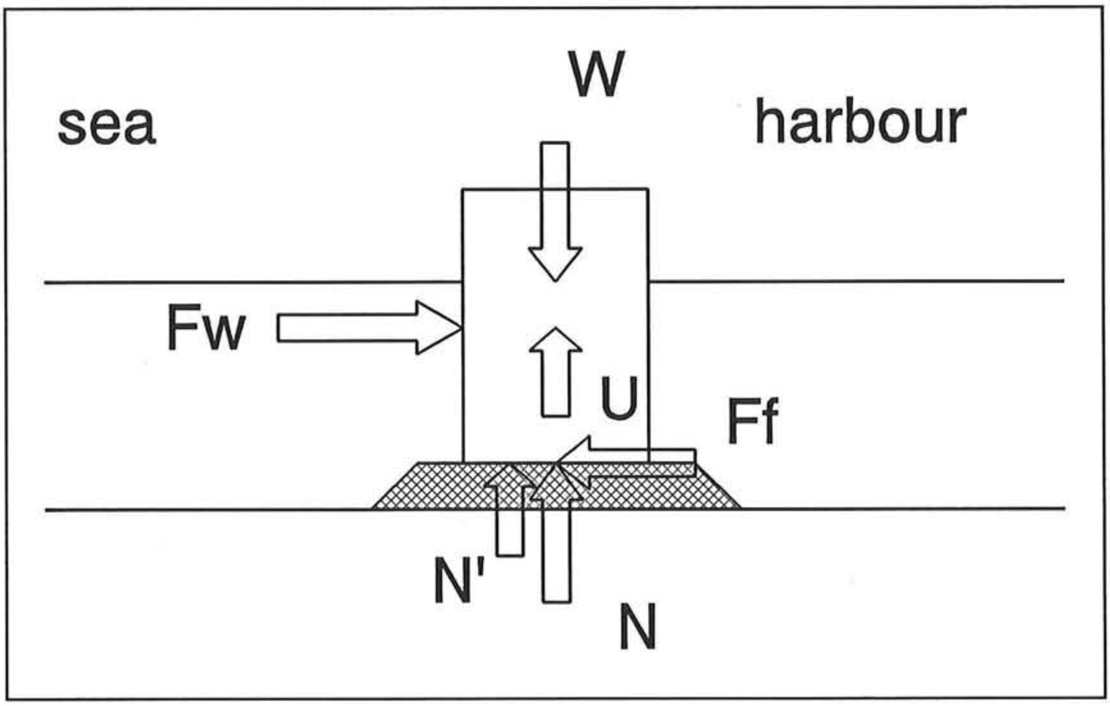
DESIGN CAISSON BREAKWATER

An evaluation of the formula of Goda

Carlita L. Vis



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Delft, August 1995
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Technology

SUMMARY

The growing need for breakwaters in deep water due to the increasing draught of large vessels draws the attention to caisson breakwaters. These monolithic structures are more economical compared to rubble mound breakwaters. Especially in deep water lower construction and maintenance costs and considerable savings in construction time can be realised. A caisson is built on shore and towed out to the actual offshore site. Unfortunately, damage at a caisson is often progressive. This causes an abrupt collapse of the structure. By understanding the dynamic processes involved, the design of the structure can be soundly based.

The formula of Goda (1985) is a worldwide used design method for vertical breakwaters based on the quasi-static approach. His design method is very useful as a first indication for the dimensions of the caisson. In order to be able to analyse Goda's method, the design of a caisson breakwater is roughly divided in three phases. First the crest elevation of the caisson, the design wave and the design water depth, are determined with probabilistic considerations about the economy of the harbour. Subsequently the wave load follows from the wave pressure formulae. Thirdly, the width of the structure sets the weight of the structure which defines the safety against failure.

Goda sets the design parameters on definite values regardless the cost-benefit analysis of the harbour. His design wave is the highest wave in the design sea state, which is based on the principle that a breakwater should be designed to be safe against the single wave with the largest pressure among storm waves.

From the comparison of the measured wave forces of the hydraulic model study and the values calculated with the wave pressure formulae of Goda and of the linear wave theory no conclusions can be drawn. This is partly due to the close resemblance of the results of the linear wave theory and Goda's formula for the conditions at Europoort Rotterdam and partly caused by the scatter in the measurements.

An experiment about the failure mechanisms of the caisson confirms the introducing of uncertainties concerning the placing of the caisson on the rubble mound foundation.

Goda's wave pressure formulae turned out to be in fact design formulae. Not only his design parameters but the formulae themselves include safety considerations. Evaluation of Goda's formula is therefore only valid when the whole design process is taken into account.

It is noted that the accuracy of the calculated wave pressure on the wall is very good with respect to the uncertainties introduced in the foundation forces and the determination of the design parameters.

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PREFACE

This report is written as a part of my study for the MSc. degree at the Faculty of Civil Engineering at the Delft University of Technology, Hydraulic engineering group.

Part of this study about the design of a breakwater is performed at the Imperial College for Science, Technology and Medicine in London. In the hydraulics laboratories of the department of Civil Engineering, a hydraulic model study has been carried out in order to compare experimental results with the results of theoretical calculations. I realise that learning about the English way of hydraulic engineering at Imperial College was a great opportunity, for which I am very grateful.

The advice and practical assistance of Professor P. Holmes and Dr. D. Hardwick of Imperial College of Science, Technology and Medicine are gratefully acknowledged.

Finally, I would like to express my gratitude to Professor J.K. Vrijling and Mr. K.G. Bezuyen of the Delft University of Technology for their supervision.

Delft, August 1995

Carlita L. Vis

1 INTRODUCTION

A breakwater can be designed for several different purposes. In the first section of this chapter background information is given about caisson breakwaters in general. The design process of a caisson breakwater is discussed in the second section. Subsequently, the objective of this study is defined in the third section followed by the explanation of the outline of this report in the last section.

1.1 Why building a caisson breakwater?

The main functions of a breakwater

The basic function of a breakwater is to provide protection against waves. This protection may be necessary for an approach channel or for a harbour itself, in order to provide a sufficient tranquil harbour basin for ships to navigate and moor. Other purposes of a breakwater can be:

- Reduce the amount of dredging required in a harbour entrance by cutting off the littoral transport supply.
- Guide the current in the approach channel or along the coast.
- Reduce the gradient of the cross current in an approach channel in order to make the ships entering the harbour better steerable.

In this study the protection against waves is considered to be the only function of a breakwater.

A caisson breakwater

The choice of a breakwater type for a given situation depends on many factors. Two types of breakwaters can be distinguished:

- Caisson breakwater
- Rubble mound breakwater

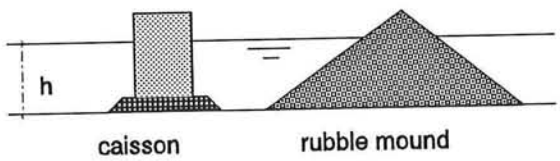

Figure 1.1 Caisson breakwater and rubble mound breakwater

Monolithic structures, the so called caisson breakwaters, have major advantages compared to rubble mound breakwaters in deep water. For instance the volume of a caisson in deep water is less than that needed for a rubble mound breakwater because the latter increases with the square of the water depth, see figure 1.1. Monolithic breakwaters are also more economical because of their lower construction and maintenance costs and their considerable savings in construction time, for a caisson is built onshore and towed out to the actual offshore site. A rubble mound breakwater can only be built offshore which is considerably more expensive. Rubble mound breakwaters are nevertheless more popular in western countries because they can fulfil their function even when they are severely damaged. Damage at a caisson breakwater is on the other hand most of the times progressive, which results in an abrupt collapse of the monolith.

1.2 Design process

The design of a caisson breakwater is an iterative process. It can be divided roughly into three phases, see figure 1.2. Firstly the design parameters have to be determined in accordance with the design principles. The design principles consist of economical considerations because an very high and heavy structure is not favourable. Secondly, the design parameters are used as input for the wave pressure formulae, which results in a design wave load. Subsequently the dimensions of the caisson can be calculated. These dimensions have to be checked with the design principles again because the optimum strength of the structure is related to the stability of the structure, which is provided only by the weight of the structure. In other words, the optimum ratio between the width and the height of the structure has to be determined.

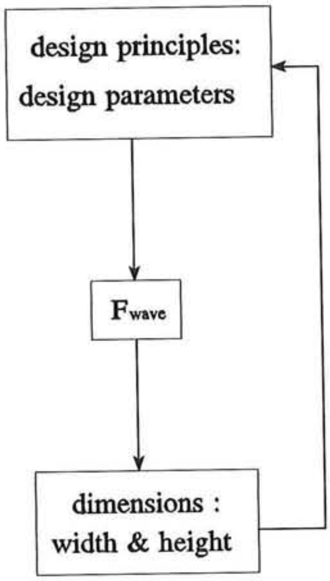

Figure 1.2 *General design process*

A standard design method for vertical wall breakwaters was developed by the Japanese Goda [ref 4] and is used worldwide. He made his formula after numerous hydraulic model studies. The wave pressure formulae of Goda were empirically derived and validated by the performance of prototype breakwaters.

Design principles

A breakwater is assumed to have failed when the main function is no longer fulfilled. That is, the protection against waves is less than required. Overtopping of waves is therefore considered as failure. A distinction has to be made between failure in the sense of total collapse of the structure and malfunction of the breakwater .

The <u>strength against collapse of a structure</u> should be designed in such a way that the structure can resist the extreme hydraulic design load on the structure, otherwise ultimate failure occurs. These chosen extreme design conditions determine therefore the needed strength or stability of the caisson.

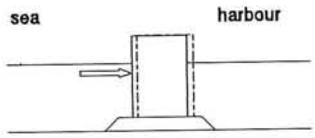

Figure 1.3 *Sliding*

The fulfilment of functioning of the structure under normal loading conditions is depending on the crest elevation of the breakwater. The amount of allowed overtopping should result from a cost-benefit analysis in relation with 'the economy' of the harbour and the hydraulic design conditions. In other words, the question needs to be answered is: 'What is the accepted downtime of the harbour resulting from overtopping of waves for the lifetime of the caisson' . This design condition sets the minimum crest elevation of the breakwater.

The strength against extreme loading results from the ultimate failure mechanisms with including safety measures against failure. The judging of the accepted chance of ultimate failure of the caisson during its lifetime is also an economic decision problem, because the probability of exceedance of the design parameters sets the probability of ultimate failure of the caisson.

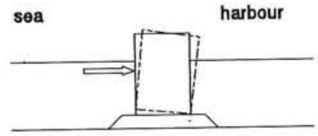

Figure 1.4 *Overturning*

The most important ultimate failure mechanisms for a caisson breakwater are:

- Sliding (see figure 1.3)
- Overturning (see figure 1.4)
- Failure of the foundation (figure 1.5 gives two failure possibilities)

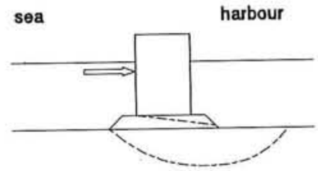

Figure 1.5 *Failure of the foundation*

Design parameters
Once the amount of allowed overtopping is determined, the crest elevation of the caisson is established with taking into account the requirements from mariners. Accordingly the design water depth and the design wave with an accepted probability should be chosen.

Wave loading
The wave load on the structure can be calculated with the wave pressure formulae if the following parameters are known:

- crest height
- characteristics of the rubble mound foundation
- water depth
- wave height and wave period

Dimensions caisson
The probabilistic loading on the caisson determines the probability of ultimate failure through the failure mechanisms. Sliding and overturning are caused by a horizontal wave force acting on the exposed front and by a vertical uplift force acting on the base of the caisson. Both forces are resulting from the dynamic wave pressure. Immediate total failure of a caisson breakwater occurs by definition when the design conditions are exceeded. The width of the caisson sets the total weight of the structure which provides the designed stability for a constant height of the caisson.

1.3 Aims of this study

In this study the design process of a caisson breakwater will be analysed. Goda's design method will therefore be compared with a design method that makes use of the linear wave theory for the conditions of a breakwater at Europoort Rotterdam.

An important aspect of the evaluation of the design process is the comparison of Goda's wave pressure formulae with the linear wave theory and with the results of a hydraulic model study.

The linear wave theory is based upon the concept that waves can be characterised as linear, sinusoidal waves [ref 1]. The resulting simple mathematical representation is easy to apply and gives a good approximation of wave behaviour.

Restrictions of this study
The following limiting conditions are applied:

- A quasi-static approach is used to analyse the wave forces on the monolithic breakwater.
- The waves are considered not to break as breaking is not taken into account in the calculation of the wave pressures with the linear wave theory.
- The very complex problems of the foundation fall outside the scope of this study.

Figure 1.6 *The Netherlands*

- The hydraulic design data of a breakwater at Europoort Rotterdam will be used for the calculations, see figure 1.6 and figure 1.7.
- The direction of the wave crests is assumed to be constant and normal to the breakwater axis.
- The breakwater is considered to have a certain length, see figure 1.8. The interaction with the sides (other caissons) is neglected.

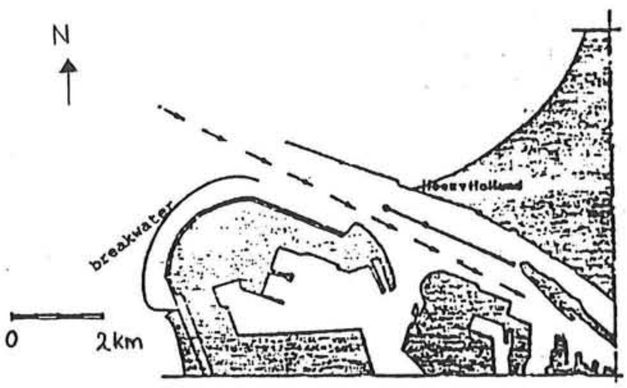

Figure 1.7 *Situation approach channel Europoort Rotterdam*

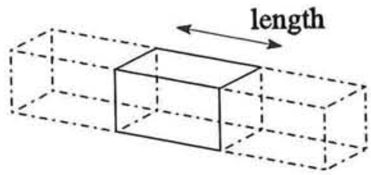

Figure 1.8 *Length of caisson*

1.4 Outline of contents

In order to analyse the design process of a caisson breakwater the design philosophy is first discussed in chapter 2. This includes the failure mechanisms, the determination of the design parameters by means of an economic decision problem and Goda's design principles.

Prior to the actual description of the design wave pressure formulae in chapter 4 (linear wave theory) and 5 (Goda), chapter 3 summarises the hydraulic design conditions for Europoort Rotterdam. The hydraulic conditions at deep water are transformed during the propagation into shallower water which influences the probability density function of the wave height.

In chapter 6 the experimental study is described. Hydraulic model tests were carried out to compare the theoretical results with experimental data. A model caisson was placed in a wave channel and attacked with regular waves. The horizontal dynamic wave force has been measured and the ultimate failure mechanism have been considered.

The results of the probabilistic design method with the linear wave theory, the formula of Goda and the experimental data are discussed in chapter 7. Recommendations for further research are given also.

The final conclusions are given in chapter 8.

It is noted that detailed background information about the experiments are given in the appendices.

2 DESIGN PRINCIPLES

Goda developed an easy to apply practical design method [ref 4]. In order to be able to analyse his design philosophy, this chapter deals with the question: When is a breakwater design at an optimum for a particular site ? The answer is:

> *The best design is defined as the structure that fulfils the requirements at minimum total costs.*

An investment in a breakwater structure is an economic decision problem and depends on all harbour related activities. For a breakwater protects the harbour against waves in such a way that the harbour basin is sufficient tranquil for the ships to navigate and moor. Without the breakwater the ships would only be able to use the harbour with reasonable good weather conditions. Whether the breakwater can improve the earning capacity of the harbour depends for instance on the type and number of ships using the harbour, the needed quay facilities, the meteorological data, the hydrographical data, the harbour related economic systems, the future development of the harbour, etc. This implies that the functional requirements of a breakwater are related to the economy of the harbour.

The total costs of the design depend on the investment and maintenance of the structure. The investment will be high for a structure with a high strength. The strength of the structure will be designed so as to resist the extreme design conditions. These extreme design conditions result from the accepted probability of ultimate failure for the lifetime of the structure, while the probability of failure due to the amount of overtopping is dependent on the crest elevation of the structure.

In order to determine the probability of failure, it is first necessary to define when failure of a caisson breakwater occurs. This is described in section 1. The second section presents subsequently a theory of how to find the optimum design load in relation to the costs. Goda's design principles concerning the design parameters and accordingly failure of the structure are given in the third section.

2.1 Failure mechanisms

A breakwater fails when it does not fulfil its main function: protect the harbour against waves. For example, when a critical value of wave disturbance in the harbour basin is exceeded, the ship handling has to stop, which reduces the earning capacity of the harbour. The design of a breakwater depends therefore on the required degree of protection of the harbour against the waves. This degree of protection is defined by the layout of the structure, the permeability, the crest level (amount of overtopping) and the energy absorption (percentage of reflection of the incoming waves). The definition of failure of a breakwater is:

<u>The breakwater fails when the waves in the harbour are higher than allowed according to the design criteria.</u>

Although failure can occur during both construction and operation, in this study only failure during operation of the breakwater has been considered because the construction can be carried out during good weather conditions. The probability of failure represents the probabilities of exceeding a given limit state. The two different states are the serviceability limit state and the ultimate limit state

The Serviceability Limit State (SLS)
The serviceability limit state is the state of the breakwater during normal loading conditions. For this state the performance of the breakwater is evaluated under the 'normal' or daily conditions to which the structure will be exposed during most of its lifetime.

Failure is defined in this state as: the breakwater does not fulfil its function because the amount of overtopping is too high, which disturbs the harbour activities. The harbour has to be closed down. This can happen regularly and therefore the costs, whereas the losses due to the closing of the harbour for a certain period can be substantial, should be taken into account. The higher the crest height of the breakwater the less overtopping will occur.

Another state of failure is, that the breakwater does not fulfil its requirements any more after a few years, which is deterioration of structural resistance over time. This means for instance that the structure has moved through the years or that the scour protection is dismantled. This type of failure can be prevented by:

- Increasing the design resistance in order to guarantee sufficient strength during the service life.
- Controlling the deterioration through inspection and maintenance procedures.

Both methods of improvement should be taken into account at the design stage and will affect the costs of the design.

The Ultimate Limit State (ULS)
The ultimate limit state occurs during extreme conditions and has a very small probability of occurrence. The breakwater fails when the extreme hydraulic loading is higher than the resistance of the structure. By evaluating all the failure mechanisms that are likely to occur under specified extreme conditions, the ability of the structure to survive extreme conditions is checked.

The three most important failure mechanisms of the ultimate limit state are sliding, overturning and failure of the foundation, see figure 2.1, 2.2 and 2.3. Ultimate failure will be considered to have occurred when:

- A displacement is caused by the horizontal wave force exceeding the horizontal friction force, see section 2.1.1.
- An overturning is caused by the horizontal and uplift wave forces, see section 2.1.2.

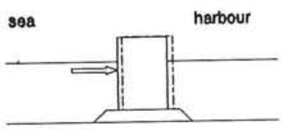

Figure 2.1 *Sliding*

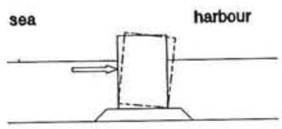

Figure 2.2 *Overturning*

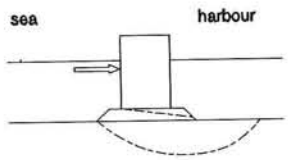

Figure 2.3 *Failure of the foundation*

Failure of the foundation can be caused by several phenomena. Wave impact forces for instance are relatively high because they result from wave breaking. These forces can cause the formation of quicksand due to rocking motions of the caisson. These problems fall outside the scope of this study but in order to avoid that problems with the foundation will occur, a reasonably thick porous filter layer has to be placed on the sand bottom to prevent high pore pressures.

2.1.1 Breakwater sliding

Breakwater sliding is the horizontal translation of the caisson, which occurs when the horizontal wave load is higher than the horizontal friction force.

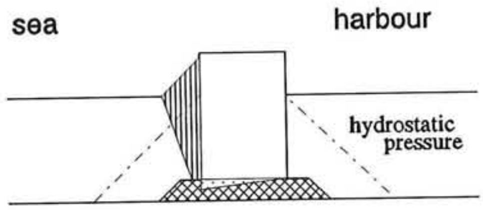

Figure 2.5 *Wave pressure on caisson for a wave crest*

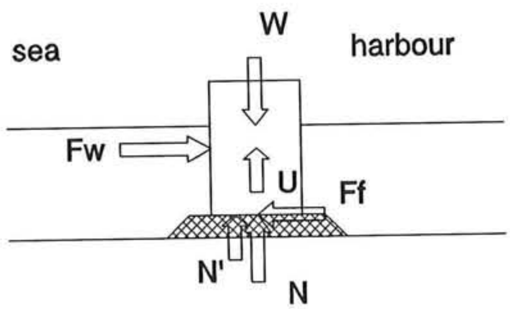

Figure 2.4 *Schematization of forces under a wave crest*

The waterlevel at the harbour side is assumed to be the same as the waterlevel at the seaside. So the same hydrostatic pressure acts on both sides of the caisson, see figure 2.5.
The resulting force is consequently the horizontal dynamic wave force F_w. Displacement will occur when this force F_w exceeds the horizontal foundation

friction force F_f, see figure 2.4. As an approximation it is assumed that the caisson fails when the friction force is exceeded and any displacement occurs.

The horizontal dynamic wave force F_w is:

$$F_w = \hat{F}_w \sin \omega t \qquad [2.1]$$

in which
- ω is the angular frequency $= 2\pi/T$
- T is the wave period
- t is the time

The load frequency ω is far less than the natural frequency of the structure therefore the forces can be considered as static.

When there is no vertical motion, there is vertical equilibrium:

$$N = W - U - N' \qquad [2.2]$$

in which
- N is the resulting upward normal force
- W is the weight of the caisson
- U is the buoyant force of the caisson
- N' is the instantaneous resultant vertical dynamic force caused by propagation of wave pressures under the structure

The instantaneous resultant vertical dynamic force N' can be expressed in terms of the horizontal wave force F_w:

$$N' = \epsilon F_w = \epsilon \hat{F}_w \sin \omega t \qquad [2.3]$$

in which
- ϵ is a coefficient, which can be found from a foundation model

The horizontal friction force F_f is depending on the normal force N and on the friction between concrete and rubble mound. The formula is:

$$F_f \leq \mu N \qquad [2.4]$$

in which
- μ is the friction coefficient, which can be found empirically

The friction coefficient is related to the underlying soil properties according to Coulomb [ref 18]:

$$\mu = \tan \delta = \tan(\frac{2}{3}\phi) \qquad [2.5]$$

in which
- δ is the angle of friction between soil and concrete
- ϕ is the angle of internal friction of the soil

For $\phi = 45°$: μ = tan (2/3·45°) = tan 30° = 0.58
This is actually an internal failure mechanism and is considered as 'failure of the foundation'.

The actual friction between the top layer of the foundation and the base of the caisson has to be empirically derived. For a ribbed caisson base the design value for this friction factor is approximately 0.5. This decreases to μ = 0.4 for a flat base [ref 11].

If there is horizontal motion, it follows that:

$$\hat{F}_w - \mu N = m_b \frac{dv}{dt} \tag{2.6}$$

in which m_b is the virtual mass of the caisson
dv/dt is the acceleration of the caisson

The water and soil mass surrounding the caisson will influence the inertia characteristics of the caisson by taking part in the movement as well. Therefore the virtual mass is defined as an equivalent mass which would begin to move when a displacement of the caisson occurs. Motion starts when the static friction force is first exceeded. The extra virtual mass which has to start accelerating is considered to contribute extra resistance against any movement of the structure.

2.1.2 Breakwater overturning

The horizontal dynamic wave force F_w and the vertical dynamic wave force N' tend to rotate the caisson to the harbour side, see figure 2.6. The counter moment is provided by the turning moment originating from the weight of the structure.

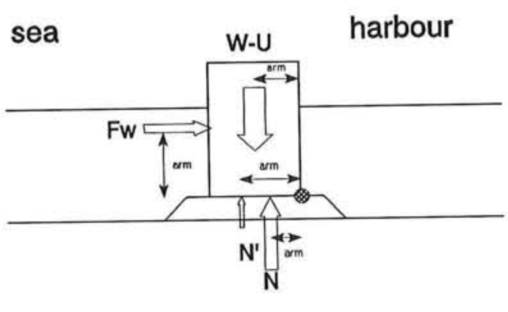

Figure 2.6 *Turning moments*

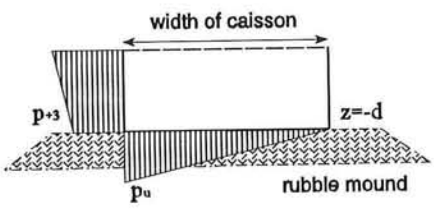

Figure 2.7 *Dynamic wave pressure p_u*

The vertical dynamic wave force N' is assumed to have a triangular distribution over the base, see figure 2.7. However, the pressure at the heel of the caisson does not have to be zero. It depends on the characteristics of the rubble mound foundation because the dynamic uplift pressure depends on the velocity distribution of the water particles underneath the caisson. The latter is in its turn dependent on the permeability of the rubble mound foundation. The velocity will decrease due to friction and turbulence. The velocity distribution is assumed to be linear but the curve in the pressure distribution will probably be much more gentle. So a triangular pressure distribution for the vertical dynamic force N' seems a conservative assumption.

Equilibrium of moments around the heel, see figure 2.6, yields:

$$(\hat{F}_w \cdot arm_{\hat{F}_w}) + (N' \cdot \frac{2b}{3}) = (W - U) \cdot \frac{b}{2} \qquad [2.7]$$

in which b is the width of the caisson

The moment arm of the wave force F_w can be derived, see chapter 4, for a known wave pressure distribution along the front. This pressure distribution depends on the wave height. This results in a different moment arm for every different wave height.

In case of a wave trough the wave forces act in the opposite direction that is F_w acts seaward. The centre of rotation shifts to the lower left corner, which reduces the moment arm of N'.

2.2 Probabilistic design process

The design of a prismatic caisson is the determination of the required width and crest height of the caisson. These dimensions are depending on stability requirements and on the functional requirements of the harbour. An economic decision problem is the result.

2.2.1 The design parameters result from an economic decision problem

The total costs of the design depend on the probability of failure of the caisson. It is therefore necessary to determine the relation between the probability of failure and the stability (expressed in the dimensions) of the caisson and the relation between the probability of failure and the economics of the harbour.

Risk is the product of failure probability and the consequences of failure. The consequences of failure are often expressed in terms of capital cost. In this case the consequences of failure are in terms of:

- loss of investments
- loss of expected future income of the harbour

It follows that the total costs consist of the costs of construction and maintenance, and the costs of risk, which include the economic loss due to failure of the structure times the probability of failure. The income from the harbour activities and the to the harbour related economic systems on account of the breakwater should compensate the total costs.

Every design wave or design load has a probability of exceedance. If the design wave is small, the costs of construction will be relatively low but the risk will be relatively great. As the magnitude of the design load increases, the risk will decrease, due to the decreasing probability that the design conditions will be exceeded. This implies that the design load must be such that the total costs are minimized, see figure 2.8.

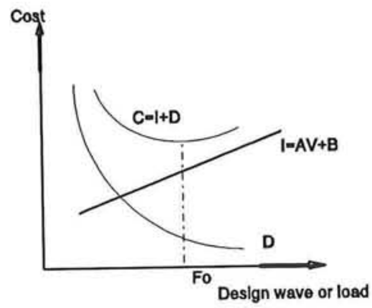

Figure 2.8 *Determine optimum design wave*

If design load F_0 is exceeded then displacement x will occur (sliding is considered as the first occurring failure mechanism). Failure will be defined as displacement $x=x_0$, the load is then F_1. Thus the probability of collapse is the probability of force F_1 being exceeded ($P(F_1)$). The dimensions of the caisson are known if the design load F_0 is chosen. Hence the cost of construction, investment I, is a function of F_0:

$$I = f(F_0) \qquad [2.8]$$

Damage is defined as a certain change in the state of the structure, which does not influence the functioning of the breakwater. Damage to a monolithic breakwater is often progressive. However, it is assumed that a second storm of a given intensity causes just as much displacement as the first one. Repair work will only be carried out in the calm season once per year. The annual chance of damage repair costs is then independent of the number of damage occurrences in that year. Because if a breakwater moves twice as much as a result of a second storm, it will cost as much to jack it into place again.

To determine the amount of risk, or the so called anticipated damage, it is assumed that an insurance company is willing to insure a caisson against damage. If the theoretical annual premium is s:

$$s = (\text{probability of damage}) \cdot (\text{the cost of repairing damage})$$

The anticipated damage per year is:

$$s = P(F_1)\ W \qquad [2.9]$$

in which

	$P(F_1)$	is the probability that force F_1 is exceeded, which is the probability of ultimate failure
	W	is the cost of repairing when a failure of the structure occurs

The capitalized value of the sum of the 'premiums' s depends on the life of the structure. If its life is 100 years, the capitalized anticipated damage D is [ref 16]:

$$D = \frac{100}{\delta} \left(1 - \frac{1}{(1+\delta)^{100}}\right) \cdot s \qquad [2.10]$$

in which δ is the rate of interest in % per year

The total costs C are defined as the costs of construction I and the capitalized anticipated damage D. Hence $C = I + D$. It is assumed that the cost of construction I is a linear function of the required volume of the caisson per metre of exposed front V, so

$$I = AV + B \qquad [2.11]$$

in which
- A is the price per cubic metre volume of the caisson
- B is the additional price per cubic metre length of the caisson (cost of toe protection etc.)

The relation between the required volume of the caisson per metre of exposed front V and the design load F_0 results from the failure mechanisms.

2.2.2 Dimensions of caisson

Failure will be considered to have occurred when the caisson is translated (sliding) or rotated (overturning). Both failure mechanism are related to the weight and the geometry of the structure. For a prismatic caisson the height and the width have to be optimized.

The minimum required width b is related to the sliding mechanism because for a certain crest height (resulting from the overtopping criterion) the width determines the weight of the caisson which provides the stability. A Safety Factor illustrates the stability through a ratio of the force of resistance and the driving force. The Safety Factor of sliding is expressed as:

$$S.F._{sliding} = \frac{F_f}{F_w} \geq constant_1 > 1 \qquad [2.12]$$

The value of $constant_1$ depends on the uncertainties in the assumptions and formulae but should be at least more than 1 to assure stability. When the input data are not very reliable, the value of the safety factor should be made higher than 1.

Another important safety requirement for the stability is that the entire base should contribute to the upward normal pressure. The moment arm of N is in that case equal to 1/3 of the width. A triangular pressure distribution for N is assumed, see figure 2.9. The maximum bearing pressure p_{max} acts at the heel of the structure for a wave crest. This maximum bearing pressure depends on the soil properties. See figure 2.10 for the possible pressure distribution with the resulting lever arm.

In case of a wave trough the pressure distribution for N is opposite. The maximum bearing pressure acts at the toe of the structure in this situation.

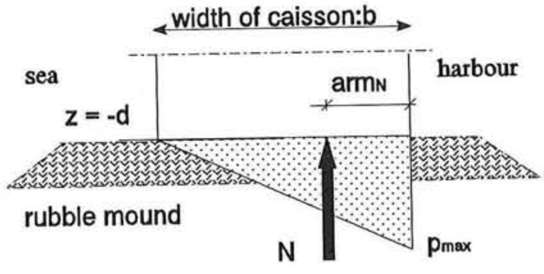

Figure 2.9 *Resulting upward normal force N*

The Safety Factor of overturning illustrates once more the resistance against failure. The design value *constant$_2$* is expressed as:

$$S.F._{overturning} = \frac{M_{W-U}}{M_{F_w} + M_{N'}} \geq constant_2 > 1 \qquad [2.13]$$

Crest elevation
The minimum height of a breakwater is determined by considerations as overtopping and visibility for mariners. Since overtopping does not necessarily cause ultimate failure some overtopping is accepted. A cost-benefit analysis should give the optimum allowed amount of overtopping, see section 2.2.1. Assume overtopping is allowed x times per year. The breakwater should be at least high enough to reflect the highest wave expected with that frequency, see figure 2.9

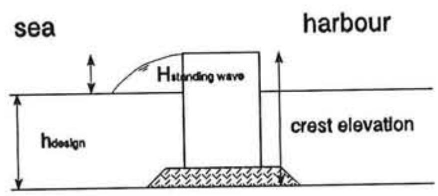

Figure 2.11 *Minimum crest elevation*

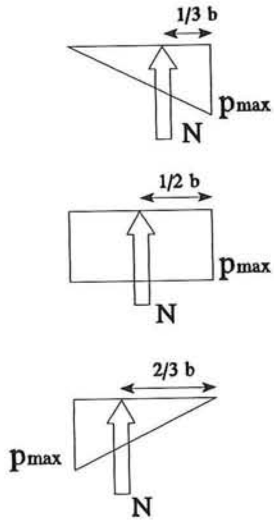

Figure 2.10 *Normal force*

Width of caisson
The determination of the width is dependent on the failure mechanisms. Assume that sliding will first occur before overturning. The crest elevation is held constant so the minimum width can be calculated. This width has to be sufficient to withstand overturning as well. Finally the maximum bearing pressure on the foundation has to be below the defined limit.

This procedure has to be executed for several heights if the minimum crest height can be taken higher as the optimum height. According to the theory the optimum design follows from an economic analysis.

2.3 Design according to Goda

The formula of Goda [ref 4] is a worldwide used design method for vertical breakwaters based on the quasi-static approach. See chapter 5 for the wave pressure formulae. Goda made his formula after a lot of hydraulic scale model studies. He judged the reliability of his formula by predicting the accuracy of breakwater stability with the aid of the performance of prototype breakwaters. His formula is valid for breaking and nonbreaking waves. The basic source of this section is Goda's 'Random seas and design of maritime structures' (1985).

2.3.1 Design parameters

The design parameters are the design wave, characterized by its wave height and wave period and the design water depth.

Design wave height
Goda states that the highest wave in the design sea state must be employed. This is based on the principle that a breakwater should be designed in order to be safe against the single wave that has the largest pressure among storm waves. According to Goda the design wave H_d is the highest wave out of 250 waves. This wave has a probability of exceedance of 0.4% seaward of the surfzone, whereas within the surfzone the height is taken as the highest of random breaking waves at a distance $5 \cdot H_s$ (H_s is the mean of one-third of the highest waves, see chapter 3) seaward of the breakwater. Goda defines the surfzone or breaking zone as: 'A relatively wide zone of variable water depth in which wave breaking takes place. Concerning the breaking of random sea waves, the breaking point as well as the breaking wave height cannot be defined clearly, in contrast to the case of regular waves'. So $H_d = H_{max} = H_{0.4\%}$. Goda states that the ratio H_{max}/H_s is affected by the number of waves in a record. The value of H_{max} should therefore be estimated, based upon the duration of the storm and the number of waves. He writes that the prediction generally falls in the range:

$$H_d = (1.6 \; ... \; 2.0) \; H_s \qquad [2.14]$$

To avoid possible confusion in the design, a definite value of $H_d = 1.8 \; H_s$ is recommended in consideration of the performance of many prototype breakwaters as well as with regard to the accuracy of the wave pressure estimation. Certainly there remains the possibility that some waves exceeding $1.8 \cdot H_s$ will hit the site of the breakwater when storm waves equivalent to the design condition attack. But the distance of sliding of an upright section, if it were to slide, would be very small. It should be remarked, however, that the prescription $H_d = 1.8 \cdot H_s$ is a recommendation and not a rule.

Design wave height H_d is the smaller one of $1.8 \cdot H_s$ or H_b. H_b is the limiting wave height of a broken wave at $5 \cdot H_s$ distance offshore.

Design wave period
The period of the highest wave is taken as that of the significant wave, $T_d = T_s$. The wave period does not exhibit a universal distribution law such as the Rayleigh distribution for wave heights according to Goda. Nevertheless found empirically that the representative period parameters are interrelated. Goda found that T_d lies in the range $(0.6...1.3)T_s$ and takes T_d in the middle of that range.

Design water depth
The recommended design water depth is based on the fact that the greatest wave pressure is exerted not by waves just breaking at the site, but by waves which have already begun to break at a distance. For the sake of convenience, the distance $5 \cdot H_s$ from the breakwater will be used for the design water depth. Goda derived this from laboratory data on breaking wave pressures.

2.3.2 Resistance against failure

The caisson must be safe against sliding and overturning. The safety factor against sliding of Goda is defined as:

$$S.F._{sliding} = \frac{\mu\ (W - U - N'_g)}{F_{w_{goda}}} = \frac{F_f}{F_{w_{goda}}} \qquad [2.15]$$

in which	W	is the weight of the caisson
	U	is the buoyant force
	N'_g	is the instantaneous resultant vertical dynamic force caused by propagation of the waves in the rubble mound foundation according to Goda
	F_f	is the horizontal friction force
	F_{w_goda}	is the wave force according to Goda
	μ	is the friction coefficient

The safety factor against overturning is defined as:

$$S.F._{overturning} = \frac{(M_W - M_U) - M_{N'_{goda}}}{M_{F_{w_{goda}}}} \qquad [2.16]$$

in which	M_W	is the turning moment due to the weight of the caisson
	M_U	is the turning moment due to the buoyant force
	$M_{N'goda}$	is the turning moment due to the vertical dynamical uplift force according to Goda

M_{Fw_goda} is the turning moment due to the dynamical wave force according to Goda

The safety factors should not be less than 1.2 according to Goda. He takes the coefficient of friction μ as 0.6 (friction coefficient between concrete and rubble stones).

The bearing capacity of the foundation should be analysed. Goda assumes that a trapezoidal distribution of bearing pressure exists beneath the base. The largest bearing pressure at the heel p_{max_goda} is calculated as:

$$p_{\max\text{-}goda} = \frac{2\,W}{3\,a_{goda}} \quad : a_{goda} \leq \frac{1}{3}\,b,$$
$$p_{\max\text{-}goda} = \frac{2\,N_{goda}}{b}\left(2 - 3\,\frac{a_{goda}}{b}\right) \quad : a_{goda} > \frac{1}{3}\,b, \qquad [2.17]$$

in which N_{goda} is the upward normal force according to Goda
a_{goda} is the lever arm of the upward normal force according to Goda:

$$a_{goda} = \frac{M_{N_{goda}}}{N_{goda}} \qquad [2.18]$$

in which M_{N_goda} is the turning moment of the upward normal force according to Goda around the heel of the structure

Precautions against Impulsive Breaking Wave pressure

The pressure due to breaking waves may rise to more than ten times the hydrostatic pressure corresponding to the wave height, though its duration will be very short. Goda explains that it would be rather foolish to design a vertical breakwater that is directly exposed to impulsive breaking wave pressures. A rubble mound breakwater would be the natural choice in such a situation. It is not the magnitude of the greatest pressure but, rather, the occurrence of the impulsive breaking wave pressure that is most important. Table 2.1 is a guide for judging the possible danger of impulsive breaking wave pressure.

2.3.3 Dimensions of caisson

The width satisfying the conditions of the safety factors and the maximum bearing pressure is the minimum required width in relation to a certain crest elevation. The criterion of the crest elevation in Japan is at a height of 0.6 times the significant wave height above design water level. This criterion is used in situations where a small amount of wave overtopping and resultant wave transmission is tolerated.

Goda's experiments showed that the required caisson width depends on the wave period. The width has to increase with an increasing wave period (see

Table 2.1 *Questionnaire for judging the danger of impulsive breaking wave pressure*

A-1 Is the angle between the wave direction and the line normal to the breakwater less than 20°? — No → Little Danger

↓ Yes

A-2 Is the rubble mound sufficiently small to be considered negligible? — No → Go to B-1

↓ Yes

A-3 Is the sea bottom slope steeper than 1/50? — No → Little Danger

↓ Yes

A-4 Is the steepness of the equivalent deepwater wave less than about 0.03? — No → Little Danger

↓ Yes

A-5 Is the breaking point of a progressive wave (in the absence of a structure) located only slightly in front of the breakwater? — No → Little Danger

↓ Yes

A-6 Is the crest elevation so high as not to allow much overtopping? — No → Little Danger

↓ Yes

Danger of Impulsive Pressure Exists

B-1 Is the combined sloping section and top berm of the rubble mound broad enough (refer to Fig. 4.20)? — No → Little Danger

↓ Yes

B-2 Is the mound so high that the wave height becomes nearly equal to or greater than the water depth above the mound (refer to Fig. 4.21)? — No → Little Danger

↓ Yes

B-3 Is the crest elevation so high as not to cause much overtopping? — No → Little Danger

↓ Yes

Danger of Impulsive Pressure Exists

chapter 5 for explanation and appendix F for the calculations).

2.3.4 Rubble mound foundation

Berm height
"It is best to set the height of the rubble mound foundation as low as possible to prevent the generation of large wave pressure. But the function of a rubble mound - to spread the vertical load due to the weight of the upright section and the wave force over a wide area of the seabed- necessitates a minimum height, which is required not to be less than 1.5 m in Japan. Further more the top should not be too deep, in order to facilitate underwater operations of divers in levelling the surface of the rubble mound for even setting of the upright section. A cost analysis will yield the optimum height."[1]

Berm width
"If the seabed is soft, the dimensions of the rubble mound should be determined by safety considerations against circular slip of the ground. The berm in front of an upright section functions to provide protection against possible scouring of the seabed. A wide berm is desirable in this respect, but the cost and the danger of inducing impulsive breaking wave pressure precludes the design of too great a berm width. The practice in Japan is for a minimum of 5 m under normal conditions and about 10 m in areas attacked by large storm waves. The berm to the rear of an upright section has the function of safely transmitting the vertical load to the seabed. It also provides an allowance of some distance if sliding should occur.The gradient of the slope of the ruble mound is usually set at 1:2 or 1:3 for the seaward side and 1:1.5 to 1:2 for the harbour"[2]

Foot-protection blocks
"In breakwater construction in Japan, it is customary to provide a few rows of foot-protection concrete blocks at the front and rear of the upright section, see figure 2.12.

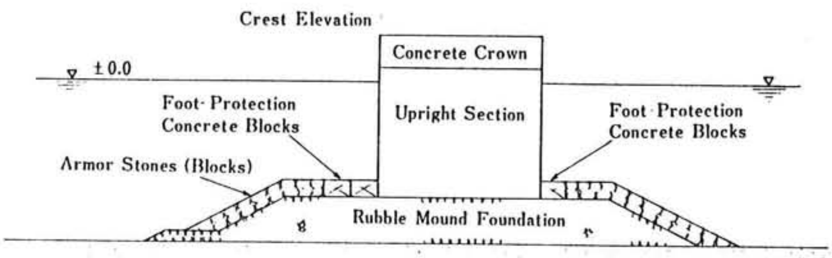

Figure 2.12 *Idealized typical section [ref 4]*

The foot protection usually consists of rectangular blocks weighing from 10 to 40 tons, depending on the design wave height. Foot-protection blocks are

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1 *Goda, Y., Random seas and design of maritime structures. University of Tokyo Press, 1985. page 139*

2 *Goda, Y., Random seas and design of maritime structures. University of Tokyo Press, 1985. page 139*

indispensable, especially when storm waves attack a vertical breakwater at an oblique angle."

"The remainder of the berm and slope of the rubble mound foundation must be protected with armour units of sufficient weight to withstand wave action."[3]

Protection against scouring of the seabed in front of a breakwater
"A vertical breakwater reflects most of the wave energy incident on it, thus creating great agitation at its front. Various materials such as plastic filters and asphalt mats are spread beneath the area of the tip of the rubble mound and extended beyond it."[4]

3 *Goda, Y., Random seas and design of maritime structures. University of Tokyo Press, 1985. page 140*

4 *Goda, Y., Random seas and design of maritime structures. University of Tokyo Press, 1985. page 142*

3 HYDRAULIC DESIGN CONDITIONS

To be able to say something about the probability of failure of the breakwater, the probability of the wave load should be determined while the strength of the structure is considered to be constant. A breakwater fails in the ultimate limit state (ULS) when the extreme wave load is higher than the resistance of the structure. The probability of exceedance of this extreme wave load determines therefore the resistance and the dimensions of the structure (chapter 2).

The wave load is a function of the water depth h, the wave height H and the wave period T. Therefore the joint probability density function of the high water level (including tides and meteorologic effects), the wave height and the wave period is needed.

The extreme wave load results from a single wave in a storm. The probability of exceedance of this single wave cannot be related to the probability of exceedance of a characteristic wave height. Therefore the frequency of exceedance of individual design wave heights is needed. The chance that a certain design wave height H_d is exceeded during the lifetime l of the structure needs to be found. When the joint probability density function of H and T is given for a constant water depth, the probability of exceedance of H and T can be determined.

The variation in the seabed level has a significant influence on the hydraulic loadings because a change in the water depth will affect the characteristics of the waves. This implies that for a constant design water depth, shoaling and breaking of waves influence the joint probability density function of the wave height and the wave period. The probability of the wave loads changes accordingly.

In the first section the probability density functions of the water depth, the wave height and the wave period are given for the North Sea (deep water). In the second section the transformation of waves entering from deep water into shallower water is described. The chance that a certain design wave height is exceeded is determined in the third section.

3.1 Wave statistics in open sea

A wave can be characterized by its wave height and wave period. Therefore the distribution of wave heights and wave periods give the probability of occurrence of a single wave for a constant water depth.

In deep water a storm can be characterized by the significant wave height H_s and the peak period T_p, assuming a statistically stationary sea state during the storm. For shallow water conditions this assumption can be unrealistic due to variations in water level caused by tidal and/or set up effects. See figure 3.1 for the origin of the probability density functions (p.d.f.).

In figure 3.1 the following expressions are used:

- mean sea level (MSL), which is the reference water level. A rise of the MSL due to long term climatic variations (usually taken as 0.1 ~ 0.15 m) is not taken into account;
- vertical tide, which is because of the astronomical driven force entirely deterministic;

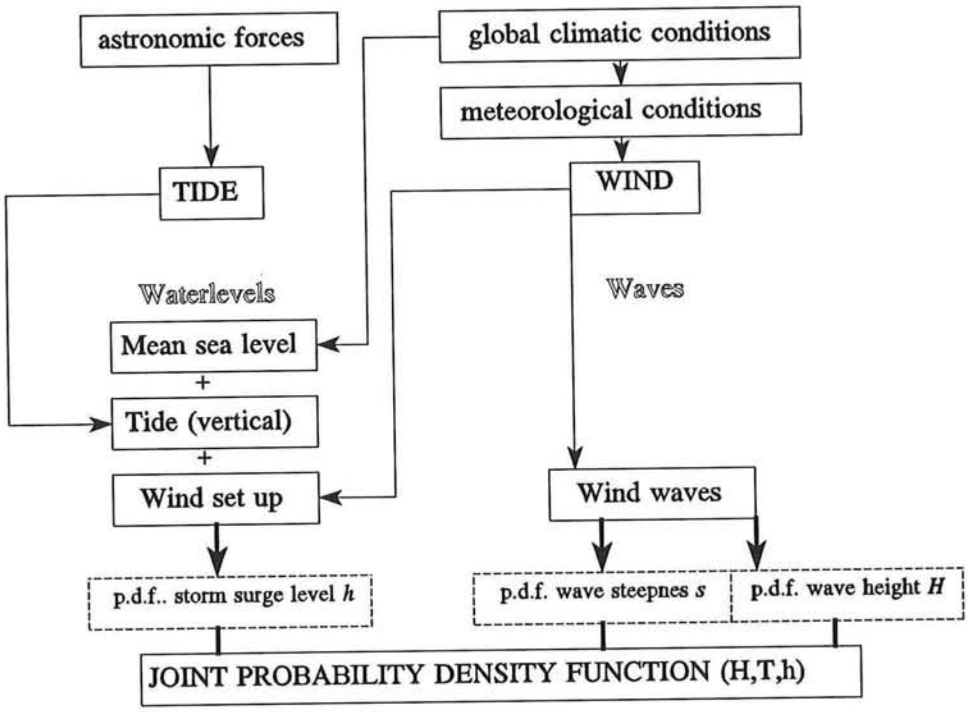

Figure 3.1 *Hydraulic design conditions for deep water*

- wind set up, which is caused by shear stress, exerted by wind, on the water surface causes a slope in the water surface as a result of which wind set up and set down occur at down and up wind shorelines;
- storm surge level, which is the highest still water level during a storm;

Individual sea states

An actual wave record from a wave gauge in the sea gives an irregular wave profile. For an example see figure 3.2. On the horizontal axis the time is given

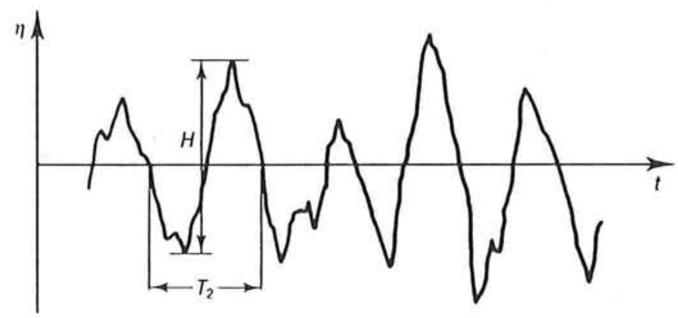

Figure 3.2 *Typical wave record [ref 5]*

and the water surface elevation η is given on the vertical axis. To be able to analyse the waves, the mean water surface level is defined as the zero line.

A wave is defined as a water movement between a point where the surface profile crosses the zero line upward and the next zero-up-crossing point. So the horizontal distance between two adjacent zero-up-crossing points defines the wave period T. The vertical distance between the highest and lowest points in a wave is defined as the wave height H. When the waves are listed in increasing order of the wave height, a representative wave height can be defined. Often the significant wave height H_s is used, which is the mean of one-third of the highest waves.

The standard recording period of a wave record is 20 minutes and represents wave conditions over a 3 hour period, during which the conditions are assumed to be 'stationary'. During each stationary sea state a short-term wave height distribution applies.

3.1.1 Distribution of wave heights

When the characteristic values, the significant wave heights H_s of each storm, are plotted, a significant relation is found: the long term distribution.

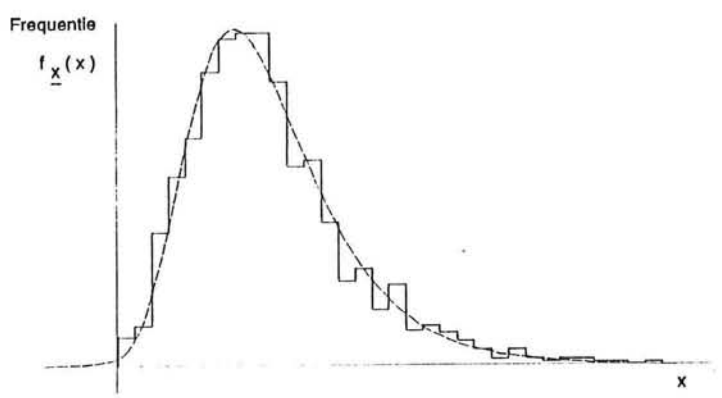

Figure 3.3 *Histogram of wave heights [ref 15]*

A smooth distribution of wave heights is obtained by using many wave records, in which the ordinate is then the relative frequency so that the area under the histogram is equal to 1, see figure 3.3. Normally the wave heights are normalised by the significant wave height which can be the Rayleigh distribution for the distribution of individual wave heights (see figure 3.4):

$$P(\underline{H}<H) = \exp\left[-2\left(\frac{H}{H_s}\right)^2\right] \quad [3.1]$$

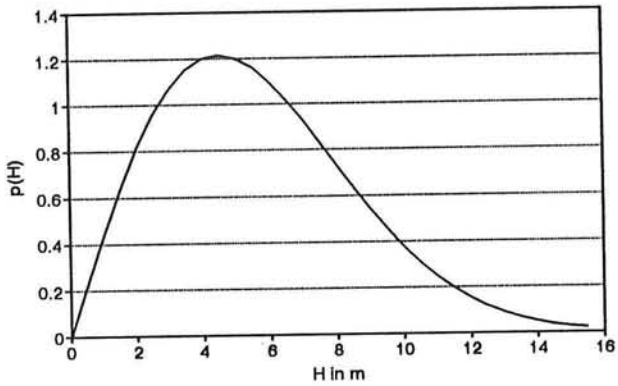

Figure 3.4 *Rayleigh distribution for H_{so} = 9 m (R = 100 years)*

Table 3.1 gives the long term distribution of significant wave heights for deep water (North Sea).

3.1.2 Distribution of wave periods

The wave period does not exhibit an universal distribution law. The range of the periods depends on the origin of the waves. In some cases, the period distribution is even bi-modal, with 2 peaks corresponding to the mean periods of the wind waves and swell (waves generated in another wind field area). The wave periods can be analysed by assuming that sea waves consist of an infinite number of waves with different frequencies, see chapter 4.

To determine the probability density function of the wave period, the probability density function of the wave steepness s is used. The relation between the wave period and the wave steepness is:

$$s_p = \frac{H_s}{L_p} = \frac{H_s}{\dfrac{g T_p^2}{2\pi}} \quad [3.2]$$

in which
- s_p is the wave steepness with period T_p
- H_s is the significant wave height
- L_p is the wave length of the wave with period T_p
- T_p is the peak period (around which the wave energy is concentrated)

H_s and s_p are assumed to be independent stochasts. This assumption is fairly

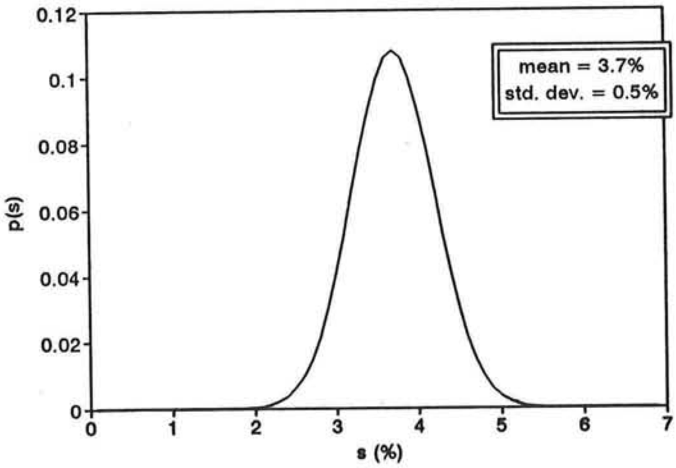

Figure 3.5 *Probability density function of the wave steepness in the North Sea [ref 15]*

conservative because there <u>is</u> a relation between H_s and s_p: high steep waves are more likely to occur than small steep waves. Figure 3.5 gives the probability density function of the wave steepness of the North Sea.

Table 3.1 *Hydraulic design conditions [ref 13]*

Hydraulic design conditions			
At deep water			*At the site*
R (years)	Hso (m)	T (s)	h (m)
0.1	4.5	7.4	12.8
0.5	5.5	9.0	13.0
1	6.0	10.0	13.2
5	7.0	11.0	13.7
10	7.5	11.5	13.9
20	8.0	12.0	14.2
50	8.5	12.5	14.4
100	9.0	13.0	14.6
500	10.0	14.0	15.1
1000	10.5	15.0	15.3
5000	11.5	16.0	15.8

It is a normal distribution given by:

$$f_{s_p}(s) = \frac{1}{\sqrt{2\pi}}\frac{1}{\sigma}\exp[-\frac{(s-\xi)^2}{2\sigma^2}] \qquad [3.3]$$

in which s is the wave steepness
ξ is the mean = 3.7%
σ is the standard deviation = 0.5%

When the two probability density functions are combined the boundaries of the joint probability density function of the wave height and the wave period is

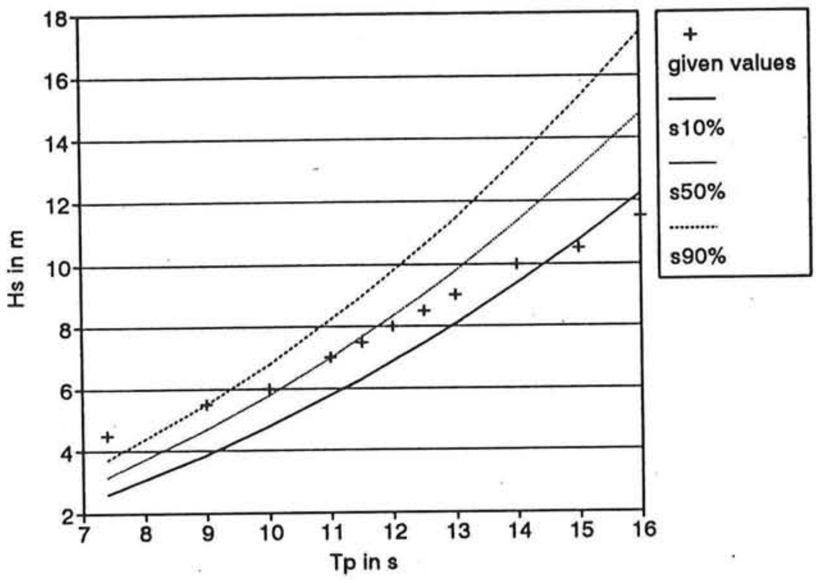

Figure 3.6 *Boundaries of the joint probability density function of H_s and T_p and the given values from Table 3.1 [ref 13]*

found, see figure 3.6 and appendix A for the derivation.

Astronomic tides and meteorologic effects give the statistics of high water levels.
It is assumed that both the water levels and the storm waves occur simultaneously and that one storm lasts 6 hours. Wave conditions measured and extrapolated at deep water near the design location are given in Table 3.1.

in which R is the return period
H_{so} is the significant wave height at deep water
T is the wave period
h is the water depth at the site

The chance of occurrence in terms of the return period can be transformed by assuming that a year can be divided in a number of storm intervals. This is a conservative assumption because a storm does not occur in every interval in reality. This transformation is only valid when the probability of exceedance is expressed in years, which is called the long term distribution. For such a distribution many wave records over a certain period of time are needed.

The frequency $f = 1/R$ is the number of storm intervals in a year multiplied by the chance that the wave height H is exceeded during a storm. A storm duration is taken as 6 hours. So

$$f = \frac{365\text{ days} * 24\text{ hours}}{\text{storm duration hours}} * P(H) = \frac{365 * 24}{6} P(H) = 1460\ P(H) \quad [3.4]$$

Which implies that 1460 storms per year occur. For example:

R = 1 year → $f=1$ → $P(H) = 1/1460 = 6.85*10^{-4}$
R = 10 years → $f=0.1$ → $P(H) = 0.1/1460 = 6.85*10^{-5}$

3.2 Transformation of deep water data to data at the site

The transformation of waves propagating from deep water into shallower water can be schematised as illustrated in figure 3.7. Waves can be transformed due to shoaling, breaking, diffraction and refraction.

- Shoaling is a change in wave height when waves propagate in varying water depths as a result of the change in the rate of energy flux.
- Wave breaking occurs because of the limitation of the wave height in relation to the water depth and the wave steepness.
- Diffraction is the transformation of the waves due to the interference of the waves with the structures they meet. The resulting wave field around a breakwater is different from the undisturbed wave field. The wave direction is neglected in this study therefore only the influence of waves reflected by the structure will be taken into account (see chapter 4 for the theory on standing waves).
- Refraction is the change in the wave propagation velocity and in the direction of wave propagation when waves propagate in varying water depth.

When waves approach shallower water with their crests at an angle to the depth contours, the wave crests appear to curve in a way that the angle with the depth contours decreases. The wave celerity decreases as the water depth decreases. For simplicity, refraction influences will be neglected.

Wave shoaling
The variation in wave height due to variation in the speed of energy propagation, i.e. the group velocity is given by [ref 1]:

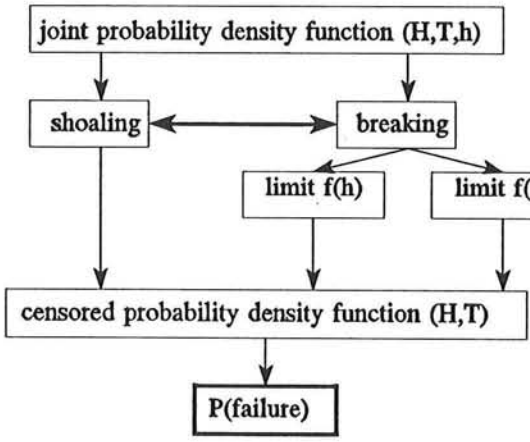

Figure 3.7 *Transformation deep water data*

$$K_{sh} = \frac{H}{H_o} = \sqrt{\frac{(C_g)_o}{C_g}} = \frac{1}{\sqrt{[1+\frac{2kh}{\sinh(2kh)}]\tanh kh}} \qquad [3.5]$$

in which
- K_{sh} is the shoaling coefficient
- H is the wave height at the site
- H_o is the wave height at deep water
- C_g is the group velocity of the waves
- $(C_g)_o$ is the group velocity of the waves in deep water
- k is the wave number ($2\pi/L$)
- h is the water depth at the site

The phenomenon of shoaling can not be neglected because K_{sh} is purely a function of h/L. The shoaling coefficient for Europoort Rotterdam is indicated in Table 3.2.

Table 3.2 *Transformed hydraulic design conditions*

R (yrs)	Hso (m)	h (m)	Hmax1=0.5h	L (m)	Ksh=H/Ho	Hmax2=Hso*Ksh	Hs (m)	Hx	P(Hs)	N
0.1	4.5	12.8	6.4	70	0.9133	4.1	4.1	6.2	0.00685	3000
0.5	5.5	13	6.5	91	0.9308	5.1	5.1	7	0.00137	2500
1	6	13.2	6.6	104	0.9487	5.7	5.7	7.5	0.000685	2000
5	7	13.7	6.9	118	0.9667	6.8	6.8	8	0.000137	1000
10	7.5	13.9	7	125	0.9766	7.3	7	8.2	6.85E-05	1000
20	8	14.2	7.1	132	0.9858	7.9	7.1	8.5	3.42E-05	1000
50	8.5	14.4	7.2	139	0.9958	8.5	7.2	8.7	1.37E-05	900
100	9	14.6	7.3	147	1.006	9.1	7.3	8.9	6.85E-06	800
500	10	15.1	7.6	162	1.025	10.3	7.6	9.3	1.37E-06	600
1000	10.5	15.3	7.7	175	1.048	11	7.7	9.5	6.85E-07	500
5000	11.5	15.8	7.9	191	1.066	12.3	7.9	9.9	1.37E-07	500

The ratio H/H_0 is obtained from the value of h/L_0 using appendix C from the *Shore Protection Manual* [ref 14]. The deep water wave length is $L_0=gT^2/2\pi$.

Wave breaking
Breaking of waves can occur for two reasons. The first reason is the limitation of wave height due to the water depth. Secondly, the wave steepness is limited.

The breaking criterion due to the water depth is normally given by the breaker index (γ_{br}) defined as the ratio of the maximum wave height to water depth ratio (H/h):

$$\frac{H}{h} \leq [\frac{H}{h}]_{max} = \gamma_{br} \qquad [3.6]$$

For regular waves γ_{br} has a theoretical value of 0.78. While for irregular waves (represented by H_s) values are found for $\gamma_{br}=0.5\text{-}0.6$ [ref 5]. The actual limiting wave height ratio γ_{br} depends mainly on the bed slope m and the wave steepness s. In this study $\gamma_{br}=0.5$ is taken for irregular waves.

Waves in deep water break when a certain limiting wave steepness s is exceeded. Miche [ref 5] states that the maximum steepness of a nonbreaking wave is 0.142=1/7. The wave steepness is defined as the ratio of wave height to wave length H/L.

However the breaking criterium for standing waves differs from those for travelling waves according to Wiegel [ref 13]:

$$H_x = 0.109\ L \tanh kh \qquad [3.7]$$

in which
- H_x is the maximum progressive wave height
- k is the wave number ($2\pi/L$)
- h is the water depth
- L is the wave length

As indicated in Table 3.2, the standing wave breaking criterium is never a governing factor for the significant wave, since the higher of these break long before reaching the breakwater.

The numerical model ENDEC [ref 5] gives design graphs in which the influence of <u>both shoaling and wave breaking</u> is included. See figure 3.8.

The input parameters for Europoort are:

1. Local relative water depth h/L_{op}
   in which
   - L_{op} is the deep water wave length (with peak period $T_p=10$ s) = $gT_p^2/2\pi$ = $(9.81*10^2)/2\pi$ = 156 m
   - h is the design water depth (R=50 years has been taken) = 14.4 m
   - h/L_{op} =14.4/156 = **0.09**

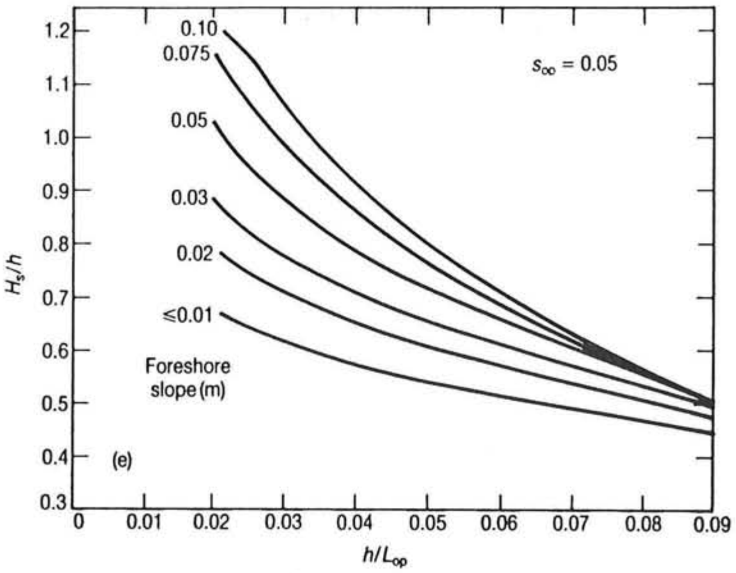

Figure 3.8 *Shallow water significant wave heights for uniform foreshore slopes [ref 5]*

2. Slope of foreshore m is 1:100 ($\approx$ 0.01)

3. Deep water wave steepness $s_{op} = H_{so}/L_{op}$
   in which H_{so} $= 9$ m (R = 100 years has been taken)
   s_{op} $= 9/156 = 0.06$

The maximum steepness available in the design graphs is 0.05. For 0.05 the output is:

$$H_s/h = 0.45 \quad : H_s = 0.45 \cdot 14.4 = 6.5 \text{ m}$$

So $H_s = 0.5 \cdot h$ seems to be a good approximation.
When $h = 14.4$ m the design significant wave height H_s is:
$H_s = 0.5 \cdot 14.4 = \underline{7.2 \text{ m}}$

3.3 Chance that design wave height H_d is exceeded

Each storm can be characterized by a given value of H_s, the significant wave height. Assume this storm consists of n waves, which are distributed according to a Rayleigh distribution.
The chance that an arbitrary chosen design wave height H_d <u>is exceeded</u> by any given wave is:

$$P(H_d) = e^{-2\left(\frac{H_d}{H_s}\right)^2} \qquad [3.8]$$

The chance that this wave <u>is not exceeded</u> in a series of n waves is:

$$[1 - P(H_d)]^n \qquad [3.9]$$

So the chance that H_d is exceeded at least once in a single storm containing n waves is:

$$E_1 = 1 - [1 - P(H_d)]^n \qquad [3.10]$$

This chance has to be combined with the chance that H_s occurs, which must come from a long term distribution of significant wave heights. p(H_s) can be determined as the chance that some wave height H_s-ΔH_s is exceeded minus the chance that the height $H_s+\Delta H_s$ is exceeded. p(H_s) is the chance that H_s falls in the interval having a width of $2\Delta H_s$. Take as an approximation ΔH_s is 0.5 m then E_1 is not changed significantly. So the chance that H_d occurs during any single storm period is:

$$E_2 = p(H_s)\ E_1 \qquad [3.11]$$

It is still possible that the chosen design wave height occurs as well in another wave field characterised by a different value of H_s, completely outside the interval which was just defined. The same procedure has to be repeated for other storms.

The sum of all the possible p(H_{si}) values must be equal to one. The overall chance that the chosen design wave height is exceeded at least once in the single storm period is:

$$E_3 = \sum_{i=1}^{n'} E_{2i} \qquad [3.12]$$

in which n' is the number of intervals depending on ΔH_s

If there are M storms in a year and the design life of the structure is l years. The breakwater is then exposed to $M{\cdot}l$ storms. The chance that H_d is exceeded during l years is:

$$p(H_d) = 1 - (1 - E_3)^{Ml} \qquad [3.13]$$

If this chance is not in accordance with the requirements according to the economy of the harbour (see chapter 2), the entire procedure must be repeated with a different design wave height.

Due to the lack of economical data another approach has to be used in this case. The most probable maximum wave height in the design storm represented by $H_s=0.5{\cdot}h$ is chosen. This most probable maximum wave height is usually taken as the one with the highest probability density given by:

$$H_d = \sqrt{\frac{1}{2} \ln n}\; H_s \qquad [3.14]$$

in which n is the number of waves in the design storm.

For $H_s = 7.2$ m results for 2000 waves in the design storm a design wave height H_d of:

$H_d = \sqrt{(½ \ln 2000)} \cdot 7.2 = 1.96 \cdot 7.2 = 14.1$ m

This design wave is limited by the standing wave breaking criterium.

$H_x = 0.109 \cdot L \cdot \tanh kh = 8.7$ m (see table 3.2)

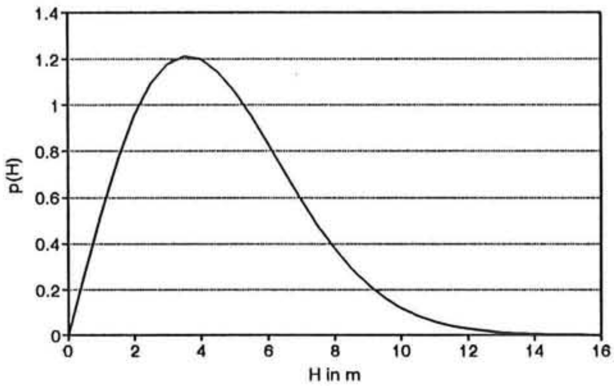

Figure 3.9 *Censored Rayleigh distribution $H_s = 7.2$ m*

4 LINEAR WAVE THEORY

Water-wave phenomena are complex and difficult to describe mathematically because of non linearities, three-dimensional characteristics and apparent random behaviour. However, the small-amplitude or linear wave theory presents a mathematical representation of waves. The linear wave theory is very easy to apply and gives a good approximation of wave behaviour.

In the first section of this chapter the wave pressure formulae of the linear wave theory are derived. In the second section the influence of the wave period on the wave load is discussed. A design of a caisson breakwater using the linear wave theory is made in the third section.

4.1 Formulae of wave pressure

The linear wave theory is based upon the concept that waves can be characterised as linear, sinusoidal waves. The waves are considered to be two dimensional: they will propagate along the horizontal x-axis while the z-axis (positive upward) will have its origin at the still water level (SWL), see figure 4.1.

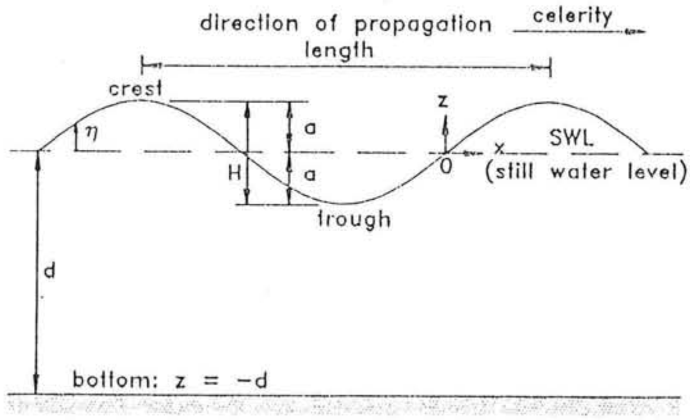

Figure 4.1 *Definition of sinusoidal wave*

The following assumptions are commonly made for simple wave theories [ref 14]:

1. The fluid is homogeneous and incompressible, the mass density of water ρ_w is constant.
2. Surface tension can be neglected.
3. Coriolis effect can be neglected.
4. Pressure at the free surface is uniform and constant.
5. The fluid is ideal or inviscid (no viscosity influences).
6. The particular wave under consideration does not interact with any other water motions.
7. The bed is a horizontal, fixed, impermeable boundary.
8. The wave amplitude is small and the waveform is invariant in time and space.

9. Waves are plane or long crested (two dimensional).

4.1.1 The reflection of incoming waves

The short wave theory says that a standing wave results from the superposition of two travelling waves. When nonbreaking waves attack a vertical impermeable wall with their crests parallel to the breakwater axis, they are totally reflected, see figure 4.2. Hence a standing wave will result.

The surface elevation of an incoming wave η_i is characterised as:

$$\eta_i = a_i \sin(\omega t - kx) \qquad [4.1]$$

in which
- a_i is the amplitude of the incoming wave
- ω is the angular frequency ($=2\pi/T$)
- k is the wave number ($=2\pi/L$)

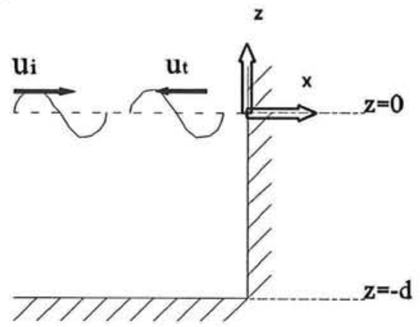

Figure 4.2 *Incoming wave is reflected*

The horizontal velocity u_i of an incoming wave is:

$$u_i = \hat{u}_i \sin(\omega t - kx) \qquad [4.2]$$

The reflected wave (with subscript t) can be described as:

$$\eta_t = a_t \sin(\omega t + kx + \alpha) \qquad [4.3]$$

$$u_t = -\hat{u}_t \sin(\omega t + kx + \alpha) \qquad [4.4]$$

in which α is the phase difference between the incoming wave and the reflected wave

Because of the impermeability of the wall, the velocity of a water particle at the wall (x=0) has to be zero. Hence at $x=0$ yields:

$$u = 0 \qquad [4.5]$$

From this boundary condition results that the phase difference α is zero and the velocity of the incoming wave is equal to and contrary to the velocity of the reflected wave:

$$\hat{u}_t = \hat{u}_i \qquad [4.6]$$

This implies that there is always an antinode at the vertical wall, because at an antinode the horizontal velocity is zero and the vertical velocity is at a maximum.

The maximum amplitude of the standing wave will be the superposition of both amplitudes: $a_s = a_i + a_t = 2 \cdot a_i$. This standing wave will only result when there is total reflection which means that the reflection coefficient $r = a_t / a_i = 1$.

When the incoming waves are not totally reflected the reflection coefficient is less than 1. An intermediate form of a standing wave and a travelling wave will occur. The amplitude η varies in that case from:

$$a_i + a_t = (1+r)a_i \quad \text{to} \quad a_i - a_t = (1-r)a_i$$

4.1.2 Wave pressure on the front of the vertical wall

The derivation of the dynamic wave pressure is obtained in two steps. First the wave pressure below still water level (SWL: $z=0$) is discussed. Secondly the wave pressure above design water level is derived. The total pressure distribution is shown in figure 4.3.

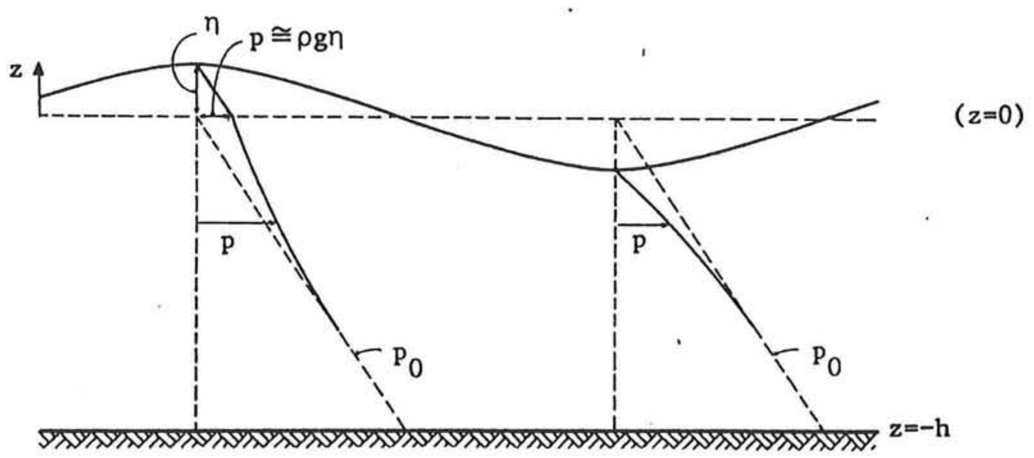

Figure 4.3 *Pressure distribution under wave crest and wave trough*

1. <u>Wave pressure below design water level</u>

The expression for the wave pressure p is derived from Bernoulli's equation for non stationary flow [ref 1]:

$$p = -\rho_w g z - \rho_w \frac{\partial \phi}{\partial t} - \frac{1}{2} \rho_w q^2 \qquad [4.7]$$

in which ρ_w is the mass density of sea water (1030 kg/m^3)
g is the acceleration of gravity (9.81 m/s^2)

z is the vertical position along the z-axis (positive upward)
ϕ is the velocity potential:

$$\phi(x,z,t) = \frac{\omega a}{k} \frac{\cosh k(h+z)}{\sinh kh} \cos(\omega t - kx) \qquad [4.8]$$

q is the absolute value of the velocity vector

The first term on the right-hand side $\rho_w gz$ in equation 4.7 is the hydrostatic pressure which acts on the harbour side of the breakwater as well. In a linear approximation the third term on the right-hand side $\frac{1}{2}\rho_w q^2$ in equation 4.7 is neglected because it is assumed to be very small compared to the second term $\rho_w d\phi/dt$.

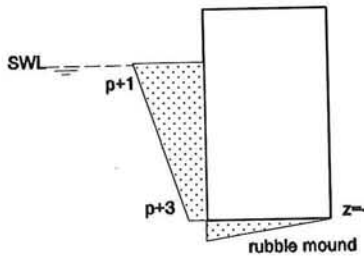

Figure 4.4 *Wave pressure below SWL*

Only this linear term remains:

$$\rho_w \frac{\partial \phi}{\partial t} = \rho_w \frac{\omega^2 a_s}{k} \frac{\cosh k(h+z)}{\sinh kh} \sin(\omega t - kx) \qquad [4.9]$$

in which a_s is the amplitude of the standing wave

Combining this equation with the dispersion relation, which characterises a wave by its wave number k and angular frequency ω:

$$\omega^2 = g\, k \tanh kh \qquad [4.10]$$

gives the expression for the dynamic wave pressure $p_{+/-}$:

$$p_{+/-} = \rho_w\, g\, a_s \frac{\cosh k(h+z)}{\cosh kh} \sin(\omega t - kx) \qquad [4.11]$$

It is noted that:

- subscript + means positive (onshore directed) pressure under a wave crest
- subscript – means negative (offshore directed) pressure under a wave trough

The amplitude of the dynamic wave pressure at a certain depth z is given by:

$$\hat{p}_{+/-} = \rho_w\, g\, a_s \frac{\cosh k(h+z)}{\cosh kh} \qquad [4.12]$$

This formula is only valid from $z=-h$ to $z=0$, since for the expression of ϕ (equation 4.8) an approximation around the surface water level is made [ref 1].

In figure 4.5 the dynamic pressure under a wave crest is illustrated (in this example the wave height reaches just the top of the caisson).

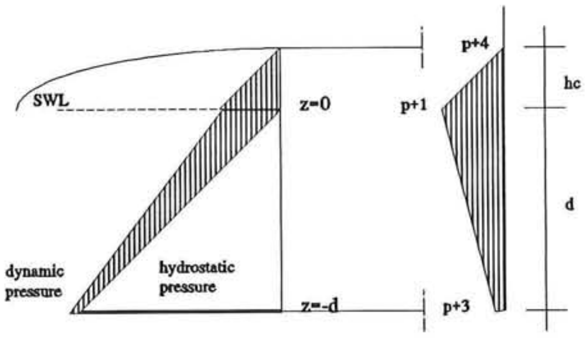

Figure 4.5 *Wave pressure under wave crest*

At $z=0$ the dynamic wave pressure (under a wave crest) is indicated as p_{+1}:

$$\hat{p}_{+1} = \rho_w \, g \, a_s \qquad [4.13]$$

At $z=-d$ (at the base of the caisson or top of the foundation) the dynamic wave pressure (under a wave crest) is indicated as p_{+3}:

$$\hat{p}_{+3} = \rho_w \, g \, a_s \frac{\cosh k(h-d)}{\cosh kh} = \hat{p}_{+1} \frac{\cosh 1.5k}{\cosh kh} \qquad [4.14]$$

In figure 4.6 the dynamic pressure under a wave trough is illustrated.

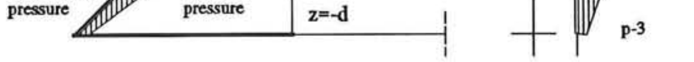

Figure 4.6 *Wave pressure under a wave trough*

At $z=0$ the wave pressure is zero. At $z=-H$ the dynamic wave pressure is indicated as p_{-1}. This is negative because the resultant dynamic pressure is directed offshore. This is in formula:
This is the same expression as for p_{+1} because the wave amplitude is assumed to be small compared to the water depth.

$$\hat{p}_{-1} = \rho_w\, g\, a_s \frac{\cosh k(h-H)}{\cosh kh} \approx \rho_w\, g\, a_s \qquad [4.15]$$

2. <u>Wave pressure above design waterlevel</u>
For $0<z<\eta$ the dynamic wave pressure is assumed to be hydrostatic, see figure 4.7. A distinction has to be made between the following two situations.

A. **The height of the standing wave does not reach the top of the caisson ($a_s < h_c$)**

At $z=a_s=H_d$ for $a_s < H_d$ the dynamic wave pressure is indicated as p_{+4}:

$$\hat{p}_{+4} = 0 \qquad [4.16]$$

The value of the reflection coefficient r remains 1.

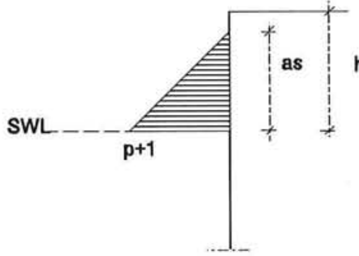

Figure 4.7 Wave pressure above SWL, $a_s<h_c$

B. **The height of the 'standing wave' exceeds the top of the caisson ($a_s > h_c$)**

It is assumed that there is still a fictive 'standing wave' with height $a_s=2\cdot a_i=H_d$ although the incoming wave is not totally reflected. As visualized in figure 4.8, the dynamic wave pressure decreases linearly to the top and pressure p_{+4} is not equal to zero at the top of the caisson:

$$\hat{p}_{+4} = \rho_w\, g\, (H_d - h_c) \qquad [4.17]$$

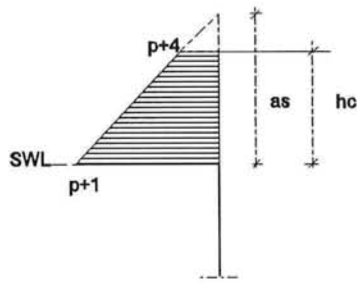

Figure 4.8 Wave pressure above SWL, $a_s>h_c$

The value of the reflection coefficient r becomes less than 1.

By integrating the dynamic wave pressure over the water depth, the amplitude of the horizontal dynamic wave force acting on the front of the caisson is obtained.

$$\hat{F}_{w1+} = \frac{\rho_w\, g\, H_d}{\cosh kh} \int_{z=-d}^{0} \cosh k(z+h) = \frac{L\, \rho_w\, g\, H_d}{2\pi\, \cosh kh} \sinh k(z+h) \Big|_{z=-d}^{0} \qquad [4.18]$$

$$\hat{F}_{w1-} = \frac{\rho_w\, g\, H_d}{\cosh kh} \int_{z=-d}^{z=-H} \cosh k(z+h) = \frac{L\, \rho_w\, g\, H_d}{2\pi\, \cosh kh} \sinh k(z+h) \Big|_{z=-d}^{z=-H} \qquad [4.19]$$

The dynamic wave force above design water level F_{w2+} is:

$$\hat{F}_{w2+A} = \frac{1}{2} \rho_w g H_d^2 \qquad [4.20]$$

or

$$\hat{F}_{w2+B} = \frac{1}{2} \hat{p}_{+1} h_c + \frac{1}{2} \hat{p}_{+4} h_c \qquad [4.21]$$

The amplitude of the total dynamic positive wave force F_{w+} is given by:

$$\hat{F}_{w+} = \hat{F}_{w1+} + \hat{F}_{w2+} \qquad [4.22]$$

For the resultant wave force under a wave trough, the resultant hydrostatic wave force from $z=-H_d$ to $z=0$ should be added to the dynamic part. The amplitude of the total dynamic negative wave force F_{w-} is given by:

$$\hat{F}_{w-} = \hat{F}_{w1-} + \frac{1}{2}\rho_w g H_d^2 \qquad [4.23]$$

4.1.3 Wave pressure on the base of the caisson

Underneath the structure acts a 'static' buoyant force and a vertical dynamic wave force. This dynamic force is caused by propagation of wave pressures in the rubble mound foundation. This means that this vertical dynamic wave force N' depends on the horizontal dynamic wave force F_w (see chapter 2). It is assumed that the dynamic wave pressure p_u on the base of the caisson decreases linearly across the width b. For a wave crest the maximum pressure p_u at the toe of the caisson (seaside) is equal to the wave pressure p_{+3} at the front at $z=-d$ and the minimum pressure is zero at the heel of the caisson (harbour side). The distribution could be parabolical and not zero at the heel (depending on the existence of foot-blocks and the void ratio of the foundation). For simplicity it is assumed that for a wave crest the expression for N' yields:

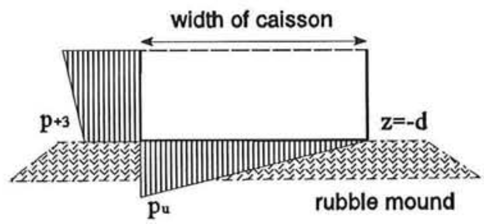

Figure 4.9 *Uplift pressure on the base*

$$N' = \frac{1}{2} b \hat{p}_u = \frac{1}{2} b \hat{p}_{+3} \qquad [4.24]$$

4.2 Spectral analysis

Not just one wave period can have influence on the wave load, but a whole spectrum of periods must be taken into account. By introducing linear spectral transfer functions between the load and the hydraulic parameters, the wave load can be found as a function of the wave frequency.

Transfer functions

In order to transfer the hydraulic parameters into hydraulic loads, the wave loads have to be written as functions of the parameters:

$$F_{wave} = f\,(H_d, T) \tag{4.25}$$

The transformation of waves into wave loads can be done with a spectral method. To allow the application of such a method, the transformation from waves to wave loads has to be a linear system. The transfer functions have to be determined with the aid of a mathematical model. For irregular waves the following method can be used.

Mathematical model

An incoming wave field with elevation η_i is considered as a stochastic process in (x,y,t). The energy density spectrum of η_i is $S_{\eta i}(f)$.

The wave periods can be analyzed by assuming that sea waves consist of an infinite number of waves with different frequencies, see figure 4.10. The distribution of the energy of these individual waves plotted versus the frequency f ($=1/T$), irrespective of the wave direction, is called the frequency spectrum.

The square of the amplitude a_n gives the quantity of energy per m² sea state. Therefore the contribution of each sine wave to the variance of the water surface elevation η(t) in terms of energy is given by a_n^2.The variance density or energy density spectrum is the curve which describes the average amount of energy within a frequency band $\Delta\omega$ as a function of the frequency ω. In formula:

$$S(\omega) = \frac{\Sigma \frac{1}{2} a_n^2}{\Delta\omega} \tag{4.26}$$

The irregular wave profile of figure 4.10 is represented by the diagram in figure 4.11 which shows 6 bars of the wave components A..F.
In reality the energy distribution is a continuous curve because there exists an infinite number of frequency components.

Such a frequency spectral density function for the North Sea is shown in figure 4.12. The dotted line can be described as:

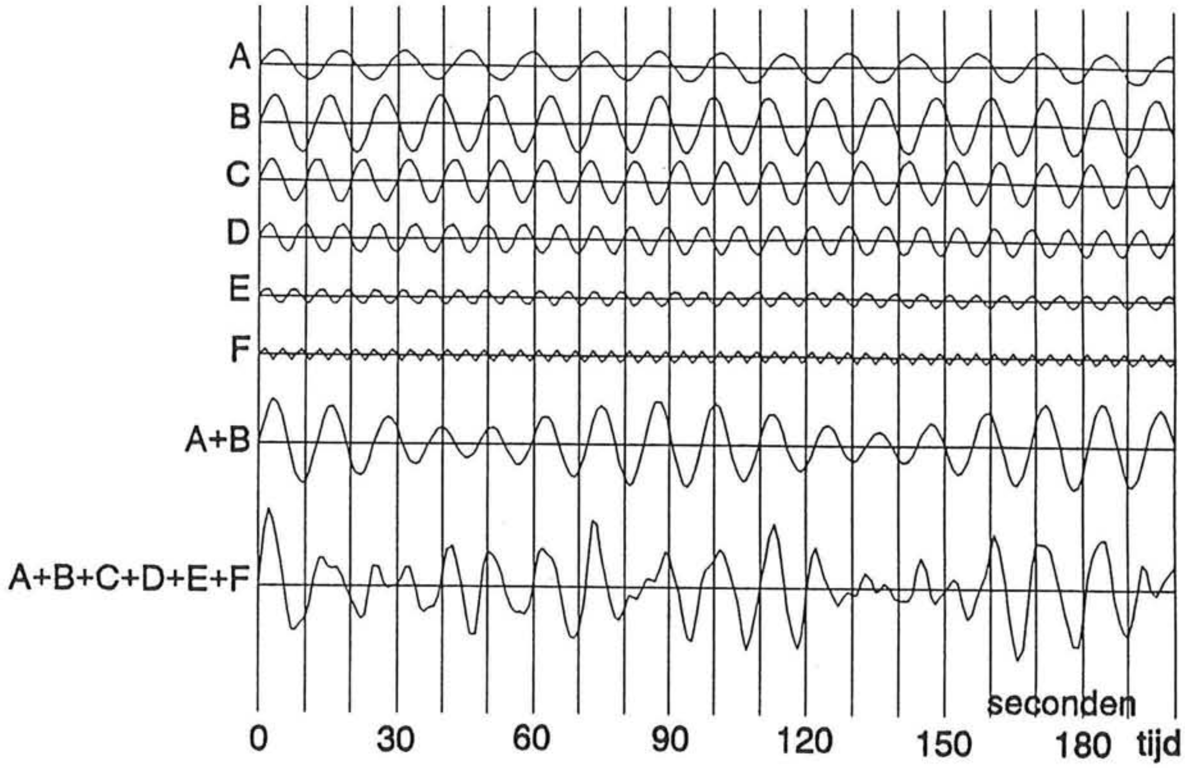

Figure 4.10 *Superposition of wave components [ref 15]*

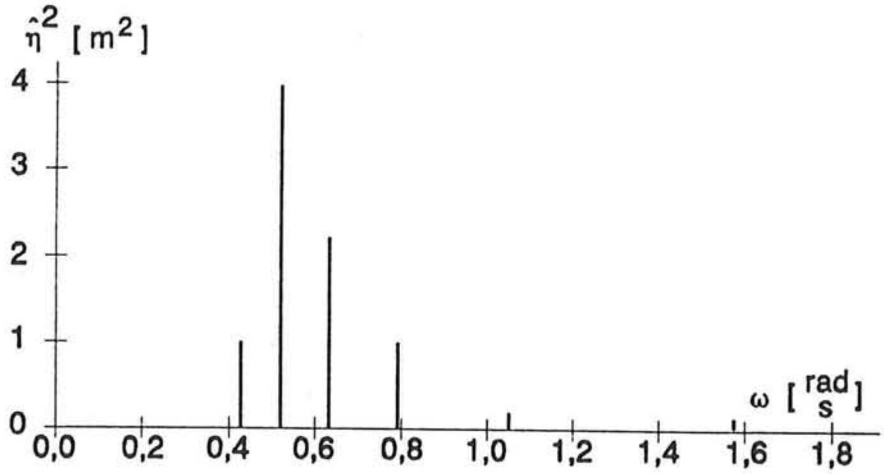

Figure 4.11 *Spectral representation of superposed waves [ref 15]*

$$S(f) = \gamma\ f_p^{-6.5}\ f^4 \qquad \text{for } f < f_p \qquad [4.27]$$

$$S(f) = \gamma\ f^{-2.5} \qquad \text{for } f \geq f_p \qquad [4.28]$$

Figure 4.12 indicates that the wave energy is concentrated around the frequency 0.1 Hz. So the peak period $T_p = 10$ s. The second peak is strongly correlated with the local wind speed [ref 15].

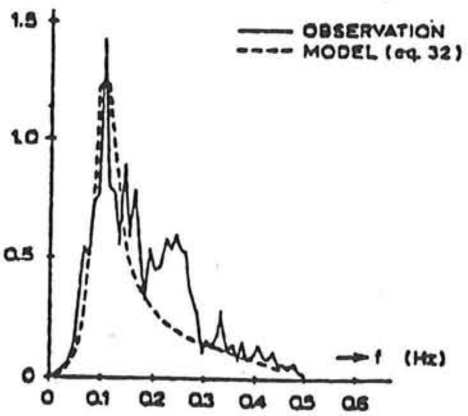

Figure 4.12 *Spectral form for energy penetrating from the North Sea [ref 15]*

The energy density spectrum *S(f)* describes the short-term wave field. The energy density spectrum $S_{wave}(f)$ of the wave load F_{wave} at the structure can be determined as:

$$S_{wave}(f) = O^2(f)\, S_{\eta i}(f) \qquad [4.29]$$

in which *O(f)* is the transfer function which is the wave load per unit of incoming wave amplitude, as a function of the frequency f

Assuming a relatively narrow wave load spectrum $S_{wave}(f)$ and a Rayleigh distribution of the individual wave loads, the traditional parameters F_s (significant wave load) and T_w (mean wave load period) can be obtained by the following relations.

$$F_s = 2\sqrt{m_0} \qquad [4.30]$$

$$T_w = \sqrt{\frac{m_0}{m_2}} \qquad [4.32]$$

$$m_n = \int_0^\infty f^n\, S_W(f)\, df \qquad [4.33]$$

in which m_o is the area of the energy density spectrum of the wave load

The basis of this calculation is the wave pressure distribution according to a linear wave theory. By integration of the pressure distribution over the height of the structure the wave load per meter length of the structure can be determined. This wave load function $F_{wave}(t)$ divided by the incoming wave amplitude gives the transfer value for the wave period considered.

For quasi-static reacting structures a 'high frequency filter' is the result. Wave loads with high frequencies (small wave periods) have more impact than the loads with low frequencies.

4.3 Calculation for Europoort Rotterdam

To give an indication of the order of magnitude of the dimensions of a caisson breakwater at Europoort Rotterdam, a calculation with the wave pressure formulae using the design criteria of chapter 2 is executed.

Design criteria

- Safety factor of sliding and overturning more than or equal to 1.2.
- The entire base under pressure which gives the requirement for the moment arm of the upward normal force. This lever arm should be more than or equal to 1/3 of the width of the caisson.

Mass density caisson: rho_c

In order to determine the mass density of the entire caisson, assume that the structural walls are 1 m thick. For the estimated dimensions of $h_c = 19$ m and $b = 15$ m results an indication for the mass density, see figure 4.13 (per running metre length):

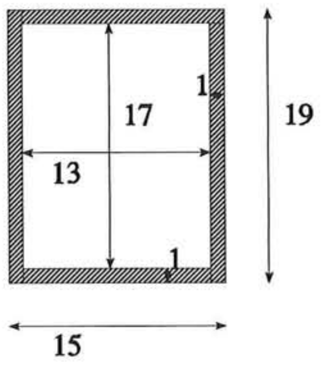

Figure 4.13 *Rough estimation dimensions caisson*

Area filled with concrete =
$= 19 \cdot 2 \cdot 1 + 13 \cdot 2 \cdot 1$
$= 38 + 26 =$ **64 m²**

Area filled with sand =
$= 13 \cdot 17 =$ **221 m²**

Total area is **285 m²**. The contribution to the weight of the concrete can be estimated by 64/285 = 0.22 ~ 25%. The contribution of the sand-water mixture is then 75%. The overall mass density of the caisson can be estimated as:

Assume $\rho_{concrete} = 25 \text{ kN/m}^3 \approx 2500 \text{ kg/m}^3$
$\rho_{wet\ sand} = 19 \text{ kN/m}^3 \approx 1900 \text{ kg/m}^3$

$$\rho_c = 0.25 \cdot 2500 + 0.75 \cdot 1900 = \underline{2050 \text{ kg/m}^3}$$

The design parameters:

For a given crest elevation of the caisson h_c determines the width b the stability of the structure. The needed design parameters are:

Length is the length of the caisson considered = 22.5 m [1]

H_d is the design wave height = 8.7 m (which should give an acceptable probability of failure, see chapter 3)

h is the design water depth with return period R = 50 years = 14.4

[1] *in the formulae are the forces calculated per running metre, this length results from a given length in the experiments, see chapter 6.*

	m (see chapter 3)
d	is the submerged part of the caisson = 14.4 - 1.5 (foundation) = 12.9 m
h_caisson	is the crest height of the caisson = 19 m (see chapter 2)
T	is a characteristic wave period = 12.5 s
L_0	is the wave length at deep water = $gT^2/2\pi$ = 244 m
L	is the wave length at the site = $L_0 \cdot tanh(kh)$ = 139 m
rho_w (ρ_w)	is the mass density of sea water = 1030 kg/m³
rho_c (ρ_c)	is the mass density of the entire caisson = 2050 kg/m³ (see explanation above)
p_{max}	is the maximum allowable bearing pressure = 600 kN/m² (see chapter 2) multiplied by the length of the caisson (22.5 m) = 13500 kN/m'

Table 4.1 *Calculation design caisson*

Length	22.5	m	SLIDING			OVERTURNING in heel					
Hd	8.7	m	p+1	1980	kN/m'	arm_Fw1.1	6.5	m	M_Fw1.1	136676	kNm
h	14.4	m	p+3	1630	kN/m'	arm_Fw1.2	8.6	m	M_Fw1.2	19415	kNm
d	12.9	m	p+4	930	kN/m'	arm_Fw2.1	15.2	m	M_Fw2.1	65026	kNm
hc	4.6	m	pu	1630	kN/m'	arm_Fw2.2	14.4	m	M_Fw2.2	34776	kNm
h_caisson	19	m	p_up	2930	kN/m'	arm_U	10.75	m	M_Fw	255890	kNm
h_overtop?	23.1	m	p_weight	7920	kN/m'	arm_W	10.75	m	M_uplift	677250	kNm
f	0.08	Hz	Fw1	22610	kN	arm_N'	14.3	m	M_W	-1830188	kNm
T	12.5	s	Fw2	6690	kN	arm_N	7.21	m	M_N'	250536	kNm
L0	243.9547	m	Fw	29300	kN				M_N	646511.5	kNm
h/L0	0.059027	-	W	170250	kN	b/3	7.17	m			
h/l0	0.059287	-	N'	17520	kN				S.F.overt	2.28	
L	139	m	N	89730	kN	Fw1.1	21027	kN			
kh	0.65092	-	Uplift	63000	kN	Fw1.2	2257.5	kN	pmax	8297	kN/m'
kd	0.583116	-	mu	0.58	-	Fw1.	23284.5	kN			
sinhkh	0.697869	-	Ff	52040	kN	Fw2.1	4278	kN			
sinhk(h-d)	0.067856	-	S.F.sliding	1.78		Fw2.2	2415	kN			
coshkh	1.219435	-									
coshk(h-d)	1.0023	-				Overestimation Fw:					
coshkd	1.174884	-	b	21.5	m		1.03				
tanhkh	0.572289	-									
c	11.1	m/s									
rho_w	1030	kg/m^3									

The minimum required width in order to fulfil all the design criteria, see Table 4.1 is *b* = 21.5 m.

The requirement for the lever arm of the upward normal force *N* turns out to be the critical factor for these design parameters. The factor of safety for sliding is 1.78 and the safety factor for overturning is 2.28 which assumes that sliding would occur before overturning.

The maximum bearing pressure p_{max} = 8297 kN/m' which is less than 13500 kN/m'. Per running metre is p_{max} = 8297/22.5 = 369 kN/m².

The moment arm of the horizontal dynamic wave force F_w is calculated according to figure 4.14.

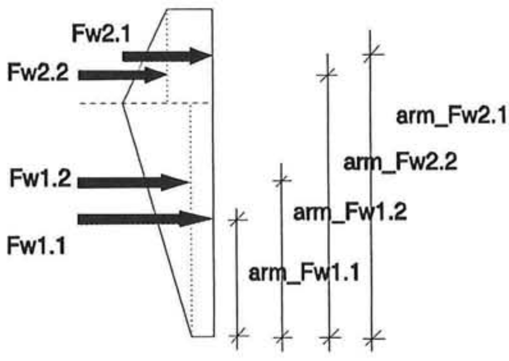

Figure 4.14 *Linear approximation of F_w*

The final layout is illustrated in figure 4.15.

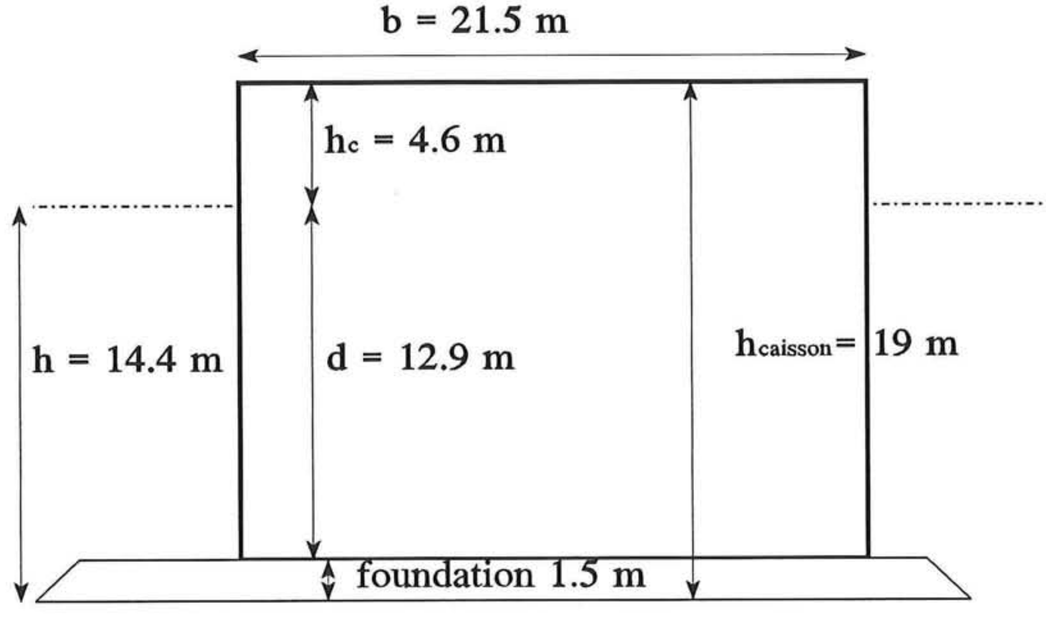

Figure 4.15 *Design caisson for Europoort Rotterdam ($\underline{H}_d = 8.7$ m)*

5 FORMULA OF GODA

Goda has served as an expert and consultant to various technical projects and has published in 1985 'Random seas and design of maritime structures' [ref 4] which is the basic source of this chapter. Goda developed some immediate answers for design and construction problems. The formulae he derived about wave pressures on a vertical wall caisson, based on numerous hydraulic model studies, are called 'The formula of Goda'. His design principles are described in chapter 2.

In the first section Goda's formulae for the wave pressures are described. With these formulae a design for a vertical wall breakwater is made in the second section using his design principles of chapter 2.

5.1 Formulae of wave pressure

Goda states that the difference between theory and experiments decreases as the theory of higher order approximation is incorporated. He made his formulae using the fourth order theory [ref 9] (see chapter 7 about higher order theories).

The wave pressure formulae proposed by Goda assume the existence of a trapezoidal pressure distribution along the vertical wall, as shown in figure 5.1, regardless of the breaking of waves. In this figure, *h* denotes the water depth in front of the breakwater, *d* the depth above the rubble mound foundation, *h'* the distance from the design water level to the bottom of the upright section, and h_c the crest elevation above the design water level.

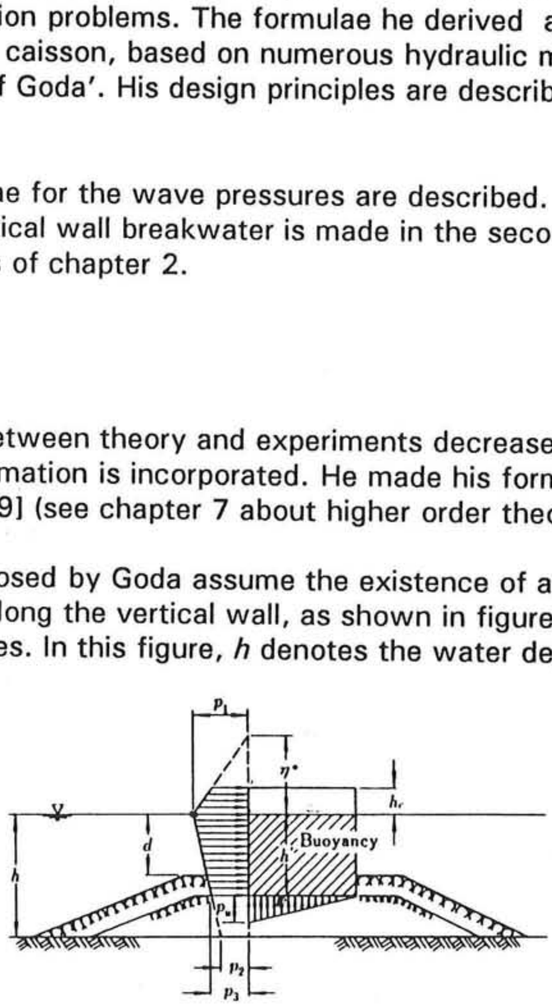

Figure 5.1 *Wave pressure according to Goda*

From this point forward on, Goda's original notation is changed in the notation used for the linear wave theory with subscript *g*.

5.1.1 Wave pressure on the front of a vertical wall

The pressure intensities Goda gives are assumed not to change even if wave overtopping takes place. The formulae are valid for wave pressures under a wave crests. For the wave pressures under a wave trough a design diagram is given in following section 5.1.2.

1. The wave pressure at the design water level: p_{+1g}

$$p_{+1g} = \frac{1}{2}(1 + \cos\beta)(\alpha_1 + \alpha_2 \cos^2\beta)\, \rho_w\, g\, H_d \qquad [5.1]$$

For perpendicular wave attack yields $\beta = 0$, that gives:

$$p_{+1g} = (\alpha_1 + \alpha_2)\, \rho_w\, g\, H_d \qquad [5.2]$$

in which

$$\alpha_1 = 0.6 + \frac{1}{2}\left[\frac{4\pi h/L}{\sinh(4\pi h/L)}\right]^2 \qquad [5.3]$$

$$\alpha_2 = \min\left\{\frac{h_b - d}{3h_b}\left(\frac{H_d}{d}\right)^2, \frac{2d}{H_d}\right\} \qquad [5.4]$$

min {i,j} means the smallest value of *i* or *j*; h_b is the design water depth at a distance of $5 \cdot H_s$ seaward of the breakwater.

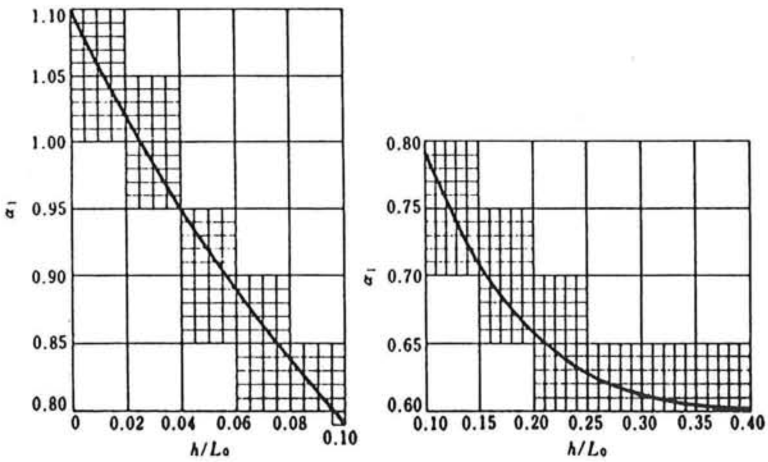

Figure 5.2 *Diagram for the parameter α_1*

The reduction factors α_1 and α_2 are empirically determined. Factor α_1 accounts for the influence of the wave period and α_2 represents the tendency of the pressure to increase with the height of the rubble mound foundation. The presence of a rubble mound foundation may result in a changed behaviour of waves from non breaking to breaking. The value of α_1 can be derived from figure 5.2.

If the wave period becomes greater, the wave length will be greater and h/L_0 will be smaller: α_1 will increase. However, the influence is not very great. α_1 does not carry any theoretical significance according to Goda.

If no rubble mound is present α_2 is almost zero.

2. The wave pressure at depth h: p_{+2g}

The pressure at depth h is the pressure at the design water level multiplied with a reduction factor.

$$p_{+2g} = \frac{p_{+1g}}{\cosh(2\pi h/L)} \qquad [5.5]$$

The reduction factor $1/(\cosh kh)$ can be obtained from figure 5.3.

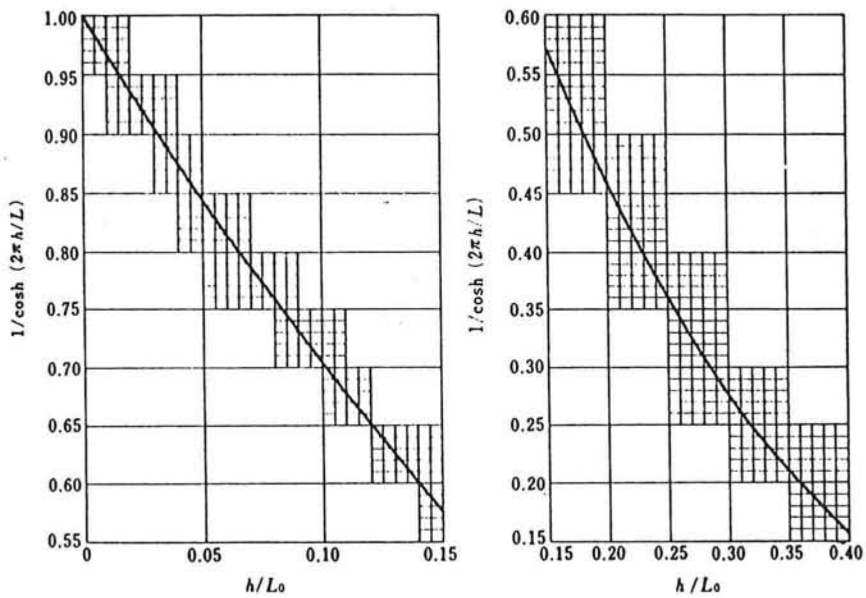

Figure 5.3 *Diagram for 1/cosh(2πh/L)*

This reduction factor is derived from the first order linear wave theory. The pressure at depth h will also increase with increasing wave period. Hence the factors p_{+1g} and $1/(\cosh kh)$ are both influenced by the wave period.

3. The wave pressure at depth d: p_{+3g}

$$p_{+3g} = \alpha_3 \, p_{+1g} \qquad [5.6]$$

in which

$$\alpha_3 = 1 - \frac{d}{h}\left[1 - \frac{1}{\cosh(2\pi h/L)}\right] \qquad [5.7]$$

Based on the assumption that between p_{+1g} and p_{+2g} a linear pressure variation exists, α_3 can be explained.

4. Wave pressure above design water level: p_{+4g}

With perpendicular wave attack Goda assumes a maximum elevation η^* to which the wave pressure is exerted of $1.5 \cdot H_d$ above the design water level. For $\eta^* > h_c$ yields:

$$p_{+4g} = p_{+1g} \left(1 - \frac{h_c}{\eta^*}\right) \qquad [5.8]$$

in which h^*_c is the elevation to which the pressure is exerted = min $\{\eta^*, h_c\}$

If $\eta^* < h_c$ is $p_{+4g} = 0$

With the following equations the total wave pressure and its moment around the bottom of an upright section can be calculated:

$$F_{w+g} = \frac{1}{2} (p_{+1g} + p_{+3g})\, d + \frac{1}{2} (p_{+1g} + p_{+4g})\, h_c^* \qquad [5.9]$$

$$M_{F_{w+g}} = \frac{1}{6} (2p_{+1g} + p_{+3g})\, d^2 + \frac{1}{2} (p_{+1g} + p_{+4g})\, d\, h_c^* + \frac{1}{6} (p_{+1g} + 2p_{+4g})\, h_c^{*2}$$

[5.10]

5. The maximum uplift wave pressure: p_{ug}

Theoretically, p_u at the toe of the upright section should be the same as the pressure in front of the wall, p_{+3}. Goda assumes that the uplift pressure would be too great if $p_u = p_{+3}$ resulting from the performance of prototype breakwaters.

The uplift pressure is assumed to have a triangular distribution with toe pressure p_{ug} given by:

$$p_{ug} = \alpha_1\, \alpha_3\, \rho_w\, g\, H_d \qquad [5.11]$$

So when a rubble mound foundation is present, the difference between the expressions for p_{+3g} and p_{ug} is that α_2 is left out in the expression for p_{ug}. Goda states that the omission of α_2 is the consequence of the expectation that the part of the wave pressure represented by α_2 is of short duration and will not contribute much to the total uplift.

The total uplift pressure N'_g and its moments around the heel of the upright section are calculated with:

$$N'_g = \frac{1}{2} p_{ug} b \tag{5.12}$$

$$M_{N'_g} = \frac{2}{3} N'_g b \tag{5.13}$$

where b denotes the width of the caisson.

5.1.2 Wave pressure under a wave trough

Under a wave trough the nett pressure is directed offshore. Goda developed a diagram based on theoretical calculations using the finite amplitude standing wave theory, with modifications introduced on laboratory data. Figure 5.4 gives the total offshore directed force.

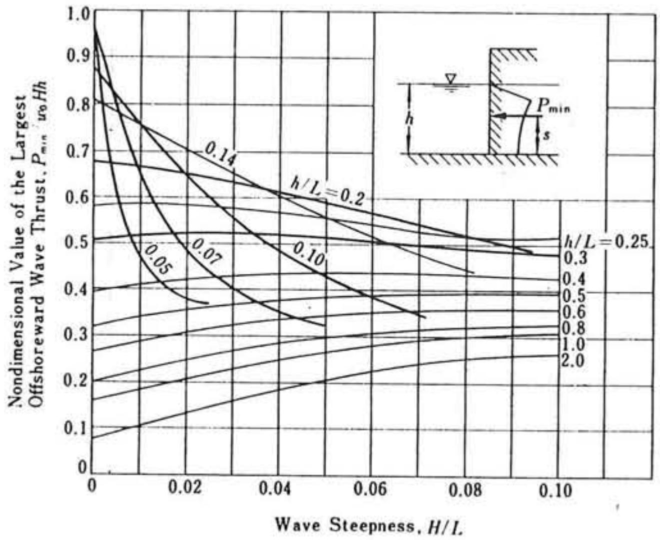

Figure 5.4 *Calculation diagram for the total pressure of standing waves under a wave trough*

5.2 Calculation for Europoort Rotterdam

In order to give an idea of the design of a caisson for Europoort Rotterdam with Goda's formula. A calculation with the following design criteria (see chapter 2) is done.

Design criteria

- Safety factor of sliding and overturning more than or equal to 1.2.
- The maximum bearing pressure of the foundation is
  $p_{max} = 600$ kN/m²

The design parameters are:

Length	is the length of the caisson considered = 22.5 m [1]
H_d	is the design wave height = 8.7 m (which is maximum breaking height, see chapter 3)
h	is the design water depth with return period R=50 years = 14.4 m (see chapter 3)
d	is the submerged part of the caisson = 14.4 - 1.5 (foundation) = 12.9 m
h_caisson	is the crest height of the caisson = 19 m (see chapter 2)
T	is a characteristic wave period = 12.5 s
L_0	is the wave length at deep water = $gT^2/2\pi$ = 244 m
L	is the wave length at the site = $L_0 \cdot tanh(kh)$ = 139 m
rho_w (ρ_w)	is the mass density of sea water = 1030 kg/m³
rho_c (ρ_c)	is the mass density of the entire caisson = 2050 kg/m³ (see chapter 4)
p_{max}	is the maximum allowable bearing pressure = 600 kN/m² multiplied by the length of the caisson (22.5 m) = 13500 kN/m'
μ	is the friction coefficient which Goda takes as 0.6

1 *in the formulae are the forces calculated per running metre, this length results from a given length in the experiments, see chapter 6.*

Table 5.1 *Calculation design caisson*

Length	22.5	m	SLIDING			OVERTURNING in heel		
Hd	8.7	m	p+1	1806	kN/m'	M_Fw	245260	kNm
h	14.4	m	p+3	1520	kN/m'	M_uplift	329930	kNm
d	12.9	m	p+4	1170	kN/m'	M_W	-890850	kNm
hc	4.6	m	pu	1480	kN/m'	M_N'	111000	kNm
h_caisson	19	m	p_up	2930	kN/m'	M_N	-204660	kNm
h_overtop	23.1	m	p_weight	7920	kN/m'			
f	0.08	Hz	Fw1	21450	kN	S.F. overt	1.57	
T	12.5	s	Fw2	6840	kN			
L0	243.9547	m	Fw	28290	kN	1/3b	5	m
h/L0	0.059027	-	W	118780	kN	arm_N	3.21	m
h/l0	0.059027	-	N'	11100	kN			
L	139.3471	m	N	63690	kN	pmax	13230	kN/m'
kh	0.649298	-	Uplift	43990	kN			
sinh 2kh	1.695618	-	mu	0.6	-			
hb	14.84	m	Ff	38214	kN			
alpha1	0.893266	-	S.F.sliding	1.35				
i	0.01982	-						
j	2.965517	-						
alpha2	0.01982	-	b	15	m			
1/coshkh	0.820813	-						
alpha3	0.839478	-						
eta*	13.05	m						
hc*	4.6	m						
rho_w	1030	kg/m^3						
rho_c	2050	kg/m^3						

The minimum required width in order to fulfil all the design criteria, see Table 5.1 is b = 15 m.

The limit on the maximum bearing pressure is the critical factor for these design parameters.

The safety factor for sliding is 1.35 and the safety factor for overturning is 1.57 which implies that sliding would occur before overturning.

The final layout of the structure is illustrated in figure 5.5.

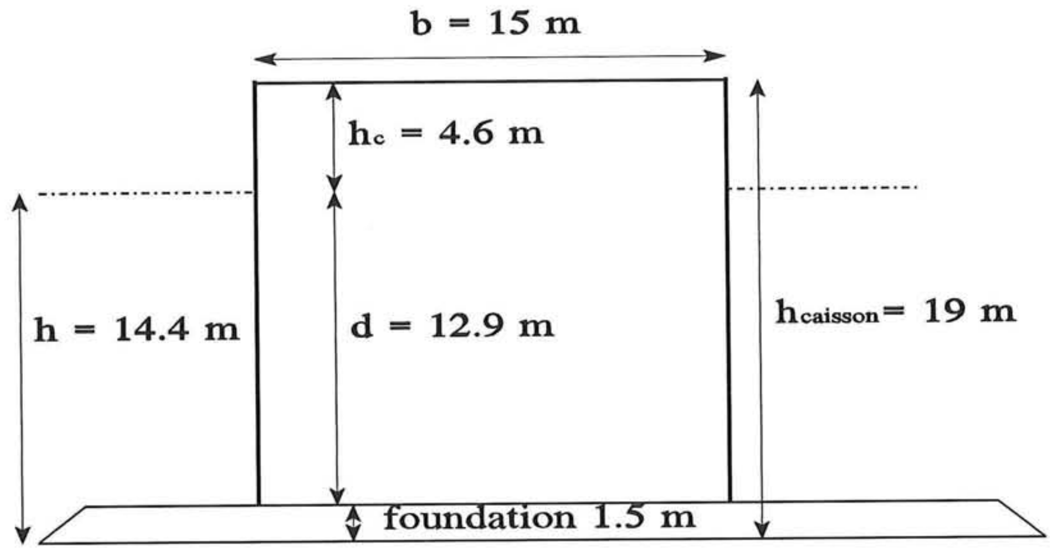

Figure 5.5 *Design caisson for Europoort Rotterdam with the formula of Goda (H_s=8.7 m)*

6 EXPERIMENTS IN WAVE CHANNEL

Hydraulic model tests were carried out in the Hydraulic Laboratories of Imperial College of Science, Technology and Medicine in London. In order to be able to compare Goda's wave pressure formulae with the linear wave pressure formulae, the horizontal wave load on the front of the caisson was measured for regular waves. This validated horizontal dynamic wave force was used

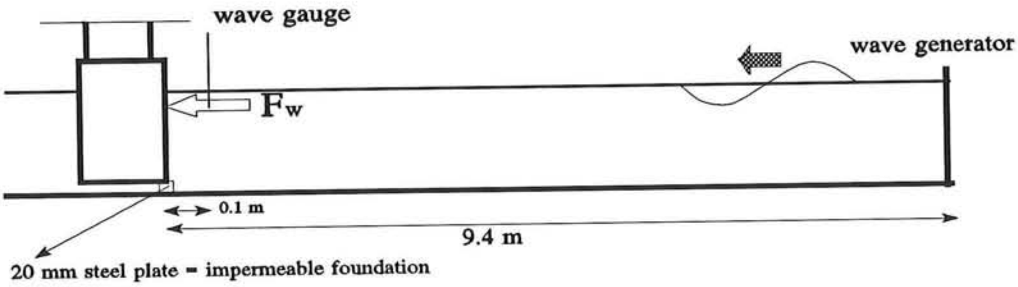

Figure 6.1 *Experimental set up of experiment 1 (not on scale)*

consequently to examine the failure mechanisms of the caisson. Two different types of experiments have been done.

The horizontal dynamic wave force on a vertical wall caisson has been considered in the first experiment. The model of the caisson made of perspex was placed in a wave channel (0.3 m wide) and was attacked with regular waves, see figure 6.1. The caisson was supported by a measuring frame which was attached to the wave channel in such a way that the horizontal wave load could be measured by means of a strain gauge system. The electrical output signal of the wave gauge and the strain gauge system were sent to a chart recorder which plotted the sinusoidal wave elevation and wave load simultaneously.

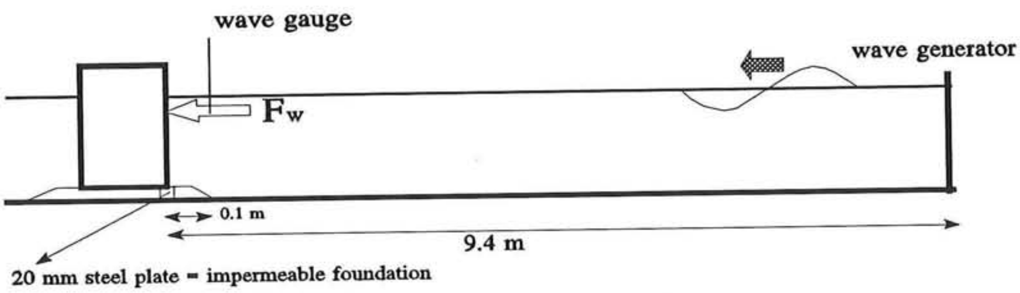

Figure 6.2 *Experimental set up of experiment 2 (not on scale)*

The second experiment has been done to be able to say something about the failure mechanisms of a caisson breakwater. The perspex model used in the first experiment was now placed on a prepared gravel bed in the wave channel without the measuring frame, see figure 6.2. The relation between the horizontal dynamic wave force and the resulting upward normal force was determined at the moment of failure. The submerged weight of the caisson was known. The vertical dynamic instantaneous wave force underneath the structure was zero for the cases in which the propagation of waves under the structure was prevented by a steel bar in the rubble mound foundation, see figure 6.2. The influence of the vertical dynamic instantaneous wave force was distinguished by comparing the results of the experiments with and without the steel bar in the foundation.

In this chapter the following items are described. The aims of the experiments are given in the first section. The second section explains the requirements according to the scaling down of the dimensions of the model. The first experiment dealing with the measurements of the dynamic horizontal wave force is described in the third section. The determination of the conditions at the moment of failure of the caisson, experiment 2, is described in the fourth section.

6.1 Aims of experimental study

The aims of this experimental study are twofold. One target is to compare the theoretical predictions from the wave pressure formulae (the linear wave theory and Goda's formula) with the results of a physical model. The other objective is to examine the ultimate failure mechanisms. In other words:

1. *Determine the horizontal dynamic wave load on a vertical wall caisson.*

2. *Determine the relation between the horizontal dynamic wave load and the resulting upward normal force N at the moment of failure of the caisson.*

The moment of failure is defined as <u>any movement of the model</u> resulting from the wave attack. Three different ultimate failure mechanisms (see chapter 2) can be distinguished:

- Sliding
- Overturning
- Failure of the foundation

Although 'failure of the foundation' is not studied theoretically it can certainly occur during the experiments.

6.2 Scaling considerations

In order to get reliable results from a physical model, scaling rules have to be obeyed. When these rules cannot be obeyed due to practical restrictions scale effects will occur in the results of the experiments. This means that certain phenomena are being represented incorrectly as 'the reality'.

Scaling rules can be derived from mathematical descriptions of physical processes. Assumptions were often made to be able to derive these mathematical formulae. Therefore the assumptions or simplifications made for the formulae have to be applied to the experiments as well.

E.g. one assumption of the linear wave theory is 'surface tension can be neglected' (see chapter 4). The formula for the wave celerity c of a wave is:

$$c = \sqrt{\left[\frac{gL}{2\pi} + \frac{2\pi\sigma}{\rho_w L}\right] \tanh\left(\frac{2\pi h}{L}\right)} \qquad [6.1]$$

in which σ is the surface tension

It is assumed that:

$$\frac{2\pi\sigma}{\rho_w L} = \alpha \frac{gL}{2\pi} \qquad [6.2]$$

in which α is a constant value

The influence of the surface tension can be neglected if $\alpha << 1$. For $\rho_w = 1030$ kg/m^3 and $\sigma = 0.074$ N/m [ref 6] results:

$$\alpha L^2 = \frac{4\pi^2\sigma}{\rho_w g} = \frac{4*\pi^2*0.074}{1030*9.81} = 2.9*10^{-4} \qquad [6.3]$$

Accordingly for $L = 0.1$ m $\rightarrow$ $\alpha = 0.029$
$L = 1.0$ m $\rightarrow$ $\alpha = 2.9*10^{-4}$

This means that the minimum wave length is apparently $L = 0.1$ m for which the surface tension can be neglected.

Another scaling condition from equation 6.1 deals with the dimensionless parameter $kh = 2\pi h/L$, which should be the same for the model and the prototype. A scale factor n_y is given as:

$$n_y = \frac{y_{prototype}}{y_{model}} \qquad [6.4]$$

Therefore:

$$n_{kh} = \frac{kh_{prototype}}{kh_{model}} = 1 \qquad [6.5]$$

The formula is:

$$n_{kh} = n_k \cdot n_h = \frac{1}{n_L} \cdot n_h = 1 \qquad [6.6]$$

This implies that the scaling factor n_h of the water depth *h* has to be same as the scaling factor n_L of the wave length *L*.

The scaling factor of the wave length n_L determines the scaling factor n_T for the wave period *T* as well, because $c = L/T$:

$n_c = n_L/n_T$ while $n_c = \sqrt{n_L} = \sqrt{n_h}$ (according to equation 6.5)

The scaling factor $n_T = n_L/n_c = \sqrt{n_L}$

The same result is given by Froude's Law which considers the influence of gravitational and inertial forces in relation to the behaviour of the waves.

The dimensions of the wave channel determined the geometric scale of the model. The wave channel used in the Hydraulic Laboratories of the Imperial College was 0.30 m wide, 0.32 m high and had a length of 10 m (see figure 6.1: *Experimental set up*). The needed height in the wave channel was:

water level + wave height (of standing wave, take arbitrary value 7 m)
14.4 m + 7 m = 21.4 m (for prototype)

This results in 21.4 m/0.32 m = 67

The geometric scale is taken as $n_{geometric}$ = *75* to make sure that the waves do not cause an overflow.
In order to be sure that the caisson will fail in this channel with limited wave heights, which is required for experiment 2, the width of the model was taken as 0.133 m. This results in a width of the prototype of 10 metres which is certainly not in accordance with the design criteria! The main dimensions of the prototype and the model are given in table 6.1.

It is noted that it is very difficult to scale down the grain size of the gravel foundation. Nevertheless, it is assumed that the geometric scale **1:75** is valid for the rubble mound foundation. Pea gravel with a mean diameter of 5 mm was used which results for the prototype in a mean grain size of $0.005 \cdot 75 = 0.375$ m. This introduces many uncertainties. The void ratio for instance is different, which can have consequences for the dynamic upward force *N'*. The Reynolds number Re, which is a function of the horizontal velocity, the diameter of the rubble mound and the viscosity, can have influence on the pore pressures in the gravel bed.

Table 6.1 *Dimensions prototype and model*

	Prototype (m)	Model (mm)
Wave height *H* (variable)	7	93
Water depth *h*	14.4	192
Height caisson *h_caisson*	19	253
Width caisson *b*	10	133
Length caisson *x*	22.5	300
Height foundation *h_found*	1.5	20
Wave length *L* (variable)	139	1858
Wave period *T* (s) (variable)	12.5	1.44
Water *rho_w* (kg/m^3)	1030	1000
Caisson *rho_c* (kg/m^3)	2050	variable

6.3 Experimental set up

In this section the model and the measuring devices of the experiments are described.

6.3.1 Construction of the caisson model

Caisson

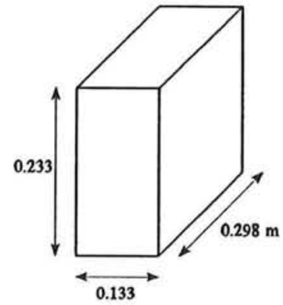

Figure 6.3 *Caisson model*

The dimensions of the caisson model were established as shown in figure 6.3. The perspex plates were attached by screws. Silicon glue was used to make the model watertight. The design of the caisson was in such a way that the top of the caisson could easily be taken off to be able to change the weight of the caisson.

Foundation

In *experiment 1* a 20 mm high steel bar was used as foundation to stop the waves from propagating under the structure, see figure 6.1.
In *experiment 2* a 20 mm high (mean grain size 5 mm) pea gravel bed was prepared. The steel bar used in *experiment 1* was placed for some experimental runs in the gravel bed to stop the waves propagating in the rubble mound foundation.

6.3.2 Measuring system

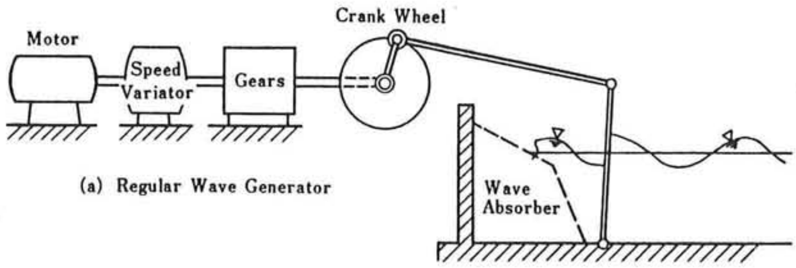

Figure 6.4 *Regular wave generator*

Wave generator

Figure 6.4 illustrates a standard wave generator which makes regular waves. The rotational speed of the motor can be adjusted to change the wave period. The wave height can only be changed mechanically by changing the arm of the crank wheel which rotates at a constant speed. Therefore a change in wave height results in a changed wave period as well. This is the reason why it is impossible to adjust the wave period <u>and</u> the wave height exactly on required values. The wave height is limited because of the limitation of the amplitude of the wave paddle motion.

Wave gauge

The wave gauge is a resistance meter. The gauge measures the vertically integrated conductivity of the water column between the submerged part of two electrodes. The wave gauge is therefore sensitive for a change in the water temperature. The probe is sensitive to the instantaneous difference in waterlevel and hence good calibration is required. Calibration has been executed before every experiment and after every experiment, an example is given in figure 6.5. The actual output of the plotting device is shown in appendix D. The readings of the voltages given in figure 6.5 were taken from

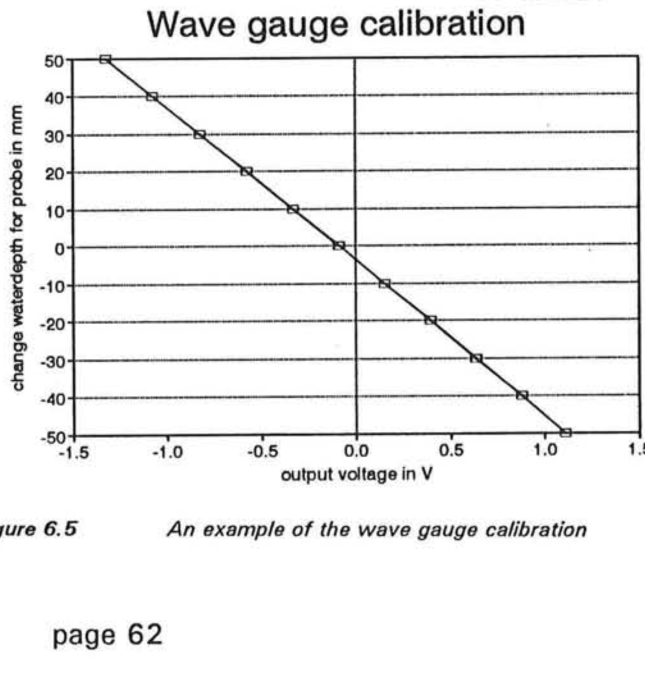

Figure 6.5 *An example of the wave gauge calibration*

a Digital Volt Meter (DVM), while at the same time the plotting device turned the voltage signal into a visual output. The wave monitor multiplied and filtered the signal of the wave gauge. Figure 6.5 shows a difference in voltage of 0.24 V, which results in a theoretical plotting output of 0.24/0.2=1.2 cm (the output of the chart recorder was set at 0.2 V/cm).

Measuring frame

A measuring frame attached to the top of the channel (see the detailed drawings in appendix J) was designed first. The requirements for the design of this frame were:

- Obtain a fixed connection with the caisson.
- Be able to slide over the rails on top of the wave channel (it might be necessary to change the location of the caisson in the channel).
- The construction of the frame should be cheap, easy to make and still very rigid and stiff.

These conditions were satisfied by a steel plate sitting on top of the channel connected to four mild steel bars which were connected to the caisson. The final design is shown in appendix J.

Schematization

The configuration of four mild steel bars supporting the caisson can be schematised as a portal frame. As is indicated in figure 6.6, spacers have been used to enlarge the span of the portal frame. The front of the caisson is assumed to spread the wave load equally, so the lever arm of the force is always length *l*, the length of the steel bars.

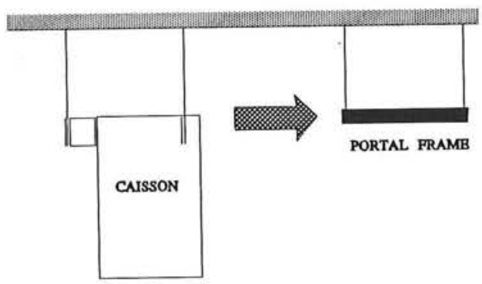

Figure 6.6 *Schematization portal frame*

Strain gauges

In order to transform the hydraulic wave load into an electrical signal, on both sides on top of the steel bars strain gauges were placed. A displacement of the box in the order of 0.5 mm is needed to get sufficient strain in the strain gauges. See appendix C for the calculation of the required flexibility of the steel bars.

Strain gauges measure strain and go into compression or into tension depending on the direction of the applied load. A change in initial stress results in a change of the resistance of the wire, which is the conductor of the strain gauges. Accordingly a different output in volts is obtained. Therefore a difference in hydraulic loading is related to a difference in the output voltage, which is plotted by the chart recorder. See appendix B for the detailed background of the (for this special purpose) designed strain gauge system.

6.4 Experiment 1: Determine horizontal dynamic wave force

The aim for this experiment was:

> *Determine the horizontal dynamic wave load F_w on a vertical wall caisson for a given water depth h, wave height H and wave period T.*

Procedure

First a loose attachment of the caisson with the measuring frame was made. Subsequently this construction was attached loosely to the rails on top of the channel. The sequence of tightening of the screws on either the connection caisson-steel bars and steel bars-top plate was done carefully and accurately because at every side of the box there had to be a clearance of 0.5 mm to allow the box to move under the loading. No influence of water currents along the sides and no friction of the box with the walls of the channel were allowed. The top level of the caisson was +0.253 m relative to the bottom of the channel. A steel bar of 20 mm was used as 'impermeable foundation' underneath the caisson. Obviously, friction between this 'foundation' and the caisson was not allowed as well.

It is noted that the caisson was actually hanging on the steel bars due to the considerable buoyancy of the empty box.

Several tests were done with different wave heights and wave periods for a constant water depth of 192 mm.

Results

An example of the output of the plotter is given is in figure 6.7, all the results in numbers are shown in appendix E.

Performance and accuracy

- wave period:
  The wave periods have been measured by hand with a stopwatch. The mean period of 20 cycles of the wave paddle has been taken as the representative wave period. In some cases 10 cycles have been taken because for small wave periods the waves reflected at the caisson began to hit the wave paddle

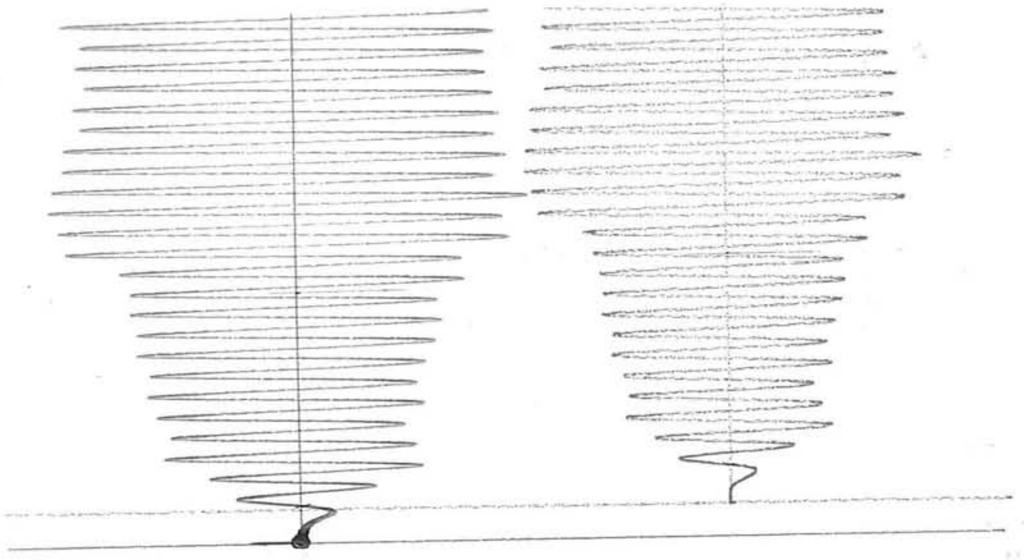

Figure 6.7 *Output chart recorder: Wave elevation (right) and wave load (left)*

again which could have influenced the wave period. The accuracy is therefore in the order of only a few percent which means only a few hundreds of seconds.

- wave height:
  The accuracy of the wave height depends on the margin error of the plotting device, the sensitivity of the probe of the wave gauge, the amplifying signal through wave monitor and the human error in taking the reading of the plots. The calibration is very accurate as indicated in figure 6.5.
  The position of the wave gauge is 10 cm from caisson front. At the wall should theoretically a node of the standing wave occur. A representative wave length L is 1.85 m. The distance of 0.1 m is than 0.1/1.85 = 0.05 this is 1/20 L.
  $\cos 1/20 * 2\pi = 0.99$.
  Which is negligible. The total accuracy is in the order of a few percent.

- wave load:
  The accuracy of the wave load depends on the margin error of the plotting device, the amplifying signal of the strain gauge system and the human error in taking the reading of the plots. The output signal of the strain gauges was not filtered, therefore noise appeared, as can be seen in some output graphs. This noise was however not significant compared to the measured signal. Finally there are uncertainties introduced by the assumptions. The schematization of the portal frame for instance introduces

uncertainties (fixed connection of steel bars at caisson and frame, caisson considered to be one rigid mass). Although the measured force was dynamic only a static calibration could be done, which is considered as very accurate because of its repeatability, see appendix B.
The total accuracy is in the order of only a few percent.

6.5 Experiment 2: Determine the horizontal dynamic wave force at moment of failure of the caisson

The aim for this experiment was:

Determine the relation between the wave load F_w and the upward normal force N at the moment of failure of the caisson.

Because of the precise prediction of the dynamic horizontal wave force F_w with either the linear wave theory or Goda's wave pressure formulae, the only unknown is the dynamic upward force N' caused by propagation of wave pressures in the rubble mound foundation under the structure (see chapter 2), because at the moment of failure the submerged weight $W\text{-}U$ of the caisson is known as well. By preventing the waves from propagating under the structure the dynamic upward force N' under the structure can be eliminated from the equation for the vertical equilibrium. This is tried to accomplish by placing a steel bar in the rubble mound foundation, see figure 6.2. For sliding is the relation between the wave load F_w and the upward normal force $N = W\text{-}U$ in that case expressed in terms of the friction coefficient μ. For overturning the problems of the (scaled down) maximum bearing pressure under the base have to be taken into account.

6.5.1 Procedure

The perspex caisson was placed on a 20 mm thick prepared gravel bed, see figure 6.2. The caisson was filled with water and weights, the total weight was therefore known. Waves attacked the caisson in a constant water depth of 192 mm. To be able to distinguish whether the caisson had moved, a microscope was used. Any displacement of the caisson was considered to be failure of the caisson. For the same wave height and wave period the weight of the caisson was increased until failure no longer occurred. Subsequently the wave period or wave height was changed and the same procedure was repeated.

6.5.2 Results

The results of every run of the experiment 2 are given in appendix K. For a wave (defined by its wave height and wave period) the caisson failed with a known weight. The total results are shown in figure 6.8. 'Without sill' indicates that the dynamic vertical upward force N' has been calculated according to the

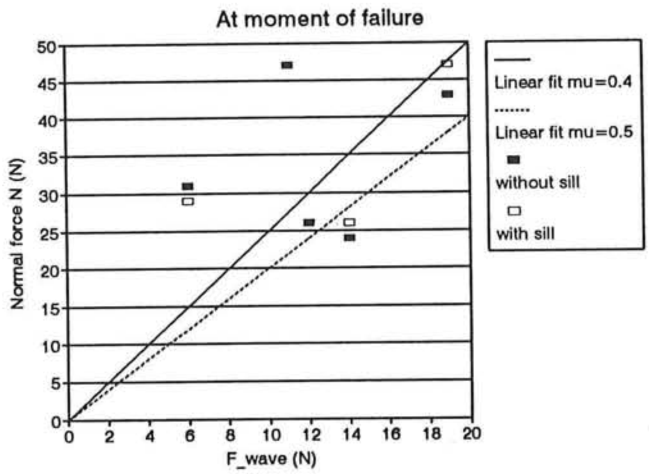

Figure 6.8 *Wave load versus upward normal force at moment of failure*

assumptions made in chapter 2 (triangular distribution) and 'with sill' indicates that the steel bar stopped the waves from propagating in the rubble mound foundation, which means that $N'=0$. The solid line is expressed as:

$$F_f - 0.4 \cdot N - F_w \qquad [6.7]$$

In which 0.4 is the friction coefficient $\mu=0.4$. For the dashed line yields $\mu=0.5$.

Performance and accuracy

The preparation of the gravel bed was the main uncertainty. Every single run of the experiment had the same random bearing area under the base. In this way every initial settlement of the caisson influenced the stability of the structure with a random probability. To start with failure until failure no longer occurs was a method to check whether the caisson failed as well for weights less than the critical weight.

It is noted that the execution of actual placing of the caisson was very sensitive to the resistance to sliding and overturning of the caisson. Just before putting the caisson on its bed, a current underneath the caisson was distinguished. Not always was the whole base placed at once on the bed, sometimes the front or back was touching the foundation first. Therefore when placing a caisson on the sill, gaps under the caisson will be present with a height at least as great as the diameter of the rubble depending on the method of execution.

Some consequences of these named irregularities can be:

- There is no full support along the entire base;
- Seepage can occur underneath the base;

For the performance of experiment 2 yield of course all the uncertainties of experiment 1 concerning the waves and the caisson model as well.

7 RESULTS AND DISCUSSION

The formula of Goda has been analysed in three phases of the design process, see figure 7.1.

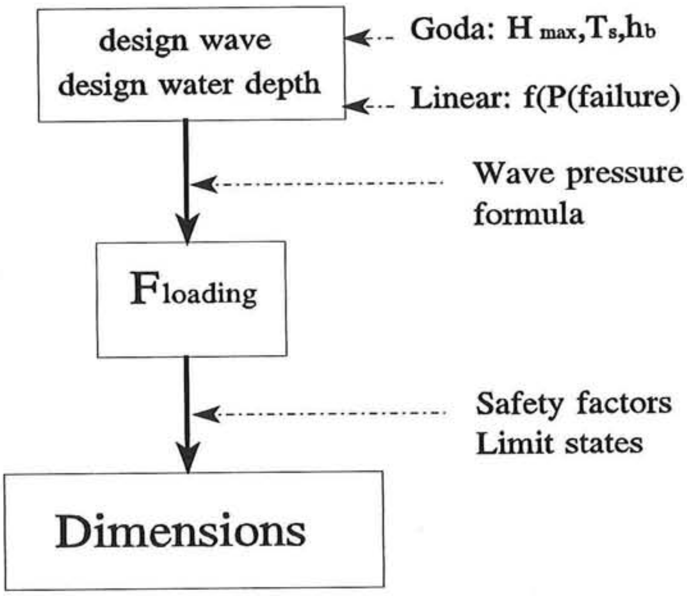

Figure 7.1 *Design process*

Although the design process is iterative, these phases are analysed separately in order to get a better overview.

The first section of this chapter describes the differences between the design principles of Goda and the probabilistic design method. The theoretical results of the linear wave theory (chapter 4) and the formula of Goda (chapter 5) are compared in the second section. Subsequently in the third section, the experimental results are compared to the two theories. Finally some recommendations for further research are made.

7.1 Analysis of Goda's design principles

Determination design parameters
The probability of exceedance of the design parameters sets the probability of failure of the caisson for a constant strength. The determination of the design parameters is therefore an economic decision problem. Nevertheless Goda recommends definite values for the design parameters based on the principle that a breakwater should be designed to be safe against the single wave with the largest pressure among storm waves. For this extreme wave height he

takes the significant period whereas in reality a whole spectrum of wave periods are involved. Goda does take into account the influence of the wave period in his reduction factors for the wave pressure.

Resistance against failure
Goda calculates a safety factor for sliding in accordance with the basic principle that this safety factor is the calculated by dividing the resistance force by the driving force. However, for the safety factor for overturning Goda does not follow this principle any more.
The maximum bearing pressure of the foundation is not related to a minimum lever arm of the upward normal force according to Goda. This results in different dimensions of the caisson, see the calculations for a caisson at Europoort in chapter 4 and chapter 5.

7.2 Linear wave theory compared with Goda's formula

Only the formulae for the wave pressure are compared regardless of the design philosophy of Goda.

7.2.1 Wave pressure for wave crest

The wave pressure formulae are given in Table 7.1. of which the symbols, see figure 7.2 are explained in chapter 4 (linear wave theory) and chapter 5 (Goda).

Table 7.1 *Wave pressure formulae under a wave crest*

	LINEAR WAVE THEORY	FORMULA OF GODA
p_{+1}	$\rho_w\, g\, H_d$	$(\alpha_1 + \alpha_2)\, \rho_w\, g\, H_d$
p_{+3}	$p_{+1}\,(\cosh k(h-d))/(\cosh kh)$	$p_{1g}\, \alpha_3$
p_{+4}	$p_{+1}\,(1 - (h_c/H_d))$	$p_{1g}\,(1 - (h_c/1.5H_d))$
p_u	p_{+3}	$\alpha_1\, \alpha_3\, \rho_w\, g\, H_d = (\alpha_1/(\alpha_1+\alpha_2))\, p_{3g}$
F_{w1+}	INT from $z=-d$ to $z=0$	$0.5\,(p_1 + p_3)\, d$
F_{w2+A}	$0.5\, \rho_w\, g\, H_d^2$	$0.5\, \rho_w\, g\, (1.5\, H_d)^2$
F_{w2+B}	$0.5\,(p_{+1} + p_{+4})\, h_c$	$0.5\,(p_{1g} + p_{4g})\, h_c$

The notation for the linear wave theory is p_{+1} while the formula of Goda is indicated as p_{1g}.

The wave pressure at the design water level, p_{+1}:
The difference between the linear wave theory and Goda's formula is the factor

$(\alpha_1 + \alpha_2)$. The factor α_1 represents the mean tendency that the wave pressure increases with the wave period. If no rubble mound is present, α_2 is almost zero. If a horizontal foreshore is present, α_2 is exactly zero. The influence of α_1 is often greater than the influence of α_2.

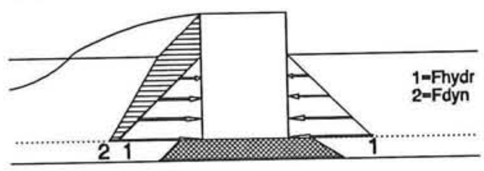

Figure 7.2 *Wave pressure under a wave crest*

The wave pressure at depth d, p_{+3}:
The linear wave theory reduces the wave pressure from design water level to depth d with the factor (cosh $k(h-d)$/cosh kh) while Goda reduces the pressure with his factor α_3. Goda states that the coefficient α_3 was derived from the simplified assumption of a linear pressure variation between p_{1_g} and p_{2_g} (which is the wave pressure at depth h: $p_{2\_g} = p_1/\cosh kh$).

The wave pressure p_{+4} with wave overtopping:
Goda assumes that the elevation to which the wave pressure is exerted $1.5{\cdot}H_d$ is. This results in a higher wave pressure p_{+4}, see figure 7.3.

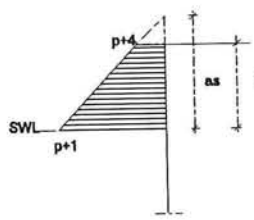

Figure 7.3 *Wave pressure with overtopping*

The maximum uplift pressure, p_u:
Goda reduces the uplift pressure in spite of the theory that states that $p_u = p_{+3}$. He assumes that the uplift pressure would be too great if p_u were set equal to p_{+3}, in view of the performance of prototype breakwaters and other considerations.

The dynamic horizontal wave force below design water level F_{w1+}:
Goda reduces the horizontal wave pressures p_{+1} and p_{+3} with his α-factors and linearises the pressures in between. This results in a smaller dynamic horizontal wave force F_{w1+} than is given by the linear wave theory, see figure 7.4. The linear wave theory integrates the wave pressure along the front of the caisson.

The dynamic horizontal wave force above design water level F_{w2+}:
Goda takes the maximum elevation to which the pressure is exerted as $1.5{\cdot}H_d$, while the standing wave theory assumes a reflection coefficient of 1 which implies an elevation of H_d. F_{w2+_g} is higher than predicted by the linear wave theory, see figure 7.4.

The dynamic horizontal wave force F_{w+}:
Goda reduces F_{w1+} while he introduces an extra safety in F_{w2+} with his elevation level of $1.5{\cdot}H_d$. Depending on the relation wave height H_d and water depth h, the two theories compute roughly the same total wave force F_{w+}, see appendix H .

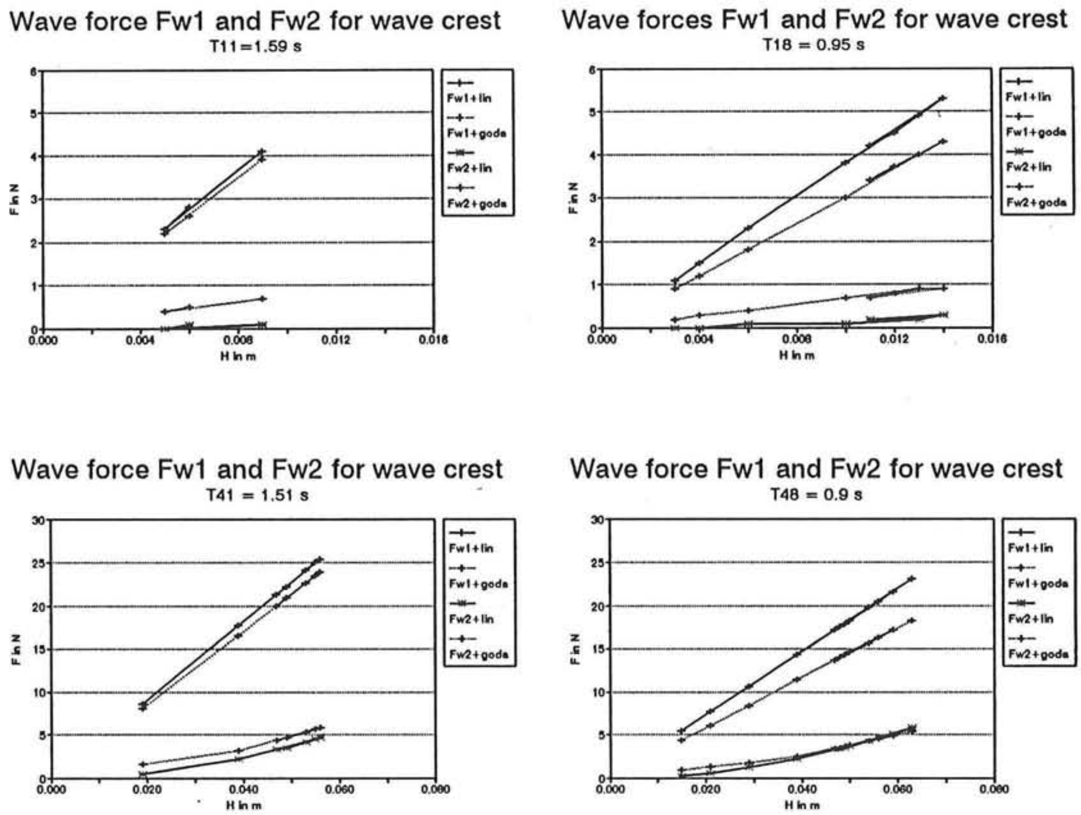

Figure 7.4 *Wave forces according to Goda and the linear wave theory*

7.2.2 Wave pressure for wave trough

The linear wave theory takes as much dynamic pressure of the hydrostatic pressure off for the offshore directed force as it adds up for the positive dynamic wave force. Goda gives a diagram based on theoretical calculations using finite amplitude standing waves, with modifications introduced on laboratory data.

7.3 The experimental data compared with the theory

Before any conclusions can be drawn from the experimental results, the relevance of the influence of the assumptions has to be determined.

Reliability measured wave height *H*

The relation wave height H versus wave load F_{wave} has been manipulated firstly through the location of the wave gauge (0.1 m from the caisson front). Secondly, the measured wave height is not twice the incoming wave height for waves overtopping the caisson. An intermediate form of a standing wave and a travelling wave occurs, see figure 7.5. The amplitude is a function of the reflection coefficient which is less than one for overtopping.

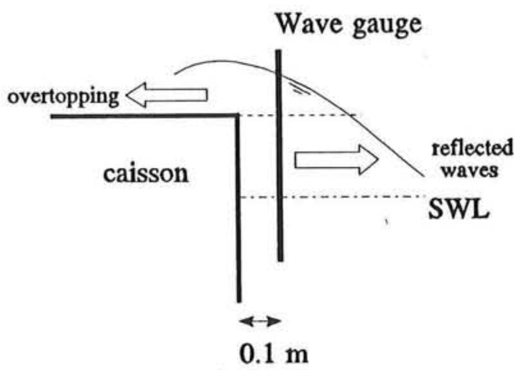

Figure 7.5 *Set up to measure wave height*

Ratio wave amplitude for wave crest and wave trough

Figure 7.6 shows the ratio of the height of the wave crest H_+ and the wave trough H_-. This is illustrated for two measurements.

The waves in Measurement M11 and M18 do not overtop the caisson. As indicated in the graph, the wave crests are equal to the wave troughs which implicates a reflection coefficient of 1 according to the theory.

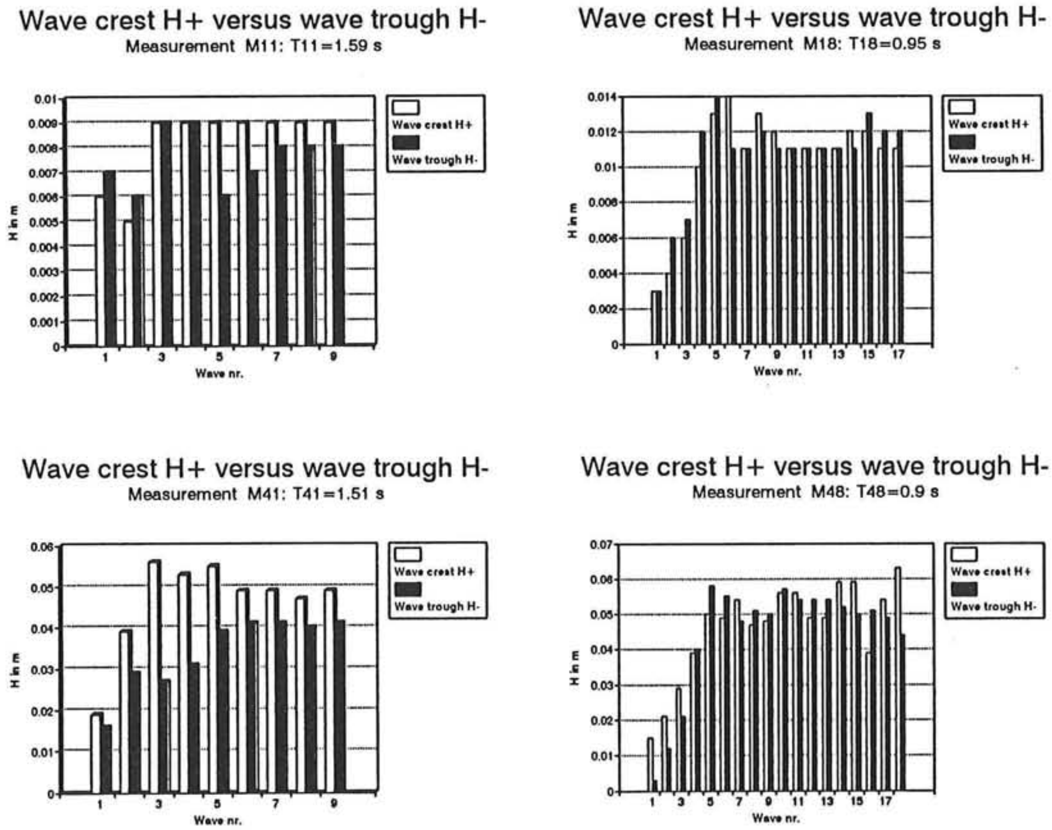

Figure 7.6 *Ratio of height of wave crest and wave trough*

In Measurement M41 and M48 the waves overtop the caisson and the reflection coefficient is less than 1. These graphs show that the ratio H_+/H_- is less precise than in M11 and M18. Nevertheless M41 indicates that the measured wave crest H_+ was higher than the wave trough H_- , M48 does not

give any correlation. Apparently the reflection coefficient is affected by the wave length and the length of the channel, because these determine the intermediate form of a standing wave in the channel.
The reflection coefficient for this mechanism is theoretically less than 1 because the displacement of the caisson dissipates energy which is not reflected.

It is therefore concluded that the graphs confirm the assumption that there is no significant rise in water level due to the standing waves in front of the vertical wall in this experimental set up.

Validity linear wave theory
Figure 7.7 gives the regions of validity of various wave theories. The input parameters for this case can be found by the following characteristic values:

$$d/(gT^2) = 0.192/(9.81\cdot 1^2) = \underline{0.02}$$
$$H_{small}/(gT^2) = 0.01/(9.81\cdot 1^2) = \underline{0.001}$$

$$H_{high}/(gT^2) = 0.06/(9.81\cdot 1^2) = \underline{0.006}$$

Which implies that the experimental conditions find themselves outside the interval for which the linear wave theory is valid. Actually Stokes' second-order and for the higher waves even Stokes' third-order theory are valid.

$$\eta = a\sin(\omega t - kx) = a\sin(\theta) \qquad [7.1]$$

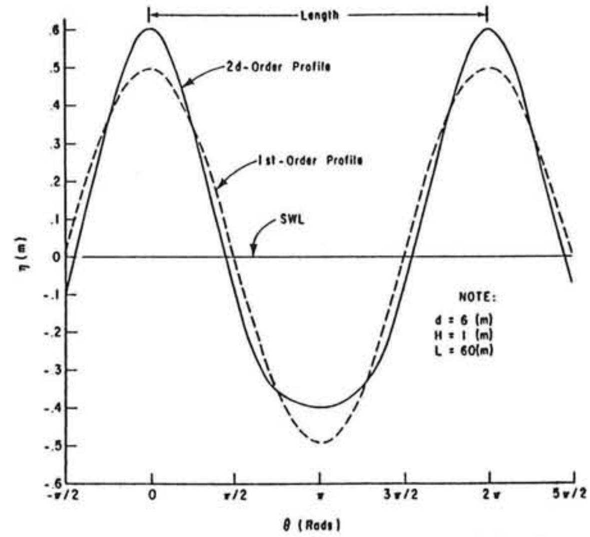

Figure 7.8 *Comparison of second-order Stokes' profile with linear profile [ref 14]*

Linear wave theory is based on the assumption that the motions are so small that the free surface can be described to the first order of approximation by equation 7.1 (see also chapter 4). Linear wave theory assumes that the contribution made to the solution by higher order terms is negligible. A more general expression would be [ref 14]:

$$\eta = a\sin(\theta) + a^2 B_2(L,d)\sin(2\theta) + a^3 B_3(L,d)\sin(3\theta) + \dots a^n B_n(L,d)\sin(n\theta) \qquad [7.2]$$

The order of the approximation is determined by the highest order term of the series considered. It is noted that the linear wave theory applies to a wave that is symmetrical about the SWL and Stokes' second-order theory predicts a waveform that is unsymmetrical about the SWL, see figure 7.8.

Goda found that the difference between theory and experiments decreases as

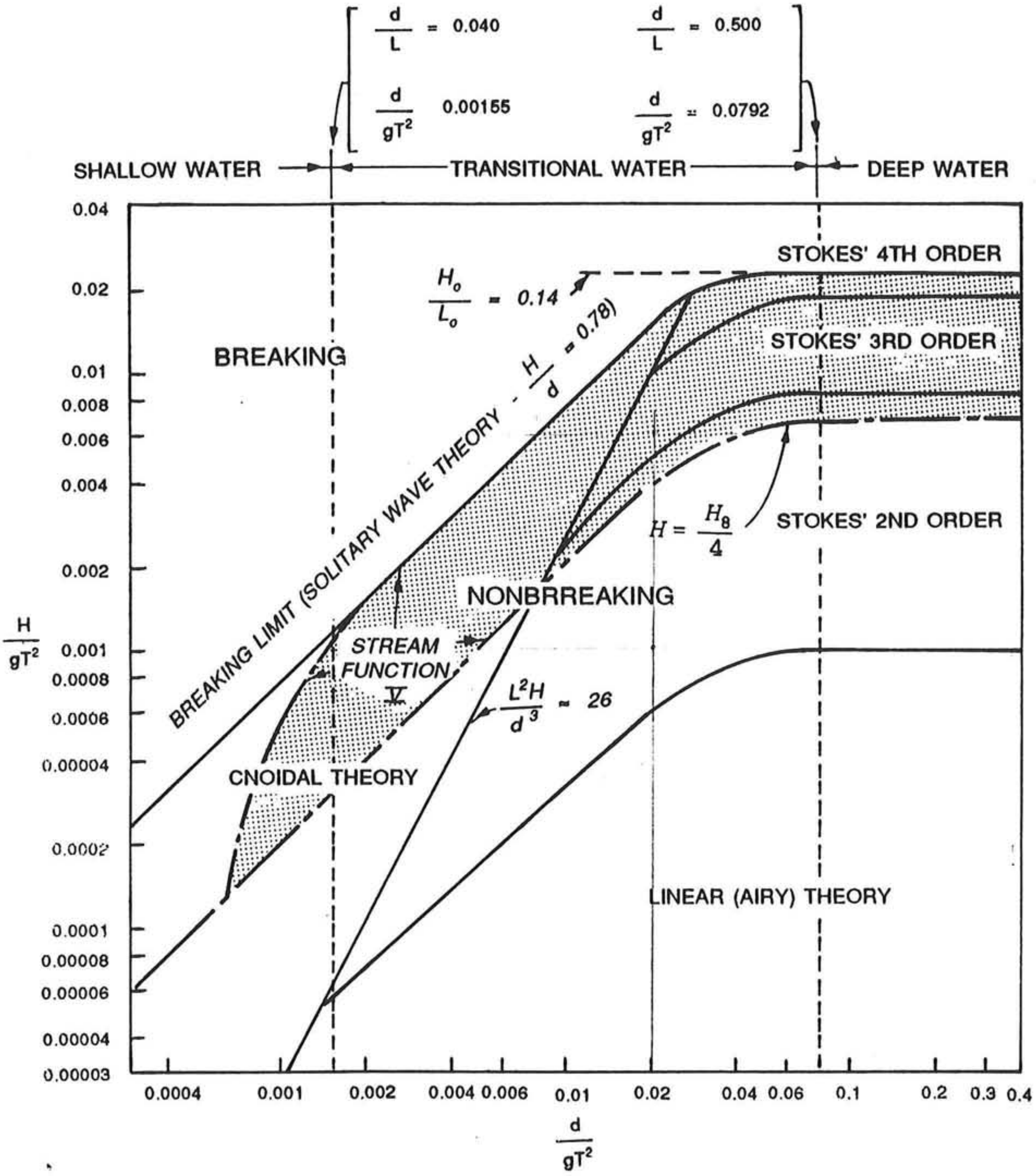

Figure 7.7 *Validity of various wave theories*

higher order approximations are used. The profile in figure 7.8 illustrates a higher wave top and a less deep wave trough. Which implies that the wave force for a wave crest would increase and the wave force for a wave trough would decrease in a higher order approximation. Is this the reason for the maximum elevation of wave pressure of $1.5 \cdot H_d$ and for the reduction factors below the design level? Goda states that some discrepancies between the theory and the experiments have been taken as the basis of modification to the theoretical diagrams for maximum total wave forces.

It is noted that when primarily the oscillating character of the waves important is, that still the amplitude and the wave period have to estimated. These estimates must be determined from empirical data. In such problems, the uncertainty of the accurate wave height and period leads to a greater uncertainty of the ultimate answer than does neglecting the effect of nonlinear processes.

7.3.1 Experiment 1

The scatter of the results of the experiments is to such an extent that no distinction between the two theories can be soundly based.

Horizontal dynamic wave force F_{w+} under wave crest
The experimental values for waves overtopping the caisson are less than predicted and for small waves the measured wave force is often even higher than the calculated wave force.

See appendix H for the results of the experiments and the theoretical values. The graphs show clearly that for low wave periods (high frequency) the linear wave theory predicts a higher wave force than Goda's formula. This can be explained by the dynamic characteristics of the model. As indicated in appendix C, the caisson is schematised as a portal frame which is considered to behave as an one mass-spring system. The contribution of the inertia influences is probably higher for small wave periods than for high wave periods. A better schematisation would be a one mass-spring system with a damper. The damping results from the water mass behind the caisson that has to be pushed away to allow the caisson to move.

Measurement M31 to M38 have been carried out twice to check the repeatability. Apart from M31 with M31* the repeatability is very good.

The reduction factors of Goda are calculated for the experimental input parameters H, T, h:

$0.7 < \alpha_1 < 0.93$
α_2 is zero (horizontal foreshore)
$0.61 < \alpha_3 < 0.87$

Horizontal dynamic wave force F_{w-} under wave trough:
The measured forces F_{w-} are less than the predicted values, see figure 7.9. But Goda's offshore directed force has to be derived from a design diagram (see chapter 5) and is therefore not very reliable.

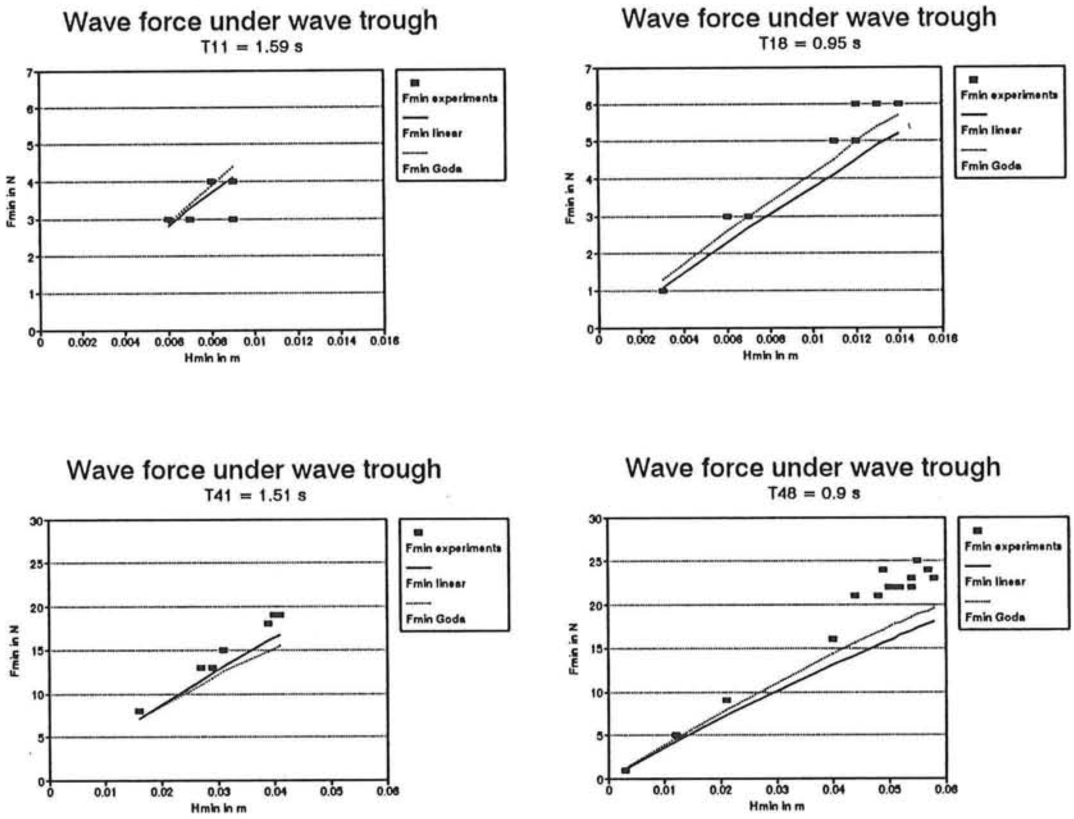

Figure 7.9 *Wave force under wave trough according to Goda, the linear wave theory and a hydraulic model test*

7.3.2 Experiment 2

The scatter in the results is to such an extent that no reliable conclusions can be drawn. This is partly due to the fact that the dimensions of the model caisson were not in accordance with the design criteria. The bearing pressure of the foundation was above the allowed limit. The results of the experiment are therefore not reliable. The coefficient of friction was nevertheless not that far from the predicted value. The scatter in the measurements can be explained by the uncertainties concerning the placing of the caisson.

7.4 Recommendations

Further update of the present model
In order to increase both the accuracy and reliability of the present model, special attention should be paid to the effects of:

- The generated waves:

  For the use of regular waves it would be more convenient when the wave paddle is able to make waves with a defined wave height and period. A wave generator which can make irregular waves will give better insight in the effects of random waves. In order to be able to run the experiment for a longer period of time, a wave absorber is needed at the rear end of the wave channel because more waves are valid in that case.
- Model with smaller scale.
- The use of a computer to work out the data.
- An extra wave gauge in the middle of the channel.

  Only then can be defined what the incoming wave height is. Subsequently the reflection coefficient can be measured .

Further research
For a complete understanding of Goda's formula more information is needed about his hydraulic model studies.

For a reliable design of a breakwater the problems of the foundation play a major role. Although these problems fall outside the scope of this study, the influence of the foundation requirements cannot be considered as a separate problem. Especially the pore pressures need to be considered.

8 CONCLUSIONS

The main conclusion concerning Goda's design formula is:

> Goda's design formula is useful as a first indication for the dimensions of the caisson. For a detailed design a probabilistic design method that makes use of the linear wave theory is a better alternative.

Other conclusions are:

- Goda's wave pressure formulae are in fact design formulae. For the reason that safety considerations are included in the formulae.
- Goda's safety requirements against failure of the foundation are less stringent than usual applied in Holland. Goda only restricts the maximum bearing pressure whereas in Holland the full base has to be under pressure.
- Goda does not take the economy of the harbour into account for the determination of the dimensions of the caisson.
- Goda reduces the horizontal dynamic wave force under sea water level and increases the horizontal dynamic wave force above sea water level with regard to the linear wave theory.

LIST OF SYMBOLS

The notation used in this report differs from that in many papers. This is intentional. To do otherwise would lead to considerable duplication and confusion. The parameters in Goda's formula which are the same for the linear wave theory are indicated with the subscript '_g' and are therefore not listed below.

a	m	Wave amplitude
a_{goda}	m	Lever arm of the upward normal force according to Goda
a_i	m	Amplitude of incoming wave
arm_{Fw}	m	Lever arm of the horizontal dynamic wave force F_w
arm_N	m	Lever arm of the upward normal force N
a_s	m	Amplitude of standing wave
a_t	m	Amplitude of reflected wave
A	Dfl/m	Price per cubic metre volume caisson
α	-	Phase difference
$\alpha_1, \alpha_2, \alpha_3$	-	Parameters for wave pressure calculation according to Goda
b	m	Width of caisson
B	Dfl/m	Additional price per length of the caisson
β	o	Angle of wave attack
C	Dfl	Total costs of caisson
C_g	m/s	Group velocity of the waves
$(C_g)_0$	m/s	Group velocity of the waves in deep water
γ_{br}	-	Breaking index
d	m	Waterdepth above the rubble mound foundation in front of caisson
D	Dfl	Capitalized anticipated damage
δ	o	Angle of friction between soil and concrete
δ	%	Rate of interest per year
E_1	-	Chance that the design wave height is exceeded at least once in a single storm containing n waves.
E_2	-	Chance that the design wave height occurs during any single storm period
E_3	-	Overall chance that the design wave height H_d is exceeded in a storm period
ϵ	-	Coefficient of a foundation model
f	s^{-1}	Frequency

F	N	Wave load
F_0	N	Design wave load
F_1	N	Wave load at moment of failure
F_f	N	Horizontal friction force between foundation and caisson
F_w	N	Horizontal dynamic wave force
F_{w+}	N	Horizontal dynamic wave force directed onshore under a wave crest
F_{w-}	N	Horizontal dynamic wave force directed offshore under a wave trough
F_{w1+}	N	Horizontal dynamic wave force from $z=-d$ to $z=0$ under a wave crest
F_{w1-}	N	Horizontal dynamic wave force from $z=-d$ to $z=0$ under a wave trough
F_{w2+}	N	Horizontal dynamic wave force from $z=0$ to $z=\eta$ under a wave crest
F_{w2+A}	N	Horizontal dynamic wave force from $z=0$ to $z=H_d$, for $H_d<h_c$
F_{w2+B}	N	Horizontal dynamic wave force from $z=0$ to $z=H_d$, for $H_d>h_c$
Φ	m^2/s	Velocity potential
ϕ	^{o}	Angle of internal friction of the soil
g	m/s^2	Gravity acceleration (9.81 m/s^2)
h	m	Water depth in front of caisson
h_b	m	Water depth at a distance of $5{\cdot}H_{1/3}$
h_c	m	Length between still water level and top of caisson
h_c^*	m	Maximum value of h_c and η^*
$h_{caisson}$	m	Crest height of the caisson
h_d	m	Design water depth
h_{found}	m	Height of the foundation
H	m	Wave height
H_0	m	Wave height at deep water
H_b	m	Limiting breaker height at $5{\cdot}H_s$ distance offshore
H_d	m	Design wave height
H_s	m	Significant wave height at the site
H_{so}	m	Significant wave height at deep water
$H_{max}=H_{1/250}=H_{0.4\%}$	m	Design wave height according to Goda with a probability of exceedance of 0.4%
H_x	m	Maximum progressive wave component according to the standing wave breaking criterium
I	Dfl	Costs of the construction of caisson (Investment)
k	s^{-1}	Wave number ($=2\pi/L$)

K_{sh}	-	Shoaling coefficient
l	years	Design life of the structure
L	m	Wave length at the site
L_0	m	Wave length at deep water
L_p	m	Wave length with period T_p
Length	m	Length of caisson (perpendicular to the width and the height)
m_0	m²	Area of the energy density spectrum of the wave load
m_b	kg	Virtual mass of the caisson
M	-	Number of storms per year
M_{Fw}	Nm	Turning moment caused by the horizontal dynamic wave force F_w
M_N	Nm	Turning moment due to the upward normal force N
$M_{N'}$	Nm	Turning moment due to the instantaneous vertical dynamic force N'
M_U	Nm	Turning moment due to the buoyant force of the caisson U
M_W	Nm	Turning moment due to the weight of the caisson W
$M_{W\text{-}U}$	Nm	Turning moment due to the submerged weight (W-U) of the caisson
MSL	m	Mean sea level
μ	-	Coefficient of friction
n	-	Number of waves in a storm
n_y	-	Scaling factor of a parameter y
n'	-	Number of intervals depending on ΔH_s
N	N	Resulting upward normal force
N'	N	Instantaneous vertical dynamic force caused by propagation of wave pressures under the caisson
η	m	Water surface elevation of wave
η^*	m	Maximum elevation above the design water level to which the pressure is exerted according to Goda
η_i	m	Elevation of incoming wave
η_t	m	Elevation of reflected wave
ξ	%	Mean of normal distribution
p	N/m'	Total water pressure
$p_{+/-}$	N/m'	Dynamic wave pressure, directed onshore '+' or directed offshore '-'
p_{+1}	N/m'	Dynamic wave pressure at $z=0$
p_{+2}	N/m'	Dynamic wave pressure $z=-h$
p_{+3}	N/m'	Dynamic wave pressure at $z=-d$

p_{+4}	N/m'	Dynamic wave pressure at $z=h_c$
p_{1g}	N/m'	Wave pressure at still water level according to Goda
p_{2g}	N/m'	Wave pressure at $z=-h$ according to Goda
p_{3g}	N/m'	Wave pressure at $z=-d$ according to Goda
p_{max}	N/m'	Maximum bearing pressure of foundation
p_u	N/m'	Maximum uplift wave pressure caused by propagation of wave pressures under the caisson
p(H_s)	-	Chance that the significant wave height H_s occurs
p(H_d)	-	Chance that the design wave height H_d is exceeded at all during *l* years
P(F_1)	-	Probability of collapse or the probability of force F_1 being exceeded
P(H_s)	-	Chance that the significant wave height H_s is exceeded
P(H_d)	-	Chance that design wave height H_d is exceeded by any given wave in a single storm containing n waves characterized by H_s
q	-	Absolute value of the velocity vector
r	-	Coefficient of reflection
R	years	Return period
ρ_c	kg/m^3	Specific mass density of caisson
ρ_w	kg/m^3	Specific mass density of sea water
σ	N/m	Surface tension
σ	%	Standard deviation of normal distribution
s	Dfl	Theoretical annual premium
s	-	Wave steepness
s_p	-	Wave steepness of peak period
S		Energy density spectrum
t	s	Time
T	s	Wave period
T_d	s	Design wave period
$T_s=T_{max}$	s	Significant wave period
T_p	s	Peak wave period
T_z	s	Mean wave period
u_i	m/s	Horizontal velocity of water particle of incoming wave
u_t	m/s	Horizontal velocity of water particle of reflected wave
U	N	Buoyant force of the caisson
V	m^2	Required volume of caisson per running metre exposed front

θ	-	Slope angle of the foreshore
W	Dfl	Cost of repairing when failure occurs
W	N	Weight of the caisson
x	m	Displacement of caisson
x_o	m	Ultimate displacement of caisson considered as failure
z	-	Vertical position along z-axis
ω	rad/s	Angular frequency of the wave

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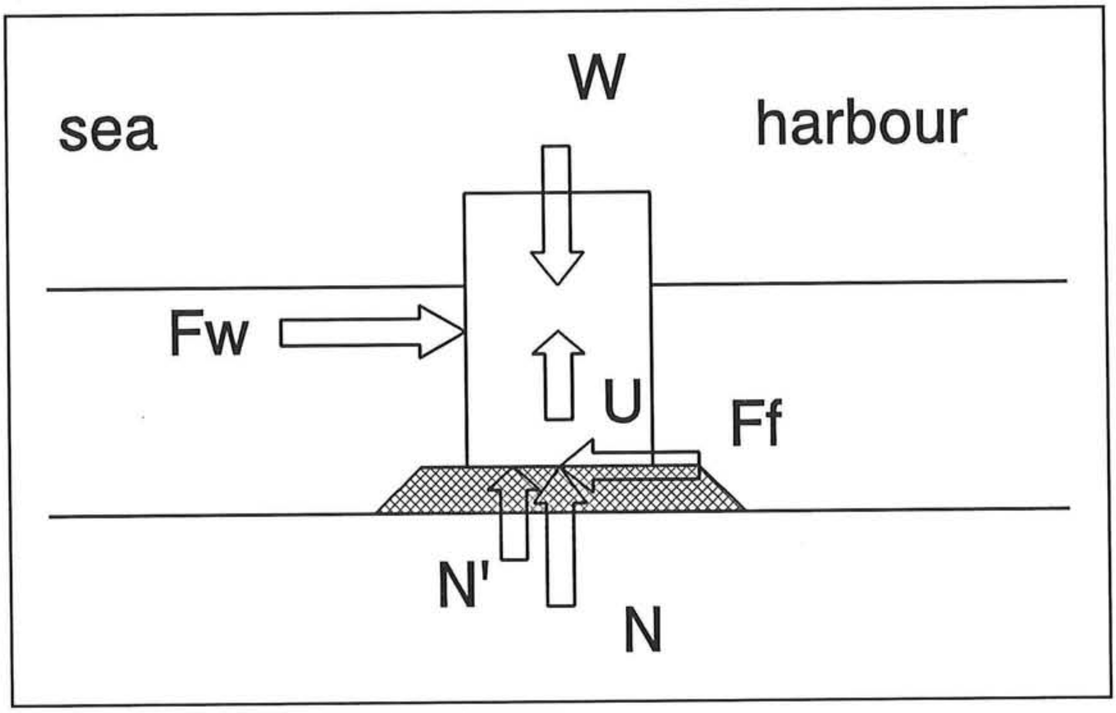
DESIGN CAISSON BREAKWATER

Appendices

Carlita L. Vis



APPENDICES:

APPENDIX A. JOINT PROBABILITY DENSITY FUNCTION OF H_s AND T_p

In this appendix the two dimensional probability density function of wave height and wave period is derived. When the long term distribution for the significant wave height H_s and the probability density function of the wave steepness s_p are known, the joint probability density function of H_s and T_p can be calculated because H_s and s_p are assumed to be independent stochasts, which is a conservative assumption. High steep waves are more likely to occur than small steep waves, so there is a relation.

The probability density function of the wave steepness s_p is given by [ref 15]:

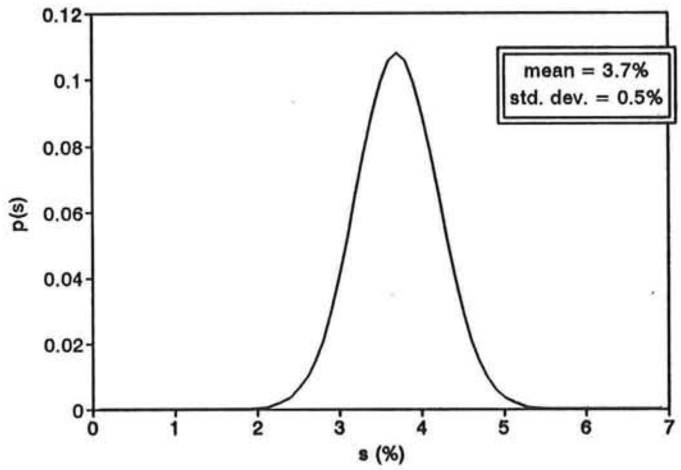


Figure A.1 *Probability density function wave steepness s_p*

The formula is:

$$p_{s_p}(s) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(s-\xi)^2}{2\sigma^2}} \qquad [A.1]$$

in which
- s_p is the wave steepness (H_s/L_p)
- L_p is the wave length with wave period T_p ($= gT_p^2/2\pi$)
- ξ is the mean wave steepness = 3.7%
- σ is the standard deviation = 0.5%

The normal distribution is totally determined by its two parameters ξ and σ. The cumulative distribution is than given by, see figure A.2:

$$P\{s_p \le s\} = \frac{1}{0.5\sqrt{2\pi}} \int_{-\infty}^{s} e^{-\frac{1}{2}\frac{(t-3.7)^2}{0.5^2}} dt \qquad [A.2]$$

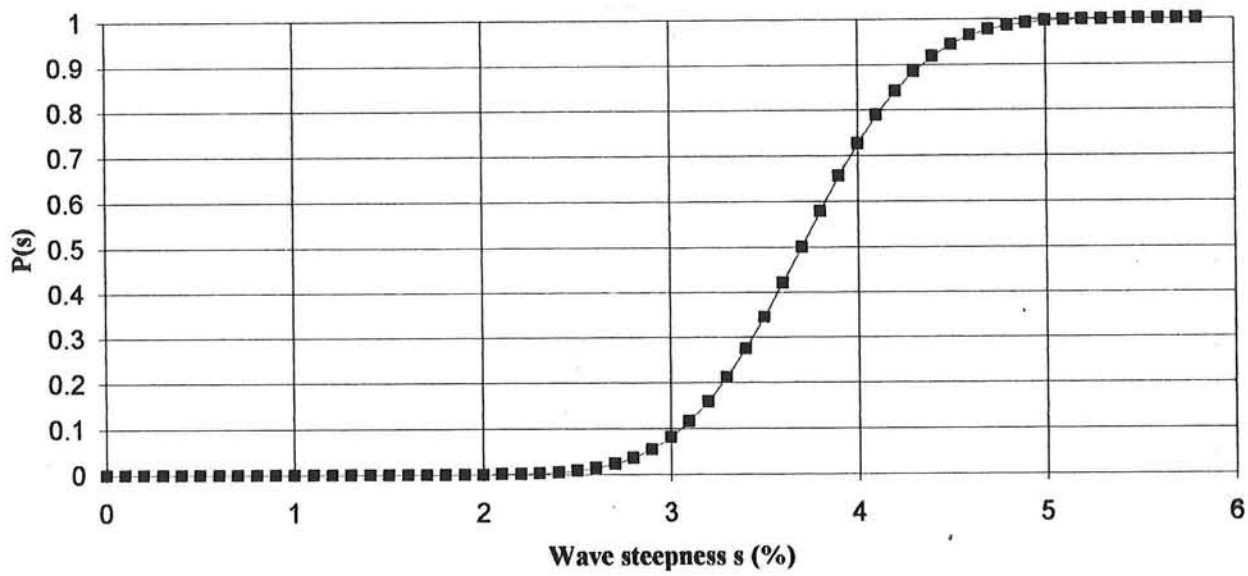


Figure A.2 *Cumulative normal distribution P(s)*

It is easier to use the standardized normal distribution with mean=0 and standard deviation=1. The probability density function must be expressed in the new variable u:

$$u = \frac{s-\xi}{\sigma} \tag{A.3}$$

Figure A.3 gives values $x(\alpha)$ defined by the equation:

$$\alpha = \frac{1}{\sqrt{2\pi}} \int_{x(\alpha)}^{\infty} e^{-u^2} du \tag{A.4}$$

If X is a normal $N(0,1)$ random variable, $P\{X \geq x(\alpha)\} = \alpha$.
$x(\alpha)$ corresponds to the upper P percent point, where $P = 100 \cdot x(\alpha)$. The lower P percent point $x(1-\alpha)$ is obtained by symmetry, as $x(1-\alpha) = -x(\alpha)$.

The wave steepness $s_{10\%}$ which is not reached by 10% of the waves comes from (see figure A.3 for $\alpha=0.1$):

$$\frac{1}{0.5\sqrt{2\pi}} \int_{-\infty}^{s} e^{-\frac{1}{2}u^2} du = 0.1 \quad \Rightarrow \quad u = -1.2817 \tag{A.5}$$

$$\Rightarrow \quad \frac{s-3.7}{0.5} = -1.2817 \qquad s_{10\%} = 3.06\,\%$$

The same procedure yields for $s_{50\%}$ and $s_{90\%}$ see Table A.1.

α	$x(\alpha)$	α	$x(\alpha)$	α	$x(\alpha)$	α	$x(\alpha)$
0.50	0.0000	0.34	0.4120	0.18	0.9153	0.060	1.5551
0.49	0.0250	0.33	0.4395	0.17	0.9541	0.055	1.5985
0.48	0.0500	0.32	0.4673	0.16	0.9944	0.050	1.5985
0.48	0.0500	0.32	0.4673	0.16	0.9944	0.050	1.6452
0.47	0.0751	0.31	0.4954	0.15	1.0364	0.045	1.6958
0.46	0.1002	0.30	0.5240	0.14	1.0804	0.040	1.7511
0.45	0.1254	0.29	0.5530	0.13	1.1265	0.035	1.8123
0.44	0.1507	0.28	0.5825	0.12	1.1751	0.030	1.8812
0.43	0.1760	0.27	0.6125	0.11	1.2267	0.025	1.9604
0.42	0.2015	0.26	0.6430	0.10	1.2817	0.020	2.0542
0.41	0.2271	0.25	0.6742	0.095	1.3108	0.015	2.1705
0.40	0.2529	0.24	0.7060	0.090	1.3410	0.010	2.3268
0.39	0.2789	0.23	0.7386	0.085	1.3724	0.005	2.5762
0.38	0.3050	0.22	0.7720	0.080	1.4053	0.001	3.0905
0.37	0.3314	0.21	0.8062	0.075	1.4398	0.0005	3.2907
0.36	0.3580	0.20	0.8415	0.070	1.4761	0.0001	3.7191
0.35	0.3849	0.19	0.8778	0.065	1.5144	0.00005	3.8906

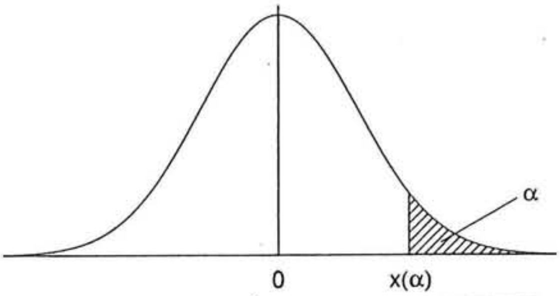


Figure A.3 *Percentiles of the normal N (0,1) distribution*

Table A.1 *Boundaries of the wave steepness*

	α	$x(\alpha)$	s (%)	H_s (m)
$s_{10\%}$	0.1	-1.2817	3.06	$0.0478\ T_p^2$
$s_{50\%}$	0.5	0	3.70	$0.0578\ T_p^2$
$s_{90\%}$	0.9	+1.2817	4.34	$0.0678\ T_p^2$

These parabolic functions display the two dimensional probability function of the wave height H_s and wave period T_p on a one dimensional graph:

Hso (m)	T (s)	s10%	s50%	s90%
4.5	7.4	2.617528	3.165128	3.712728
5.5	9	3.8718	4.6818	5.4918
6	10	4.78	5.78	6.78
7	11	5.7838	6.9938	8.2038
7.5	11.5	6.32155	7.64405	8.96655
8	12	6.8832	8.3232	9.7632
8.5	12.5	7.46875	9.03125	10.59375
9	13	8.0782	9.7682	11.4582
10	14	9.3688	11.3288	13.2888
10.5	15	10.755	13.005	15.255
11.5	16	12.2368	14.7968	17.3568

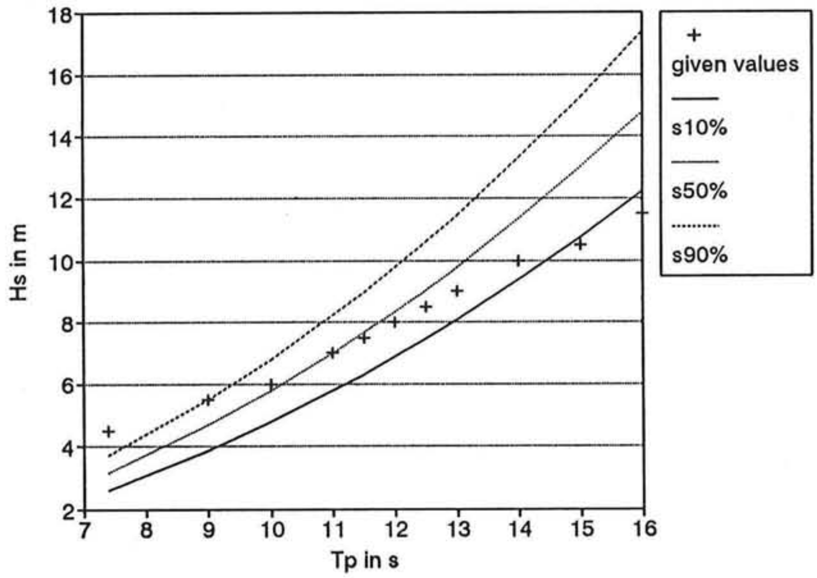


Figure A.4 *Boundaries of the joint probability density function $\underline{H}_s$ and $\underline{T}_p$ and given values [ref 13]*

APPENDIX B. STRAIN GAUGES

Strain gauges are small diameter wires made of electrical resistance alloys which are adhesively bonded to a structure to measure the surface strain of the structure. When the structure is loaded, the stress in the material is changed. The difference in stress in the wires affects the resistance of the conductive material thus an electrical signal as output can be obtained. The following items are described subsequently :

1. Basic operating principle
2. Strain gauge characteristics
3. Installation
4. Instrumentation
5. Calibration

1. Basic operating principle

Strain sensitivity is a function of dimensional changes which take place when a conductor (i.e. the small diameter wire) is stretched elastically plus any change in the basic resistivity due to changing internal stresses of the material with strain.
The electrical resistance of the wire is given by:

$$R = \frac{\rho\, l}{A} \qquad [B.1]$$

in which	R	is the resistance of the wire
	l	is the length of the wire
	A	is the cross-sectional area of the wire
	ρ	is the resistivity of the material the wire is made of

Strain sensitivity which, for a strain gauge is defined as the **gauge factor**, is a dimensionless relationship expressed as:

$$K = \frac{\frac{\Delta R}{R}}{\frac{\Delta l}{l}} \qquad [B.2]$$

in which	K	is the gauge factor
	R	is the initial resistance
	ΔR	is the change in resistance
	l	is the initial length
	Δl	is the change in length

From these two formulae, the basic strain sensitivity can be established due to the dimensional changes, assuming that the resistivity ρ remains constant.

Thus materials for which the resistivity is affected by the internal stress in the material are undesirable for strain gauges.

If the wire is stretched elastically, for a given change in length (Δl) there will be an associated reduction in cross-sectional area due to the Poisson effect. If Poisson's ratio υ approaches 0.5 then the gauge factor K will be 2.0 ($K = 1 + 2\upsilon$) [ref 17].

2. Strain gauge characteristics

The wire is the strain sensitive resistance element and is made of a copper-nickel alloy. This material is widely used because of its high strain sensitivity which is relatively independent of strain level and temperature.

Table B.1 *Data of the used strain gauges*

	Wire strain gauge	Foil strain gauge
Type	PL-5-11 [1]	PFL-10-11
Gauge length l	5 mm	10 mm
Gauge resistance R	120 ± 0.3 Ω	120 ± 0.3 Ω
Gauge factor K	2.02	2.13
Backing material	polyester	polyester

The functions of the backing material are:

- handling the gauge
- providing a readily bondable surface for bonding the gauge to the test material
- providing electrical insulation between the grid and the steel
- transmitting strain from steel via the adhesive to the gauge grid

Basic electric circuit measurements require an resistance value which is not too low. The standard resistance is 120 ohms. Because of practical limitations on the diameter of the wire, the total length needed to achieve the minimum desired resistance using a single filament would generally be considerably longer than the desired length. Therefore most strain gauges consist of a grid configuration of a single wire. Since the grid will respond to the average value of strain between the ends of the grid, this dimension is the basic measuring length of a strain gauge, and is called the gauge length. Because it would be very difficult to attach instrumentation wires to the fine diameter wires used in the grid (~0.02 mm), heavier wires of about 0.2 mm diameter are soldered to the grid for connection to the signal wires after the gauge installation (see figure B.1).

The wire strain gauge consists typically of a grid of resistance wire to which the paper backing is attached, see figure B.1. The foil strain gauge, see figure B.2, is essentially a small printed circuit. The gauge grid differs from that of a wire gauge in that the cross-sectional area is rectangular instead of circular. In this particular case this difference is of no importance.

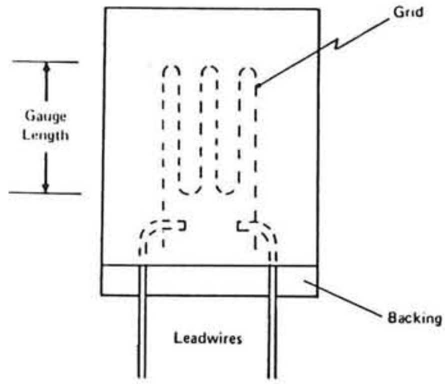


Figure B.1 *Wire strain gauge outline*

In this study two types of wire strain gauges were used: 5 mm 'flat-grid type wire strain gauges' and 10 mm 'foil strain gauges'.
Table B.1 gives the details. The physical size of the backing of the 10 mm foil strain gauge is the same of that of the 5 mm gauge. That was the reason that after applying two 10 mm foil gauges on one steel bar less expensive 5 mm strain gauges were applied on the remaining bars.

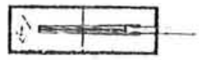


Figure B.2 *Foil gauge (leads attached)*

3. Installation

The performance of the strain gauge is critically dependent on the quality of the installation and the adhesive used. The adhesive used is *Micro-Measurements Certified M_Bond 200* which is a cyanoacrylate compound. This material is simple to use, the application of thumb pressure is sufficient for a good bonding.

Preparation surface
The standard procedure for the surface preparation consists of five basic steps:

1. Solvent degreasing
2. Abrading
3. Application of gauge lay out lines
4. Conditioning
5. Neutralising

Degreasing cleans as far as possible the surface of the steel, this was done with alcohol. Final abrading was done with silicon carbide paper 600 grit dry and wet. Wet abrading is preferred as conditioners (oil was used in this case) accelerate the cleaning. Accurate alignment of the strain gauge is always a requirement. Just beneath the clamping of the bar to the measuring frame the position of the strain gauge was marked. To remove all residue a conditioner was used subsequently. This conditioner left the surface slightly acidic and adhesives (particularly cyanoacrylates) will not bond to an acidic surface. Therefore a neutralizer was applied to neutralize the surface.

Once the surface was ready, the *M-bond 200 catalyst* was applied on the bonding surface of the gauge. Together with the *M-bond 200 adhesive* on the steel surface the bond was quickly made.

Lead wire attachment and protection

Soft soldering was used after the wires from the gauge were knotted around the
lead wires making use of two tweezers. Afterwards, several layers of protective coat were applied to make the gauge 'spatproof'. Waterproofness was tried to accomplish by making a cone of tape around the strain gauges and filling it with silicon glue.

Verification

To check the quality of the installation the installed resistance was verified because this should be the standard 120 ohms. Testing should not be confined to the completed installation but carried out at various stages during the installation process. Therefore after attachment of the leads and after application of the protective coating the resistance of the gauge was tested. A difference in resistance was distinguished before and after soldering the lead wires to the signal wires which proofed that a good connection was made.

4. Instrumentation

Almost all strain measurement systems can be broken down into the components shown in figure B.3. A strain gauge can be considered as a passive resistor which requires a power source. Changes in resistance caused by mechanical strain are measured in a bridge circuit which produces an out-of-balance voltage. This voltage needs to be amplified and displayed.

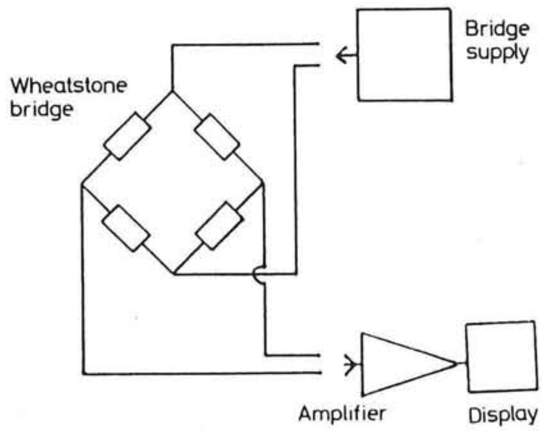


Figure B.3 *Schematic-strain measurement system*

Wheatstone bridge

The wheatstone bridge is most commonly used for converting the small change in the resistance of the strain gauge into a voltage suitable for amplification. Consider figure B.4 in which R_1, R_2, R_3 and R_4 are resistors. Assuming that the condition $R_1/R_4 = R_2/R_3$ is satisfied then the output voltage V_{out} will be zero, or 'the bridge is balanced'. A change in resistance in R_1 will unbalance the bridge and produce a voltage across the output terminals.

If a similar change, in both magnitude and polarity occurs in an adjacent arm of the bridge, say R_4, then the voltage V_{out} will remain at zero and the bridge will remain in a balanced condition. If, in adjacent arms, resistance changes occur of equal magnitude but opposite polarity, than the voltage V_{out} will be twice that due to resistance changes in one arm. The eight strain gauges on the four steel bars were therefore in such a configuration connected that the output signals were added up. The output equation for the bridge is:

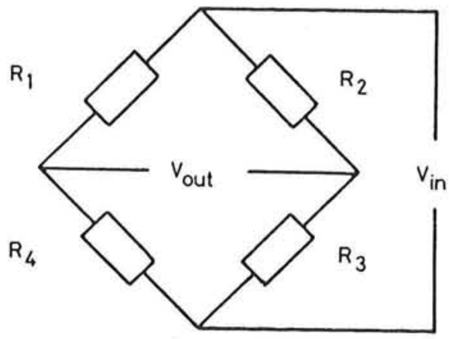


Figure B.4 *Wheatstone bridge*

$$V_{out} = \frac{K \epsilon N V_{input}}{4} \qquad [B.3]$$

in which K is the gauge factor
V_{input} is the voltage over the bridge
ϵ is the strain
N is the number of active arms of the bridge

This includes that the output is independent of the gauge resistance. The output voltage V_{out} was directly measured and displayed with a Digital Volt Meter (DVM).

Chart recorder

The output voltage was amplified and plotted with a chart recorder, see appendix D for the plots.

5. Calibration

To calibrate the measuring system with the strain gauges first every single strain gauge was tested. This was done with a so called 'Quarter Bridge', see figure B.5.

Resistors of 120 Ω were used to form the bridge. The order of resistance changes in the strain gauges are:

$$\Delta R = K * R * \epsilon$$

If $K=2$, $R=120\ \Omega$ and $\epsilon=1\ \mu\epsilon$:

$\Delta R = 2 \times 120 \times 1 * 10^{-6} = 0.24\ m\Omega$

This is very small. For comparison a two-conductor copper cable of 1 mm² section and 10 m length would change in resistance by approximately 0.0128 ohms for a 10°C change in temperature. For the above example this is equivalent to a shift

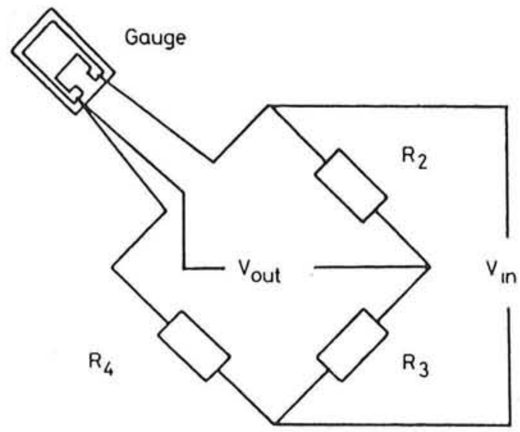


Figure B.5 *Quarter Bridge, three lead system* of 54 $\mu\epsilon$ in the gauge. The advantage of a three lead wire system is:

- The resistance of the lead wires, irrespective of length does not unbalance the bridge because there are similar lead wires in adjacent arms of the bridge and their effects will cancel out.
- Resistance changes of the lead wires produced by temperature changes are cancelled out in the bridge.
- Desensitisation effects of the lead wires are halved.

In this case an example of the obtained values are:

$$V_{out} = \frac{2*30*10^{-6}*1*2}{4} = 3*10^{-5}V = 300mV$$

The separate testing of the strain gauges showed that the strain gauges were measuring different values of strain on different bars. On one bar the amount of strain turned out to be the same value. This is probably the effect of the slightly different locations of the strain gauges with respect to the clamping of the steel bars to the measuring frame.

After separate calibration the eight strain gauges were used as four arms of the Wheatstone bridge, the sensitivity of the system increased significantly. However, the greatest advantage is that all lead wires from the measuring point to the instrumentation, including plugs and connectors are outside the measuring circuit, see figure B.6.

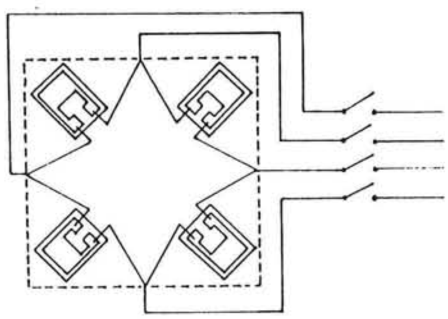


Figure B.6 *Full Wheatstone bridge configuration*

The final configuration of the strain gauges is given in figure B.7 en figure B.8. In this configuration the signals are added up so a maximum signal can be obtained. For convenience the input voltage is set on 5.8 V because the output for 1 N loading is then 10 mV.

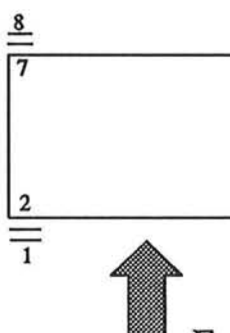


Figure B.7 *Gauge numbers on steel bars*
Odd nr.: tension
Even nr.: compression

Static calibration
Two types of calibration are done. One without water and one in the wave channel with water. The 'dry' calibration was mainly to determine the convenient voltage and to proof that the measuring system was linear.

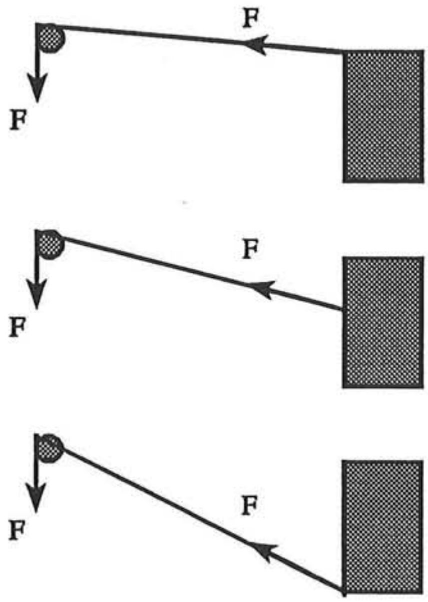


Figure B.8 *Calibration in water*

The actual 'wet' calibration was done with the complete set up in the channel as shown in figure B.9.
The output from the plotter gave for the three different types of loading the same result which proofs the assumption that the caisson is a stiff mass which spreads the load equally.
See figure B.10 for the output of the calibration.

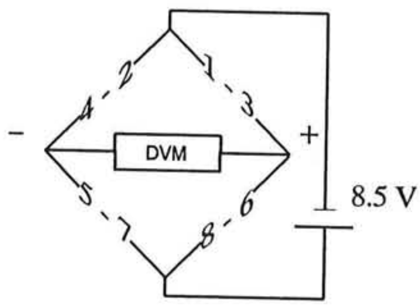


Figure B.9 *Final lay out bridge*

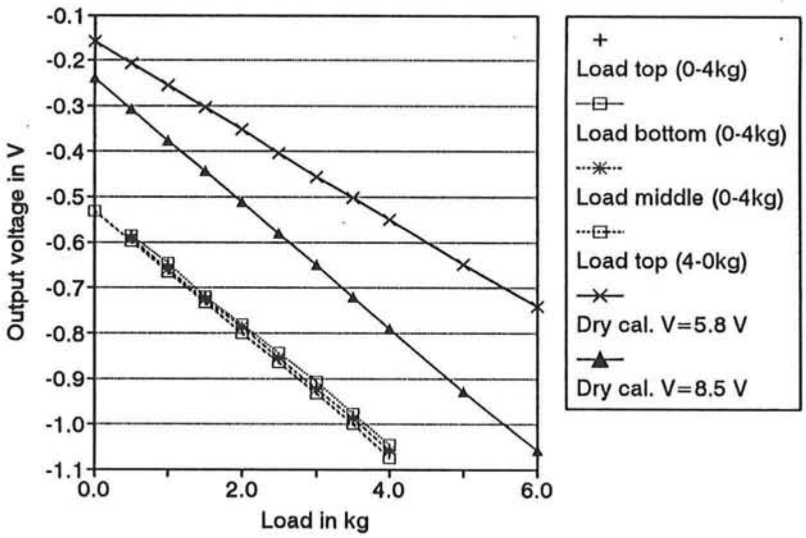


Figure B.10 *Calibration strain gauges*

APPENDIX C. DETERMINATION OF REQUIRED FLEXIBILITY OF THE STEEL BARS SUPPORTING THE CAISSON

When the measuring frame attached to the caisson is schematized as a portal frame with an infinite rigid girder, the dynamic horizontal wave load can be regarded as a dynamic load on a one degree mass-spring system. The required flexibility of the steel bars supporting the caisson is than determined for a given order of magnitude for the horizontal displacement of the girder.

1. Schematization

Figure C.1 shows the schematization of the measuring frame as a portal frame. Two assumptions are made:

- The connections of the steel bars to the caisson are fixed.
- The caisson is a rigid mass.
- The vertical loads on the frame are negligible.

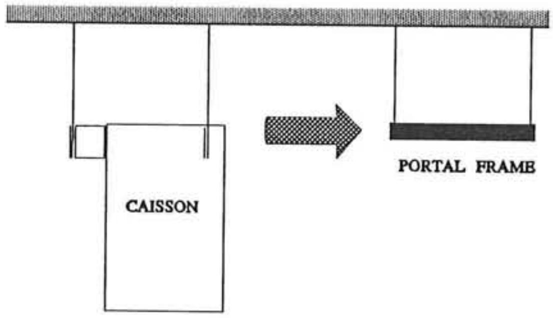


Figure C.1 *Schematization portal frame*

Which implies that the horizontal wave load on the caisson can be considered as a horizontal load on a infinite rigid (flexibility $EI \sim \infty$) girder. The lever arm of the wave load is for every wave different but can be considered equal to the length of the bars when the caisson spreads the wave load equally over the front.

The weight of the steel bars and steel spacers (see appendix J for the detailed drawings of the measuring frame) and the uplift force of the caisson (because it is an empty perspex box in water) are not taken into account. In fact this vertical load can be considered as prestressing of the columns but can be neglected because there is no significant influence on the linear behaviour of the strain gauges with the horizontal load.

Although the connections between the steel bars and the caisson are bolted, every connection is considered to be a fixed connection. That denotes that no rotation at the top and the bottom of the bars is allowed. A horizontal load results therefore in only a horizontal displacement u, see figure C.2.
The rigid frame can be represented by a one-degree mass-spring system, see figure C.3.

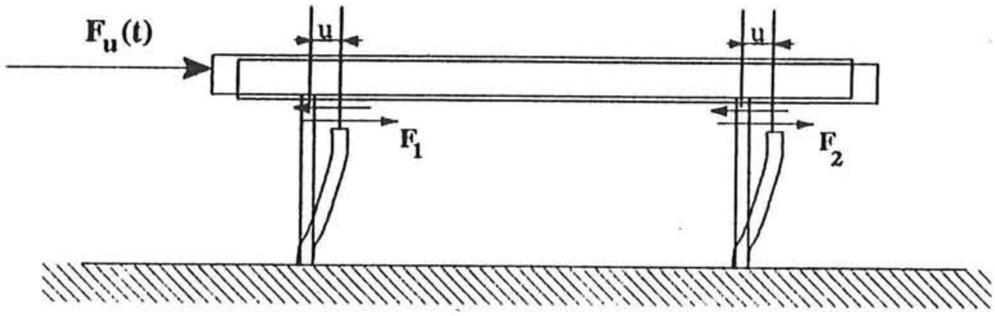


Figure C.2 *Horizontal displacement u*

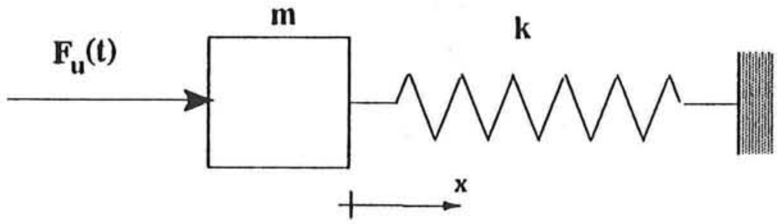


Figure C.3 *Mass-spring system*

The spring constant k of each column is simply equal to the inverse of the deflection x at the top of the frame due to the unit horizontal load F_{wave}:

$$F_{wave} = 2\,k\,x \qquad [C.1]$$

in which F_{wave} is the horizontal dynamic wave load
x is the displacement of the caisson
k is the spring constant of a column, given as:

$$k = \frac{12\,E\,I}{(l_o)^3} \qquad [C.2]$$

in which l_o is the length of a column, which is the distance from clamping (at the top of the caisson) to the clamping of the steel bar (at the measuring frame) (0.15 m)
E is the elasticity modulus of steel ($210*10^9$ N/m²)
I is the moment of inertia ,given as:

$$I = \frac{1}{12}\,b\,h^3 \qquad [C.3]$$

in which b is the width of the steel bar (0.012 m)
h is the height of the steel bar (0.006 m)

2. Calculation

The length l_o of the steel bars was determined by the height of the caisson and the lay out of the measuring frame attached to the channel (see appendix J). Which resulted in a length l_o = 0.15 m. The cross area of steel bars available was 0.5" x 0.25" = 12 mm x 6 mm.

The flexibility *EI* and the spring constant *k* of one steel bar are given by:

$$EI = 210*10^9\ (N/m^2) * 1/12*0.012*(0.006)^3\ (m^4) = \underline{45.36\ Nm^2}$$

$$k = (12*45.36)/(0.15)\text{^}3 = \underline{161280\ N/m}$$

That gives a maximum displacement *u* for the maximum expected wave force F_w = 50 N:

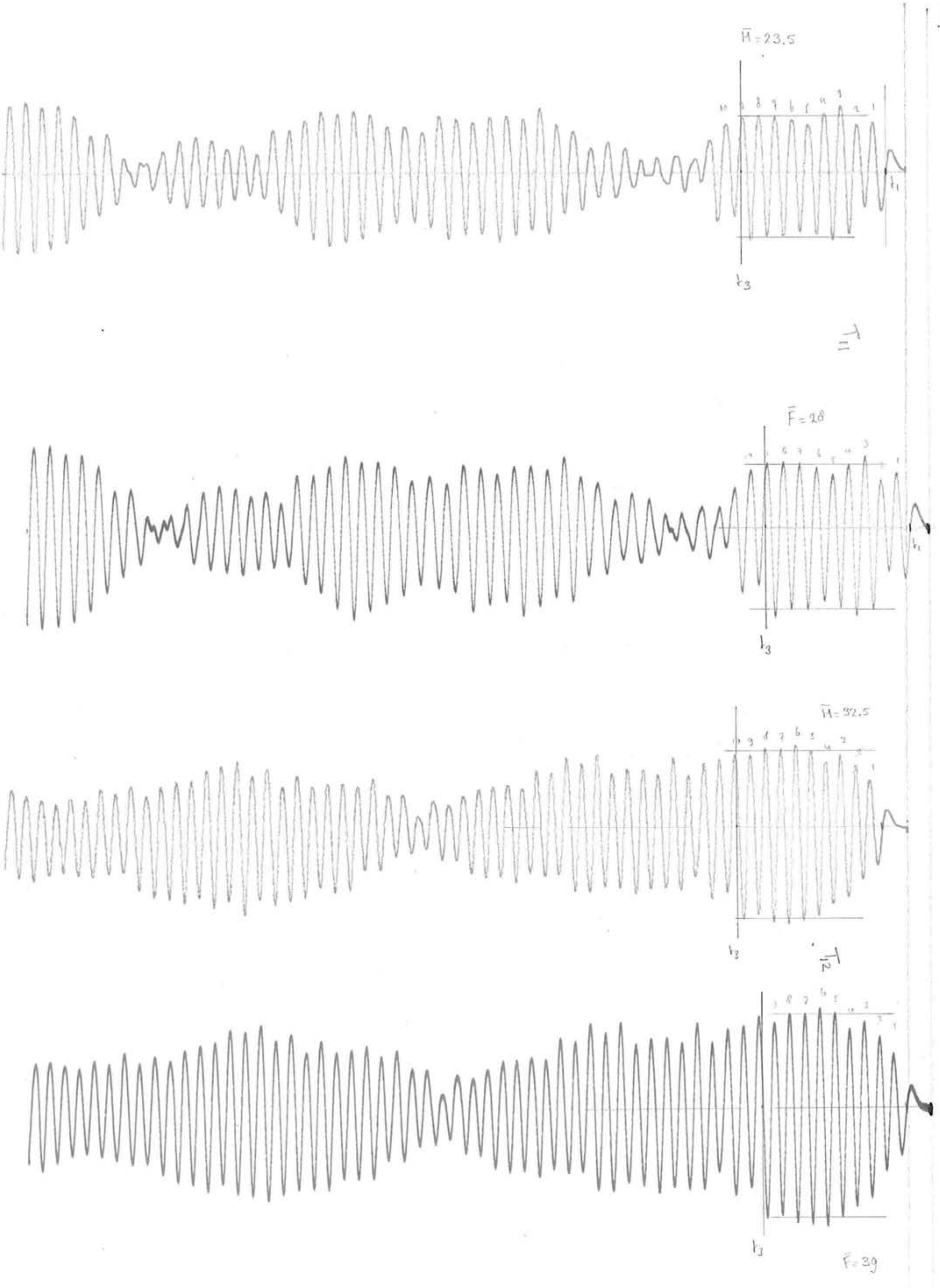
$$u = 50/(2*161280) = \underline{1.55*10^{-4}\ m = 0.15\ mm}$$

Which is sufficient for the strain gauges to measure strain.

APPENDIX D. RESULTS EXPERIMENT 1:

OUTPUT CHART RECORDER

The chart recorder plotted the wave height and the wave load in different colours. It was not possible to copy these graphs properly in black and white. Some output is given for the illustration.


H1
H̄=23.5
t3
TII
F̄=28
t3
H̄=32.5
t3
T2
t3
F=39

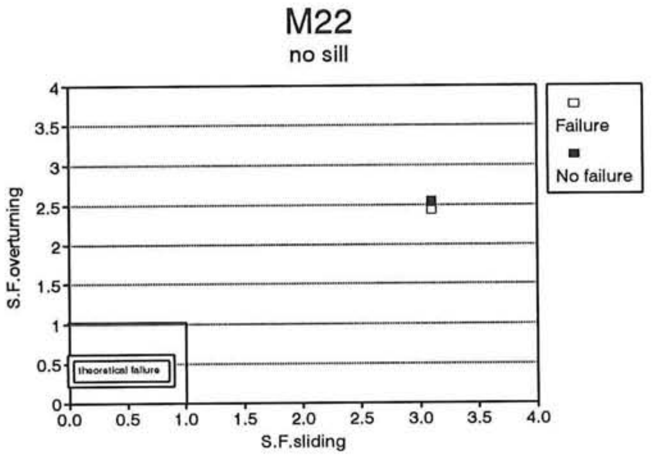
<u>APPENDIX K.</u> <u>RESULTS EXPERIMENT 2:</u>

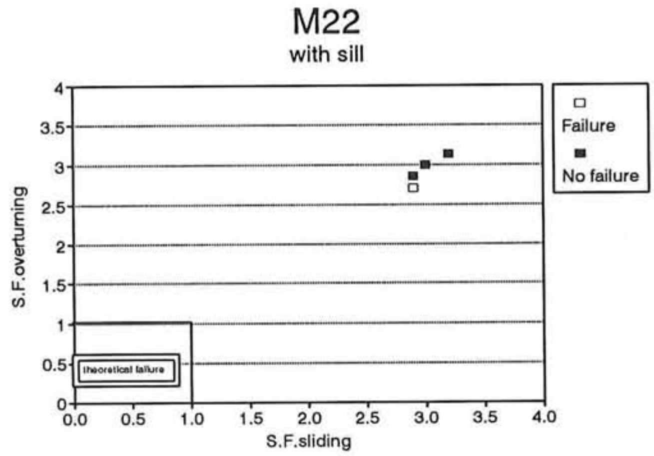
The measurements are given in numbers and graphs. For every wave, characterised by the wave height and the wave period, failure occurred for a certain weight of the caisson. Only for this weight the calculation with the linear wave theory is printed. All these occurrences of failure are plotted in the final graph.

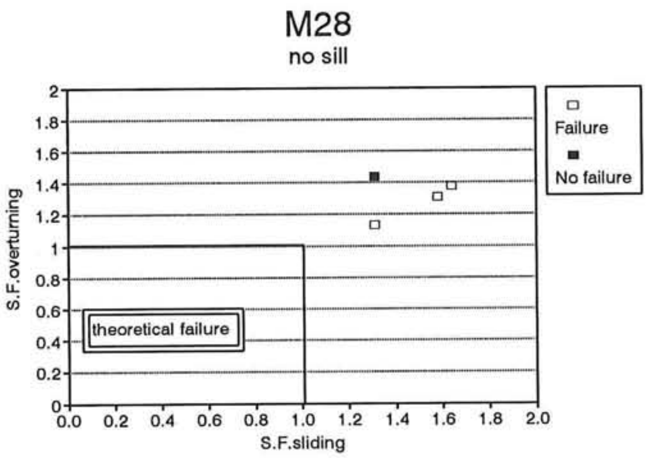
For every measurement is the relation between the weight of the caisson and the safety factors for sliding and overturning given.

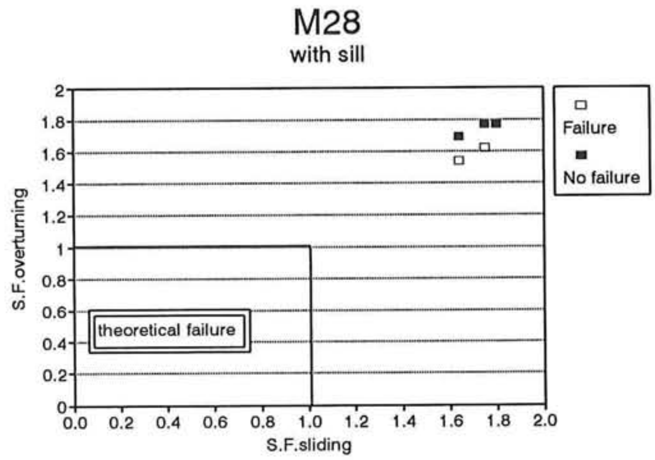
Finally the horizontal dynamic wave force F_w is plotted against the upward normal force N to distinguish the friction coefficient μ.

EXPERIMENT 2 For $\mu = 0.6$

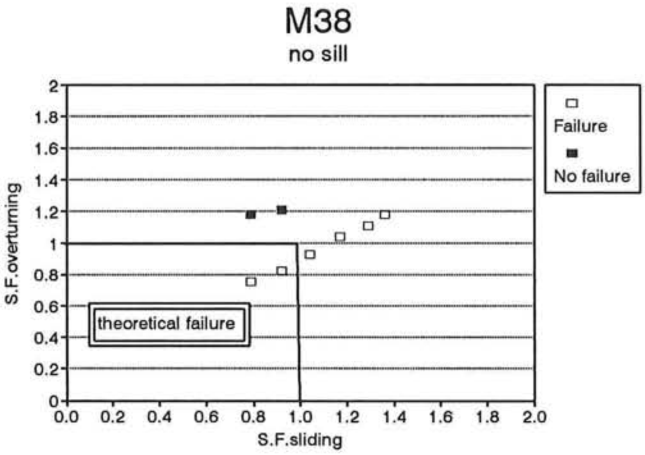


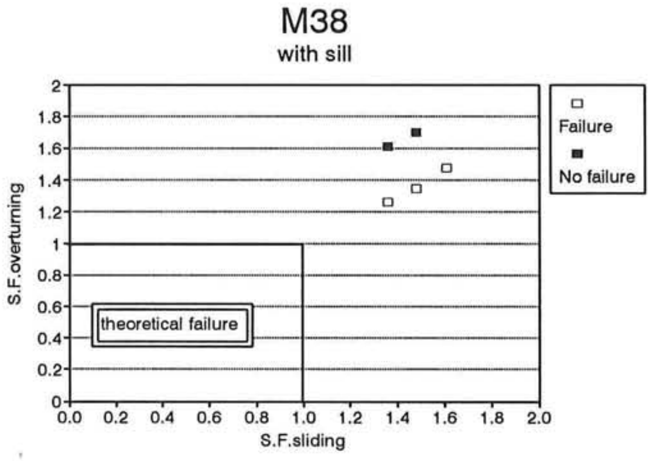


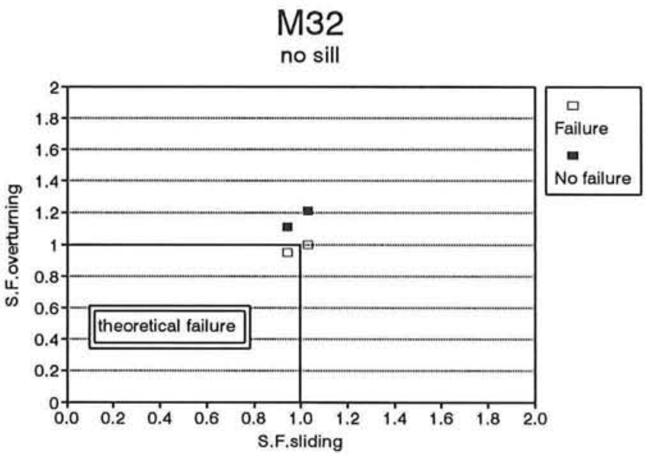


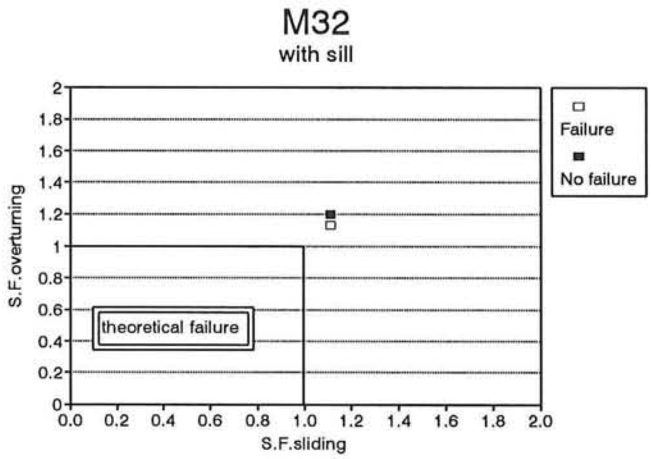


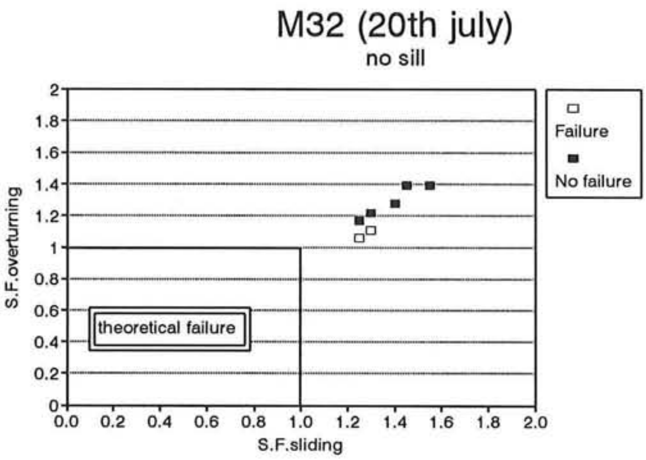
EXPERIMENT 2 For $\mu=0.6$

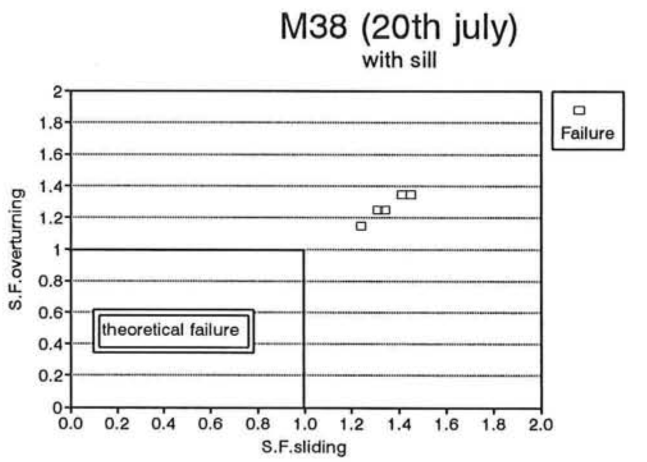




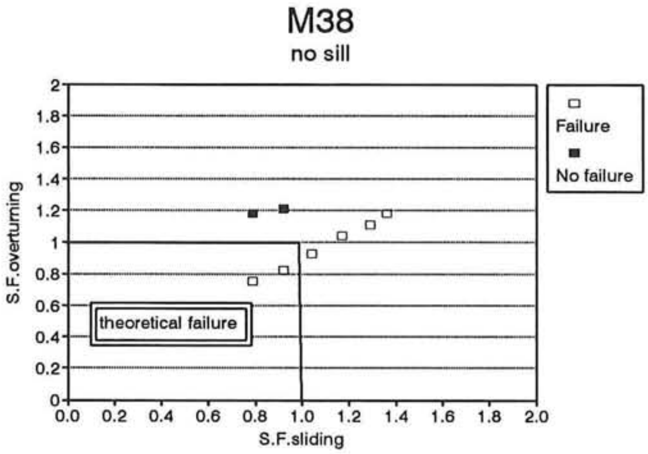




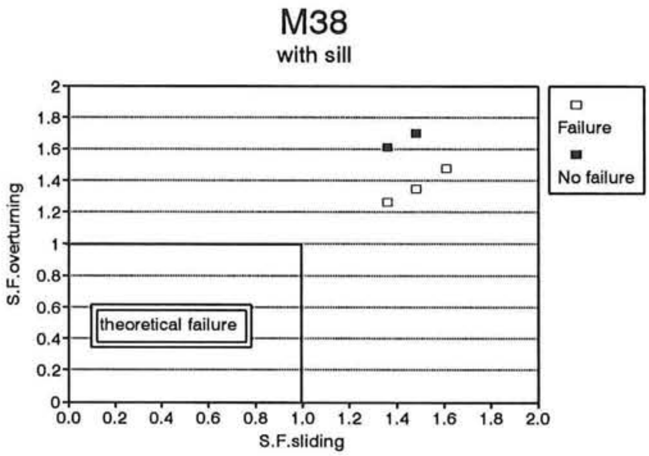




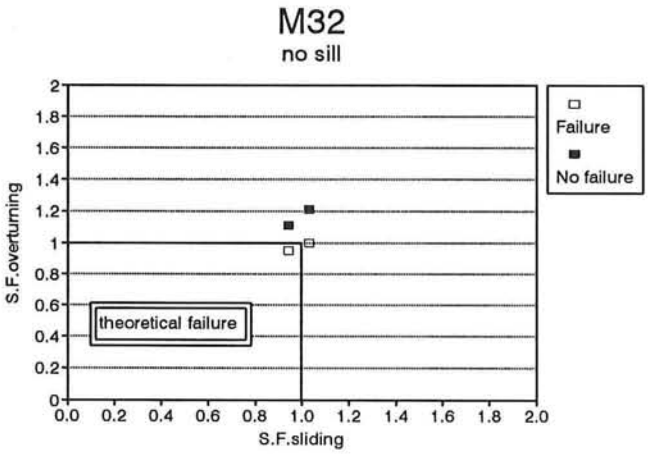
For $\mu = 0.6$



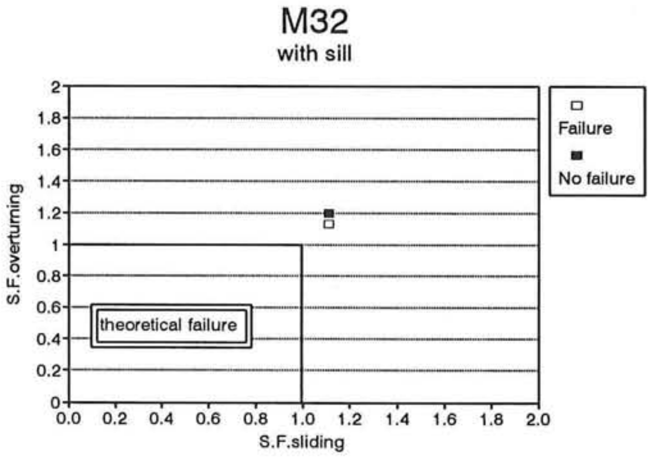
M38
no sill
S.F.overturning
S.F.sliding
Failure
No failure
theoretical failure



M38
with sill
S.F.overturning
S.F.sliding
Failure
No failure
theoretical failure



M32
no sill
S.F.overturning
S.F.sliding
Failure
No failure
theoretical failure



M32
with sill
S.F.overturning
S.F.sliding
Failure
No failure
theoretical failure

EXPERIMENT 2

MEASUREMENTS OF THE 21ST OF JULY:

M38

No sill	W (N)	N (N)	S.F.sliding	S.F.turn	arm_N (m)	Pmax (N/m)
failure	98	25	0.79	0.75	0.028	595
failure	102	29	0.92	0.82	0.017	1137
failure	106	33	1.04	0.93	0.006	3667
failure	110	37	1.17	1.04	0	err
failure	114	41	1.29	1.11	0	err
failure	114	41	1.29	1.11	0	err
failure	116	43	1.36	1.18	0	err
no failure	117	44	1.39	1.18	0	err
no failure	118	45	1.42	1.21	0	err

With sill	W (N)	N (N)	S.F.sliding	S.F.turn	arm_N (m)	Pmax (N/m)
failure	110	43	1.36	1.26	0	err
no failure	114	47	1.48	1.35	0	err
failure	118	51	1.61	1.48	0	err
no failure	122	55	1.74	1.61	0	err
no failure	126	59	1.86	1.7	0	err

M32

No sill	W (N)	N (N)	S.F.sliding	S.F.turn	arm_N (m)	Pmax (N/m)
failure	94	22	0.94	0.95	0.005	2933
failure	96	24	1.03	1	0	err
no failure	98	26	1.11	1.11	0	err
no failure	102	30	1.29	1.21	0	err

With sill	W (N)	N (N)	S.F.sliding	S.F.turn	arm_N (m)	Pmax (N/m)
failure	93	26	1.11	1.13	0	err
failure	93	26	1.11	1.13	0	err
no failure	94	27	1.16	1.2	0	err
no failure	94	27	1.16	1.2	0	err

MEASUREMENTS OF THE 20TH OF JULY:

M22

No sill	W (N)	N (N)	S.F.sliding	S.F.turn	arm_N (m)	Pmax (N/m)
failure	100	31	3.1	2.44	0	err
failure	100	31	3.1	2.44	0	err
no failure	101	32	3.2	2.56	0	err
no failure	102	33	3.3	2.56	0	err

With sill	W (N)	N (N)	S.F.sliding	S.F.turn	arm_N (m)	Pmax (N/m)
failure	96	29	2.9	2.71	0	err
no failure	97	30	3	2.86	0	err
rocking	99	32	3.2	3	0	err
rocking	100	33	3.3	3.14	0	err

M28

No sill	W (N)	N (N)	S.F.sliding	S.F.turn	arm_N (m)	Pmax (N/m)
failure	94	24	1.31	1.13	0	err
failure	99	29	1.58	1.31	0	err
failure	100	30	1.64	1.38	0	err
no failure	102	32	1.75	1.44	0	err

With sill	W (N)	N (N)	S.F.sliding	S.F.turn	arm_N (m)	Pmax (N/m)
failure	97	30	1.64	1.54	0	err
failure	99	32	1.75	1.62	0	err
no failure	100	33	1.8	1.69	0	err
rocking	101	34	1.85	1.77	0	err
no failure	102	35	1.91	1.77	0	err

M32

No sill	W (N)	N (N)	S.F.sliding	S.F.turn	arm_N (m)	Pmax (N/m)
failure	96	25	1.25	1.06	0	err
failure	97	26	1.3	1.11	0	err
no failure	99	28	1.4	1.17	0	err
no failure	100	29	1.45	1.22	0	err
no failure	102	31	1.55	1.28	0	err
no failure	104	33	1.65	1.39	0	err
no failure	105	34	1.7	1.39	0	err

M38

With sill	W (N)	N (N)	S.F.sliding	S.F.turn	arm_N (m)	Pmax (N/m)
failure	102	35	1.24	1.15	0	err
failure	104	37	1.31	1.25	0	err
failure	105	38	1.34	1.25	0	err
failure	107	40	1.41	1.35	0	err
failure	108	41	1.45	1.35	0	err

M_{22} - no sill

LINEAR WAVE THEORY			(R=50)					
Geometric-scale		75		(slope foreshore=1:100)				
Water-scale		1.03						
Rho_c-scale		0.561086						
	Prototype		Model					
			Scaling	Formulae				
Length	22.5	m	0.3					
Hd	0.975	m	0.013					
h	14.4	m	0.192					
d	12.9	m	0.172					
hc	4.6	m	0.061					
h_caisson	19	m	0.253					
h_overtop	15.4	m	0.205		T32	T22	T38	T28
f	0.11	Hz	0.95	0.93	0.52	0.63	0.92	0.93
T	9.3	s	1.07		1.91	1.59	1.09	1.07
L0	135	m	1.8	1.788	5.695815	3.947148	1.854992	1.787544
h/L0	0.106667	-		0.107383	0.033709	0.048643	0.103504	0.10741
h/l0	0.106887	-		0.107896	0.033697	0.048624	0.103522	0.10741
L	98	m	1.307	1.299	2.529	2.071	1.333	1.302683
kh	0.923244	-		0.928693	0.477015	0.582507	0.905005	0.926067
kd	0.827072	-		0.831954	0.427326	0.521829	0.810734	0.829602
sinhkh	1.060107	-		1.068064	0.495312	0.616012	1.033702	1.064226
sinhk(h-d)	0.09632	-		0.09689	0.04971	0.060715	0.094411	0.096615
coshkh	1.457336	-		1.463134	1.115946	1.174509	1.438242	1.460334
coshk(h-d)	1.004628	-		1.004683	1.001235	1.001841	1.004447	1.004656
coshkd	1.361971	-		1.366501	1.092702	1.139271	1.347045	1.364314
tanhkh	0.727428	-		0.729984	0.44385	0.524485	0.718726	0.728755
c	10.6	m/s		1.22	1.3	1.3	1.2	1.21746
rho_w	1030	kg/m^3	1000	1000				
rho_c	1240	kg/m^3	2210	2210	1060	1100	1260	2230
					T32	T22	T38	T28
SLIDING			Scaling	Formulae	1.91	1.59	1.09	1.07
p+1	220	kN/m'	38	38	38	38	38	38
p+3	150	kN/m'	26	26	34	33	27	26
p+4	0	kN/m'	0	0	0	0	0	0
pu	150	kN/m'	26	26	34	33	27	26
p_up	2930	kN/m'	506	506	506	506	506	506
p_weight	4790	kN/m'	1518	1515	1515	1515	1515	1515
Fw1	2290	kN	5	5	6	6	5	5
Fw2	110	kN	0	0	0	0	0	0
Fw	2400	kN	6	5	6	6	5	5
W	48090	kN	203	200	96	100	114	202
N'	750	kN	2	2	2	2	0	2
N	18040	kN	76	131	27	31	47	133
Uplift	29300	kN	67	67	67	67	67	67
mu	0.6	-	0.6	0.6	0.6	0.6	0.6	0.6
Ff	10820	kN	46	78.6	16.2	18.6	28.2	79.8
S.F.sliding	4.51		7.67	15.72	2.7	3.1	5.64	15.96
b	10	m	0.133	0.133	0.133	0.133	0.133	0.133
OVERTURNING in heel								
arm_Fw1.1	6.5	m	0.087	0.086	0.086	0.086	0.086	0.086
arm_Fw1.2	8.6	m	0.115	0.115	0.115	0.115	0.115	0.115
arm_Fw2.1	15.2	m	0.203	0.203	0.203	0.203	0.203	0.203
arm_Fw2.2	14.4	m	0.192	0.192	0.192	0.192	0.192	0.192
arm_U	5	m	0.067	0.067	0.067	0.067	0.067	0.067
arm_W	5	m	0.067	0.067	0.067	0.067	0.067	0.067
arm_N'	6.7	m	0.089	0.089	0.089	0.089	0.089	0.089
arm_N	0	m	0	0	0	0	0	0
b/3	3.3	m	0.044	0.044	0.044	0.044	0.044	0.044
Fw1.1	1935	kN	4	4	6	6	5	4
Fw1.2	451.5	kN	1	1	0	0	1	1
Fw1.	2386.5	kN	5	5	6	6	6	5
Fw2.1	0	kN	0	0	0	0	0	0
Fw2.2	107	kN	0	1	1	1	1	1
Overestimation Fw:								
	1.04214							
M_Fw1.1	12578	kNm	0.4	0.3	0.5	0.5	0.4	0.3
M_Fw1.2	3883	kNm	0.1	0.1	0	0	0.1	0.1
M_Fw2.1	0	kNm	0	0	0	0	0	0
M_Fw2.2	1541	kNm	0	0.2	0.2	0.2	0.2	0.2
M_Fw	18000	kNm	0.6	0.6	0.7	0.7	0.7	0.6
M_uplift	146500	kNm	4.5	4.5	4.5	4.5	4.5	4.5
M_W	-240450	kNm	-13.5	-13.4	-6.4	-6.7	-7.6	-13.5
M_N'	5025	kNm	0.2	0.2	0.2	0.2	0	0.2
M_N	0	kNm	0	0	0	0	0	0
S.F.overt	4.08		11.25	11.13	2.11	2.44	4.43	11.25
pmax	ERR	kN/m'<	13500	kN/m' (prototype)				
	ERR	N/m' <	4280	N/m' (mod	ERR	ERR	ERR	ERR

M_{22} - with sill

LINEAR WAVE THEORY			(R=50)					
Geometric-scale		75		(slope foreshore=1:100)				
Water-scale		1.03						
Rho_c-scale		0.561086						
	Prototype		Model					
			Scaling	Formulae				
Length	22.5	m	0.3					
Hd	0.975	m	0.013					
h	14.4	m	0.192					
d	12.9	m	0.172					
hc	4.6	m	0.061					
h_caisson	19	m	0.253					
h_overtop	15.4	m	0.205		T32	T22	T38	T28
f	0.11	Hz	0.95	0.93	0.52	0.63	0.92	0.93
T	9.3	s	1.07		1.91	1.59	1.09	1.07
L0	135	m	1.8	1.788	5.695815	3.947148	1.854992	1.787544
h/L0	0.106667	-		0.107383	0.033709	0.048643	0.103504	0.10741
h/l0	0.106887	-		0.107896	0.033697	0.048624	0.103522	0.10741
L	98	m	1.307	1.299	2.529	2.071	1.333	1.302683
kh	0.923244	-		0.928693	0.477015	0.582507	0.905005	0.926067
kd	0.827072	-		0.831954	0.427326	0.521829	0.810734	0.829602
sinhkh	1.060107	-		1.068064	0.495312	0.616012	1.033702	1.064226
sinhk(h-d)	0.09632	-		0.09689	0.04971	0.060715	0.094411	0.096615
coshkh	1.457336	-		1.463134	1.115946	1.174509	1.438242	1.460334
coshk(h-d)	1.004628	-		1.004683	1.001235	1.001841	1.004447	1.004656
coshkd	1.361971	-		1.366501	1.092702	1.139271	1.347045	1.364314
tanhkh	0.727428	-		0.729984	0.44385	0.524485	0.718726	0.728755
c	10.6	m/s		1.22	1.3	1.3	1.2	1.21746
rho_w	1030	kg/m^3	1000	1000				
rho_c	1240	kg/m^3	2210	2210	1060	1060	1260	2230
					T32	T22	T38	T28
SLIDING			Scaling	Formulae	1.91	1.59	1.09	1.07
p+1	220	kN/m'	38	38	38	38	38	38
p+3	150	kN/m'	26	26	34	33	27	26
p+4	0	kN/m'	0	0	0	0	0	0
pu	150	kN/m'	26	26	34	33	27	26
p_up	2930	kN/m'	506	506	506	506	506	506
p_weight	4790	kN/m'	1518	1515	1515	1515	1515	1515
Fw1	2290	kN	5	5	6	6	5	5
Fw2	110	kN	0	0	0	0	0	0
Fw	2400	kN	6	5	6	6	5	5
W	48090	kN	203	200	96	96	114	202
N'	750	kN	2	2	2	0	0	2
N	18040	kN	76	131	27	29	47	133
Uplift	29300	kN	67	67	67	67	67	67
mu	0.6	-	0.6	0.6	0.6	0.6	0.6	0.6
Ff	10820	kN	46	78.6	16.2	17.4	28.2	79.8
S.F.sliding	4.51		7.67	15.72	2.7	2.9	5.64	15.96
b	10	m	0.133	0.133	0.133	0.133	0.133	0.133
OVERTURNING in heel								
arm_Fw1.1	6.5	m	0.087	0.086	0.086	0.086	0.086	0.086
arm_Fw1.2	8.6	m	0.115	0.115	0.115	0.115	0.115	0.115
arm_Fw2.1	15.2	m	0.203	0.203	0.203	0.203	0.203	0.203
arm_Fw2.2	14.4	m	0.192	0.192	0.192	0.192	0.192	0.192
arm_U	5	m	0.067	0.067	0.067	0.067	0.067	0.067
arm_W	5	m	0.067	0.067	0.067	0.067	0.067	0.067
arm_N'	6.7	m	0.089	0.089	0.089	0.089	0.089	0.089
arm_N	0	m	0	0	0	0	0	0
b/3	3.3	m	0.044	0.044	0.044	0.044	0.044	0.044
Fw1.1	1935	kN	4	4	6	6	5	4
Fw1.2	451.5	kN	1	1	0	0	1	1
Fw1.	2386.5	kN	5	5	6	6	6	5
Fw2.1	0	kN	0	0	0	0	0	0
Fw2.2	107	kN	0	1	1	1	1	1
Overestimation Fw:								
	1.04214							
M_Fw1.1	12578	kNm	0.4	0.3	0.5	0.5	0.4	0.3
M_Fw1.2	3883	kNm	0.1	0.1	0	0	0.1	0.1
M_Fw2.1	0	kNm	0	0	0	0	0	0
M_Fw2.2	1541	kNm	0	0.2	0.2	0.2	0.2	0.2
M_Fw	18000	kNm	0.6	0.6	0.7	0.7	0.7	0.6
M_uplift	146500	kNm	4.5	4.5	4.5	4.5	4.5	4.5
M_W	-240450	kNm	-13.5	-13.4	-6.4	-6.4	-7.6	-13.5
M_N'	5025	kNm	0.2	0.2	0.2	0	0	0.2
M_N	0	kNm	0	0	0	0	0	0
S.F.overt	4.08		11.25	11.13	2.11	2.71	4.43	11.25
pmax	ERR	kN/m'<	13500	kN/m' (prototype)				
	ERR	N/m' <	4280	N/m' (mod	ERR	ERR	ERR	ERR

M28 - no sill

LINEAR WAVE THEORY (R=50)
Geometric-scale 75 (slope foreshore=1:100)
Water-scale 1.03
Rho_c-scale 0.561086

	Prototype		Model Scaling	Formulae	T32	T22	T38	T28	
Length	22.5	m	0.3						m
Hd	1.8	m	0.024						m
h	14.4	m	0.192						m
d	12.9	m	0.172						m
hc	4.6	m	0.061						m
h_caisson	19	m	0.253						m
h_overtop	16.2	m	0.216						m
f	0.11	Hz	0.95	0.93	0.52	0.63	0.92	0.93	Hz
T	9.3	s	1.07		1.91	1.59	1.09	1.07	s
L0	135	m	1.8	1.788	5.695815	3.947148	1.854992	1.787544	m
h/L0	0.106667	-		0.107383	0.033709	0.048643	0.103504	0.10741	-
h/l0	0.106887	-		0.107896	0.033697	0.048624	0.103522	0.10741	-
L	98	m	1.307	1.299	2.529	2.071	1.333	1.302683	m
kh	0.923244	-		0.928693	0.477015	0.582507	0.905005	0.926067	-
kd	0.827072	-		0.831954	0.427326	0.521829	0.810734	0.829602	-
sinhkh	1.060107	-		1.068064	0.495312	0.616012	1.033702	1.064226	-
sinhk(h-d)	0.09632	-		0.09689	0.04971	0.060715	0.094411	0.096615	-
coshkh	1.457336	-		1.463134	1.115946	1.174509	1.438242	1.460334	-
coshk(h-d)	1.004628	-		1.004683	1.001235	1.001841	1.004447	1.004656	-
coshkd	1.361971	-		1.366501	1.092702	1.139271	1.347045	1.364314	-
tanhkh	0.727428	-		0.729984	0.44385	0.524485	0.718726	0.728755	-
c	10.6	m/s		1.22	1.3	1.3	1.2	1.21746	m/s
rho_w	1030	kg/m^3	1000	1000					kg/m^3
rho_c	1240	kg/m^3	2210	2210	1060	1100	1260	1100	kg/m^3
					T32	T22	T38	T28	
SLIDING			Scaling	Formulae	1.91	1.59	1.09	1.07	
p+1	410	kN/m'	71	71	71	71	71	71	N/m
p+3	280	kN/m'	48	49	63	60	49	49	N/m
p+4	0	kN/m'	0	0	0	0	0	0	N/m
pu	280	kN/m'	48	49	63	60	49	49	N/m
p_up	2930	kN/m'	506	506	506	506	506	506	N/m
p_weight	4790	kN/m'	1518	1515	1515	1515	1515	1515	N/m
Fw1	4220	kN	10	10	11	11	10	10	N
Fw2	370	kN	1	1	1	1	1	1	N
Fw	4590	kN	11	11	12	12	11	11	N
W	48090	kN	203	200	96	100	114	100	N
N'	1400	kN	3	3	4	4	0	3	N
N	17390	kN	73	130	25	29	47	30	N
Uplift	29300	kN	67	67	67	67	67	67	N
mu	0.6	-	0.6	0.6	0.6	0.6	0.6	0.6	-
Ff	10430	kN	44	78	15	17.4	28.2	18	N
S.F.sliding	2.27		4	7.09	1.25	1.45	2.56	1.64	
b	10	m	0.133	0.133	0.133	0.133	0.133	0.133	m
OVERTURNING in heel									
arm_Fw1.1	6.5	m	0.087	0.086	0.086	0.086	0.086	0.086	m
arm_Fw1.2	8.6	m	0.115	0.115	0.115	0.115	0.115	0.115	m
arm_Fw2.1	15.2	m	0.203	0.203	0.203	0.203	0.203	0.203	m
arm_Fw2.2	14.4	m	0.192	0.192	0.192	0.192	0.192	0.192	m
arm_U	5	m	0.067	0.067	0.067	0.067	0.067	0.067	m
arm_W	5	m	0.067	0.067	0.067	0.067	0.067	0.067	m
arm_N'	6.7	m	0.089	0.089	0.089	0.089	0.089	0.089	m
arm_N	0	m	0	0	0	0	0	0	m
b/3	3.3	m	0.044	0.044	0.044	0.044	0.044	0.044	m
Fw1.1	3612	kN	8	8	11	10	8	8	N
Fw1.2	838.5	kN	2	2	1	1	2	2	N
Fw1.	4450.5	kN	10	10	12	11	10	10	N
Fw2.1	0	kN	0	0	0	0	0	0	N
Fw2.2	369	kN	1	2	2	2	2	2	N
Overestimation Fw:									
	1.054621								
M_Fw1.1	23478	kNm	0.7	0.7	0.9	0.9	0.7	0.7	Nm
M_Fw1.2	7211	kNm	0.2	0.2	0.1	0.1	0.2	0.2	Nm
M_Fw2.1	0	kNm	0	0	0	0	0	0	Nm
M_Fw2.2	5314	kNm	0.2	0.4	0.4	0.4	0.4	0.4	Nm
M_Fw	36000	kNm	1.1	1.3	1.4	1.4	1.3	1.3	Nm
M_uplift	146500	kNm	4.5	4.5	4.5	4.5	4.5	4.5	Nm
M_W	-240450	kNm	-13.5	-13.4	-6.4	-6.7	-7.6	-6.7	Nm
M_N'	9380	kNm	0.3	0.3	0.4	0.4	0	0.3	Nm
M_N	0	kNm	0	0	0	0	0	0	Nm
S.F.overt	2.07		6.43	5.56	1.06	1.22	2.38	1.38	-
pmax	ERR	kN/m'<	13500	kN/m' (prototype)					
	ERR	N/m' <	4280	N/m' (mod	ERR	ERR	ERR	ERR	

M_{28} - with sill

LINEAR WAVE THEORY			(R=50)						
Geometric-scale		75		(slope foreshore=1:100)					
Water-scale		1.03							
Rho_c-scale		0.561086							
	Prototype		Model						
			Scaling	Formulae					
Length	22.5	m	0.3						m
Hd	1.8	m	0.024						m
h	14.4	m	0.192						m
d	12.9	m	0.172						m
hc	4.6	m	0.061						m
h_caisson	19	m	0.253						m
h_overtop	16.2	m	0.216		T32	T22	T38	T28	m
f	0.11	Hz	0.95	0.93	0.52	0.63	0.92	0.93	Hz
T	9.3	s	1.07		1.91	1.59	1.09	1.07	s
L0	135	m	1.8	1.788	5.695815	3.947148	1.854992	1.787544	m
h/L0	0.106667	-		0.107383	0.033709	0.048643	0.103504	0.10741	-
h/l0	0.106887	-		0.107896	0.033697	0.048624	0.103522	0.10741	-
L	98	m	1.307	1.299	2.529	2.071	1.333	1.302683	m
kh	0.923244	-		0.928693	0.477015	0.582507	0.905005	0.926067	-
kd	0.827072	-		0.831954	0.427326	0.521829	0.810734	0.829602	-
sinhkh	1.060107	-		1.068064	0.495312	0.616012	1.033702	1.064226	-
sinhk(h-d)	0.09632	-		0.09689	0.04971	0.060715	0.094411	0.096615	-
coshkh	1.457336	-		1.463134	1.115946	1.174509	1.438242	1.460334	-
coshk(h-d)	1.004628	-		1.004683	1.001235	1.001841	1.004447	1.004656	-
coshkd	1.361971	-		1.366501	1.092702	1.139271	1.347045	1.364314	-
tanhkh	0.727428	-		0.729984	0.44385	0.524485	0.718726	0.728755	
c	10.6	m/s		1.22	1.3	1.3	1.2	1.21746	m/s
rho_w	1030	kg/m^3	1000	1000					kg/m^3
rho_c	1240	kg/m^3	2210	2210	1060	1100	1260	1100	kg/m^3
					T32	T22	T38	T28	
SLIDING			Scaling	Formulae	1.91	1.59	1.09	1.07	
p+1	410	kN/m'	71	71	71	71	71	71	N/m
p+3	280	kN/m'	48	49	63	60	49	49	N/m
p+4	0	kN/m'	0	0	0	0	0	0	N/m
pu	280	kN/m'	48	49	63	60	49	49	N/m
p_up	2930	kN/m'	506	506	506	506	506	506	N/m
p_weight	4790	kN/m'	1518	1515	1515	1515	1515	1515	N/m
Fw1	4220	kN	10	10	11	11	10	10	N
Fw2	370	kN	1	1	1	1	1	1	N
Fw	4590	kN	11	11	12	12	11	11	N
W	48090	kN	203	200	96	100	114	100	N
N'	1400	kN	3	3	4	4	0	0	N
N	17390	kN	73	130	25	29	47	33	N
Uplift	29300	kN	67	67	67	67	67	67	N
mu	0.6	-	0.6	0.6	0.6	0.6	0.6	0.6	-
Ff	10430	kN	44	78	15	17.4	28.2	19.8	N
S.F.sliding	2.27		4	7.09	1.25	1.45	2.56	1.8	
b	10	m	0.133	0.133	0.133	0.133	0.133	0.133	m
OVERTURNING in heel									
arm_Fw1.1	6.5	m	0.087	0.086	0.086	0.086	0.086	0.086	m
arm_Fw1.2	8.6	m	0.115	0.115	0.115	0.115	0.115	0.115	m
arm_Fw2.1	15.2	m	0.203	0.203	0.203	0.203	0.203	0.203	m
arm_Fw2.2	14.4	m	0.192	0.192	0.192	0.192	0.192	0.192	m
arm_U	5	m	0.067	0.067	0.067	0.067	0.067	0.067	m
arm_W	5	m	0.067	0.067	0.067	0.067	0.067	0.067	m
arm_N'	6.7	m	0.089	0.089	0.089	0.089	0.089	0.089	m
arm_N	0	m	0	0	0	0	0	0	m
b/3	3.3	m	0.044	0.044	0.044	0.044	0.044	0.044	m
Fw1.1	3612	kN	8	8	11	10	8	8	N
Fw1.2	838.5	kN	2	2	1	1	2	2	N
Fw1.	4450.5	kN	10	10	12	11	10	10	N
Fw2.1	0	kN	0	0	0	0	0	0	N
Fw2.2	369	kN	1	2	2	2	2	2	N
Overestimation Fw:									
	1.054621								
M_Fw1.1	23478	kNm	0.7	0.7	0.9	0.9	0.7	0.7	Nm
M_Fw1.2	7211	kNm	0.2	0.2	0.1	0.1	0.2	0.2	Nm
M_Fw2.1	0	kNm	0	0	0	0	0	0	Nm
M_Fw2.2	5314	kNm	0.2	0.4	0.4	0.4	0.4	0.4	Nm
M_Fw	36000	kNm	1.1	1.3	1.4	1.4	1.3	1.3	Nm
M_uplift	146500	kNm	4.5	4.5	4.5	4.5	4.5	4.5	Nm
M_W	-240450	kNm	-13.5	-13.4	-6.4	-6.7	-7.6	-6.7	Nm
M_N'	9380	kNm	0.3	0.3	0.4	0.4	0	0	Nm
M_N	0	kNm	0	0	0	0	0	0	Nm
S.F.overt	2.07		6.43	5.56	1.06	1.22	2.38	1.69	-
pmax	ERR	kN/m'<	13500	kN/m' (prototype)					
	ERR	N/m' <	4280	N/m' (mod	ERR	ERR	ERR	ERR	

M_{32} - no sill *

LINEAR WAVE THEORY			(R=50)						
Geometric-scale		75		(slope foreshore=1:100)					
Water-scale		1.03							
Rho_c-scale		0.561086							
	Prototype		Model						
			Scaling	Formulae					
Length	22.5	m	0.3						m
Hd	1.725	m	0.023						m
h	14.4	m	0.192						m
d	12.9	m	0.172						m
hc	4.6	m	0.061						m
h_caisson	19	m	0.253						m
h_overtop	16.1	m	0.215		T32	T22	T38	T28	m
f	0.11	Hz	0.95	0.93	0.52	0.63	0.92	0.93	Hz
T	9.3	s	1.07		1.91	1.59	1.09	1.07	s
L0	135	m	1.8	1.788	5.695815	3.947148	1.854992	1.787544	m
h/L0	0.106667	-		0.107383	0.033709	0.048643	0.103504	0.10741	-
h/l0	0.106887	-		0.107896	0.033697	0.048624	0.103522	0.10741	-
L	98	m	1.307	1.299	2.529	2.071	1.333	1.302683	m
kh	0.923244	-		0.928693	0.477015	0.582507	0.905005	0.926067	-
kd	0.827072	-		0.831954	0.427326	0.521829	0.810734	0.829602	-
sinhkh	1.060107	-		1.068064	0.495312	0.616012	1.033702	1.064226	-
sinhk(h-d)	0.09632	-		0.09689	0.04971	0.060715	0.094411	0.096615	-
coshkh	1.457336	-		1.463134	1.115946	1.174509	1.438242	1.460334	-
coshk(h-d)	1.004628	-		1.004683	1.001235	1.001841	1.004447	1.004656	-
coshkd	1.361971	-		1.366501	1.092702	1.139271	1.347045	1.364314	-
tanhkh	0.727428	-		0.729984	0.44385	0.524485	0.718726	0.728755	
c	10.6	m/s		1.22	1.3	1.3	1.2	1.21746	m/s
rho_w	1030	kg/m^3	1000	1000					kg/m^3
rho_c	1240	kg/m^3	2210	2210	1070	1100	1260	1100	kg/m^3
					T32	T22	T38	T28	
SLIDING			Scaling	Formulae	1.91	1.59	1.09	1.07	
p+1	390	kN/m'	67	68	68	68	68	68	N/m
p+3	270	kN/m'	47	46	61	58	47	47	N/m
p+4	0	kN/m'	0	0	0	0	0	0	N/m
pu	270	kN/m'	47	46	61	58	47	47	N/m
p_up	2930	kN/m'	506	506	506	506	506	506	N/m
p_weight	4790	kN/m'	1518	1515	1515	1515	1515	1515	N/m
Fw1	4050	kN	9	9	11	11	9	9	N
Fw2	340	kN	1	1	1	1	1	1	N
Fw	4390	kN	10	10	12	12	10	10	N
W	48090	kN	203	200	97	100	114	100	N
N'	1350	kN	3	3	4	4	0	3	N
N	17440	kN	74	130	26	29	47	30	N
Uplift	29300	kN	67	67	67	67	67	67	N
mu	0.6	-	0.6	0.6	0.6	0.6	0.6	0.6	-
Ff	10460	kN	44	78	15.6	17.4	28.2	18	N
S.F.sliding	2.38		4.4	7.8	1.3	1.45	2.82	1.8	
b	10	m	0.133	0.133	0.133	0.133	0.133	0.133	m
OVERTURNING in heel									
arm_Fw1.1	6.5	m	0.087	0.086	0.086	0.086	0.086	0.086	m
arm_Fw1.2	8.6	m	0.115	0.115	0.115	0.115	0.115	0.115	m
arm_Fw2.1	15.2	m	0.203	0.203	0.203	0.203	0.203	0.203	m
arm_Fw2.2	14.4	m	0.192	0.192	0.192	0.192	0.192	0.192	m
arm_U	5	m	0.067	0.067	0.067	0.067	0.067	0.067	m
arm_W	5	m	0.067	0.067	0.067	0.067	0.067	0.067	m
arm_N'	6.7	m	0.089	0.089	0.089	0.089	0.089	0.089	m
arm_N	0	m	0	0	0	0	0	0	m
b/3	3.3	m	0.044	0.044	0.044	0.044	0.044	0.044	m
Fw1.1	3483	kN	8	8	10	10	8	8	N
Fw1.2	774	kN	2	2	1	1	2	2	N
Fw1.	4257	kN	10	10	11	11	10	10	N
Fw2.1	0	kN	0	0	0	0	0	0	N
Fw2.2	336	kN	1	2	2	2	2	2	N
Overestimation Fw:									
	1.051111								
M_Fw1.1	22640	kNm	0.7	0.7	0.9	0.9	0.7	0.7	Nm
M_Fw1.2	6656	kNm	0.2	0.2	0.1	0.1	0.2	0.2	Nm
M_Fw2.1	0	kNm	0	0	0	0	0	0	Nm
M_Fw2.2	4838	kNm	0.1	0.4	0.4	0.4	0.4	0.4	Nm
M_Fw	34130	kNm	1	1.3	1.4	1.4	1.3	1.3	Nm
M_uplift	146500	kNm	4.5	4.5	4.5	4.5	4.5	4.5	Nm
M_W	-240450	kNm	-13.5	-13.4	-6.5	-6.7	-7.6	-6.7	Nm
M_N'	9045	kNm	0.3	0.3	0.4	0.4	0	0.3	Nm
M_N	0	kNm	0	0	0	0	0	0	Nm
S.F.overt	2.18		6.92	5.56	1.11	1.22	2.38	1.38	-
pmax	ERR	kN/m'<	13500	kN/m' (pro					
	ERR	N/m' <	4280	N/m' (mod	ERR	ERR	ERR	ERR	

M32 - no sill

LINEAR WAVE THEORY			(R=50)					
Geometric-scale		75		(slope foreshore=1:100)				
Water-scale		1.03						
Rho_c-scale		0.561086						
	Prototype		Model					
			Scaling	Formulae				
Length	22.5	m	0.3					
Hd	2.025	m	0.027					
h	14.4	m	0.192					
d	12.9	m	0.172					
hc	4.6	m	0.061					
h_caisson	19	m	0.253					
h_overtop	16.4	m	0.219		T32	T22	T38	T28
f	0.11	Hz	0.95	0.93	0.52	0.63	0.92	0.93
T	9.3	s	1.07		1.91	1.59	1.09	1.07
L0	135	m	1.8	1.788	5.695815	3.947148	1.854992	1.787544
h/L0	0.106667	-		0.107383	0.033709	0.048643	0.103504	0.10741
h/l0	0.106887	-		0.107896	0.033697	0.048624	0.103522	0.10741
L	98	m	1.307	1.299	2.529	2.071	1.333	1.302683
kh	0.923244	-		0.928693	0.477015	0.582507	0.905005	0.926067
kd	0.827072	-		0.831954	0.427326	0.521829	0.810734	0.829602
sinhkh	1.060107	-		1.068064	0.495312	0.616012	1.033702	1.064226
sinhk(h-d)	0.09632	-		0.09689	0.04971	0.060715	0.094411	0.096615
coshkh	1.457336	-		1.463134	1.115946	1.174509	1.438242	1.460334
coshk(h-d)	1.004628	-		1.004683	1.001235	1.001841	1.004447	1.004656
coshkd	1.361971	-		1.366501	1.092702	1.139271	1.347045	1.364314
tanhkh	0.727428	-		0.729984	0.44385	0.524485	0.718726	0.728755
c	10.6	m/s		1.22	1.3	1.3	1.2	1.21746
rho_w	1030	kg/m^3	1000	1000				
rho_c	1240	kg/m^3	2210	2210	1060	2230	1260	2230
					T32	T22	T38	T28
SLIDING			Scaling	Formulae	1.91	1.59	1.09	1.07
p+1	460	kN/m'	79	79	79	79	79	79
p+3	320	kN/m'	55	55	71	68	55	55
p+4	0	kN/m'	0	0	0	0	0	0
pu	320	kN/m'	55	55	71	68	55	55
p_up	2930	kN/m'	506	506	506	506	506	506
p_weight	4790	kN/m'	1518	1515	1515	1515	1515	1515
Fw1	4750	kN	11	11	13	12	11	11
Fw2	470	kN	1	1	1	1	1	1
Fw	5220	kN	12	12	14	13	12	12
W	48090	kN	203	200	96	202	114	202
N'	1600	kN	4	4	5	5	0	4
N	17190	kN	73	129	24	130	47	131
Uplift	29300	kN	67	67	67	67	67	67
mu	0.6	-	0.6	0.6	0.6	0.6	0.6	0.6
Ff	10310	kN	44	77.4	14.4	78	28.2	78.6
S.F.sliding	1.98		3.67	6.45	1.03	6	2.35	6.55
b	10	m	0.133	0.133	0.133	0.133	0.133	0.133
OVERTURNING in heel								
arm_Fw1.1	6.5	m	0.087	0.086	0.086	0.086	0.086	0.086
arm_Fw1.2	8.6	m	0.115	0.115	0.115	0.115	0.115	0.115
arm_Fw2.1	15.2	m	0.203	0.203	0.203	0.203	0.203	0.203
arm_Fw2.2	14.4	m	0.192	0.192	0.192	0.192	0.192	0.192
arm_U	5	m	0.067	0.067	0.067	0.067	0.067	0.067
arm_W	5	m	0.067	0.067	0.067	0.067	0.067	0.067
arm_N'	6.7	m	0.089	0.089	0.089	0.089	0.089	0.089
arm_N	0	m	0	0	0	0	0	0
b/3	3.3	m	0.044	0.044	0.044	0.044	0.044	0.044
Fw1.1	4128	kN	9	9	12	12	9	9
Fw1.2	903	kN	2	2	1	1	2	2
Fw1.	5031	kN	11	11	13	13	11	11
Fw2.1	0	kN	0	0	0	0	0	0
Fw2.2	466	kN	1	2	2	2	2	2
Overestimation Fw:								
	1.059158							
M_Fw1.1	26832	kNm	0.8	0.8	1	1	0.8	0.8
M_Fw1.2	7766	kNm	0.2	0.2	0.1	0.1	0.2	0.2
M_Fw2.1	0	kNm	0	0	0	0	0	0
M_Fw2.2	6710	kNm	0.2	0.4	0.4	0.4	0.4	0.4
M_Fw	41310	kNm	1.3	1.4	1.5	1.5	1.4	1.4
M_uplift	146500	kNm	4.5	4.5	4.5	4.5	4.5	4.5
M_W	-240450	kNm	-13.5	-13.4	-6.4	-13.5	-7.6	-13.5
M_N'	10720	kNm	0.3	0.4	0.4	0.4	0	0.4
M_N	0	kNm	0	0	0	0	0	0
S.F.overt	1.81		5.63	4.94	1	4.74	2.21	5
pmax	ERR	kN/m'<	13500	kN/m' (pro				
	ERR	N/m' <	4280	N/m' (mod	ERR	ERR	ERR	ERR

M32 - with sill

LINEAR WAVE THEORY (R=50)

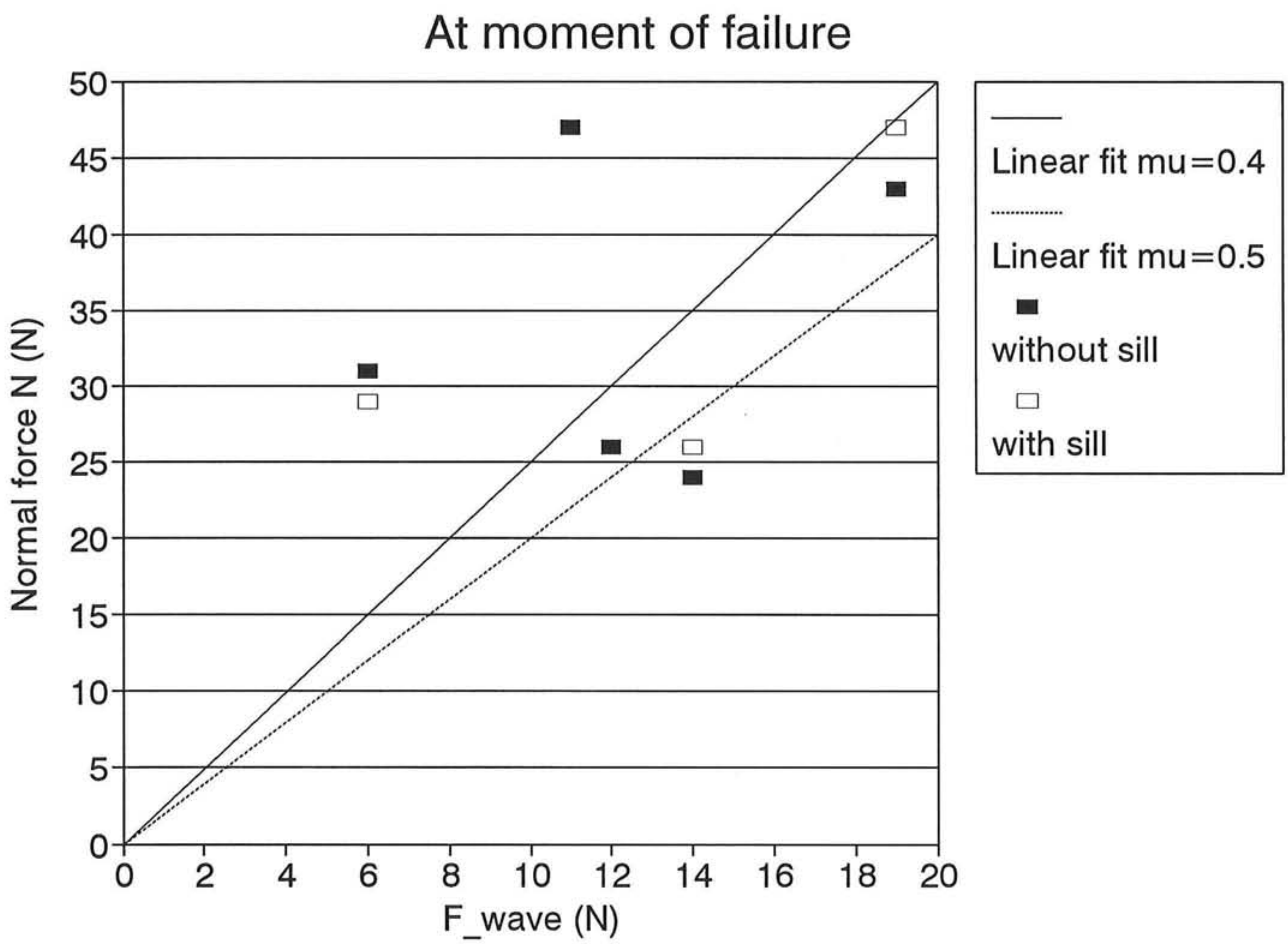
Geometric-scale		75		(slope foreshore=1:100)				
Water-scale		1.03						
Rho_c-scale		0.561086						
	Prototype		Model					
			Scaling	Formulae				
Length	22.5	m	0.3					
Hd	2.025	m	0.027					
h	14.4	m	0.192					
d	12.9	m	0.172					
hc	4.6	m	0.061					
h_caisson	19	m	0.253					
h_overtop	16.4	m	0.219		T32	T22	T38	T28
f	0.11	Hz	0.95	0.93	0.52	0.63	0.92	0.93
T	9.3	s	1.07		1.91	1.59	1.09	1.07
L0	135	m	1.8	1.788	5.695815	3.947148	1.854992	1.787544
h/L0	0.106667	-		0.107383	0.033709	0.048643	0.103504	0.10741
h/l0	0.106887	-		0.107896	0.033697	0.048624	0.103522	0.10741
L	98	m	1.307	1.299	2.529	2.071	1.333	1.302683
kh	0.923244	-		0.928693	0.477015	0.582507	0.905005	0.926067
kd	0.827072	-		0.831954	0.427326	0.521829	0.810734	0.829602
sinhkh	1.060107	-		1.068064	0.495312	0.616012	1.033702	1.064226
sinhk(h-d)	0.09632	-		0.09689	0.04971	0.060715	0.094411	0.096615
coshkh	1.457336	-		1.463134	1.115946	1.174509	1.438242	1.460334
coshk(h-d)	1.004628	-		1.004683	1.001235	1.001841	1.004447	1.004656
coshkd	1.361971	-		1.366501	1.092702	1.139271	1.347045	1.364314
tanhkh	0.727428	-		0.729984	0.44385	0.524485	0.718726	0.728755
c	10.6	m/s		1.22	1.3	1.3	1.2	1.21746
rho_w	1030	kg/m^3	1000	1000				
rho_c	1240	kg/m^3	2210	2210	1030	2230	1260	2230
					T32	T22	T38	T28
SLIDING			Scaling	Formulae	1.91	1.59	1.09	1.07
p+1	460	kN/m'	79	79	79	79	79	79
p+3	320	kN/m'	55	55	71	68	55	55
p+4	0	kN/m'	0	0	0	0	0	0
pu	320	kN/m'	55	55	71	68	55	55
p_up	2930	kN/m'	506	506	506	506	506	506
p_weight	4790	kN/m'	1518	1515	1515	1515	1515	1515
Fw1	4750	kN	11	11	13	12	11	11
Fw2	470	kN	1	1	1	1	1	1
Fw	5220	kN	12	12	14	13	12	12
W	48090	kN	203	200	93	202	114	202
N'	1600	kN	4	4	0	5	0	4
N	17190	kN	73	129	26	130	47	131
Uplift	29300	kN	67	67	67	67	67	67
mu	0.6	-	0.6	0.6	0.6	0.6	0.6	0.6
Ff	10310	kN	44	77.4	15.6	78	28.2	78.6
S.F.sliding	1.98		3.67	6.45	1.11	6	2.35	6.55
b	10	m	0.133	0.133	0.133	0.133	0.133	0.133
OVERTURNING in heel								
arm_Fw1.1	6.5	m	0.087	0.086	0.086	0.086	0.086	0.086
arm_Fw1.2	8.6	m	0.115	0.115	0.115	0.115	0.115	0.115
arm_Fw2.1	15.2	m	0.203	0.203	0.203	0.203	0.203	0.203
arm_Fw2.2	14.4	m	0.192	0.192	0.192	0.192	0.192	0.192
arm_U	5	m	0.067	0.067	0.067	0.067	0.067	0.067
arm_W	5	m	0.067	0.067	0.067	0.067	0.067	0.067
arm_N'	6.7	m	0.089	0.089	0.089	0.089	0.089	0.089
arm_N	0	m	0	0	0	0	0	0
b/3	3.3	m	0.044	0.044	0.044	0.044	0.044	0.044
Fw1.1	4128	kN	9	9	12	12	9	9
Fw1.2	903	kN	2	2	1	1	2	2
Fw1.	5031	kN	11	11	13	13	11	11
Fw2.1	0	kN	0	0	0	0	0	0
Fw2.2	466	kN	1	2	2	2	2	2
Overestimation Fw:								
	1.059158							
M_Fw1.1	26832	kNm	0.8	0.8	1	1	0.8	0.8
M_Fw1.2	7766	kNm	0.2	0.2	0.1	0.1	0.2	0.2
M_Fw2.1	0	kNm	0	0	0	0	0	0
M_Fw2.2	6710	kNm	0.2	0.4	0.4	0.4	0.4	0.4
M_Fw	41310	kNm	1.3	1.4	1.5	1.5	1.4	1.4
M_uplift	146500	kNm	4.5	4.5	4.5	4.5	4.5	4.5
M_W	-240450	kNm	-13.5	-13.4	-6.2	-13.5	-7.6	-13.5
M_N'	10720	kNm	0.3	0.4	0	0.4	0	0.4
M_N	0	kNm	0	0	0	0	0	0
S.F.overt	1.81		5.63	4.94	1.13	4.74	2.21	5
pmax	ERR	kN/m'<	13500	kN/m' (pro				
	ERR	N/m' <	4280	N/m' (mod	ERR	ERR	ERR	ERR

M_{38} - no sill

LINEAR WAVE THEORY			(R=50)					
Geometric-scale		75		(slope foreshore=1:100)				
Water-scale		1.03						
Rho_c-scale		0.574661						
	Prototype		Model					
			Scaling	Formulae				
Length	22.5	m	0.3					
Hd	3.075	m	0.041					
h	14.4	m	0.192					
d	12.9	m	0.172					
hc	4.6	m	0.061					
h_caisson	19	m	0.253					
h_overtop	17.5	m	0.233		T32	T22	T38	T28
f	0.11	Hz	0.95	0.93	0.52	0.63	0.92	0.93
T	9.3	s	1.07		1.91	1.59	1.09	1.07
L0	135	m	1.8	1.788	5.695815	3.947148	1.854992	1.787544
h/L0	0.106667	-		0.107383	0.033709	0.048643	0.103504	0.10741
h/l0	0.106887	-		0.107896	0.033697	0.048624	0.103522	0.10741
L	98	m	1.307	1.299	2.529	2.071	1.333	1.302683
kh	0.923244	-		0.928693	0.477015	0.582507	0.905005	0.926067
kd	0.827072	-		0.831954	0.427326	0.521829	0.810734	0.829602
sinhkh	1.060107	-		1.068064	0.495312	0.616012	1.033702	1.064226
sinhk(h-d)	0.09632	-		0.09689	0.04971	0.060715	0.094411	0.096615
coshkh	1.457336	-		1.463134	1.115946	1.174509	1.438242	1.460334
coshk(h-d)	1.004628	-		1.004683	1.001235	1.001841	1.004447	1.004656
coshkd	1.361971	-		1.366501	1.092702	1.139271	1.347045	1.364314
tanhkh	0.727428	-		0.729984	0.44385	0.524485	0.718726	0.728755
c	10.6	m/s		1.22	1.3	1.3	1.2	1.21746
rho_w	1030	kg/m^3	1000	1000				
rho_c	1270	kg/m^3	2210	2210	1030	2230	1280	2230
					T32	T22	T38	T28
SLIDING			Scaling	Formulae	1.91	1.59	1.09	1.07
p+1	700	kN/m'	121	121	121	121	121	121
p+3	480	kN/m'	83	83	108	103	84	83
p+4	0	kN/m'	0	0	0	0	0	0
pu	480	kN/m'	83	83	108	103	84	83
p_up	2930	kN/m'	506	506	506	506	506	506
p_weight	4910	kN/m'	1519	1515	1515	1515	1515	1515
Fw1	7210	kN	17	17	19	19	17	17
Fw2	1080	kN	2	2	2	2	2	2
Fw	8290	kN	19	19	21	21	19	19
W	48940	kN	202	200	93	202	116	202
N'	2400	kN	6	6	0	7	6	6
N	17240	kN	71	127	26	128	43	129
Uplift	29300	kN	67	67	67	67	67	67
mu	0.6	-	0.6	0.6	0.6	0.6	0.6	0.6
Ff	10340	kN	43	76.2	15.6	76.8	25.8	77.4
S.F.sliding	1.25		2.26	4.01	0.74	3.66	1.36	4.07
b	10	m	0.133	0.133	0.133	0.133	0.133	0.133
OVERTURNING in heel								
arm_Fw1.1	6.5	m	0.087	0.086	0.086	0.086	0.086	0.086
arm_Fw1.2	8.6	m	0.115	0.115	0.115	0.115	0.115	0.115
arm_Fw2.1	15.2	m	0.203	0.203	0.203	0.203	0.203	0.203
arm_Fw2.2	14.4	m	0.192	0.192	0.192	0.192	0.192	0.192
arm_U	5	m	0.067	0.067	0.067	0.067	0.067	0.067
arm_W	5	m	0.067	0.067	0.067	0.067	0.067	0.067
arm_N'	6.7	m	0.089	0.089	0.089	0.089	0.089	0.089
arm_N	0	m	0	0	0.031	0	0	0
b/3	3.3	m	0.044	0.044	0.044	0.044	0.044	0.044
Fw1.1	6192	kN	14	14	19	18	14	14
Fw1.2	1419	kN	3	3	1	2	3	3
Fw1.	7611	kN	17	17	20	20	17	17
Fw2.1	0	kN	0	0	0	0	0	0
Fw2.2	1076	kN	2	4	4	4	4	4
Overestimation Fw:								
	1.055617							
M_Fw1.1	40248	kNm	1.2	1.2	1.6	1.5	1.2	1.2
M_Fw1.2	12203	kNm	0.4	0.3	0.1	0.2	0.3	0.3
M_Fw2.1	0	kNm	0	0	0	0	0	0
M_Fw2.2	15494	kNm	0.5	0.8	0.8	0.8	0.8	0.8
M_Fw	67950	kNm	2.1	2.3	2.5	2.5	2.3	2.3
M_uplift	146500	kNm	4.5	4.5	4.5	4.5	4.5	4.5
M_W	-244700	kNm	-13.5	-13.4	-6.2	-13.5	-7.8	-13.5
M_N'	16080	kNm	0.5	0.5	0	0.6	0.5	0.5
M_N	0	kNm	0	0	0.8	0	0	0
S.F.overt	1.17		3.46	3.18	0.68	2.9	1.18	3.21
pmax	ERR	kN/m'<	13500	kN/m' (prototype)				
	ERR	N/m' <	4180	N/m' (mod	559	ERR	ERR	ERR

M_{38} - with sill

LINEAR WAVE THEORY			(R=50)					
Geometric-scale		75		(slope foreshore=1:100)				
Water-scale		1.03						
Rho_c-scale		0.561086						
	Prototype		Model					
			Scaling	Formulae				
Length	22.5	m	0.3					
Hd	3.075	m	0.041					
h	14.4	m	0.192					
d	12.9	m	0.172					
hc	4.6	m	0.061					
h_caisson	19	m	0.253					
h_overtop	17.5	m	0.233		T32	T22	T38	T28
f	0.11	Hz	0.95	0.93	0.52	0.63	0.92	0.93
T	9.3	s	1.07		1.91	1.59	1.09	1.07
L0	135	m	1.8	1.788	5.695815	3.947148	1.854992	1.787544
h/L0	0.106667	-		0.107383	0.033709	0.048643	0.103504	0.10741
h/l0	0.106887	-		0.107896	0.033697	0.048624	0.103522	0.10741
L	98	m	1.307	1.299	2.529	2.071	1.333	1.302683
kh	0.923244	-		0.928693	0.477015	0.582507	0.905005	0.926067
kd	0.827072	-		0.831954	0.427326	0.521829	0.810734	0.829602
sinhkh	1.060107	-		1.068064	0.495312	0.616012	1.033702	1.064226
sinhk(h-d)	0.09632	-		0.09689	0.04971	0.060715	0.094411	0.096615
coshkh	1.457336	-		1.463134	1.115946	1.174509	1.438242	1.460334
coshk(h-d)	1.004628	-		1.004683	1.001235	1.001841	1.004447	1.004656
coshkd	1.361971	-		1.366501	1.092702	1.139271	1.347045	1.364314
tanhkh	0.727428	-		0.729984	0.44385	0.524485	0.718726	0.728755
c	10.6	m/s		1.22	1.3	1.3	1.2	1.21746
rho_w	1030	kg/m^3	1000	1000				
rho_c	1240	kg/m^3	2210	2210	1030	2230	1260	2230
					T32	T22	T38	T28
SLIDING			Scaling	Formulae	1.91	1.59	1.09	1.07
p+1	700	kN/m'	121	121	121	121	121	121
p+3	480	kN/m'	83	83	108	103	84	83
p+4	0	kN/m'	0	0	0	0	0	0
pu	480	kN/m'	83	83	108	103	84	83
p_up	2930	kN/m'	506	506	506	506	506	506
p_weight	4790	kN/m'	1518	1515	1515	1515	1515	1515
Fw1	7210	kN	17	17	19	19	17	17
Fw2	1080	kN	2	2	2	2	2	2
Fw	8290	kN	19	19	21	21	19	19
W	48090	kN	203	200	93	202	114	202
N'	2400	kN	6	6	0	7	0	6
N	16390	kN	69	127	26	128	47	129
Uplift	29300	kN	67	67	67	67	67	67
mu	0.6	-	0.6	0.6	0.6	0.6	0.6	0.6
Ff	9830	kN	42	76.2	15.6	76.8	28.2	77.4
S.F.sliding	1.19		2.21	4.01	0.74	3.66	1.48	4.07
b	10	m	0.133	0.133	0.133	0.133	0.133	0.133
OVERTURNING in heel								
arm_Fw1.1	6.5	m	0.087	0.086	0.086	0.086	0.086	0.086
arm_Fw1.2	8.6	m	0.115	0.115	0.115	0.115	0.115	0.115
arm_Fw2.1	15.2	m	0.203	0.203	0.203	0.203	0.203	0.203
arm_Fw2.2	14.4	m	0.192	0.192	0.192	0.192	0.192	0.192
arm_U	5	m	0.067	0.067	0.067	0.067	0.067	0.067
arm_W	5	m	0.067	0.067	0.067	0.067	0.067	0.067
arm_N'	6.7	m	0.089	0.089	0.089	0.089	0.089	0.089
arm_N	0	m	0	0	0.031	0	0	0
b/3	3.3	m	0.044	0.044	0.044	0.044	0.044	0.044
Fw1.1	6192	kN	14	14	19	18	14	14
Fw1.2	1419	kN	3	3	1	2	3	3
Fw1.	7611	kN	17	17	20	20	17	17
Fw2.1	0	kN	0	0	0	0	0	0
Fw2.2	1076	kN	2	4	4	4	4	4
Overestimation Fw:								
	1.055617							
M_Fw1.1	40248	kNm	1.2	1.2	1.6	1.5	1.2	1.2
M_Fw1.2	12203	kNm	0.4	0.3	0.1	0.2	0.3	0.3
M_Fw2.1	0	kNm	0	0	0	0	0	0
M_Fw2.2	15494	kNm	0.5	0.8	0.8	0.8	0.8	0.8
M_Fw	67950	kNm	2.1	2.3	2.5	2.5	2.3	2.3
M_uplift	146500	kNm	4.5	4.5	4.5	4.5	4.5	4.5
M_W	-240450	kNm	-13.5	-13.4	-6.2	-13.5	-7.6	-13.5
M_N'	16080	kNm	0.5	0.5	0	0.6	0	0.5
M_N	0	kNm	0	0	0.8	0	0	0
S.F.overt	1.12		3.46	3.18	0.68	2.9	1.35	3.21
pmax	ERR	kN/m'<	13500	kN/m' (prototype)				
	ERR	N/m' <	4280	N/m' (mod	559	ERR	ERR	ERR



At moment of failure
Normal force N (N)
F_wave (N)
0
5
10
15
20
25
30
35
40
45
50
0
2
4
6
8
10
12
14
16
18
20
Linear fit mu=0.4
Linear fit mu=0.5
without sill
with sill

APPENDIX L. EXPERIMENTAL RECORDING TIME

The data of the waves is only valid before reflections of the wave generator do influence the waves.

The propagating speed of the waves is depending on the wave period of the waves, therefore for every wave period the number of valid waves is calculated. These waves have been measured to calculate the wave force.

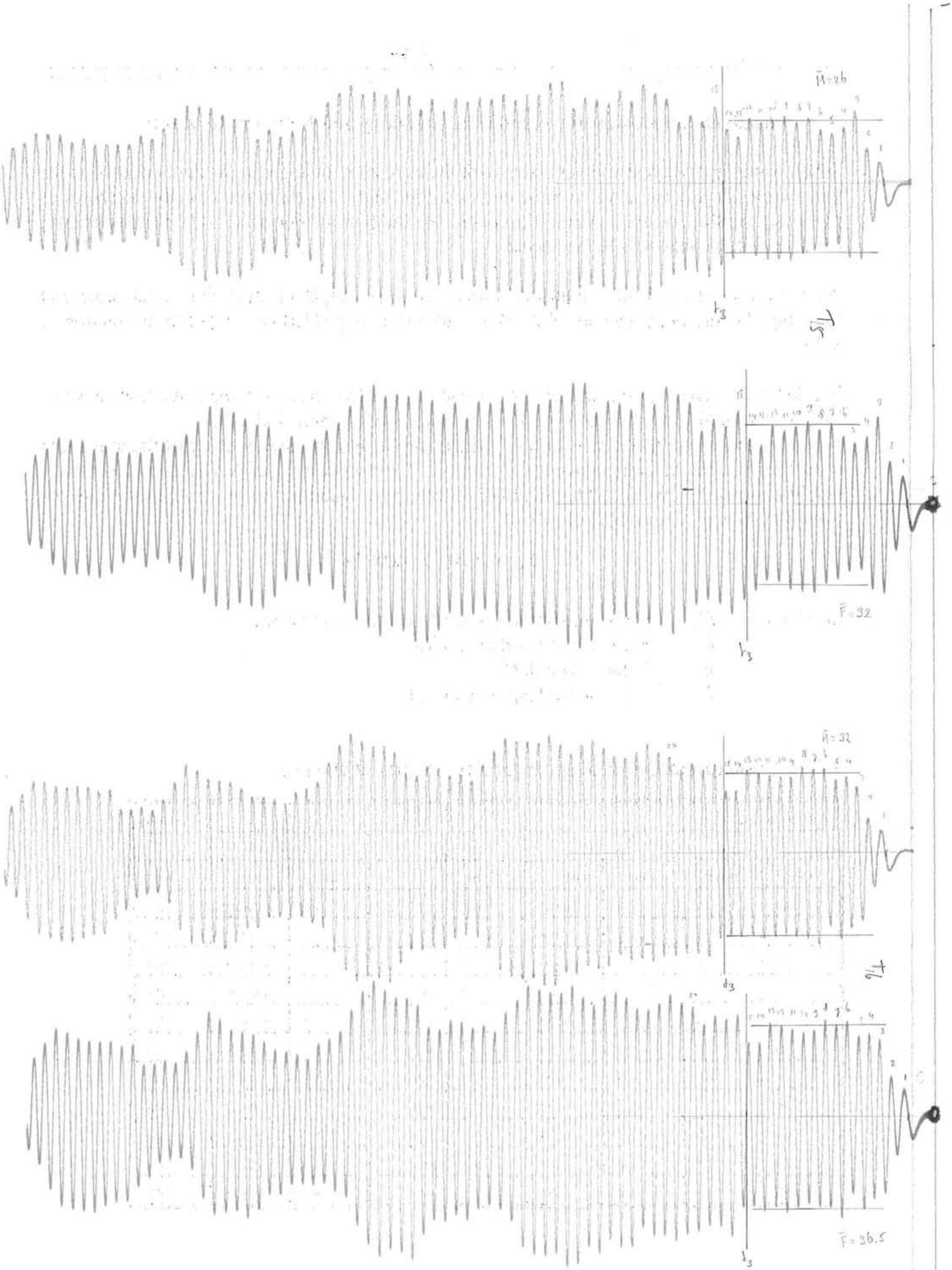
Experimental recording time

		Model	T21	T11	T41	T31	T12		T42
h	14.4	0.192	0.192	0.192	0.192	0.192	0.192	0.192	0.192
T	12.5	1.44	1.64	1.59	1.51	1.49	1.46	1.44	1.41
L0	243.9547	3.252729	4.199299	3.947148	3.559943	3.466264	3.328088	3.237532	3.10404
h/L0	0.059027	0.059304	0.045722	0.048643	0.053933	0.055391	0.057691	0.059304	0.061855
h/l0	0.059027	0.059303	0.045722	0.048643	0.053933	0.055391	0.057691	0.059304	0.061855
L	139.3471	1.857962	2.142603	2.070561	1.954846	1.925808	1.882175	1.853041	1.809231
kh	0.649298	0.651017	0.56304	0.58263	0.617118	0.626424	0.640945	0.651023	0.666787
sinhkh	0.695892	0.697987	0.593264	0.616157	0.657041	0.668204	0.68574	0.697994	0.717307
sinhk(h-d)	0.067687	0.067687	0.058684	0.060728	0.064327	0.065299	0.066815	0.067867	0.069513
coshkh	1.218305	1.219503	1.162739	1.174585	1.196538	1.202704	1.212534	1.219506	1.230662
tanhkh	0.571197	0.572354	0.51023	0.524574	0.549119	0.555585	0.565543	0.572358	0.582862
c	11.14774	1.288533	1.306466	1.302244	1.294595	1.292487	1.289162	1.286829	1.283142
distance		9.375	9.375	9.375	9.375	9.375	9.375	9.375	9.375
t1		7	7	7	7	7	7	7	7
t2		14	14	14	14	14	14	14	14
t3=3*t1		21	21	21	21	21	21	21	21
t3-t1		14	14	14	14	14	14	14	14
# waves		10	9	9	9	9	10	10	10
pos. wave gauge (in L)			0.046672	0.048296	0.051155	0.051926	0.05313	0.053965	0.055272
cos x*L			0.957309	0.95431	0.948789	0.947247	0.944796	0.943063	0.9403
			T21	T11	T41	T31	T12		T42

T32	T22	T13	T43	T33	T23	T14	T15	T44	T34	T24
0.192	0.192	0.192	0.192	0.192	0.192	0.192	0.192	0.192	0.192	0.192
1.39	1.38	1.37	1.31	1.29	1.27	1.23	1.17	1.16	1.15	1.13
3.016607	2.973359	2.930423	2.679364	2.598176	2.518237	2.362106	2.137277	2.100899	2.064832	1.993637
0.063648	0.064573	0.06552	0.071659	0.073898	0.076244	0.081283	0.089834	0.091389	0.092986	0.096306
0.063648	0.064574	0.06552	0.071659	0.073898	0.076244	0.081283	0.089834	0.091389	0.092986	0.096306
1.779952	1.765306	1.750639	1.66235	1.632804	1.603181	1.543745	1.454006	1.438984	1.423927	1.393767
0.677755	0.683378	0.689104	0.725702	0.738834	0.752486	0.781458	0.829688	0.83835	0.847215	0.865548
0.730848	0.737824	0.744952	0.791099	0.807912	0.825538	0.863458	0.928209	0.940062	0.952266	0.977743
0.070658	0.071245	0.071843	0.075666	0.077038	0.078464	0.081492	0.086533	0.087439	0.088366	0.090283
1.238603	1.242733	1.246977	1.275083	1.285582	1.296732	1.321197	1.364394	1.372485	1.380873	1.398564
0.590058	0.593711	0.597406	0.620429	0.62844	0.63663	0.653543	0.680308	0.684934	0.689612	0.699105
1.280549	1.279211	1.277843	1.268972	1.265737	1.262349	1.255074	1.242741	1.2405	1.2382	1.23342
9.375	9.375	9.375	9.375	9.375	9.375	9.375	9.375	9.375	9.375	9.375
7	7	7	7	7	7	7	8	8	8	8
14	14	14	14	14	14	14	16	16	16	16
21	21	21	21	21	21	21	24	24	24	24
14	14	14	14	14	14	14	16	16	16	16
10	10	10	11	11	11	11	14	14	14	14
0.056181	0.056647	0.057122	0.060156	0.061244	0.062376	0.064778	0.068775	0.069493	0.070228	0.071748
0.938341	0.937324	0.936281	0.929416	0.92687	0.924177	0.918309	0.908076	0.906178	0.904215	0.900096
T32	T22	T13	T43	T33	T23	T14	T15	T44	T34	T24

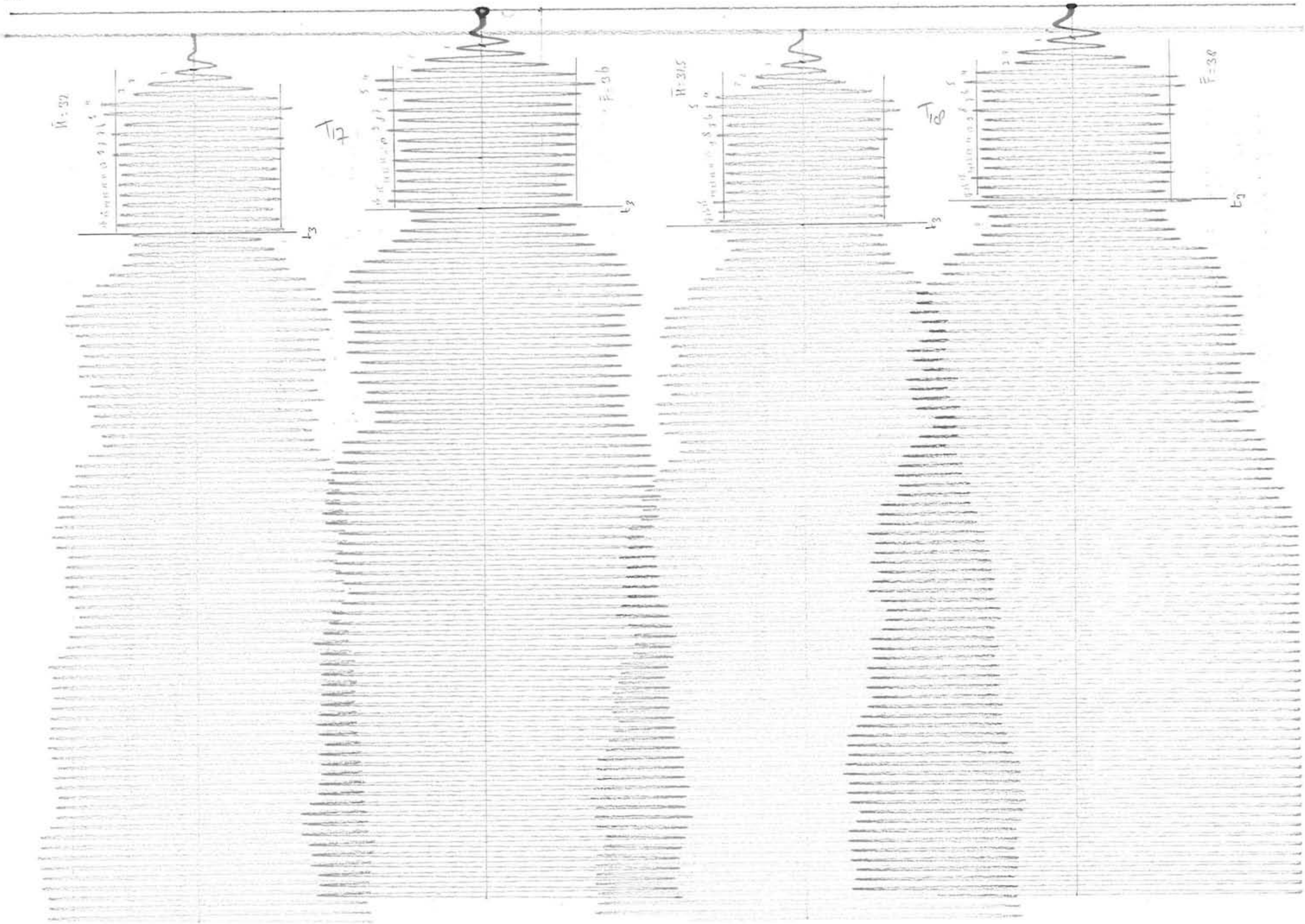
T45	T16	T35	T25	T46	T36	T26		T17	T18	T37/T47	T27	T48	T38/T28
0.192	0.192	0.192	0.192	0.192	0.192	0.192	0.192	0.192	0.192	0.192	0.192	0.192	0.192
1.1	1.09	1.08	1.07	1.04	1.02	1.01	1	0.99	0.95	0.94	0.92	0.9	0.89
1.88919	1.85499	1.82111	1.78754	1.68871	1.62439	1.59269	1.56131	1.53024	1.40908	1.37957	1.32149	1.26466	1.23671
0.10163	0.1035	0.10543	0.10741	0.1137	0.1182	0.12055	0.12297	0.12547	0.13626	0.13917	0.14529	0.15182	0.15525
0.10163	0.1035	0.10543	0.10741	0.1137	0.1182	0.12055	0.12297	0.12547	0.13626	0.13917	0.14529	0.15182	0.15525
1.34834	1.33315	1.31793	1.30268	1.25679	1.22605	1.21062	1.19518	1.1797	1.11746	1.10181	1.07041	1.03886	1.02302
0.89471	0.9049	0.91536	0.92607	0.95989	0.98395	0.99649	1.00937	1.02261	1.07957	1.0949	1.12702	1.16125	1.17923
1.01895	1.03356	1.04864	1.06423	1.11423	1.15059	1.16979	1.18971	1.21039	1.30183	1.32715	1.38122	1.44041	1.47217
0.09333	0.0944	0.09549	0.09661	0.10015	0.10267	0.10399	0.10534	0.10672	0.11269	0.1143	0.11767	0.12126	0.12315
1.42768	1.43814	1.44902	1.46033	1.49717	1.52442	1.53896	1.55416	1.57005	1.64157	1.66172	1.70522	1.75351	1.77969
0.71371	0.71868	0.72369	0.72875	0.74423	0.75477	0.76011	0.7655	0.77093	0.79304	0.79866	0.81	0.82145	0.82721
1.22576	1.22307	1.2203	1.21746	1.20845	1.202	1.19864	1.19518	1.19162	1.17627	1.17214	1.16349	1.15428	1.14946
9.375	9.375	9.375	9.375	9.375	9.375	9.375	9.375	9.375	9.375	9.375	9.375	9.375	9.375
8	8	8	8	8	8	8	8	8	8	8	8	8	8
16	16	16	16	16	16	16	16	16	16	16	16	16	16
24	24	24	24	24	24	24	24	24	24	24	24	24	24
16	16	16	16	16	16	16	16	16	16	16	16	16	16
15	15	15	15	15	16	16	16	16	17	17	17	18	18
0.07417	0.07501	0.07588	0.07676	0.07957	0.08156	0.0826	0.08367	0.08477	0.08949	0.09076	0.09342	0.09626	0.09775
0.89337	0.89098	0.88849	0.88592	0.87761	0.87153	0.86831	0.86497	0.86149	0.84604	0.84176	0.83261	0.82261	0.81725
T45	T16	T35	T25	T46	T36	T26		T17	T18	T37/T47	T27	T48	T38/T28

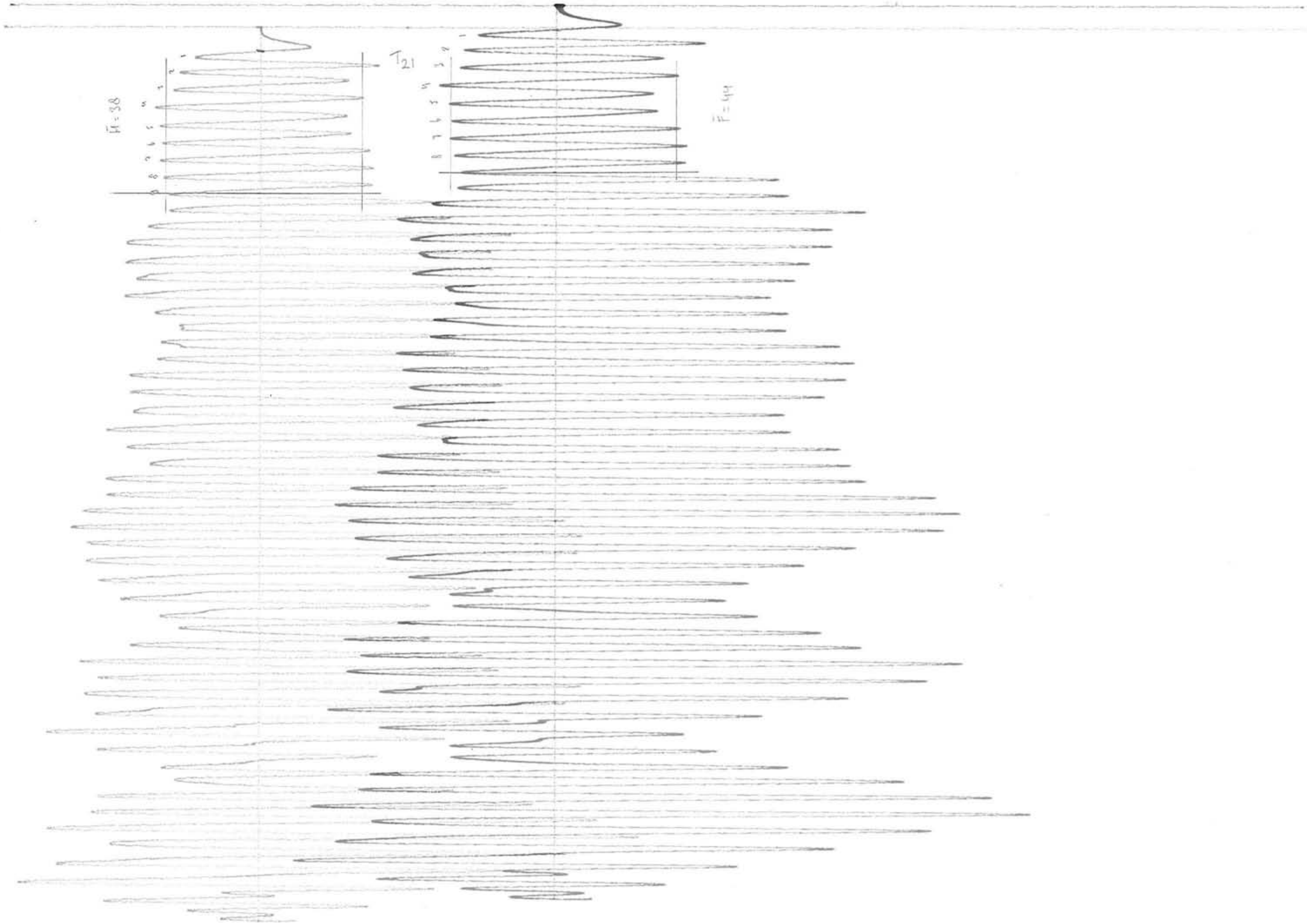
(11) H_1


F=32
F=36.5

13

H_1




H2
H̄ = 38
T21
F̄ = 44

APPENDIX E. RESULTS EXPERIMENT 1:

OUTPUT DATA

The output from the plotter of appendix D have been measured in order to calculate the real wave heights and wave load. The calibration of the wave gauge and the strain gauge system has been used to transform the measured numbers.

H_{+plot}	is the plotted wave crest
H_{-plot}	is the plotted wave trough
H_{tot}	is the total wave height plotted
F_{+plot}	is the positive plotted wave load
F_{-plot}	is the negative plotted wave load
F_{tot}	is the total wave load plotted
H_{+}	is the measured wave crest according to the wave gauge calibration
H_{-}	is the measured wave trough according to the wave gauge calibration
F_{+}	is the measured positive wave load according to the strain gauge calibration
F_{-}	is the measured negative wave load according to the strain gauge calibration

T11	1.59						T11			
Wave nr.	H+plot (mm)	H-plot (mm)	Htot (mm)	F+plot (mm)	F-plot (mm)	Ftot (mm)	H+ (m)	H- (m)	F+ (N)	F- (N)
1	8	10	18	10	11	21	0.006	0.007	3	3
2	7	9	16	9	9	18	0.005	0.006	3	3
3	12	13	25	16	14	30	0.009	0.009	5	4
4	13	12	25	17	12	29	0.009	0.009	5	3
5	12	9	21	16	10	26	0.009	0.006	5	3
6	12	10	22	14	12	26	0.009	0.007	4	3
7	12	11	23	16	13	29	0.009	0.008	5	4
8	12	11	23	16	13	29	0.009	0.008	5	4
9	13	11	24	17	13	30	0.009	0.008	5	4

T12	1.46						T12			
Wave nr.	H+plot (mm)	H-plot (mm)	Htot (mm)	F+plot (mm)	F-plot (mm)	Ftot (mm)	H+ (m)	H- (m)	F+ (N)	F- (N)
1	7	9	16	9	11	20	0.005	0.006	3	3
2	10	12	22	12	14	26	0.007	0.009	3	4
3	14	14	28	18	17	35	0.01	0.01	5	5
4	15	12	27	19	15	34	0.011	0.009	6	4
5	17	15	32	21	19	40	0.012	0.011	6	6
6	18	16	34	23	20	43	0.013	0.011	7	6
7	19	15	34	23	18	41	0.014	0.011	7	5
8	18	15	33	22	18	40	0.013	0.011	6	5
9	17	14	31	21	17	38	0.012	0.01	6	5

T13	1.37						T13			
Wave nr.	H+plot (mm)	H-plot (mm)	Htot (mm)	F+plot (mm)	F-plot (mm)	Ftot (mm)	H+ (m)	H- (m)	F+ (N)	F- (N)
1	7	8	15	8	10	18	0.005	0.006	2	3
2	10	14	24	12	16	28	0.007	0.01	3	5
3	14	12	26	18	16	34	0.01	0.009	5	5
4	13	11	24	17	14	31	0.009	0.008	5	4
5	14	14	28	19	17	36	0.01	0.01	6	5
6	15	13	28	20	16	36	0.011	0.009	6	5
7	15	14	29	20	17	37	0.011	0.01	6	5
8	17	15	32	21	13	34	0.012	0.011	6	4
9	16	16	32	21	19	40	0.011	0.011	6	6

T14	1.23						T14			
Wave nr.	H+plot (mm)	H-plot (mm)	Htot (mm)	F+plot (mm)	F-plot (mm)	Ftot (mm)	H+ (m)	H- (m)	F+ (N)	F- (N)
1	3	5	8	5	6	11	0.002	0.004	1	2
2	8	10	18	10	11	21	0.006	0.007	3	3
3	15	15	30	19	17	36	0.011	0.011	6	5
4	12	8	20	15	10	25	0.009	0.006	4	3
5	10	10	20	13	12	25	0.007	0.007	4	3
6	7	8	15	9	9	18	0.005	0.006	3	3
7	7	7	14	9	9	18	0.005	0.005	3	3
8	8	8	16	10	9	19	0.006	0.006	3	3
9	8	8	16	10	9	19	0.006	0.006	3	3
10	9	9	18	12	10	22	0.006	0.006	3	3
11	9	10	19	12	12	24	0.006	0.007	3	3

T15	1.17						T15			
Wave nr.	H+plot (mm)	H-plot (mm)	Htot (mm)	F+plot (mm)	F-plot (mm)	Ftot (mm)	H+ (m)	H- (m)	F+ (N)	F- (N)
1	5	4	9	5	6	11	0.004	0.003	1	2
2	8	7	15	9	9	18	0.006	0.005	3	3
3	15	14	29	18	18	36	0.011	0.01	5	5
4	15	11	26	17	14	31	0.011	0.008	5	4
5	12	10	22	13	12	25	0.009	0.007	4	3
6	13	11	24	13	14	27	0.009	0.008	4	4
7	13	13	26	15	16	31	0.009	0.009	4	5
8	14	12	26	16	15	31	0.01	0.009	5	4
9	15	13	28	18	16	34	0.011	0.009	5	5
10	15	13	28	17	16	33	0.011	0.009	5	5
11	15	12	27	17	14	31	0.011	0.009	5	4
12	14	13	27	15	16	31	0.01	0.009	4	5
13	14	9	23	15	12	27	0.01	0.006	4	3
14	15	11	26	17	13	30	0.011	0.008	5	4

T16	1.09						T16			
Wave nr.	H+plot (mm)	H-plot (mm)	Htot (mm)	F+plot (mm)	F-plot (mm)	Ftot (mm)	H+ (m)	H- (m)	F+ (N)	F- (N)
1	4	4	8	5	5	10	0.003	0.003	1	1
2	7	7	14	8	8	16	0.005	0.005	2	2
3	14	13	27	15	15	30	0.01	0.009	4	4
4	15	15	30	16	17	33	0.011	0.011	5	5
5	17	15	32	19	16	35	0.012	0.011	6	5
6	15	17	32	16	19	35	0.011	0.012	5	6
7	18	17	35	20	18	38	0.013	0.012	6	5
8	17	17	34	18	19	37	0.012	0.012	5	6
9	17	15	32	18	17	35	0.012	0.011	5	5
10	16	15	31	17	17	34	0.011	0.011	5	5
11	17	16	33	18	17	35	0.012	0.011	5	5
12	17	16	33	19	18	37	0.012	0.011	6	5
13	16	17	33	18	19	37	0.011	0.012	5	6
14	17	12	29	19	15	34	0.012	0.009	6	4
15	16	12	28	18	15	33	0.011	0.009	5	4

T17	0.99						T17			
Wave nr.	H+plot (mm)	H-plot (mm)	Htot (mm)	F+plot (mm)	F-plot (mm)	Ftot (mm)	H+ (m)	H- (m)	F+ (N)	F- (N)
1	4	4	8	6	5	11	0.003	0.003	2	1
2	7	9	16	9	11	20	0.005	0.006	3	3
3	11	12	23	13	14	27	0.008	0.009	4	4
4	16	19	35	19	21	40	0.011	0.014	6	6
5	19	18	37	22	21	43	0.014	0.013	6	6
6	17	14	31	20	15	35	0.012	0.01	6	4
7	16	17	33	18	19	37	0.011	0.012	5	6
8	17	15	32	19	17	36	0.012	0.011	6	5
9	18	16	34	19	19	38	0.013	0.011	6	6
10	17	15	32	18	17	35	0.012	0.011	5	5
11	16	14	30	18	16	34	0.011	0.01	5	5
12	17	15	32	18	18	36	0.012	0.011	5	5
13	17	15	32	18	17	35	0.012	0.011	5	5
14	17	14	31	18	17	35	0.012	0.01	5	5
15	15	15	30	16	18	34	0.011	0.011	5	5
16	17	15	32	18	19	37	0.012	0.011	5	6

T18	0.95						T18			
Wave nr.	H+plot (mm)	H-plot (mm)	Htot (mm)	F+plot (mm)	F-plot (mm)	Ftot (mm)	H+ (m)	H- (m)	F+ (N)	F- (N)
1	4	4	8	6	5	11	0.003	0.003	2	1
2	5	9	14	7	11	18	0.004	0.006	2	3
3	8	10	18	11	11	22	0.006	0.007	3	3
4	14	17	31	15	19	34	0.01	0.012	4	6
5	18	19	37	21	22	43	0.013	0.014	6	6
6	19	16	35	22	18	40	0.014	0.011	6	5
7	15	15	30	17	18	35	0.011	0.011	5	5
8	18	17	35	20	20	40	0.013	0.012	6	6
9	17	15	32	20	17	37	0.012	0.011	6	5
10	15	15	30	18	18	36	0.011	0.011	5	5
11	16	15	31	19	18	37	0.011	0.011	6	5
12	16	15	31	19	18	37	0.011	0.011	6	5
13	16	15	31	18	18	36	0.011	0.011	5	5
14	17	15	32	20	18	38	0.012	0.011	6	5
15	17	18	35	20	20	40	0.012	0.013	6	6
16	16	17	33	19	19	38	0.011	0.012	6	6
17	16	17	33	18	18	36	0.011	0.012	5	5

T21	1.64						T21			
Wave nr.	H+plot (mm)	H-plot (mm)	Htot (mm)	F+plot (mm)	F-plot (mm)	Ftot (mm)	H+ (m)	H- (m)	F+ (N)	F- (N)
1	10	13	23	13	15	28	0.007	0.009	4	4
2	23	16	39	29	18	47	0.016	0.011	8	5
3	17	17	34	21	19	40	0.012	0.012	6	6
4	20	21	41	24	23	47	0.014	0.015	7	7
5	17	20	37	19	21	40	0.012	0.014	6	6
6	18	19	37	20	20	40	0.013	0.014	6	6
7	21	20	41	24	21	45	0.015	0.014	7	6
8	22	19	41	26	20	46	0.016	0.014	8	6
9	22	18	40	25	18	43	0.016	0.013	7	5

T22	1.38						T22			
Wave nr.	H+plot (mm)	H-plot (mm)	Htot (mm)	F+plot (mm)	F-plot (mm)	Ftot (mm)	H+ (m)	H- (m)	F+ (N)	F- (N)
1	12	14	26	15	17	32	0.009	0.01	4	5
2	24	26	50	28	30	58	0.017	0.019	8	9
3	34	23	57	40	28	68	0.024	0.016	12	8
4	31	25	56	37	31	68	0.022	0.018	11	9
5	32	30	62	39	36	75	0.023	0.021	11	10
6	37	29	66	44	34	78	0.026	0.021	13	10
7	39	29	68	46	34	80	0.028	0.021	13	10
8	41	30	71	50	35	85	0.029	0.021	15	10
9	42	33	75	50	39	89	0.03	0.024	15	11

T23	1.27						T23			
Wave nr.	H+plot (mm)	H-plot (mm)	Htot (mm)	F+plot (mm)	F-plot (mm)	Ftot (mm)	H+ (m)	H- (m)	F+ (N)	F- (N)
1	11	12	23	12	14	26	0.008	0.009	3	4
2	22	25	47	24	28	52	0.016	0.018	7	8
3	35	31	66	39	36	75	0.025	0.022	11	10
4	25	20	45	29	24	53	0.018	0.014	8	7
5	27	20	47	30	24	54	0.019	0.014	9	7
6	21	20	41	22	24	46	0.015	0.014	6	7
7	19	19	38	21	23	44	0.014	0.014	6	7
8	18	17	35	20	21	41	0.013	0.012	6	6
9	18	16	34	19	20	39	0.013	0.011	6	6
10	19	16	35	22	18	40	0.014	0.011	6	5
11	20	20	40	23	24	47	0.014	0.014	7	7

T24	1.13						T24			
Wave nr.	H+plot (mm)	H-plot (mm)	Htot (mm)	F+plot (mm)	F-plot (mm)	Ftot (mm)	H+ (m)	H- (m)	F+ (N)	F- (N)
1	10	9	19	12	10	22	0.007	0.006	3	3
2	17	23	40	21	26	47	0.012	0.016	6	8
3	30	29	59	36	33	69	0.021	0.021	10	10
4	33	29	62	38	32	70	0.024	0.021	11	9
5	30	24	54	33	26	59	0.021	0.017	10	8
6	34	33	67	39	37	76	0.024	0.024	11	11
7	34	31	65	38	36	74	0.024	0.022	11	10
8	36	29	65	41	33	74	0.026	0.021	12	10
9	34	28	62	40	32	72	0.024	0.02	12	9
10	31	26	57	37	29	66	0.022	0.019	11	8
11	29	26	55	34	30	64	0.021	0.019	10	9
12	32	28	60	37	31	68	0.023	0.02	11	9
13	32	33	65	38	37	75	0.023	0.024	11	11
14	35	32	67	38	36	74	0.025	0.023	11	10

T25	1.07						T25			
Wave nr.	H+plot (mm	H-plot (mm)	Htot (mm)	F+plot (mm)	F-plot (mm)	Ftot (mm)	H+ (m)	H- (m)	F+ (N)	F- (N)
1	10	8	18	11	10	21	0.007	0.006	3	3
2	16	20	36	18	23	41	0.011	0.014	5	7
3	28	25	53	32	29	61	0.02	0.018	9	8
4	35	36	71	38	39	77	0.025	0.026	11	11
5	40	33	73	44	36	80	0.029	0.024	13	10
6	36	35	71	39	38	77	0.026	0.025	11	11
7	41	33	74	44	34	78	0.029	0.024	13	10
8	37	35	72	39	38	77	0.026	0.025	11	11
9	39	33	72	42	36	78	0.028	0.024	12	10
10	40	35	75	43	37	80	0.029	0.025	12	11
11	40	35	75	43	38	81	0.029	0.025	12	11
12	40	34	74	43	37	80	0.029	0.024	12	11
13	40	34	74	43	38	81	0.029	0.024	12	11
14	38	34	72	41	37	78	0.027	0.024	12	11
15	39	36	75	44	38	82	0.028	0.026	13	11

T26	1.01						T26			
Wave nr.	H+plot (mm	H-plot (mm)	Htot (mm)	F+plot (mm)	F-plot (mm)	Ftot (mm)	H+ (m)	H- (m)	F+ (N)	F- (N)
1	10	9	19	13	10	23	0.007	0.006	4	3
2	15	21	36	17	25	42	0.011	0.015	5	7
3	24	25	49	29	28	57	0.017	0.018	8	8
4	33	38	71	37	42	79	0.024	0.027	11	12
5	39	37	76	45	41	86	0.028	0.026	13	12
6	38	30	68	43	33	76	0.027	0.021	12	10
7	37	36	73	40	39	79	0.026	0.026	12	11
8	38	32	70	42	34	76	0.027	0.023	12	10
9	37	37	74	41	39	80	0.026	0.026	12	11
10	38	34	72	41	37	78	0.027	0.024	12	11
11	37	33	70	40	35	75	0.026	0.024	12	10
12	37	35	72	41	36	77	0.026	0.025	12	10
13	38	33	71	42	34	76	0.027	0.024	12	10
14	38	37	75	42	39	81	0.027	0.026	12	11
15	37	33	70	40	34	74	0.026	0.024	12	10
16	36	36	72	41	36	77	0.026	0.026	12	10

T27	0.92						T27			
Wave nr.	H+plot (mm	H-plot (mm)	Htot (mm)	F+plot (mm)	F-plot (mm)	Ftot (mm)	H+ (m)	H- (m)	F+ (N)	F- (N)
1	9	5	14	10	6	16	0.006	0.004	3	2
2	14	13	27	16	15	31	0.01	0.009	5	4
3	18	21	39	21	25	46	0.013	0.015	6	7
4	32	33	65	35	38	73	0.023	0.024	10	11
5	38	40	78	42	45	87	0.027	0.029	12	13
6	40	38	78	45	43	88	0.029	0.027	13	12
7	37	32	69	42	37	79	0.026	0.023	12	11
8	38	36	74	41	42	83	0.027	0.026	12	12
9	39	35	74	45	41	86	0.028	0.025	13	12
10	37	36	73	41	42	83	0.026	0.026	12	12
11	39	36	75	45	40	85	0.028	0.026	13	12
12	39	38	77	43	43	86	0.028	0.027	12	12
13	39	37	76	43	40	83	0.028	0.026	12	12
14	39	37	76	45	40	85	0.028	0.026	13	12
15	40	37	77	44	41	85	0.029	0.026	13	12
16	39	37	76	42	43	85	0.028	0.026	12	12
17	44	36	80	46	43	89	0.031	0.026	13	12

T28	0.89						T28			
Wave nr.	H+plot (mm	H-plot (mm)	Htot (mm)	F+plot (mm)	F-plot (mm)	Ftot (mm)	H+ (m)	H- (m)	F+ (N)	F- (N)
1	8	4	12	11	5	16	0.006	0.003	3	1
2	11	6	17	13	7	20	0.008	0.004	4	2
3	19	11	30	22	13	35	0.014	0.008	6	4
4	18	23	41	20	25	45	0.013	0.016	6	7
5	33	33	66	37	38	75	0.024	0.024	11	11
6	39	42	81	44	47	91	0.028	0.03	13	14
7	39	42	81	44	48	92	0.028	0.03	13	14
8	40	35	75	46	39	85	0.029	0.025	13	11
9	36	36	72	38	42	80	0.026	0.026	11	12
10	40	39	79	45	45	90	0.029	0.028	13	13
11	41	39	80	45	44	89	0.029	0.028	13	13
12	40	38	78	44	44	88	0.029	0.027	13	13
13	41	38	79	42	43	85	0.029	0.027	12	12
14	40	36	76	46	42	88	0.029	0.026	13	12
15	39	37	76	42	44	86	0.028	0.026	12	13
16	39	35	74	41	42	83	0.028	0.025	12	12
17	45	35	80	49	40	89	0.032	0.025	14	12
18	42	32	74	46	36	82	0.03	0.023	13	10

T31	1.49						T31			
Wave nr.	H+plot (mm)	H-plot (mm)	Htot (mm)	F+plot (mm)	F-plot (mm)	Ftot (mm)	H+ (m)	H- (m)	F+ (N)	F- (N)
1	18	19	37	22	23	45	0.013	0.014	6	7
2	37	31	68	45	36	81	0.026	0.022	13	10
3	51	28	79	62	34	96	0.036	0.02	18	10
4	53	34	87	66	40	106	0.038	0.024	19	12
5	55	41	96	67	48	115	0.039	0.029	19	14
6	51	45	96	64	52	116	0.036	0.032	19	15
7	50	44	94	61	52	113	0.036	0.031	18	15
8	48	42	90	60	49	109	0.034	0.03	17	14
9	46	42	88	57	49	106	0.033	0.03	17	14
T31B							T31B	H- (m)	F+ (N)	F- (N)
1	24	26	50	30	30	60	0.017	0.019	9	9
2	38	34	72	45	39	84	0.027	0.024	13	11
3	49	37	86	60	44	104	0.035	0.026	17	13
4	54	36	90	67	43	110	0.039	0.026	19	12
5	56	43	99	70	51	121	0.04	0.031	20	15
6	55	45	100	71	53	124	0.039	0.032	21	15
7	53	43	96	64	51	115	0.038	0.031	19	15
8	51	43	94	65	50	115	0.036	0.031	19	15
9	50	39	89	61	46	107	0.036	0.028	18	13
T31*							T31*	H- (m)	F+ (N)	F- (N)
1	23	25	48	30	30	60	0.016	0.018	9	9
2	36	32	68	45	38	83	0.026	0.023	13	11
3	37	46	83	58	43	101	0.026	0.033	17	12
4	36	52	88	66	42	108	0.026	0.037	19	12
5	43	52	95	66	50	116	0.031	0.037	19	15
6	44	48	92	63	52	115	0.031	0.034	18	15
7	40	48	88	60	47	107	0.029	0.034	17	14
8	42	45	87	59	50	109	0.03	0.032	17	15
9	39	43	82	55	46	101	0.028	0.031	16	13

T32	1.39						T32			
Wave nr.	H+plot (mm)	H-plot (mm)	Htot (mm)	F+plot (mm)	F-plot (mm)	Ftot (mm)	H+ (m)	H- (m)	F+ (N)	F- (N)
1	24	24	48	29	28	57	0.017	0.017	8	8
2	39	37	76	45	42	87	0.028	0.026	13	12
3	51	34	85	61	41	102	0.036	0.024	18	12
4	53	37	90	65	45	110	0.038	0.026	19	13
5	56	41	97	70	49	119	0.04	0.029	20	14
6	62	36	98	76	43	119	0.044	0.026	22	12
7	63	41	104	78	48	126	0.045	0.029	23	14
8	65	45	110	80	52	132	0.046	0.032	23	15
9	66	42	108	80	49	129	0.047	0.03	23	14
10	70	46	116	85	54	139	0.05	0.033	25	16
T32*							T32*	H- (m)	F+ (N)	F- (N)
1	20	21	41	26	26	52	0.014	0.015	8	8
2	37	36	73	46	43	89	0.026	0.026	13	12
3	51	32	83	63	40	103	0.036	0.023	18	12
4	50	38	88	62	46	108	0.036	0.027	18	13
5	51	41	92	66	50	116	0.036	0.029	19	15
6	58	37	95	73	45	118	0.041	0.026	21	13
7	60	38	98	76	46	122	0.043	0.027	22	13
8	62	42	104	79	50	129	0.044	0.03	23	15
9	64	43	107	78	52	130	0.046	0.031	23	15
10	64	46	110	83	55	138	0.046	0.033	24	16

T33	1.29						T33			
Wave nr.	H+plot (mm)	H-plot (mm)	Htot (mm)	F+plot (mm)	F-plot (mm)	Ftot (mm)	H+ (m)	H- (m)	F+ (N)	F- (N)
1	18	17	35	23	20	43	0.013	0.012	7	6
2	36	37	73	43	41	84	0.026	0.026	12	12
3	54	43	97	64	49	113	0.039	0.031	19	14
4	38	34	72	47	40	87	0.027	0.024	14	12
5	46	31	77	56	36	92	0.033	0.022	16	10
6	46	34	80	55	39	94	0.033	0.024	16	11
7	42	34	76	51	40	91	0.03	0.024	15	12
8	41	35	76	50	40	90	0.029	0.025	15	12
9	39	37	76	46	43	89	0.028	0.026	13	12
10	41	32	73	49	37	86	0.029	0.023	14	11
11	40	37	77	51	42	93	0.029	0.026	15	12
T33*							T33*	H- (m)	F+ (N)	F- (N)
1	15	15	30	22	18	40	0.011	0.011	6	5
2	33	31	64	41	36	77	0.024	0.022	12	10
3	53	42	95	65	50	115	0.038	0.03	19	15
4	37	32	69	48	39	87	0.026	0.023	14	11
5	44	30	74	55	37	92	0.031	0.021	16	11
6	44	33	77	54	39	93	0.031	0.024	16	11
7	38	34	72	48	41	89	0.027	0.024	14	12
8	37	32	69	46	38	84	0.026	0.023	13	11
9	35	33	68	43	40	83	0.025	0.024	12	12
10	36	31	67	43	38	81	0.026	0.022	12	11
11	36	35	71	45	40	85	0.026	0.025	13	12

T34	1.15						T34			
Wave nr.	H+plot (mm)	H-plot (mm)	Htot (mm)	F+plot (mm)	F-plot (mm)	Ftot (mm)	H+ (m)	H- (m)	F+ (N)	F- (N)
1	18	12	30	21	15	36	0.013	0.009	6	4
2	31	31	62	35	36	71	0.022	0.022	10	10
3	49	43	92	55	51	106	0.035	0.031	16	15
4	52	42	94	60	48	108	0.037	0.03	17	14
5	45	35	80	50	40	90	0.032	0.025	15	12
6	50	42	92	56	49	105	0.036	0.03	16	14
7	48	43	91	54	51	105	0.034	0.031	16	15
8	51	40	91	58	47	105	0.036	0.029	17	14
9	49	39	88	57	46	103	0.035	0.028	17	13
10	49	38	87	56	45	101	0.035	0.027	16	13
11	50	39	89	57	45	102	0.036	0.028	17	13
12	51	44	95	57	51	108	0.036	0.031	17	15
13	49	41	90	51	48	99	0.035	0.029	15	14
14	53	44	97	59	50	109	0.038	0.031	17	15
T34*							T34*	H- (m)	F+ (N)	F- (N)
1	18	11	29	22	13	35	0.013	0.008	6	4
2	29	21	50	34	24	58	0.021	0.015	10	7
3	48	44	92	57	51	108	0.034	0.031	17	15
4	51	42	93	58	47	105	0.036	0.03	17	14
5	45	32	77	51	37	88	0.032	0.023	15	11
6	43	37	80	47	43	90	0.031	0.026	14	12
7	45	42	87	52	49	101	0.032	0.03	15	14
8	49	37	86	56	43	99	0.035	0.026	16	12
9	51	39	90	60	45	105	0.036	0.028	17	13
10	48	36	84	55	42	97	0.034	0.026	16	12
11	49	35	84	57	39	96	0.035	0.025	17	11
12	50	43	93	56	49	105	0.036	0.031	16	14
13	49	30	79	57	36	93	0.035	0.021	17	10
14	56	41	97	62	46	108	0.04	0.029	18	13

T35	1.08						T35			
Wave nr.	H+plot (mm	H-plot (mm)	Htot (mm)	F+plot (mm	F-plot (mm)	Ftot (mm)	H+ (m)	H- (m)	F+ (N)	F- (N)
1	16	9	25	20	11	31	0.011	0.006	6	3
2	27	24	51	31	28	59	0.019	0.017	9	8
3	44	39	83	52	45	97	0.031	0.028	15	13
4	54	51	105	61	55	116	0.039	0.036	18	16
5	57	42	99	65	47	112	0.041	0.03	19	14
6	51	50	101	57	56	113	0.036	0.036	17	16
7	58	43	101	65	48	113	0.041	0.031	19	14
8	56	53	109	62	58	120	0.04	0.038	18	17
9	56	48	104	60	54	114	0.04	0.034	17	16
10	56	47	103	62	54	116	0.04	0.034	18	16
11	54	44	98	63	50	113	0.039	0.031	18	15
12	56	44	100	65	50	115	0.04	0.031	19	15
13	57	50	107	63	57	120	0.041	0.036	18	17
14	59	39	98	64	46	110	0.042	0.028	19	13
15	59	36	95	65	40	105	0.042	0.026	19	12
T35*							T35*	H- (m)	F+ (N)	F- (N)
1	20	13	33	24	16	40	0.014	0.009	7	5
2	29	35	64	34	40	74	0.021	0.025	10	12
3	45	37	82	52	43	95	0.032	0.026	15	12
4	55	51	106	60	56	116	0.039	0.036	17	16
5	57	43	100	62	48	110	0.041	0.031	18	14
6	57	52	109	64	58	122	0.041	0.037	19	17
7	58	44	102	64	48	112	0.041	0.031	19	14
8	56	49	105	63	55	118	0.04	0.035	18	16
9	56	48	104	61	54	115	0.04	0.034	18	16
10	56	48	104	60	54	114	0.04	0.034	17	16
11	56	48	104	62	55	117	0.04	0.034	18	16
12	57	44	101	64	51	115	0.041	0.031	19	15
13	59	52	111	62	60	122	0.042	0.037	18	17
14	58	43	101	59	50	109	0.041	0.031	17	15
15	60	43	103	64	48	112	0.043	0.031	19	14

T36	1.02						T36			
Wave nr.	H+plot (mm	H-plot (mm)	Htot (mm)	F+plot (mm	F-plot (mm)	Ftot (mm)	H+ (m)	H- (m)	F+ (N)	F- (N)
1	16	8	24	20	9	29	0.011	0.006	6	3
2	24	17	41	29	19	48	0.017	0.012	8	6
3	40	30	70	48	34	82	0.029	0.021	14	10
4	50	53	103	56	57	113	0.036	0.038	16	17
5	64	57	121	71	62	133	0.046	0.041	21	18
6	60	47	107	66	52	118	0.043	0.034	19	15
7	57	50	107	62	53	115	0.041	0.036	18	15
8	58	48	106	63	52	115	0.041	0.034	18	15
9	59	55	114	65	58	123	0.042	0.039	19	17
10	61	54	115	63	57	120	0.044	0.039	18	17
11	61	51	112	65	54	119	0.044	0.036	19	16
12	59	49	108	66	50	116	0.042	0.035	19	15
13	62	54	116	69	55	124	0.044	0.039	20	16
14	62	59	121	67	62	129	0.044	0.042	19	18
15	69	49	118	71	52	123	0.049	0.035	21	15
16	76	40	116	74	43	117	0.054	0.029	21	12
T36*							T36*	H- (m)	F+ (N)	F- (N)
1	20	12	32	25	14	39	0.014	0.009	7	4
2	27	33	60	32	38	70	0.019	0.024	9	11
3	41	35	76	48	40	88	0.029	0.025	14	12
4	52	53	105	57	58	115	0.037	0.038	17	17
5	61	54	115	65	59	124	0.044	0.039	19	17
6	61	47	108	66	50	116	0.044	0.034	19	15
7	61	54	115	64	58	122	0.044	0.039	19	17
8	61	48	109	64	52	116	0.044	0.034	19	15
9	60	55	115	64	57	121	0.043	0.039	19	17
10	62	51	113	65	53	118	0.044	0.036	19	15
11	61	53	114	61	55	116	0.044	0.038	18	16
12	62	53	115	63	55	118	0.044	0.038	18	16
13	65	48	113	67	50	117	0.046	0.034	19	15
14	65	62	127	64	65	129	0.046	0.044	19	19
15	71	51	122	64	54	118	0.051	0.036	19	16
16	70	40	110	65	42	107	0.05	0.029	19	12

T37	0.94						T37			
Wave nr.	H+plot (mm	H-plot (mm)	Htot (mm)	F+plot (mm)	F-plot (mm)	Ftot (mm)	H+ (m)	H- (m)	F+ (N)	F- (N)
1	15	5	20	19	6	25	0.011	0.004	6	2
2	20	11	31	24	13	37	0.014	0.008	7	4
3	33	20	53	39	24	63	0.024	0.014	11	7
4	38	45	83	42	50	92	0.027	0.032	12	15
5	57	60	117	63	66	129	0.041	0.043	18	19
6	60	62	122	65	68	133	0.043	0.044	19	20
7	55	47	102	58	53	111	0.039	0.034	17	15
8	53	51	104	59	58	117	0.038	0.036	17	17
9	52	49	101	60	57	117	0.037	0.035	17	17
10	57	52	109	60	61	121	0.041	0.037	17	18
11	55	48	103	62	55	117	0.039	0.034	18	16
12	55	52	107	63	60	123	0.039	0.037	18	17
13	59	51	110	64	59	123	0.042	0.036	19	17
14	60	51	111	64	59	123	0.043	0.036	19	17
15	55	54	109	60	61	121	0.039	0.039	17	18
16	61	49	110	68	55	123	0.044	0.035	20	16
17	61	48	109	62	56	118	0.044	0.034	18	16
T37*							T37*	H- (m)	F+ (N)	F- (N)
1	17	6	23	21	7	28	0.012	0.004	6	2
2	22	11	33	25	12	37	0.016	0.008	7	3
3	37	19	56	43	22	65	0.026	0.014	12	6
4	38	48	86	41	52	93	0.027	0.034	12	15
5	61	60	121	65	65	130	0.044	0.043	19	19
6	62	60	122	63	65	128	0.044	0.043	18	19
7	56	44	100	55	47	102	0.04	0.031	16	14
8	52	53	105	56	57	113	0.037	0.038	16	17
9	54	48	102	56	53	109	0.039	0.034	16	15
10	57	51	108	58	57	115	0.041	0.036	17	17
11	52	46	98	56	51	107	0.037	0.033	16	15
12	53	52	105	61	60	121	0.038	0.037	18	17
13	58	48	106	63	57	120	0.041	0.034	18	17
14	57	52	109	61	60	121	0.041	0.037	18	17
15	52	51	103	60	59	119	0.037	0.036	17	17
16	61	45	106	73	51	124	0.044	0.032	21	15
17	62	44	106	67	49	116	0.044	0.031	19	14

T38	0.89						T38			
Wave nr.	H+plot (mm	H-plot (mm)	Htot (mm)	F+plot (mm)	F-plot (mm)	Ftot (mm)	H+ (m)	H- (m)	F+ (N)	F- (N)
1	19	8	27	24	10	34	0.014	0.006	7	3
2	22	22	44	26	26	52	0.016	0.016	8	8
3	28	31	59	32	36	68	0.02	0.022	9	10
4	48	46	94	52	51	103	0.034	0.033	15	15
5	51	55	106	55	61	116	0.036	0.039	16	18
6	57	59	116	62	65	127	0.041	0.042	18	19
7	58	55	113	62	62	124	0.041	0.039	18	18
8	57	56	113	61	63	124	0.041	0.04	18	18
9	57	61	118	67	71	138	0.041	0.044	19	21
10	60	55	115	62	62	124	0.043	0.039	18	18
11	58	56	114	63	63	126	0.041	0.04	18	18
12	59	57	116	62	64	126	0.042	0.041	18	19
13	56	55	111	61	62	123	0.04	0.039	18	18
14	56	54	110	64	59	123	0.04	0.039	19	17
15	60	52	112	66	59	125	0.043	0.037	19	17
16	54	58	112	58	66	124	0.039	0.041	17	19
17	67	57	124	68	65	133	0.048	0.041	20	19
18	62	44	106	61	52	113	0.044	0.031	18	15
T38*							T38*	H- (m)	F+ (N)	F- (N)
1	15	4	19	18	4	22	0.011	0.003	5	1
2	19	9	28	22	10	32	0.014	0.006	6	3
3	30	18	48	35	21	56	0.021	0.013	10	6
4	35	40	75	38	43	81	0.025	0.029	11	12
5	54	56	110	58	61	119	0.039	0.04	17	18
6	61	67	128	66	72	138	0.044	0.048	19	21
7	59	57	116	59	63	122	0.042	0.041	17	18
8	57	49	106	61	54	115	0.041	0.035	18	16
9	53	58	111	60	65	125	0.038	0.041	17	19
10	57	55	112	61	61	122	0.041	0.039	18	18
11	59	61	120	64	67	131	0.042	0.044	19	19
12	59	55	114	60	62	122	0.042	0.039	17	18
13	54	56	110	62	61	123	0.039	0.04	18	18
14	60	55	115	64	60	124	0.043	0.039	19	17
15	61	57	118	60	63	123	0.044	0.041	17	18
16	57	53	110	59	59	118	0.041	0.038	17	17
17	68	53	121	70	60	130	0.049	0.038	20	17
18	74	47	121	66	56	122	0.053	0.034	19	16

T41	1.51						T41			
Wave nr.	H+plot (mm)	H-plot (mm)	Htot (mm)	F+plot (mm)	F-plot (mm)	Ftot (mm)	H+ (m)	H- (m)	F+ (N)	F- (N)
1	27	22	49	36	27	63	0.019	0.016	10	8
2	54	40	94	65	45	110	0.039	0.029	19	13
3	78	38	116	93	45	138	0.056	0.027	27	13
4	74	43	117	91	51	142	0.053	0.031	26	15
5	77	55	132	93	63	156	0.055	0.039	27	18
6	69	58	127	88	65	153	0.049	0.041	26	19
7	69	57	126	83	65	148	0.049	0.041	24	19
8	66	56	122	82	64	146	0.047	0.04	24	19
9	69	57	126	84	64	148	0.049	0.041	24	19

T42	1.41						T42			
Wave nr.	H+plot (mm)	H-plot (mm)	Htot (mm)	F+plot (mm)	F-plot (mm)	Ftot (mm)	H+ (m)	H- (m)	F+ (N)	F- (N)
1	30	25	55	36	27	63	0.021	0.018	10	8
2	55	46	101	63	50	113	0.039	0.033	18	15
3	77	47	124	91	55	146	0.055	0.034	26	16
4	70	52	122	86	61	147	0.05	0.037	25	18
5	75	54	129	92	63	155	0.054	0.039	27	18
6	84	48	132	100	58	158	0.06	0.034	29	17
7	85	50	135	102	60	162	0.061	0.036	30	17
8	84	51	135	103	62	165	0.06	0.036	30	18
9	91	56	147	104	69	173	0.065	0.04	30	20
10	91	64	155	113	72	185	0.065	0.046	33	21
T42B							T42B	0	0	0
1	35	29	64	44	34	78	0.025	0.021	13	10
2	57	49	106	68	54	122	0.041	0.035	20	16
3	77	46	123	95	54	149	0.055	0.033	28	16
4	75	52	127	93	59	152	0.054	0.037	27	17
5	80	54	134	101	62	163	0.057	0.039	29	18
6	86	48	134	105	56	161	0.061	0.034	30	16
7	84	51	135	108	57	165	0.06	0.036	31	17
8	85	54	139	107	64	171	0.061	0.039	31	19
9	91	55	146	108	65	173	0.065	0.039	31	19
10	95	63	158	117	73	190	0.068	0.045	34	21

T43	1.31						T43			
Wave nr.	H+plot (mm)	H-plot (mm)	Htot (mm)	F+plot (mm)	F-plot (mm)	Ftot (mm)	H+ (m)	H- (m)	F+ (N)	F- (N)
1	28	17	45	35	20	55	0.02	0.012	10	6
2	48	32	80	56	35	91	0.034	0.023	16	10
3	80	62	142	93	68	161	0.057	0.044	27	20
4	64	37	101	75	45	120	0.046	0.026	22	13
5	67	46	113	78	54	132	0.048	0.033	23	16
6	67	53	120	77	60	137	0.048	0.038	22	17
7	59	55	114	69	63	132	0.042	0.039	20	18
8	62	51	113	70	58	128	0.044	0.036	20	17
9	60	50	110	68	57	125	0.043	0.036	20	17
10	64	46	110	72	53	125	0.046	0.033	21	15
11	65	53	118	73	58	131	0.046	0.038	21	17

T44	1.16						T44			
Wave nr.	H+plot (mm)	H-plot (mm)	Htot (mm)	F+plot (mm)	F-plot (mm)	Ftot (mm)	H+ (m)	H- (m)	F+ (N)	F- (N)
1	28	18	46	33	19	52	0.02	0.013	10	6
2	47	45	92	53	49	102	0.034	0.032	15	14
3	67	60	127	75	67	142	0.048	0.043	22	19
4	70	60	130	78	62	140	0.05	0.043	23	18
5	59	53	112	65	56	121	0.042	0.038	19	16
6	66	50	116	72	55	127	0.047	0.036	21	16
7	65	55	120	73	62	135	0.046	0.039	21	18
8	69	56	125	76	61	137	0.049	0.04	22	18
9	71	59	130	77	65	142	0.051	0.042	22	19
10	70	54	124	76	61	137	0.05	0.039	22	18
11	70	48	118	76	52	128	0.05	0.034	22	15
12	71	53	124	81	56	137	0.051	0.038	23	16
13	62	39	101	73	43	116	0.044	0.028	21	12
14	81	41	122	82	47	129	0.058	0.029	24	14

T45	1.1						T45			
Wave nr.	H+plot (mm	H-plot (mm)	Htot (mm)	F+plot (mm)	F-plot (mm)	Ftot (mm)	H+ (m)	H- (m)	F+ (N)	F- (N)
1	26	12	38	33	14	47	0.019	0.009	10	4
2	41	34	75	49	38	87	0.029	0.024	14	11
3	64	53	117	73	59	132	0.046	0.038	21	17
4	77	68	145	83	72	155	0.055	0.049	24	21
5	79	56	135	83	60	143	0.056	0.04	24	17
6	73	66	139	80	71	151	0.052	0.047	23	21
7	75	57	132	82	62	144	0.054	0.041	24	18
8	74	65	139	82	70	152	0.053	0.046	24	20
9	74	63	137	80	69	149	0.053	0.045	23	20
10	77	64	141	80	69	149	0.055	0.046	23	20
11	75	58	133	81	65	146	0.054	0.041	23	19
12	75	55	130	83	58	141	0.054	0.039	24	17
13	72	65	137	86	67	153	0.051	0.046	25	19
14	73	49	122	83	56	139	0.052	0.035	24	16
15	83	33	116	89	39	128	0.059	0.024	26	11

T46	1.04						T46			
Wave nr.	H+plot (mm	H-plot (mm)	Htot (mm)	F+plot (mm)	F-plot (mm)	Ftot (mm)	H+ (m)	H- (m)	F+ (N)	F- (N)
1	27	11	38	33	13	46	0.019	0.008	10	4
2	38	21	59	44	24	68	0.027	0.015	13	7
3	59	38	97	69	43	112	0.042	0.027	20	12
4	71	69	140	78	71	149	0.051	0.049	23	21
5	83	70	153	87	72	159	0.059	0.05	25	21
6	79	61	140	82	65	147	0.056	0.044	24	19
7	77	61	138	79	62	141	0.055	0.044	23	18
8	80	70	150	78	72	150	0.057	0.05	23	21
9	76	64	140	78	63	141	0.054	0.046	23	18
10	79	71	150	80	72	152	0.056	0.051	23	21
11	82	68	150	78	70	148	0.059	0.049	23	20
12	85	65	150	80	68	148	0.061	0.046	23	20
13	88	80	168	82	78	160	0.063	0.057	24	23
14	89	65	154	82	68	150	0.064	0.046	24	20
15	82	68	150	81	70	151	0.059	0.049	23	20
16	83	64	147	91	65	156	0.059	0.046	26	19

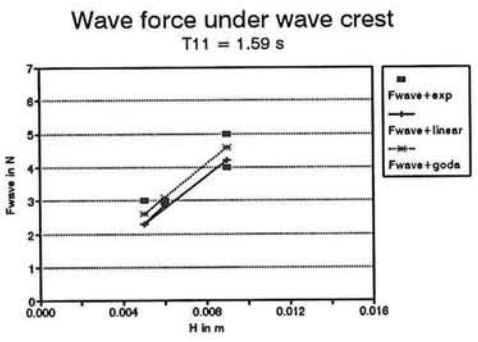
T47	0.94						T47			
Wave nr.	H+plot (mm	H-plot (mm)	Htot (mm)	F+plot (mm)	F-plot (mm)	Ftot (mm)	H+ (m)	H- (m)	F+ (N)	F- (N)
1	26	8	34	33	7	40	0.019	0.006	10	2
2	31	15	46	37	14	51	0.022	0.011	11	4
3	50	24	74	59	26	85	0.036	0.017	17	8
4	55	68	123	59	67	126	0.039	0.049	17	19
5	76	85	161	85	85	170	0.054	0.061	25	25
6	76	72	148	80	75	155	0.054	0.051	23	22
7	70	67	137	66	68	134	0.05	0.048	19	20
8	65	69	134	78	74	152	0.046	0.049	23	21
9	73	70	143	73	75	148	0.052	0.05	21	22
10	72	70	142	76	78	154	0.051	0.05	22	23
11	74	67	141	74	73	147	0.053	0.048	21	21
12	69	72	141	77	78	155	0.049	0.051	22	23
13	74	68	142	79	72	151	0.053	0.049	23	21
14	79	68	147	74	74	148	0.056	0.049	21	21
15	72	75	147	71	80	151	0.051	0.054	21	23
16	88	61	149	85	68	153	0.063	0.044	25	20
17	95	53	148	80	64	144	0.068	0.038	23	19

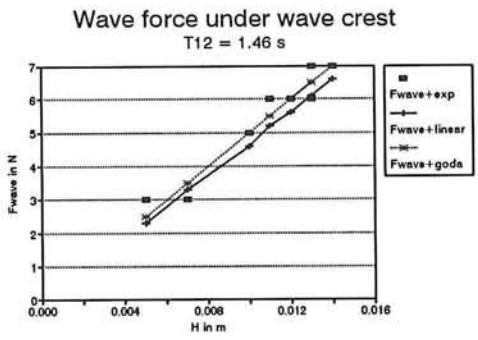
T48	0.9						T48			
Wave nr.	H+plot (mm	H-plot (mm)	Htot (mm)	F+plot (mm)	F-plot (mm)	Ftot (mm)	H+ (m)	H- (m)	F+ (N)	F- (N)
1	21	4	25	26	5	31	0.015	0.003	8	1
2	30	17	47	34	18	52	0.021	0.012	10	5
3	40	30	70	45	32	77	0.029	0.021	13	9
4	55	56	111	57	56	113	0.039	0.04	17	16
5	70	81	151	74	80	154	0.05	0.058	21	23
6	69	77	146	83	85	168	0.049	0.055	24	25
7	76	67	143	69	71	140	0.054	0.048	20	21
8	66	72	138	77	77	154	0.047	0.051	22	22
9	67	70	137	75	75	150	0.048	0.05	22	22
10	79	80	159	70	83	153	0.056	0.057	20	24
11	78	75	153	69	78	147	0.056	0.054	20	23
12	68	75	143	67	76	143	0.049	0.054	19	22
13	68	76	144	71	80	151	0.049	0.054	21	23
14	82	73	155	70	77	147	0.059	0.052	20	22
15	82	70	152	70	75	145	0.059	0.05	20	22
16	54	71	125	72	76	148	0.039	0.051	21	22
17	76	69	145	85	82	167	0.054	0.049	25	24
18	88	62	150	72	71	143	0.063	0.044	21	21

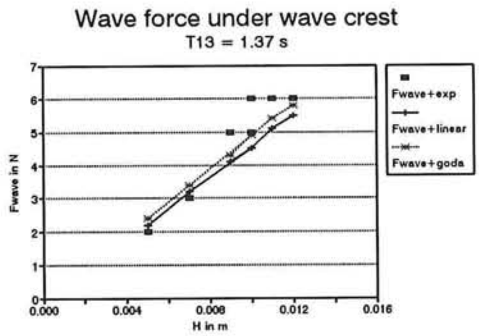
APPENDIX F. RESULTS EXPERIMENT 1:

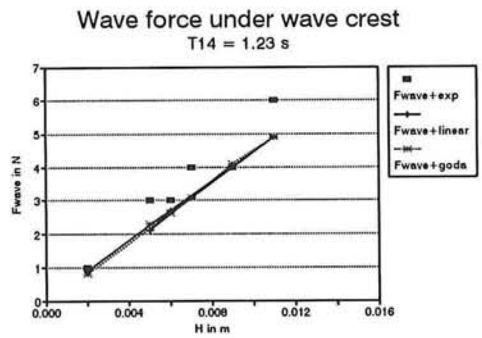
CALCULATION WAVE FORCE UNDER WAVE CREST WITH LINEAR WAVE THEORY AND GODA'S FORMULA

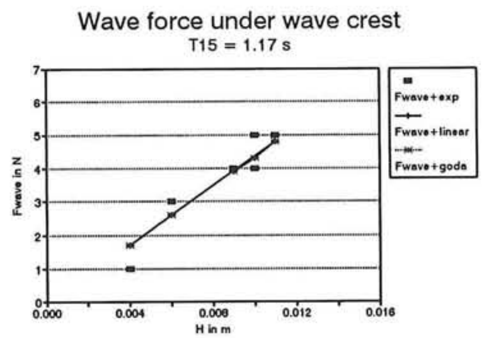
Measurement T11..T18

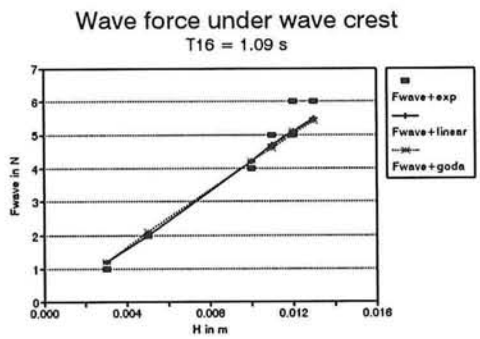


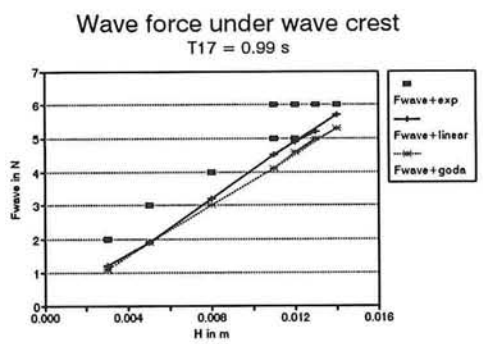


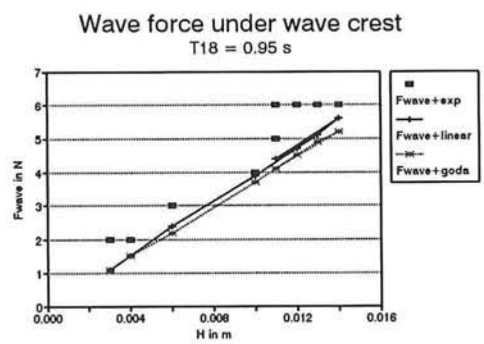




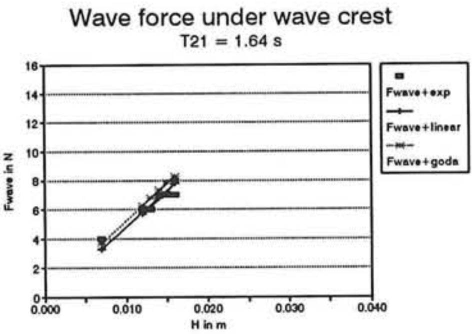


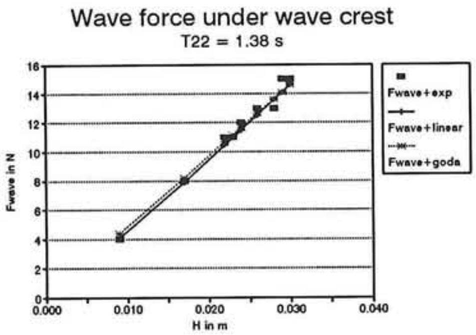


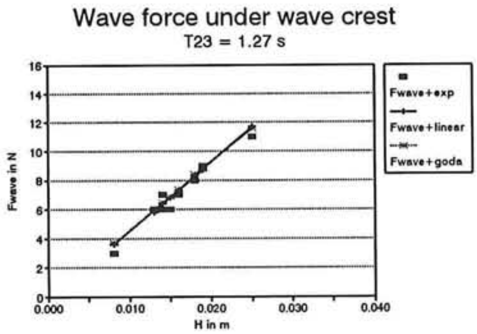


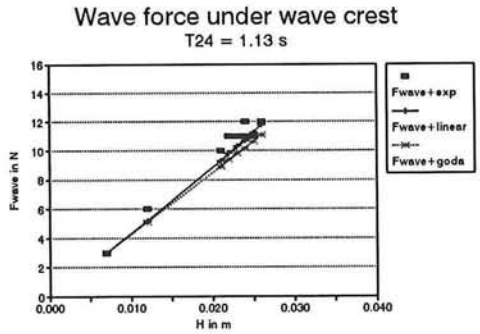


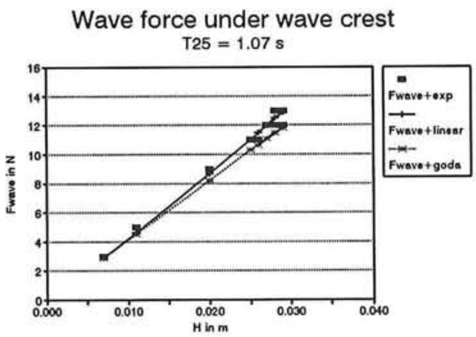
Measurement T21..T28

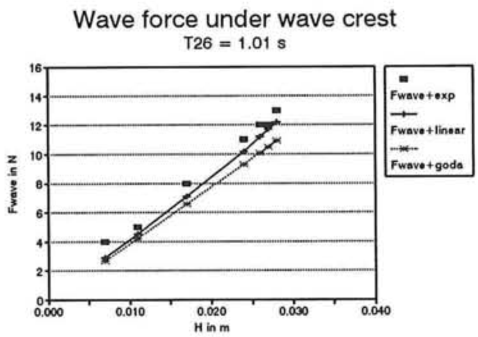


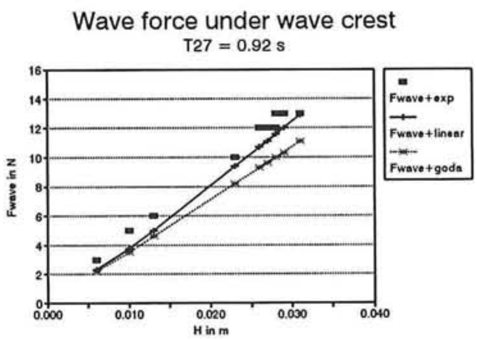


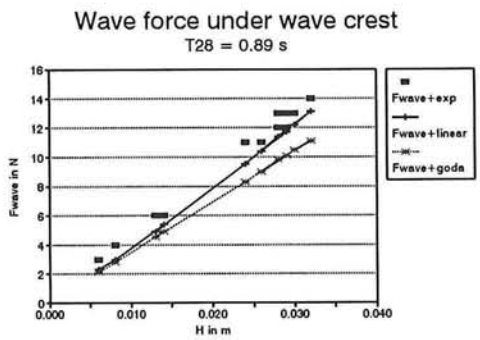




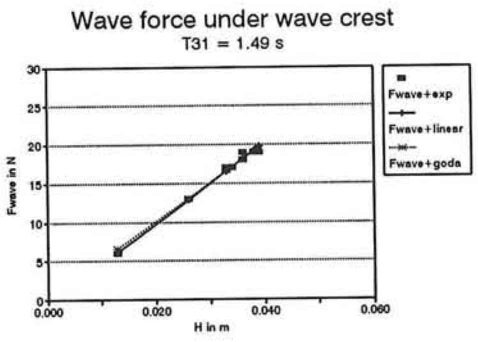


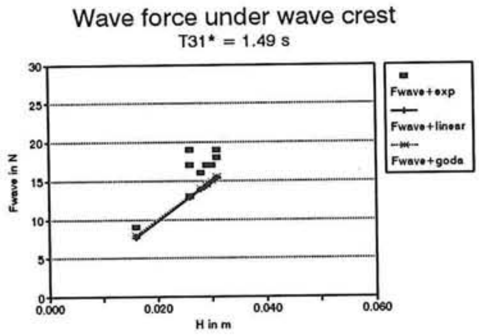


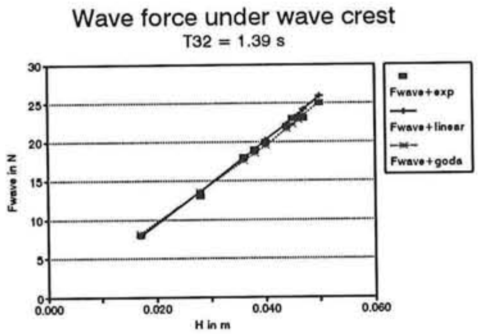


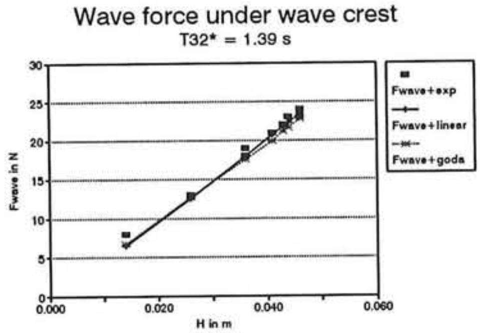


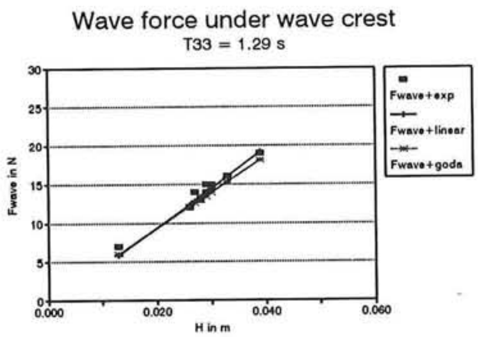
Measurement T31..T34*

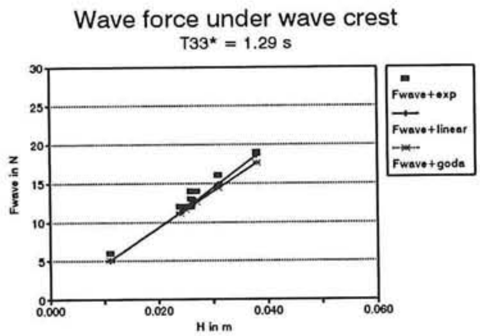


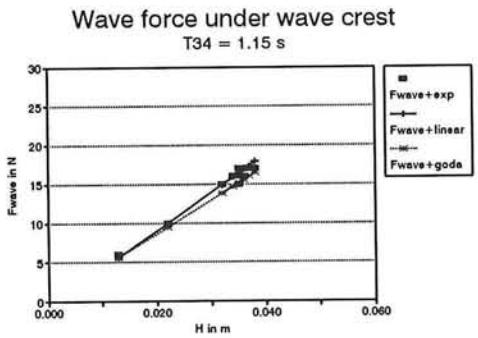


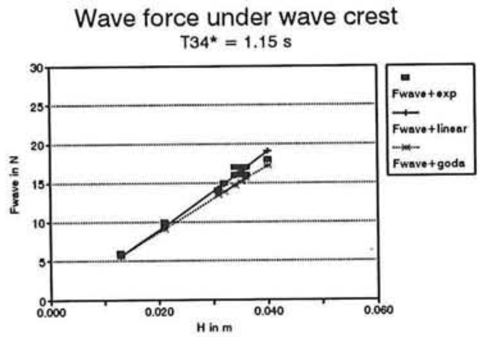




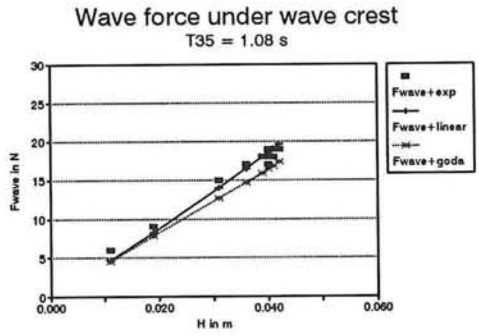


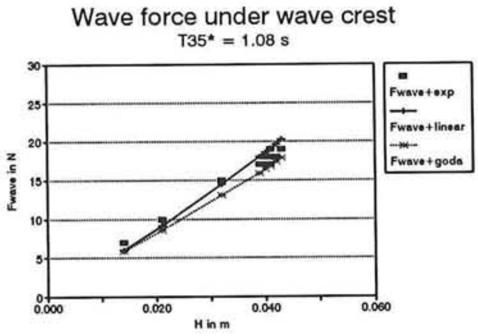


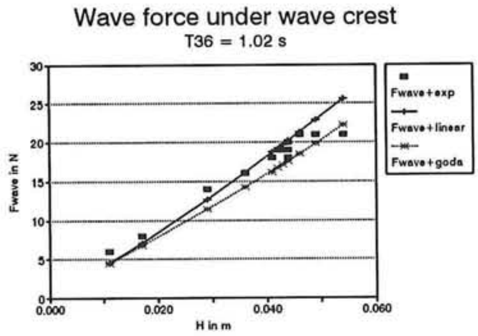


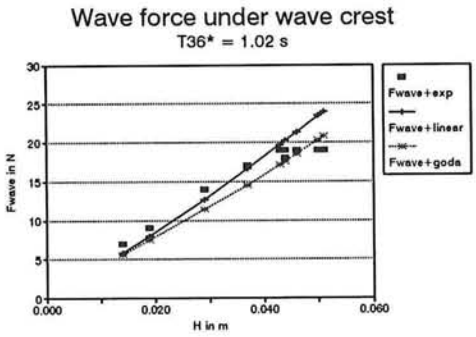


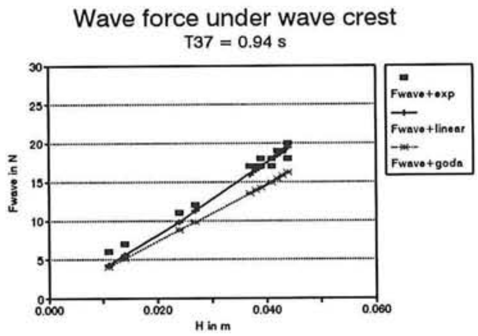
Measurement T35..T38*

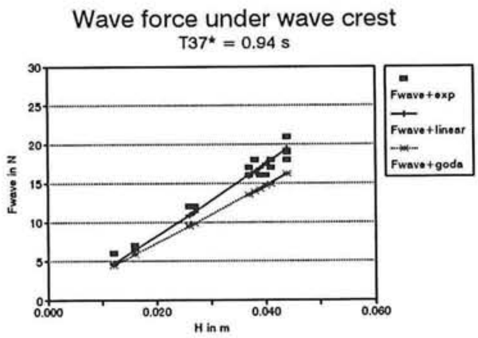


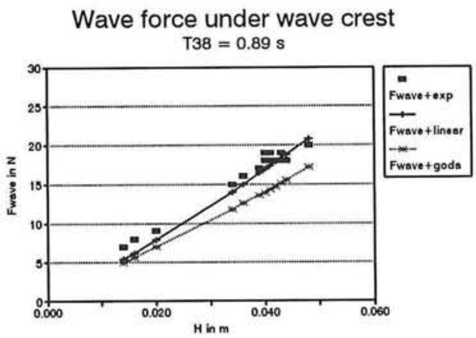


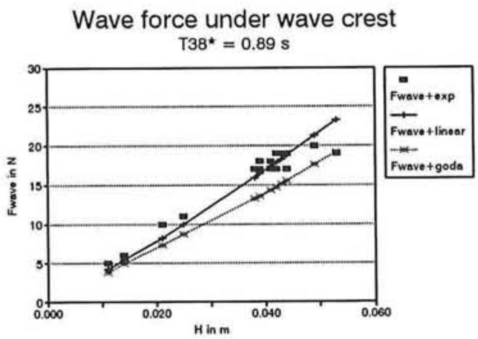




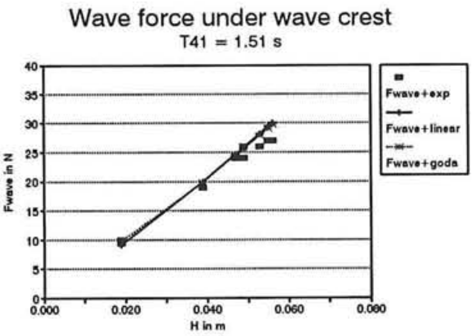


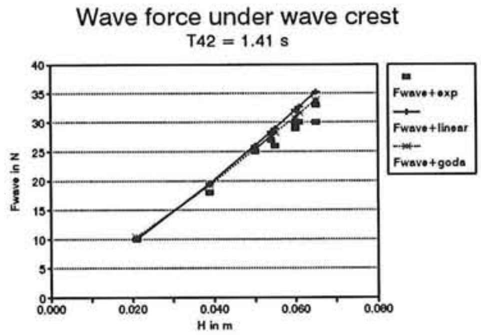


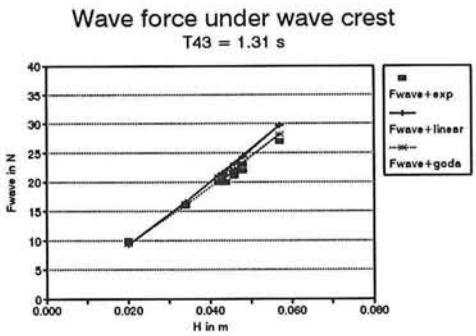


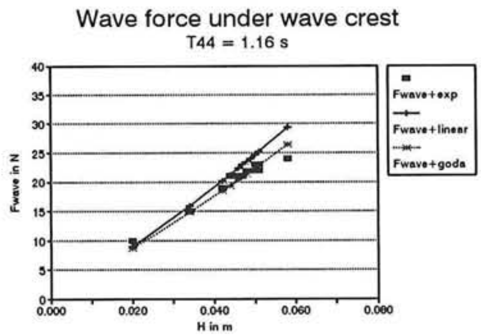


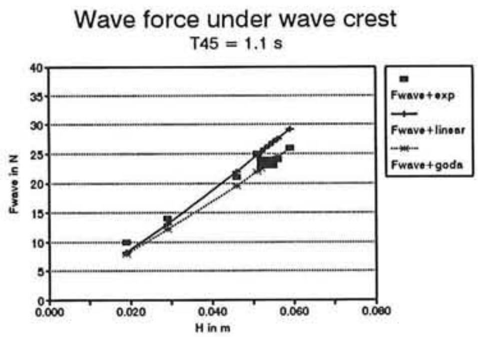
Measurement T41..T48

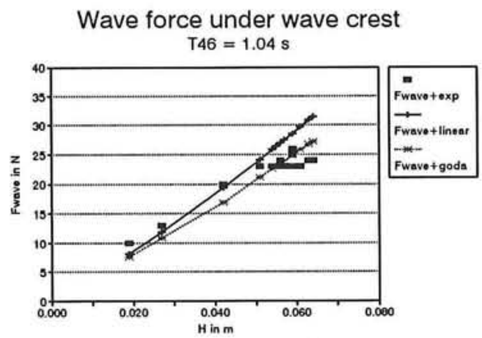


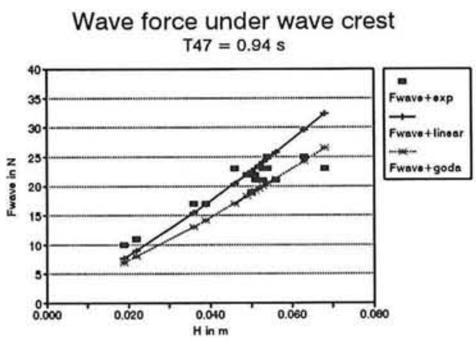


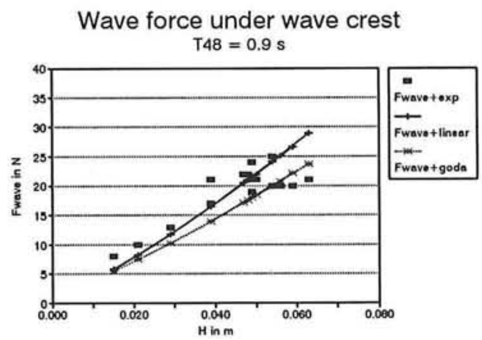


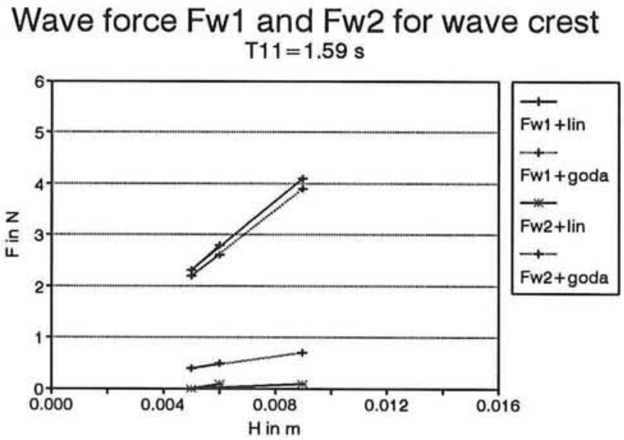


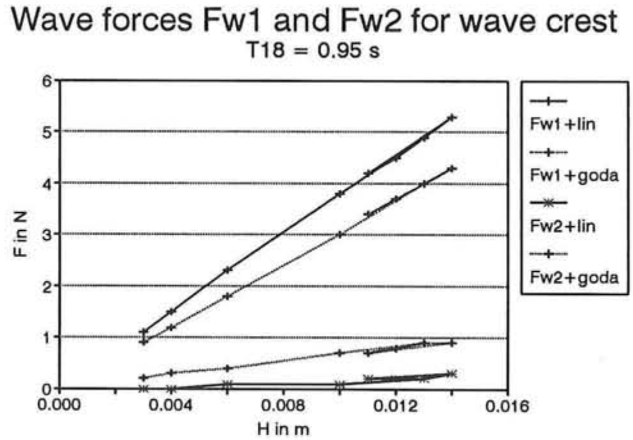


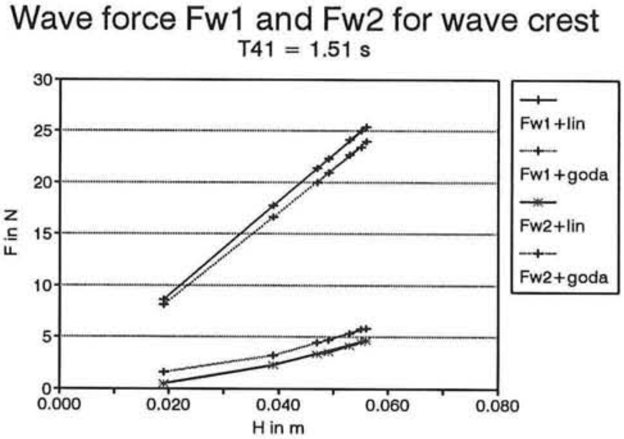


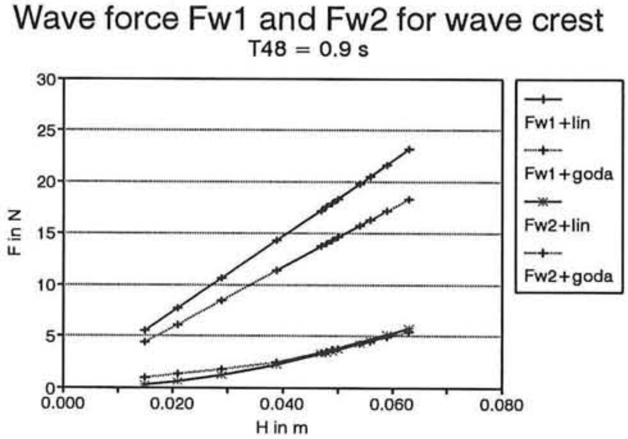





Wave force Fw1 and Fw2 for wave crest
T11=1.59 s
F in N
H in m
Fw1+lin
Fw1+goda
Fw2+lin
Fw2+goda


Wave forces Fw1 and Fw2 for wave crest
T18 = 0.95 s
F in N
H in m
Fw1+lin
Fw1+goda
Fw2+lin
Fw2+goda


Wave force Fw1 and Fw2 for wave crest
T41 = 1.51 s
F in N
H in m
Fw1+lin
Fw1+goda
Fw2+lin
Fw2+goda


Wave force Fw1 and Fw2 for wave crest
T48 = 0.9 s
F in N
H in m
Fw1+lin
Fw1+goda
Fw2+lin
Fw2+goda

T11

H+ (m)	H- (m)	F+ (N)	F- (N)	p+1+ (N/m)	p+3+ (N/m)	p+4+ (N/m)	Fw1+ (N)	Fw2+ (N)	Fw+lin (N)
0.006	0.007	3	3	17.66	15.06	0	2.8	0.1	2.9
0.005	0.006	3	3	14.72	12.55	0	2.3	0	2.3
0.009	0.009	5	4	26.49	22.59	0	4.1	0.1	4.2
0.009	0.009	5	3	26.49	22.59	0	4.1	0.1	4.2
0.009	0.006	5	3	26.49	22.59	0	4.1	0.1	4.2
0.009	0.007	4	3	26.49	22.59	0	4.1	0.1	4.2
0.009	0.008	5	4	26.49	22.59	0	4.1	0.1	4.2
0.009	0.008	5	4	26.49	22.59	0	4.1	0.1	4.2
0.009	0.008	5	4	26.49	22.59	0	4.1	0.1	4.2

T12

H+ (m)	H- (m)	F+ (N)	F- (N)	p+1+ (N/m)	p+3+ (N/m)	p+4+ (N/m)	Fw1+ (N)	Fw2+ (N)	Fw+lin (N)
0.005	0.006	3	3	14.72	12.17	0	2.3	0	2.3
0.007	0.009	3	4	20.6	17.03	0	3.2	0.1	3.3
0.01	0.01	5	5	29.43	24.33	0	4.5	0.1	4.6
0.011	0.009	6	4	32.37	26.76	0	5	0.2	5.2
0.012	0.011	6	6	35.32	29.2	0	5.4	0.2	5.6
0.013	0.011	7	6	38.26	31.63	0	5.9	0.2	6.1
0.014	0.011	7	5	41.2	34.06	0	6.3	0.3	6.6
0.013	0.011	6	5	38.26	31.63	0	5.9	0.2	6.1
0.012	0.01	6	5	35.32	29.2	0	5.4	0.2	5.6

T13

H+ (m)	H- (m)	F+ (N)	F- (N)	p+1+ (N/m)	p+3+ (N/m)	p+4+ (N/m)	Fw1+ (N)	Fw2+ (N)	Fw+lin (N)
0.005	0.006	2	3	14.72	11.83	0	2.2	0	2.2
0.007	0.01	3	5	20.6	16.56	0	3.1	0.1	3.2
0.01	0.009	5	5	29.43	23.66	0	4.4	0.1	4.5
0.009	0.008	5	4	26.49	21.29	0	4	0.1	4.1
0.01	0.01	6	5	29.43	23.66	0	4.4	0.1	4.5
0.011	0.009	6	5	32.37	26.03	0	4.9	0.2	5.1
0.011	0.01	6	5	32.37	26.03	0	4.9	0.2	5.1
0.012	0.011	6	4	35.32	28.39	0	5.3	0.2	5.5
0.011	0.011	6	6	32.37	26.03	0	4.9	0.2	5.1

T14

H+ (m)	H- (m)	F+ (N)	F- (N)	p+1+ (N/m)	p+3+ (N/m)	p+4+ (N/m)	Fw1+ (N)	Fw2+ (N)	Fw+lin (N)
0.002	0.004	1	2	5.89	4.47	0	0.9	0	0.9
0.006	0.007	3	3	17.66	13.41	0	2.6	0.1	2.7
0.011	0.011	6	5	32.37	24.59	0	4.7	0.2	4.9
0.009	0.006	4	3	26.49	20.12	0	3.9	0.1	4
0.007	0.007	4	3	20.6	15.65	0	3	0.1	3.1
0.005	0.006	3	3	14.72	11.18	0	2.1	0	2.1
0.005	0.005	3	3	14.72	11.18	0	2.1	0	2.1
0.006	0.006	3	3	17.66	13.41	0	2.6	0.1	2.7
0.006	0.006	3	3	17.66	13.41	0	2.6	0.1	2.7
0.006	0.006	3	3	17.66	13.41	0	2.6	0.1	2.7
0.006	0.007	3	3	17.66	13.41	0	2.6	0.1	2.7

T15

H+ (m)	H- (m)	F+ (N)	F- (N)	p+1+ (N/m	p+3+ (N/m	p+4+ (N/m	Fw1+ (N)	Fw2+ (N)	Fw+lin (N)
0.004	0.003	1	2	11.77	8.66	0	1.7	0	1.7
0.006	0.005	3	3	17.66	12.99	0	2.5	0.1	2.6
0.011	0.01	5	5	32.37	23.82	0	4.6	0.2	4.8
0.011	0.008	5	4	32.37	23.82	0	4.6	0.2	4.8
0.009	0.007	4	3	26.49	19.49	0	3.8	0.1	3.9
0.009	0.008	4	4	26.49	19.49	0	3.8	0.1	3.9
0.009	0.009	4	5	26.49	19.49	0	3.8	0.1	3.9
0.01	0.009	5	4	29.43	21.65	0	4.2	0.1	4.3
0.011	0.009	5	5	32.37	23.82	0	4.6	0.2	4.8
0.011	0.009	5	5	32.37	23.82	0	4.6	0.2	4.8
0.011	0.009	5	4	32.37	23.82	0	4.6	0.2	4.8
0.01	0.009	4	5	29.43	21.65	0	4.2	0.1	4.3
0.01	0.006	4	3	29.43	21.65	0	4.2	0.1	4.3
0.011	0.008	5	4	32.37	23.82	0	4.6	0.2	4.8

T16

H+ (m)	H- (m)	F+ (N)	F- (N)	p+1+ (N/m	p+3+ (N/m	p+4+ (N/m	Fw1+ (N)	Fw2+ (N)	Fw+lin (N)
0.003	0.003	1	1	8.83	6.17	0	1.2	0	1.2
0.005	0.005	2	2	14.72	10.28	0	2	0	2
0.01	0.009	4	4	29.43	20.55	0	4.1	0.1	4.2
0.011	0.011	5	5	32.37	22.61	0	4.5	0.2	4.7
0.012	0.011	6	5	35.32	24.66	0	4.9	0.2	5.1
0.011	0.012	5	6	32.37	22.61	0	4.5	0.2	4.7
0.013	0.012	6	5	38.26	26.72	0	5.3	0.2	5.5
0.012	0.012	5	6	35.32	24.66	0	4.9	0.2	5.1
0.012	0.011	5	5	35.32	24.66	0	4.9	0.2	5.1
0.011	0.011	5	5	32.37	22.61	0	4.5	0.2	4.7
0.012	0.011	5	5	35.32	24.66	0	4.9	0.2	5.1
0.012	0.011	6	5	35.32	24.66	0	4.9	0.2	5.1
0.011	0.012	5	6	32.37	22.61	0	4.5	0.2	4.7
0.012	0.009	6	4	35.32	24.66	0	4.9	0.2	5.1
0.011	0.009	5	4	32.37	22.61	0	4.5	0.2	4.7

T17

H+ (m)	H- (m)	F+ (N)	F- (N)	p+1+ (N/m	p+3+ (N/m	p+4+ (N/m	Fw1+ (N)	Fw2+ (N)	Fw+lin (N)
0.003	0.003	2	1	8.83	5.66	0	1.2	0	1.2
0.005	0.006	3	3	14.72	9.43	0	1.9	0	1.9
0.008	0.009	4	4	23.54	15.08	0	3.1	0.1	3.2
0.011	0.014	6	6	32.37	20.74	0	4.3	0.2	4.5
0.014	0.013	6	6	41.2	26.39	0	5.4	0.3	5.7
0.012	0.01	6	4	35.32	22.62	0	4.7	0.2	4.9
0.011	0.012	5	6	32.37	20.74	0	4.3	0.2	4.5
0.012	0.011	6	5	35.32	22.62	0	4.7	0.2	4.9
0.013	0.011	6	6	38.26	24.51	0	5	0.2	5.2
0.012	0.011	5	5	35.32	22.62	0	4.7	0.2	4.9
0.011	0.01	5	5	32.37	20.74	0	4.3	0.2	4.5
0.012	0.011	5	5	35.32	22.62	0	4.7	0.2	4.9
0.012	0.011	5	5	35.32	22.62	0	4.7	0.2	4.9
0.012	0.01	5	5	35.32	22.62	0	4.7	0.2	4.9
0.011	0.011	5	5	32.37	20.74	0	4.3	0.2	4.5
0.012	0.011	5	6	35.32	22.62	0	4.7	0.2	4.9

T18

H+ (m)	H- (m)	F+ (N)	F- (N)						
0.003	0.003	2	1	8.83	5.41	0	1.1	0	1.1
0.004	0.006	2	3	11.77	7.22	0	1.5	0	1.5
0.006	0.007	3	3	17.66	10.82	0	2.3	0.1	2.4
0.01	0.012	4	6	29.43	18.04	0	3.8	0.1	3.9
0.013	0.014	6	6	38.26	23.45	0	4.9	0.2	5.1
0.014	0.011	6	5	41.2	25.26	0	5.3	0.3	5.6
0.011	0.011	5	5	32.37	19.84	0	4.2	0.2	4.4
0.013	0.012	6	6	38.26	23.45	0	4.9	0.2	5.1
0.012	0.011	6	5	35.32	21.65	0	4.5	0.2	4.7
0.011	0.011	5	5	32.37	19.84	0	4.2	0.2	4.4
0.011	0.011	6	5	32.37	19.84	0	4.2	0.2	4.4
0.011	0.011	6	5	32.37	19.84	0	4.2	0.2	4.4
0.011	0.011	5	5	32.37	19.84	0	4.2	0.2	4.4
0.012	0.011	6	5	35.32	21.65	0	4.5	0.2	4.7
0.012	0.013	6	6	35.32	21.65	0	4.5	0.2	4.7
0.011	0.012	6	6	32.37	19.84	0	4.2	0.2	4.4
0.011	0.012	5	5	32.37	19.84	0	4.2	0.2	4.4

T21

H+ (m)	H- (m)	F+ (N)	F- (N)	p+1+ (N/m	p+3+ (N/m	p+4+ (N/m	Fw1+ (N)	Fw2 (N)	Fw+lin (N
0.007	0.009	4	4	20.6	17.75	0	3.2	0.1	3.3
0.016	0.011	8	5	47.09	40.56	0	7.4	0.4	7.8
0.012	0.012	6	6	35.32	30.42	0	5.5	0.2	5.7
0.014	0.015	7	7	41.2	35.49	0	6.5	0.3	6.8
0.012	0.014	6	6	35.32	30.42	0	5.5	0.2	5.7
0.013	0.014	6	6	38.26	32.96	0	6	0.2	6.2
0.015	0.014	7	6	44.15	38.03	0	6.9	0.3	7.2
0.016	0.014	8	6	47.09	40.56	0	7.4	0.4	7.8
0.016	0.013	7	5	47.09	40.56	0	7.4	0.4	7.8

T22

H+ (m)	H- (m)	F+ (N)	F- (N)	p+1+ (N/m	p+3+ (N/m	p+4+ (N/m	Fw1+ (N)	Fw2 (N)	Fw+lin (N
0.009	0.01	4	5	26.49	21.37	0	4	0.1	4.1
0.017	0.019	8	9	50.03	40.36	0	7.5	0.4	7.9
0.024	0.016	12	8	70.63	56.98	0	10.7	0.8	11.5
0.022	0.018	11	9	64.75	52.23	0	9.8	0.7	10.5
0.023	0.021	11	10	67.69	54.6	0	10.2	0.8	11
0.026	0.021	13	10	76.52	61.72	0	11.5	1	12.5
0.028	0.021	13	10	82.4	66.47	0	12.4	1.2	13.6
0.029	0.021	15	10	85.35	68.85	0	12.9	1.2	14.1
0.03	0.024	15	11	88.29	71.22	0	13.3	1.3	14.6

T23

H+ (m)	H- (m)	F+ (N)	F- (N)	p+1+ (N/m	p+3+ (N/m	p+4+ (N/m	Fw1+ (N)	Fw2 (N)	Fw+lin (N
0.008	0.009	3	4	23.54	18.22	0	3.5	0.1	3.6
0.016	0.018	7	8	47.09	36.43	0	6.9	0.4	7.3
0.025	0.022	11	10	73.58	56.93	0	10.8	0.9	11.7
0.018	0.014	8	7	52.97	40.99	0	7.8	0.5	8.3
0.019	0.014	9	7	55.92	43.26	0	8.2	0.5	8.7
0.015	0.014	6	7	44.15	34.16	0	6.5	0.3	6.8
0.014	0.014	6	7	41.2	31.88	0	6.1	0.3	6.4
0.013	0.012	6	6	38.26	29.6	0	5.6	0.2	5.8
0.013	0.011	6	6	38.26	29.6	0	5.6	0.2	5.8
0.014	0.011	6	5	41.2	31.88	0	6.1	0.3	6.4
0.014	0.014	7	7	41.2	31.88	0	6.1	0.3	6.4

T24

H+ (m)	H- (m)	F+ (N)	F- (N)	p+1+ (N/m	p+3+ (N/m	p+4+ (N/m	Fw1+ (N)	Fw2 (N)	Fw+lin (N
0.007	0.006	3	3	20.6	14.79	0	2.9	0.1	3
0.012	0.016	6	8	35.32	25.36	0	5	0.2	5.2
0.021	0.021	10	10	61.8	44.37	0	8.7	0.6	9.3
0.024	0.021	11	9	70.63	50.71	0	9.9	0.8	10.7
0.021	0.017	10	8	61.8	44.37	0	8.7	0.6	9.3
0.024	0.024	11	11	70.63	50.71	0	9.9	0.8	10.7
0.024	0.022	11	10	70.63	50.71	0	9.9	0.8	10.7
0.026	0.021	12	10	76.52	54.94	0	10.8	1	11.8
0.024	0.02	12	9	70.63	50.71	0	9.9	0.8	10.7
0.022	0.019	11	8	64.75	46.49	0	9.1	0.7	9.8
0.021	0.019	10	9	61.8	44.37	0	8.7	0.6	9.3
0.023	0.02	11	9	67.69	48.6	0	9.5	0.8	10.3
0.023	0.024	11	11	67.69	48.6	0	9.5	0.8	10.3
0.025	0.023	11	10	73.58	52.83	0	10.4	0.9	11.3

T25

H+ (m)	H- (m)	F+ (N)	F- (N)	p+1+ (N/	p+3+ (N/	p+4+ (N/	Fw1+ (N)	Fw2 (N)	Fw+lin (N
0.007	0.006	3	3	20.6	14.18	0	2.8	0.1	2.9
0.011	0.014	5	7	32.37	22.28	0	4.4	0.2	4.6
0.02	0.018	9	8	58.86	40.5	0	8.1	0.6	8.7
0.025	0.026	11	11	73.58	50.63	0	10.1	0.9	11
0.029	0.024	13	10	85.35	58.73	0	11.7	1.2	12.9
0.026	0.025	11	11	76.52	52.65	0	10.5	1	11.5
0.029	0.024	13	10	85.35	58.73	0	11.7	1.2	12.9
0.026	0.025	11	11	76.52	52.65	0	10.5	1	11.5
0.028	0.024	12	10	82.4	56.7	0	11.3	1.2	12.5
0.029	0.025	12	11	85.35	58.73	0	11.7	1.2	12.9
0.029	0.025	12	11	85.35	58.73	0	11.7	1.2	12.9
0.029	0.024	12	11	85.35	58.73	0	11.7	1.2	12.9
0.029	0.024	12	11	85.35	58.73	0	11.7	1.2	12.9
0.027	0.024	12	11	79.46	54.68	0	10.9	1.1	12
0.028	0.026	13	11	82.4	56.7	0	11.3	1.2	12.5

T26

H+ (m)	H- (m)	F+ (N)	F- (N)	p+1+ (N/	p+3+ (N/	p+4+ (N/	Fw1+ (N)	Fw2 (N)	Fw+lin (N
0.007	0.006	4	3	20.6	13.46	0	2.8	0.1	2.9
0.011	0.015	5	7	32.37	21.15	0	4.3	0.2	4.5
0.017	0.018	8	8	50.03	32.69	0	6.7	0.4	7.1
0.024	0.027	11	12	70.63	46.15	0	9.4	0.8	10.2
0.028	0.026	13	12	82.4	53.84	0	11	1.2	12.2
0.027	0.021	12	10	79.46	51.92	0	10.6	1.1	11.7
0.026	0.026	12	11	76.52	50	0	10.2	1	11.2
0.027	0.023	12	10	79.46	51.92	0	10.6	1.1	11.7
0.026	0.026	12	11	76.52	50	0	10.2	1	11.2
0.027	0.024	12	11	79.46	51.92	0	10.6	1.1	11.7
0.026	0.024	12	10	76.52	50	0	10.2	1	11.2
0.026	0.025	12	10	76.52	50	0	10.2	1	11.2
0.027	0.024	12	10	79.46	51.92	0	10.6	1.1	11.7
0.027	0.026	12	11	79.46	51.92	0	10.6	1.1	11.7
0.026	0.024	12	10	76.52	50	0	10.2	1	11.2
0.026	0.026	12	10	76.52	50	0	10.2	1	11.2

T27

H+ (m)	H- (m)	F+ (N)	F- (N)	p+1+ (N/	p+3+ (N/	p+4+ (N/	Fw1+ (N)	Fw2 (N)	Fw+lin (N
0.006	0.004	3	2	17.66	10.43	0	2.2	0.1	2.3
0.01	0.009	5	4	29.43	17.38	0	3.7	0.1	3.8
0.013	0.015	6	7	38.26	22.59	0	4.8	0.2	5
0.023	0.024	10	11	67.69	39.97	0	8.6	0.8	9.4
0.027	0.029	12	13	79.46	46.93	0	10	1.1	11.1
0.029	0.027	13	12	85.35	50.4	0	10.8	1.2	12
0.026	0.023	12	11	76.52	45.19	0	9.7	1	10.7
0.027	0.026	12	12	79.46	46.93	0	10	1.1	11.1
0.028	0.025	13	12	82.4	48.66	0	10.4	1.2	11.6
0.026	0.026	12	12	76.52	45.19	0	9.7	1	10.7
0.028	0.026	13	12	82.4	48.66	0	10.4	1.2	11.6
0.028	0.027	12	12	82.4	48.66	0	10.4	1.2	11.6
0.028	0.026	12	12	82.4	48.66	0	10.4	1.2	11.6
0.028	0.026	13	12	82.4	48.66	0	10.4	1.2	11.6
0.029	0.026	13	12	85.35	50.4	0	10.8	1.2	12
0.028	0.026	12	12	82.4	48.66	0	10.4	1.2	11.6
0.031	0.026	13	12	91.23	53.88	0	11.5	1.4	12.9

T28

H+ (m)	H- (m)	F+ (N)	F- (N)	p+1+ (N/	p+3+ (N/	p+4+ (N/	Fw1+ (N)	Fw2 (N)	Fw+lin (N
0.006	0.003	3	1	17.66	10	0	2.2	0.1	2.3
0.008	0.004	4	2	23.54	13.33	0	2.9	0.1	3
0.014	0.008	6	4	41.2	23.32	0	5.1	0.3	5.4
0.013	0.016	6	7	38.26	21.66	0	4.7	0.2	4.9
0.024	0.024	11	11	70.63	39.98	0	8.7	0.8	9.5
0.028	0.03	13	14	82.4	46.65	0	10.2	1.2	11.4
0.028	0.03	13	14	82.4	46.65	0	10.2	1.2	11.4
0.029	0.025	13	11	85.35	48.31	0	10.5	1.2	11.7
0.026	0.026	11	12	76.52	43.32	0	9.4	1	10.4
0.029	0.028	13	13	85.35	48.31	0	10.5	1.2	11.7
0.029	0.028	13	13	85.35	48.31	0	10.5	1.2	11.7
0.029	0.027	13	13	85.35	48.31	0	10.5	1.2	11.7
0.029	0.027	12	12	85.35	48.31	0	10.5	1.2	11.7
0.029	0.026	13	12	85.35	48.31	0	10.5	1.2	11.7
0.028	0.026	12	13	82.4	46.65	0	10.2	1.2	11.4
0.028	0.025	12	12	82.4	46.65	0	10.2	1.2	11.4
0.032	0.025	14	12	94.18	53.31	0	11.6	1.5	13.1
0.03	0.023	13	10	88.29	49.98	0	10.9	1.3	12.2

T31

H+ (m)	H- (m)	F+ (N)	F- (N)	p+1+ (N/m)	p+3+ (N/	p+4+ (N/	Fw1+ (N)	Fw2 (N)	Fw+lin (N)
0.013	0.014	6	7	38.26	31.88	0	5.9	0.2	6.1
0.026	0.022	13	10	76.52	63.75	0	11.8	1	12.8
0.036	0.02	18	10	105.95	88.27	0	16.3	1.9	18.2
0.038	0.024	19	12	111.83	93.18	0	17.2	2.1	19.3
0.039	0.029	19	14	114.78	95.63	0	17.6	2.2	19.8
0.036	0.032	19	15	105.95	88.27	0	16.3	1.9	18.2
0.036	0.031	18	15	105.95	88.27	0	16.3	1.9	18.2
0.034	0.03	17	14	100.06	83.37	0	15.4	1.7	17.1
0.033	0.03	17	14	97.12	80.92	0	14.9	1.6	16.5
T31B	H- (m)	F+ (N)	F- (N)	p+1+ (N/m)	p+3+ (N/	p+4+ (N/	Fw1+ (N)	Fw2 (N)	Fw+lin (N)
0.017	0.019	9	9	50.03	41.68	0	7.7	0.4	8.1
0.027	0.024	13	11	79.46	66.2	0	12.2	1.1	13.3
0.035	0.026	17	13	103.01	85.82	0	15.8	1.8	17.6
0.039	0.026	19	12	114.78	95.63	0	17.6	2.2	19.8
0.04	0.031	20	15	117.72	98.08	0	18.1	2.4	20.5
0.039	0.032	21	15	114.78	95.63	0	17.6	2.2	19.8
0.038	0.031	19	15	111.83	93.18	0	17.2	2.1	19.3
0.036	0.031	19	15	105.95	88.27	0	16.3	1.9	18.2
0.036	0.028	18	13	105.95	88.27	0	16.3	1.9	18.2
T31*	H- (m)	F+ (N)	F- (N)	p+1+ (N/m)	p+3+ (N/	p+4+ (N/	Fw1+ (N)	Fw2 (N)	Fw+lin (N)
0.016	0.018	9	9	47.09	39.23	0	7.2	0.4	7.6
0.026	0.023	13	11	76.52	63.75	0	11.8	1	12.8
0.026	0.033	17	12	76.52	63.75	0	11.8	1	12.8
0.026	0.037	19	12	76.52	63.75	0	11.8	1	12.8
0.031	0.037	19	15	91.23	76.01	0	14	1.4	15.4
0.031	0.034	18	15	91.23	76.01	0	14	1.4	15.4
0.029	0.034	17	14	85.35	71.11	0	13.1	1.2	14.3
0.03	0.032	17	15	88.29	73.56	0	13.6	1.3	14.9
0.028	0.031	16	13	82.4	68.66	0	12.7	1.2	13.9
				0	0	0	0	0	0
T32				0	0	0	0	0	0
H+ (m)	H- (m)	F+ (N)	F- (N)	p+1+ (N/m)	p+3+ (N/	p+4+ (N/	Fw1+ (N)	Fw2 (N)	Fw+lin (N)
0.017	0.017	8	8	50.03	40.49	0	7.5	0.4	7.9
0.028	0.026	13	12	82.4	66.7	0	12.4	1.2	13.6
0.036	0.024	18	12	105.95	85.75	0	16	1.9	17.9
0.038	0.026	19	13	111.83	90.52	0	16.9	2.1	19
0.04	0.029	20	14	117.72	95.28	0	17.8	2.4	20.2
0.044	0.026	22	12	129.49	104.81	0	19.5	2.8	22.3
0.045	0.029	23	14	132.44	107.19	0	20	3	23
0.046	0.032	23	15	135.38	109.57	0	20.4	3.1	23.5
0.047	0.03	23	14	138.32	111.95	0	20.9	3.3	24.2
0.05	0.033	25	16	147.15	119.1	0	22.2	3.7	25.9
T32*	H- (m)	F+ (N)	F- (N)	p+1+ (N/m)	p+3+ (N/	p+4+ (N/	Fw1+ (N)	Fw2 (N)	Fw+lin (N)
0.014	0.015	8	8	41.2	33.35	0	6.2	0.3	6.5
0.026	0.026	13	12	76.52	61.93	0	11.5	1	12.5
0.036	0.023	18	12	105.95	85.75	0	16	1.9	17.9
0.036	0.027	18	13	105.95	85.75	0	16	1.9	17.9
0.036	0.029	19	15	105.95	85.75	0	16	1.9	17.9
0.041	0.026	21	13	120.66	97.66	0	18.2	2.5	20.7
0.043	0.027	22	13	126.55	102.43	0	19.1	2.7	21.8
0.044	0.03	23	15	129.49	104.81	0	19.5	2.8	22.3
0.046	0.031	23	15	135.38	109.57	0	20.4	3.1	23.5
0.046	0.033	24	16	135.38	109.57	0	20.4	3.1	23.5

T33

H+ (m)	H- (m)	F+ (N)	F- (N)	p+1+ (N/m	p+3+ (N/	p+4+ (N/	Fw1+ (N)	Fw2 (N)	Fw+lin (N)
0.013	0.012	7	6	38.26	29.85	0	5.7	0.2	5.9
0.026	0.026	12	12	76.52	59.7	0	11.3	1	12.3
0.039	0.031	19	14	114.78	89.54	0	17	2.2	19.2
0.027	0.024	14	12	79.46	61.99	0	11.7	1.1	12.8
0.033	0.022	16	10	97.12	75.77	0	14.4	1.6	16
0.033	0.024	16	11	97.12	75.77	0	14.4	1.6	16
0.03	0.024	15	12	88.29	68.88	0	13.1	1.3	14.4
0.029	0.025	15	12	85.35	66.58	0	12.6	1.2	13.8
0.028	0.026	13	12	82.4	64.29	0	12.2	1.2	13.4
0.029	0.023	14	11	85.35	66.58	0	12.6	1.2	13.8
0.029	0.026	15	12	85.35	66.58	0	12.6	1.2	13.8
T33*	H- (m)	F+ (N)	F- (N)	p+1+ (N/m	p+3+ (N/	p+4+ (N/	Fw1+ (N)	Fw2 (N)	Fw+lin (N)
0.011	0.011	6	5	32.37	25.26	0	4.8	0.2	5
0.024	0.022	12	10	70.63	55.1	0	10.4	0.8	11.2
0.038	0.03	19	15	111.83	87.25	0	16.5	2.1	18.6
0.026	0.023	14	11	76.52	59.7	0	11.3	1	12.3
0.031	0.021	16	11	91.23	71.18	0	13.5	1.4	14.9
0.031	0.024	16	11	91.23	71.18	0	13.5	1.4	14.9
0.027	0.024	14	12	79.46	61.99	0	11.7	1.1	12.8
0.026	0.023	13	11	76.52	59.7	0	11.3	1	12.3
0.025	0.024	12	12	73.58	57.4	0	10.9	0.9	11.8
0.026	0.022	12	11	76.52	59.7	0	11.3	1	12.3
0.026	0.025	13	12	76.52	59.7	0	11.3	1	12.3

T34

H+ (m)	H- (m)	F+ (N)	F- (N)	p+1+ (N/m	p+3+ (N/	p+4+ (N/	Fw1+ (N)	Fw2 (N)	Fw+lin (N)
0.013	0.009	6	4	38.26	27.82	0	5.4	0.2	5.6
0.022	0.022	10	10	64.75	47.08	0	9.2	0.7	9.9
0.035	0.031	16	15	103.01	74.9	0	14.6	1.8	16.4
0.037	0.03	17	14	108.89	79.18	0	15.4	2	17.4
0.032	0.025	15	12	94.18	68.48	0	13.3	1.5	14.8
0.036	0.03	16	14	105.95	77.04	0	15	1.9	16.9
0.034	0.031	16	15	100.06	72.76	0	14.2	1.7	15.9
0.036	0.029	17	14	105.95	77.04	0	15	1.9	16.9
0.035	0.028	17	13	103.01	74.9	0	14.6	1.8	16.4
0.035	0.027	16	13	103.01	74.9	0	14.6	1.8	16.4
0.036	0.028	17	13	105.95	77.04	0	15	1.9	16.9
0.036	0.031	17	15	105.95	77.04	0	15	1.9	16.9
0.035	0.029	15	14	103.01	74.9	0	14.6	1.8	16.4
0.038	0.031	17	15	111.83	81.32	0	15.8	2.1	17.9
T34*	H- (m)	F+ (N)	F- (N)	p+1+ (N/m	p+3+ (N/	p+4+ (N/	Fw1+ (N)	Fw2 (N)	Fw+lin (N)
0.013	0.008	6	4	38.26	27.82	0	5.4	0.2	5.6
0.021	0.015	10	7	61.8	44.94	0	8.8	0.6	9.4
0.034	0.031	17	15	100.06	72.76	0	14.2	1.7	15.9
0.036	0.03	17	14	105.95	77.04	0	15	1.9	16.9
0.032	0.023	15	11	94.18	68.48	0	13.3	1.5	14.8
0.031	0.026	14	12	91.23	66.34	0	12.9	1.4	14.3
0.032	0.03	15	14	94.18	68.48	0	13.3	1.5	14.8
0.035	0.026	16	12	103.01	74.9	0	14.6	1.8	16.4
0.036	0.028	17	13	105.95	77.04	0	15	1.9	16.9
0.034	0.026	16	12	100.06	72.76	0	14.2	1.7	15.9
0.035	0.025	17	11	103.01	74.9	0	14.6	1.8	16.4
0.036	0.031	16	14	105.95	77.04	0	15	1.9	16.9
0.035	0.021	17	10	103.01	74.9	0	14.6	1.8	16.4
0.04	0.029	18	13	117.72	85.6	0	16.7	2.4	19.1

T35

H+ (m)	H- (m)	F+ (N)	F- (N)	p+1+ (N/	p+3+ (N/	p+4+ (N/	Fw1+ (N)	Fw2 (N)	Fw+lin (N
0.011	0.006	6	3	32.37	22.44	0	4.5	0.2	4.7
0.019	0.017	9	8	55.92	38.76	0	7.7	0.5	8.2
0.031	0.028	15	13	91.23	63.24	0	12.6	1.4	14
0.039	0.036	18	16	114.78	79.56	0	15.8	2.2	18
0.041	0.03	19	14	120.66	83.64	0	16.6	2.5	19.1
0.036	0.036	17	16	105.95	73.44	0	14.6	1.9	16.5
0.041	0.031	19	14	120.66	83.64	0	16.6	2.5	19.1
0.04	0.038	18	17	117.72	81.6	0	16.2	2.4	18.6
0.04	0.034	17	16	117.72	81.6	0	16.2	2.4	18.6
0.04	0.034	18	16	117.72	81.6	0	16.2	2.4	18.6
0.039	0.031	18	15	114.78	79.56	0	15.8	2.2	18
0.04	0.031	19	15	117.72	81.6	0	16.2	2.4	18.6
0.041	0.036	18	17	120.66	83.64	0	16.6	2.5	19.1
0.042	0.028	19	13	123.61	85.68	0	17.1	2.6	19.7
0.042	0.026	19	12	123.61	85.68	0	17.1	2.6	19.7

T35*	H- (m)	F+ (N)	F- (N)	p+1+ (N/	p+3+ (N/	p+4+ (N/	Fw1+ (N)	Fw2 (N)	Fw+lin (N
0.014	0.009	7	5	41.2	28.56	0	5.7	0.3	6
0.021	0.025	10	12	61.8	42.84	0	8.5	0.6	9.1
0.032	0.026	15	12	94.18	65.28	0	13	1.5	14.5
0.039	0.036	17	16	114.78	79.56	0	15.8	2.2	18
0.041	0.031	18	14	120.66	83.64	0	16.6	2.5	19.1
0.041	0.037	19	17	120.66	83.64	0	16.6	2.5	19.1
0.041	0.031	19	14	120.66	83.64	0	16.6	2.5	19.1
0.04	0.035	18	16	117.72	81.6	0	16.2	2.4	18.6
0.04	0.034	18	16	117.72	81.6	0	16.2	2.4	18.6
0.04	0.034	17	16	117.72	81.6	0	16.2	2.4	18.6
0.04	0.034	18	16	117.72	81.6	0	16.2	2.4	18.6
0.041	0.031	19	15	120.66	83.64	0	16.6	2.5	19.1
0.042	0.037	18	17	123.61	85.68	0	17.1	2.6	19.7
0.041	0.031	17	15	120.66	83.64	0	16.6	2.5	19.1
0.043	0.031	19	14	126.55	87.72	0	17.5	2.7	20.2

T36

H+ (m)	H- (m)	F+ (N)	F- (N)	p+1+ (N/	p+3+ (N/	p+4+ (N/	Fw1+ (N)	Fw2 (N)	Fw+lin (N
0.011	0.006	6	3	32.37	21.35	0	4.3	0.2	4.5
0.017	0.012	8	6	50.03	33	0	6.7	0.4	7.1
0.029	0.021	14	10	85.35	56.29	0	11.5	1.2	12.7
0.036	0.038	16	17	105.95	69.88	0	14.2	1.9	16.1
0.046	0.041	21	18	135.38	89.29	0	18.2	3.1	21.3
0.043	0.034	19	15	126.55	83.46	0	17	2.7	19.7
0.041	0.036	18	15	120.66	79.58	0	16.2	2.5	18.7
0.041	0.034	18	15	120.66	79.58	0	16.2	2.5	18.7
0.042	0.039	19	17	123.61	81.52	0	16.6	2.6	19.2
0.044	0.039	18	17	129.49	85.4	0	17.4	2.8	20.2
0.044	0.036	19	16	129.49	85.4	0	17.4	2.8	20.2
0.042	0.035	19	15	123.61	81.52	0	16.6	2.6	19.2
0.044	0.039	20	16	129.49	85.4	0	17.4	2.8	20.2
0.044	0.042	19	18	129.49	85.4	0	17.4	2.8	20.2
0.049	0.035	21	15	144.21	95.11	0	19.4	3.5	22.9
0.054	0.029	21	12	158.92	104.81	0	21.3	4.3	25.6

T36*	H- (m)	F+ (N)	F- (N)	p+1+ (N/	p+3+ (N/	p+4+ (N/	Fw1+ (N)	Fw2 (N)	Fw+lin (N
0.014	0.009	7	4	41.2	27.17	0	5.5	0.3	5.8
0.019	0.024	9	11	55.92	36.88	0	7.5	0.5	8
0.029	0.025	14	12	85.35	56.29	0	11.5	1.2	12.7
0.037	0.038	17	17	108.89	71.82	0	14.6	2	16.6
0.044	0.039	19	17	129.49	85.4	0	17.4	2.8	20.2
0.044	0.034	19	15	129.49	85.4	0	17.4	2.8	20.2
0.044	0.039	19	17	129.49	85.4	0	17.4	2.8	20.2
0.044	0.034	19	15	129.49	85.4	0	17.4	2.8	20.2
0.043	0.039	19	17	126.55	83.46	0	17	2.7	19.7
0.044	0.036	19	15	129.49	85.4	0	17.4	2.8	20.2
0.044	0.038	18	16	129.49	85.4	0	17.4	2.8	20.2
0.044	0.038	18	16	129.49	85.4	0	17.4	2.8	20.2
0.046	0.034	19	15	135.38	89.29	0	18.2	3.1	21.3
0.046	0.044	19	19	135.38	89.29	0	18.2	3.1	21.3
0.051	0.036	19	16	150.09	98.99	0	20.1	3.8	23.9
0.05	0.029	19	12	147.15	97.05	0	19.8	3.7	23.5

T37

H+ (m)	H- (m)	F+ (N)	F- (N)	p+1+ (N/	p+3+ (N/	p+4+ (N/	Fw1+ (N)	Fw2 (N)	Fw+lin (N
0.011	0.004	6	2	32.37	19.61	0	4.1	0.2	4.3
0.014	0.008	7	4	41.2	24.96	0	5.3	0.3	5.6
0.024	0.014	11	7	70.63	42.79	0	9	0.8	9.8
0.027	0.032	12	15	79.46	48.14	0	10.2	1.1	11.3
0.041	0.043	18	19	120.66	73.1	0	15.5	2.5	18
0.043	0.044	19	20	126.55	76.67	0	16.2	2.7	18.9
0.039	0.034	17	15	114.78	69.54	0	14.7	2.2	16.9
0.038	0.036	17	17	111.83	67.75	0	14.3	2.1	16.4
0.037	0.035	17	17	108.89	65.97	0	13.9	2	15.9
0.041	0.037	17	18	120.66	73.1	0	15.5	2.5	18
0.039	0.034	18	16	114.78	69.54	0	14.7	2.2	16.9
0.039	0.037	18	17	114.78	69.54	0	14.7	2.2	16.9
0.042	0.036	19	17	123.61	74.89	0	15.8	2.6	18.4
0.043	0.036	19	17	126.55	76.67	0	16.2	2.7	18.9
0.039	0.039	17	18	114.78	69.54	0	14.7	2.2	16.9
0.044	0.035	20	16	129.49	78.45	0	16.6	2.8	19.4
0.044	0.034	18	16	129.49	78.45	0	16.6	2.8	19.4

T37*	H- (m)	F+ (N)	F- (N)	p+1+ (N/	p+3+ (N/	p+4+ (N/	Fw1+ (N)	Fw2 (N)	Fw+lin (N
0.012	0.004	6	2	35.32	21.4	0	4.5	0.2	4.7
0.016	0.008	7	3	47.09	28.53	0	6	0.4	6.4
0.026	0.014	12	6	76.52	46.36	0	9.8	1	10.8
0.027	0.034	12	15	79.46	48.14	0	10.2	1.1	11.3
0.044	0.043	19	19	129.49	78.45	0	16.6	2.8	19.4
0.044	0.043	18	19	129.49	78.45	0	16.6	2.8	19.4
0.04	0.031	16	14	117.72	71.32	0	15.1	2.4	17.5
0.037	0.038	16	17	108.89	65.97	0	13.9	2	15.9
0.039	0.034	16	15	114.78	69.54	0	14.7	2.2	16.9
0.041	0.036	17	17	120.66	73.1	0	15.5	2.5	18
0.037	0.033	16	15	108.89	65.97	0	13.9	2	15.9
0.038	0.037	18	17	111.83	67.75	0	14.3	2.1	16.4
0.041	0.034	18	17	120.66	73.1	0	15.5	2.5	18
0.041	0.037	18	17	120.66	73.1	0	15.5	2.5	18
0.037	0.036	17	17	108.89	65.97	0	13.9	2	15.9
0.044	0.032	21	15	129.49	78.45	0	16.6	2.8	19.4
0.044	0.031	19	14	129.49	78.45	0	16.6	2.8	19.4

T38

H+ (m)	H- (m)	F+ (N)	F- (N)	p+1+ (N/	p+3+ (N/	p+4+ (N/	Fw1+ (N)	Fw2 (N)	Fw+lin (N
0.014	0.006	7	3	41.2	23.32	0	5.1	0.3	5.4
0.016	0.016	8	8	47.09	26.66	0	5.8	0.4	6.2
0.02	0.022	9	10	58.86	33.32	0	7.3	0.6	7.9
0.034	0.033	15	15	100.06	56.64	0	12.3	1.7	14
0.036	0.039	16	18	105.95	59.98	0	13.1	1.9	15
0.041	0.042	18	19	120.66	68.31	0	14.9	2.5	17.4
0.041	0.039	18	18	120.66	68.31	0	14.9	2.5	17.4
0.041	0.04	18	18	120.66	68.31	0	14.9	2.5	17.4
0.041	0.044	19	21	120.66	68.31	0	14.9	2.5	17.4
0.043	0.039	18	18	126.55	71.64	0	15.6	2.7	18.3
0.041	0.04	18	18	120.66	68.31	0	14.9	2.5	17.4
0.042	0.041	18	19	123.61	69.97	0	15.2	2.6	17.8
0.04	0.039	18	18	117.72	66.64	0	14.5	2.4	16.9
0.04	0.039	19	17	117.72	66.64	0	14.5	2.4	16.9
0.043	0.037	19	17	126.55	71.64	0	15.6	2.7	18.3
0.039	0.041	17	19	114.78	64.97	0	14.2	2.2	16.4
0.048	0.041	20	19	141.26	79.97	0	17.4	3.4	20.8
0.044	0.031	18	15	129.49	73.3	0	16	2.8	18.8

T38*	H- (m)	F+ (N)	F- (N)	p+1+ (N/	p+3+ (N/	p+4+ (N/	Fw1+ (N)	Fw2 (N)	Fw+lin (N
0.011	0.003	5	1	32.37	18.33	0	4	0.2	4.2
0.014	0.006	6	3	41.2	23.32	0	5.1	0.3	5.4
0.021	0.013	10	6	61.8	34.99	0	7.6	0.6	8.2
0.025	0.029	11	12	73.58	41.65	0	9.1	0.9	10
0.039	0.04	17	18	114.78	64.97	0	14.2	2.2	16.4
0.044	0.048	19	21	129.49	73.3	0	16	2.8	18.8
0.042	0.041	17	18	123.61	69.97	0	15.2	2.6	17.8
0.041	0.035	18	16	120.66	68.31	0	14.9	2.5	17.4
0.038	0.041	17	19	111.83	63.31	0	13.8	2.1	15.9
0.041	0.039	18	18	120.66	68.31	0	14.9	2.5	17.4
0.042	0.044	19	19	123.61	69.97	0	15.2	2.6	17.8
0.042	0.039	17	18	123.61	69.97	0	15.2	2.6	17.8
0.039	0.04	18	18	114.78	64.97	0	14.2	2.2	16.4
0.043	0.039	19	17	126.55	71.64	0	15.6	2.7	18.3
0.044	0.041	17	18	129.49	73.3	0	16	2.8	18.8
0.041	0.038	17	17	120.66	68.31	0	14.9	2.5	17.4
0.049	0.038	20	17	144.21	81.63	0	17.8	3.5	21.3
0.053	0.034	19	16	155.98	88.3	0	19.2	4.1	23.3

T41

H+ (m)	H- (m)	F+ (N)	F- (N)	p+1+ (N/m	p+3+ (N/m	p+4+ (N/m	Fw1+ (N)	Fw2 (N)	Fw+lin (N
0.019	0.016	10	8	55.92	46.84	0	8.6	0.5	9.1
0.039	0.029	19	13	114.78	96.14	0	17.7	2.2	19.9
0.056	0.027	27	13	164.81	138.04	0	25.4	4.6	30
0.053	0.031	26	15	155.98	130.65	0	24.1	4.1	28.2
0.055	0.039	27	18	161.87	135.58	0	25	4.5	29.5
0.049	0.041	26	19	144.21	120.79	0	22.2	3.5	25.7
0.049	0.041	24	19	144.21	120.79	0	22.2	3.5	25.7
0.047	0.04	24	19	138.32	115.86	0	21.3	3.3	24.6
0.049	0.041	24	19	144.21	120.79	0	22.2	3.5	25.7

T42

H+ (m)	H- (m)	F+ (N)	F- (N)	p+1+ (N/m	p+3+ (N/m	p+4+ (N/m	Fw1+ (N)	Fw2 (N)	Fw+lin (N
0.021	0.018	10	8	61.8	50.34	0	9.4	0.6	10
0.039	0.033	18	15	114.78	93.48	0	17.4	2.2	19.6
0.055	0.034	26	16	161.87	131.84	0	24.5	4.5	29
0.05	0.037	25	18	147.15	119.85	0	22.3	3.7	26
0.054	0.039	27	18	158.92	129.44	0	24.1	4.3	28.4
0.06	0.034	29	17	176.58	143.82	0	26.8	5.3	32.1
0.061	0.036	30	17	179.52	146.22	0	27.2	5.5	32.7
0.06	0.036	30	18	176.58	143.82	0	26.8	5.3	32.1
0.065	0.04	30	20	191.3	155.81	11.77	29	6.2	35.2
0.065	0.046	33	21	191.3	155.81	11.77	29	6.2	35.2
T42B	0	0	0	p+1+ (N/m	p+3+ (N/m	p+4+ (N/m	Fw1+ (N)	Fw2 (N)	Fw+lin (N
0.025	0.021	13	10	73.58	59.93	0	11.2	0.9	12.1
0.041	0.035	20	16	120.66	98.28	0	18.3	2.5	20.8
0.055	0.033	28	16	161.87	131.84	0	24.5	4.5	29
0.054	0.037	27	17	158.92	129.44	0	24.1	4.3	28.4
0.057	0.039	29	18	167.75	136.63	0	25.4	4.8	30.2
0.061	0.034	30	16	179.52	146.22	0	27.2	5.5	32.7
0.06	0.036	31	17	176.58	143.82	0	26.8	5.3	32.1
0.061	0.039	31	19	179.52	146.22	0	27.2	5.5	32.7
0.065	0.039	31	19	191.3	155.81	11.77	29	6.2	35.2
0.068	0.045	34	21	200.12	163	20.6	30.3	6.7	37

T43

H+ (m)	H- (m)	F+ (N)	F- (N)	p+1+ (N/m	p+3+ (N/m	p+4+ (N/m	Fw1+ (N)	Fw2 (N)	Fw+lin (N
0.02	0.012	10	6	58.86	46.3	0	8.7	0.6	9.3
0.034	0.023	16	10	100.06	78.71	0	14.9	1.7	16.6
0.057	0.044	27	20	167.75	131.96	0	24.9	4.8	29.7
0.046	0.026	22	13	135.38	106.49	0	20.1	3.1	23.2
0.048	0.033	23	16	141.26	111.12	0	21	3.4	24.4
0.048	0.038	22	17	141.26	111.12	0	21	3.4	24.4
0.042	0.039	20	18	123.61	97.23	0	18.4	2.6	21
0.044	0.036	20	17	129.49	101.86	0	19.2	2.8	22
0.043	0.036	20	17	126.55	99.55	0	18.8	2.7	21.5
0.046	0.033	21	15	135.38	106.49	0	20.1	3.1	23.2
0.046	0.038	21	17	135.38	106.49	0	20.1	3.1	23.2

T44

H+ (m)	H- (m)	F+ (N)	F- (N)	p+1+ (N/m	p+3+ (N/m	p+4+ (N/m	Fw1+ (N)	Fw2 (N)	Fw+lin (N
0.02	0.013	10	6	58.86	43.04	0	8.4	0.6	9
0.034	0.032	15	14	100.06	73.17	0	14.2	1.7	15.9
0.048	0.043	22	19	141.26	103.3	0	20.1	3.4	23.5
0.05	0.043	23	18	147.15	107.6	0	21	3.7	24.7
0.042	0.038	19	16	123.61	90.38	0	17.6	2.6	20.2
0.047	0.036	21	16	138.32	101.14	0	19.7	3.3	23
0.046	0.039	21	18	135.38	98.99	0	19.3	3.1	22.4
0.049	0.04	22	18	144.21	105.45	0	20.5	3.5	24
0.051	0.042	22	19	150.09	109.75	0	21.4	3.8	25.2
0.05	0.039	22	18	147.15	107.6	0	21	3.7	24.7
0.05	0.034	22	15	147.15	107.6	0	21	3.7	24.7
0.051	0.038	23	16	150.09	109.75	0	21.4	3.8	25.2
0.044	0.028	21	12	129.49	94.69	0	18.4	2.8	21.2
0.058	0.029	24	14	170.69	124.82	0	24.3	5	29.3

T45

H+ (m)	H- (m)	F+ (N)	F- (N)	p+1+ (N/	p+3+ (N/	p+4+ (N/	Fw1+ (N)	Fw2 (N)	Fw+lin (N
0.019	0.009	10	4	55.92	39.33	0	7.8	0.5	8.3
0.029	0.024	14	11	85.35	60.03	0	11.9	1.2	13.1
0.046	0.038	21	17	135.38	95.22	0	18.8	3.1	21.9
0.055	0.049	24	21	161.87	113.85	0	22.5	4.5	27
0.056	0.04	24	17	164.81	115.92	0	22.9	4.6	27.5
0.052	0.047	23	21	153.04	107.64	0	21.3	4	25.3
0.054	0.041	24	18	158.92	111.78	0	22.1	4.3	26.4
0.053	0.046	24	20	155.98	109.71	0	21.7	4.1	25.8
0.053	0.045	23	20	155.98	109.71	0	21.7	4.1	25.8
0.055	0.046	23	20	161.87	113.85	0	22.5	4.5	27
0.054	0.041	23	19	158.92	111.78	0	22.1	4.3	26.4
0.054	0.039	24	17	158.92	111.78	0	22.1	4.3	26.4
0.051	0.046	25	19	150.09	105.57	0	20.9	3.8	24.7
0.052	0.035	24	16	153.04	107.64	0	21.3	4	25.3
0.059	0.024	26	11	173.64	122.13	0	24.1	5.1	29.2

T46

H+ (m)	H- (m)	F+ (N)	F- (N)	p+1+ (N/	p+3+ (N/	p+4+ (N/	Fw1+ (N)	Fw2 (N)	Fw+lin (N
0.019	0.008	10	4	55.92	37.54	0	7.6	0.5	8.1
0.027	0.015	13	7	79.46	53.35	0	10.8	1.1	11.9
0.042	0.027	20	12	123.61	82.99	0	16.8	2.6	19.4
0.051	0.049	23	21	150.09	100.78	0	20.3	3.8	24.1
0.059	0.05	25	21	173.64	116.58	0	23.5	5.1	28.6
0.056	0.044	24	19	164.81	110.66	0	22.3	4.6	26.9
0.055	0.044	23	18	161.87	108.68	0	21.9	4.5	26.4
0.057	0.05	23	21	167.75	112.63	0	22.7	4.8	27.5
0.054	0.046	23	18	158.92	106.7	0	21.5	4.3	25.8
0.056	0.051	23	21	164.81	110.66	0	22.3	4.6	26.9
0.059	0.049	23	20	173.64	116.58	0	23.5	5.1	28.6
0.061	0.046	23	20	179.52	120.54	0	24.3	5.5	29.8
0.063	0.057	24	23	185.41	124.49	5.89	25.1	5.8	30.9
0.064	0.046	24	20	188.35	126.46	8.83	25.5	6	31.5
0.059	0.049	23	20	173.64	116.58	0	23.5	5.1	28.6
0.059	0.046	26	19	173.64	116.58	0	23.5	5.1	28.6

T47

H+ (m)	H- (m)	F+ (N)	F- (N)	p+1+ (N/	p+3+ (N/	p+4+ (N/	Fw1+ (N)	Fw2 (N)	Fw+lin (N
0.019	0.006	10	2	55.92	33.88	0	7.2	0.5	7.7
0.022	0.011	11	4	64.75	39.23	0	8.3	0.7	9
0.036	0.017	17	8	105.95	64.19	0	13.6	1.9	15.5
0.039	0.049	17	19	114.78	69.54	0	14.7	2.2	16.9
0.054	0.061	25	25	158.92	96.28	0	20.4	4.3	24.7
0.054	0.051	23	22	158.92	96.28	0	20.4	4.3	24.7
0.05	0.048	19	20	147.15	89.15	0	18.9	3.7	22.6
0.046	0.049	23	21	135.38	82.02	0	17.3	3.1	20.4
0.052	0.05	21	22	153.04	92.72	0	19.6	4	23.6
0.051	0.05	22	23	150.09	90.93	0	19.2	3.8	23
0.053	0.048	21	21	155.98	94.5	0	20	4.1	24.1
0.049	0.051	22	23	144.21	87.37	0	18.5	3.5	22
0.053	0.049	23	21	155.98	94.5	0	20	4.1	24.1
0.056	0.049	21	21	164.81	99.85	0	21.1	4.6	25.7
0.051	0.054	21	23	150.09	90.93	0	19.2	3.8	23
0.063	0.044	25	20	185.41	112.33	5.89	23.8	5.8	29.6
0.068	0.038	23	19	200.12	121.24	20.6	25.6	6.7	32.3

T48

H+ (m)	H- (m)	F+ (N)	F- (N)	p+1+ (N/	p+3+ (N/	p+4+ (N/	Fw1+ (N)	Fw2 (N)	Fw+lin (N
0.015	0.003	8	1	44.15	25.37	0	5.5	0.3	5.8
0.021	0.012	10	5	61.8	35.51	0	7.7	0.6	8.3
0.029	0.021	13	9	85.35	49.04	0	10.6	1.2	11.8
0.039	0.04	17	16	114.78	65.95	0	14.3	2.2	16.5
0.05	0.058	21	23	147.15	84.55	0	18.3	3.7	22
0.049	0.055	24	25	144.21	82.86	0	17.9	3.5	21.4
0.054	0.048	20	21	158.92	91.31	0	19.8	4.3	24.1
0.047	0.051	22	22	138.32	79.48	0	17.2	3.3	20.5
0.048	0.05	22	22	141.26	81.17	0	17.6	3.4	21
0.056	0.057	20	24	164.81	94.7	0	20.5	4.6	25.1
0.056	0.054	20	23	164.81	94.7	0	20.5	4.6	25.1
0.049	0.054	19	22	144.21	82.86	0	17.9	3.5	21.4
0.049	0.054	21	23	144.21	82.86	0	17.9	3.5	21.4
0.059	0.052	20	22	173.64	99.77	0	21.6	5.1	26.7
0.059	0.05	20	22	173.64	99.77	0	21.6	5.1	26.7
0.039	0.051	21	22	114.78	65.95	0	14.3	2.2	16.5
0.054	0.049	25	24	158.92	91.31	0	19.8	4.3	24.1
0.063	0.044	21	21	185.41	106.53	5.89	23.1	5.8	28.9

T11					T11						
H+ (m)	H- (m)	F+ (N)	F- (N)	alpha1	p+1+_g (N/m)	alpha3	p+3+_g	p+4+_g	Fw1+_g (N)	Fw2+_g (N)	Fw+_g (N)
0.006	0.007	3	3	0.92	16.25	0.87	14.14	0	2.6	0.5	3.1
0.005	0.006	3	3	0.92	13.54	0.87	11.78	0	2.2	0.4	2.6
0.009	0.009	5	4	0.92	24.37	0.87	21.2	0	3.9	0.7	4.6
0.009	0.009	5	3	0.92	24.37	0.87	21.2	0	3.9	0.7	4.6
0.009	0.006	5	3	0.92	24.37	0.87	21.2	0	3.9	0.7	4.6
0.009	0.007	4	3	0.92	24.37	0.87	21.2	0	3.9	0.7	4.6
0.009	0.008	5	4	0.92	24.37	0.87	21.2	0	3.9	0.7	4.6
0.009	0.008	5	4	0.92	24.37	0.87	21.2	0	3.9	0.7	4.6
0.009	0.008	5	4	0.92	24.37	0.87	21.2	0	3.9	0.7	4.6

T12					T12						
H+ (m)	H- (m)	F+ (N)	F- (N)	alpha1	p+1+_g (N/m)	alpha3	p+3+_g	p+4+_g	Fw1+_g (N)	Fw2+_g (N)	Fw+_g (N)
0.005	0.006	3	3	0.9	13.24	0.84	11.12	0	2.1	0.4	2.5
0.007	0.009	3	4	0.9	18.54	0.84	15.57	0	2.9	0.6	3.5
0.01	0.01	5	5	0.9	26.49	0.84	22.25	0	4.2	0.8	5
0.011	0.009	6	4	0.9	29.14	0.84	24.48	0	4.6	0.9	5.5
0.012	0.011	6	6	0.9	31.78	0.84	26.7	0	5	1	6
0.013	0.011	7	6	0.9	34.43	0.84	28.92	0	5.4	1.1	6.5
0.014	0.011	7	5	0.9	37.08	0.84	31.15	0	5.9	1.1	7
0.013	0.011	6	5	0.9	34.43	0.84	28.92	0	5.4	1.1	6.5
0.012	0.01	6	5	0.9	31.78	0.84	26.7	0	5	1	6

T13					T13						
H+ (m)	H- (m)	F+ (N)	F- (N)	alpha1	p+1+_g (N/m)	alpha3	p+3+_g	p+4+_g	Fw1+_g (N)	Fw2+_g (N)	Fw+_g (N)
0.005	0.006	2	3	0.88	12.95	0.82	10.62	0	2	0.4	2.4
0.007	0.01	3	5	0.88	18.13	0.82	14.87	0	2.8	0.6	3.4
0.01	0.009	5	5	0.88	25.9	0.82	21.24	0	4.1	0.8	4.9
0.009	0.008	5	4	0.88	23.31	0.82	19.11	0	3.6	0.7	4.3
0.01	0.01	6	5	0.88	25.9	0.82	21.24	0	4.1	0.8	4.9
0.011	0.009	6	5	0.88	28.49	0.82	23.36	0	4.5	0.9	5.4
0.011	0.01	6	5	0.88	28.49	0.82	23.36	0	4.5	0.9	5.4
0.012	0.011	6	4	0.88	31.08	0.82	25.49	0	4.9	0.9	5.8
0.011	0.011	6	6	0.88	28.49	0.82	23.36	0	4.5	0.9	5.4

T14					T14						
H+ (m)	H- (m)	F+ (N)	F- (N)	alpha1	p+1+_g (N/m)	alpha3	p+3+_g	p+4+_g	Fw1+_g (N)	Fw2+_g (N)	Fw+_g (N)
0.002	0.004	1	2	0.83	4.89	0.78	3.81	0	0.7	0.1	0.8
0.006	0.007	3	3	0.83	14.66	0.78	11.43	0	2.2	0.4	2.6
0.011	0.011	6	5	0.83	26.87	0.78	20.96	0	4.1	0.8	4.9
0.009	0.006	4	3	0.83	21.98	0.78	17.14	0	3.4	0.7	4.1
0.007	0.007	4	3	0.83	17.1	0.78	13.34	0	2.6	0.5	3.1
0.005	0.006	3	3	0.83	12.21	0.78	9.52	0	1.9	0.4	2.3
0.005	0.005	3	3	0.83	12.21	0.78	9.52	0	1.9	0.4	2.3
0.006	0.006	3	3	0.83	14.66	0.78	11.43	0	2.2	0.4	2.6
0.006	0.006	3	3	0.83	14.66	0.78	11.43	0	2.2	0.4	2.6
0.006	0.006	3	3	0.83	14.66	0.78	11.43	0	2.2	0.4	2.6
0.006	0.007	3	3	0.83	14.66	0.78	11.43	0	2.2	0.4	2.6

T15					T15						
H+ (m)	H- (m)	F+ (N)	F- (N)	alpha1	p+1+_g (N/m	alpha3	p+3+_g	p+4+_g	Fw1+_g (N)	Fw2+_g (N)	Fw+_g (N)
0.004	0.003	1	2	0.81	9.54	0.76	7.25	0	1.4	0.3	1.7
0.006	0.005	3	3	0.81	14.3	0.76	10.87	0	2.2	0.4	2.6
0.011	0.01	5	5	0.81	26.22	0.76	19.93	0	4	0.8	4.8
0.011	0.008	5	4	0.81	26.22	0.76	19.93	0	4	0.8	4.8
0.009	0.007	4	3	0.81	21.45	0.76	16.3	0	3.2	0.7	3.9
0.009	0.008	4	4	0.81	21.45	0.76	16.3	0	3.2	0.7	3.9
0.009	0.009	4	5	0.81	21.45	0.76	16.3	0	3.2	0.7	3.9
0.01	0.009	5	4	0.81	23.84	0.76	18.12	0	3.6	0.7	4.3
0.011	0.009	5	5	0.81	26.22	0.76	19.93	0	4	0.8	4.8
0.011	0.009	5	5	0.81	26.22	0.76	19.93	0	4	0.8	4.8
0.011	0.009	5	4	0.81	26.22	0.76	19.93	0	4	0.8	4.8
0.01	0.009	4	5	0.81	23.84	0.76	18.12	0	3.6	0.7	4.3
0.01	0.006	4	3	0.81	23.84	0.76	18.12	0	3.6	0.7	4.3
0.011	0.008	5	4	0.81	26.22	0.76	19.93	0	4	0.8	4.8

T16					T16						
H+ (m)	H- (m)	F+ (N)	F- (N)	alpha1	p+1+_g (N/m	alpha3	p+3+_g	p+4+_g	Fw1+_g (N)	Fw2+_g (N)	Fw+_g (N)
0.003	0.003	1	1	0.79	6.97	0.73	5.09	0	1	0.2	1.2
0.005	0.005	2	2	0.79	11.62	0.73	8.48	0	1.7	0.4	2.1
0.01	0.009	4	4	0.79	23.25	0.73	16.97	0	3.5	0.7	4.2
0.011	0.011	5	5	0.79	25.57	0.73	18.67	0	3.8	0.8	4.6
0.012	0.011	6	5	0.79	27.9	0.73	20.37	0	4.2	0.9	5.1
0.011	0.012	5	6	0.79	25.57	0.73	18.67	0	3.8	0.8	4.6
0.013	0.012	6	5	0.79	30.22	0.73	22.06	0	4.5	0.9	5.4
0.012	0.012	5	6	0.79	27.9	0.73	20.37	0	4.2	0.9	5.1
0.012	0.011	5	5	0.79	27.9	0.73	20.37	0	4.2	0.9	5.1
0.011	0.011	5	5	0.79	25.57	0.73	18.67	0	3.8	0.8	4.6
0.012	0.011	5	5	0.79	27.9	0.73	20.37	0	4.2	0.9	5.1
0.012	0.011	6	5	0.79	27.9	0.73	20.37	0	4.2	0.9	5.1
0.011	0.012	5	6	0.79	25.57	0.73	18.67	0	3.8	0.8	4.6
0.012	0.009	6	4	0.79	27.9	0.73	20.37	0	4.2	0.9	5.1
0.011	0.009	5	4	0.79	25.57	0.73	18.67	0	3.8	0.8	4.6

T17					T17						
H+ (m)	H- (m)	F+ (N)	F- (N)	alpha1	p+1+_g (N/m	alpha3	p+3+_g	p+4+_g	Fw1+_g (N)	Fw2+_g (N)	Fw+_g (N)
0.003	0.003	2	1	0.74	6.53	0.67	4.38	0	0.9	0.2	1.1
0.005	0.006	3	3	0.74	10.89	0.67	7.3	0	1.6	0.3	1.9
0.008	0.009	4	4	0.74	17.42	0.67	11.67	0	2.5	0.5	3
0.011	0.014	6	6	0.74	23.96	0.67	16.05	0	3.4	0.7	4.1
0.014	0.013	6	6	0.74	30.49	0.67	20.43	0	4.4	0.9	5.3
0.012	0.01	6	4	0.74	26.13	0.67	17.51	0	3.8	0.8	4.6
0.011	0.012	5	6	0.74	23.96	0.67	16.05	0	3.4	0.7	4.1
0.012	0.011	6	5	0.74	26.13	0.67	17.51	0	3.8	0.8	4.6
0.013	0.011	6	6	0.74	28.31	0.67	18.97	0	4.1	0.9	5
0.012	0.011	5	5	0.74	26.13	0.67	17.51	0	3.8	0.8	4.6
0.011	0.01	5	5	0.74	23.96	0.67	16.05	0	3.4	0.7	4.1
0.012	0.011	5	5	0.74	26.13	0.67	17.51	0	3.8	0.8	4.6
0.012	0.011	5	5	0.74	26.13	0.67	17.51	0	3.8	0.8	4.6
0.012	0.01	5	5	0.74	26.13	0.67	17.51	0	3.8	0.8	4.6
0.011	0.011	5	5	0.74	23.96	0.67	16.05	0	3.4	0.7	4.1
0.012	0.011	5	6	0.74	26.13	0.67	17.51	0	3.8	0.8	4.6

T18					T18						
H+ (m)	H- (m)	F+ (N)	F- (N)	alpha1	p+1+_g (N/m	alpha3	p+3+_g	p+4+_g	Fw1+_g (N)	Fw2+_g (N)	Fw+_g (N)
0.003	0.003	2	1	0.73	6.45	0.65	4.19	0	0.9	0.2	1.1
0.004	0.006	2	3	0.73	8.59	0.65	5.58	0	1.2	0.3	1.5
0.006	0.007	3	3	0.73	12.89	0.65	8.38	0	1.8	0.4	2.2
0.01	0.012	4	6	0.73	21.48	0.65	13.96	0	3	0.7	3.7
0.013	0.014	6	6	0.73	27.93	0.65	18.15	0	4	0.9	4.9
0.014	0.011	6	5	0.73	30.08	0.65	19.55	0	4.3	0.9	5.2
0.011	0.011	5	5	0.73	23.63	0.65	15.36	0	3.4	0.7	4.1
0.013	0.012	6	6	0.73	27.93	0.65	18.15	0	4	0.9	4.9
0.012	0.011	6	5	0.73	25.78	0.65	16.76	0	3.7	0.8	4.5
0.011	0.011	5	5	0.73	23.63	0.65	15.36	0	3.4	0.7	4.1
0.011	0.011	6	5	0.73	23.63	0.65	15.36	0	3.4	0.7	4.1
0.011	0.011	6	5	0.73	23.63	0.65	15.36	0	3.4	0.7	4.1
0.011	0.011	5	5	0.73	23.63	0.65	15.36	0	3.4	0.7	4.1
0.012	0.011	6	5	0.73	25.78	0.65	16.76	0	3.7	0.8	4.5
0.012	0.013	6	6	0.73	25.78	0.65	16.76	0	3.7	0.8	4.5
0.011	0.012	6	6	0.73	23.63	0.65	15.36	0	3.4	0.7	4.1
0.011	0.012	5	5	0.73	23.63	0.65	15.36	0	3.4	0.7	4.1

T21					T21						
H+ (m)	H- (m)	F+ (N)	F- (N)	alpha1	p+1+_g (N/m)	alpha3	p+3+_g	p+4+_g	Fw1+_g (N)	Fw2+_g (N)	Fw+_g (N)
0.007	0.009	4	4	0.93	19.16	0.87	16.67	0	3.1	0.6	3.7
0.016	0.011	8	5	0.93	43.79	0.87	38.1	0	7	1.3	8.3
0.012	0.012	6	6	0.93	32.84	0.87	28.57	0	5.3	1	6.3
0.014	0.015	7	7	0.93	38.32	0.87	33.34	0	6.2	1.2	7.4
0.012	0.014	6	6	0.93	32.84	0.87	28.57	0	5.3	1	6.3
0.013	0.014	6	6	0.93	35.58	0.87	30.95	0	5.7	1.1	6.8
0.015	0.014	7	6	0.93	41.05	0.87	35.71	0	6.6	1.3	7.9
0.016	0.014	8	6	0.93	43.79	0.87	38.1	0	7	1.3	8.3
0.016	0.013	7	5	0.93	43.79	0.87	38.1	0	7	1.3	8.3

T22					T22						
H+ (m)	H- (m)	F+ (N)	F- (N)	alpha1	p+1+_g (N/m)	alpha3	p+3+_g	p+4+_g	Fw1+_g (N)	Fw2+_g (N)	Fw+_g (N)
0.009	0.01	4	5	0.88	23.31	0.83	19.35	0	3.7	0.7	4.4
0.017	0.019	8	9	0.88	44.03	0.83	36.54	0	6.9	1.3	8.2
0.024	0.016	12	8	0.88	62.16	0.83	51.59	0	9.8	1.9	11.7
0.022	0.018	11	9	0.88	56.98	0.83	47.29	0	9	1.7	10.7
0.023	0.021	11	10	0.88	59.57	0.83	49.44	0	9.4	1.8	11.2
0.026	0.021	13	10	0.88	67.34	0.83	55.89	0	10.6	2.1	12.7
0.028	0.021	13	10	0.88	72.52	0.83	60.19	0	11.4	2.2	13.6
0.029	0.021	15	10	0.88	75.11	0.83	62.34	0	11.8	2.3	14.1
0.03	0.024	15	11	0.88	77.7	0.83	64.49	0	12.2	2.4	14.6

T23					T23						
H+ (m)	H- (m)	F+ (N)	F- (N)	alpha1	p+1+_g (N/m)	alpha3	p+3+_g	p+4+_g	Fw1+_g (N)	Fw2+_g (N)	Fw+_g (N)
0.008	0.009	3	4	0.85	20.01	0.8	16.01	0	3.1	0.6	3.7
0.016	0.018	7	8	0.85	40.02	0.8	32.02	0	6.2	1.2	7.4
0.025	0.022	11	10	0.85	62.54	0.8	50.03	0	9.7	1.9	11.6
0.018	0.014	8	7	0.85	45.03	0.8	36.02	0	7	1.4	8.4
0.019	0.014	9	7	0.85	47.53	0.8	38.02	0	7.4	1.4	8.8
0.015	0.014	6	7	0.85	37.52	0.8	30.02	0	5.8	1.1	6.9
0.014	0.014	6	7	0.85	35.02	0.8	28.02	0	5.4	1.1	6.5
0.013	0.012	6	6	0.85	32.52	0.8	26.02	0	5	1	6
0.013	0.011	6	6	0.85	32.52	0.8	26.02	0	5	1	6
0.014	0.011	6	5	0.85	35.02	0.8	28.02	0	5.4	1.1	6.5
0.014	0.014	7	7	0.85	35.02	0.8	28.02	0	5.4	1.1	6.5

T24					T24						
H+ (m)	H- (m)	F+ (N)	F- (N)	alpha1	p+1+_g (N/m)	alpha3	p+3+_g	p+4+_g	Fw1+_g (N)	Fw2+_g (N)	Fw+_g (N)
0.007	0.006	3	3	0.8	16.48	0.74	12.2	0	2.5	0.5	3
0.012	0.016	6	8	0.8	28.25	0.74	20.91	0	4.2	0.9	5.1
0.021	0.021	10	10	0.8	49.44	0.74	36.59	0	7.4	1.5	8.9
0.024	0.021	11	9	0.8	56.51	0.74	41.82	0	8.5	1.7	10.2
0.021	0.017	10	8	0.8	49.44	0.74	36.59	0	7.4	1.5	8.9
0.024	0.024	11	11	0.8	56.51	0.74	41.82	0	8.5	1.7	10.2
0.024	0.022	11	10	0.8	56.51	0.74	41.82	0	8.5	1.7	10.2
0.026	0.021	12	10	0.8	61.21	0.74	45.3	0	9.2	1.9	11.1
0.024	0.02	12	9	0.8	56.51	0.74	41.82	0	8.5	1.7	10.2
0.022	0.019	11	8	0.8	51.8	0.74	38.33	0	7.8	1.6	9.4
0.021	0.019	10	9	0.8	49.44	0.74	36.59	0	7.4	1.5	8.9
0.023	0.02	11	9	0.8	54.15	0.74	40.07	0	8.1	1.7	9.8
0.023	0.024	11	11	0.8	54.15	0.74	40.07	0	8.1	1.7	9.8
0.025	0.023	11	10	0.8	58.86	0.74	43.56	0	8.8	1.8	10.6

T25					T25						
H+ (m)	H- (m)	F+ (N)	F- (N)	alpha1	p+1+_g (N/	alpha3	p+3+_g	p+4+_g	Fw1+_g (N	Fw2+_g (N	Fw+_g (N
0.007	0.006	3	3	0.78	16.07	0.72	11.57	0	2.4	0.5	2.9
0.011	0.014	5	7	0.78	25.25	0.72	18.18	0	3.7	0.8	4.5
0.02	0.018	9	8	0.78	45.91	0.72	33.06	0	6.8	1.4	8.2
0.025	0.026	11	11	0.78	57.39	0.72	41.32	0	8.5	1.8	10.3
0.029	0.024	13	10	0.78	66.57	0.72	47.93	0	9.8	2	11.8
0.026	0.025	11	11	0.78	59.68	0.72	42.97	0	8.8	1.8	10.6
0.029	0.024	13	10	0.78	66.57	0.72	47.93	0	9.8	2	11.8
0.026	0.025	11	11	0.78	59.68	0.72	42.97	0	8.8	1.8	10.6
0.028	0.024	12	10	0.78	64.28	0.72	46.28	0	9.5	2	11.5
0.029	0.025	12	11	0.78	66.57	0.72	47.93	0	9.8	2	11.8
0.029	0.025	12	11	0.78	66.57	0.72	47.93	0	9.8	2	11.8
0.029	0.024	12	11	0.78	66.57	0.72	47.93	0	9.8	2	11.8
0.029	0.024	12	11	0.78	66.57	0.72	47.93	0	9.8	2	11.8
0.027	0.024	12	11	0.78	61.98	0.72	44.63	0	9.2	1.9	11.1
0.028	0.026	13	11	0.78	64.28	0.72	46.28	0	9.5	2	11.5

T26					T26						
H+ (m)	H- (m)	F+ (N)	F- (N)	alpha1	p+1+_g (N/	alpha3	p+3+_g	p+4+_g	Fw1+_g (N	Fw2+_g (N	Fw+_g (N
0.007	0.006	4	3	0.75	15.45	0.69	10.66	0	2.2	0.5	2.7
0.011	0.015	5	7	0.75	24.28	0.69	16.75	0	3.5	0.7	4.2
0.017	0.018	8	8	0.75	37.52	0.69	25.89	0	5.5	1.1	6.6
0.024	0.027	11	12	0.75	52.97	0.69	36.55	0	7.7	1.6	9.3
0.028	0.026	13	12	0.75	61.8	0.69	42.64	0	9	1.9	10.9
0.027	0.021	12	10	0.75	59.6	0.69	41.12	0	8.7	1.8	10.5
0.026	0.026	12	11	0.75	57.39	0.69	39.6	0	8.3	1.8	10.1
0.027	0.023	12	10	0.75	59.6	0.69	41.12	0	8.7	1.8	10.5
0.026	0.026	12	11	0.75	57.39	0.69	39.6	0	8.3	1.8	10.1
0.027	0.024	12	11	0.75	59.6	0.69	41.12	0	8.7	1.8	10.5
0.026	0.024	12	10	0.75	57.39	0.69	39.6	0	8.3	1.8	10.1
0.026	0.025	12	10	0.75	57.39	0.69	39.6	0	8.3	1.8	10.1
0.027	0.024	12	10	0.75	59.6	0.69	41.12	0	8.7	1.8	10.5
0.027	0.026	12	11	0.75	59.6	0.69	41.12	0	8.7	1.8	10.5
0.026	0.024	12	10	0.75	57.39	0.69	39.6	0	8.3	1.8	10.1
0.026	0.026	12	10	0.75	57.39	0.69	39.6	0	8.3	1.8	10.1

T27					T27						
H+ (m)	H- (m)	F+ (N)	F- (N)	alpha1	p+1+_g (N/	alpha3	p+3+_g	p+4+_g	Fw1+_g (N	Fw2+_g (N	Fw+_g (N
0.006	0.004	3	2	0.71	12.54	0.63	7.9	0	1.8	0.4	2.2
0.01	0.009	5	4	0.71	20.9	0.63	13.17	0	2.9	0.6	3.5
0.013	0.015	6	7	0.71	27.16	0.63	17.11	0	3.8	0.8	4.6
0.023	0.024	10	11	0.71	48.06	0.63	30.28	0	6.7	1.5	8.2
0.027	0.029	12	13	0.71	56.42	0.63	35.54	0	7.9	1.7	9.6
0.029	0.027	13	12	0.71	60.6	0.63	38.18	0	8.5	1.8	10.3
0.026	0.023	12	11	0.71	54.33	0.63	34.23	0	7.6	1.7	9.3
0.027	0.026	12	12	0.71	56.42	0.63	35.54	0	7.9	1.7	9.6
0.028	0.025	13	12	0.71	58.51	0.63	36.86	0	8.2	1.8	10
0.026	0.026	12	12	0.71	54.33	0.63	34.23	0	7.6	1.7	9.3
0.028	0.026	13	12	0.71	58.51	0.63	36.86	0	8.2	1.8	10
0.028	0.027	12	12	0.71	58.51	0.63	36.86	0	8.2	1.8	10
0.028	0.026	12	12	0.71	58.51	0.63	36.86	0	8.2	1.8	10
0.028	0.026	13	12	0.71	58.51	0.63	36.86	0	8.2	1.8	10
0.029	0.026	13	12	0.71	60.6	0.63	38.18	0	8.5	1.8	10.3
0.028	0.026	12	12	0.71	58.51	0.63	36.86	0	8.2	1.8	10
0.031	0.026	13	12	0.71	64.78	0.63	40.81	0	9.1	2	11.1

T28					T28						
H+ (m)	H- (m)	F+ (N)	F- (N)	alpha1	p+1+_g (N/	alpha3	p+3+_g	p+4+_g	Fw1+_g (N	Fw2+_g (N	Fw+_g (N
0.006	0.003	3	1	0.7	12.36	0.61	7.54	0	1.7	0.4	2.1
0.008	0.004	4	2	0.7	16.48	0.61	10.05	0	2.3	0.5	2.8
0.014	0.008	6	4	0.7	28.84	0.61	17.59	0	4	0.9	4.9
0.013	0.016	6	7	0.7	26.78	0.61	16.34	0	3.7	0.8	4.5
0.024	0.024	11	11	0.7	49.44	0.61	30.16	0	6.8	1.5	8.3
0.028	0.03	13	14	0.7	57.68	0.61	35.18	0	8	1.8	9.8
0.028	0.03	13	14	0.7	57.68	0.61	35.18	0	8	1.8	9.8
0.029	0.025	13	11	0.7	59.74	0.61	36.44	0	8.3	1.8	10.1
0.026	0.026	11	12	0.7	53.56	0.61	32.67	0	7.4	1.6	9
0.029	0.028	13	13	0.7	59.74	0.61	36.44	0	8.3	1.8	10.1
0.029	0.028	13	13	0.7	59.74	0.61	36.44	0	8.3	1.8	10.1
0.029	0.027	13	13	0.7	59.74	0.61	36.44	0	8.3	1.8	10.1
0.029	0.027	12	12	0.7	59.74	0.61	36.44	0	8.3	1.8	10.1
0.029	0.026	13	12	0.7	59.74	0.61	36.44	0	8.3	1.8	10.1
0.028	0.026	12	13	0.7	57.68	0.61	35.18	0	8	1.8	9.8
0.028	0.025	12	12	0.7	57.68	0.61	35.18	0	8	1.8	9.8
0.032	0.025	14	12	0.7	65.92	0.61	40.21	0	9.1	2	11.1
0.03	0.023	13	10	0.7	61.8	0.61	37.7	0	8.6	1.9	10.5

T31					T31						
H+ (m)	H- (m)	F+ (N)	F- (N)	alpha1	p+1+_g (N/m)	alpha3	p+3+_g	p+4+_g	Fw1+_g (N)	Fw2+_g (N)	Fw+_g (N)
0.013	0.014	6	7	0.9	34.43	0.85	29.27	0	5.5	1.1	6.6
0.026	0.022	13	10	0.9	68.87	0.85	58.54	0	11	2.1	13.1
0.036	0.02	18	10	0.9	95.35	0.85	81.05	0	15.2	2.9	18.1
0.038	0.024	19	12	0.9	100.65	0.85	85.55	0	16	3.1	19.1
0.039	0.029	19	14	0.9	103.3	0.85	87.81	0	16.4	3.2	19.6
0.036	0.032	19	15	0.9	95.35	0.85	81.05	0	15.2	2.9	18.1
0.036	0.031	18	15	0.9	95.35	0.85	81.05	0	15.2	2.9	18.1
0.034	0.03	17	14	0.9	90.06	0.85	76.55	0	14.3	2.7	17
0.033	0.03	17	14	0.9	87.41	0.85	74.3	0	13.9	2.7	16.6
T31B	H- (m)	F+ (N)	F- (N)	alpha1	p+1+_g (N/m)	alpha3	p+3+_g	p+4+_g	Fw1+_g (N)	Fw2+_g (N)	Fw+_g (N)
0.017	0.019	9	9	0.9	45.03	0.85	38.28	0	7.2	1.4	8.6
0.027	0.024	13	11	0.9	71.51	0.85	60.78	0	11.4	2.2	13.6
0.035	0.026	17	13	0.9	92.7	0.85	78.8	0	14.7	2.8	17.5
0.039	0.026	19	12	0.9	103.3	0.85	87.81	0	16.4	3.2	19.6
0.04	0.031	20	15	0.9	105.95	0.85	90.06	0	16.9	3.2	20.1
0.039	0.032	21	15	0.9	103.3	0.85	87.81	0	16.4	3.2	19.6
0.038	0.031	19	15	0.9	100.65	0.85	85.55	0	16	3.1	19.1
0.036	0.031	19	15	0.9	95.35	0.85	81.05	0	15.2	2.9	18.1
0.036	0.028	18	13	0.9	95.35	0.85	81.05	0	15.2	2.9	18.1
T31*	H- (m)	F+ (N)	F- (N)	alpha1	p+1+_g (N/m)	alpha3	p+3+_g	p+4+_g	Fw1+_g (N)	Fw2+_g (N)	Fw+_g (N)
0.016	0.018	9	9	0.9	42.38	0.85	36.02	0	6.7	1.3	8
0.026	0.023	13	11	0.9	68.87	0.85	58.54	0	11	2.1	13.1
0.026	0.033	17	12	0.9	68.87	0.85	58.54	0	11	2.1	13.1
0.026	0.037	19	12	0.9	68.87	0.85	58.54	0	11	2.1	13.1
0.031	0.037	19	15	0.9	82.11	0.85	69.79	0	13.1	2.5	15.6
0.031	0.034	18	15	0.9	82.11	0.85	69.79	0	13.1	2.5	15.6
0.029	0.034	17	14	0.9	76.81	0.85	65.29	0	12.2	2.3	14.5
0.03	0.032	17	15	0.9	79.46	0.85	67.54	0	12.6	2.4	15
0.028	0.031	16	13	0.9	74.16	0.85	63.04	0	11.8	2.3	14.1

T32					T32						
H+ (m)	H- (m)	F+ (N)	F- (N)	alpha1	p+1+_g (N/m)	alpha3	p+3+_g	p+4+_g	Fw1+_g (N)	Fw2+_g (N)	Fw+_g (N)
0.017	0.017	8	8	0.88	44.03	0.83	36.54	0	6.9	1.3	8.2
0.028	0.026	13	12	0.88	72.52	0.83	60.19	0	11.4	2.2	13.6
0.036	0.024	18	12	0.88	93.23	0.83	77.38	0	14.7	2.8	17.5
0.038	0.026	19	13	0.88	98.41	0.83	81.68	0	15.5	3	18.5
0.04	0.029	20	14	0.88	103.59	0.83	85.98	0	16.3	3.2	19.5
0.044	0.026	22	12	0.88	113.95	0.83	94.58	8.63	17.9	3.7	21.6
0.045	0.029	23	14	0.88	116.54	0.83	96.73	11.22	18.3	3.9	22.2
0.046	0.032	23	15	0.88	119.13	0.83	98.88	13.81	18.7	4.1	22.8
0.047	0.03	23	14	0.88	121.72	0.83	101.03	16.4	19.2	4.2	23.4
0.05	0.033	25	16	0.88	129.49	0.83	107.48	24.17	20.4	4.7	25.1
T32*	H- (m)	F+ (N)	F- (N)	alpha1	p+1+_g (N/m)	alpha3	p+3+_g	p+4+_g	Fw1+_g (N)	Fw2+_g (N)	Fw+_g (N)
0.014	0.015	8	8	0.88	36.26	0.83	30.1	0	5.7	1.1	6.8
0.026	0.026	13	12	0.88	67.34	0.83	55.89	0	10.6	2.1	12.7
0.036	0.023	18	12	0.88	93.23	0.83	77.38	0	14.7	2.8	17.5
0.036	0.027	18	13	0.88	93.23	0.83	77.38	0	14.7	2.8	17.5
0.036	0.029	19	15	0.88	93.23	0.83	77.38	0	14.7	2.8	17.5
0.041	0.026	21	13	0.88	106.18	0.83	88.13	0	16.7	3.2	19.9
0.043	0.027	22	13	0.88	111.36	0.83	92.43	6.04	17.5	3.6	21.1
0.044	0.03	23	15	0.88	113.95	0.83	94.58	8.63	17.9	3.7	21.6
0.046	0.031	23	15	0.88	119.13	0.83	98.88	13.81	18.7	4.1	22.8
0.046	0.033	24	16	0.88	119.13	0.83	98.88	13.81	18.7	4.1	22.8

T33					T33						
H+ (m)	H- (m)	F+ (N)	F- (N)	alpha1	p+1+_g (N/m)	alpha3	p+3+_g	p+4+_g	Fw1+_g (N)	Fw2+_g (N)	Fw+_g (N)
0.013	0.012	7	6	0.85	32.52	0.8	26.02	0	5	1	6
0.026	0.026	12	12	0.85	65.04	0.8	52.03	0	10.1	2	12.1
0.039	0.031	19	14	0.85	97.56	0.8	78.05	0	15.1	3	18.1
0.027	0.024	14	12	0.85	67.54	0.8	54.03	0	10.5	2.1	12.6
0.033	0.022	16	10	0.85	82.55	0.8	66.04	0	12.8	2.5	15.3
0.033	0.024	16	11	0.85	82.55	0.8	66.04	0	12.8	2.5	15.3
0.03	0.024	15	12	0.85	75.05	0.8	60.04	0	11.6	2.3	13.9
0.029	0.025	15	12	0.85	72.54	0.8	58.03	0	11.2	2.2	13.4
0.028	0.026	13	12	0.85	70.04	0.8	56.03	0	10.8	2.1	12.9
0.029	0.023	14	11	0.85	72.54	0.8	58.03	0	11.2	2.2	13.4
0.029	0.026	15	12	0.85	72.54	0.8	58.03	0	11.2	2.2	13.4
T33*	H- (m)	F+ (N)	F- (N)	alpha1	p+1+_g (N/m)	alpha3	p+3+_g	p+4+_g	Fw1+_g (N)	Fw2+_g (N)	Fw+_g (N)
0.011	0.011	6	5	0.85	27.52	0.8	22.02	0	4.3	0.8	5.1
0.024	0.022	12	10	0.85	60.04	0.8	48.03	0	9.3	1.8	11.1
0.038	0.03	19	15	0.85	95.06	0.8	76.05	0	14.7	2.9	17.6
0.026	0.023	14	11	0.85	65.04	0.8	52.03	0	10.1	2	12.1
0.031	0.021	16	11	0.85	77.55	0.8	62.04	0	12	2.4	14.4
0.031	0.024	16	11	0.85	77.55	0.8	62.04	0	12	2.4	14.4
0.027	0.024	14	12	0.85	67.54	0.8	54.03	0	10.5	2.1	12.6
0.026	0.023	13	11	0.85	65.04	0.8	52.03	0	10.1	2	12.1
0.025	0.024	12	12	0.85	62.54	0.8	50.03	0	9.7	1.9	11.6
0.026	0.022	12	11	0.85	65.04	0.8	52.03	0	10.1	2	12.1
0.026	0.025	13	12	0.85	65.04	0.8	52.03	0	10.1	2	12.1

T34					T34						
H+ (m)	H- (m)	F+ (N)	F- (N)	alpha1	p+1+_g (N/m)	alpha3	p+3+_g	p+4+_g	Fw1+_g (N)	Fw2+_g (N)	Fw+_g (N)
0.013	0.009	6	4	0.81	30.99	0.75	23.24	0	4.7	0.9	5.6
0.022	0.022	10	10	0.81	52.44	0.75	39.33	0	7.9	1.6	9.5
0.035	0.031	16	15	0.81	83.43	0.75	62.57	0	12.6	2.5	15.1
0.037	0.03	17	14	0.81	88.2	0.75	66.15	0	13.3	2.7	16
0.032	0.025	15	12	0.81	76.28	0.75	57.21	0	11.5	2.3	13.8
0.036	0.03	16	14	0.81	85.82	0.75	64.37	0	12.9	2.6	15.5
0.034	0.031	16	15	0.81	81.05	0.75	60.79	0	12.2	2.5	14.7
0.036	0.029	17	14	0.81	85.82	0.75	64.37	0	12.9	2.6	15.5
0.035	0.028	17	13	0.81	83.43	0.75	62.57	0	12.6	2.5	15.1
0.035	0.027	16	13	0.81	83.43	0.75	62.57	0	12.6	2.5	15.1
0.036	0.028	17	13	0.81	85.82	0.75	64.37	0	12.9	2.6	15.5
0.036	0.031	17	15	0.81	85.82	0.75	64.37	0	12.9	2.6	15.5
0.035	0.029	15	14	0.81	83.43	0.75	62.57	0	12.6	2.5	15.1
0.038	0.031	17	15	0.81	90.59	0.75	67.94	0	13.6	2.8	16.4
T34*	H- (m)	F+ (N)	F- (N)	alpha1	p+1+_g (N/m)	alpha3	p+3+_g	p+4+_g	Fw1+_g (N)	Fw2+_g (N)	Fw+_g (N)
0.013	0.008	6	4	0.81	30.99	0.75	23.24	0	4.7	0.9	5.6
0.021	0.015	10	7	0.81	50.06	0.75	37.55	0	7.5	1.5	9
0.034	0.031	17	15	0.81	81.05	0.75	60.79	0	12.2	2.5	14.7
0.036	0.03	17	14	0.81	85.82	0.75	64.37	0	12.9	2.6	15.5
0.032	0.023	15	11	0.81	76.28	0.75	57.21	0	11.5	2.3	13.8
0.031	0.026	14	12	0.81	73.9	0.75	55.43	0	11.1	2.3	13.4
0.032	0.03	15	14	0.81	76.28	0.75	57.21	0	11.5	2.3	13.8
0.035	0.026	16	12	0.81	83.43	0.75	62.57	0	12.6	2.5	15.1
0.036	0.028	17	13	0.81	85.82	0.75	64.37	0	12.9	2.6	15.5
0.034	0.026	16	12	0.81	81.05	0.75	60.79	0	12.2	2.5	14.7
0.035	0.025	17	11	0.81	83.43	0.75	62.57	0	12.6	2.5	15.1
0.036	0.031	16	14	0.81	85.82	0.75	64.37	0	12.9	2.6	15.5
0.035	0.021	17	10	0.81	83.43	0.75	62.57	0	12.6	2.5	15.1
0.04	0.029	18	13	0.81	95.35	0.75	71.51	0	14.3	2.9	17.2

T35					T35						
H+ (m)	H- (m)	F+ (N)	F- (N)	alpha1	p+1+_g (N/	alpha3	p+3+_g	p+4+_g	Fw1+_g (	Fw2+_g (	Fw+_g (N
0.011	0.006	6	3	0.78	25.25	0.72	18.18	0	3.7	0.8	4.5
0.019	0.017	9	8	0.78	43.62	0.72	31.41	0	6.5	1.3	7.8
0.031	0.028	15	13	0.78	71.16	0.72	51.24	0	10.5	2.2	12.7
0.039	0.036	18	16	0.78	89.53	0.72	64.46	0	13.2	2.7	15.9
0.041	0.03	19	14	0.78	94.12	0.72	67.77	0	13.9	2.9	16.8
0.036	0.036	17	16	0.78	82.64	0.72	59.5	0	12.2	2.5	14.7
0.041	0.031	19	14	0.78	94.12	0.72	67.77	0	13.9	2.9	16.8
0.04	0.038	18	17	0.78	91.82	0.72	66.11	0	13.6	2.8	16.4
0.04	0.034	17	16	0.78	91.82	0.72	66.11	0	13.6	2.8	16.4
0.04	0.034	18	16	0.78	91.82	0.72	66.11	0	13.6	2.8	16.4
0.039	0.031	18	15	0.78	89.53	0.72	64.46	0	13.2	2.7	15.9
0.04	0.031	19	15	0.78	91.82	0.72	66.11	0	13.6	2.8	16.4
0.041	0.036	18	17	0.78	94.12	0.72	67.77	0	13.9	2.9	16.8
0.042	0.028	19	13	0.78	96.41	0.72	69.42	3.06	14.3	3	17.3
0.042	0.026	19	12	0.78	96.41	0.72	69.42	3.06	14.3	3	17.3
T35*	H- (m)	F+ (N)	F- (N)	alpha1	p+1+_g (N/	alpha3	p+3+_g	p+4+_g	Fw1+_g (	Fw2+_g (	Fw+_g (N
0.014	0.009	7	5	0.78	32.14	0.72	23.14	0	4.8	1	5.8
0.021	0.025	10	12	0.78	48.21	0.72	34.71	0	7.1	1.5	8.6
0.032	0.026	15	12	0.78	73.46	0.72	52.89	0	10.9	2.2	13.1
0.039	0.036	17	16	0.78	89.53	0.72	64.46	0	13.2	2.7	15.9
0.041	0.031	18	14	0.78	94.12	0.72	67.77	0	13.9	2.9	16.8
0.041	0.037	19	17	0.78	94.12	0.72	67.77	0	13.9	2.9	16.8
0.041	0.031	19	14	0.78	94.12	0.72	67.77	0	13.9	2.9	16.8
0.04	0.035	18	16	0.78	91.82	0.72	66.11	0	13.6	2.8	16.4
0.04	0.034	18	16	0.78	91.82	0.72	66.11	0	13.6	2.8	16.4
0.04	0.034	17	16	0.78	91.82	0.72	66.11	0	13.6	2.8	16.4
0.04	0.034	18	16	0.78	91.82	0.72	66.11	0	13.6	2.8	16.4
0.041	0.031	19	15	0.78	94.12	0.72	67.77	0	13.9	2.9	16.8
0.042	0.037	18	17	0.78	96.41	0.72	69.42	3.06	14.3	3	17.3
0.041	0.031	17	15	0.78	94.12	0.72	67.77	0	13.9	2.9	16.8
0.043	0.031	19	14	0.78	98.71	0.72	71.07	5.36	14.6	3.2	17.8

T36					T36						
H+ (m)	H- (m)	F+ (N)	F- (N)	alpha1	p+1+_g (N/	alpha3	p+3+_g	p+4+_g	Fw1+_g (	Fw2+_g (	Fw+_g (N
0.011	0.006	6	3	0.76	24.6	0.69	16.97	0	3.6	0.8	4.4
0.017	0.012	8	6	0.76	38.02	0.69	26.23	0	5.5	1.2	6.7
0.029	0.021	14	10	0.76	64.86	0.69	44.75	0	9.4	2	11.4
0.036	0.038	16	17	0.76	80.52	0.69	55.56	0	11.7	2.5	14.2
0.046	0.041	21	18	0.76	102.89	0.69	70.99	11.93	15	3.5	18.5
0.043	0.034	19	15	0.76	96.18	0.69	66.36	5.22	14	3.1	17.1
0.041	0.036	18	15	0.76	91.7	0.69	63.27	0	13.3	2.8	16.1
0.041	0.034	18	15	0.76	91.7	0.69	63.27	0	13.3	2.8	16.1
0.042	0.039	19	17	0.76	93.94	0.69	64.82	2.98	13.7	3	16.7
0.044	0.039	18	17	0.76	98.41	0.69	67.9	7.46	14.3	3.2	17.5
0.044	0.036	19	16	0.76	98.41	0.69	67.9	7.46	14.3	3.2	17.5
0.042	0.035	19	15	0.76	93.94	0.69	64.82	2.98	13.7	3	16.7
0.044	0.039	20	16	0.76	98.41	0.69	67.9	7.46	14.3	3.2	17.5
0.044	0.042	19	18	0.76	98.41	0.69	67.9	7.46	14.3	3.2	17.5
0.049	0.035	21	15	0.76	109.6	0.69	75.62	18.64	15.9	3.9	19.8
0.054	0.029	21	12	0.76	120.78	0.69	83.34	29.82	17.6	4.6	22.2
T36*	H- (m)	F+ (N)	F- (N)	alpha1	p+1+_g (N/	alpha3	p+3+_g	p+4+_g	Fw1+_g (	Fw2+_g (	Fw+_g (N
0.014	0.009	7	4	0.76	31.31	0.69	21.6	0	4.6	1	5.6
0.019	0.024	9	11	0.76	42.5	0.69	29.33	0	6.2	1.3	7.5
0.029	0.025	14	12	0.76	64.86	0.69	44.75	0	9.4	2	11.4
0.037	0.038	17	17	0.76	82.76	0.69	57.1	0	12	2.5	14.5
0.044	0.039	19	17	0.76	98.41	0.69	67.9	7.46	14.3	3.2	17.5
0.044	0.034	19	15	0.76	98.41	0.69	67.9	7.46	14.3	3.2	17.5
0.044	0.039	19	17	0.76	98.41	0.69	67.9	7.46	14.3	3.2	17.5
0.044	0.034	19	15	0.76	98.41	0.69	67.9	7.46	14.3	3.2	17.5
0.043	0.039	19	17	0.76	96.18	0.69	66.36	5.22	14	3.1	17.1
0.044	0.036	19	15	0.76	98.41	0.69	67.9	7.46	14.3	3.2	17.5
0.044	0.038	18	16	0.76	98.41	0.69	67.9	7.46	14.3	3.2	17.5
0.044	0.038	18	16	0.76	98.41	0.69	67.9	7.46	14.3	3.2	17.5
0.046	0.034	19	15	0.76	102.89	0.69	70.99	11.93	15	3.5	18.5
0.046	0.044	19	19	0.76	102.89	0.69	70.99	11.93	15	3.5	18.5
0.051	0.036	19	16	0.76	114.07	0.69	78.71	23.11	16.6	4.2	20.8
0.05	0.029	19	12	0.76	111.83	0.69	77.16	20.87	16.3	4	20.3

T37					T37						
H+ (m)	H- (m)	F+ (N)	F- (N)	alpha1	p+1+_g (N/	alpha3	p+3+_g	p+4+_g	Fw1+_g (N	Fw2+_g (N	Fw+_g (N
0.011	0.004	6	2	0.72	23.31	0.64	14.92	0	3.3	0.7	4
0.014	0.008	7	4	0.72	29.67	0.64	18.99	0	4.2	0.9	5.1
0.024	0.014	11	7	0.72	50.86	0.64	32.55	0	7.2	1.6	8.8
0.027	0.032	12	15	0.72	57.21	0.64	36.61	0	8.1	1.7	9.8
0.041	0.043	18	19	0.72	86.88	0.64	55.6	0	12.3	2.6	14.9
0.043	0.044	19	20	0.72	91.12	0.64	58.32	4.94	12.9	2.9	15.8
0.039	0.034	17	15	0.72	82.64	0.64	52.89	0	11.7	2.5	14.2
0.038	0.036	17	17	0.72	80.52	0.64	51.53	0	11.4	2.5	13.9
0.037	0.035	17	17	0.72	78.4	0.64	50.18	0	11.1	2.4	13.5
0.041	0.037	17	18	0.72	86.88	0.64	55.6	0	12.3	2.6	14.9
0.039	0.034	18	16	0.72	82.64	0.64	52.89	0	11.7	2.5	14.2
0.039	0.037	18	17	0.72	82.64	0.64	52.89	0	11.7	2.5	14.2
0.042	0.036	19	17	0.72	89	0.64	56.96	2.83	12.6	2.8	15.4
0.043	0.036	19	17	0.72	91.12	0.64	58.32	4.94	12.9	2.9	15.8
0.039	0.039	17	18	0.72	82.64	0.64	52.89	0	11.7	2.5	14.2
0.044	0.035	20	16	0.72	93.23	0.64	59.67	7.06	13.1	3.1	16.2
0.044	0.034	18	16	0.72	93.23	0.64	59.67	7.06	13.1	3.1	16.2
T37*	H- (m)	F+ (N)	F- (N)	alpha1	p+1+_g (N/	alpha3	p+3+_g	p+4+_g	Fw1+_g (N	Fw2+_g (N	Fw+_g (N
0.012	0.004	6	2	0.72	25.43	0.64	16.28	0	3.6	0.8	4.4
0.016	0.008	7	3	0.72	33.9	0.64	21.7	0	4.8	1	5.8
0.026	0.014	12	6	0.72	55.09	0.64	35.26	0	7.8	1.7	9.5
0.027	0.034	12	15	0.72	57.21	0.64	36.61	0	8.1	1.7	9.8
0.044	0.043	19	19	0.72	93.23	0.64	59.67	7.06	13.1	3.1	16.2
0.044	0.043	18	19	0.72	93.23	0.64	59.67	7.06	13.1	3.1	16.2
0.04	0.031	16	14	0.72	84.76	0.64	54.25	0	12	2.6	14.6
0.037	0.038	16	17	0.72	78.4	0.64	50.18	0	11.1	2.4	13.5
0.039	0.034	16	15	0.72	82.64	0.64	52.89	0	11.7	2.5	14.2
0.041	0.036	17	17	0.72	86.88	0.64	55.6	0	12.3	2.6	14.9
0.037	0.033	16	15	0.72	78.4	0.64	50.18	0	11.1	2.4	13.5
0.038	0.037	18	17	0.72	80.52	0.64	51.53	0	11.4	2.5	13.9
0.041	0.034	18	17	0.72	86.88	0.64	55.6	0	12.3	2.6	14.9
0.041	0.037	18	17	0.72	86.88	0.64	55.6	0	12.3	2.6	14.9
0.037	0.036	17	17	0.72	78.4	0.64	50.18	0	11.1	2.4	13.5
0.044	0.032	21	15	0.72	93.23	0.64	59.67	7.06	13.1	3.1	16.2
0.044	0.031	19	14	0.72	93.23	0.64	59.67	7.06	13.1	3.1	16.2

T38					T38						
H+ (m)	H- (m)	F+ (N)	F- (N)	alpha1	p+1+_g (N/	alpha3	p+3+_g	p+4+_g	Fw1+_g (N	Fw2+_g (N	Fw+_g (N
0.014	0.006	7	3	0.7	28.84	0.61	17.59	0	4	0.9	4.9
0.016	0.016	8	8	0.7	32.96	0.61	20.11	0	4.6	1	5.6
0.02	0.022	9	10	0.7	41.2	0.61	25.13	0	5.7	1.3	7
0.034	0.033	15	15	0.7	70.04	0.61	42.72	0	9.7	2.1	11.8
0.036	0.039	16	18	0.7	74.16	0.61	45.24	0	10.3	2.3	12.6
0.041	0.042	18	19	0.7	84.46	0.61	51.52	0	11.7	2.6	14.3
0.041	0.039	18	18	0.7	84.46	0.61	51.52	0	11.7	2.6	14.3
0.041	0.04	18	18	0.7	84.46	0.61	51.52	0	11.7	2.6	14.3
0.041	0.044	19	21	0.7	84.46	0.61	51.52	0	11.7	2.6	14.3
0.043	0.039	18	18	0.7	88.58	0.61	54.03	4.81	12.3	2.8	15.1
0.041	0.04	18	18	0.7	84.46	0.61	51.52	0	11.7	2.6	14.3
0.042	0.041	18	19	0.7	86.52	0.61	52.78	2.75	12	2.7	14.7
0.04	0.039	18	18	0.7	82.4	0.61	50.26	0	11.4	2.5	13.9
0.04	0.039	19	17	0.7	82.4	0.61	50.26	0	11.4	2.5	13.9
0.043	0.037	19	17	0.7	88.58	0.61	54.03	4.81	12.3	2.8	15.1
0.039	0.041	17	19	0.7	80.34	0.61	49.01	0	11.1	2.5	13.6
0.048	0.041	20	19	0.7	98.88	0.61	60.32	15.11	13.7	3.5	17.2
0.044	0.031	18	15	0.7	90.64	0.61	55.29	6.87	12.5	3	15.5
T38*	H- (m)	F+ (N)	F- (N)	alpha1	p+1+_g (N/	alpha3	p+3+_g	p+4+_g	Fw1+_g (N	Fw2+_g (N	Fw+_g (N
0.011	0.003	5	1	0.7	22.66	0.61	13.82	0	3.1	0.7	3.8
0.014	0.006	6	3	0.7	28.84	0.61	17.59	0	4	0.9	4.9
0.021	0.013	10	6	0.7	43.26	0.61	26.39	0	6	1.3	7.3
0.025	0.029	11	12	0.7	51.5	0.61	31.42	0	7.1	1.6	8.7
0.039	0.04	17	18	0.7	80.34	0.61	49.01	0	11.1	2.5	13.6
0.044	0.048	19	21	0.7	90.64	0.61	55.29	6.87	12.5	3	15.5
0.042	0.041	17	18	0.7	86.52	0.61	52.78	2.75	12	2.7	14.7
0.041	0.035	18	16	0.7	84.46	0.61	51.52	0	11.7	2.6	14.3
0.038	0.041	17	19	0.7	78.28	0.61	47.75	0	10.8	2.4	13.2
0.041	0.039	18	18	0.7	84.46	0.61	51.52	0	11.7	2.6	14.3
0.042	0.044	19	19	0.7	86.52	0.61	52.78	2.75	12	2.7	14.7
0.042	0.039	17	18	0.7	86.52	0.61	52.78	2.75	12	2.7	14.7
0.039	0.04	18	18	0.7	80.34	0.61	49.01	0	11.1	2.5	13.6
0.043	0.039	19	17	0.7	88.58	0.61	54.03	4.81	12.3	2.8	15.1
0.044	0.041	17	18	0.7	90.64	0.61	55.29	6.87	12.5	3	15.5
0.041	0.038	17	17	0.7	84.46	0.61	51.52	0	11.7	2.6	14.3
0.049	0.038	20	17	0.7	100.94	0.61	61.57	17.17	14	3.6	17.6
0.053	0.034	19	16	0.7	109.19	0.61	66.61	25.41	15.1	4.1	19.2

T41					T41						
H+ (m)	H- (m)	F+ (N)	F- (N)	alpha1	p+1+_g (N/m	alpha3	p+3+_g	p+4+_g	Fw1+_g (N	Fw2+_g (N	Fw+_g (N
0.019	0.016	10	8	0.91	50.88	0.85	43.25	0	8.1	1.6	9.7
0.039	0.029	19	13	0.91	104.45	0.85	88.78	0	16.6	3.2	19.8
0.056	0.027	27	13	0.91	149.98	0.85	127.48	41.07	23.9	5.8	29.7
0.053	0.031	26	15	0.91	141.94	0.85	120.65	33.03	22.6	5.3	27.9
0.055	0.039	27	18	0.91	147.3	0.85	125.21	38.39	23.4	5.7	29.1
0.049	0.041	26	19	0.91	131.23	0.85	111.55	22.32	20.9	4.7	25.6
0.049	0.041	24	19	0.91	131.23	0.85	111.55	22.32	20.9	4.7	25.6
0.047	0.04	24	19	0.91	125.87	0.85	106.99	16.96	20	4.4	24.4
0.049	0.041	24	19	0.91	131.23	0.85	111.55	22.32	20.9	4.7	25.6

T42					T42						
H+ (m)	H- (m)	F+ (N)	F- (N)	alpha1	p+1+_g (N/m	alpha3	p+3+_g	p+4+_g	Fw1+_g (N	Fw2+_g (N	Fw+_g (N
0.021	0.018	10	8	0.89	55	0.83	45.65	0	8.7	1.7	10.4
0.039	0.033	18	15	0.89	102.15	0.83	84.78	0	16.1	3.1	19.2
0.055	0.034	26	16	0.89	144.06	0.83	119.57	37.54	22.7	5.5	28.2
0.05	0.037	25	18	0.89	130.96	0.83	108.7	24.45	20.6	4.7	25.3
0.054	0.039	27	18	0.89	141.44	0.83	117.4	34.92	22.3	5.4	27.7
0.06	0.034	29	17	0.89	157.16	0.83	130.44	50.64	24.7	6.3	31
0.061	0.036	30	17	0.89	159.78	0.83	132.62	53.26	25.1	6.5	31.6
0.06	0.036	30	18	0.89	157.16	0.83	130.44	50.64	24.7	6.3	31
0.065	0.04	30	20	0.89	170.25	0.83	141.31	63.73	26.8	7.1	33.9
0.065	0.046	33	21	0.89	170.25	0.83	141.31	63.73	26.8	7.1	33.9
T42B	0	0	0	0.89	0	0.83	0	0	0	0	0
0.025	0.021	13	10	0.89	65.48	0.83	54.35	0	10.3	2	12.3
0.041	0.035	20	16	0.89	107.39	0.83	89.13	0	16.9	3.3	20.2
0.055	0.033	28	16	0.89	144.06	0.83	119.57	37.54	22.7	5.5	28.2
0.054	0.037	27	17	0.89	141.44	0.83	117.4	34.92	22.3	5.4	27.7
0.057	0.039	29	18	0.89	149.3	0.83	123.92	42.78	23.5	5.9	29.4
0.061	0.034	30	16	0.89	159.78	0.83	132.62	53.26	25.1	6.5	31.6
0.06	0.036	31	17	0.89	157.16	0.83	130.44	50.64	24.7	6.3	31
0.061	0.039	31	19	0.89	159.78	0.83	132.62	53.26	25.1	6.5	31.6
0.065	0.039	31	19	0.89	170.25	0.83	141.31	63.73	26.8	7.1	33.9
0.068	0.045	34	21	0.89	178.11	0.83	147.83	71.59	28	7.6	35.6

T43					T43						
H+ (m)	H- (m)	F+ (N)	F- (N)	alpha1	p+1+_g (N/m	alpha3	p+3+_g	p+4+_g	Fw1+_g (N	Fw2+_g (N	Fw+_g (N
0.02	0.012	10	6	0.86	50.62	0.81	41	0	7.9	1.5	9.4
0.034	0.023	16	10	0.86	86.05	0.81	69.7	0	13.4	2.6	16
0.057	0.044	27	20	0.86	144.27	0.81	116.86	41.34	22.5	5.7	28.2
0.046	0.026	22	13	0.86	116.43	0.81	94.31	13.5	18.1	4	22.1
0.048	0.033	23	16	0.86	121.49	0.81	98.41	18.56	18.9	4.3	23.2
0.048	0.038	22	17	0.86	121.49	0.81	98.41	18.56	18.9	4.3	23.2
0.042	0.039	20	18	0.86	106.3	0.81	86.1	3.37	16.5	3.3	19.8
0.044	0.036	20	17	0.86	111.36	0.81	90.2	8.44	17.3	3.7	21
0.043	0.036	20	17	0.86	108.83	0.81	88.15	5.91	16.9	3.5	20.4
0.046	0.033	21	15	0.86	116.43	0.81	94.31	13.5	18.1	4	22.1
0.046	0.038	21	17	0.86	116.43	0.81	94.31	13.5	18.1	4	22.1

T44					T44						
H+ (m)	H- (m)	F+ (N)	F- (N)	alpha1	p+1+_g (N/m	alpha3	p+3+_g	p+4+_g	Fw1+_g (N	Fw2+_g (N	Fw+_g (N
0.02	0.013	10	6	0.81	47.68	0.76	36.24	0	7.2	1.5	8.7
0.034	0.032	15	14	0.81	81.05	0.76	61.6	0	12.3	2.5	14.8
0.048	0.043	22	19	0.81	114.42	0.76	86.96	17.48	17.3	4	21.3
0.05	0.043	23	18	0.81	119.19	0.76	90.58	22.25	18	4.3	22.3
0.042	0.038	19	16	0.81	100.12	0.76	76.09	3.18	15.2	3.2	18.4
0.047	0.036	21	16	0.81	112.04	0.76	85.15	15.1	17	3.9	20.9
0.046	0.039	21	18	0.81	109.66	0.76	83.34	12.71	16.6	3.7	20.3
0.049	0.04	22	18	0.81	116.81	0.76	88.78	19.87	17.7	4.2	21.9
0.051	0.042	22	19	0.81	121.58	0.76	92.4	24.63	18.4	4.5	22.9
0.05	0.039	22	18	0.81	119.19	0.76	90.58	22.25	18	4.3	22.3
0.05	0.034	22	15	0.81	119.19	0.76	90.58	22.25	18	4.3	22.3
0.051	0.038	23	16	0.81	121.58	0.76	92.4	24.63	18.4	4.5	22.9
0.044	0.028	21	12	0.81	104.89	0.76	79.72	7.95	15.9	3.4	19.3
0.058	0.029	24	14	0.81	138.26	0.76	105.08	41.32	20.9	5.5	26.4

T45					T45						
H+ (m)	H- (m)	F+ (N)	F- (N)	alpha1	p+1+_g (N/	alpha3	p+3+_g	p+4+_g	Fw1+_g (N	Fw2+_g (N	Fw+_g (N
0.019	0.009	10	4	0.79	44.17	0.73	32.24	0	6.6	1.3	7.9
0.029	0.024	14	11	0.79	67.42	0.73	49.22	0	10	2.1	12.1
0.046	0.038	21	17	0.79	106.95	0.73	78.07	12.4	15.9	3.6	19.5
0.055	0.049	24	21	0.79	127.87	0.73	93.35	33.32	19	4.9	23.9
0.056	0.04	24	17	0.79	130.2	0.73	95.05	35.65	19.4	5.1	24.5
0.052	0.047	23	21	0.79	120.9	0.73	88.26	26.35	18	4.5	22.5
0.054	0.041	24	18	0.79	125.55	0.73	91.65	31	18.7	4.8	23.5
0.053	0.046	24	20	0.79	123.22	0.73	89.95	28.67	18.3	4.6	22.9
0.053	0.045	23	20	0.79	123.22	0.73	89.95	28.67	18.3	4.6	22.9
0.055	0.046	23	20	0.79	127.87	0.73	93.35	33.32	19	4.9	23.9
0.054	0.041	23	19	0.79	125.55	0.73	91.65	31	18.7	4.8	23.5
0.054	0.039	24	17	0.79	125.55	0.73	91.65	31	18.7	4.8	23.5
0.051	0.046	25	19	0.79	118.57	0.73	86.56	24.02	17.6	4.3	21.9
0.052	0.035	24	16	0.79	120.9	0.73	88.26	26.35	18	4.5	22.5
0.059	0.024	26	11	0.79	137.17	0.73	100.13	42.62	20.4	5.5	25.9

T46					T46						
H+ (m)	H- (m)	F+ (N)	F- (N)	alpha1	p+1+_g (N/	alpha3	p+3+_g	p+4+_g	Fw1+_g (N	Fw2+_g (N	Fw+_g (N
0.019	0.008	10	4	0.77	43.06	0.7	30.14	0	6.3	1.3	7.6
0.027	0.015	13	7	0.77	61.18	0.7	42.83	0	8.9	1.9	10.8
0.042	0.027	20	12	0.77	95.18	0.7	66.63	3.02	13.9	3	16.9
0.051	0.049	23	21	0.77	115.57	0.7	80.9	23.42	16.9	4.2	21.1
0.059	0.05	25	21	0.77	133.7	0.7	93.59	41.55	19.5	5.3	24.8
0.056	0.044	24	19	0.77	126.9	0.7	88.83	34.75	18.6	4.9	23.5
0.055	0.044	23	18	0.77	124.64	0.7	87.25	32.48	18.2	4.8	23
0.057	0.05	23	21	0.77	129.17	0.7	90.42	37.01	18.9	5.1	24
0.054	0.046	23	18	0.77	122.37	0.7	85.66	30.21	17.9	4.7	22.6
0.056	0.051	23	21	0.77	126.9	0.7	88.83	34.75	18.6	4.9	23.5
0.059	0.049	23	20	0.77	133.7	0.7	93.59	41.55	19.5	5.3	24.8
0.061	0.046	23	20	0.77	138.23	0.7	96.76	46.08	20.2	5.6	25.8
0.063	0.057	24	23	0.77	142.76	0.7	99.93	50.61	20.9	5.9	26.8
0.064	0.046	24	20	0.77	145.03	0.7	101.52	52.88	21.2	6	27.2
0.059	0.049	23	20	0.77	133.7	0.7	93.59	41.55	19.5	5.3	24.8
0.059	0.046	26	19	0.77	133.7	0.7	93.59	41.55	19.5	5.3	24.8

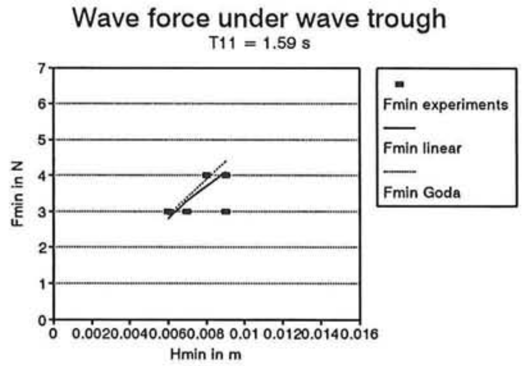
T47					T47						
H+ (m)	H- (m)	F+ (N)	F- (N)	alpha1	p+1+_g (N/	alpha3	p+3+_g	p+4+_g	Fw1+_g (N	Fw2+_g (N	Fw+_g (N
0.019	0.006	10	2	0.72	40.26	0.64	25.77	0	5.7	1.2	6.9
0.022	0.011	11	4	0.72	46.62	0.64	29.84	0	6.6	1.4	8
0.036	0.017	17	8	0.72	76.28	0.64	48.82	0	10.8	2.3	13.1
0.039	0.049	17	19	0.72	82.64	0.64	52.89	0	11.7	2.5	14.2
0.054	0.061	25	25	0.72	114.42	0.64	73.23	28.25	16.1	4.4	20.5
0.054	0.051	23	22	0.72	114.42	0.64	73.23	28.25	16.1	4.4	20.5
0.05	0.048	19	20	0.72	105.95	0.64	67.81	19.78	14.9	3.8	18.7
0.046	0.049	23	21	0.72	97.47	0.64	62.38	11.3	13.7	3.3	17
0.052	0.05	21	22	0.72	110.19	0.64	70.52	24.02	15.5	4.1	19.6
0.051	0.05	22	23	0.72	108.07	0.64	69.16	21.9	15.2	4	19.2
0.053	0.048	21	21	0.72	112.3	0.64	71.87	26.13	15.8	4.2	20
0.049	0.051	22	23	0.72	103.83	0.64	66.45	17.66	14.6	3.7	18.3
0.053	0.049	23	21	0.72	112.3	0.64	71.87	26.13	15.8	4.2	20
0.056	0.049	21	21	0.72	118.66	0.64	75.94	32.49	16.7	4.6	21.3
0.051	0.054	21	23	0.72	108.07	0.64	69.16	21.9	15.2	4	19.2
0.063	0.044	25	20	0.72	133.49	0.64	85.43	47.32	18.8	5.5	24.3
0.068	0.038	23	19	0.72	144.09	0.64	92.22	57.92	20.3	6.2	26.5

T48					T48						
H+ (m)	H- (m)	F+ (N)	F- (N)	alpha1	p+1+_g (N/	alpha3	p+3+_g	p+4+_g	Fw1+_g (N	Fw2+_g (N	Fw+_g (N
0.015	0.003	8	1	0.71	31.34	0.62	19.43	0	4.4	1	5.4
0.021	0.012	10	5	0.71	43.88	0.62	27.21	0	6.1	1.3	7.4
0.029	0.021	13	9	0.71	60.6	0.62	37.57	0	8.4	1.8	10.2
0.039	0.04	17	16	0.71	81.49	0.62	50.52	0	11.4	2.5	13.9
0.05	0.058	21	23	0.71	104.48	0.62	64.78	19.5	14.6	3.8	18.4
0.049	0.055	24	25	0.71	102.39	0.62	63.48	17.41	14.3	3.7	18
0.054	0.048	20	21	0.71	112.83	0.62	69.95	27.86	15.7	4.3	20
0.047	0.051	22	22	0.71	98.21	0.62	60.89	13.23	13.7	3.4	17.1
0.048	0.05	22	22	0.71	100.3	0.62	62.19	15.32	14	3.5	17.5
0.056	0.057	20	24	0.71	117.01	0.62	72.55	32.04	16.3	4.5	20.8
0.056	0.054	20	23	0.71	117.01	0.62	72.55	32.04	16.3	4.5	20.8
0.049	0.054	19	22	0.71	102.39	0.62	63.48	17.41	14.3	3.7	18
0.049	0.054	21	23	0.71	102.39	0.62	63.48	17.41	14.3	3.7	18
0.059	0.052	20	22	0.71	123.28	0.62	76.43	38.31	17.2	4.9	22.1
0.059	0.05	20	22	0.71	123.28	0.62	76.43	38.31	17.2	4.9	22.1
0.039	0.051	21	22	0.71	81.49	0.62	50.52	0	11.4	2.5	13.9
0.054	0.049	25	24	0.71	112.83	0.62	69.95	27.86	15.7	4.3	20
0.063	0.044	21	21	0.71	131.64	0.62	81.62	46.67	18.3	5.4	23.7

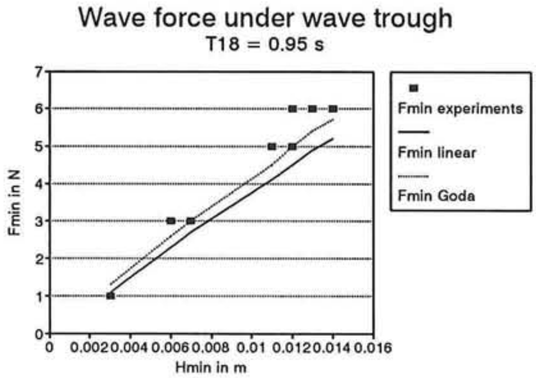
APPENDIX G. RESULTS EXPERIMENT 1:

CALCULATION WAVE FORCE UNDER WAVE TROUGH WITH LINEAR WAVE THEORY AND GODA'S FORMULA

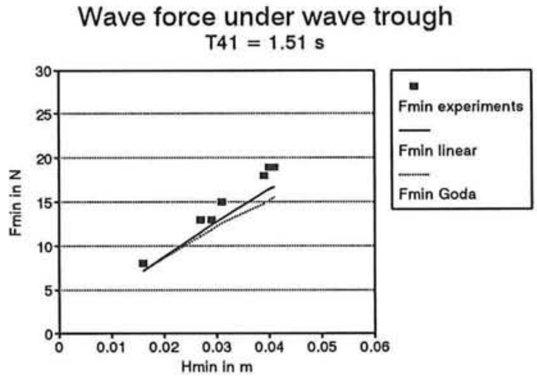
T11	1.59		
H- (m)	F- (N)	Fmin_lin (N	Fmin_g (N)
0.006	3	2.8	2.9
0.006	3	2.8	2.9
0.007	3	3.3	3.4
0.007	3	3.3	3.4
0.008	4	3.7	3.9
0.008	4	3.7	3.9
0.008	4	3.7	3.9
0.009	3	4.1	4.4
0.009	4	4.1	4.4



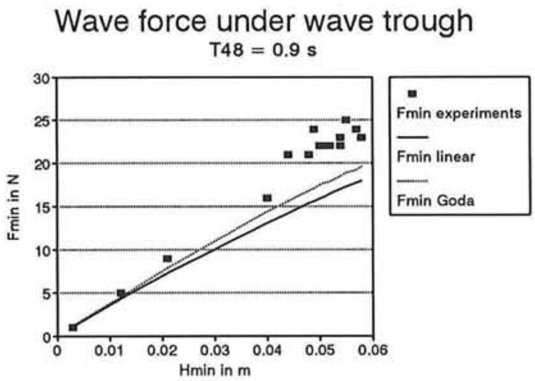
T18	0.95		
H- (m)	F- (N)	Fmin_lin (N	Fmin_g (N)
0.003	1	1.1	1.3
0.006	3	2.3	2.6
0.007	3	2.7	3
0.011	5	4.1	4.5
0.011	5	4.1	4.5
0.011	5	4.1	4.5
0.011	5	4.1	4.5
0.011	5	4.1	4.5
0.011	5	4.1	4.5
0.011	5	4.1	4.5
0.011	5	4.1	4.5
0.012	6	4.5	5
0.012	6	4.5	5
0.012	6	4.5	5
0.012	5	4.5	5
0.013	6	4.9	5.4
0.014	6	5.2	5.7



T41	1.51		
H- (m)	F- (N)	Fmin_lin (N	Fmin_g (N)
0.016	8	7.1	7.1
0.027	13	11.5	11
0.029	13	12.4	11.8
0.031	15	13.1	12.6
0.039	18	16.1	14.8
0.04	19	16.4	15.1
0.041	19	16.7	15.5
0.041	19	16.7	15.5
0.041	19	16.7	15.5



T48	0.9		
H- (m)	F- (N)	Fmin_lin (N	Fmin_g (N)
0.003	1	1.1	1.2
0.012	5	4.3	4.6
0.021	9	7.3	7.9
0.04	16	13.1	14.4
0.044	21	14.2	15.6
0.048	21	15.4	16.8
0.049	24	15.6	17.1
0.05	22	15.9	17.5
0.05	22	15.9	17.5
0.051	22	16.1	17.8
0.051	22	16.1	17.8
0.052	22	16.5	17.9
0.054	23	17	18.5
0.054	22	17	18.5
0.054	23	17	18.5
0.055	25	17.3	18.9
0.057	24	17.8	19.2
0.058	23	18	19.6



T11	1.59											
H- (m)	F- (N)	h/L	H/L	Table	rho*g*h*	Fmin_g	C1_lin	k(h-H)	C2_lin	Fw3-lin (N	Fhydr-	Fmin_lin (N
0.007	3	0.09	0.003	0.84	4.07	3.4	850.455	0.5614	0.531	3.2	0.1	3.3
0.006	3	0.09	0.003	0.84	3.49	2.9	850.455	0.5644	0.534	2.7	0.1	2.8
0.009	4	0.09	0.004	0.84	5.24	4.4	850.455	0.5553	0.524	4	0.1	4.1
0.009	3	0.09	0.004	0.84	5.24	4.4	850.455	0.5553	0.524	4	0.1	4.1
0.006	3	0.09	0.003	0.84	3.49	2.9	850.455	0.5644	0.534	2.7	0.1	2.8
0.007	3	0.09	0.003	0.84	4.07	3.4	850.455	0.5614	0.531	3.2	0.1	3.3
0.008	4	0.09	0.004	0.84	4.66	3.9	850.455	0.5584	0.527	3.6	0.1	3.7
0.008	4	0.09	0.004	0.84	4.66	3.9	850.455	0.5584	0.527	3.6	0.1	3.7
0.008	4	0.09	0.004	0.84	4.66	3.9	850.455	0.5584	0.527	3.6	0.1	3.7

T18	0.95											
H- (m)	F- (N)	h/L	H/L	Table	rho*g*h*	Fmin_g	C1_lin	k(h-H)	C2_lin	Fw3-lin (N	Fhydr-	Fmin_lin (N
0.003	1	0.17	0.003	0.75	1.75	1.3	328.411	1.0627	1.162	1.1	0	1.1
0.006	3	0.17	0.005	0.74	3.49	2.6	328.411	1.0458	1.134	2.2	0.1	2.3
0.007	3	0.17	0.006	0.73	4.07	3	328.411	1.0402	1.126	2.6	0.1	2.7
0.012	6	0.17	0.011	0.72	6.98	5	328.411	1.0121	1.081	4.3	0.2	4.5
0.014	6	0.17	0.013	0.7	8.15	5.7	328.411	1.0008	1.064	4.9	0.3	5.2
0.011	5	0.17	0.01	0.71	6.4	4.5	328.411	1.0177	1.09	3.9	0.2	4.1
0.011	5	0.17	0.01	0.71	6.4	4.5	328.411	1.0177	1.09	3.9	0.2	4.1
0.012	6	0.17	0.011	0.71	6.98	5	328.411	1.0121	1.081	4.3	0.2	4.5
0.011	5	0.17	0.01	0.71	6.4	4.5	328.411	1.0177	1.09	3.9	0.2	4.1
0.011	5	0.17	0.01	0.71	6.4	4.5	328.411	1.0177	1.09	3.9	0.2	4.1
0.011	5	0.17	0.01	0.71	6.4	4.5	328.411	1.0177	1.09	3.9	0.2	4.1
0.011	5	0.17	0.01	0.71	6.4	4.5	328.411	1.0177	1.09	3.9	0.2	4.1
0.011	5	0.17	0.01	0.71	6.4	4.5	328.411	1.0177	1.09	3.9	0.2	4.1
0.011	5	0.17	0.01	0.71	6.4	4.5	328.411	1.0177	1.09	3.9	0.2	4.1
0.013	6	0.17	0.012	0.71	7.57	5.4	328.411	1.0065	1.073	4.6	0.3	4.9
0.012	6	0.17	0.011	0.71	6.98	5	328.411	1.0121	1.081	4.3	0.2	4.5
0.012	5	0.17	0.011	0.71	6.98	5	328.411	1.0121	1.081	4.3	0.2	4.5

$$C_{1\_lin} = \frac{L\, \rho_w\, g \cdot \text{length}}{2\pi \cosh kh}$$

$$C_{2\_lin} = \sinh k(h-H) - \sinh k(h-d)$$

$$F_{hydr} = \frac{1}{2} \rho g H^2 \cdot \text{length}$$

T41 1.51

H- (m)	F- (N)	h/L	H/L	Table	rho*g*h*	Fmin_g (N	C1_lin	k(h-H)	C2_lin	Fw3-lin	Fhydr-	Fmin_lin (N
0.016	8	0.1	0.008	0.76	9.31	7.1	788.195	0.566	0.532	6.7	0.4	7.1
0.029	13	0.1	0.015	0.7	16.88	11.8	788.195	0.524	0.484	11.1	1.3	12.4
0.027	13	0.1	0.014	0.7	15.71	11	788.195	0.53	0.491	10.4	1.1	11.5
0.031	15	0.1	0.016	0.7	18.04	12.6	788.195	0.517	0.476	11.6	1.5	13.1
0.039	18	0.1	0.02	0.65	22.7	14.8	788.195	0.492	0.448	13.8	2.3	16.1
0.041	19	0.1	0.021	0.65	23.86	15.5	788.195	0.485	0.44	14.2	2.5	16.7
0.041	19	0.1	0.021	0.65	23.86	15.5	788.195	0.485	0.44	14.2	2.5	16.7
0.04	19	0.1	0.02	0.65	23.28	15.1	788.195	0.489	0.444	14	2.4	16.4
0.041	19	0.1	0.021	0.65	23.86	15.5	788.195	0.485	0.44	14.2	2.5	16.7

T48 0.9

H- (m)	F- (N)	h/L	H/L	Table	rho*g*h*	Fmin_g (N	C1_lin	k(h-H)	C2_lin	Fw3-lin	Fhydr-	Fmin_lin (N
0.003	1	0.18	0.003	0.68	1.75	1.2	285.822	1.143	1.287	1.1	0	1.1
0.012	5	0.18	0.012	0.66	6.98	4.6	285.822	1.089	1.196	4.1	0.2	4.3
0.021	9	0.18	0.02	0.65	12.22	7.9	285.822	1.034	1.107	6.6	0.7	7.3
0.04	16	0.18	0.039	0.62	23.28	14.4	285.822	0.919	0.933	10.7	2.4	13.1
0.058	23	0.18	0.056	0.58	33.76	19.6	285.822	0.81	0.78	12.9	5.1	18
0.055	25	0.18	0.053	0.59	32.01	18.9	285.822	0.829	0.806	12.7	4.6	17.3
0.048	21	0.18	0.046	0.6	27.94	16.8	285.822	0.871	0.864	11.9	3.5	15.4
0.051	22	0.18	0.049	0.6	29.68	17.8	285.822	0.853	0.839	12.2	3.9	16.1
0.05	22	0.18	0.048	0.6	29.1	17.5	285.822	0.859	0.847	12.1	3.8	15.9
0.057	24	0.18	0.055	0.58	33.17	19.2	285.822	0.817	0.79	12.9	4.9	17.8
0.054	23	0.18	0.052	0.59	31.43	18.5	285.822	0.835	0.814	12.6	4.4	17
0.054	22	0.18	0.052	0.59	31.43	18.5	285.822	0.835	0.814	12.6	4.4	17
0.054	23	0.18	0.052	0.59	31.43	18.5	285.822	0.835	0.814	12.6	4.4	17
0.052	22	0.18	0.05	0.59	30.26	17.9	285.822	0.847	0.831	12.4	4.1	16.5
0.05	22	0.18	0.048	0.6	29.1	17.5	285.822	0.859	0.847	12.1	3.8	15.9
0.051	22	0.18	0.049	0.6	29.68	17.8	285.822	0.853	0.839	12.2	3.9	16.1
0.049	24	0.18	0.047	0.6	28.52	17.1	285.822	0.865	0.856	12	3.6	15.6
0.044	21	0.18	0.042	0.61	25.61	15.6	285.822	0.895	0.898	11.3	2.9	14.2

APPENDIX H. RESULTS EXPERIMENT 1:

CALCULATION TOTAL WAVE FORCE WITH LINEAR WAVE THEORY AND GODA'S FORMULA

T11 1.59

H+ (m)	F+ (N)	Fw1+ (N)	Fw2+ (N)	Fw+lin (N)	Fw1+_g (N)	Fw2+_g (N)	Fw+_g (N)
0.006	3	2.8	0.1	2.9	2.6	0.5	3.1
0.005	3	2.3	0	2.3	2.2	0.4	2.6
0.009	5	4.1	0.1	4.2	3.9	0.7	4.6
0.009	5	4.1	0.1	4.2	3.9	0.7	4.6
0.009	5	4.1	0.1	4.2	3.9	0.7	4.6
0.009	4	4.1	0.1	4.2	3.9	0.7	4.6
0.009	5	4.1	0.1	4.2	3.9	0.7	4.6
0.009	5	4.1	0.1	4.2	3.9	0.7	4.6
0.009	5	4.1	0.1	4.2	3.9	0.7	4.6

T12 1.46

H+ (m)	F+ (N)	Fw1+ (N)	Fw2+ (N)	Fw+lin (N)	Fw1+_g (N)	Fw2+_g (N)	Fw+_g (N)
0.005	3	2.3	0	2.3	2.1	0.4	2.5
0.007	3	3.2	0.1	3.3	2.9	0.6	3.5
0.01	5	4.5	0.1	4.6	4.2	0.8	5
0.011	6	5	0.2	5.2	4.6	0.9	5.5
0.012	6	5.4	0.2	5.6	5	1	6
0.013	7	5.9	0.2	6.1	5.4	1.1	6.5
0.014	7	6.3	0.3	6.6	5.9	1.1	7
0.013	6	5.9	0.2	6.1	5.4	1.1	6.5
0.012	6	5.4	0.2	5.6	5	1	6

T13 1.37

H+ (m)	F+ (N)	Fw1+ (N)	Fw2+ (N)	Fw+lin (N)	Fw1+_g (N)	Fw2+_g (N)	Fw+_g (N)
0.005	2	2.2	0	2.2	2	0.4	2.4
0.007	3	3.1	0.1	3.2	2.8	0.6	3.4
0.01	5	4.4	0.1	4.5	4.1	0.8	4.9
0.009	5	4	0.1	4.1	3.6	0.7	4.3
0.01	6	4.4	0.1	4.5	4.1	0.8	4.9
0.011	6	4.9	0.2	5.1	4.5	0.9	5.4
0.011	6	4.9	0.2	5.1	4.5	0.9	5.4
0.012	6	5.3	0.2	5.5	4.9	0.9	5.8
0.011	6	4.9	0.2	5.1	4.5	0.9	5.4

T14 1.23

H+ (m)	F+ (N)	Fw1+ (N)	Fw2+ (N)	Fw+lin (N)	Fw1+_g (N)	Fw2+_g (N)	Fw+_g (N)
0.002	1	0.9	0	0.9	0.7	0.1	0.8
0.006	3	2.6	0.1	2.7	2.2	0.4	2.6
0.011	6	4.7	0.2	4.9	4.1	0.8	4.9
0.009	4	3.9	0.1	4	3.4	0.7	4.1
0.007	4	3	0.1	3.1	2.6	0.5	3.1
0.005	3	2.1	0	2.1	1.9	0.4	2.3
0.005	3	2.1	0	2.1	1.9	0.4	2.3
0.006	3	2.6	0.1	2.7	2.2	0.4	2.6
0.006	3	2.6	0.1	2.7	2.2	0.4	2.6
0.006	3	2.6	0.1	2.7	2.2	0.4	2.6
0.006	3	2.6	0.1	2.7	2.2	0.4	2.6

T15	1.17						
H+ (m)	F+ (N)	Fw1+ (N)	Fw2+ (N)	Fw+lin (N)	Fw1+_g (N)	Fw2+_g (N)	Fw+_g (N)
0.004	1	1.7	0	1.7	1.4	0.3	1.7
0.006	3	2.5	0.1	2.6	2.2	0.4	2.6
0.011	5	4.6	0.2	4.8	4	0.8	4.8
0.011	5	4.6	0.2	4.8	4	0.8	4.8
0.009	4	3.8	0.1	3.9	3.2	0.7	3.9
0.009	4	3.8	0.1	3.9	3.2	0.7	3.9
0.009	4	3.8	0.1	3.9	3.2	0.7	3.9
0.01	5	4.2	0.1	4.3	3.6	0.7	4.3
0.011	5	4.6	0.2	4.8	4	0.8	4.8
0.011	5	4.6	0.2	4.8	4	0.8	4.8
0.011	5	4.6	0.2	4.8	4	0.8	4.8
0.01	4	4.2	0.1	4.3	3.6	0.7	4.3
0.01	4	4.2	0.1	4.3	3.6	0.7	4.3
0.011	5	4.6	0.2	4.8	4	0.8	4.8

T16	1.09						
H+ (m)	F+ (N)	Fw1+ (N)	Fw2+ (N)	Fw+lin (N)	Fw1+_g (N)	Fw2+_g (N)	Fw+_g (N)
0.003	1	1.2	0	1.2	1	0.2	1.2
0.005	2	2	0	2	1.7	0.4	2.1
0.01	4	4.1	0.1	4.2	3.5	0.7	4.2
0.011	5	4.5	0.2	4.7	3.8	0.8	4.6
0.012	6	4.9	0.2	5.1	4.2	0.9	5.1
0.011	5	4.5	0.2	4.7	3.8	0.8	4.6
0.013	6	5.3	0.2	5.5	4.5	0.9	5.4
0.012	5	4.9	0.2	5.1	4.2	0.9	5.1
0.012	5	4.9	0.2	5.1	4.2	0.9	5.1
0.011	5	4.5	0.2	4.7	3.8	0.8	4.6
0.012	5	4.9	0.2	5.1	4.2	0.9	5.1
0.012	6	4.9	0.2	5.1	4.2	0.9	5.1
0.011	5	4.5	0.2	4.7	3.8	0.8	4.6
0.012	6	4.9	0.2	5.1	4.2	0.9	5.1
0.011	5	4.5	0.2	4.7	3.8	0.8	4.6

T17	0.99						
H+ (m)	F+ (N)	Fw1+ (N)	Fw2+ (N)	Fw+lin (N)	Fw1+_g (N)	Fw2+_g (N)	Fw+_g (N)
0.003	2	1.2	0	1.2	0.9	0.2	1.1
0.005	3	1.9	0	1.9	1.6	0.3	1.9
0.008	4	3.1	0.1	3.2	2.5	0.5	3
0.011	6	4.3	0.2	4.5	3.4	0.7	4.1
0.014	6	5.4	0.3	5.7	4.4	0.9	5.3
0.012	6	4.7	0.2	4.9	3.8	0.8	4.6
0.011	5	4.3	0.2	4.5	3.4	0.7	4.1
0.012	6	4.7	0.2	4.9	3.8	0.8	4.6
0.013	6	5	0.2	5.2	4.1	0.9	5
0.012	5	4.7	0.2	4.9	3.8	0.8	4.6
0.011	5	4.3	0.2	4.5	3.4	0.7	4.1
0.012	5	4.7	0.2	4.9	3.8	0.8	4.6
0.012	5	4.7	0.2	4.9	3.8	0.8	4.6
0.012	5	4.7	0.2	4.9	3.8	0.8	4.6
0.011	5	4.3	0.2	4.5	3.4	0.7	4.1
0.012	5	4.7	0.2	4.9	3.8	0.8	4.6

T18	0.95						
H+ (m)	F+ (N)	Fw1+ (N)	Fw2+ (N)	Fw+lin (N)	Fw1+_g (N)	Fw2+_g (N)	Fw+_g (N)
0.003	2	1.1	0	1.1	0.9	0.2	1.1
0.004	2	1.5	0	1.5	1.2	0.3	1.5
0.006	3	2.3	0.1	2.4	1.8	0.4	2.2
0.01	4	3.8	0.1	3.9	3	0.7	3.7
0.013	6	4.9	0.2	5.1	4	0.9	4.9
0.014	6	5.3	0.3	5.6	4.3	0.9	5.2
0.011	5	4.2	0.2	4.4	3.4	0.7	4.1
0.013	6	4.9	0.2	5.1	4	0.9	4.9
0.012	6	4.5	0.2	4.7	3.7	0.8	4.5
0.011	5	4.2	0.2	4.4	3.4	0.7	4.1
0.011	6	4.2	0.2	4.4	3.4	0.7	4.1
0.011	6	4.2	0.2	4.4	3.4	0.7	4.1
0.011	5	4.2	0.2	4.4	3.4	0.7	4.1
0.012	6	4.5	0.2	4.7	3.7	0.8	4.5
0.012	6	4.5	0.2	4.7	3.7	0.8	4.5
0.011	6	4.2	0.2	4.4	3.4	0.7	4.1
0.011	5	4.2	0.2	4.4	3.4	0.7	4.1

T21 1.64

H+ (m)	F+ (N)	Fw1+ (N)	Fw2 (N)	Fw+lin (N	Fw1+_g (N	Fw2+_g (N	Fw+_g (N
0.007	4	3.2	0.1	3.3	3.1	0.6	3.7
0.016	8	7.4	0.4	7.8	7	1.3	8.3
0.012	6	5.5	0.2	5.7	5.3	1	6.3
0.014	7	6.5	0.3	6.8	6.2	1.2	7.4
0.012	6	5.5	0.2	5.7	5.3	1	6.3
0.013	6	6	0.2	6.2	5.7	1.1	6.8
0.015	7	6.9	0.3	7.2	6.6	1.3	7.9
0.016	8	7.4	0.4	7.8	7	1.3	8.3
0.016	7	7.4	0.4	7.8	7	1.3	8.3

T22 1.38

H+ (m)	F+ (N)	Fw1+ (N)	Fw2 (N)	Fw+lin (N	Fw1+_g (N	Fw2+_g (N	Fw+_g (N
0.009	4	4	0.1	4.1	3.7	0.7	4.4
0.017	8	7.5	0.4	7.9	6.9	1.3	8.2
0.024	12	10.7	0.8	11.5	9.8	1.9	11.7
0.022	11	9.8	0.7	10.5	9	1.7	10.7
0.023	11	10.2	0.8	11	9.4	1.8	11.2
0.026	13	11.5	1	12.5	10.6	2.1	12.7
0.028	13	12.4	1.2	13.6	11.4	2.2	13.6
0.029	15	12.9	1.2	14.1	11.8	2.3	14.1
0.03	15	13.3	1.3	14.6	12.2	2.4	14.6

T23 1.27

H+ (m)	F+ (N)	Fw1+ (N)	Fw2 (N)	Fw+lin (N	Fw1+_g (N	Fw2+_g (N	Fw+_g (N
0.008	3	3.5	0.1	3.6	3.1	0.6	3.7
0.016	7	6.9	0.4	7.3	6.2	1.2	7.4
0.025	11	10.8	0.9	11.7	9.7	1.9	11.6
0.018	8	7.8	0.5	8.3	7	1.4	8.4
0.019	9	8.2	0.5	8.7	7.4	1.4	8.8
0.015	6	6.5	0.3	6.8	5.8	1.1	6.9
0.014	6	6.1	0.3	6.4	5.4	1.1	6.5
0.013	6	5.6	0.2	5.8	5	1	6
0.013	6	5.6	0.2	5.8	5	1	6
0.014	6	6.1	0.3	6.4	5.4	1.1	6.5
0.014	7	6.1	0.3	6.4	5.4	1.1	6.5

T24 1.13

H+ (m)	F+ (N)	Fw1+ (N)	Fw2 (N)	Fw+lin (N	Fw1+_g (N	Fw2+_g (N	Fw+_g (N
0.007	3	2.9	0.1	3	2.5	0.5	3
0.012	6	5	0.2	5.2	4.2	0.9	5.1
0.021	10	8.7	0.6	9.3	7.4	1.5	8.9
0.024	11	9.9	0.8	10.7	8.5	1.7	10.2
0.021	10	8.7	0.6	9.3	7.4	1.5	8.9
0.024	11	9.9	0.8	10.7	8.5	1.7	10.2
0.024	11	9.9	0.8	10.7	8.5	1.7	10.2
0.026	12	10.8	1	11.8	9.2	1.9	11.1
0.024	12	9.9	0.8	10.7	8.5	1.7	10.2
0.022	11	9.1	0.7	9.8	7.8	1.6	9.4
0.021	10	8.7	0.6	9.3	7.4	1.5	8.9
0.023	11	9.5	0.8	10.3	8.1	1.7	9.8
0.023	11	9.5	0.8	10.3	8.1	1.7	9.8
0.025	11	10.4	0.9	11.3	8.8	1.8	10.6

T25 1.07

H+ (m)	F+ (N)	Fw1+ (N)	Fw2 (N)	Fw+lin (N	Fw1+_g (N	Fw2+_g (N	Fw+_g (N
0.007	3	2.8	0.1	2.9	2.4	0.5	2.9
0.011	5	4.4	0.2	4.6	3.7	0.8	4.5
0.02	9	8.1	0.6	8.7	6.8	1.4	8.2
0.025	11	10.1	0.9	11	8.5	1.8	10.3
0.029	13	11.7	1.2	12.9	9.8	2	11.8
0.026	11	10.5	1	11.5	8.8	1.8	10.6
0.029	13	11.7	1.2	12.9	9.8	2	11.8
0.026	11	10.5	1	11.5	8.8	1.8	10.6
0.028	12	11.3	1.2	12.5	9.5	2	11.5
0.029	12	11.7	1.2	12.9	9.8	2	11.8
0.029	12	11.7	1.2	12.9	9.8	2	11.8
0.029	12	11.7	1.2	12.9	9.8	2	11.8
0.029	12	11.7	1.2	12.9	9.8	2	11.8
0.027	12	10.9	1.1	12	9.2	1.9	11.1
0.028	13	11.3	1.2	12.5	9.5	2	11.5

T26 1.01

H+ (m)	F+ (N)	Fw1+ (N)	Fw2 (N)	Fw+lin (N	Fw1+_g (N	Fw2+_g (N	Fw+_g (N
0.007	4	2.8	0.1	2.9	2.2	0.5	2.7
0.011	5	4.3	0.2	4.5	3.5	0.7	4.2
0.017	8	6.7	0.4	7.1	5.5	1.1	6.6
0.024	11	9.4	0.8	10.2	7.7	1.6	9.3
0.028	13	11	1.2	12.2	9	1.9	10.9
0.027	12	10.6	1.1	11.7	8.7	1.8	10.5
0.026	12	10.2	1	11.2	8.3	1.8	10.1
0.027	12	10.6	1.1	11.7	8.7	1.8	10.5
0.026	12	10.2	1	11.2	8.3	1.8	10.1
0.027	12	10.6	1.1	11.7	8.7	1.8	10.5
0.026	12	10.2	1	11.2	8.3	1.8	10.1
0.026	12	10.2	1	11.2	8.3	1.8	10.1
0.027	12	10.6	1.1	11.7	8.7	1.8	10.5
0.027	12	10.6	1.1	11.7	8.7	1.8	10.5
0.026	12	10.2	1	11.2	8.3	1.8	10.1
0.026	12	10.2	1	11.2	8.3	1.8	10.1

T27 0.92

H+ (m)	F+ (N)	Fw1+ (N)	Fw2 (N)	Fw+lin (N	Fw1+_g (N	Fw2+_g (N	Fw+_g (N
0.006	3	2.2	0.1	2.3	1.8	0.4	2.2
0.01	5	3.7	0.1	3.8	2.9	0.6	3.5
0.013	6	4.8	0.2	5	3.8	0.8	4.6
0.023	10	8.6	0.8	9.4	6.7	1.5	8.2
0.027	12	10	1.1	11.1	7.9	1.7	9.6
0.029	13	10.8	1.2	12	8.5	1.8	10.3
0.026	12	9.7	1	10.7	7.6	1.7	9.3
0.027	12	10	1.1	11.1	7.9	1.7	9.6
0.028	13	10.4	1.2	11.6	8.2	1.8	10
0.026	12	9.7	1	10.7	7.6	1.7	9.3
0.028	13	10.4	1.2	11.6	8.2	1.8	10
0.028	12	10.4	1.2	11.6	8.2	1.8	10
0.028	12	10.4	1.2	11.6	8.2	1.8	10
0.028	13	10.4	1.2	11.6	8.2	1.8	10
0.029	13	10.8	1.2	12	8.5	1.8	10.3
0.028	12	10.4	1.2	11.6	8.2	1.8	10
0.031	13	11.5	1.4	12.9	9.1	2	11.1

T28 0.89

H+ (m)	F+ (N)	Fw1+ (N)	Fw2 (N)	Fw+lin (N	Fw1+_g (N	Fw2+_g (N	Fw+_g (N
0.006	3	2.2	0.1	2.3	1.7	0.4	2.1
0.008	4	2.9	0.1	3	2.3	0.5	2.8
0.014	6	5.1	0.3	5.4	4	0.9	4.9
0.013	6	4.7	0.2	4.9	3.7	0.8	4.5
0.024	11	8.7	0.8	9.5	6.8	1.5	8.3
0.028	13	10.2	1.2	11.4	8	1.8	9.8
0.028	13	10.2	1.2	11.4	8	1.8	9.8
0.029	13	10.5	1.2	11.7	8.3	1.8	10.1
0.026	11	9.4	1	10.4	7.4	1.6	9
0.029	13	10.5	1.2	11.7	8.3	1.8	10.1
0.029	13	10.5	1.2	11.7	8.3	1.8	10.1
0.029	13	10.5	1.2	11.7	8.3	1.8	10.1
0.029	12	10.5	1.2	11.7	8.3	1.8	10.1
0.029	13	10.5	1.2	11.7	8.3	1.8	10.1
0.028	12	10.2	1.2	11.4	8	1.8	9.8
0.028	12	10.2	1.2	11.4	8	1.8	9.8
0.032	14	11.6	1.5	13.1	9.1	2	11.1
0.03	13	10.9	1.3	12.2	8.6	1.9	10.5

T31	1.49						
H+ (m)	F+ (N)	Fw1+ (N)	Fw2 (N)	Fw+lin (N)	Fw1+_g (N)	Fw2+_g (N)	Fw+_g (N)
0.013	6	5.9	0.2	6.1	5.5	1.1	6.6
0.026	13	11.8	1	12.8	11	2.1	13.1
0.036	18	16.3	1.9	18.2	15.2	2.9	18.1
0.038	19	17.2	2.1	19.3	16	3.1	19.1
0.039	19	17.6	2.2	19.8	16.4	3.2	19.6
0.036	19	16.3	1.9	18.2	15.2	2.9	18.1
0.036	18	16.3	1.9	18.2	15.2	2.9	18.1
0.034	17	15.4	1.7	17.1	14.3	2.7	17
0.033	17	14.9	1.6	16.5	13.9	2.7	16.6
T31B	F+ (N)	Fw1+ (N)	Fw2 (N)	Fw+lin (N)	Fw1+_g (N)	Fw2+_g (N)	Fw+_g (N)
0.017	9	7.7	0.4	8.1	7.2	1.4	8.6
0.027	13	12.2	1.1	13.3	11.4	2.2	13.6
0.035	17	15.8	1.8	17.6	14.7	2.8	17.5
0.039	19	17.6	2.2	19.8	16.4	3.2	19.6
0.04	20	18.1	2.4	20.5	16.9	3.2	20.1
0.039	21	17.6	2.2	19.8	16.4	3.2	19.6
0.038	19	17.2	2.1	19.3	16	3.1	19.1
0.036	19	16.3	1.9	18.2	15.2	2.9	18.1
0.036	18	16.3	1.9	18.2	15.2	2.9	18.1
T31*	F+ (N)	Fw1+ (N)	Fw2 (N)	Fw+lin (N)	Fw1+_g (N)	Fw2+_g (N)	Fw+_g (N)
0.016	9	7.2	0.4	7.6	6.7	1.3	8
0.026	13	11.8	1	12.8	11	2.1	13.1
0.026	17	11.8	1	12.8	11	2.1	13.1
0.026	19	11.8	1	12.8	11	2.1	13.1
0.031	19	14	1.4	15.4	13.1	2.5	15.6
0.031	18	14	1.4	15.4	13.1	2.5	15.6
0.029	17	13.1	1.2	14.3	12.2	2.3	14.5
0.03	17	13.6	1.3	14.9	12.6	2.4	15
0.028	16	12.7	1.2	13.9	11.8	2.3	14.1

T32	1.39						
H+ (m)	F+ (N)	Fw1+ (N)	Fw2 (N)	Fw+lin (N)	Fw1+_g (N)	Fw2+_g (N)	Fw+_g (N)
0.017	8	7.5	0.4	7.9	6.9	1.3	8.2
0.028	13	12.4	1.2	13.6	11.4	2.2	13.6
0.036	18	16	1.9	17.9	14.7	2.8	17.5
0.038	19	16.9	2.1	19	15.5	3	18.5
0.04	20	17.8	2.4	20.2	16.3	3.2	19.5
0.044	22	19.5	2.8	22.3	17.9	3.7	21.6
0.045	23	20	3	23	18.3	3.9	22.2
0.046	23	20.4	3.1	23.5	18.7	4.1	22.8
0.047	23	20.9	3.3	24.2	19.2	4.2	23.4
0.05	25	22.2	3.7	25.9	20.4	4.7	25.1
T32*	F+ (N)	Fw1+ (N)	Fw2 (N)	Fw+lin (N)	Fw1+_g (N)	Fw2+_g (N)	Fw+_g (N)
0.014	8	6.2	0.3	6.5	5.7	1.1	6.8
0.026	13	11.5	1	12.5	10.6	2.1	12.7
0.036	18	16	1.9	17.9	14.7	2.8	17.5
0.036	18	16	1.9	17.9	14.7	2.8	17.5
0.036	19	16	1.9	17.9	14.7	2.8	17.5
0.041	21	18.2	2.5	20.7	16.7	3.2	19.9
0.043	22	19.1	2.7	21.8	17.5	3.6	21.1
0.044	23	19.5	2.8	22.3	17.9	3.7	21.6
0.046	23	20.4	3.1	23.5	18.7	4.1	22.8
0.046	24	20.4	3.1	23.5	18.7	4.1	22.8

T33	1.29						
H+ (m)	F+ (N)	Fw1+ (N)	Fw2 (N)	Fw+lin (N)	Fw1+_g (N)	Fw2+_g (N)	Fw+_g (N)
0.013	7	5.7	0.2	5.9	5	1	6
0.026	12	11.3	1	12.3	10.1	2	12.1
0.039	19	17	2.2	19.2	15.1	3	18.1
0.027	14	11.7	1.1	12.8	10.5	2.1	12.6
0.033	16	14.4	1.6	16	12.8	2.5	15.3
0.033	16	14.4	1.6	16	12.8	2.5	15.3
0.03	15	13.1	1.3	14.4	11.6	2.3	13.9
0.029	15	12.6	1.2	13.8	11.2	2.2	13.4
0.028	13	12.2	1.2	13.4	10.8	2.1	12.9
0.029	14	12.6	1.2	13.8	11.2	2.2	13.4
0.029	15	12.6	1.2	13.8	11.2	2.2	13.4
T33*	F+ (N)	Fw1+ (N)	Fw2 (N)	Fw+lin (N)	Fw1+_g (N)	Fw2+_g (N)	Fw+_g (N)
0.011	6	4.8	0.2	5	4.3	0.8	5.1
0.024	12	10.4	0.8	11.2	9.3	1.8	11.1
0.038	19	16.5	2.1	18.6	14.7	2.9	17.6
0.026	14	11.3	1	12.3	10.1	2	12.1
0.031	16	13.5	1.4	14.9	12	2.4	14.4
0.031	16	13.5	1.4	14.9	12	2.4	14.4
0.027	14	11.7	1.1	12.8	10.5	2.1	12.6
0.026	13	11.3	1	12.3	10.1	2	12.1
0.025	12	10.9	0.9	11.8	9.7	1.9	11.6
0.026	12	11.3	1	12.3	10.1	2	12.1
0.026	13	11.3	1	12.3	10.1	2	12.1

T34	1.15						
H+ (m)	F+ (N)	Fw1+ (N)	Fw2 (N)	Fw+lin (N)	Fw1+_g (N)	Fw2+_g (N)	Fw+_g (N)
0.013	6	5.4	0.2	5.6	4.7	0.9	5.6
0.022	10	9.2	0.7	9.9	7.9	1.6	9.5
0.035	16	14.6	1.8	16.4	12.6	2.5	15.1
0.037	17	15.4	2	17.4	13.3	2.7	16
0.032	15	13.3	1.5	14.8	11.5	2.3	13.8
0.036	16	15	1.9	16.9	12.9	2.6	15.5
0.034	16	14.2	1.7	15.9	12.2	2.5	14.7
0.036	17	15	1.9	16.9	12.9	2.6	15.5
0.035	17	14.6	1.8	16.4	12.6	2.5	15.1
0.035	16	14.6	1.8	16.4	12.6	2.5	15.1
0.036	17	15	1.9	16.9	12.9	2.6	15.5
0.036	17	15	1.9	16.9	12.9	2.6	15.5
0.035	15	14.6	1.8	16.4	12.6	2.5	15.1
0.038	17	15.8	2.1	17.9	13.6	2.8	16.4
T34*	F+ (N)	Fw1+ (N)	Fw2 (N)	Fw+lin (N)	Fw1+_g (N)	Fw2+_g (N)	Fw+_g (N)
0.013	6	5.4	0.2	5.6	4.7	0.9	5.6
0.021	10	8.8	0.6	9.4	7.5	1.5	9
0.034	17	14.2	1.7	15.9	12.2	2.5	14.7
0.036	17	15	1.9	16.9	12.9	2.6	15.5
0.032	15	13.3	1.5	14.8	11.5	2.3	13.8
0.031	14	12.9	1.4	14.3	11.1	2.3	13.4
0.032	15	13.3	1.5	14.8	11.5	2.3	13.8
0.035	16	14.6	1.8	16.4	12.6	2.5	15.1
0.036	17	15	1.9	16.9	12.9	2.6	15.5
0.034	16	14.2	1.7	15.9	12.2	2.5	14.7
0.035	17	14.6	1.8	16.4	12.6	2.5	15.1
0.036	16	15	1.9	16.9	12.9	2.6	15.5
0.035	17	14.6	1.8	16.4	12.6	2.5	15.1
0.04	18	16.7	2.4	19.1	14.3	2.9	17.2

T35	1.08						
H+ (m)	F+ (N)	Fw1+ (N)	Fw2 (N)	Fw+lin (N	Fw1+_g (	Fw2+_g (	Fw+_g (N
0.011	6	4.5	0.2	4.7	3.7	0.8	4.5
0.019	9	7.7	0.5	8.2	6.5	1.3	7.8
0.031	15	12.6	1.4	14	10.5	2.2	12.7
0.039	18	15.8	2.2	18	13.2	2.7	15.9
0.041	19	16.6	2.5	19.1	13.9	2.9	16.8
0.036	17	14.6	1.9	16.5	12.2	2.5	14.7
0.041	19	16.6	2.5	19.1	13.9	2.9	16.8
0.04	18	16.2	2.4	18.6	13.6	2.8	16.4
0.04	17	16.2	2.4	18.6	13.6	2.8	16.4
0.04	18	16.2	2.4	18.6	13.6	2.8	16.4
0.039	18	15.8	2.2	18	13.2	2.7	15.9
0.04	19	16.2	2.4	18.6	13.6	2.8	16.4
0.041	18	16.6	2.5	19.1	13.9	2.9	16.8
0.042	19	17.1	2.6	19.7	14.3	3	17.3
0.042	19	17.1	2.6	19.7	14.3	3	17.3

T35*	F+ (N)	Fw1+ (N)	Fw2 (N)	Fw+lin (N	Fw1+_g (	Fw2+_g (	Fw+_g (N
0.014	7	5.7	0.3	6	4.8	1	5.8
0.021	10	8.5	0.6	9.1	7.1	1.5	8.6
0.032	15	13	1.5	14.5	10.9	2.2	13.1
0.039	17	15.8	2.2	18	13.2	2.7	15.9
0.041	18	16.6	2.5	19.1	13.9	2.9	16.8
0.041	19	16.6	2.5	19.1	13.9	2.9	16.8
0.041	19	16.6	2.5	19.1	13.9	2.9	16.8
0.04	18	16.2	2.4	18.6	13.6	2.8	16.4
0.04	18	16.2	2.4	18.6	13.6	2.8	16.4
0.04	17	16.2	2.4	18.6	13.6	2.8	16.4
0.04	18	16.2	2.4	18.6	13.6	2.8	16.4
0.041	19	16.6	2.5	19.1	13.9	2.9	16.8
0.042	18	17.1	2.6	19.7	14.3	3	17.3
0.041	17	16.6	2.5	19.1	13.9	2.9	16.8
0.043	19	17.5	2.7	20.2	14.6	3.2	17.8

T36	1.02						
H+ (m)	F+ (N)	Fw1+ (N)	Fw2 (N)	Fw+lin (N	Fw1+_g (	Fw2+_g (	Fw+_g (N
0.011	6	4.3	0.2	4.5	3.6	0.8	4.4
0.017	8	6.7	0.4	7.1	5.5	1.2	6.7
0.029	14	11.5	1.2	12.7	9.4	2	11.4
0.036	16	14.2	1.9	16.1	11.7	2.5	14.2
0.046	21	18.2	3.1	21.3	15	3.5	18.5
0.043	19	17	2.7	19.7	14	3.1	17.1
0.041	18	16.2	2.5	18.7	13.3	2.8	16.1
0.041	18	16.2	2.5	18.7	13.3	2.8	16.1
0.042	19	16.6	2.6	19.2	13.7	3	16.7
0.044	18	17.4	2.8	20.2	14.3	3.2	17.5
0.044	19	17.4	2.8	20.2	14.3	3.2	17.5
0.042	19	16.6	2.6	19.2	13.7	3	16.7
0.044	20	17.4	2.8	20.2	14.3	3.2	17.5
0.044	19	17.4	2.8	20.2	14.3	3.2	17.5
0.049	21	19.4	3.5	22.9	15.9	3.9	19.8
0.054	21	21.3	4.3	25.6	17.6	4.6	22.2

T36*	F+ (N)	Fw1+ (N)	Fw2 (N)	Fw+lin (N	Fw1+_g (	Fw2+_g (	Fw+_g (N
0.014	7	5.5	0.3	5.8	4.6	1	5.6
0.019	9	7.5	0.5	8	6.2	1.3	7.5
0.029	14	11.5	1.2	12.7	9.4	2	11.4
0.037	17	14.6	2	16.6	12	2.5	14.5
0.044	19	17.4	2.8	20.2	14.3	3.2	17.5
0.044	19	17.4	2.8	20.2	14.3	3.2	17.5
0.044	19	17.4	2.8	20.2	14.3	3.2	17.5
0.044	19	17.4	2.8	20.2	14.3	3.2	17.5
0.043	19	17	2.7	19.7	14	3.1	17.1
0.044	19	17.4	2.8	20.2	14.3	3.2	17.5
0.044	18	17.4	2.8	20.2	14.3	3.2	17.5
0.044	18	17.4	2.8	20.2	14.3	3.2	17.5
0.046	19	18.2	3.1	21.3	15	3.5	18.5
0.046	19	18.2	3.1	21.3	15	3.5	18.5
0.051	19	20.1	3.8	23.9	16.6	4.2	20.8
0.05	19	19.8	3.7	23.5	16.3	4	20.3

T37	0.94						
H+ (m)	F+ (N)	Fw1+ (N)	Fw2 (N)	Fw+lin (N	Fw1+_g (N	Fw2+_g (N	Fw+_g (N
0.011	6	4.1	0.2	4.3	3.3	0.7	4
0.014	7	5.3	0.3	5.6	4.2	0.9	5.1
0.024	11	9	0.8	9.8	7.2	1.6	8.8
0.027	12	10.2	1.1	11.3	8.1	1.7	9.8
0.041	18	15.5	2.5	18	12.3	2.6	14.9
0.043	19	16.2	2.7	18.9	12.9	2.9	15.8
0.039	17	14.7	2.2	16.9	11.7	2.5	14.2
0.038	17	14.3	2.1	16.4	11.4	2.5	13.9
0.037	17	13.9	2	15.9	11.1	2.4	13.5
0.041	17	15.5	2.5	18	12.3	2.6	14.9
0.039	18	14.7	2.2	16.9	11.7	2.5	14.2
0.039	18	14.7	2.2	16.9	11.7	2.5	14.2
0.042	19	15.8	2.6	18.4	12.6	2.8	15.4
0.043	19	16.2	2.7	18.9	12.9	2.9	15.8
0.039	17	14.7	2.2	16.9	11.7	2.5	14.2
0.044	20	16.6	2.8	19.4	13.1	3.1	16.2
0.044	18	16.6	2.8	19.4	13.1	3.1	16.2
T37*	F+ (N)	Fw1+ (N)	Fw2 (N)	Fw+lin (N	Fw1+_g (N	Fw2+_g (N	Fw+_g (N
0.012	6	4.5	0.2	4.7	3.6	0.8	4.4
0.016	7	6	0.4	6.4	4.8	1	5.8
0.026	12	9.8	1	10.8	7.8	1.7	9.5
0.027	12	10.2	1.1	11.3	8.1	1.7	9.8
0.044	19	16.6	2.8	19.4	13.1	3.1	16.2
0.044	18	16.6	2.8	19.4	13.1	3.1	16.2
0.04	16	15.1	2.4	17.5	12	2.6	14.6
0.037	16	13.9	2	15.9	11.1	2.4	13.5
0.039	16	14.7	2.2	16.9	11.7	2.5	14.2
0.041	17	15.5	2.5	18	12.3	2.6	14.9
0.037	16	13.9	2	15.9	11.1	2.4	13.5
0.038	18	14.3	2.1	16.4	11.4	2.5	13.9
0.041	18	15.5	2.5	18	12.3	2.6	14.9
0.041	18	15.5	2.5	18	12.3	2.6	14.9
0.037	17	13.9	2	15.9	11.1	2.4	13.5
0.044	21	16.6	2.8	19.4	13.1	3.1	16.2
0.044	19	16.6	2.8	19.4	13.1	3.1	16.2

T38	0.89						
H+ (m)	F+ (N)	Fw1+ (N)	Fw2 (N)	Fw+lin (N	Fw1+_g (N	Fw2+_g (N	Fw+_g (N
0.014	7	5.1	0.3	5.4	4	0.9	4.9
0.016	8	5.8	0.4	6.2	4.6	1	5.6
0.02	9	7.3	0.6	7.9	5.7	1.3	7
0.034	15	12.3	1.7	14	9.7	2.1	11.8
0.036	16	13.1	1.9	15	10.3	2.3	12.6
0.041	18	14.9	2.5	17.4	11.7	2.6	14.3
0.041	18	14.9	2.5	17.4	11.7	2.6	14.3
0.041	18	14.9	2.5	17.4	11.7	2.6	14.3
0.041	19	14.9	2.5	17.4	11.7	2.6	14.3
0.043	18	15.6	2.7	18.3	12.3	2.8	15.1
0.041	18	14.9	2.5	17.4	11.7	2.6	14.3
0.042	18	15.2	2.6	17.8	12	2.7	14.7
0.04	18	14.5	2.4	16.9	11.4	2.5	13.9
0.04	19	14.5	2.4	16.9	11.4	2.5	13.9
0.043	19	15.6	2.7	18.3	12.3	2.8	15.1
0.039	17	14.2	2.2	16.4	11.1	2.5	13.6
0.048	20	17.4	3.4	20.8	13.7	3.5	17.2
0.044	18	16	2.8	18.8	12.5	3	15.5
T38*	F+ (N)	Fw1+ (N)	Fw2 (N)	Fw+lin (N	Fw1+_g (N	Fw2+_g (N	Fw+_g (N
0.011	5	4	0.2	4.2	3.1	0.7	3.8
0.014	6	5.1	0.3	5.4	4	0.9	4.9
0.021	10	7.6	0.6	8.2	6	1.3	7.3
0.025	11	9.1	0.9	10	7.1	1.6	8.7
0.039	17	14.2	2.2	16.4	11.1	2.5	13.6
0.044	19	16	2.8	18.8	12.5	3	15.5
0.042	17	15.2	2.6	17.8	12	2.7	14.7
0.041	18	14.9	2.5	17.4	11.7	2.6	14.3
0.038	17	13.8	2.1	15.9	10.8	2.4	13.2
0.041	18	14.9	2.5	17.4	11.7	2.6	14.3
0.042	19	15.2	2.6	17.8	12	2.7	14.7
0.042	17	15.2	2.6	17.8	12	2.7	14.7
0.039	18	14.2	2.2	16.4	11.1	2.5	13.6
0.043	19	15.6	2.7	18.3	12.3	2.8	15.1
0.044	17	16	2.8	18.8	12.5	3	15.5
0.041	17	14.9	2.5	17.4	11.7	2.6	14.3
0.049	20	17.8	3.5	21.3	14	3.6	17.6
0.053	19	19.2	4.1	23.3	15.1	4.1	19.2

T41	1.51						
H+ (m)	F+ (N)	Fw1+ (N)	Fw2 (N)	Fw+lin (N	Fw1+_g (N	Fw2+_g (N	Fw+_g (N
0.019	10	8.6	0.5	9.1	8.1	1.6	9.7
0.039	19	17.7	2.2	19.9	16.6	3.2	19.8
0.056	27	25.4	4.6	30	23.9	5.8	29.7
0.053	26	24.1	4.1	28.2	22.6	5.3	27.9
0.055	27	25	4.5	29.5	23.4	5.7	29.1
0.049	26	22.2	3.5	25.7	20.9	4.7	25.6
0.049	24	22.2	3.5	25.7	20.9	4.7	25.6
0.047	24	21.3	3.3	24.6	20	4.4	24.4
0.049	24	22.2	3.5	25.7	20.9	4.7	25.6

T42	1.41						
H+ (m)	F+ (N)	Fw1+ (N)	Fw2 (N)	Fw+lin (N	Fw1+_g (N	Fw2+_g (N	Fw+_g (N
0.021	10	9.4	0.6	10	8.7	1.7	10.4
0.039	18	17.4	2.2	19.6	16.1	3.1	19.2
0.055	26	24.5	4.5	29	22.7	5.5	28.2
0.05	25	22.3	3.7	26	20.6	4.7	25.3
0.054	27	24.1	4.3	28.4	22.3	5.4	27.7
0.06	29	26.8	5.3	32.1	24.7	6.3	31
0.061	30	27.2	5.5	32.7	25.1	6.5	31.6
0.06	30	26.8	5.3	32.1	24.7	6.3	31
0.065	30	29	6.2	35.2	26.8	7.1	33.9
0.065	33	29	6.2	35.2	26.8	7.1	33.9
T42B	F+ (N)	Fw1+ (N)	Fw2 (N)	Fw+lin (N	Fw1+_g (N	Fw2+_g (N	Fw+_g (N
0.025	13	11.2	0.9	12.1	10.3	2	12.3
0.041	20	18.3	2.5	20.8	16.9	3.3	20.2
0.055	28	24.5	4.5	29	22.7	5.5	28.2
0.054	27	24.1	4.3	28.4	22.3	5.4	27.7
0.057	29	25.4	4.8	30.2	23.5	5.9	29.4
0.061	30	27.2	5.5	32.7	25.1	6.5	31.6
0.06	31	26.8	5.3	32.1	24.7	6.3	31
0.061	31	27.2	5.5	32.7	25.1	6.5	31.6
0.065	31	29	6.2	35.2	26.8	7.1	33.9
0.068	34	30.3	6.7	37	28	7.6	35.6

T43	1.31						
H+ (m)	F+ (N)	Fw1+ (N)	Fw2 (N)	Fw+lin (N	Fw1+_g (N	Fw2+_g (N	Fw+_g (N
0.02	10	8.7	0.6	9.3	7.9	1.5	9.4
0.034	16	14.9	1.7	16.6	13.4	2.6	16
0.057	27	24.9	4.8	29.7	22.5	5.7	28.2
0.046	22	20.1	3.1	23.2	18.1	4	22.1
0.048	23	21	3.4	24.4	18.9	4.3	23.2
0.048	22	21	3.4	24.4	18.9	4.3	23.2
0.042	20	18.4	2.6	21	16.5	3.3	19.8
0.044	20	19.2	2.8	22	17.3	3.7	21
0.043	20	18.8	2.7	21.5	16.9	3.5	20.4
0.046	21	20.1	3.1	23.2	18.1	4	22.1
0.046	21	20.1	3.1	23.2	18.1	4	22.1

T44	1.16						
H+ (m)	F+ (N)	Fw1+ (N)	Fw2 (N)	Fw+lin (N	Fw1+_g (N	Fw2+_g (N	Fw+_g (N
0.02	10	8.4	0.6	9	7.2	1.5	8.7
0.034	15	14.2	1.7	15.9	12.3	2.5	14.8
0.048	22	20.1	3.4	23.5	17.3	4	21.3
0.05	23	21	3.7	24.7	18	4.3	22.3
0.042	19	17.6	2.6	20.2	15.2	3.2	18.4
0.047	21	19.7	3.3	23	17	3.9	20.9
0.046	21	19.3	3.1	22.4	16.6	3.7	20.3
0.049	22	20.5	3.5	24	17.7	4.2	21.9
0.051	22	21.4	3.8	25.2	18.4	4.5	22.9
0.05	22	21	3.7	24.7	18	4.3	22.3
0.05	22	21	3.7	24.7	18	4.3	22.3
0.051	23	21.4	3.8	25.2	18.4	4.5	22.9
0.044	21	18.4	2.8	21.2	15.9	3.4	19.3
0.058	24	24.3	5	29.3	20.9	5.5	26.4

T45	1.1						
H+ (m)	F+ (N)	Fw1+ (N)	Fw2 (N)	Fw+lin (N	Fw1+_g (N	Fw2+_g (N	Fw+_g (N
0.019	10	7.8	0.5	8.3	6.6	1.3	7.9
0.029	14	11.9	1.2	13.1	10	2.1	12.1
0.046	21	18.8	3.1	21.9	15.9	3.6	19.5
0.055	24	22.5	4.5	27	19	4.9	23.9
0.056	24	22.9	4.6	27.5	19.4	5.1	24.5
0.052	23	21.3	4	25.3	18	4.5	22.5
0.054	24	22.1	4.3	26.4	18.7	4.8	23.5
0.053	24	21.7	4.1	25.8	18.3	4.6	22.9
0.053	23	21.7	4.1	25.8	18.3	4.6	22.9
0.055	23	22.5	4.5	27	19	4.9	23.9
0.054	23	22.1	4.3	26.4	18.7	4.8	23.5
0.054	24	22.1	4.3	26.4	18.7	4.8	23.5
0.051	25	20.9	3.8	24.7	17.6	4.3	21.9
0.052	24	21.3	4	25.3	18	4.5	22.5
0.059	26	24.1	5.1	29.2	20.4	5.5	25.9

T46	1.04						
H+ (m)	F+ (N)	Fw1+ (N)	Fw2 (N)	Fw+lin (N	Fw1+_g (N	Fw2+_g (N	Fw+_g (N
0.019	10	7.6	0.5	8.1	6.3	1.3	7.6
0.027	13	10.8	1.1	11.9	8.9	1.9	10.8
0.042	20	16.8	2.6	19.4	13.9	3	16.9
0.051	23	20.3	3.8	24.1	16.9	4.2	21.1
0.059	25	23.5	5.1	28.6	19.5	5.3	24.8
0.056	24	22.3	4.6	26.9	18.6	4.9	23.5
0.055	23	21.9	4.5	26.4	18.2	4.8	23
0.057	23	22.7	4.8	27.5	18.9	5.1	24
0.054	23	21.5	4.3	25.8	17.9	4.7	22.6
0.056	23	22.3	4.6	26.9	18.6	4.9	23.5
0.059	23	23.5	5.1	28.6	19.5	5.3	24.8
0.061	23	24.3	5.5	29.8	20.2	5.6	25.8
0.063	24	25.1	5.8	30.9	20.9	5.9	26.8
0.064	24	25.5	6	31.5	21.2	6	27.2
0.059	23	23.5	5.1	28.6	19.5	5.3	24.8
0.059	26	23.5	5.1	28.6	19.5	5.3	24.8

T47	0.94						
H+ (m)	F+ (N)	Fw1+ (N)	Fw2 (N)	Fw+lin (N	Fw1+_g (N	Fw2+_g (N	Fw+_g (N
0.019	10	7.2	0.5	7.7	5.7	1.2	6.9
0.022	11	8.3	0.7	9	6.6	1.4	8
0.036	17	13.6	1.9	15.5	10.8	2.3	13.1
0.039	17	14.7	2.2	16.9	11.7	2.5	14.2
0.054	25	20.4	4.3	24.7	16.1	4.4	20.5
0.054	23	20.4	4.3	24.7	16.1	4.4	20.5
0.05	19	18.9	3.7	22.6	14.9	3.8	18.7
0.046	23	17.3	3.1	20.4	13.7	3.3	17
0.052	21	19.6	4	23.6	15.5	4.1	19.6
0.051	22	19.2	3.8	23	15.2	4	19.2
0.053	21	20	4.1	24.1	15.8	4.2	20
0.049	22	18.5	3.5	22	14.6	3.7	18.3
0.053	23	20	4.1	24.1	15.8	4.2	20
0.056	21	21.1	4.6	25.7	16.7	4.6	21.3
0.051	21	19.2	3.8	23	15.2	4	19.2
0.063	25	23.8	5.8	29.6	18.8	5.5	24.3
0.068	23	25.6	6.7	32.3	20.3	6.2	26.5

T48	0.9						
H+ (m)	F+ (N)	Fw1+ (N)	Fw2 (N)	Fw+lin (N	Fw1+_g (N	Fw2+_g (N	Fw+_g (N
0.015	8	5.5	0.3	5.8	4.4	1	5.4
0.021	10	7.7	0.6	8.3	6.1	1.3	7.4
0.029	13	10.6	1.2	11.8	8.4	1.8	10.2
0.039	17	14.3	2.2	16.5	11.4	2.5	13.9
0.05	21	18.3	3.7	22	14.6	3.8	18.4
0.049	24	17.9	3.5	21.4	14.3	3.7	18
0.054	20	19.8	4.3	24.1	15.7	4.3	20
0.047	22	17.2	3.3	20.5	13.7	3.4	17.1
0.048	22	17.6	3.4	21	14	3.5	17.5
0.056	20	20.5	4.6	25.1	16.3	4.5	20.8
0.056	20	20.5	4.6	25.1	16.3	4.5	20.8
0.049	19	17.9	3.5	21.4	14.3	3.7	18
0.049	21	17.9	3.5	21.4	14.3	3.7	18
0.059	20	21.6	5.1	26.7	17.2	4.9	22.1
0.059	20	21.6	5.1	26.7	17.2	4.9	22.1
0.039	21	14.3	2.2	16.5	11.4	2.5	13.9
0.054	25	19.8	4.3	24.1	15.7	4.3	20
0.063	21	23.1	5.8	28.9	18.3	5.4	23.7

APPENDIX I. RESULTS EXPERIMENT 1:

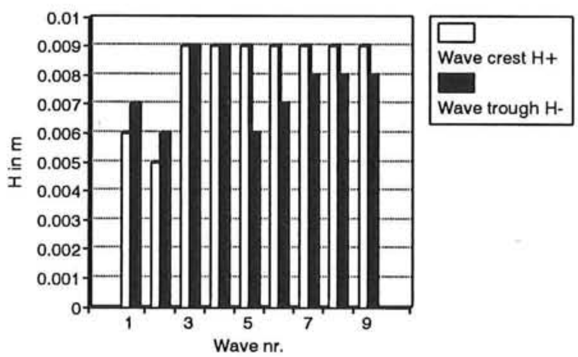
RATIO WAVE HEIGHT OF WAVE CREST AND WAVE TROUGH

T11	1.59			T11	1.59		
H+ (m)	F+ (N)	Fw+lin (N)	Fw+_g (N)	H- (m)	F- (N)	Fmin_lin (N)	Fmin_g (N)
0.006	3	2.9	3.1	0.007	3	3.3	3.4
0.005	3	2.3	2.6	0.006	3	2.8	2.9
0.009	5	4.2	4.6	0.009	4	4.1	4.4
0.009	5	4.2	4.6	0.009	3	4.1	4.4
0.009	5	4.2	4.6	0.006	3	2.8	2.9
0.009	4	4.2	4.6	0.007	3	3.3	3.4
0.009	5	4.2	4.6	0.008	4	3.7	3.9
0.009	5	4.2	4.6	0.008	4	3.7	3.9
0.009	5	4.2	4.6	0.008	4	3.7	3.9

T18	0.95			T18	0.95			
H+ (m)	F+ (N)	Fw+lin (N)	Fw+_g (N)	H- (m)	F- (N)	Fmin_lin (N)	Fmin_g (N)	
0.003	2	1.1	1.1	0.003	1	1.1	1.3	1
0.004	2	1.5	1.5	0.006	3	2.3	2.6	2
0.006	3	2.4	2.2	0.007	3	2.7	3	3
0.01	4	3.9	3.7	0.012	6	4.5	5	4
0.013	6	5.1	4.9	0.014	6	5.2	5.7	5
0.014	6	5.6	5.2	0.011	5	4.1	4.5	6
0.011	5	4.4	4.1	0.011	5	4.1	4.5	7
0.013	6	5.1	4.9	0.012	6	4.5	5	8
0.012	6	4.7	4.5	0.011	5	4.1	4.5	9
0.011	5	4.4	4.1	0.011	5	4.1	4.5	10
0.011	6	4.4	4.1	0.011	5	4.1	4.5	11
0.011	6	4.4	4.1	0.011	5	4.1	4.5	12
0.011	5	4.4	4.1	0.011	5	4.1	4.5	13
0.012	6	4.7	4.5	0.011	5	4.1	4.5	14
0.012	6	4.7	4.5	0.013	6	4.9	5.4	15
0.011	6	4.4	4.1	0.012	6	4.5	5	16
0.011	5	4.4	4.1	0.012	5	4.5	5	17

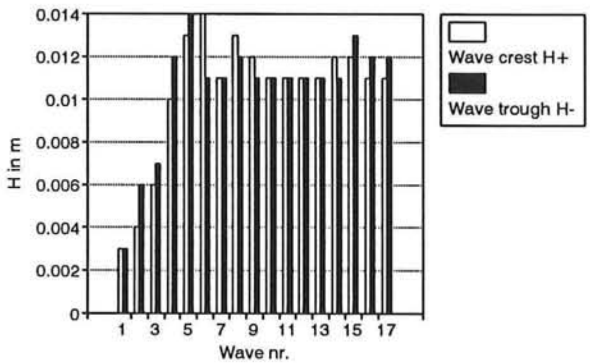
Wave crest H+ versus wave trough H-

Measurement M11: T11=1.59 s



Wave crest H+ versus wave trough H-

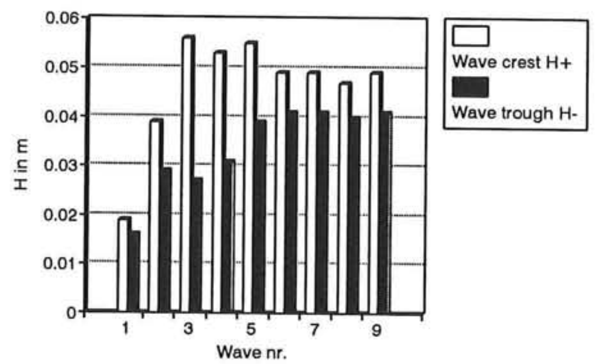
Measurement M18: T18=0.95 s



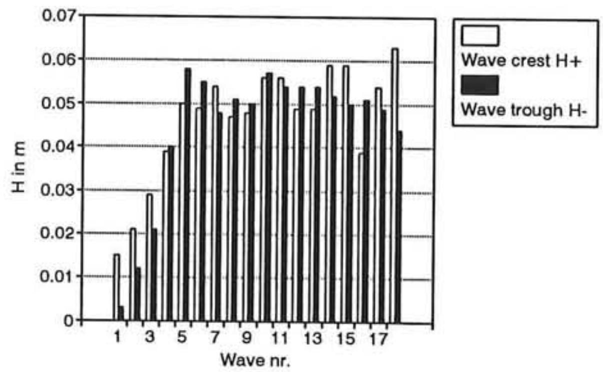
T41	1.51			T41	1.51		
H+ (m)	F+ (N)	Fw+lin (N)	Fw+_g (N)	H- (m)	F- (N)	Fmin_lin (N)	Fmin_g (N)
0.019	10	9.1	9.7	0.016	8	7.1	7.1
0.039	19	19.9	19.8	0.029	13	12.4	11.8
0.056	27	30	29.7	0.027	13	11.5	11
0.053	26	28.2	27.9	0.031	15	13.1	12.6
0.055	27	29.5	29.1	0.039	18	16.1	14.8
0.049	26	25.7	25.6	0.041	19	16.7	15.5
0.049	24	25.7	25.6	0.041	19	16.7	15.5
0.047	24	24.6	24.4	0.04	19	16.4	15.1
0.049	24	25.7	25.6	0.041	19	16.7	15.5

T48	0.9			T48	0.9			
H+ (m)	F+ (N)	Fw+lin (N)	Fw+_g (N)	H- (m)	F- (N)	Fmin_lin (N)	Fmin_g (N)	
0.015	8	5.8	5.4	0.003	1	1.1	1.2	1
0.021	10	8.3	7.4	0.012	5	4.3	4.6	2
0.029	13	11.8	10.2	0.021	9	7.3	7.9	3
0.039	17	16.5	13.9	0.04	16	13.1	14.4	4
0.05	21	22	18.4	0.058	23	18	19.6	5
0.049	24	21.4	18	0.055	25	17.3	18.9	6
0.054	20	24.1	20	0.048	21	15.4	16.8	7
0.047	22	20.5	17.1	0.051	22	16.1	17.8	8
0.048	22	21	17.5	0.05	22	15.9	17.5	9
0.056	20	25.1	20.8	0.057	24	17.8	19.2	10
0.056	20	25.1	20.8	0.054	23	17	18.5	11
0.049	19	21.4	18	0.054	22	17	18.5	12
0.049	21	21.4	18	0.054	23	17	18.5	13
0.059	20	26.7	22.1	0.052	22	16.5	17.9	14
0.059	20	26.7	22.1	0.05	22	15.9	17.5	15
0.039	21	16.5	13.9	0.051	22	16.1	17.8	16
0.054	25	24.1	20	0.049	24	15.6	17.1	17
0.063	21	28.9	23.7	0.044	21	14.2	15.6	18

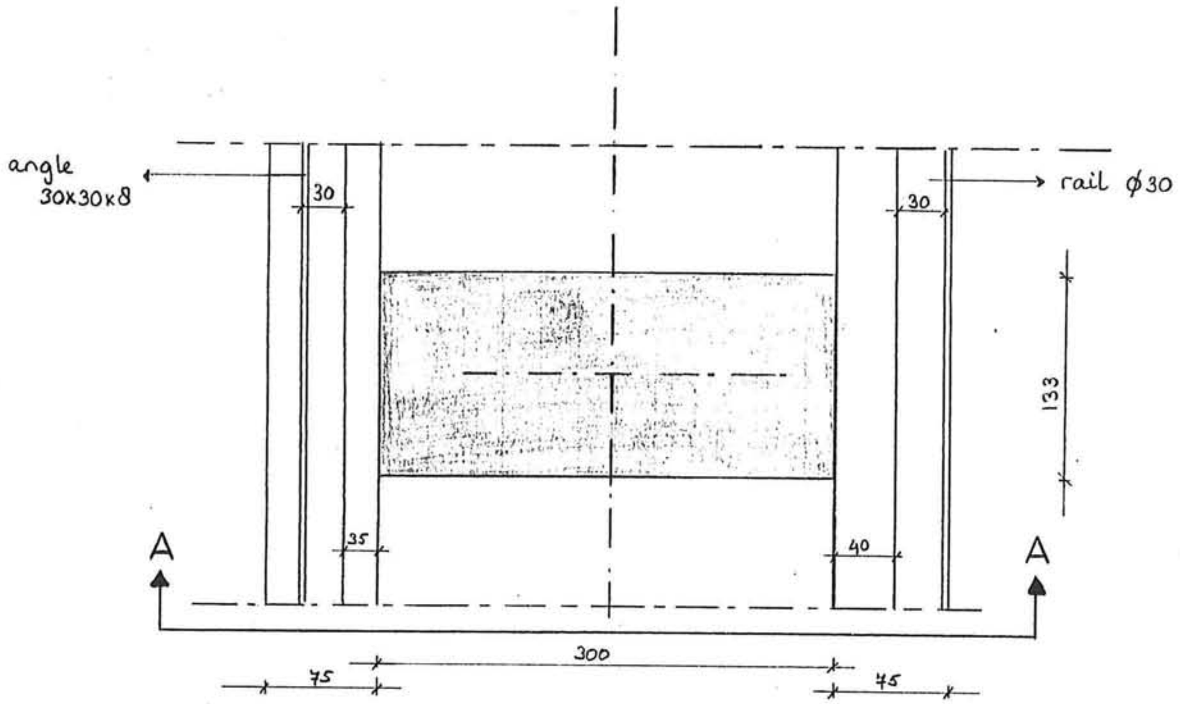
Wave crest H+ versus wave trough H-
Measurement M41: T41=1.51 s



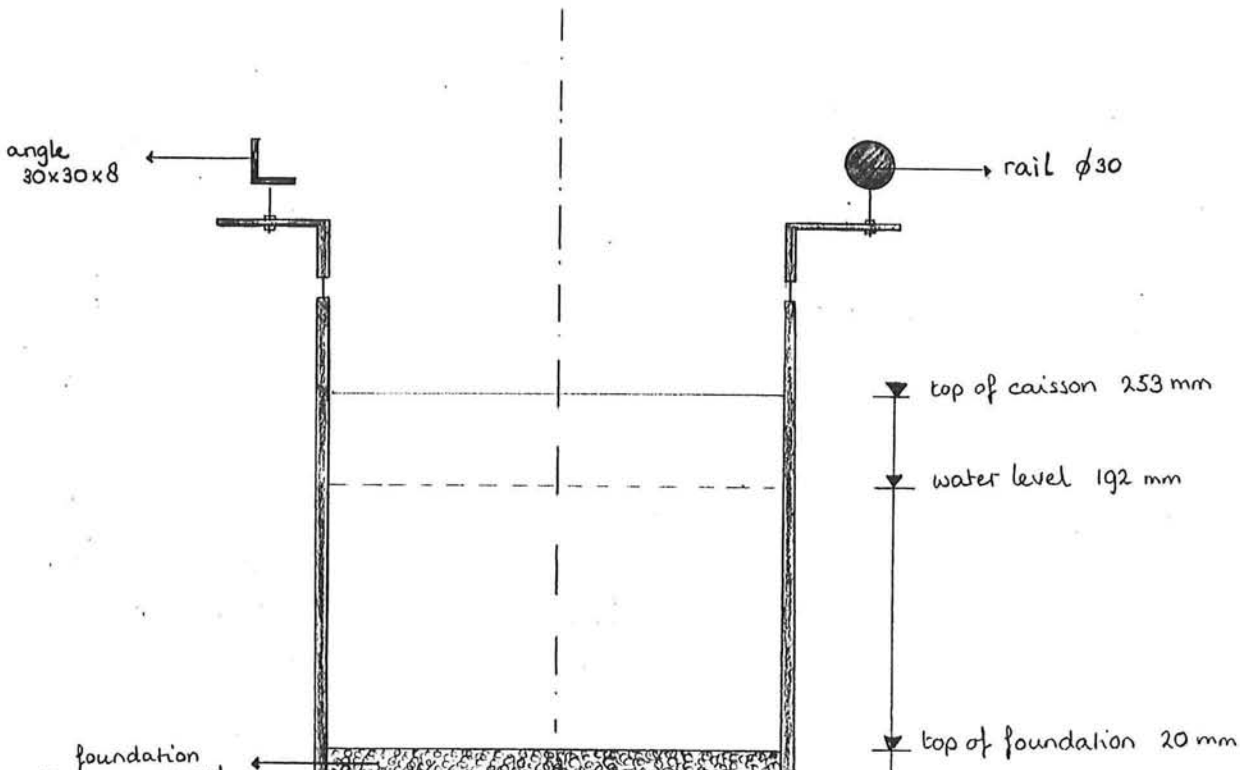
Wave crest H+ versus wave trough H-
Measurement M48: T48=0.9 s



APPENDIX J. DRAWINGS EXPERIMENTAL SET UP



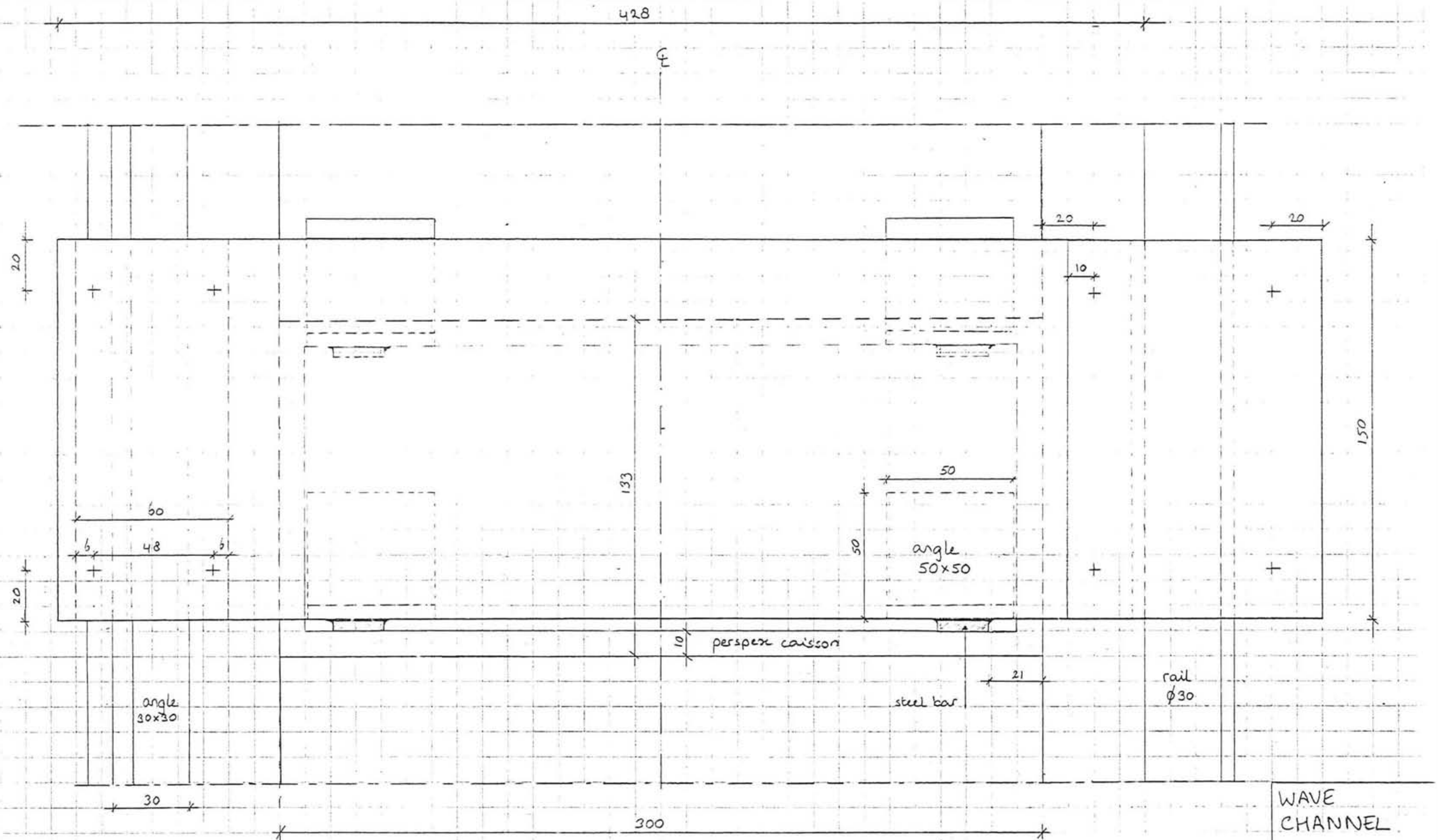
PLAN VIEW



CROSS SECTION A-A

WAVE CHANNEL

SCALE 1:5



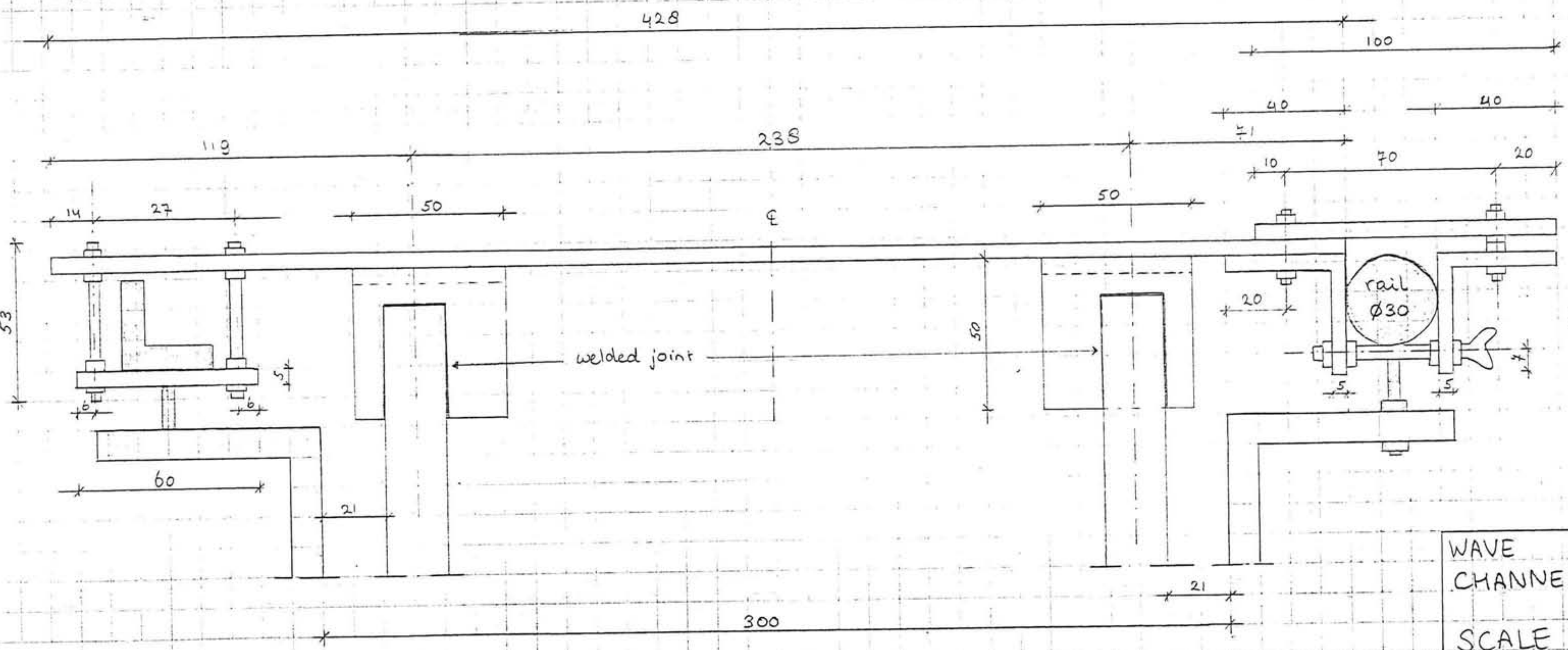
PLAN VIEW

WAVE CHANNEL

SCALE 1:2

10/5/95

□ = is starting stituation



CROSS SECTION

WAVE
CHANNEL
SCALE 1:2
10/5/95