
A1	25	3.3	6.6	8.4	+0.0	3.5	6.6	8.4	+0.0
A1	100	4.0	7.2	9.2	+0.0	4.2	7.2	9.2	+0.0
A1	500	5.0	8.0	10.2	+0.0	5.0	8.0	10.2	+0.0

Table 2 Wave conditions used in Test Series B0-B1

Test Series	Return period (years)	Nearshore				Offshore			
		H_s (m)	T_m (s)	T_p (s)	SWL (mCD)	H_s (m)	T_m (s)	T_p (s)	SWL (mCD)
B0	5	2.5	5.8	7.3	+0.0	2.7	5.8	7.3	+0.0
B0	25	3.3	6.6	8.4	+0.0	3.5	6.6	8.4	+0.0
B0	100	4.0	7.2	9.2	+0.0	4.2	7.2	9.2	+0.0
B0	500	5.0	8.0	10.2	+0.0	5.2	8.0	10.2	+0.0
B1	5	2.5	5.8	7.3	+0.0	2.7	5.8	7.3	+0.0
B1	25	3.3	6.6	8.4	+0.0	3.5	6.6	8.4	+0.0
B1	100	4.0	7.2	9.2	+0.0	4.2	7.2	9.2	+0.0
B1	500	5.0	8.0	10.2	+0.0	5.2	8.0	10.2	+0.0

Waves were calibrated using an offshore wave probe located on the -42.5mCD (Test Series A) and -48mCD (Test Series B) contour. The first stage in calibrating each wave condition was to calculate a JONSWAP spectrum from given significant wave height and peak period. The precise wave calibration was then achieved using an iterative process whereby the wave condition was run, measured at the calibration probe, analysed, and then the gain of the input signal to the paddle was changed create the correct sea state to within +- 5%.

Wave conditions in the model were analysed in two ways; spectrally and statistically. These methods are outlined briefly here:

i) Spectral analysis allows the distribution of the energy content of the waves across the frequency spectrum to be determined via a Fast Fourier Transform Technique. The parameters determined by spectral analysis include the spectral significant wave height, H_{mo}, determined from the area under the spectrum, the peak wave period, T_p (taken here equivalent to $1.28T_z$), and the mean spectral period, $T_{m-1,0}$.

ii) Measurements of surface elevation were made relative to the mean value of the water level. A wave is defined as lasting between two successive down crossings of the mean water level. At the end of each sea state record, wave heights calculated from the sum of the maximum departure above and below the mean water level, are sorted in descending order from which statistical values of $H_{1/3}$ and H_{max} can be determined. The total length of the calibration period is divided by the number of waves recorded to give the mean zero-crossing wave period T_m.

The calibrated wave conditions are shown in Table 3 and 4 respectively for Test Conditions A0-A1 and B0-B1. Wave spectra derived from surface elevation time histories recorded during calibration at the offshore probe are superimposed on target wave spectra in Appendix A.

Table 3 Calibrated wave conditions, Test Series A0-A1

Target Condition				Measured					
				Stat			Spectral		
Return Period	H_s (m)	T_{m-10} (s)	T_p (s)	$H_{1/3}$ (m)	H_{max} (m)	T_m (s)	H_{m0} (m)	$T_{m-1,0}$ (s)	T_p (s)
1:5	2.7	5.8	7.3	2.8	5.4	5.9	2.9	6.5	7.0
1:25	3.5	6.6	8.4	3.6	6.4	6.6	3.7	7.6	8.2
1:100	4.2	7.2	9.2	4.3	7.5	7.3	4.5	8.3	8.8
1:500	5.0	8.0	10.2	5.2	8.6	8.0	5.3	9.4	10.5

Table 4 Calibrated wave conditions Test Series B0-B1

Target Condition				Measured					
				Stat			Spectral		
Return Period	H_s (m)	T_{m-10} (s)	T_p (s)	$H_{1/3}$ (m)	H_{max} (m)	T_m (s)	H_{m0} (m)	$T_{m-1,0}$ (s)	T_p (s)
1:5	2.7	5.8	7.3	2.6	4.3	5.9	2.7	6.3	7.2
1:25	3.5	6.6	8.4	3.4	5.5	6.5	3.6	7.3	8.4
1:100	4.2	7.2	9.2	4.0	6.9	7.2	4.3	8.2	9.2
1:500	5.2	8.0	10.2	5.3	8.6	8.1	5.4	9.1	10.2

2.4 NON-CALIBRATED WAVE CONDITIONS

After completion of Test Series B1, Technital asked for further overload conditions, including a raised water level of +0.5mCD. These were run using non-calibrated waves generated to match conditions summarised in Table 5. The return period for H_s = 6.0m was estimated to be 1:3547yrs and to have corresponding wave period T_p = 11.4s.

Table 5 Calibrated wave conditions Test Series B2

Target Condition				Measured				
				Stat			Spectral	
Return Period (wave conditions only)	SWL (mCD)	H_s (m)	T_p (s)	$H_{1/3}$ (m)	H_{max} (m)	T_m (s)	H_{m0} (m)	T_p (s)
1:3547	+0.00	6.0	11.4	6.5	10.3	8.7	6.7	11.3
1:100	+0.50	4.2	9.2	4.1	7.7	7.1	4.2	8.8
1:500	+0.50	5.2	10.2	5.4	9.1	7.9	5.5	9.9
1:3547	+0.50	6.0	11.4	6.6	10.7	8.5	6.7	11.3

2.5 MODEL STRUCTURE

The structure was formed in timber. The foundation caissons were formed as hollow timber boxes and the vertical piles were bolted down into the caissons. The beams were bolted into the deck and the superstructure lowered into position in the flume. The deck, the beams and the supporting elements (piles and caissons) were carefully designed to provide the required stiffness while allowing installation of pressure and force transducers at agreed location.

Rock scour protection was reproduced using appropriately scaled armour over a length in the wave flume of 90m. The model rock was prepared by sieving to match the design size specification (2-300kg).

2.5.1 Wave gauges

Wave conditions were measured using twin wire wave gauges, with 32 used to measure conditions at the generation point (offshore) and within the model area.

After calibration and before testing, the model structure was installed (without deck units) and 32 wave gauges were deployed both offshore (Probe N.1) and at critical locations along the model structure (Figure 5) to identify the most critical locations along the platform in terms of both wave agitation and maximum crest elevation and support the selection of key elements to be instrument during Test Series A1 and B1.

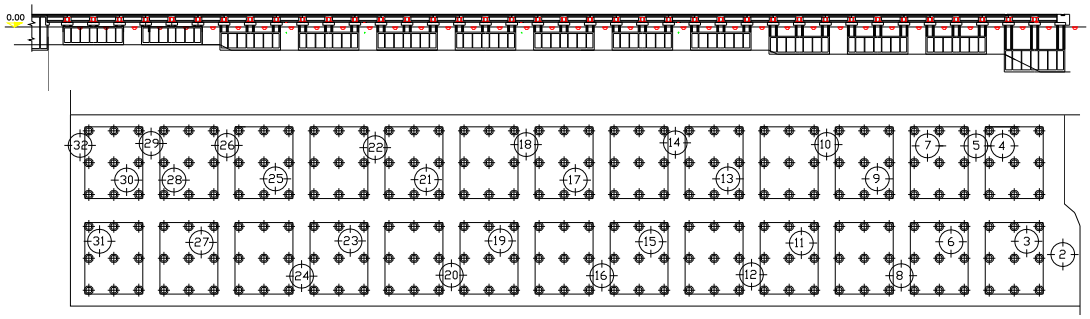


Figure 5 Longitudinal section (top) and plan view (bottom) of model structure (Test Series A0), showing location of gauges along the structure



Figure 6 Overall side view showing location of gauges along the structure

2.5.2 Pressure measurements

Pressures (pulsating and impulsive) were measured on the deck elements as well as on the foundation caisson using 37 pressure sensors, permitting the following:

First unit (23 pressure sensors, see Figures 7 and 9)

- 1 x 5 pressure sensors on one deck element (down-looking);
- 1 x 5 pressure sensors on one deck element (up-looking);
- 1 x 1 pressure sensors for the longitudinal beams (down-looking);
- 1 x 1 pressure sensors for the longitudinal beams (up-looking);
- 2 x 1 pressure sensors for the transversal beams (down-looking);
- 2 x 1 pressure sensors for the transversal beams (up-looking);
- 2 x 1 pressure sensors for the transversal beams (horizontal-seaward);
- 2 x 1 pressure sensors for the transversal beams (horizontal-shoreward);
- 2 x 1 pressure sensors on one caisson (horizontal);
- 1 x 1 pressure sensors on one pile (horizontal).

Second unit (14 pressure sensors, see Figures 8, 9 and 10)

- 1 x 5 pressure sensors on one deck element (down-looking);
- 1 x 1 pressure sensors for the longitudinal beams (down-looking);
- 2 x 1 pressure sensors for the transversal beams (down-looking);
- 2 x 1 pressure sensors for the transversal beams (horizontal-seaward);
- 2 x 1 pressure sensors for the transversal beams (horizontal-shoreward);
- 2 x 1 pressure sensors on one caisson (horizontal);

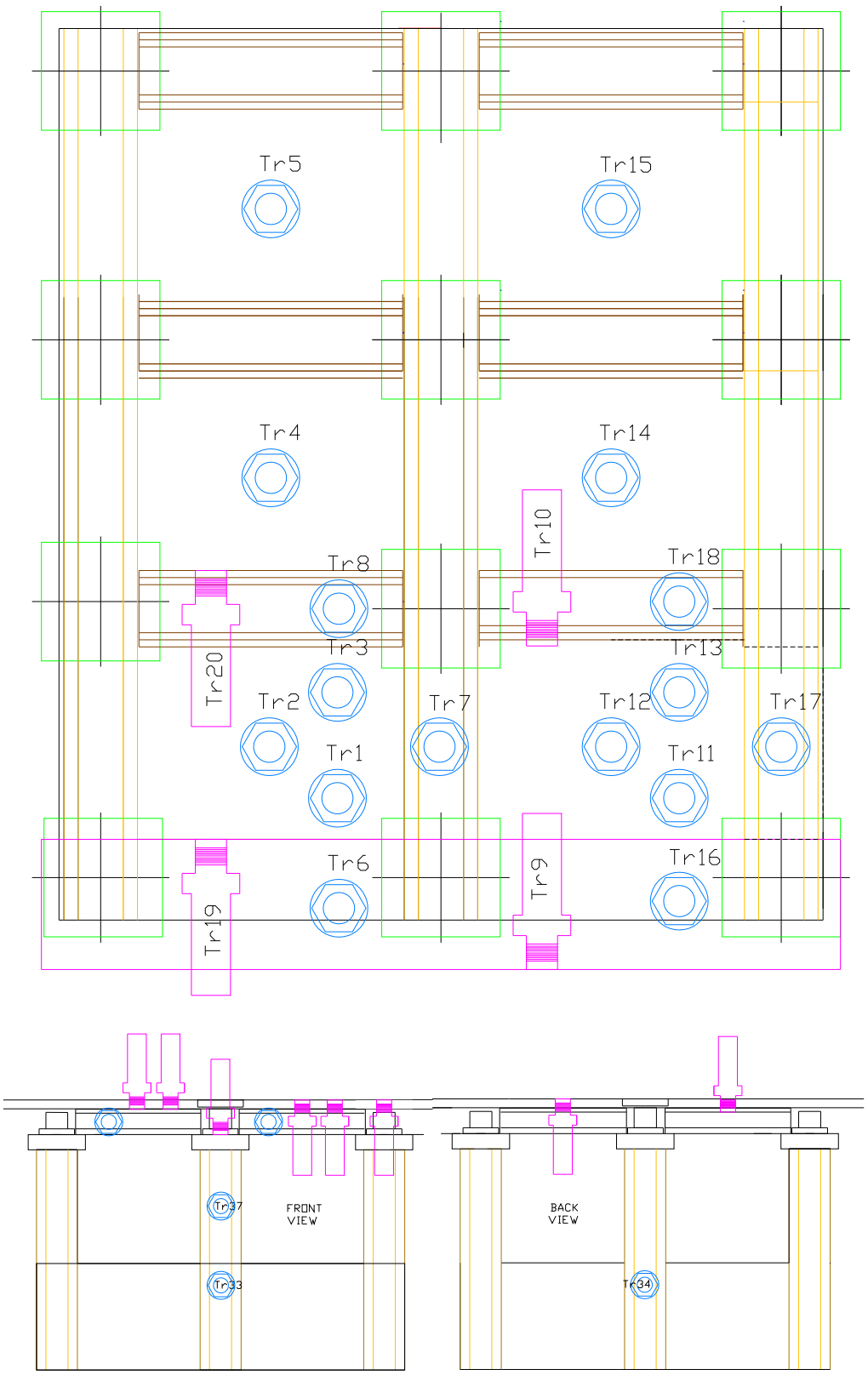


Figure 7 Location of pressure sensors on the first unit

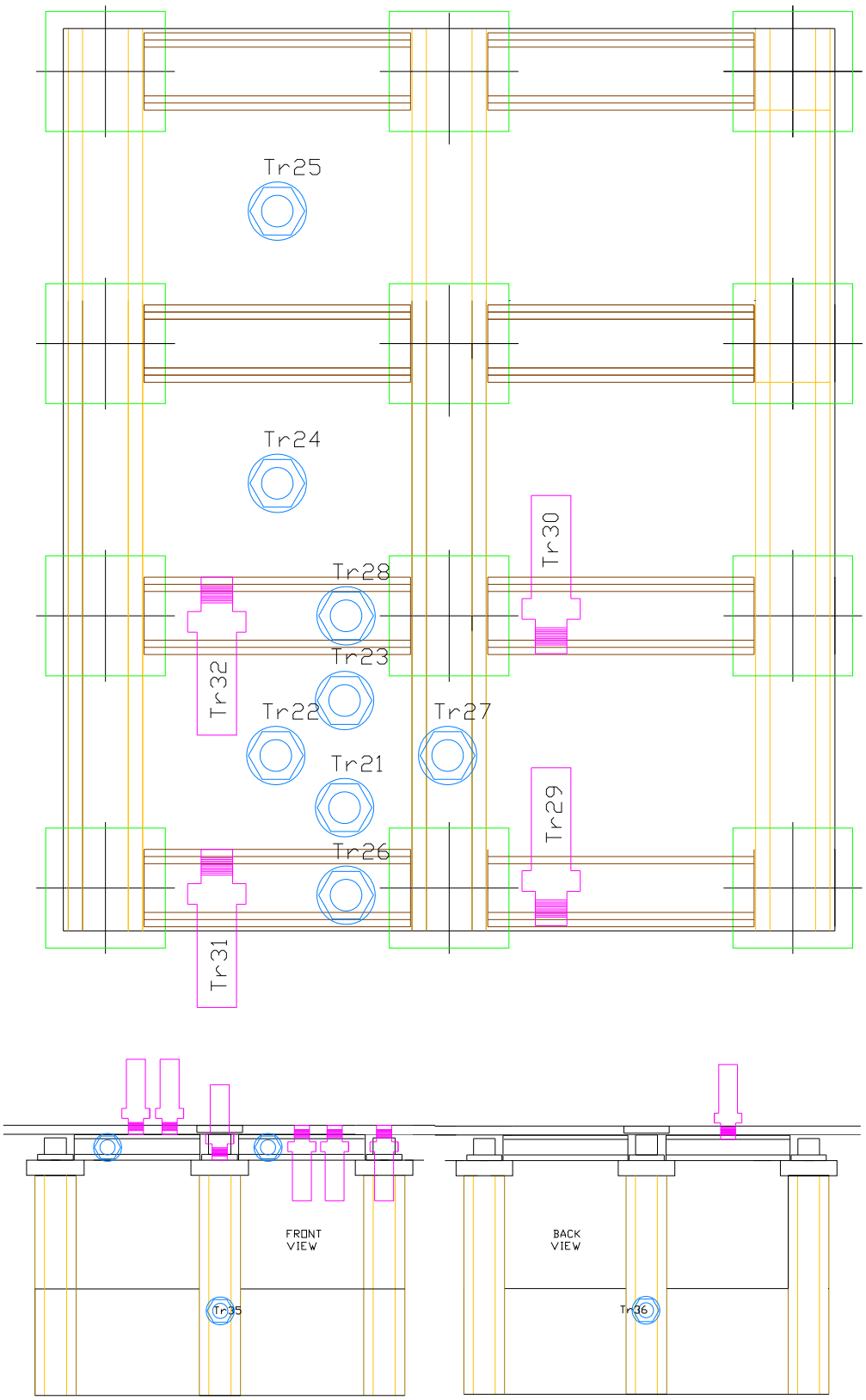


Figure 8 Location of pressure sensors on the second unit

Pressures were logged at a (model) frequency of 5000Hz (~650Hz prototype) in order to capture both impulsive and pulsating loads on the structural elements of the platform.

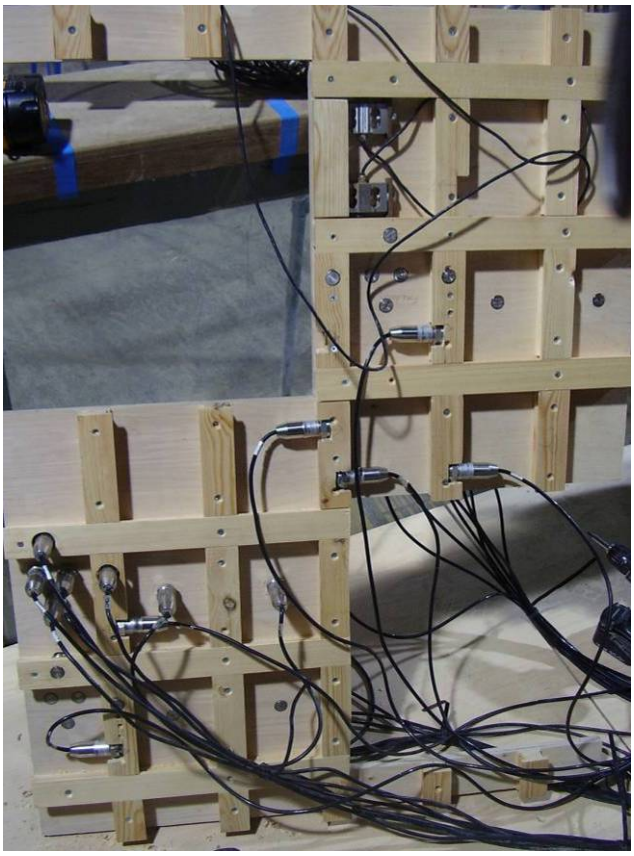


Figure 9 Instrumented platform deck during assembling of model structure



Figure 10 Close-up of force (left) and pressure (right) transducer during model construction and installation

2.5.3 *Force measurements*

Wave-in-deck forces were measured using:

- 3 force transducers connected to each of the deck panel (Figure 10)
- 2 force transducers connected to each of beam element

Plan view and cross sections are given in Figure 11.

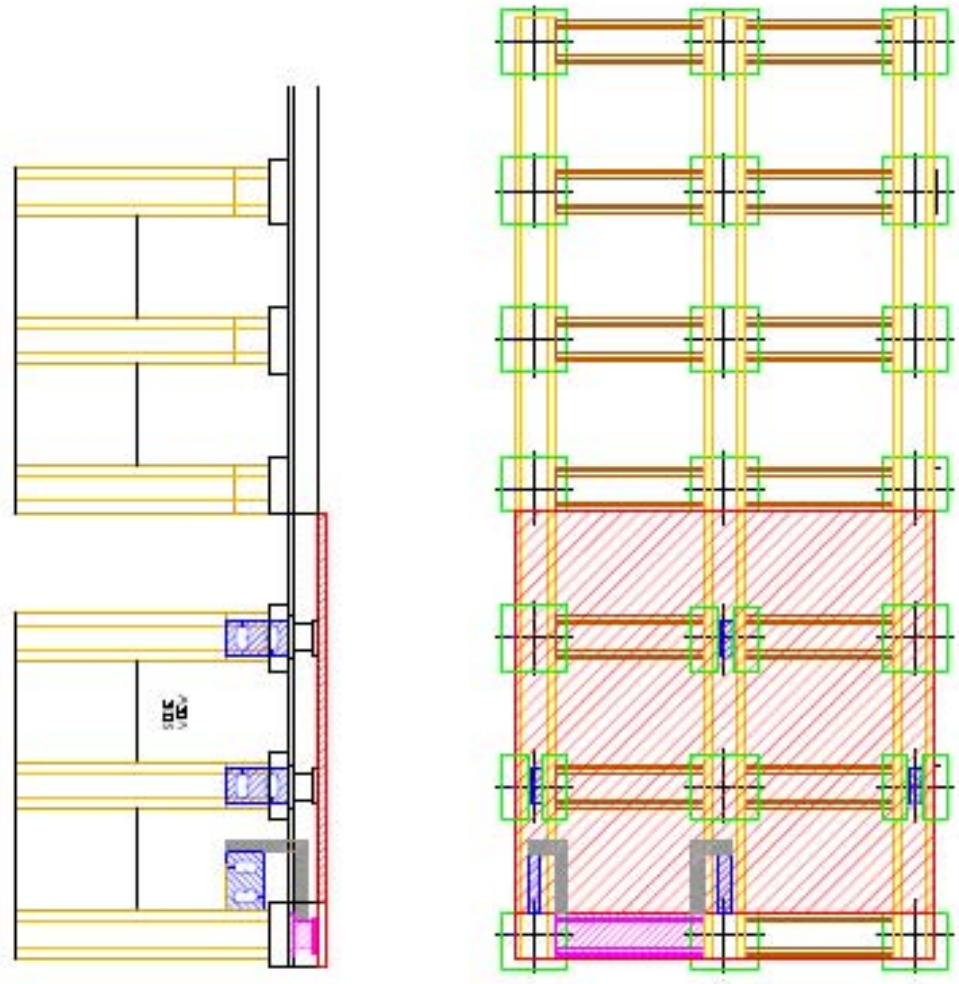


Figure 11 Location of force sensors on an example instrumented deck

2.6 OVERTOPPING OBSERVATION

Wave overtopping was observed visually during test series A1 and recorded using two cameras pointing at the structure head from the top and the side.

2.7 ARMOUR MOVEMENT

Overhead pictures were taken before and after each test to record movement of the scour armour. These images were then overlaid and flicked between before and after images to identify when armour had moved. Observations were made during the tests to identify any displaced armour units.

For the scour protection material, the damage categories were defined according to BSI 6349: Pt 7 (1991), as summarised in Table 3, where D_{n50} is the nominal diameter of the relevant armour size. For each category of damage, BSI 6349 (1991) defines a damage classification, and these are given here in Tables 6-7.

Table 6 Rock armour damage categories (BS 6349-7:1991)

Category	Displacement (% of D_{n50})
1	$0.2 \sim 0.5 D_{n50}$
2	$0.5 > D_{n50}$
3	$> D_{n50}$

Table 7 Damage classification (BS 6349-7:1991)

Damage	Description
Destroyed	Core of breakwater affected
Serious	Core of breakwater visible
Much	Large gaps in primary layer: 5% of units displaced
Moderate	Gaps in primary layer: 3% of units displaced
Little	2% of units displaced
Slight	1% of units displaced
Hardly	No damage

3. Test Programme

Two Test Series A and B were carried out on the model. Test Series A0 and B0 looked at wave transformation over the platform area, conditions 1:5, 1:25, 1:100 and 1:500 years were tested. Test Series A1, B1 and B2 looked at:

- Force measurement
- Pressure measurement
- Overtopping visual observation
- Scour protection
- Wave reflection at the toe of the structure

During Test Series A1 and B1 conditions corresponding to 1:5, 1:25, 1:100 and 1:500 years were tested, extended during Test Series B2 to explore the effect of sea level rise and extreme storm event (up to 1:3547yrs return period).

The complete test programme is summarised in Table 8 (Test Series A) and 9 (Test Series B) below. For Test Series A1 and B1 stability photos were taken before and after each test. Each test was run for 1000 waves.

Table 8 Summary of tests

Test Series	Test number	Return period	Measurements
A0	01	1:5 years	W
A0	02	1:25 years	W
A0	03	1:100 years	W
A0	04	1:500 years	W
A1	05	1:5 years	F/P/S/O/W
A1	06	1:25 years	F/P/S/O/W
A1	07	1:100 years	F/P/S/O/W
A1	08	1:500 years	F/P/S/O/W

Table 9 Summary of tests

Test Series	Test number	Return period	Measurements
B0	09	1:5 years	W
B0	10	1:25 years	W
B0	11	1:100 years	W
B0	12	1:500 years	W
B1	13	1:5 years	F/P/S/O/W
B1	14	1:25 years	F/P/S/O/W
B1	15	1:100 years	F/P/S/O/W
B1	16	1:500 years	F/P/S/O/W
B2	17	1:3547 years	F/P/W
B2	18	1:100 years	F/P/W
B2	19	1:500 years	F/P/W
B2	20	1:3547 years	F/P/W

Legend:
F = Forces
P = Pressures
S = Scour
O = Overtopping
W = Waves

4. Results

4.1 TEST SERIES A0 AND B0: WAVE PROPAGATION OVER THE MODEL AREA

Wave transformation over the model structure exhibited a very similar pattern for all conditions tested during both Test Series A and B. Wave heights reduced dramatically over the first two caissons due to depth-limited breaking and destructive interference over the top face of the caissons.

This is represented in Figures 12-15 (Test Series A0) and Figures 16-19 (Test Series B0) showing variation of extreme wave parameters (H_s, H_{max}, $H_{1/10}$ and η_{max}) at instrumented locations along the model structure respectively for the 1:5, 1:25, 1:100 and 1:500 years conditions.

Wave spectra derived from surface elevation time histories recorded during testing at each instrumented location are reproduced in Appendix B.

In Figures 12-19, H_{max} was the highest wave height in 1000 waves, so represents an estimate of $H_{0.1\%}$. Similarly, the extreme crest elevation, η_{max} might therefore be more correctly given as: $\eta_{0.1\%}$.

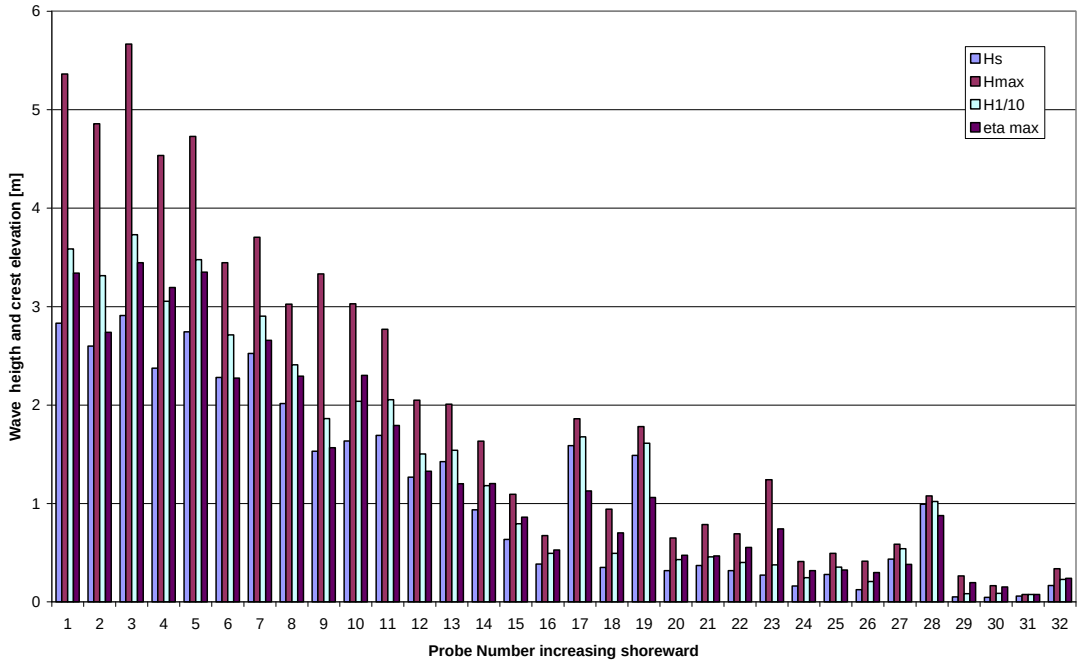


Figure 12 Wave transformation over the model structure, Test Series A0, 1:5 year condition

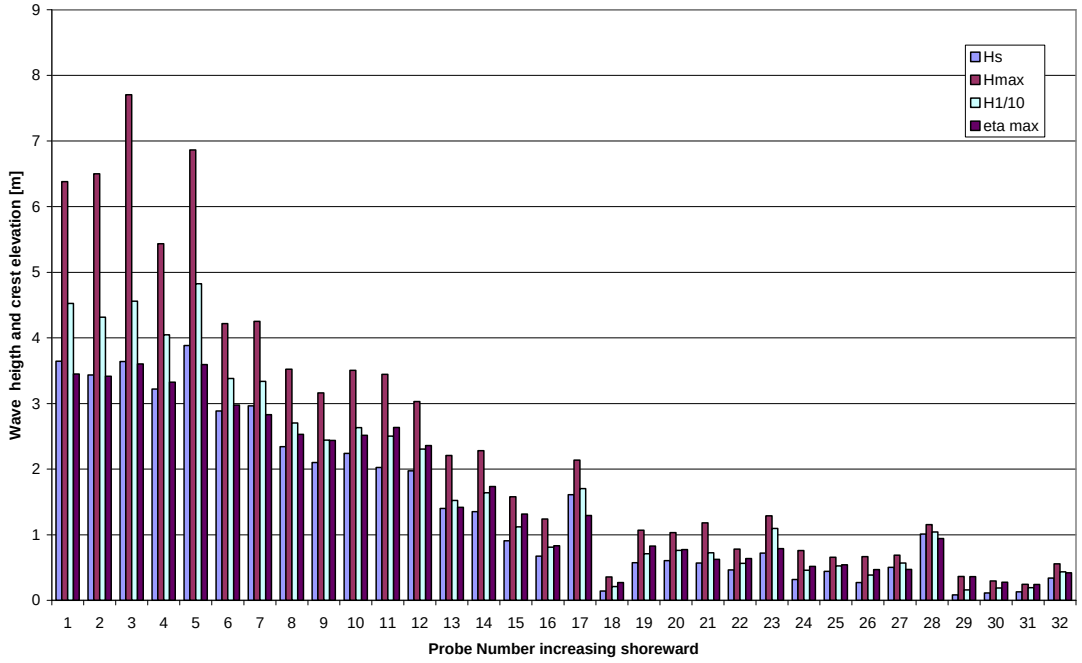


Figure 13 Wave transformation over the model structure, Test Series A0, 1:25 year condition

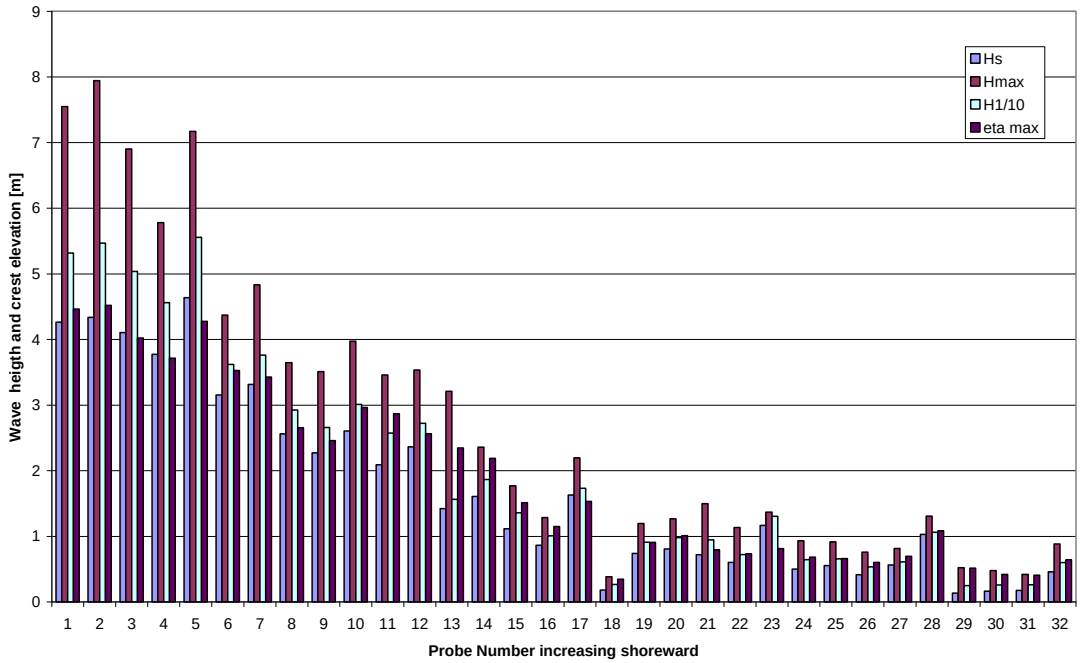


Figure 14 Wave transformation over the model structure, Test Series A0, 1:100 year condition

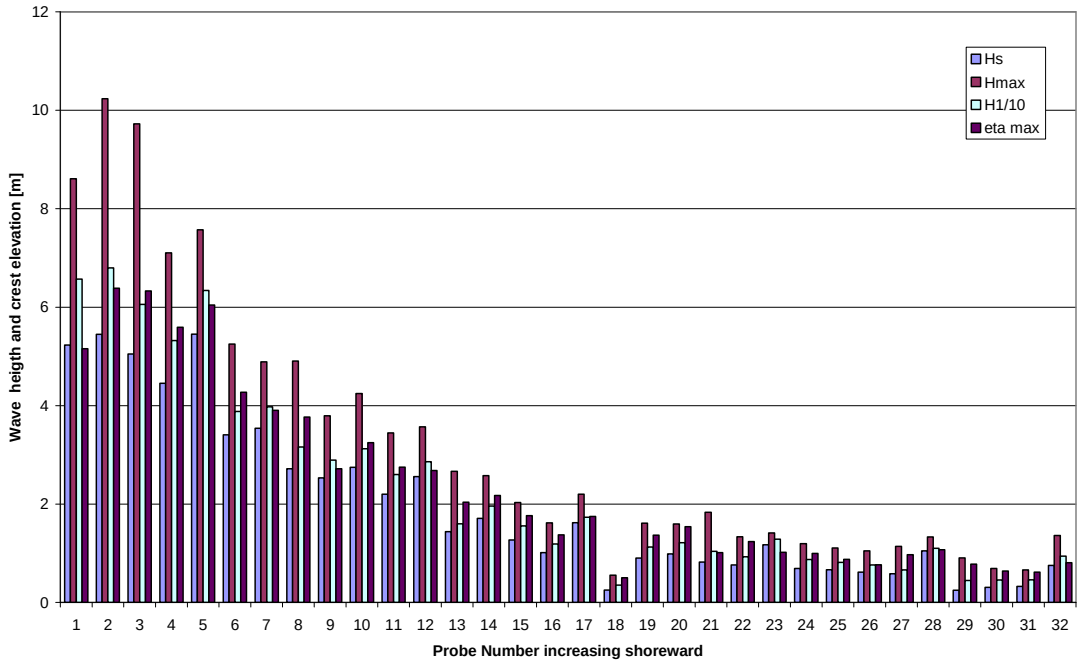


Figure 15 Wave transformation over the model structure, Test Series A0, 1:500 year condition

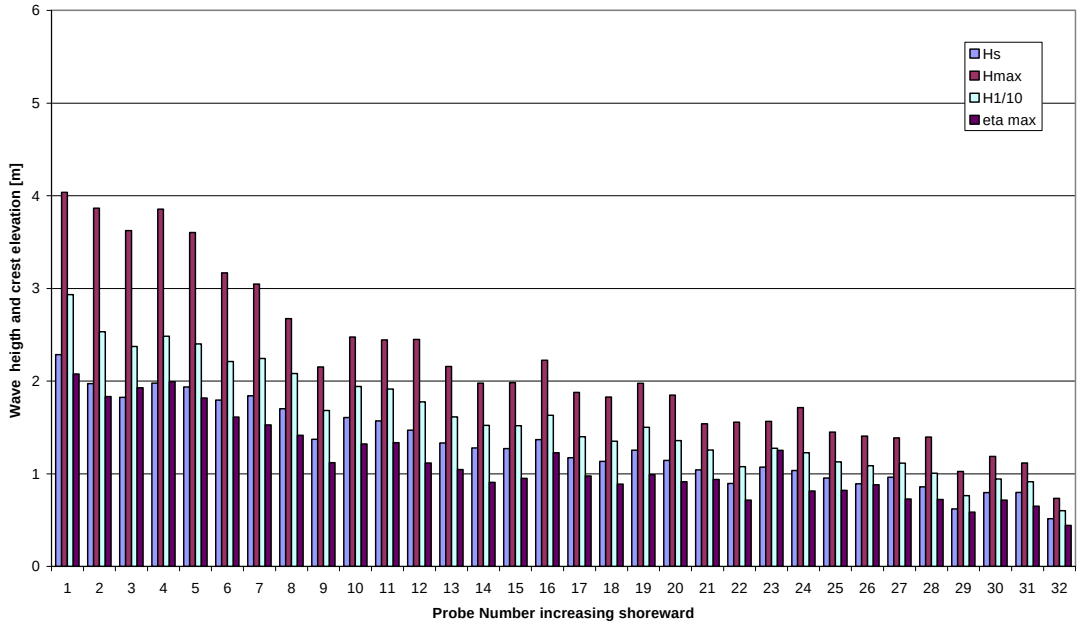


Figure 16 Wave transformation over the model structure, Test Series B0, 1:5 year condition

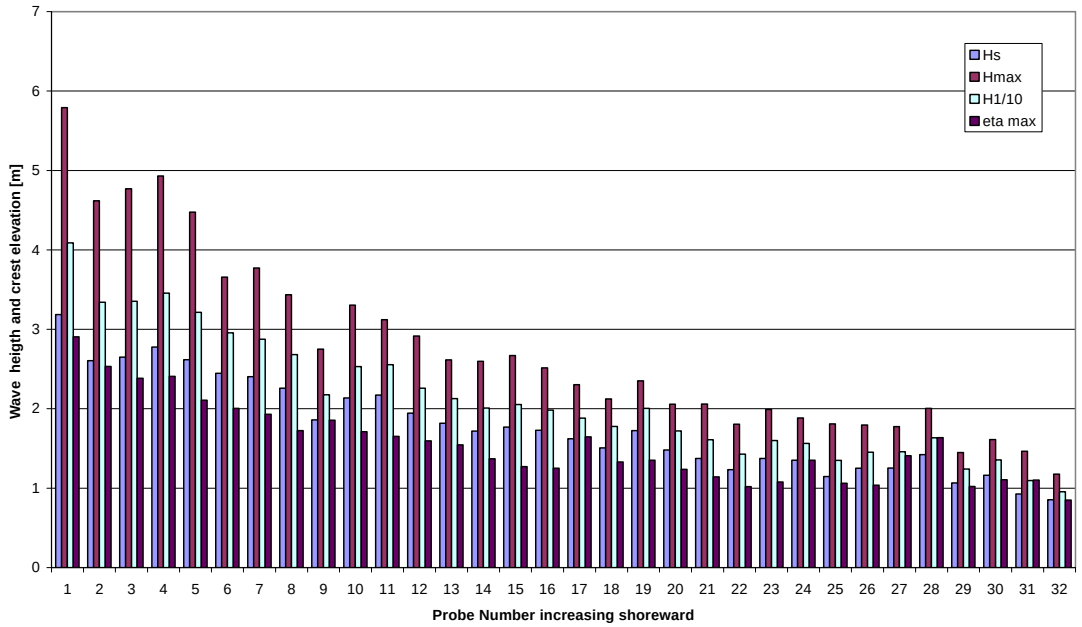


Figure 17 Wave transformation over the model structure, Test Series B0, 1:25 year condition

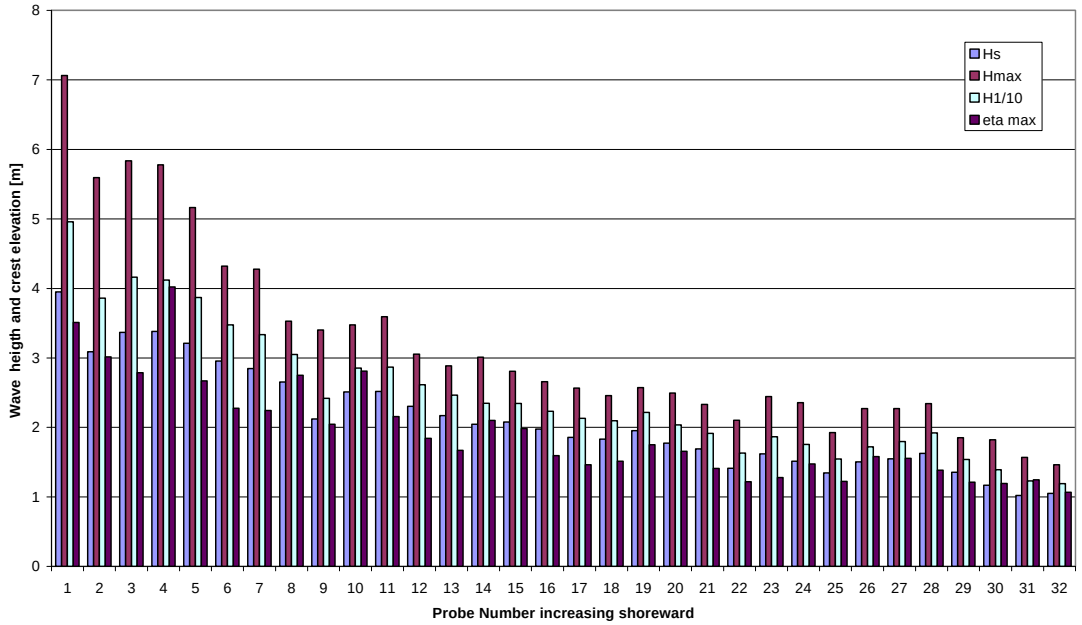


Figure 18 Wave transformation over the model structure, Test Series B0, 1:100 year condition

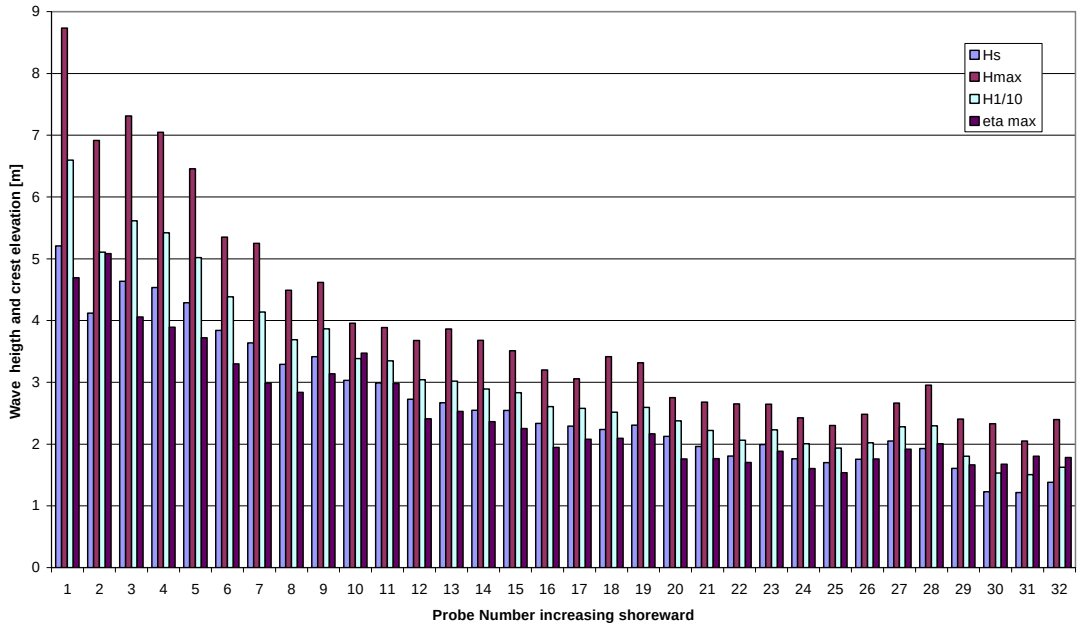


Figure 19 Wave transformation over the model structure, Test Series B0, 1:500 year condition

4.2 TEST SERIES A1, B1 AND B2: WAVE LOADING

4.2.1 Pressures

Time histories recorded by each pressure transducer were analysed to extract the following information:

- Pressure maxima at 1/1000* and 1/250 significance level

- Time histories of the severest 4 events.

* For tests of 1000 waves, this value becomes the 0.1% exceedence value. The 1/250 significance level was computed as the (arithmetic) average of the top 4 values in 1000.

Pressure at 1/1000 and 1/250 significance level are summarised in Table 10-13 (Test Series A1) and Table 14-17 (Test Series B1) respectively for the 1:5, 1:25, 1:100 and 1:500 years conditions.

Results corresponding to Test Series B2 are summarised in Table 18 for the 1:3547 years condition (+0.00mCD) and Tables 19-21 for the 1:100, 1:500 and 1:3547 years condition (+0.50mCD).

Time histories corresponding to the severest 4 events in each time history are reproduced in Appendix C.

Table 10 Test Series A1: summary of pressure at 1/1000 and 1/250 significance level, 1:5ys condition

Unit	Element	Load	Direction	N.	$P_{imp,max}$ [kPa]	$P_{imp,1/250}$ [kPa]	$P_{qs+,max}$ [kPa]	$P_{qs+,1/250}$ [kPa]	$P_{qs-,max}$ [kPa]	$P_{qs-,1/250}$ [kPa]
1	Deck	Vertical	Upward	1	3.1	2.5	0.4	0.4	-6.7	-5.9
1	Deck	Vertical	Upward	1	1.2	1.2	0.5	0.5	-6.4	-5.7
1	Deck	Vertical	Upward	1	4.5	3.3	1.5	0.9	-6.7	-5.9
1	Deck	Vertical	Upward	2	2.2	1.7	0.3	0.3	-6.7	-4.6
1	Deck	Vertical	Upward	3	1.1	1.1	0.5	0.3	-1.4	-1.3
1	Beam (L)	Vertical	Upward	1	94.8	48.1	19.5	16.7	-12.3	-11.0
1	Beam (T)	Vertical	Upward	1	123.4	92.9	32.8	26.7	-7.6	-6.7
1	Beam (T)	Vertical	Upward	2	136.7	73.6	20.3	17.2	-10.6	-7.6
1	Beam (T)	Horizontal	Seaward	1	19.9	12.8	13.1	8.6	-0.8	-0.5
1	Beam (T)	Horizontal	Seaward	2	49.2	41.4	10.7	9.2	-5.5	-4.3
1	Deck	Vertical	Downward	1	3.0	2.5	0.1	0.1	-0.1	-0.1
1	Deck	Vertical	Downward	1	3.9	3.3	0.2	0.2	-0.2	-0.1
1	Deck	Vertical	Downward	1	2.5	1.9	0.1	0.1	-0.1	-0.1
1	Deck	Vertical	Downward	2	5.6	4.3	0.1	0.1	-0.1	-0.1
1	Deck	Vertical	Downward	3	3.9	3.3	0.1	0.1	-0.1	-0.1
1	Beam (L)	Vertical	Downward	1	3.6	3.4	0.2	0.1	-0.1	-0.1
1	Beam (T)	Vertical	Downward	1	3.8	2.7	0.2	0.1	-0.2	-0.1
1	Beam (T)	Vertical	Downward	2	3.9	2.9	0.2	0.1	-0.1	-0.1
1	Beam (T)	Horizontal	Shoreward	1	9.2	6.7	0.5	0.4	-6.6	-5.8
1	Beam (T)	Horizontal	Shoreward	2	4.3	2.6	0.3	0.3	-6.6	-4.5
2	Deck	Vertical	Upward	1	3.9	3.0	0.2	0.2	-0.7	-0.6
2	Deck	Vertical	Upward	1	4.1	3.6	0.6	0.3	-0.8	-0.6
2	Deck	Vertical	Upward	1	8.1	4.9	1.2	1.1	-3.2	-2.4
2	Deck	Vertical	Upward	2	3.9	3.6	0.2	0.2	-1.2	-0.7
2	Deck	Vertical	Upward	3	5.5	4.9	0.2	0.1	-0.1	-0.1
2	Beam (L)	Vertical	Upward	1	72.3	40.5	11.6	10.6	-5.7	-5.3
2	Beam (T)	Vertical	Upward	1	175.4	162.1	38.7	29.5	-4.7	-4.2
2	Beam (T)	Vertical	Upward	1	134.5	92.4	30.5	23.4	-6.3	-6.0
2	Beam (T)	Horizontal	Seaward	1	78.0	36.7	12.0	9.3	-0.9	-0.8
2	Beam (T)	Horizontal	Seaward	2	10.3	4.3	6.1	2.8	-0.4	-0.4
2	Beam (T)	Horizontal	Shoreward	1	2.1	1.8	0.2	0.2	-0.4	-0.4

Unit	Element	Load	Direction	N.	$P_{imp,max}$ [kPa]	$P_{imp,1/250}$ [kPa]	$P_{qs+,max}$ [kPa]	$P_{qs+,1/250}$ [kPa]	$P_{qs-,max}$ [kPa]	$P_{qs-,1/250}$ [kPa]
2	Beam (T)	Horizontal	Shoreward	2	2.4	1.9	0.2	0.2	-1.2	-0.7
1	Caisson	Horizontal	Seaward	1	13.8	13.3	12.0	11.6	-15.0	-13.5
1	Caisson	Horizontal	Shoreward	1	13.5	13.5	12.9	12.6	-12.9	-12.7
2	Caisson	Horizontal	Seaward	2	13.5	12.8	11.7	10.9	-13.1	-11.9
2	Caisson	Horizontal	Shoreward	2	12.8	12.0	11.2	10.8	-8.2	-7.9
1	Pile	Horizontal	Seaward	1	44.9	33.0	16.4	16.1	-24.7	-21.8

Table 11 Test Series A1: summary of pressure at 1/1000 and 1/250 significance level, 1:25ys condition

Unit	Element	Load	Direction	N.	$P_{imp,max}$ [kPa]	$P_{imp,1/250}$ [kPa]	$P_{qs+,max}$ [kPa]	$P_{qs+,1/250}$ [kPa]	$P_{qs-,max}$ [kPa]	$P_{qs-,1/250}$ [kPa]
1	Deck	Vertical	Upward	1	4.2	3.7	1.8	1.5	-13.0	-12.2
1	Deck	Vertical	Upward	1	4.3	3.6	3.8	3.1	-11.7	-11.0
1	Deck	Vertical	Upward	1	13.1	7.7	3.6	2.4	-13.1	-12.2
1	Deck	Vertical	Upward	2	12.6	5.1	1.0	0.9	-12.8	-11.9
1	Deck	Vertical	Upward	3	6.0	4.9	5.5	4.4	-4.4	-3.9
1	Beam (L)	Vertical	Upward	1	80.6	79.3	30.6	23.1	-17.4	-15.5
1	Beam (T)	Vertical	Upward	1	231.2	143.1	30.2	24.8	-15.8	-14.1
1	Beam (T)	Vertical	Upward	2	169.5	121.1	29.5	24.1	-16.6	-14.4
1	Beam (T)	Horizontal	Seaward	1	15.3	13.2	11.4	10.3	-0.6	-0.5
1	Beam (T)	Horizontal	Seaward	2	85.1	55.9	32.3	23.2	-12.0	-10.7
1	Deck	Vertical	Downward	1	3.6	3.1	0.2	0.1	-0.1	-0.1
1	Deck	Vertical	Downward	1	4.4	4.1	0.2	0.1	-0.1	-0.1
1	Deck	Vertical	Downward	1	2.1	2.1	0.3	0.2	-0.1	-0.1
1	Deck	Vertical	Downward	2	7.8	6.2	0.1	0.1	-0.1	-0.1
1	Deck	Vertical	Downward	3	5.7	4.6	0.1	0.1	-0.1	-0.1
1	Beam (L)	Vertical	Downward	1	6.0	5.1	2.1	1.1	-0.7	-0.4
1	Beam (T)	Vertical	Downward	1	4.8	4.4	0.2	0.1	-0.2	-0.2
1	Beam (T)	Vertical	Downward	2	4.4	3.9	0.3	0.2	-0.1	-0.1
1	Beam (T)	Horizontal	Shoreward	1	8.4	6.8	1.8	1.5	-13.0	-12.1
1	Beam (T)	Horizontal	Shoreward	2	3.6	2.8	0.5	0.5	-12.7	-11.8
2	Deck	Vertical	Upward	1	2.7	2.4	0.6	0.4	-1.3	-1.3
2	Deck	Vertical	Upward	1	12.4	6.4	1.6	1.1	-2.0	-1.9
2	Deck	Vertical	Upward	1	36.3	18.9	4.2	2.2	-2.3	-2.2
2	Deck	Vertical	Upward	2	6.6	5.1	1.2	0.8	-1.5	-1.4
2	Deck	Vertical	Upward	3	6.8	5.4	1.1	0.5	-0.4	-0.2
2	Beam (L)	Vertical	Upward	1	99.2	74.2	14.8	13.7	-9.1	-8.1
2	Beam (T)	Vertical	Upward	1	286.2	239.0	39.9	35.5	-4.7	-4.6
2	Beam (T)	Vertical	Upward	1	281.1	176.7	22.5	20.2	-7.1	-6.8
2	Beam (T)	Horizontal	Seaward	1	318.4	216.8	38.1	33.7	-2.8	-2.4
2	Beam (T)	Horizontal	Seaward	2	71.0	46.2	8.3	6.5	-1.3	-0.9
2	Beam (T)	Horizontal	Shoreward	1	3.7	3.5	0.3	0.2	-0.6	-0.5
2	Beam (T)	Horizontal	Shoreward	2	3.5	2.9	0.3	0.3	-1.5	-1.4
1	Caisson	Horizontal	Seaward	1	24.0	21.8	21.0	19.3	-21.2	-20.5
1	Caisson	Horizontal	Shoreward	1	17.8	17.6	17.1	16.8	-19.9	-18.9
2	Caisson	Horizontal	Seaward	2	18.2	17.3	16.3	15.8	-21.3	-20.8
2	Caisson	Horizontal	Shoreward	2	14.9	14.3	13.4	13.2	-10.4	-9.8
1	Pile	Horizontal	Seaward	1	39.2	36.2	25.7	23.5	-31.6	-29.6

Table 12 Test Series A1: summary of pressure at 1/1000 and 1/250 significance level, 1:100ys condition

Unit	Element	Load	Direction	N.	$P_{imp,max}$ [kPa]	$P_{imp,1/250}$ [kPa]	$P_{qs+,max}$ [kPa]	$P_{qs+,1/250}$ [kPa]	$P_{qs-,max}$ [kPa]	$P_{qs-,1/250}$ [kPa]
1	Deck	Vertical	Upward	1	19.9	12.7	5.8	4.9	-19.4	-17.2
1	Deck	Vertical	Upward	1	7.7	5.8	5.5	4.5	-15.3	-14.8
1	Deck	Vertical	Upward	1	32.3	16.0	6.6	5.8	-17.8	-16.3
1	Deck	Vertical	Upward	2	8.8	6.9	6.8	4.0	-17.2	-14.9
1	Deck	Vertical	Upward	3	8.5	6.1	5.9	4.3	-8.4	-6.5
1	Beam (L)	Vertical	Upward	1	134.3	96.3	39.8	28.0	-20.2	-18.8
1	Beam (T)	Vertical	Upward	1	364.6	258.8	33.4	31.6	-19.1	-17.8
1	Beam (T)	Vertical	Upward	2	185.7	112.4	29.6	28.3	-22.2	-19.2
1	Beam (T)	Horizontal	Seaward	1	45.2	26.3	17.2	15.9	-0.7	-0.6
1	Beam (T)	Horizontal	Seaward	2	90.1	79.3	42.9	36.4	-23.5	-17.0
1	Deck	Vertical	Downward	1	3.7	3.3	2.4	2.1	-0.5	-0.4
1	Deck	Vertical	Downward	1	4.8	4.2	4.0	2.5	-0.6	-0.4
1	Deck	Vertical	Downward	1	4.2	3.3	2.2	1.7	-0.5	-0.4
1	Deck	Vertical	Downward	2	5.9	5.4	0.2	0.2	-0.2	-0.2
1	Deck	Vertical	Downward	3	5.6	5.1	0.2	0.2	-0.2	-0.2
1	Beam (L)	Vertical	Downward	1	4.8	4.4	4.1	3.2	-0.6	-0.5
1	Beam (T)	Vertical	Downward	1	7.1	6.3	2.5	2.0	-0.4	-0.3
1	Beam (T)	Vertical	Downward	2	6.2	4.9	1.7	1.2	-0.4	-0.3
1	Beam (T)	Horizontal	Shoreward	1	11.2	9.9	5.7	4.8	-19.4	-17.1
1	Beam (T)	Horizontal	Shoreward	2	8.8	6.6	6.7	4.0	-17.2	-14.8
2	Deck	Vertical	Upward	1	2.6	2.3	1.1	0.7	-3.1	-2.3
2	Deck	Vertical	Upward	1	4.1	3.5	1.0	0.8	-3.1	-2.4
2	Deck	Vertical	Upward	1	65.2	40.1	10.4	6.3	-3.2	-2.9
2	Deck	Vertical	Upward	2	5.5	4.6	2.1	1.6	-1.7	-1.6
2	Deck	Vertical	Upward	3	8.6	7.1	0.4	0.3	-0.3	-0.2
2	Beam (L)	Vertical	Upward	1	158.3	118.4	25.5	22.4	-9.3	-8.7
2	Beam (T)	Vertical	Upward	1	477.6	383.2	39.0	34.9	-5.5	-5.3
2	Beam (T)	Vertical	Upward	1	333.3	247.9	43.9	29.0	-8.4	-8.1
2	Beam (T)	Horizontal	Seaward	1	493.9	325.7	47.6	41.7	-3.5	-2.9
2	Beam (T)	Horizontal	Seaward	2	120.2	93.0	24.9	19.7	-1.7	-1.4
2	Beam (T)	Horizontal	Shoreward	1	6.8	5.2	0.4	0.3	-1.2	-1.1
2	Beam (T)	Horizontal	Shoreward	2	3.1	2.8	0.4	0.4	-1.9	-1.7
1	Caisson	Horizontal	Seaward	1	28.7	27.5	27.0	25.1	-31.9	-29.1
1	Caisson	Horizontal	Shoreward	1	26.4	23.8	24.8	22.5	-24.8	-23.7
2	Caisson	Horizontal	Seaward	2	21.6	21.3	20.9	20.1	-26.9	-25.7
2	Caisson	Horizontal	Shoreward	2	16.7	16.2	15.2	15.0	-16.3	-13.4
1	Pile	Horizontal	Seaward	1	57.1	43.4	34.3	31.4	-34.2	-33.8

Table 13 Test Series A1: summary of pressure at 1/1000 and 1/250 significance level, 1:500ys condition

Unit	Element	Load	Direction	N.	$P_{imp,max}$ [kPa]	$P_{imp,1/250}$ [kPa]	$P_{qs+,max}$ [kPa]	$P_{qs+,1/250}$ [kPa]	$P_{qs-,max}$ [kPa]	$P_{qs-,1/250}$ [kPa]
1	Deck	Vertical	Upward	1	49.2	43.8	34.6	29.0	-26.4	-23.3
1	Deck	Vertical	Upward	1	40.0	33.8	31.0	26.5	-24.6	-21.6
1	Deck	Vertical	Upward	1	87.3	57.2	34.5	29.1	-26.6	-24.1
1	Deck	Vertical	Upward	2	40.3	29.5	19.8	17.7	-25.2	-20.9
1	Deck	Vertical	Upward	3	52.1	40.2	27.5	23.7	-18.9	-15.8
1	Beam (L)	Vertical	Upward	1	256.0	168.9	36.8	35.2	-19.6	-19.1
1	Beam (T)	Vertical	Upward	1	350.4	305.8	47.8	45.7	-21.8	-20.7
1	Beam (T)	Vertical	Upward	2	185.5	144.2	37.3	33.9	-27.6	-24.7
1	Beam (T)	Horizontal	Seaward	1	47.7	36.9	35.6	32.3	-3.2	-2.3
1	Beam (T)	Horizontal	Seaward	2	341.6	265.8	107.6	82.6	-27.2	-24.8
1	Deck	Vertical	Downward	1	53.6	32.1	25.2	14.7	-2.1	-1.3
1	Deck	Vertical	Downward	1	27.3	17.7	22.0	13.5	-1.0	-0.8
1	Deck	Vertical	Downward	1	23.2	11.6	22.1	10.6	-0.9	-0.7
1	Deck	Vertical	Downward	2	13.6	10.4	10.3	7.2	-0.6	-0.5
1	Deck	Vertical	Downward	3	7.0	5.8	5.8	4.5	-0.6	-0.6
1	Beam (L)	Vertical	Downward	1	41.3	36.4	27.1	25.0	-1.8	-1.6
1	Beam (T)	Vertical	Downward	1	140.6	48.2	34.7	19.7	-2.6	-1.5
1	Beam (T)	Vertical	Downward	2	10.4	8.6	9.3	7.4	-0.7	-0.5
1	Beam (T)	Horizontal	Shoreward	1	50.1	43.8	34.5	28.8	-26.2	-23.2
1	Beam (T)	Horizontal	Shoreward	2	39.1	32.5	19.6	16.6	-24.7	-20.1
2	Deck	Vertical	Upward	1	8.6	6.1	6.9	4.1	-5.6	-4.2
2	Deck	Vertical	Upward	1	14.7	9.3	7.3	4.3	-5.5	-4.5
2	Deck	Vertical	Upward	1	54.3	37.9	7.7	6.3	-6.6	-5.7
2	Deck	Vertical	Upward	2	8.3	5.9	2.8	1.6	-2.9	-2.8
2	Deck	Vertical	Upward	3	11.8	8.4	0.5	0.3	-0.2	-0.2
2	Beam (L)	Vertical	Upward	1	235.5	195.8	30.5	25.1	-15.3	-11.9
2	Beam (T)	Vertical	Upward	1	406.2	320.3	37.9	36.7	-7.2	-6.6
2	Beam (T)	Vertical	Upward	1	312.6	251.0	28.1	27.0	-8.8	-8.3
2	Beam (T)	Horizontal	Seaward	1	569.3	386.8	68.9	64.4	-3.5	-3.3
2	Beam (T)	Horizontal	Seaward	2	210.1	145.9	42.2	29.8	-1.9	-1.8
2	Beam (T)	Horizontal	Shoreward	1	6.0	5.6	1.1	0.9	-2.5	-2.4
2	Beam (T)	Horizontal	Shoreward	2	7.9	4.6	2.8	1.5	-3.0	-2.6
1	Caisson	Horizontal	Seaward	1	40.7	39.7	38.7	37.6	-45.0	-42.6
1	Caisson	Horizontal	Shoreward	1	40.3	37.8	36.3	34.4	-31.2	-30.3
2	Caisson	Horizontal	Seaward	2	30.7	30.1	28.8	28.1	-32.5	-32.1
2	Caisson	Horizontal	Shoreward	2	20.5	19.8	17.7	17.0	-19.0	-15.1
1	Pile	Horizontal	Seaward	1	52.6	50.9	47.4	45.6	-34.0	-33.9

Table 14 Test Series B1: summary of pressure at 1/1000 and 1/250 significance level, 1:5ys condition

Unit	Element	Load	Direction	N.	$P_{imp,max}$ [kPa]	$P_{imp,1/250}$ [kPa]	$P_{qs+,max}$ [kPa]	$P_{qs+,1/250}$ [kPa]	$P_{qs-,max}$ [kPa]	$P_{qs-,1/250}$ [kPa]
1	Deck	Vertical	Upward	1	4.2	2.9	0.8	0.7	-8.2	-7.3
1	Deck	Vertical	Upward	1	2.9	2.5	2.0	1.7	-6.3	-5.9
1	Deck	Vertical	Upward	1	7.7	7.0	1.4	1.4	-7.2	-6.8
1	Deck	Vertical	Upward	2	1.9	1.7	0.7	0.6	-8.8	-8.6
1	Deck	Vertical	Upward	3	1.4	1.3	0.7	0.6	-3.9	-2.4
1	Beam (L)	Vertical	Upward	1	98.0	55.8	16.0	13.7	-13.2	-13.0
1	Beam (T)	Vertical	Upward	1	108.1	85.6	29.3	21.6	-10.3	-8.3
1	Beam (T)	Vertical	Upward	2	169.3	99.0	19.8	18.9	-13.3	-11.4
1	Beam (T)	Horizontal	Seaward	1	6.6	4.6	4.3	3.1	-0.6	-0.5
1	Beam (T)	Horizontal	Seaward	2	103.7	72.5	19.3	16.5	-6.6	-4.8
1	Deck	Vertical	Downward	1	3.5	2.4	0.6	0.5	-0.6	-0.5
1	Deck	Vertical	Downward	1	3.3	2.2	0.6	0.5	-0.6	-0.5
1	Deck	Vertical	Downward	1	1.6	1.5	0.6	0.5	-0.6	-0.5
1	Deck	Vertical	Downward	2	4.3	3.2	0.6	0.5	-0.6	-0.5
1	Deck	Vertical	Downward	3	5.3	4.7	0.6	0.5	-0.6	-0.5
1	Beam (L)	Vertical	Downward	1	2.7	2.1	0.6	0.5	-0.6	-0.5
1	Beam (T)	Vertical	Downward	1	3.2	2.9	0.6	0.5	-0.6	-0.5
1	Beam (T)	Vertical	Downward	2	3.6	2.9	0.6	0.5	-0.6	-0.5
1	Beam (T)	Horizontal	Shoreward	1	6.3	5.1	0.7	0.7	-8.2	-7.3
1	Beam (T)	Horizontal	Shoreward	2	2.8	2.5	0.7	0.6	-8.6	-8.5
2	Deck	Vertical	Upward	1	3.3	2.8	0.6	0.5	-0.7	-0.7
2	Deck	Vertical	Upward	1	6.7	4.6	0.7	0.6	-0.8	-0.8
2	Deck	Vertical	Upward	1	3.9	3.3	0.7	0.6	-0.8	-0.7
2	Deck	Vertical	Upward	2	3.8	2.7	0.7	0.5	-1.0	-0.8
2	Deck	Vertical	Upward	3	4.9	4.1	0.6	0.5	-0.6	-0.5
2	Beam (L)	Vertical	Upward	1	32.3	26.3	14.3	12.0	-7.6	-5.9
2	Beam (T)	Vertical	Upward	1	103.2	85.4	15.7	14.2	-3.5	-3.5
2	Beam (T)	Vertical	Upward	1	44.6	25.4	15.8	9.9	-4.1	-3.8
2	Beam (T)	Horizontal	Seaward	1	9.2	5.2	5.0	2.6	-0.6	-0.6
2	Beam (T)	Horizontal	Seaward	2	9.6	3.5	4.4	1.5	-0.6	-0.5
2	Beam (T)	Horizontal	Shoreward	1	2.7	2.0	0.7	0.5	-0.6	-0.5
2	Beam (T)	Horizontal	Shoreward	2	3.5	2.6	0.6	0.5	-1.0	-0.9
1	Caisson	Horizontal	Seaward	1	13.9	13.7	11.6	10.9	-12.9	-12.1
1	Caisson	Horizontal	Shoreward	1	11.0	10.6	9.8	9.4	-9.6	-9.4
2	Caisson	Horizontal	Seaward	2	15.3	12.9	10.1	9.8	-9.6	-9.2
2	Caisson	Horizontal	Shoreward	2	10.3	9.7	8.6	8.4	-8.1	-7.8
1	Pile	Horizontal	Seaward	1	30.8	30.1	15.3	14.9	-24.5	-21.4

Table 15 Test Series B1: summary of pressure at 1/1000 and 1/250 significance level, 1:25ys condition

Unit	Element	Load	Direction	N.	$P_{imp,max}$ [kPa]	$P_{imp,1/250}$ [kPa]	$P_{qs+,max}$ [kPa]	$P_{qs+,1/250}$ [kPa]	$P_{qs-,max}$ [kPa]	$P_{qs-,1/250}$ [kPa]
1	Deck	Vertical	Upward	1	5.1	4.7	3.3	2.5	-12.4	-11.6
1	Deck	Vertical	Upward	1	3.7	3.1	3.3	2.6	-10.8	-10.6
1	Deck	Vertical	Upward	1	12.6	8.9	3.4	2.5	-11.5	-11.1
1	Deck	Vertical	Upward	2	14.4	10.2	9.7	5.9	-12.1	-11.9
1	Deck	Vertical	Upward	3	4.2	2.7	3.8	2.2	-10.2	-9.1
1	Beam (L)	Vertical	Upward	1	160.6	119.2	41.7	30.8	-17.3	-16.6
1	Beam (T)	Vertical	Upward	1	695.5	474.4	42.1	33.6	-14.2	-13.8
1	Beam (T)	Vertical	Upward	2	566.6	307.9	32.1	29.6	-16.3	-15.9
1	Beam (T)	Horizontal	Seaward	1	13.2	12.3	10.5	9.6	-0.7	-0.6
1	Beam (T)	Horizontal	Seaward	2	252.5	171.4	60.0	48.5	-10.1	-9.5
1	Deck	Vertical	Downward	1	4.4	3.5	0.4	0.3	-0.3	-0.3
1	Deck	Vertical	Downward	1	2.4	2.3	0.5	0.4	-0.3	-0.3
1	Deck	Vertical	Downward	1	3.1	2.1	0.4	0.4	-0.3	-0.3
1	Deck	Vertical	Downward	2	4.1	3.9	0.5	0.4	-0.3	-0.3
1	Deck	Vertical	Downward	3	9.2	5.9	0.4	0.4	-0.3	-0.3
1	Beam (L)	Vertical	Downward	1	2.5	2.5	2.0	0.8	-0.6	-0.4
1	Beam (T)	Vertical	Downward	1	4.1	3.4	0.4	0.4	-0.3	-0.3
1	Beam (T)	Vertical	Downward	2	5.2	4.4	0.4	0.4	-0.3	-0.3
1	Beam (T)	Horizontal	Shoreward	1	18.5	10.5	3.1	2.4	-12.3	-11.6
1	Beam (T)	Horizontal	Shoreward	2	14.7	10.5	9.6	5.9	-11.8	-11.8
2	Deck	Vertical	Upward	1	4.9	4.0	0.9	0.6	-2.3	-2.1
2	Deck	Vertical	Upward	1	5.8	5.2	1.0	0.7	-2.4	-2.1
2	Deck	Vertical	Upward	1	4.5	3.6	1.2	0.8	-2.7	-2.3
2	Deck	Vertical	Upward	2	4.9	4.6	1.7	0.9	-2.1	-2.0
2	Deck	Vertical	Upward	3	8.0	7.1	1.5	0.7	-0.5	-0.4
2	Beam (L)	Vertical	Upward	1	213.0	169.5	27.6	23.5	-9.6	-8.5
2	Beam (T)	Vertical	Upward	1	334.4	231.9	25.1	22.6	-5.5	-5.1
2	Beam (T)	Vertical	Upward	1	185.8	147.1	26.9	23.8	-6.8	-6.5
2	Beam (T)	Horizontal	Seaward	1	186.7	117.1	30.6	24.6	-2.0	-1.8
2	Beam (T)	Horizontal	Seaward	2	355.4	142.0	16.4	14.3	-1.5	-1.2
2	Beam (T)	Horizontal	Shoreward	1	5.2	4.1	0.6	0.5	-1.3	-1.3
2	Beam (T)	Horizontal	Shoreward	2	6.5	4.8	0.5	0.5	-2.3	-2.0
1	Caisson	Horizontal	Seaward	1	24.5	22.8	21.5	19.1	-22.2	-19.5
1	Caisson	Horizontal	Shoreward	1	14.6	14.2	13.1	12.7	-14.2	-14.0
2	Caisson	Horizontal	Seaward	2	20.4	18.2	14.7	14.5	-14.4	-14.0
2	Caisson	Horizontal	Shoreward	2	14.7	13.6	12.3	11.8	-10.8	-10.7
1	Pile	Horizontal	Seaward	1	44.8	41.1	25.9	23.7	-36.2	-34.9

Table 16 Test Series B1: summary of pressure at 1/1000 and 1/250 significance level, 1:100ys condition

Unit	Element	Load	Direction	N.	$P_{imp,max}$ [kPa]	$P_{imp,1/250}$ [kPa]	$P_{qs+,max}$ [kPa]	$P_{qs+,1/250}$ [kPa]	$P_{qs-,max}$ [kPa]	$P_{qs-,1/250}$ [kPa]
1	Deck	Vertical	Upward	1	7.5	6.8	6.6	5.6	-21.3	-18.4
1	Deck	Vertical	Upward	1	6.6	5.9	6.1	5.4	-18.9	-17.1
1	Deck	Vertical	Upward	1	17.8	14.0	12.1	7.3	-20.8	-18.0
1	Deck	Vertical	Upward	2	42.4	31.5	18.1	16.9	-21.6	-17.4
1	Deck	Vertical	Upward	3	12.3	8.6	5.2	4.5	-13.9	-13.0
1	Beam (L)	Vertical	Upward	1	303.3	237.7	37.6	30.7	-20.4	-19.6
1	Beam (T)	Vertical	Upward	1	384.0	326.6	39.2	37.1	-18.0	-17.0
1	Beam (T)	Vertical	Upward	2	262.6	207.3	36.8	36.1	-23.5	-19.5
1	Beam (T)	Horizontal	Seaward	1	24.4	18.5	15.9	14.0	-1.1	-0.9
1	Beam (T)	Horizontal	Seaward	2	239.2	159.2	64.7	61.0	-17.8	-15.9
1	Deck	Vertical	Downward	1	4.7	4.5	2.5	1.9	-0.5	-0.4
1	Deck	Vertical	Downward	1	4.5	3.5	2.6	1.6	-0.5	-0.3
1	Deck	Vertical	Downward	1	3.5	3.0	2.2	1.3	-0.6	-0.3
1	Deck	Vertical	Downward	2	8.7	6.2	1.4	0.7	-0.5	-0.2
1	Deck	Vertical	Downward	3	7.5	6.9	0.3	0.3	-0.5	-0.2
1	Beam (L)	Vertical	Downward	1	5.1	4.5	4.5	3.6	-0.7	-0.6
1	Beam (T)	Vertical	Downward	1	7.5	5.7	2.2	1.6	-0.6	-0.4
1	Beam (T)	Vertical	Downward	2	5.8	5.7	1.0	0.6	-0.2	-0.2
1	Beam (T)	Horizontal	Shoreward	1	12.1	9.7	6.4	5.5	-21.3	-18.6
1	Beam (T)	Horizontal	Shoreward	2	42.7	31.4	18.0	16.8	-21.3	-17.2
2	Deck	Vertical	Upward	1	6.4	6.3	1.3	1.2	-4.0	-3.3
2	Deck	Vertical	Upward	1	9.8	7.8	1.3	1.1	-4.7	-3.8
2	Deck	Vertical	Upward	1	35.2	13.0	2.2	1.5	-4.6	-3.9
2	Deck	Vertical	Upward	2	11.6	8.1	3.0	2.3	-3.2	-3.0
2	Deck	Vertical	Upward	3	12.0	10.8	0.4	0.3	-1.2	-0.8
2	Beam (L)	Vertical	Upward	1	352.1	267.8	34.0	31.6	-10.4	-9.6
2	Beam (T)	Vertical	Upward	1	462.5	395.8	32.5	28.7	-6.0	-5.8
2	Beam (T)	Vertical	Upward	1	331.5	271.3	28.1	25.6	-8.6	-7.3
2	Beam (T)	Horizontal	Seaward	1	385.8	295.5	56.4	47.2	-3.4	-2.8
2	Beam (T)	Horizontal	Seaward	2	133.7	104.3	34.7	26.8	-2.2	-1.9
2	Beam (T)	Horizontal	Shoreward	1	4.8	4.1	1.8	1.3	-2.9	-2.5
2	Beam (T)	Horizontal	Shoreward	2	5.8	5.6	3.0	2.3	-3.1	-3.0
1	Caisson	Horizontal	Seaward	1	30.2	28.7	26.5	25.5	-29.9	-26.8
1	Caisson	Horizontal	Shoreward	1	20.2	18.6	17.0	16.6	-17.6	-17.2
2	Caisson	Horizontal	Seaward	2	23.1	21.8	17.5	17.2	-18.0	-17.3
2	Caisson	Horizontal	Shoreward	2	16.6	16.1	14.1	13.8	-13.3	-13.0
1	Pile	Horizontal	Seaward	1	46.3	41.4	34.7	32.6	-37.3	-37.1

Table 17 Test Series B1: summary of pressure at 1/1000 and 1/250 significance level, 1:500ys condition

Unit	Element	Load	Direction	N.	$P_{imp,max}$ [kPa]	$P_{imp,1/250}$ [kPa]	$P_{qs+,max}$ [kPa]	$P_{qs+,1/250}$ [kPa]	$P_{qs-,max}$ [kPa]	$P_{qs-,1/250}$ [kPa]
1	Deck	Vertical	Upward	1	52.6	32.2	35.4	22.4	-30.4	-29.2
1	Deck	Vertical	Upward	1	46.7	38.6	39.8	33.6	-27.5	-27.2
1	Deck	Vertical	Upward	1	239.9	135.8	61.0	52.4	-34.6	-30.5
1	Deck	Vertical	Upward	2	74.6	71.7	54.4	48.9	-22.9	-22.3
1	Deck	Vertical	Upward	3	32.4	32.1	23.7	22.0	-18.0	-17.9
1	Beam (L)	Vertical	Upward	1	219.8	188.2	61.0	49.3	-20.8	-19.7
1	Beam (T)	Vertical	Upward	1	457.0	411.2	52.8	47.2	-21.7	-20.5
1	Beam (T)	Vertical	Upward	2	284.1	258.1	50.3	44.0	-23.4	-22.1
1	Beam (T)	Horizontal	Seaward	1	56.6	50.5	50.7	32.2	-2.1	-2.0
1	Beam (T)	Horizontal	Seaward	2	300.8	264.4	141.1	114.3	-30.0	-28.2
1	Deck	Vertical	Downward	1	49.7	23.3	34.4	17.6	-3.1	-1.4
1	Deck	Vertical	Downward	1	49.2	19.6	32.8	14.9	-1.3	-0.8
1	Deck	Vertical	Downward	1	32.4	15.8	18.7	11.6	-1.6	-0.8
1	Deck	Vertical	Downward	2	18.4	10.6	7.2	5.8	-2.1	-0.9
1	Deck	Vertical	Downward	3	9.1	8.7	6.8	5.4	-1.1	-0.6
1	Beam (L)	Vertical	Downward	1	44.9	38.9	29.0	26.2	-1.7	-1.5
1	Beam (T)	Vertical	Downward	1	54.5	32.9	33.2	15.6	-2.2	-1.0
1	Beam (T)	Vertical	Downward	2	50.5	18.8	18.4	9.6	-1.9	-0.8
1	Beam (T)	Horizontal	Shoreward	1	52.7	44.2	35.8	26.4	-29.3	-28.6
1	Beam (T)	Horizontal	Shoreward	2	75.8	72.3	53.9	48.6	-23.2	-21.8
2	Deck	Vertical	Upward	1	12.4	9.1	9.1	4.9	-7.2	-6.5
2	Deck	Vertical	Upward	1	13.1	11.4	9.2	5.0	-7.8	-7.1
2	Deck	Vertical	Upward	1	12.1	8.8	9.2	5.0	-7.3	-6.8
2	Deck	Vertical	Upward	2	12.1	11.3	8.7	6.2	-7.9	-6.7
2	Deck	Vertical	Upward	3	15.3	12.6	0.8	0.7	-5.0	-3.9
2	Beam (L)	Vertical	Upward	1	466.2	308.0	45.8	38.4	-9.8	-9.7
2	Beam (T)	Vertical	Upward	1	508.6	412.7	33.6	32.0	-7.7	-7.6
2	Beam (T)	Vertical	Upward	1	242.5	227.2	32.2	31.0	-10.0	-9.6
2	Beam (T)	Horizontal	Seaward	1	479.3	393.4	82.5	78.2	-6.4	-4.7
2	Beam (T)	Horizontal	Seaward	2	328.6	223.8	36.0	34.9	-5.5	-3.9
2	Beam (T)	Horizontal	Shoreward	1	9.5	6.7	4.8	3.8	-5.7	-4.7
2	Beam (T)	Horizontal	Shoreward	2	11.7	11.1	8.8	6.3	-7.8	-6.7
1	Caisson	Horizontal	Seaward	1	41.1	40.1	38.9	37.8	-46.6	-44.7
1	Caisson	Horizontal	Shoreward	1	29.0	28.5	25.8	25.0	-21.6	-21.0
2	Caisson	Horizontal	Seaward	2	39.4	32.0	32.7	27.6	-21.6	-21.2
2	Caisson	Horizontal	Shoreward	2	20.8	19.4	18.0	17.3	-17.8	-16.8
1	Pile	Horizontal	Seaward	1	62.4	57.0	49.6	47.8	-37.1	-37.0

Table 18 Test Series B2: summary of pressure at 1/1000 and 1/250 significance level, 1:3547ys condition (0.00mCD)

Unit	Element	Load	Direction	N.	$P_{imp,max}$ [kPa]	$P_{imp,1/250}$ [kPa]	$P_{qs+,max}$ [kPa]	$P_{qs+,1/250}$ [kPa]	$P_{qs-,max}$ [kPa]	$P_{qs-,1/250}$ [kPa]
1	Deck	Vertical	Upward	1	100.9	83.5	70.4	47.8	-35.1	-34.4
1	Deck	Vertical	Upward	1	84.5	78.1	77.1	71.5	-37.5	-34.9
1	Deck	Vertical	Upward	1	369.5	338.8	123.9	119.1	-39.9	-37.6
1	Deck	Vertical	Upward	2	128.6	122.3	83.4	73.6	-27.8	-26.4
1	Deck	Vertical	Upward	3	113.8	102.4	75.4	66.0	-33.3	-26.2
1	Beam (L)	Vertical	Upward	1	339.1	298.8	66.9	62.6	-25.5	-22.9
1	Beam (T)	Vertical	Upward	1	934.8	789.3	66.7	63.2	-27.5	-25.5
1	Beam (T)	Vertical	Upward	2	387.1	313.5	55.5	53.0	-21.9	-20.9
1	Beam (T)	Horizontal	Seaward	1	256.1	108.0	43.7	39.8	-3.3	-3.0
1	Beam (T)	Horizontal	Seaward	2	590.3	453.6	185.1	175.8	-37.4	-34.7
1	Deck	Vertical	Downward	1	55.2	47.2	39.2	36.4	-3.2	-2.8
1	Deck	Vertical	Downward	1	51.4	37.4	40.6	33.5	-2.3	-1.7
1	Deck	Vertical	Downward	1	37.3	30.5	30.9	26.8	-1.9	-1.5
1	Deck	Vertical	Downward	2	144.1	81.2	39.2	19.6	-1.3	-1.2
1	Deck	Vertical	Downward	3	18.8	15.7	12.7	11.3	-1.2	-1.1
1	Beam (L)	Vertical	Downward	1	502.3	311.9	52.3	40.9	-4.9	-3.9
1	Beam (T)	Vertical	Downward	1	84.2	56.8	45.1	39.3	-2.6	-2.1
1	Beam (T)	Vertical	Downward	2	28.3	22.4	19.3	16.8	-1.4	-1.3
1	Beam (T)	Horizontal	Shoreward	1	99.8	91.4	52.0	47.1	-35.1	-33.8
1	Beam (T)	Horizontal	Shoreward	2	122.9	121.2	67.0	65.3	-27.5	-25.7
2	Deck	Vertical	Upward	1	38.4	35.2	22.8	21.8	-20.9	-18.1
2	Deck	Vertical	Upward	1	49.6	40.6	38.8	27.1	-21.7	-18.6
2	Deck	Vertical	Upward	1	106.0	85.9	61.2	50.0	-20.9	-19.3
2	Deck	Vertical	Upward	2	44.4	35.6	27.5	19.7	-14.8	-13.3
2	Deck	Vertical	Upward	3	14.6	12.5	10.5	3.6	-7.7	-6.6
2	Beam (L)	Vertical	Upward	1	369.9	287.6	62.6	57.3	-14.2	-14.1
2	Beam (T)	Vertical	Upward	1	554.2	500.6	45.2	43.1	-9.7	-9.2
2	Beam (T)	Vertical	Upward	1	358.5	303.7	51.1	43.0	-11.0	-10.9
2	Beam (T)	Horizontal	Seaward	1	990.3	766.4	142.8	120.9	-16.4	-13.1
2	Beam (T)	Horizontal	Seaward	2	399.4	266.6	76.6	72.6	-9.0	-7.7
2	Beam (T)	Horizontal	Shoreward	1	27.9	25.1	16.7	15.7	-8.5	-7.9
2	Beam (T)	Horizontal	Shoreward	2	41.7	38.4	26.4	19.7	-15.1	-13.4
1	Caisson	Horizontal	Seaward	1	57.9	55.2	55.8	53.0	-61.0	-58.5
1	Caisson	Horizontal	Shoreward	1	53.6	47.4	47.8	42.6	-26.3	-25.3
2	Caisson	Horizontal	Seaward	2	56.0	51.7	50.7	46.2	-27.7	-26.6
2	Caisson	Horizontal	Shoreward	2	25.1	22.0	23.4	20.8	-20.5	-19.2
1	Pile	Horizontal	Seaward	1	93.5	84.4	65.6	62.9	-40.3	-38.2

Table 19 Test Series B2: summary of pressure at 1/1000 and 1/250 significance level, 1:100ys condition (+0.50mCD)

Unit	Element	Load	Direction	N.	$P_{imp,max}$ [kPa]	$P_{imp,1/250}$ [kPa]	$P_{qs+,max}$ [kPa]	$P_{qs+,1/250}$ [kPa]	$P_{qs-,max}$ [kPa]	$P_{qs-,1/250}$ [kPa]
1	Deck	Vertical	Upward	1	11.7	10.5	8.6	8.4	-22.9	-21.9
1	Deck	Vertical	Upward	1	9.1	8.8	8.5	8.1	-21.3	-19.9
1	Deck	Vertical	Upward	1	39.6	32.5	27.9	21.9	-24.1	-21.5
1	Deck	Vertical	Upward	2	60.1	50.8	29.3	27.9	-20.2	-19.4
1	Deck	Vertical	Upward	3	17.6	13.4	12.0	8.9	-19.9	-18.8
1	Beam (L)	Vertical	Upward	1	269.4	248.4	45.6	40.5	-19.6	-18.0
1	Beam (T)	Vertical	Upward	1	614.8	471.8	48.9	43.3	-17.8	-17.5
1	Beam (T)	Vertical	Upward	2	337.0	265.6	41.4	39.4	-18.7	-17.2
1	Beam (T)	Horizontal	Seaward	1	37.7	25.5	23.8	18.9	-2.2	-1.5
1	Beam (T)	Horizontal	Seaward	2	218.9	188.9	81.8	78.1	-24.6	-21.9
1	Deck	Vertical	Downward	1	37.7	14.6	6.0	4.9	-2.5	-1.2
1	Deck	Vertical	Downward	1	5.3	4.6	4.6	3.8	-0.6	-0.6
1	Deck	Vertical	Downward	1	5.7	4.7	5.0	3.8	-0.6	-0.5
1	Deck	Vertical	Downward	2	6.1	5.1	2.4	1.8	-0.6	-0.5
1	Deck	Vertical	Downward	3	9.3	7.1	1.4	1.1	-0.6	-0.5
1	Beam (L)	Vertical	Downward	1	12.0	8.6	9.1	6.3	-1.0	-0.8
1	Beam (T)	Vertical	Downward	1	5.3	4.7	4.2	3.0	-0.5	-0.5
1	Beam (T)	Vertical	Downward	2	5.9	5.7	3.1	2.2	-0.6	-0.5
1	Beam (T)	Horizontal	Shoreward	1	62.1	27.5	12.5	9.3	-22.9	-21.3
1	Beam (T)	Horizontal	Shoreward	2	59.1	50.7	29.0	27.6	-20.5	-19.1
2	Deck	Vertical	Upward	1	8.3	6.4	3.3	2.4	-6.5	-5.5
2	Deck	Vertical	Upward	1	9.2	8.1	3.4	2.5	-8.0	-6.2
2	Deck	Vertical	Upward	1	6.6	5.3	3.5	2.5	-6.5	-6.3
2	Deck	Vertical	Upward	2	7.9	7.7	3.6	2.9	-7.0	-6.1
2	Deck	Vertical	Upward	3	7.8	7.1	0.7	0.7	-1.4	-1.2
2	Beam (L)	Vertical	Upward	1	327.5	298.4	33.5	30.4	-9.3	-8.6
2	Beam (T)	Vertical	Upward	1	625.2	519.5	41.0	38.2	-7.6	-7.0
2	Beam (T)	Vertical	Upward	1	772.3	421.5	25.0	24.3	-7.2	-6.5
2	Beam (T)	Horizontal	Seaward	1	505.4	419.8	71.9	58.1	-3.5	-3.4
2	Beam (T)	Horizontal	Seaward	2	238.5	229.5	37.5	33.9	-2.7	-2.4
2	Beam (T)	Horizontal	Shoreward	1	8.5	6.2	2.5	2.0	-3.8	-3.5
2	Beam (T)	Horizontal	Shoreward	2	7.6	6.1	3.7	3.0	-7.2	-6.1
1	Caisson	Horizontal	Seaward	1	29.7	27.4	26.3	25.0	-28.9	-25.4
1	Caisson	Horizontal	Shoreward	1	22.5	19.3	19.0	17.0	-18.9	-17.4
2	Caisson	Horizontal	Seaward	2	19.8	19.0	17.2	16.6	-18.1	-16.7
2	Caisson	Horizontal	Shoreward	2	14.0	13.9	12.9	12.6	-12.1	-11.8
1	Pile	Horizontal	Seaward	1	45.0	42.3	33.9	31.7	-41.3	-40.1

Table 20 Test Series B2: summary of pressure at 1/1000 and 1/250 significance level, 1:500ys condition (+0.50mCD)

Unit	Element	Load	Direction	N.	$P_{imp,max}$ [kPa]	$P_{imp,1/250}$ [kPa]	$P_{qs+,max}$ [kPa]	$P_{qs+,1/250}$ [kPa]	$P_{qs-,max}$ [kPa]	$P_{qs-,1/250}$ [kPa]
1	Deck	Vertical	Upward	1	68.2	60.0	43.3	38.3	-36.2	-31.1
1	Deck	Vertical	Upward	1	78.5	62.8	53.6	50.3	-35.1	-30.2
1	Deck	Vertical	Upward	1	626.5	275.2	81.3	75.6	-34.2	-30.6
1	Deck	Vertical	Upward	2	127.0	111.9	94.1	73.4	-26.6	-25.1
1	Deck	Vertical	Upward	3	89.0	77.0	53.0	46.7	-24.7	-22.3
1	Beam (L)	Vertical	Upward	1	381.1	329.7	65.9	51.5	-20.1	-19.9
1	Beam (T)	Vertical	Upward	1	636.9	516.0	56.7	53.5	-21.7	-21.0
1	Beam (T)	Vertical	Upward	2	484.9	434.9	55.5	51.3	-19.5	-18.7
1	Beam (T)	Horizontal	Seaward	1	86.1	71.3	51.9	40.1	-3.6	-2.9
1	Beam (T)	Horizontal	Seaward	2	917.0	472.3	153.5	134.8	-32.3	-31.6
1	Deck	Vertical	Downward	1	45.1	30.1	41.4	24.3	-3.2	-1.8
1	Deck	Vertical	Downward	1	33.3	18.8	28.6	16.6	-1.1	-0.9
1	Deck	Vertical	Downward	1	26.8	16.7	24.6	14.7	-0.9	-0.8
1	Deck	Vertical	Downward	2	15.4	9.8	13.4	8.5	-1.0	-0.8
1	Deck	Vertical	Downward	3	9.6	8.9	8.1	6.3	-0.9	-0.8
1	Beam (L)	Vertical	Downward	1	137.1	99.3	40.1	32.0	-4.3	-3.8
1	Beam (T)	Vertical	Downward	1	60.4	27.2	49.1	21.6	-3.7	-1.6
1	Beam (T)	Vertical	Downward	2	22.9	14.1	13.6	9.4	-1.6	-0.9
1	Beam (T)	Horizontal	Shoreward	1	81.1	68.1	41.3	36.4	-32.5	-29.0
1	Beam (T)	Horizontal	Shoreward	2	126.4	107.8	74.3	67.8	-25.5	-24.1
2	Deck	Vertical	Upward	1	19.8	18.1	15.5	12.6	-13.0	-11.4
2	Deck	Vertical	Upward	1	20.2	18.5	15.7	12.9	-13.1	-12.0
2	Deck	Vertical	Upward	1	32.5	24.8	24.2	16.1	-12.9	-11.6
2	Deck	Vertical	Upward	2	25.5	23.5	14.8	12.9	-11.8	-10.2
2	Deck	Vertical	Upward	3	17.3	12.9	8.6	2.9	-6.3	-5.8
2	Beam (L)	Vertical	Upward	1	431.5	351.7	55.7	51.1	-12.9	-11.4
2	Beam (T)	Vertical	Upward	1	516.9	476.3	45.2	39.6	-10.4	-9.3
2	Beam (T)	Vertical	Upward	1	438.4	357.8	40.8	37.4	-9.8	-9.1
2	Beam (T)	Horizontal	Seaward	1	765.3	585.1	113.6	97.6	-14.7	-9.8
2	Beam (T)	Horizontal	Seaward	2	553.7	455.3	79.1	75.4	-5.8	-5.0
2	Beam (T)	Horizontal	Shoreward	1	23.1	17.9	14.5	12.3	-6.7	-5.8
2	Beam (T)	Horizontal	Shoreward	2	74.9	43.5	15.1	14.0	-11.9	-10.1
1	Caisson	Horizontal	Seaward	1	42.2	40.6	40.9	38.6	-43.9	-42.7
1	Caisson	Horizontal	Shoreward	1	37.5	33.9	33.2	28.7	-22.1	-21.1
2	Caisson	Horizontal	Seaward	2	39.3	33.9	35.4	31.2	-23.5	-21.8
2	Caisson	Horizontal	Shoreward	2	19.1	18.0	17.7	16.3	-16.4	-15.1
1	Pile	Horizontal	Seaward	1	116.3	82.3	49.8	48.4	-42.0	-41.8

Table 21 Test Series B2: summary of pressure at 1/1000 and 1/250 significance level, 1:3547ys condition (+0.50mCD)

Unit	Element	Load	Direction	N.	$P_{imp,max}$ [kPa]	$P_{imp,1/250}$ [kPa]	$P_{qs+,max}$ [kPa]	$P_{qs+,1/250}$ [kPa]	$P_{qs-,max}$ [kPa]	$P_{qs-,1/250}$ [kPa]
1	Deck	Vertical	Upward	1	152.0	127.9	112.2	89.2	-35.3	-35.0
1	Deck	Vertical	Upward	1	116.0	105.7	92.3	88.2	-36.1	-35.5
1	Deck	Vertical	Upward	1	1066.4	697.3	125.5	121.6	-40.9	-38.4
1	Deck	Vertical	Upward	2	170.4	153.4	112.4	97.6	-34.5	-30.2
1	Deck	Vertical	Upward	3	144.4	137.7	103.9	89.9	-31.8	-26.3
1	Beam (L)	Vertical	Upward	1	304.4	282.3	64.9	60.7	-22.9	-21.8
1	Beam (T)	Vertical	Upward	1	1011.0	804.3	75.5	68.1	-26.7	-25.3
1	Beam (T)	Vertical	Upward	2	579.4	436.6	65.6	63.6	-20.3	-19.0
1	Beam (T)	Horizontal	Seaward	1	60.1	50.0	50.3	40.5	-4.2	-3.7
1	Beam (T)	Horizontal	Seaward	2	457.5	417.4	194.9	186.6	-38.0	-36.8
1	Deck	Vertical	Downward	1	50.3	46.7	42.3	37.6	-3.0	-2.6
1	Deck	Vertical	Downward	1	36.5	35.5	34.4	31.2	-1.9	-1.6
1	Deck	Vertical	Downward	1	59.8	38.6	39.5	27.9	-1.9	-1.7
1	Deck	Vertical	Downward	2	17.9	16.6	14.9	14.2	-1.2	-1.2
1	Deck	Vertical	Downward	3	30.9	22.4	16.7	15.3	-1.3	-1.1
1	Beam (L)	Vertical	Downward	1	219.7	166.4	50.0	43.9	-5.2	-3.9
1	Beam (T)	Vertical	Downward	1	53.1	50.4	43.6	41.8	-3.3	-2.7
1	Beam (T)	Vertical	Downward	2	37.3	29.2	16.7	16.3	-1.4	-1.4
1	Beam (T)	Horizontal	Shoreward	1	362.1	264.3	79.3	69.5	-34.9	-34.4
1	Beam (T)	Horizontal	Shoreward	2	149.6	142.4	83.8	79.3	-33.5	-28.5
2	Deck	Vertical	Upward	1	65.1	45.9	49.2	32.2	-21.0	-20.0
2	Deck	Vertical	Upward	1	178.3	129.8	66.5	49.2	-21.4	-20.9
2	Deck	Vertical	Upward	1	264.4	191.0	89.5	73.2	-22.1	-20.6
2	Deck	Vertical	Upward	2	223.5	128.8	73.5	41.6	-16.6	-15.6
2	Deck	Vertical	Upward	3	33.7	21.9	19.7	13.1	-10.8	-9.6
2	Beam (L)	Vertical	Upward	1	317.7	287.7	76.8	67.6	-21.0	-15.8
2	Beam (T)	Vertical	Upward	1	686.7	611.9	56.7	48.5	-10.7	-10.0
2	Beam (T)	Vertical	Upward	1	587.4	473.4	67.4	54.8	-10.0	-9.7
2	Beam (T)	Horizontal	Seaward	1	989.6	638.7	151.0	143.8	-20.6	-17.6
2	Beam (T)	Horizontal	Seaward	2	515.6	403.1	99.4	96.2	-13.7	-11.8
2	Beam (T)	Horizontal	Shoreward	1	53.4	46.5	28.1	25.1	-12.2	-11.1
2	Beam (T)	Horizontal	Shoreward	2	103.5	74.8	54.4	35.5	-15.6	-15.0
1	Caisson	Horizontal	Seaward	1	59.7	57.2	56.8	54.3	-61.7	-57.0
1	Caisson	Horizontal	Shoreward	1	58.8	53.8	52.5	47.2	-26.9	-25.3
2	Caisson	Horizontal	Seaward	2	60.6	54.6	53.0	49.1	-27.9	-27.0
2	Caisson	Horizontal	Shoreward	2	28.1	22.8	24.6	21.1	-20.1	-18.7
1	Pile	Horizontal	Seaward	1	79.6	74.6	74.2	65.7	-42.4	-42.0

4.2.2 Forces derived from analysis of force time-histories

Force time histories recorded during testing on each instrumented element were analysed using specifically developed software and the following parameters were extracted:

- Impulsive forces: $F_{imp,max}$; $F_{imp,1/250}$
- Quasi-static positive forces: $F_{qs+,max}$; $F_{qs+,1/250}$
- Quasi-static negative forces: $F_{qs-,max}$; $F_{qs-,1/250}$
- Impulsive overturning moments*: $M_{Vimp,max}$; $M_{Vimp,1/250}$
- Quasi-static overturning moments*: $M_{Vqs+,max}$; $M_{Vqs+,1/250}$

- Quasi-static overturning moments*: $M_{Vqs-,max}$; $M_{Vqs-,1/250}$

* Around the horizontal axis connecting the two seaward force sensors of each deck unit.

Results from Test Series A1 are presented in Tables 22 and 23 (decks) and Tables 24 and 25 (beams) in terms of wave-in-deck loads respectively at 1/1000 and 1/250 significant level.

Results from Test Series B1 are presented in Tables 26 and 27 (decks) and Tables 28 and 29 (beams) in terms of wave-in-deck loads respectively at 1/1000 and 1/250 significant level.

Results from Test Series B2 are presented in Tables 30 and 31 (decks) and Tables 32 and 33 (beams) in terms of wave-in-deck loads respectively at 1/1000 and 1/250 significant level.

Table 22 Test Series A1: summary of wave loading at 1/1000 significance level, Deck

Test	Return Period	Element	Deck $F_{Vimp,1/250}$ [kN]	Deck $F_{Vqs+,1/250}$ [kN]	Deck $F_{Vqs-,1/250}$ [kN]	Deck $M_{Vimp,1/250}$ [kNm]	Deck $M_{Vqs+,1/250}$ [kNm]	Deck $M_{Vqs-,1/250}$ [kNm]
05	1:5	#1	1026	720	-211	3911	1978	-1637
06	1:25	#1	2774	1625	-540	9355	4887	-3479
07	1:100	#1	6346	3105	-1390	23102	10899	-9481
08	1:500	#1	8260	5003	-2539	39293	22290	-16385
05	1:5	#2	1284	485	-666	6496	3034	-4056
06	1:25	#2	1953	742	-1029	10399	4016	-5469
07	1:100	#2	1614	778	-879	8966	4942	-7130
08	1:500	#2	1835	1479	-1473	12454	7023	-10155

Table 23 Test Series A1: summary of wave loading at 1/250 significance level, Deck

Test	Return Period	Element	Deck $F_{Vimp,1/250}$ [kN]	Deck $F_{Vqs+,1/250}$ [kN]	Deck $F_{Vqs-,1/250}$ [kN]	Deck $M_{Vimp,1/250}$ [kNm]	Deck $M_{Vqs+,1/250}$ [kNm]	Deck $M_{Vqs-,1/250}$ [kNm]
05	1:5	#1	797	563	-175	2965	2061	-1476
06	1:25	#1	2387	1525	-440	8069	5087	-3089
07	1:100	#1	4558	2453	-958	16070	11844	-6555
08	1:500	#1	6831	4756	-2346	33472	23394	-15392
05	1:5	#2	1146	421	-570	5874	3371	-3765
06	1:25	#2	1763	705	-897	9845	4377	-5083
07	1:100	#2	1482	665	-854	8369	5442	-6855
08	1:500	#2	1483	1108	-1157	9733	10625	-8892

Table 24 Test Series A1: summary of wave loading at 1/1000 significance level, Beam

Test	Return Period	Front Beam $F_{Himp,1/250}$ [kN]	Front Beam $F_{Hqs+,1/250}$ [kN]	Front Beam $F_{Hqs;,1/250}$ [kN]	Internal Beam $F_{Himp,1/250}$ [kN]	Internal Beam $F_{Hqs+,1/250}$ [kN]	Internal Beam $F_{Hqs;,1/250}$ [kN]
05	1:5	749	170	-17	378	88	-15
06	1:25	1076	239	-29	660	207	-27
07	1:100	778	340	-31	733	227	-38
08	1:500	1159	571	-65	1011	439	-41

Table 25 Test Series A1: summary of wave loading at 1/250 significance level, Beam

Test	Return Period	Front Beam $F_{Himp,1/250}$ [kN]	Front Beam $F_{Hqs+,1/250}$ [kN]	Front Beam $F_{Hqs;,1/250}$ [kN]	Internal Beam $F_{Himp,1/250}$ [kN]	Internal Beam $F_{Hqs+,1/250}$ [kN]	Internal Beam $F_{Hqs;,1/250}$ [kN]
05	1:5	660	140	-16	263	81	-13
06	1:25	771	203	-26	521	173	-25
07	1:100	642	307	-30	650	214	-30
08	1:500	1034	521	-50	951	399	-36

Table 26 Test Series B1: summary of wave loading at 1/1000 significance level, Deck

Test	Return Period	Element	Deck $F_{Vimp,1/250}$ [kN]	Deck $F_{Vqs+,1/250}$ [kN]	Deck $F_{Vqs-,1/250}$ [kN]	Deck $M_{Vimp,1/250}$ [kNm]	Deck $M_{Vqs+,1/250}$ [kNm]	Deck $M_{Vqs-,1/250}$ [kNm]
13	1:5	#1	1646	838	-743	6142	4189	-4091
14	1:25	#1	4026	2708	-2078	7320	6213	-9344
15	1:100	#1	6850	3766	-2986	13477	11262	-15746
16	1:500	#1	9162	7801	-8291	22089	17922	-31742
13	1:5	#2	1454	382	-411	7730	2546	-2502
14	1:25	#2	1702	811	-724	10122	3150	-5691
15	1:100	#2	1754	1147	-1121	15864	6979	-7481
16	1:500	#2	3438	2604	-2157	25088	19130	-10504

Table 27 Test Series B1: summary of wave loading at 1/250 significance level, Deck

Test	Return Period	Element	Deck $F_{Vimp,1/250}$ [kN]	Deck $F_{Vqs+,1/250}$ [kN]	Deck $F_{Vqs-,1/250}$ [kN]	Deck $M_{Vimp,1/250}$ [kNm]	Deck $M_{Vqs+,1/250}$ [kNm]	Deck $M_{Vqs-,1/250}$ [kNm]
13	1:5	#1	1350	729	-706	5147	3885	-3989
14	1:25	#1	3752	2587	-1735	7049	6053	-7958
15	1:100	#1	5541	3581	-2831	12141	9528	-13840
16	1:500	#1	8573	7175	-6664	21369	16852	-27424
13	1:5	#2	1090	332	-245	6299	1988	-2155
14	1:25	#2	1632	718	-611	9278	2949	-5002
15	1:100	#2	1676	1000	-934	13382	5635	-6955
16	1:500	#2	3003	2351	-1749	23087	16517	-10275

Table 28 Test Series B1: summary of wave loading at 1/1000 significance level, Beam

Test	Return Period	Front Beam $F_{Himp,1/250}$ [kN]	Front Beam $F_{Hqs+,1/250}$ [kN]	Front Beam $F_{Hqs;,1/250}$ [kN]	Internal Beam $F_{Himp,1/250}$ [kN]	Internal Beam $F_{Hqs+,1/250}$ [kN]	Internal Beam $F_{Hqs;,1/250}$ [kN]
13	1:5	540	99	-18	233	26	-26
14	1:25	1014	166	-28	312	61	-35
15	1:100	878	332	-44	496	96	-73
16	1:500	1580	845	-117	723	346	-101

Table 29 Test Series B1: summary of wave loading at 1/250 significance level, Beam

Test	Return Period	Front Beam $F_{Himp,1/250}$ [kN]	Front Beam $F_{Hqs+,1/250}$ [kN]	Front Beam $F_{Hqs;,1/250}$ [kN]	Internal Beam $F_{Himp,1/250}$ [kN]	Internal Beam $F_{Hqs+,1/250}$ [kN]	Internal Beam $F_{Hqs;,1/250}$ [kN]
13	1:5	499	81	-18	206	24	-22
14	1:25	941	160	-27	256	52	-33
15	1:100	735	252	-40	319	88	-64
16	1:500	1477	529	-85	604	246	-94

Table 30 Test Series B2: summary of wave loading at 1/1000 significance level, Deck

Test	Return Period	Element	Deck $F_{Vimp,1/250}$ [kN]	Deck $F_{Vqs+,1/250}$ [kN]	Deck $F_{Vqs-,1/250}$ [kN]	Deck $M_{Vimp,1/250}$ [kNm]	Deck $M_{Vqs+,1/250}$ [kNm]	Deck $M_{Vqs-,1/250}$ [kNm]
17	1:3547	#1	15790	13530	-15754	39956	30442	-74186
18	1:100	#1	7170	5710	-4771	33127	23661	-20595
19	1:500	#1	11972	8574	-11763	40861	31623	-71881
20	1:3547	#1	18153	15573	-18418	55931	42184	-105530
17	1:3547	#2	11304	8885	-6860	35288	28664	-57239
18	1:100	#2	2263	1897	-1499	15361	12428	-10779
19	1:500	#2	4062	3051	-4364	24860	22192	-34278
20	1:3547	#2	9048	6030	-11682	36126	29171	-74812

Table 31 Test Series B2: summary of wave loading at 1/250 significance level, Deck

Test	Return Period	Element	Deck $F_{Vimp,1/250}$ [kN]	Deck $F_{Vqs+,1/250}$ [kN]	Deck $F_{Vqs-,1/250}$ [kN]	Deck $M_{Vimp,1/250}$ [kNm]	Deck $M_{Vqs+,1/250}$ [kNm]	Deck $M_{Vqs-,1/250}$ [kNm]
17	1:3547	#1	15233	12529	-15066	37034	27738	-70164
18	1:100	#1	6933	4911	-4292	25668	18202	-19232
19	1:500	#1	10753	7826	-10142	36010	27958	-58791
20	1:3547	#1	17579	14066	-17917	50482	39741	-102080
17	1:3547	#2	8470	6006	-4397	33582	25585	-30016
18	1:100	#2	1877	1558	-1241	14234	10461	-9686
19	1:500	#2	3728	2969	-3503	24076	20399	-20562
20	1:3547	#2	8401	5745	-6788	33853	27442	-45288

Table 32 Test Series B2: summary of wave loading at 1/1000 significance level, Beam

Test	Return Period	Front Beam $F_{Himp,1/250}$ [kN]	Front Beam $F_{Hqs+,1/250}$ [kN]	Front Beam $F_{Hqs;,1/250}$ [kN]	Internal Beam $F_{Himp,1/250}$ [kN]	Internal Beam $F_{Hqs+,1/250}$ [kN]	Internal Beam $F_{Hqs;,1/250}$ [kN]
17	1:3547	1757	677	-104	1303	827	-193
18	1:100	2027	346	-67	518	197	-64
19	1:500	1904	560	-103	953	586	-126
20	1:3547	1901	920	-142	1538	927	-199

Table 33 Test Series B2: summary of wave loading at 1/250 significance level, Beam

Test	Return Period	Front Beam $F_{Himp,1/250}$ [kN]	Front Beam $F_{Hqs+,1/250}$ [kN]	Front Beam $F_{Hqs;,1/250}$ [kN]	Internal Beam $F_{Himp,1/250}$ [kN]	Internal Beam $F_{Hqs+,1/250}$ [kN]	Internal Beam $F_{Hqs;,1/250}$ [kN]
17	1:5	1493	644	-92	1256	769	-178
18	1:25	1563	306	-50	481	184	-54
19	1:100	1620	468	-94	857	490	-115
20	1:500	1706	697	-125	1378	872	-170

4.2.3 *Forces derived from analysis of pressure time-histories*

The method adopted to process the measured pressures is illustrated in the flow diagram in Figure 20, showing particularly the six stages of results, Outputs 1-6.

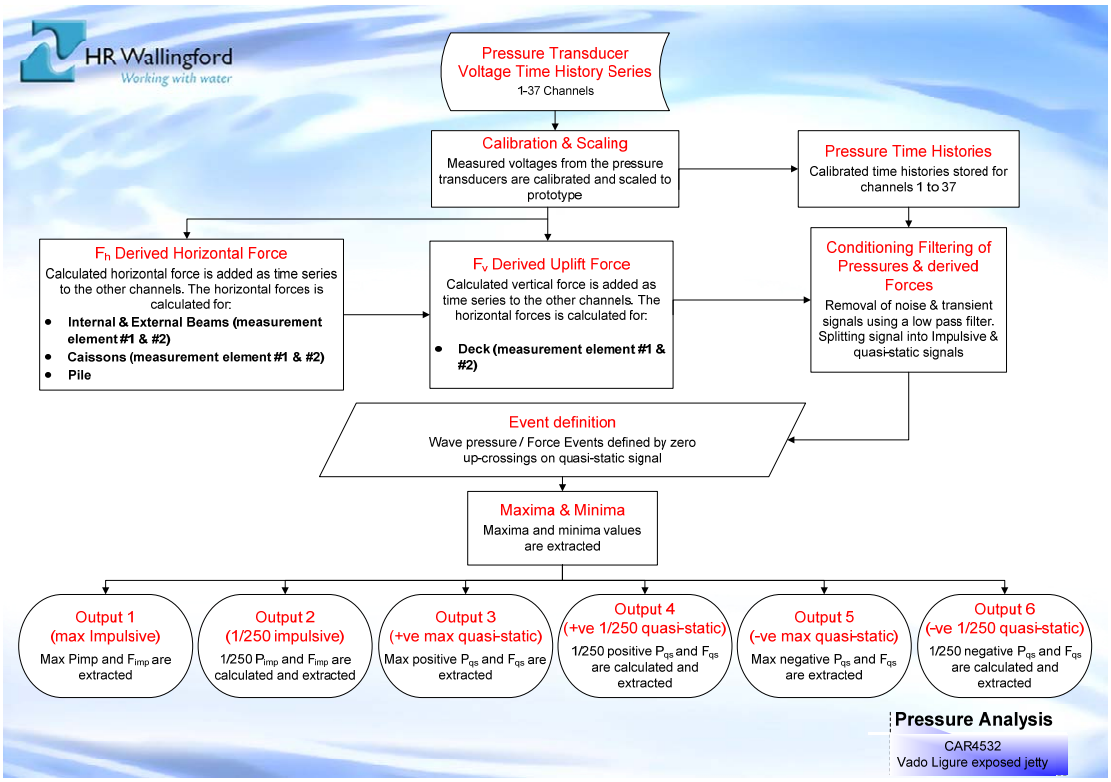


Figure 20 Flow chart of pressure analysis procedure

In these studies, wave pressures were recorded at 5000Hz (model), equivalent to 645.5Hz at full scale. For the analysis of impulsive loadings, these signals are analysed directly (after minor filtering to remove noise and transient signals). For quasi-static loads, a more severe filter (using a Chebyshev type II digital filter with a cut-off frequency, f_c = 2Hz at full scale) was applied to remove the short duration events whilst retaining information on quasi-static loads. The characteristics of the filter can be seen in Figure 21.

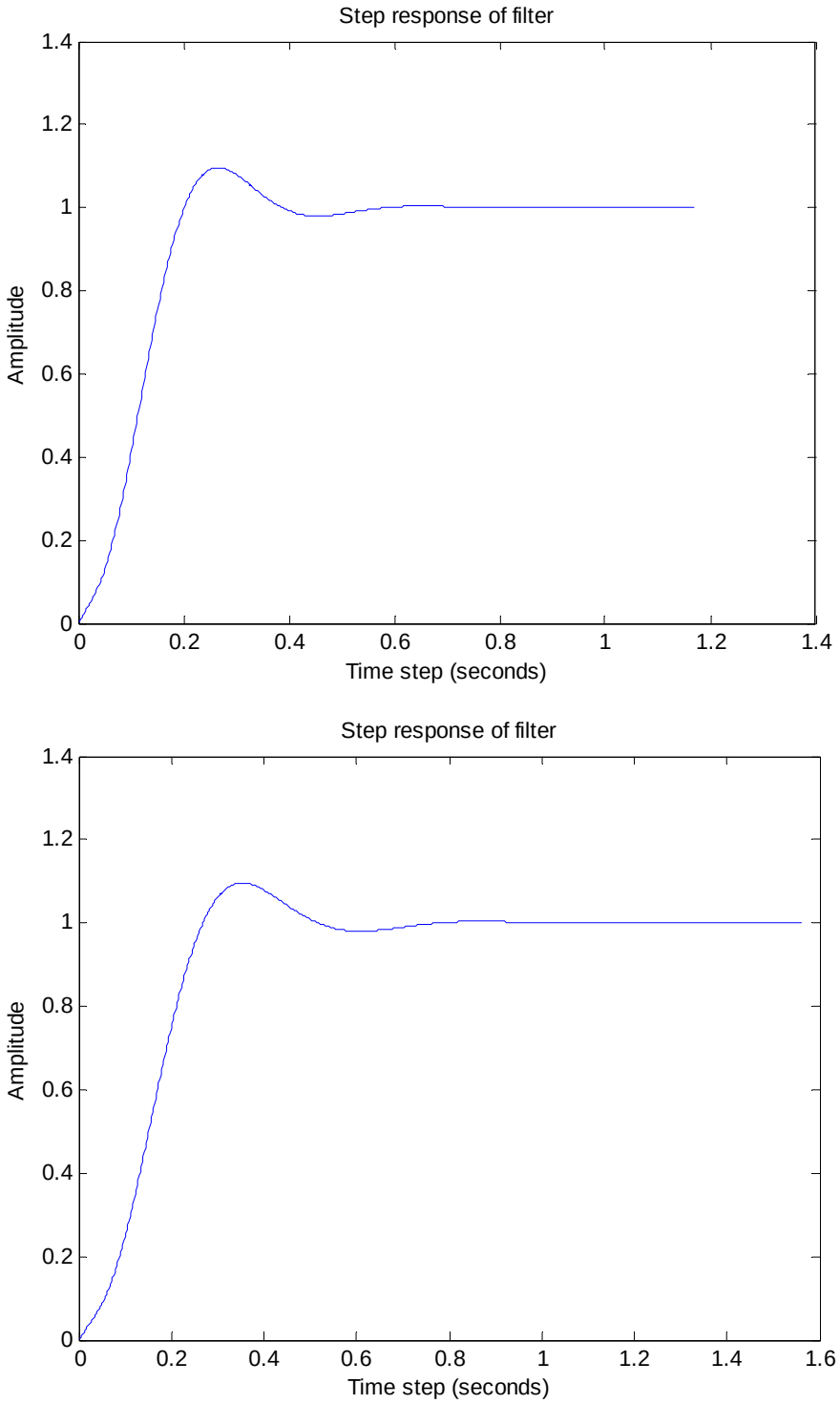


Figure 21 Filter response for pressure (top) and force (bottom) time histories

Table 34 Pressure transducer locations and representative areas

Unit	Element	Load	Contribution to force +ve or –ve	No.	Transducer No.	Test Series A Representative area (m^2 per m run)	Test Series B Representative area (m^2 per m run)
1	Deck	Vertical	+ve	1	Tr 1	42.5	same as A
1	Deck	Vertical	+ve	1	Tr 2	37.3	same as A
1	Deck	Vertical	+ve	1	Tr 3	48.4	same as A
1	Deck	Vertical	+ve	2	Tr 4	127.8	same as A
1	Deck	Vertical	+ve	3	Tr 5	127.8	same as A
1	Beam (L)	Vertical	+ve	1	Tr 6	not used	same as A
1	Beam (T)	Vertical	+ve	1	Tr 7	41.4	same as A
1	Beam (T)	Vertical	+ve	2	Tr 8	42.5	same as A
1	Beam (T)	Horiz	+ve	1	Tr 9	33.7	same as A
1	Beam (T)	Horiz	+ve	2	Tr 10	17.1	same as A
1	Deck	Vertical	-ve	1	Tr 11	42.5	same as A
1	Deck	Vertical	-ve	1	Tr 12	37.3	same as A
1	Deck	Vertical	-ve	1	Tr 13	48.4	same as A
1	Deck	Vertical	-ve	2	Tr 14	127.8	same as A
1	Deck	Vertical	-ve	3	Tr 15	127.8	same as A
1	Beam (L)	Vertical	-ve	1	Tr 16	not used	same as A
1	Beam (T)	Vertical	-ve	1	Tr 17	41.4	same as A
1	Beam (T)	Vertical	-ve	2	Tr 18	42.5	same as A
1	Beam (T)	Horiz	-ve	1	Tr 19	17.1	same as A
1	Beam (T)	Horiz	-ve	2	Tr 20	17.1	same as A
2	Deck	Vertical	+ve	1	Tr 21	42.5	same as A
2	Deck	Vertical	+ve	1	Tr 22	37.3	same as A
2	Deck	Vertical	+ve	1	Tr 23	48.4	same as A
2	Deck	Vertical	+ve	2	Tr 24	127.8	same as A
2	Deck	Vertical	+ve	3	Tr 25	127.8	same as A
2	Beam (L)	Vertical	+ve	1	Tr 26	not used	same as A
2	Beam (T)	Vertical	+ve	1	Tr 27	41.4	same as A
2	Beam (T)	Vertical	+ve	1	Tr 28	42.5	same as A
2	Beam (T)	Horiz	+ve	1	Tr 29	17.1	same as A
2	Beam (T)	Horiz	+ve	2	Tr 30	17.1	same as A
2	Beam (T)	Horiz	-ve	1	Tr 31	17.1	same as A
2	Beam (T)	Horiz	-ve	2	Tr 32	17.1	same as A
1	Caisson	Horiz	+ve	1	Tr 33	224.5	same as A
1	Caisson	Horiz	-ve	1	Tr 34	224.5	same as A
2	Caisson	Horiz	+ve	2	Tr 35	178.7	210.2
2	Caisson	Horiz	-ve	2	Tr 36	178.7	210.2
1	Pile	Horiz	+ve	1	Tr 37	25.0	same as A

The data from the transducers listed in Table 34 and shown in Figures 7 and 8 are simple pressures (p_1 to p_{37}) relative to zero pressure defined by "no waves", so net of any hydro-static element. These pressures are then used to compute a set of indirect force responses:

- Up-lift force on deck unit #1, $F_v = \sum p_1, p_2, p_3, p_4, p_5, p_7, p_8 - \sum p_{11}, p_{12}, p_{13}, p_{14}, p_{15}, p_{17}, p_{18}$ (each over appropriate areas, see Table 34);

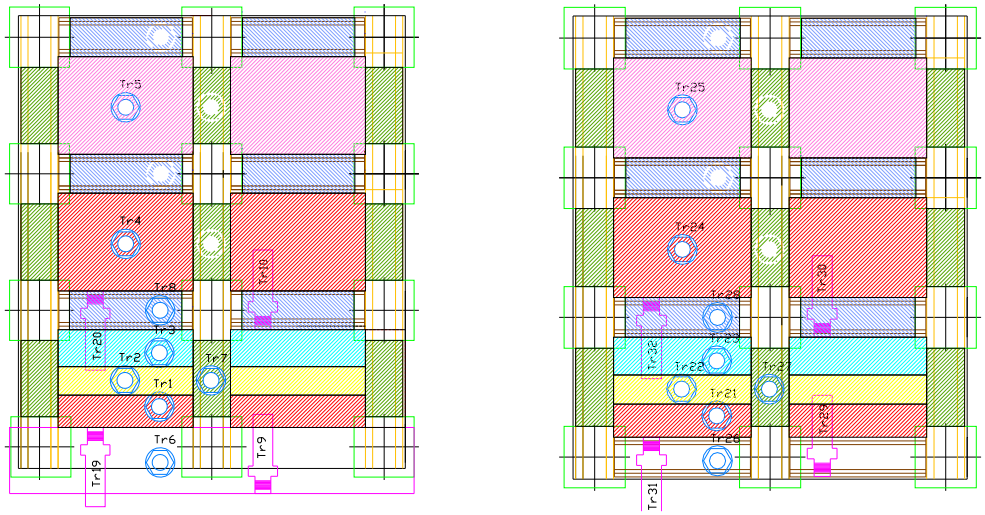
- Up-lift force on deck unit #2, $F_v = \sum p_{21}, p_{22}, p_{23}, p_{24}, p_{25}, p_{27}, p_{28}$ (each over appropriate areas);
- Horizontal force on Internal / External Beam on unit #1, $F_h = \sum p_9 - \sum p_{19}$,*and* $F_h = \sum p_{10} - \sum p_{20}$ (each over appropriate areas);
- Horizontal force on Internal / External Beam on unit #2, $F_h = \sum p_{29} - \sum p_{31}$,*and* $F_h = \sum p_{30} - \sum p_{32}$ (each over appropriate areas);
- Horizontal force on caisson at unit #1, $F_h = \sum p_{33} - \sum p_{34}$, (each over appropriate areas);
- Horizontal force on caisson at unit #2, $F_h = \sum p_{35} - \sum p_{36}$, (each over appropriate areas);
- Horizontal force on pile at unit #1, $F_h = \sum p_{37}$, (each over appropriate areas);

Within each loading event (approximately 1000 per test) peak values were extracted for each of the measured and derived channels ($p_{1\text{-}37}$, F_h *and* F_u). From the extracted peaks the 1/250 value was calculated and force time history plots created.

Reconstructed force time histories were then analysed using specifically developed software and the following parameters were extracted:

- Impulsive forces: $F_{imp,max}$; $F_{imp,1/250}$
- Quasi-static positive forces: $F_{qs+,max}$; $F_{qs+,1/250}$
- Quasi-static negative forces: $F_{qs-,max}$; $F_{qs-,1/250}$

Results from Test Series A1, B1 and B2 are presented respectively in Tables 35-44, Table 45-54 and Tables 55-64 in terms of wave-in-deck loads at 1/1000 and 1/250 significant level on Decks, Individual Beams, Caissons, Piles and combined horizontal Beams.



Front row caisson Second row caisson

Figure 22 Areas used to derive uplift force from pressures

Table 35 Test Series A1: summary of wave loading on Decks

Test	Return Period	Deck	Fimp,1/1000 [kN]	Fimp,1/250 [kN]	Fqs+,1/1000 [kN]	Fqs+,1/250 [kN]	Fqs-,1/1000 [kN]	Fqs-,1/250 [kN]
05	1:5	#1	3615	3067	1047	865	-1579	-1356
06	1:25	#1	6419	5439	1118	1093	-3126	-2931
07	1:100	#1	11604	9064	1881	1515	-4025	-3823
08	1:500	#1	12665	10527	5085	4639	-7649	-6564
05	1:5	#2	5706	4949	1197	1036	-445	-432
06	1:25	#2	9441	9111	1450	1184	-1078	-756
07	1:100	#2	12058	10875	1869	1348	-734	-694
08	1:500	#2	11571	10888	5133	2619	-1110	-931

Table 36 Test Series A1: summary of horizontal wave loading on 1st beam of caisson 1 (one beam)

Test	Return Period	Caisson	Fimp,1/1000 [kN]	Fimp,1/250 [kN]	Fqs+,1/1000 [kN]	Fqs+,1/250 [kN]	Fqs-1/1000 [kN]	Fqs-,1/250 [kN]
05	1:5	#1	668	425	439	285	-32	-20
06	1:25	#1	487	432	373	340	-29	-23
07	1:100	#1	1522	887	570	524	-37	-35
08	1:500	#1	1593	1212	1179	1067	-185	-131

Table 37 Test Series A1: summary of horizontal wave loading on 2nd beam of caisson 1 (two beams)

Test	Return Period	Caisson	Fimp,1/1000 [kN]	Fimp,1/250 [kN]	Fqs+,1/1000 [kN]	Fqs+,1/250 [kN]	Fqs-,1/1000 [kN]	Fqs-,1/250 [kN]
05	1:5	#1	1526	1318	295	231	-113	-95
06	1:25	#1	2587	1618	685	544	-163	-138
07	1:100	#1	2531	2422	1141	933	-232	-224
08	1:500	#1	9139	6818	2879	2241	-506	-473

Table 37 Test Series A1: summary of wave loading on Caissons

Test	Return Period	Caisson	Fimp,1/1000 [kN]	Fimp,1/250 [kN]	Fqs+,1/1000 [kN]	Fqs+,1/250 [kN]	Fqs-,1/1000 [kN]	Fqs-,1/250 [kN]
05	1:5	#1	5962	5568	5444	5149	-5787	-5536
06	1:25	#1	9488	8899	8833	8249	-7891	-7438
07	1:100	#1	11441	10622	11132	10121	-10001	-9447
08	1:500	#1	14761	14506	14377	13958	-11314	-11207
05	1:5	#2	4478	3809	3156	2959	-3643	-3585
06	1:25	#2	4539	4473	4083	4005	-4729	-4608
07	1:100	#2	7045	6090	6663	5694	-5269	-5211
08	1:500	#2	7100	7008	6875	6651	-6289	-5980

Table 38 Test Series A1: summary of wave loading on a front Piles

Test	Return Period	Caisson	Fimp,1/1000 [kN]	Fimp,1/250 [kN]	Fqs+,1/1000 [kN]	Fqs+,1/250 [kN]	Fqs-,1/1000 [kN]	Fqs-,1/250 [kN]
05	1:5	#1	1122	825	411	402	-616	-543
06	1:25	#1	979	904	642	585	-788	-738
07	1:100	#1	1426	1084	856	785	-853	-843
08	1:500	#1	1314	1270	1184	1139	-848	-847

Table 40 Test Series A1: summary of horizontal wave loading on 1st beam only of caisson 2 (two beams)

Test	Return Period	Caisson	Fimp,1/1000 [kN]	Fimp,1/250 [kN]	Fqs+,1/1000 [kN]	Fqs+,1/250 [kN]	Fqs-,1/1000 [kN]	Fqs-,1/250 [kN]
05	1:5	#2	2667	1175	367	255	-30	-25
06	1:25	#2	6581	5134	994	878	-88	-79
07	1:100	#2	9856	7468	1157	1063	-88	-84
08	1:500	#2	12222	8766	1710	1582	-129	-122

Table 41 Test Series A1: summary of horizontal wave loading on 2nd beam only of caisson 2(two beams)

Test	Return Period	caisson	Fimp,1/1000 [kN]	Fimp,1/250 [kN]	Fqs+,1/1000 [kN]	Fqs+,1/250 [kN]	Fqs-,1/1000 [kN]	Fqs-,1/250 [kN]
05	1:5	#2	349	156	191	100	-15	-14
06	1:25	#2	1451	1166	195	164	-34	-27
07	1:100	#2	3571	2678	612	523	-55	-46
08	1:500	#2	3936	3588	1067	815	-75	-66

Table 42 Test Series A1: summary of combined horizontal wave loading on 2nd beam of caisson 1 (two beams) and 1st beam of caisson 2(two beams)

Test	Return Period	caisson	Fimp,1/1000 [kN]	Fimp,1/250 [kN]	Fqs+,1/1000 [kN]	Fqs+,1/250 [kN]	Fqs-,1/1000 [kN]	Fqs-,1/250 [kN]
05	1:5	#1 / #2	2663	1764	401	299	-109	-95
06	1:25	#1 / #2	6600	5142	993	877	-174	-150
07	1:100	#1 / #2	9679	7359	1139	1044	-237	-225
08	1:500	#1 / #2	12218	9167	2861	2228	-521	-469

Table 43 Test Series A1: summary of combined horizontal wave loading on 2nd beam of caisson 1 (two beams) and 2nd beam of caisson 2(two beams)

Test	Return Period	caisson	Fimp,1/1000 [kN]	Fimp,1/250 [kN]	Fqs+,1/1000 [kN]	Fqs+,1/250 [kN]	Fqs-,1/1000 [kN]	Fqs-,1/250 [kN]
05	1:5	#1 / #2	1533	1319	301	246	-110	-93
06	1:25	#1 / #2	2574	1755	685	545	-161	-137
07	1:100	#1 / #2	3572	2802	1145	934	-232	-223
08	1:500	#1 / #2	9139	6818	2875	2239	-506	-474

Table 44 Test Series A1: summary of combined horizontal wave loading on 1st beams of caisson 2 (two beams) and 2nd beams of caisson 2(two beams)

Test	Return Period	Caisson	Fimp,1/1000 [kN]	Fimp,1/250 [kN]	Fqs+,1/1000 [kN]	Fqs+,1/250 [kN]	Fqs-,1/1000 [kN]	Fqs-,1/250 [kN]
05	1:5	#2	2667	1174	367	272	-28	-24
06	1:25	#2	6581	5134	994	880	-88	-78
07	1:100	#2	9866	7467	1158	1064	-87	-83
08	1:500	#2	12190	8757	1710	1580	-126	-125

Table 45 Test Series B1: summary of wave loading on Decks

Test	Return Period	Deck	Fimp,max [kN]	Fimp,1/250 [kN]	Fqs+,max [kN]	Fqs+,1/250 [kN]	Fqs-,max [kN]	Fqs-,1/250 [kN]
5	1:5	#1	6381	3983	1028	866	-2018	-1792
6	1:25	#1	18038	14947	1772	1567	-4717	-3348
7	1:100	#1	12318	9334	2600	2190	-4675	-4094
8	1:500	#1	12763	11415	5752	5609	-7804	-7013
5	1:5	#2	4084	3539	708	491	-398	-362
6	1:25	#2	9766	7805	1265	959	-668	-599
7	1:100	#2	13100	11268	1948	1497	-843	-789
8	1:500	#2	11646	11034	2499	1893	-2915	-2737

Table 46 Test Series B1: summary of horizontal wave loading on 1st beam of caisson 1 (one beam)

Test	Return Period	Caisson	Fimp,1/1000 [kN]	Fimp,1/250 [kN]	Fqs+,1/1000 [kN]	Fqs+,1/250 [kN]	Fqs-,1/1000 [kN]	Fqs-,1/250 [kN]
5	1:5	#1	215	174	138	137	-15	-14
6	1:25	#1	441	407	337	315	-34	-31
7	1:100	#1	807	625	524	462	-50	-49
8	1:500	#1	1895	1684	1683	1044	-346	-181

Table 47 Test Series B1: summary of horizontal wave loading on 2nd beam of caisson 1 (two beams)

Test	Return Period	caisson	Fimp,1/1000 [kN]	Fimp,1/250 [kN]	Fqs+,1/1000 [kN]	Fqs+,1/250 [kN]	Fqs-,1/1000 [kN]	Fqs-,1/250 [kN]
5	1:5	#1	2603	2003	485	401	-97	-81
6	1:25	#1	6011	4384	1514	1252	-228	-188
7	1:100	#1	5764	4278	1550	1512	-465	-389
8	1:500	#1	9415	7882	3456	3138	-920	-813

Table 48 Test Series B1: summary of wave loading on Caissons

Test	Return Period	Caisson	Fimp,1/1000 [kN]	Fimp,1/250 [kN]	Fqs+,1/1000 [kN]	Fqs+,1/250 [kN]	Fqs-,1/1000 [kN]	Fqs-,1/250 [kN]
13	1:5	#1	5364	5135	4470	4253	-4762	-4599
14	1:25	#1	8634	8069	7960	7228	-6930	-6376
15	1:100	#1	10764	9719	9690	8975	-8648	-8074
16	1:500	#1	14261	13539	13019	12494	-11173	-10956
13	1:5	#2	5127	4283	3544	3478	-3646	-3537
14	1:25	#2	6229	5928	5274	5019	-4399	-4378
15	1:100	#2	7476	7167	6004	5889	-4969	-4827
16	1:500	#2	10737	9861	9752	8945	-5413	-5198

Table 49 Test Series B1: summary of wave loading on a front Pile

Test	Return Period	Caisson	Fimp,1/1000 [kN]	Fimp,1/250 [kN]	Fqs+,1/1000 [kN]	Fqs+,1/250 [kN]	Fqs-,1/1000 [kN]	Fqs-,1/250 [kN]
13	1:5	#1	769	751	382	372	-611	-533
14	1:25	#1	1119	1025	646	591	-904	-871
15	1:100	#1	1156	1034	866	813	-932	-926
16	1:500	#1	1558	1423	1239	1192	-927	-923

Table 50 Test Series B1: summary of horizontal wave loading on 1st beam only of caisson 2 (two beams)

Test	Return Period	caisson	Fimp,1/1000 [kN]	Fimp,1/250 [kN]	Fqs+,1/1000 [kN]	Fqs+,1/250 [kN]	Fqs-,1/1000 [kN]	Fqs-,1/250 [kN]
13	1:5	#2	300	181	140	78	-23	-22
14	1:25	#2	4572	3182	776	625	-63	-56
15	1:100	#2	7741	6667	1517	1282	-111	-91
16	1:500	#2	11516	9567	2116	2001	-144	-137

Table 51 Test Series B1: summary of horizontal wave loading on 2nd beam only of caisson 2(two beams)

Test	Return Period	caisson	Fimp,1/1000 [kN]	Fimp,1/250 [kN]	Fqs+,1/1000 [kN]	Fqs+,1/250 [kN]	Fqs-,1/1000 [kN]	Fqs-,1/250 [kN]
13	1:5	#2	265	111	130	56	-18	-16
14	1:25	#2	6998	3443	415	364	-38	-35
15	1:100	#2	3530	2934	1001	724	-102	-75
16	1:500	#2	8603	5449	1004	939	-296	-216

Table 52 Test Series B1: summary of combined horizontal wave loading on 2nd beam of caisson 1 (two beams) and 1st beam of caisson 2(two beams)

Test	Return Period	caisson	Fimp,1/1000 [kN]	Fimp,1/250 [kN]	Fqs+,1/1000 [kN]	Fqs+,1/250 [kN]	Fqs-,1/1000 [kN]	Fqs-,1/250 [kN]
13	1:5	#1 / #2	2615	2012	485	407	-97	-80
14	1:25	#1 / #2	6007	4751	1511	1252	-230	-201
15	1:100	#1 / #2	7745	6699	1540	1522	-470	-398
16	1:500	#1 / #2	11463	9802	3418	3118	-955	-838

Table 53 Test Series A1: summary of combined horizontal wave loading on 2nd beam of caisson 1 (two beams) and 2nd beam of caisson 2(two beams)

Test	Return Period	caisson	Fimp,1/1000 [kN]	Fimp,1/250 [kN]	Fqs+,1/1000 [kN]	Fqs+,1/250 [kN]	Fqs-,1/1000 [kN]	Fqs-,1/250 [kN]
13	1:5	#1 / #2	2616	2011	485	409	-96	-80
14	1:25	#1 / #2	6995	5359	1516	1254	-228	-188
15	1:100	#1 / #2	5757	4270	1549	1511	-466	-392
16	1:500	#1 / #2	9398	8336	3445	3134	-931	-821

Table 54 Test Series B1: summary of combined horizontal wave loading on 1st beams of caisson 2 (two beams) and 2nd beams of caisson 2(two beams)

Test	Return Period	caisson	Fimp,1/1000 [kN]	Fimp,1/250 [kN]	Fqs+,1/1000 [kN]	Fqs+,1/250 [kN]	Fqs-,1/1000 [kN]	Fqs-,1/250 [kN]
13	1:5	#2	335	196	185	97	-20	-17
14	1:25	#2	7012	4334	773	624	-64	-58
15	1:100	#2	7743	6663	1516	1308	-113	-95
16	1:500	#2	11507	9591	2111	1998	-248	-192

Table 55 Test Series B2: summary of wave loading on Decks

Test	Return Period	caisson	Fimp,max [kN]	Fimp,1/250 [kN]	Fqs+,max [kN]	Fqs+,1/250 [kN]	Fqs-,max [kN]	Fqs-,1/250 [kN]
18	1:100 +0.5m SWL	#1	18705	14922	3502	3195	-5403	-4913
19	1:500 +0.5m SWL	#1	30630	28450	8657.5	8128.2	-8840	-8607.4
17	1:3547 +0m SWL	#1	26432	23851	12501	10647	-10991	-10697
20	1:3547 +0.5mSWL	#1	48193	36676	16476	13646	-11810	-11447
18	1:100 +0.5m SWL	#2	16505	14953	1676	1357	-1469	-1262
19	1:500 +0.5m SWL	#2	14245	13833	4631	3598	-6170	-3248
17	1:3547 +0m SWL	#2	17609	15354	8277	6137	-6984	-5936
20	1:3547 +0.5mSWL	#2	18192	17883	10948	8413	-9638	-5117

Table 56 Test Series B2: summary of horizontal wave loading on 1st beam of caisson 1 (one beam)

Test	Return Period	Caisson	Fimp,1/1000 [kN]	Fimp,1/250 [kN]	Fqs+,1/1000 [kN]	Fqs+,1/250 [kN]	Fqs-,1/1000 [kN]	Fqs-,1/250 [kN]
18	1:100 +0.5m SWL	#1	1288	851	624	575	-77	-66
19	1:500 +0.5m SWL	#1	2832	2368	1392	1105	-187	-153
17	1:3547 +0m SWL	#1	8631	3624	1310	1228	-169	-156
20	1:3547 +0.5mSWL	#1	6443	3418	1442	1248	-374	-250

Table 57 Test Series B2: summary of horizontal wave loading on 2nd beam of caisson 1 (two beams)

Test	Return Period	caisson	Fimp,1/1000 [kN]	Fimp,1/250 [kN]	Fqs+,1/1000 [kN]	Fqs+,1/250 [kN]	Fqs-,1/1000 [kN]	Fqs-,1/250 [kN]
18	1:100 +0.5m SWL	#1	6358	5728	2353	2188	-672	-534
19	1:500 +0.5m SWL	#1	22364	12372	3940	3744	-1022	-977
17	1:3547 +0m SWL	#1	17383	13083	4984	4627	-901	-847
20	1:3547 +0.5mSWL	#1	14206	12751	5299	4935	-965	-908

Table 58 Test Series B2: summary of wave loading on Caissons

Test	Return Period	Caisson	Fimp,1/1000 [kN]	Fimp,1/250 [kN]	Fqs+,1/1000 [kN]	Fqs+,1/250 [kN]	Fqs-,1/1000 [kN]	Fqs-,1/250 [kN]
18	1:100 +0.5m SWL	#1	10665	9857	9779	8771	-8058	-7483
19	1:500 +0.5m SWL	#1	13475	13199	12599	12379	-10333	-9958
17	1:3547 +0m SWL	#1	18001	17424	17133	16612	-13930	-13398
20	1:3547 +0.5mSWL	#1	18114	17608	17086	16505	-14025	-12855
18	1:100 +0.5m SWL	#2	6245	6126	5684	5426	-4378	-4257
19	1:500 +0.5m SWL	#2	10600	9824	8998	8535	-5074	-4782
17	1:3547 +0m SWL	#2	14665	13639	12374	11451	-5860	-5686
20	1:3547 +0.5mSWL	#2	15598	14519	12795	12464	-5558	-5380

Table 59 Test Series B2: summary of wave loading on a front Pile

Test	Return Period	Caisson	Fimp,1/1000 [kN]	Fimp,1/250 [kN]	Fqs+,1/1000 [kN]	Fqs+,1/250 [kN]	Fqs-,1/1000 [kN]	Fqs-,1/250 [kN]
18	1:100 +0.5m SWL	#1	1122	1057	840	787	-1030	-996
19	1:500 +0.5m SWL	#1	2903	2056	1226	1189	-1047	-1044
17	1:3547 +0m SWL	#1	2336	2109	1647	1564	-973	-945
20	1:3547 +0.5mSWL	#1	1992	1864	1839	1632	-1054	-1046

Table 60 Test Series B2: summary of horizontal wave loading on 1st beam only of caisson 2 (two beams)

Test	Return Period	caisson	Fimp,1/1000 [kN]	Fimp,1/250 [kN]	Fqs+,1/1000 [kN]	Fqs+,1/250 [kN]	Fqs-,1/1000 [kN]	Fqs-,1/250 [kN]
18	1:100 +0.5m SWL	#2	10998	9616	2106	1601	-129	-101
19	1:500 +0.5m SWL	#2	13040	12180	2833	2687	-447	-385
17	1:3547 +0m SWL	#2	21049	18507	3401	3297	-448	-366
20	1:3547 +0.5mSWL	#2	16886	14746	4224	3918	-449	-435

Table 61 Test Series B2: summary of horizontal wave loading on 2nd beam only of caisson 2(two beams)

Test	Return Period	caisson	Fimp,1/1000 [kN]	Fimp,1/250 [kN]	Fqs+,1/1000 [kN]	Fqs+,1/250 [kN]	Fqs-,1/1000 [kN]	Fqs-,1/250 [kN]
18	1:100 +0.5m SWL	#2	6255	5899	877	835	-96	-87
19	1:500 +0.5m SWL	#2	11857	9264	2145	1959	-398	-360
17	1:3547 +0m SWL	#2	9225	6654	2095	2028	-698	-532
20	1:3547 +0.5mSWL	#2	11358	10481	3024	2731	-859	-742

Table 62 Test Series B2: summary of combined horizontal wave loading on 2nd beam of caisson 1 (two beams) and 1st beam of caisson 2(two beams)

Test	Return Period	caisson	Fimp,1/1000 [kN]	Fimp,1/250 [kN]	Fqs+,1/1000 [kN]	Fqs+,1/250 [kN]	Fqs-,1/1000 [kN]	Fqs-,1/250 [kN]
18	1:100 +0.5m SWL	#1 / #2	10990	9624	2346	2185	-685	-547
19	1:500 +0.5m SWL	#1 / #2	22334	14911	3902	3720	-1063	-1013
17	1:3547 +0m SWL	#1 / #2	21247	18523	4929	4591	-1072	-934
20	1:3547 +0.5mSWL	#1 / #2	16893	14888	5255	4891	-1109	-1018

Table 63 Test Series B2: Test Series A1: summary of combined horizontal wave loading on 2nd beam of caisson 1 (two beams) and 2nd beam of caisson 2(two beams)

Test	Return Period	caisson	Fimp,1/1000 [kN]	Fimp,1/250 [kN]	Fqs+,1/1000 [kN]	Fqs+,1/250 [kN]	Fqs-,1/1000 [kN]	Fqs-,1/250 [kN]
18	1:100 +0.5m SWL	#1 / #2	6531	6184	2352	2183	-676	-541
19	1:500 +0.5m SWL	#1 / #2	22339	13241	3916	3730	-1044	-998
17	1:3547 +0m SWL	#1 / #2	17343	13053	4955	4610	-915	-861
20	1:3547 +0.5mSWL	#1 / #2	14189	12848	5266	4904	-1008	-981

Table 64 Test Series B2: summary of combined horizontal wave loading on 1st beams of caisson 2 (two beams) and 2nd beams of caisson 2(two beams)

Test	Return Period	caisson	Fimp,1/1000 [kN]	Fimp,1/250 [kN]	Fqs+,1/1000 [kN]	Fqs+,1/250 [kN]	Fqs-,1/1000 [kN]	Fqs-,1/250 [kN]
18	1:100 +0.5m SWL	#2	11010	9611	2099	1595	-140	-113
19	1:500 +0.5m SWL	#2	13021	12375	2821	2675	-418	-376
17	1:3547 +0m SWL	#2	20990	18485	3392	3284	-625	-517
20	1:3547 +0.5mSWL	#2	16865	14697	4189	3891	-874	-750

4.2.4 Comparison of wave loading derived from force and pressure measurement

When measuring wave loads and/or pressures, it is generally expected that forces calculated from summed-pressures will give higher peak loads unless dynamically damped. These large peak summed-pressure loads will usually be of much shorter duration than whole-element loads measured by force transducers. This is frequently seen, although comparative studies are relatively published (see Alderson and Allsop, 2007 for one of the few exceptions). The differences between these two sets of results will be least where impulsive loadings are rare and greatest where short-duration and/or spatially limited impulsive pressures are high.

This is confirmed in Tables 22-64, with wave-induced forces measured using force transducers being sometime less intense than those derived by integrating pressure over their corresponding area of influence, the latter generally providing a more conservative estimate of the loading, and therefore recommended for use in the design. This has been observed in previous studies (particularly when measuring high frequency, impulsive loads) and the results of load measurements in these tests are therefore of little surprise. The only apparent discrepancy between force and pressure measurements is due to a combination of dynamic response of the physical model setup and to the necessarily discrete distribution of pressure sensors over the monitored area. The former effect is nevertheless expected to reduce once a dynamic analysis of the prototype structure is performed using both force and pressure inputs as any dynamic response of the model structure would only have affected the measurements outside of the range of frequency of interest for the prototype structure.

4.2.5 Coherency of horizontal forces on beams

When assessing the stability of the superstructure with respect to sliding, it is important to evaluate the total horizontal loads acting on each platform segment. Bearing this in mind, it might be useful to assess the coherency of horizontal force acting on beams located at different locations along the platform. This has been done by comparing forces derived by integrating pressures over single beams and combining pressure time-histories recorded by different beam elements along the structure.

Results appears to be little sensitive to the numbers of elements combined together, suggesting a relatively low coherency of the loading in time and space.

4.3 TEST SERIES A1 AND B1: VISUAL OBSERVATION OF OVERTOPPING AND STABILITY OF SCOUR PROTECTION

Visual observations of wave overtopping and movement of the scour protection was also performed during testing.

4.3.1 Test Series A1, 1:5 year condition

During testing of 1:5 year conditions, highest wave crests were partially reflected by the front beam, but no overtopping was observed nor movement of scour protection.

4.3.2 Test Series A1, 1:25 year condition

During testing of 1:25 year conditions, some overtopping was observed during passage of highest waves, overtopping flows reached up to 12m back from the leading edge of the front beam. No obvious movement of scour protection was observed.

4.3.3 Test Series A1, 1:100 year condition

During testing of 1:100 year conditions, some overtopping was observed during passage of highest waves, overtopping flows again reached up to 18m back from the leading edge of the front beam. No obvious movement of scour protection was observed.

4.3.4 Test Series A1, 1:500 year condition

During testing of 1:500 year conditions, some overtopping was observed during passage of highest waves, overtopping roars reached up to 72m back from the leading edge of the front beam. Green water overtopping events appear to be up to 0.6m thick at the leading edge. Scour protection was observed to move along orbital trajectories, some minor scour was observed at the top of the slope.

4.3.5 Test Series B1

During Test Series B1, overtopping behaviour was very similar to that observed during Test Series A1. This is not surprising given that wave conditions in front of the structure as well as the geometry of the seaward edge of the structure were identical in the two series. During Test Series B1, scour protection was observed to be more stable due to the relatively deeper local water depth. Scour was nevertheless still concentrated at the corner of the caisson foundation.

4.4 TEST SERIES A1 AND B1: SCOUR PROTECTION

4.4.1 Test Series A1

The armour movement stability tests were carried out in Test Series A01 for the 1:5 through to the 1:500 year conditions. A light coating of paint to the upper surface of the rocks allowed easy determination of armour movement. Before and after each scour test part, the scour protection armour around selected caissons was photographed from fixed positions. The armour was not repaired between test parts so that all damage recorded by the end of testing was cumulative.

During the armour stability tests, no obvious movement of scour protection material occurred up to testing of overload condition.

The armour movement in the overload condition was concentrated at the corner of the foundation caissons and in particular at the top of the slope. This is confirmed in Figure 23, showing differential damage at the end of the overload condition with the undisturbed condition captured at the beginning of the test.

No noticeable displacement of the armour units was observed in any of the tests up to 100 years conditions, with the scour protection material showing only moderate (<3%) cumulative damage at the end of the test performed with the 1:100 years condition .

The damage after the 1:500 years condition (overload) was nevertheless serious, based on criteria given in Tables 3 and 4, with 13.9% cumulative damage observed.

Results from the stability analysis of the scour protection are summarised in Table 65 showing cumulative damage for the range of conditions tested.

Table 65 Cumulative damage of the scour protection

Test Series	Test number	Return period	Cumulative Damage (%)	Cumulative Damage (%)
A1	05	1:5 years	Hardly-Slight	0.3
A1	06	1:25 years	Slight	1.0
A1	07	1:100 years	Moderate	2.6
A1	08	1:500 years	Serious	13.9

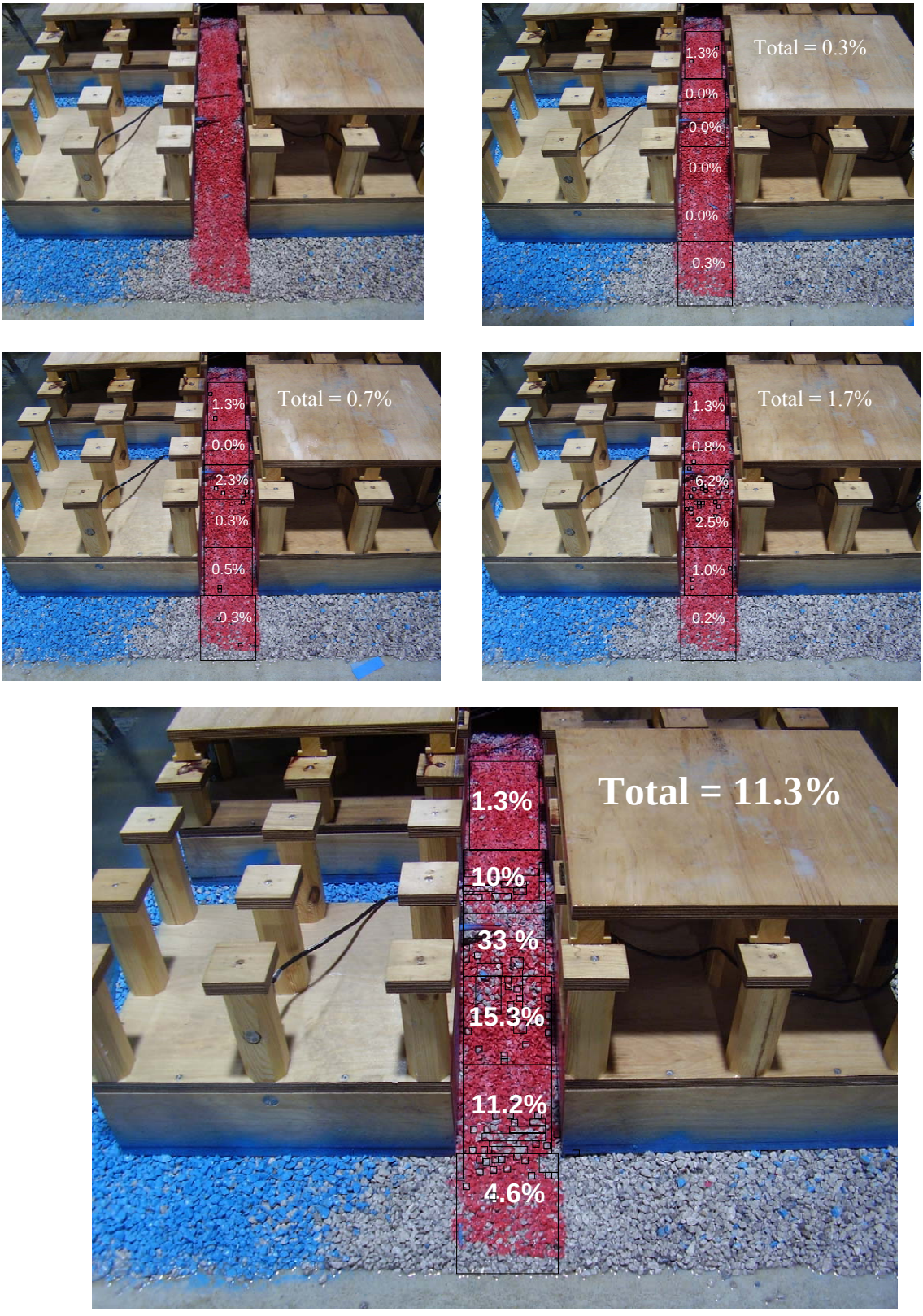


Figure 23 Rock stability analysis: comparison of undisturbed condition prior to testing (top left) and differential damage after testing wave conditions ranges between 1:5 and 1:500 years, numbers refer to damage during each test part

4.4.2 Test Series B1

The armour movement stability tests were carried out in Test Series B01 for the 1:5 through to the 1:500 year conditions. Again, a light coating of paint to the upper surface of the rocks allowed easy determination of armour movement. Before and after each scour test part, the scour protection armour around selected caissons was photographed from fixed positions. The armour was not repaired between test parts so that all damage recorded by the end of testing was cumulative.

During the armour stability tests, no significant movement of scour protection material occurred up to testing of overload condition.

The scour concentrated at the corner of the foundation caissons and in particular at the top of the slope. This is confirmed in Figure 24, showing differential damage at the end of the overload condition with the undisturbed condition captured at the beginning of the test.

Little to moderate displacement of the armour units was observed in any of the tests up to 100 years conditions, with the scour protection material showing moderate (<5%) cumulative damage at the end of the test performed with the 1:100 years condition.

The damage after the 1:500 years condition (overload) was nevertheless serious, based on criteria given in Tables 3 and 4, with 8.7% cumulative damage observed.

Results from the stability analysis of the scour protection are summarised in Table 66 showing cumulative damage for the range of conditions tested.

Table 66 Cumulative damage of the scour protection

Test Series	Test number	Return period	Cumulative Damage (%)	Cumulative Damage (%)
B1	13	1:5 years	Hardly-Slight	0.5
B1	14	1:25 years	Moderate	2.6
B1	15	1:100 years	Much	3.9
B1	16	1:500 years	Serious	9.0

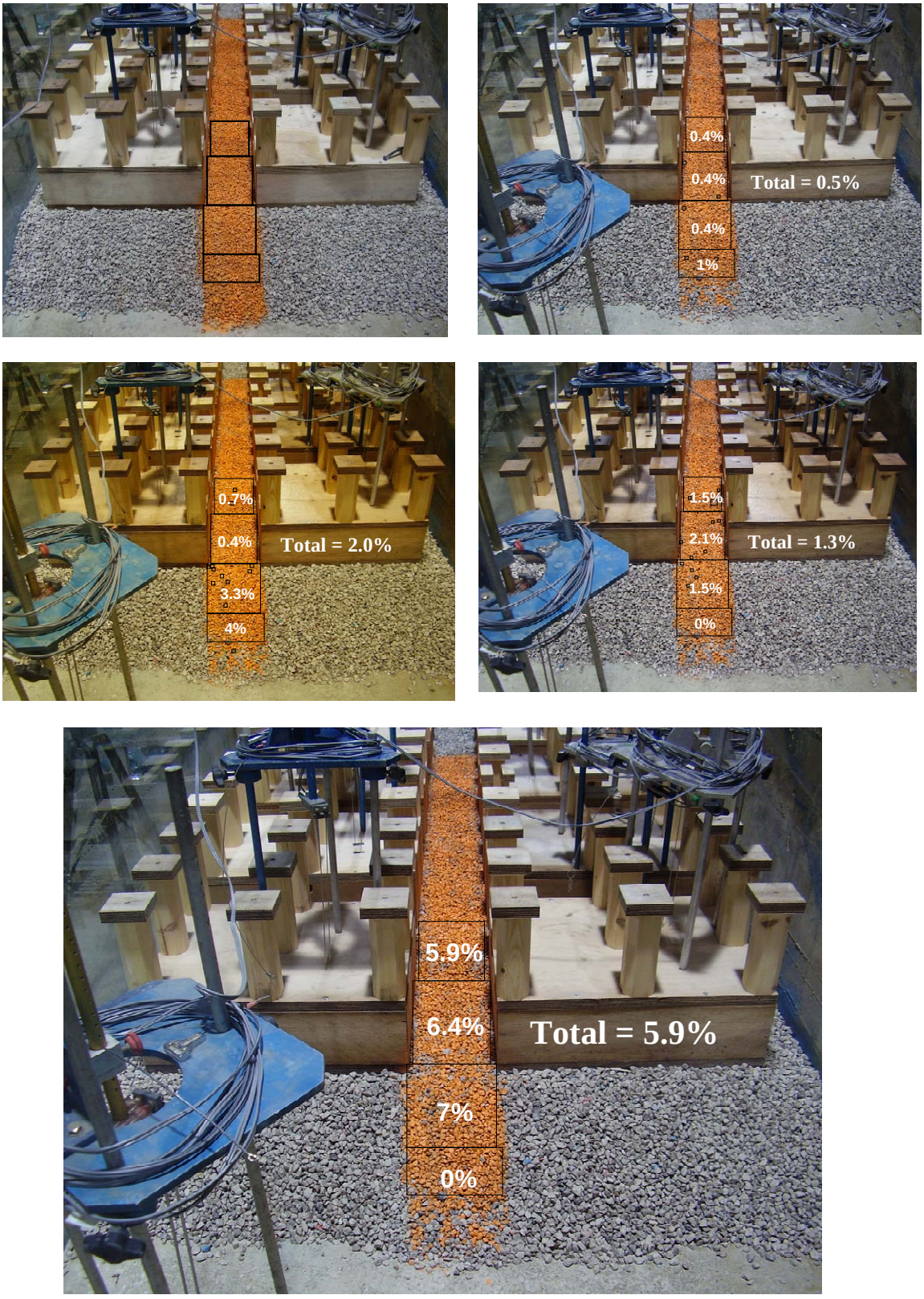


Figure 24 Rock stability analysis: comparison of undisturbed condition prior to testing (top left) and differential damage after testing wave conditions ranges between 1:5 and 1:500 years, numbers refer to damage during each test part

4.5 TEST SERIES A1, B1 AND B2: WAVE REFLECTION AT THE TOE OF THE STRUCTURE

Cross spectral analyses were carried out in order to determine the incident and reflected significant wave heights in front of the structure.

Reflected wave heights were quantified using an array of 3 in-line gauges placed in front of the structure, used to calculate reflection coefficients (C_r). It is noted that reflection coefficient may be defined either in terms of incident and reflected wave heights (H_{si} and H_{sr}) or in terms of incident and reflected energies ($E_{incident}$ and $E_{reflected}$), so:

$$C_r = H_{sr} / H_{si} \quad = \sqrt{(E_{reflected} / E_{incident})}$$

Results are summarised in Table 67, 68 and 69 in terms of reflection coefficients at the toe of the structure for each of the test conditions respectively for Test Series A1, B1 and B2.

Table 67 Test Series B1: reflection coefficients at the toe of the structure

Test Series	Test number	Return period	SWL	C_r
A1	05	1:5 years	+0.00mCD	0.66
A1	06	1:25 years	+0.00mCD	0.64
A1	07	1:100 years	+0.00mCD	0.63
A1	08	1:500 years	+0.00mCD	0.66

Table 68 Test Series B1: reflection coefficients at the toe of the structure

Test Series	Test number	Return period	SWL	C_r
B1	13	1:5 years	+0.00mCD	0.60
B1	14	1:25 years	+0.00mCD	0.66
B1	15	1:100 years	+0.00mCD	0.68
B1	16	1:500 years	+0.00mCD	0.69

Table 69 Test Series B1: reflection coefficients at the toe of the structure

Test Series	Test number	Return period	SWL	C_r
B2	17	1:3547 years	+0.00mCD	0.75
B2	18	1:100 years	+0.50mCD	0.7
B2	19	1:500 years	+0.50mCD	0.7
B2	20	1: 3547 years	+0.50mCD	0.75

5. Conclusions and Recommendations

Wave transformation over the model structure exhibited a very similar pattern for all conditions tested during Test Series A0 and B0 with wave heights reducing dramatically over the first two caissons due to reflections, depth-limited breaking and destructive interference over the top face of the caissons.

Wave loads were measured, and pressures and forces (both from direct force measurements and integrating pressures) were extracted at 1/250 and 1/1000 significance levels.

Wave loads measured on submerged structural elements were characterised by quasi-static oscillations following closely the local wave-induced variation in water surface elevation.

Wave-in-deck load time-histories recorded on the deck and beam elements exhibit the characteristic pattern with short duration peaks followed by a quasi-static oscillation.

Wave loads measured during Test Series B1 were generally higher than those measured during Test Series A1. The difference is moderate (20% in average) in terms of forces but becomes significant when comparing peak pressures. When looking at the pressure time-histories corresponding to the most severe events (Appendix C), these nevertheless appear to have significantly shorter peak durations than those recorded during Test Series A1, suggesting wave impact impulses to be more consistent and vary only moderately between the two test series.

It is recommended that appropriate dynamic analysis of the structure and its structural elements is performed to assess the relative importance of short duration impulsive loads.

Wave-induced forces measured using force transducers sometime appear to be less intense than those derived by integrating pressure over their corresponding area of influence, the latter generally providing a more conservative estimate of the loading, and therefore recommended for use in the design.

When comparing forces derived by integrating pressures over single beams and combining pressure time-histories recorded by different beam elements along the structure, results seem to be little sensitive to the numbers of elements combined together, suggesting a relatively low coherency of the loading in time and space.

No noticeable displacement of the scour armour was observed in any of the tests up to the 1:100 year conditions, with the scour protection material showing only little (<2%, Test Series A1) to moderate (<5%, Test Series B1) cumulative damage after testing the 1:100 year condition. It is nevertheless recommended that selected material having weight in the range of 100-300 kg is used to protect the most exposed top layer of the scour protection.

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