Parametric Design: Installation Methods and CO_2 Emission

by

D.D.C. van der Heijden

Internship duration:	September 1st 2021 - November 15st 2021
Supervisors:	Arthur Zoon
	Piet Zaalberg

TU Delft
Delft University of Technology

Preface

This report is an account of my internship at Van Oord B.V. in Rotterdam. I would like to thank Van Oord B.V. for giving me the opportunity to do so, with a special word of thanks to my supervisors, Arthur Zoon and Piet Zaalberg. Their help and commitment positively influenced the outcome of the internship. In addition to their professional guidance, they helped me find my way around Van Oord over the past two months, which resulted in a pleasant working environment.

Dante van der Heijden,
Rotterdam,
November 25, 2021

Abstract

This report investigates the added value of implementing installation methods and CO_2 emissions on the parametric design tool for coastal structures developed by Winkel (2020). The Python package created by Winkel can generate cross sections of rubble mound breakwaters, monolithic breakwaters and revetments based on hydraulic conditions and damage levels. Winkel's tool enables users to choose an optimal design based on the cost of material procurement of a cross section. In addition to the procurement of material, costs also arise by material transport and installation. Transport costs depending on the method of installation. These additional costs are not taken into account by Winkel. The tool also does not take into account the CO_2 emitted during material handling and extraction, transport of material and construction. As the handling and extraction of primary aggregates is responsible for 7% of total global energy consumption (Mankelow et al., 2010) and concrete production accounts for 8% of global CO_2 emissions (Ellis et al., 2020), CO_2 is an important variable to consider during the design of coastal structures.

To include installation methods, The most common construction methods for coastal structures have been schematized and their installation conditions have been determined. The construction methods are schematized into two groups, land based equipment and marine based equipment. The main installation condition for land based equipment is that the equipment must be at a dry level. Marine based equipment must have a sufficient water depth for safe navigability. Based on the installation conditions for each equipment, it is assessed which part of the structure it can install. To do so, each layer of the structure is cut into smaller parts with a maximum height of 1 metre, so called sections. For each section it is evaluated if it can be installed by the specified equipment, and if so, properties such as installation rate and CO_2 emission per unit of time are calculated. During the installation of the structure, the construction methods also emit CO_2, for example through the consumption of fuel. In the next step, different combinations of construction methods must be found, which together can install the entire structure. Different subsets are be generated by giving each equipment the possibility to install all the sections to which it is capable of. Then this subset is extended based on the "smart combinations" algorithm. This algorithm favours installation with land-based equipment and equipment that can install the most new sections compared to those already installed. After determining several combinations, the most optimal subset can be chosen based on cost, speed or CO_2 emissions. Thus, in addition to procurement of material, it is now possible to choose a design that is most beneficial in terms of installation cost, installation speed and CO_2 emissions.

A test case was used to test the new tools. All optimised designs of this test case resulted in a structure with a crest width of 5 m, a freeboard of 10.4 m and a slope of 2:3. The design with the lowest procurement cost and lowest CO_2 emission of the material resulted in a cross-section with an armour layer of 41 tons of Cubipods, an underlayer of 1-3 tons rock material and a toe of 3-6 tons rock. The procurement cost was estimated at 38.505,96 EUR /m and the CO_2 emission at 0.0447 kge/m. The design optimized on not only the procurement but also on the transport and installation costs had an additional 8-12 tonnes rock underlayer with a total construction cost of 248.264,60 EUR/m and an installation time of 0.1941 wk/m. The design with the minimum installation time consists of a 41t Cubipod armour layer, an 8-12t underlayer and a 1-3t rock toe. The installation time for this design is only 0.1277 wk/m but the total cost increases to 979.874,77 EUR/m. Moreover, in comparison to the optimisation on the total cost, other equipment was used. The core was constructed by a barge with a plate feeder entirely and no longer in combination with a dump truck. Also the Liebherr 300t crane was no longer used to place the armour from the land.

Comparing the old and the new tool, the results on the test case show that when optimizing on cost, due to transport and installation of the structure, the costs increased by a factor 5. Moreover, the design with the lowest cost now consists of an additional underlayer compared to the design of the old tool. Optimisation on installation time changed the design and also resulted in the use of other equipment. Although installation time decreased, this resulted in a cost increase of a factor 3. To conclude, the current tool makes it possible to estimate the required equipment, give a better understanding of the cost breakdown of the structure and therefore allows the designer to make a conscious trade-off between total costs, CO_2 emissions and installation time.

Equipment costs and production rates were estimated based on data from cost estimators of similar construction methods. The cost, time and installation methods determined by the algorithm are only as good as

the it is provided with. This leaves open possibilities to validate the new tool with exact inputs.

CONTENTS

1 INTRODUCTION

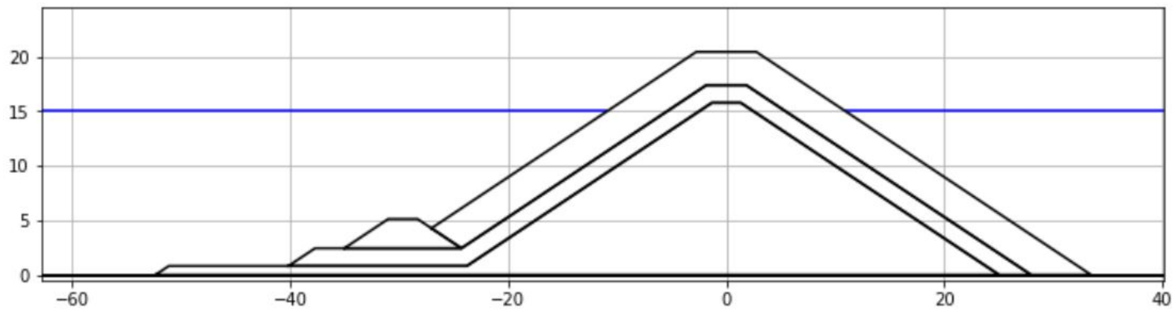
As Benjamin Franklin stated in 1748: "Time is money". Following this statement, efficiency is becoming increasingly important in the 21st century. One of the first people to come up with an efficient way of designing in the discipline of construction was Antonio Gaudi. When designing the Church of Colonia Guell, he made a model of strings into which weights or lengths could be changed. This affected the arches that were connected to them. In modern times, we call this parametric design. Parametric design is a way of designing in which the parameters are made variable.
Parametric design is also gaining interest in the field of hydraulic engineering. Winkel (2020) built a Python package called breakwater, which introduces parametric design of rubble mound and monolithic breakwaters. Using the Van der Meer equations (J. W. van der Meer, 1988), overtopping equations (J. van der Meer et al., 2018) and other stability formulas, a cross section for a breakwater is designed. Together with a cost for the material of different design variants, a first indication can be given on the most interesting design options that can be taken to the next design phase.
In addition to the procurement of materials, costs also arise from construction, transport of material and mobilisation of construction methods. Therefore, the optimization of the design will be improved by adding to the tool the constructability of the coastal structure. Transport costs also vary between installation methods. Where a side stone dumper can transport the materials itself on the ship, transport for installation with an excavator will be done separately by, for example, trucks. The estimation of transportation costs, which differ across the installation methods, is not incorporated into the tool but will have to be determined separately. The implementation of constructability will also allow to optimize the design on the duration of the installation through the production rates of the installation methods. This production rate or workability is dependent on the used method but is also site specific. Site specific conditions may be due to local weather and wave conditions. The improved tool will not be able to estimate the workability of construction methods itself. Workability will have to be determined through another tool that Van Oord has available for this purpose and then manually entered into the tool.
In addition to costs in terms of monetary values, CO_2 emissions are also important when choosing an optimal design. In a world shifting toward sustainability, governments and other project stakeholders demand designs with low CO_2 emissions. Even to such an extent that in some tenders a discount on the estimated tender price is given in case of low CO_2 emissions. A test case will be used to investigate the added value of the implementation of installation methods and CO_2 emissions on the parametric design tool and how this will result in different optimized cross-sections.
In this report, first of all, in Section 2, some background information will be given on the most commonly used construction methods and the main contributors to CO_2 emissions in construction. Some standard construction methods will be evaluated to indicate what part of a structure they can install and under what conditions. Section 3 will explain how the new features are implemented in the breakwater package. The conditions of installation for the various methods will be translated to code. Furthermore, UML diagrams will explain how the algorithms work that are used to determine the constructability of a structure and the final optimization of the design. Section 4 presents the preliminary design result of the test case for optimization on costs, CO_2 emission and installation time. Sections 5 and 6 contain the conclusion and discussion, respectively. Finally, Section 7 provides some recommendations for future implementations.

2

Literature

2.1. Breakwater Package

With the tool developed by Winkel (2020), cross sections can be generated for rubble mound and monolithic breakwaters. Within Van Oord, the possibility for a revetment design has been added. The dimensions of the cross section are calculated using the known equations such as the Van der Meer equations for armour stability (J. W. van der Meer, 1988) and the EurOtop equation for overtopping (J. van der Meer et al., 2018). Input parameters are the wave conditions, damage levels, the slope and the crest width. Together with a specified rock grading a cross-section is generated. By adding the procurement cost of the material, the cost of material for an entire cross-section can be calculated. Besides rock armour, it is also possible to create a design with concrete armour units.



(a) A breakwater cross-section and it's layers

Layer	computed Dn50	class	class Dn50	state	layers
armour	1.671	HMA_10000/15000	1.677	ULS	2
underlayer	0.680	HMA_1000/3000	0.895	see armour	2
toe	0.702	HMA_1000/3000	0.895	ULS	

Rc = 5.457 m, designed with ULS limit state

Figure 2.1: Example of a design from the breakwater python package

In addition to generating a single design, the package also allows for the generating designs within a specified design space. Multiple values can be specified for the slope, crest width and nominal diameter of the core. This design space is an evenly distributed range between a minimum value and a maximum value (min, max, step). For example:

1. slope = ((1,3), (2,3), 5)
2. crest width = (5, 25, 5)

3. Dn50 core = 0.5

All these designs are again validated with respect to the design equations. Using the design explorer (Tomasetti, n.d.) it is possible to examine all the generated outcomes and choose the most optimal one. This can be done, for example, on the total cost of material.

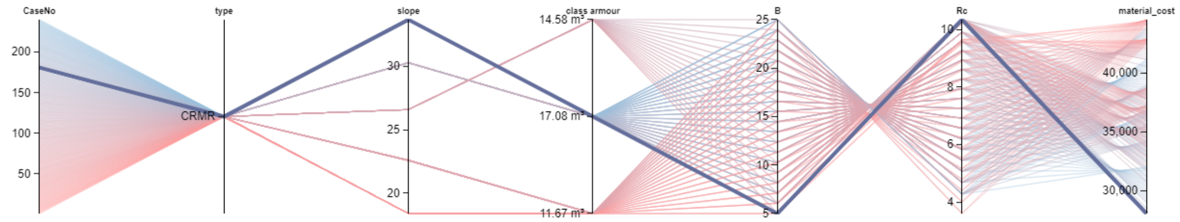


Figure 2.2: Design explorer with over 200 generated outcomes. The design with the lowest material cost is highlighted.

Figure 2.2 clearly shows that a design with a 2:3 slope, a narrow berm width and a high freeboard is favourable, as this results in the lowest material costs.

2.2. CONSTRUCTION METHODS

This section will discuss the construction methods that can used to construct breakwaters and other coastal structures. Both land based and marine based equipment will be discussed, while a distinction is also made between bulk and individual placement of material. Bulk placing means that the material is placed in place in large quantities at once. We speak of individual placement when the material needs to be put in place more precisely.

2.2.1. LAND BASED EQUIPMENT

BULK PLACEMENT

1. Dump trucks: this type of equipment is used to transport the armour stone from temporary stockpiles to final placement position. A dump truck can also install some bulk layers when combined with an excavator where the excavator forms the layer.

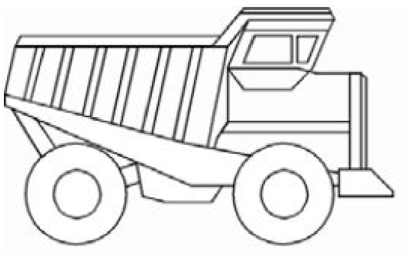


Figure 2.3: Sketch of a dump truck (Schiereck and Verhagen, 2019)

2. Wheel loaders: can place stone up to gradings of 300 kg and is thus mostly used for the installation of the core or in some cases the secondary layer.

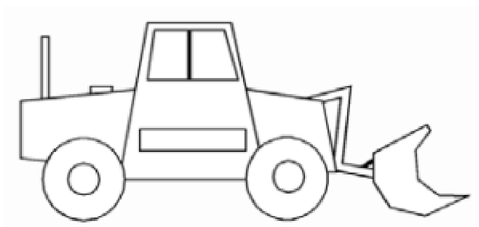


Figure 2.4: Sketch of a wheel loader (Schiereck and Verhagen, 2019)

3. Excavators: can place material either in bulk or individually. When used in bulk, excavators are often used in conjunction with a dump truck or wheel loader to bring the layer into the desired shape.

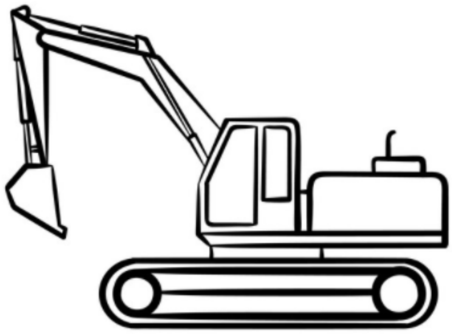


Figure 2.5: Sketch of a excavator (Schiereck and Verhagen, 2019)

INDIVIDUAL PLACEMENT

1. Excavators: are usually used for cyclic placement of smaller armoured units. Using a load graph, the maximum placing mass can be estimated that the excavator can lift at a certain distance. An example of a load chart can be found in Figure 2.6.

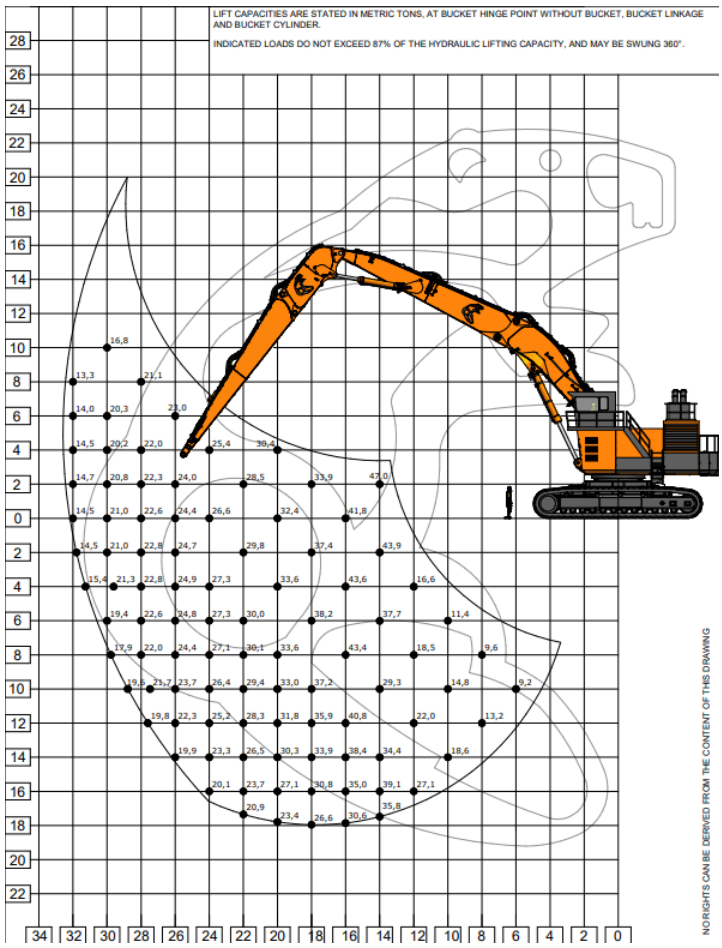


Figure 2.6: Load chart for a HITACHI EX1900. At a distance of x = 16 m and y = -14 m the maximum mass is can place is 38.4t. ("Hitachi EX1900-6 Brochure", n.d.)

2. Wire-rope cranes: for the more heavier material or when placing at a large distance is required, wire rope cranes are used. The mass a crane can lift depends on the mass of the equipment and the vertical and the horizontal distance of placement from the equipment. Also for wire-rope cranes this maximum lifting mass can be estimated from a load chart, see Figure 4.4.

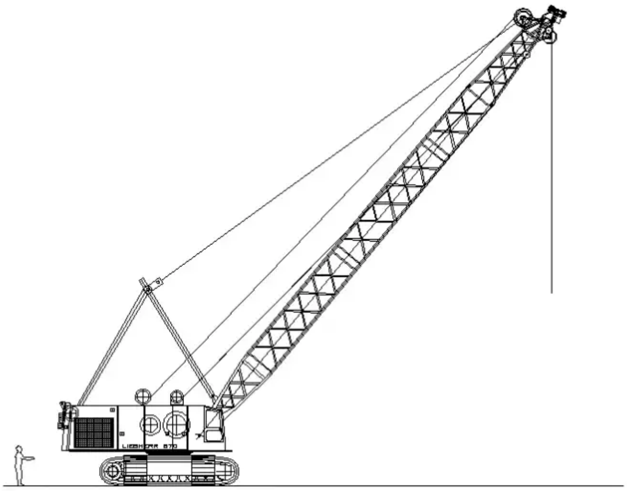


Figure 2.7: Sketch of a wire-rope crane (Luna, n.d.)

11,5 – 60 m T | 360° | 28,2 t | EN

	11,5 m		15,2 m	18,9 m	22,6 m	26,3 m	30,1 m	33,8 m	37,5 m	41,2 m	45 m	47,5 m	48,7 m	51,9 m	52,4 m	55,6 m	56,1 m	60 m	
	*																		
3	100	61,4	61,3	61,3	61,1														3
3,5	72,8	59,6	59,5	59,4	59,4	59,1													3,5
4	67,1	56,8	57	56,8	56,8	56,4	49												4
4,5	61,8	52,5	52,8	52,9	52,8	52,8	48,6												4,5
5	57,1	48,5	48,9	49	49,1	48,9	47,9	39,9											5
6	48,5	42,1	42,7	43	42,9	42,7	42,3	40,1	32,8										6
7	41,9	37	37,6	38,3	38,4	38,3	38	37,2	32,6	26,8	21,8								7
8	36,7	32,7	33,6	34,1	34,3	34,2	33,8	33,4	31,9	26,5	22,1								8
9	31,6	29,1	30,1	30,6	30,7	30,6	30,3	29,9	29	26	21,9	15,6	18,2						9
10			26,8	27,4	27,5	27,4	27	27	26,1	25	21,7	15,2	18	13,4	15,1	12	12,4		10
11			23,9	24,5	24,6	24,5	24,2	24,2	24	23,2	21,1	14,7	17,9	13,1	15	11,9	12,3	10,2	11
12			21,5	22,1	22,2	22,1	22,2	22,2	21,9	21,1	20	14,3	17,5	12,9	14,9	11,7	12,2	10,2	12
14				18,3	18,5	18,3	18,7	18,4	18,1	17,7	17,1	13,3	16,1	12,2	14,4	11,4	12	10	14
16				15,3	15,5	15,9	15,8	15,5	15,5	15,1	14,7	12,4	14,1	11,5	13,2	10,9	11,6	9,9	16
18					13,1	13,6	13,4	13,4	13,3	13,2	12,7	11,5	12,1	10,8	11,7	10,4	11	9,5	18
20					11,6	11,6	11,4	11,6	11,3	11,4	11,3	10,6	10,7	10	10,2	9,7	9,4	8,9	20
22						10	10,2	10,1	10	9,9	9,7	9,6	9,3	9,2	8,8	8,6	8,1	7,8	22
24						8,6	8,9	8,7	8,8	8,5	8,4	8,4	8,1	8	7,6	7,5	7	6,7	24
26							7,9	7,8	7,7	7,5	7,3	7,4	7	7	6,7	6,5	6	5,8	26
28								6,8	6,8	6,6	6,4	6,4	6,1	6,2	5,8	5,7	5,2	5	28
30								6,1	6	5,8	5,6	5,7	5,3	5,3	5	5	4,5	4,3	30
32									5,3	5,1	4,9	5	4,6	4,6	4,3	4,4	3,9	3,7	32
34									4,8	4,5	4,3	4,4	4	4	3,7	3,8	3,3	3,2	34
36										4	3,8	3,8	3,4	3,5	3,2	3,2	2,8	2,7	36
38										3,5	3,3	3,4	3	3	2,7	2,8	2,3	2,3	38
40											2,9	2,9	2,5	2,6	2,3	2,3	1,9	1,9	40
42											2,5	2,6	2,2	2,2	1,9	2	1,5	1,5	42
44												2,2	1,9	1,9	1,6	1,6	1,2	1,2	44
46													1,6	1,6	1,3	1,3	0,9	0,9	46
48														1,3	1	1			48
50															0,8	0,8			50

* nach hinten - over rear - en arrière - sul posteriore - hacia atrás - стрела повернута назад

t_187_01425_00_000 / 187_00013_00_000

Figure 2.8: Load chart of a 100t Liebherr crane. The columns are the length of the boom (l_{boom}) and the row indexes the reach (R). The values are the maximum lifting mass (in tons) for a given boom length at a specific reach. ("LTM 1100-4.2 Brochure", n.d.)

The crane can install only up to a maximum height of:

$$h_{max} = \sqrt{l_{boom}^2 - R^2} \tag{2.1}$$

A wire crane can install up to a depth constrained by the length of the wire.

WORKING CONDITIONS

The main limitation for land-based equipment is that it must be able to stand at a dry level. Wave run-up must be thus acceptable at this dry level. Therefore, a margin must be maintained between the water level and the level of the construction method. This margin obviously varies from one project site to another, as it depends on the wave climate and tidal variations. Also, when building downwards, the equipment is not placed at the beginning of the slope, but at a safe distance from it.

2.2.2. MARINE BASED EQUIPMENT

BULK PLACEMENT

1. Split barge: this type of waterborne equipment dumps the material by opening the bottom and releasing the rocks. A split barge is used when large quantities have to be dumped with less accuracy.

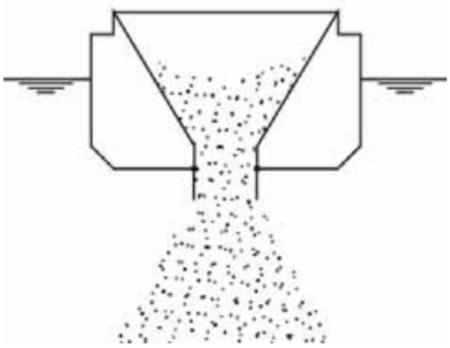


Figure 2.9: Sketch of a split barge (Verhagen, 2002)

2. Side dumping vessel: to place in a more accurate way a side dumping vessel is used. Stones are pushed into the water from the deck by a moving beam.

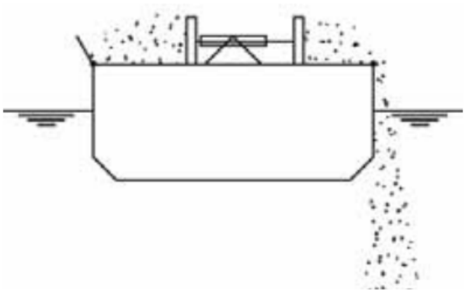


Figure 2.10: Sketch of a side dumping vessel (Verhagen, 2002)

INDIVIDUAL PLACEMENT

1. Fall pipe vessel: if accurate placing on large depths is required a fall pipe vessel can be used. This system guides the stones down to a level several metres from the sea bed and is mostly used for the toe and slope protection as well as for the seabed preparation (foundation). Installations can be up to depths of 1000 meters.

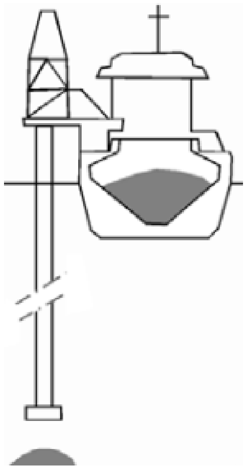


Figure 2.11: Sketch of a fall pipe vessel (Schiereck and Verhagen, 2019)

2. Crane on a barge: land based equipment can also be mounted on barges to install stones from the seaside.

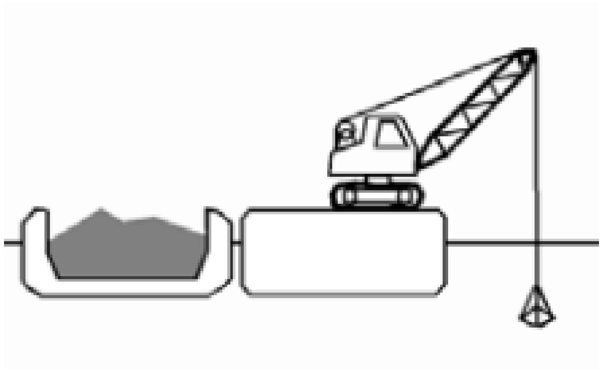


Figure 2.12: Sketch of a wire crane on a barge (Schiereck and Verhagen, 2019)

WORKING CONDITIONS

The biggest constrain for installation with marine based equipment is insufficient water depth. The water depth is insufficient if it is smaller than the vessel's draught plus an under keel clearance. In addition, currents and waves play a role. The strength of the current is important because it determines how well a vessel can be held in place. For safety reasons, a margin is always kept between the structure and the vessel, depending on waves and currents. Waves can cause downtime due to the rolling of cranes mounted on barges.

2.3. CO_2 FOOTPRINT

The CO_2 footprint is the total amount of carbon dioxide released into the atmosphere as a result of human activities. As a result of the emission of greenhouse gases, which includes carbon dioxide, the world experiences several negative consequences (Ramanathan and Feng, 2009). A few of them are listed:

1. Trapping of heat
2. Air pollution (smog)
3. Extreme weather patterns

The extraction, processing and handling of primary aggregates are responsible for about 7 percent of total global energy consumption (Mankelow et al., 2010). Concrete production is one of the largest CO_2 emitters in the world, accounting for 8 percent of the global emissions (Ellis et al., 2020). These numbers emphasize the importance to reduce these negative effect and to keep the CO_2 footprint from (coastal) structures as small as possible. The following may contribute to CO_2 emissions for a (coastal) structure:

1. Material production in a quarry or factory
2. Shipping materials to the construction site
3. Bringing the equipment to the construction site
4. Material placement by the equipment

3
Methodology

3.1. The Cost of Material

The tool design by Winkel allows the user only to calculate the cost of material in monetary values. Therefore the tool will be expanded to calculate the material cost in either terms of monetary values, CO_2 emission or both.

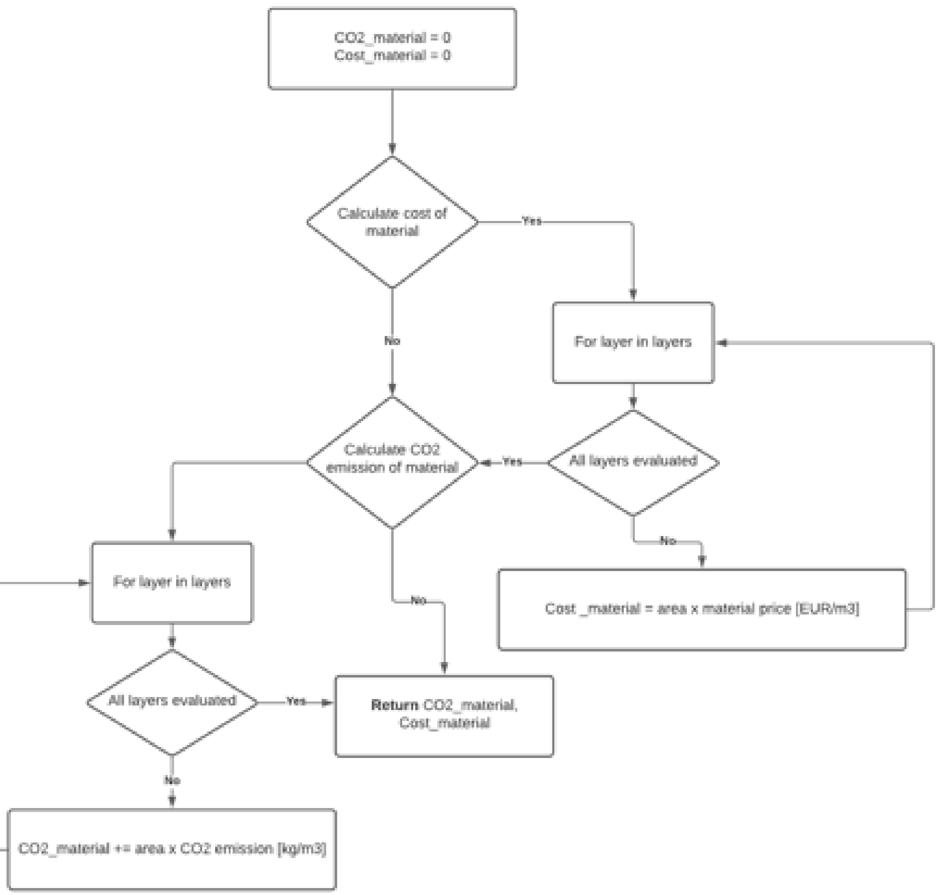


Figure 3.1: Algorithm to calculate the cost of the material. If the branch to calculate cost or CO_2 is not entered this value remains zero.

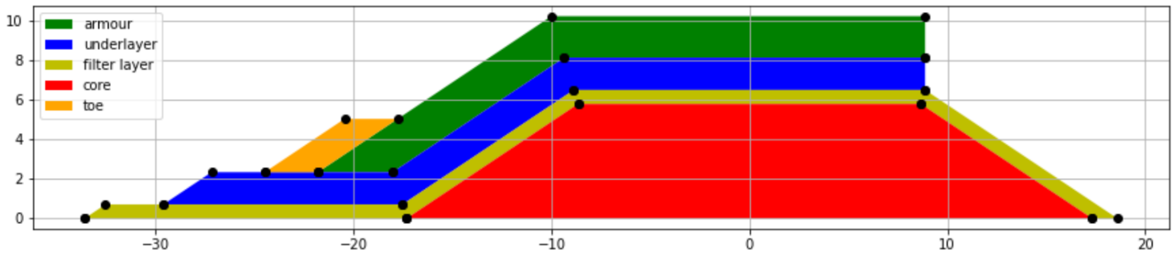
3.2. CONSTRUCTION METHODS

Winkel's cost estimate only takes into account the costs of material procurement. Additional costs arising from the installation of the structure and the transport of material for different installation techniques are not considered. Furthermore, the cost of the negative impact of carbon dioxide emissions, the carbon footprint, is not taken into account.

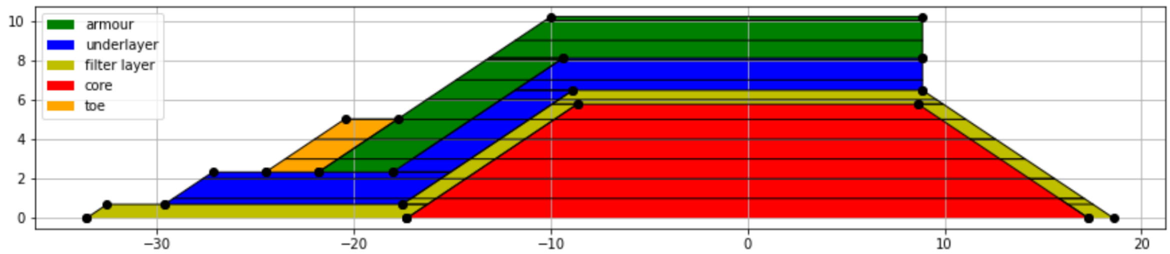
Both the installation methods and the carbon footprint can be of great value to the parametric design. The use of equipment will provide a more accurate estimate of the total cost of the breakwater and an indication of the installation time. Moreover, installation also contributes to CO_2 emission for example due to fuel consumption.

3.2.1. THE STRUCTURE

Even though an installation method is not be able to install a whole layer of the structure, it may be able to install a certain part of it. Think of a crane which can only reach up to a certain horizontal and vertical distance. Therefore the layers are divided into smaller sections, see the difference in Figure 3.2a and Figure 3.2. For each of these sections, it will be examined which equipment is capable of installing it. A section has a maximum height of 1 m.



(a) A breakwater cross-section and it's layers



(b) A breakwater cross-section with it's layers divided into sections

Figure 3.2: The difference between a layer and a section

The layers will be constructed in the following order, with the sections being built up from low to high:

1. Core
2. Underlayers
3. Armour
4. Toe

3.2.2. INSTALLATION CONDITIONS

The first step is to examine the equipment's ability to install a certain part of the structure. This will be different for each type of equipment and based on different conditions.

GENERAL

Using object-oriented programming, the construction methods will be divided into different classes. All these classes inherit from a parent class, called Equipment, which consists of a number of parameters that apply to each type of equipment:

1. name: the name of the equipment.
2. design type: what material grading can the equipment install, at what cost and at what production rate. The production rate indicates how many cubic metres the equipment can install per hour. This is an average value related to weather and site conditions.
3. water depth: at what water depth will the equipment be used. For installations with marine based equipment, it is important as navigability is only possible if a ship has sufficient keel clearance. On the other hand, for land based equipment it determines whether the to be installed area is below or above the water level.

Out of this parent class several other 'children' classes will be created. These are listed below.

DUMP TRUCKS AND WHEEL LOADERS

These installation methods will be schematized under the same class Trucks. Both tools can work under dry conditions and mainly install bulk materials. Beside the parameters from the parent class there will be one extra parameter to describe the behaviour of the Trucks:

1. h_{dry}: a margin between the installation water depth and the location of equipment to ensure dry feet. This margin depends on the wave climate.

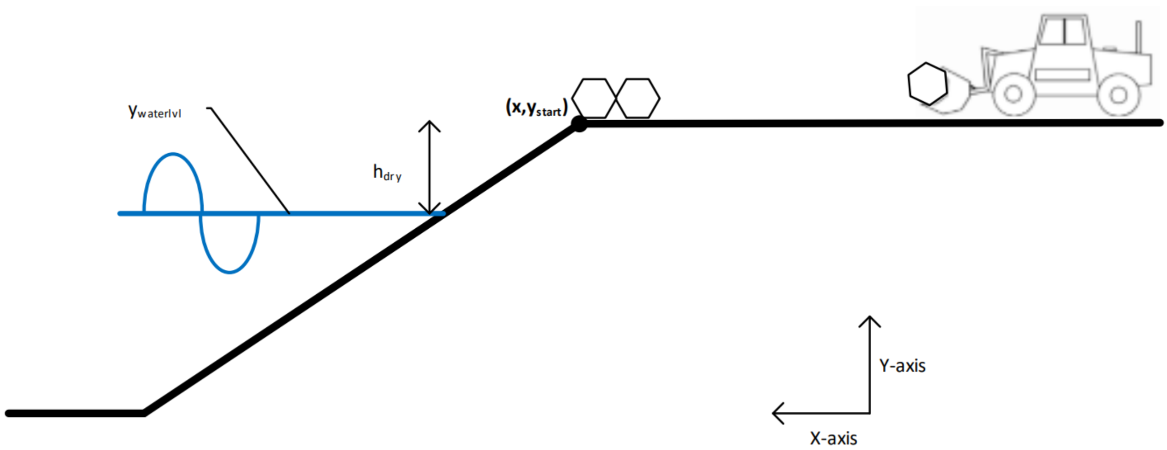


Figure 3.3: First case in which the Truck class installs at it owns level

From Figure 3.3 one can state that the truck class can be used to install a section if:

$$y_{start} - y_{waterlvl} \geq h_{dry}$$

where y_{start} corresponds to the y-coordinate of to the lowest point of the section which is to be installed.

Figure 3.4 shows another case where the trucks can dump the material from the slope downwards. In this second case the top level of the structure is on a dry level.
The following pseudocode indicates wether the Truck class can install a section:

Require: Equipment can handle the grading
Install = False
if y_{start} - $y_{waterlvl} \geq h_{dry}$ **or** y_{max} - $y_{waterlvl} \geq h_{dry}$ **then**
Install = True
end if

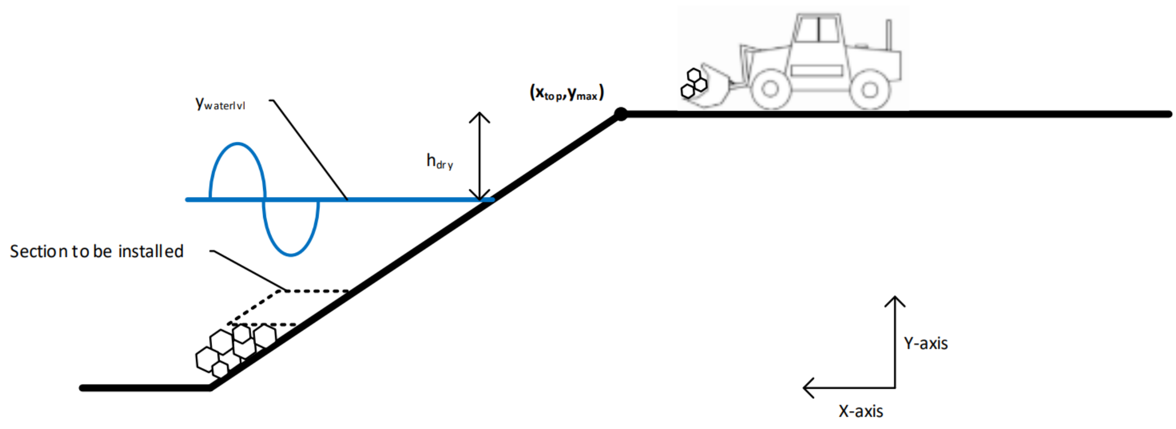


Figure 3.4: Second case in which the Truck class installs down the slope

EXCAVATORS

The excavator type of equipment will be schematized into a separate class called Excavator. In addition to the parameters of the parent class, three additional parameters must be provided:

1. h_{dry}: a margin between the installation water depth and the location of equipment to ensure dry feet.
2. Loading chart: the x,y coordinates together with the maximum mass the excavator can lift at these coordinates.
3. Offset: horizontal distance from the start of the slope where the equipment is placed.

Figure 3.5 refers to a case in which the excavator installs on it's own level. A section is then always within it's reach as the excavator can move around. This is different in the situation outlined in Figure 3.6 where the excavator builds downwards the slope. The excavator can only install the section if the section with a certain material mass falls within the loading chart.

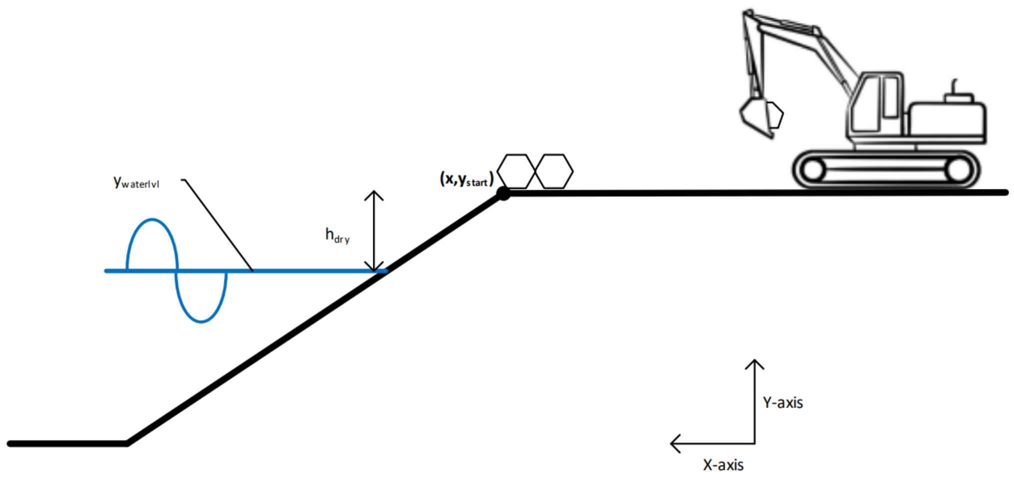


Figure 3.5: First case in which an excavator installs at it owns level

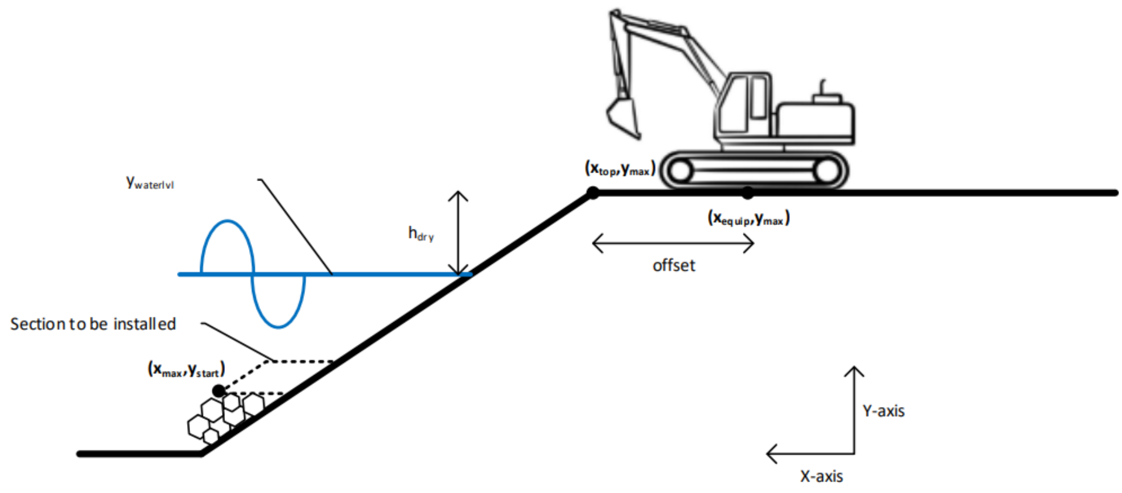


Figure 3.6: Second case in which an excavator installs down the slope

Translating these Figures to pseudocode:

Require: Equipment can handle the grading

Install = False

if y_{start} - $y_{waterlvl}$ ≥ hdry **or**
(y_{max} - $y_{waterlvl}$ ≥ h_{dry} **and** section within loading chart **then**

Install = True

end if

WIRE ROPE CRANE

The cases described in Figures 3.5 and 3.6 are similar to an excavator. But where an excavator uses a boom and a stick, the crane uses a boom in combination with a rope. The rope is assumed to reach to unlimited depths so the only constraints is the horizontal reach, except when the section lies above the crane (see Equation 2.1). Next to the parameters of the parent class, again three additional parameters must be provided:

1. h_{dry}: a margin between the installation water depth and the location of equipment to ensure dry feet.
2. Loading chart: provides a maximum lifting mass for a combination of boom length and reach.
3. Offset: horizontal distance from the start of the slope where the equipment is placed.

Converting these installation constraints into pseudo code results in:

Require: equipment can handle the grading

Install = False

if y_{start} - $y_{waterlvl}$ ≥ h_{dry} **or**
(y_{max} - $y_{waterlvl}$ ≥ h_{dry} **and** section within loading chart **then**

Install = True

end if

SPLIT BARGES AND SIDE DUMPERS

Both split barges, side dumpers and fall pipe vessel are able to install the material when the water depth is sufficient. This is illustrated in Figure 3.7.

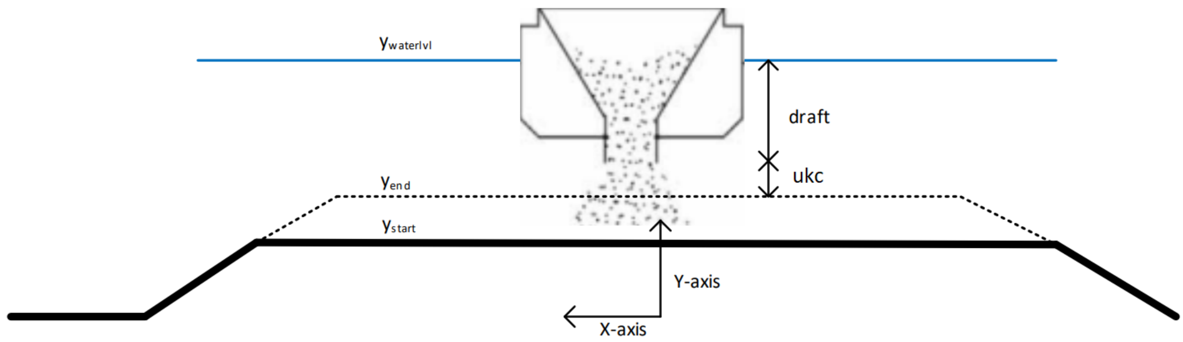


Figure 3.7: Situation when split barges, side dumpers and fall pipe vessels can install a certain part of the construction

The only restriction on the installation for split barges, side dumpers and fall pipe vessels is a sufficient water depth for save navigability. That is why these installation methods are placed in the same class, with two parameters in addition to those of the parent class:

1. installation water depth: minimum water depth required for installation (including the barge) excluding the under keel clearance. Mostly dependent on the draft of the vessel.
2. ukc: under keel clearance. Determined by site specific guidelines.

Figure 3.7 translated to pseudo-code:

Require: equipment can handle the grading
Install = False
if $y_{waterlvl}$ - (draft + ukc) ≥ y_{end} **then**
Install = True
end if

BARGES

Excavators and wire cranes can be mounted on barges to install from the seaside. The following parameters determine whether a barge in combination with excavators or cranes can be used to place a section of the structure:

1. Other: either one of the excavator or wire crane class.
2. Height: height of the barge
3. Installation water depth: minimum water depth required for installation (including the barge) excluding the under keel clearance. Mostly dependent on the draft of the vessel.
4. Ukc: under keel clearance.
5. Margin$_x$: safety margin from the construction in horizontal direction.

Let us consider both cases from Figures 3.8 and 3.9 and make a distinction between the crane and excavator:

1. Figure 3.8: In this case the barge is not limited by depth restrictions as the bottom of the vessel is above the top of the section plus the vertical margin.
   (a) Wire crane: as long as the crane can reach the section horizontally it can construct this section. As there are no depth restrictions the vessel can move freely around .There is thus no horizontal limitation and the wire crane can always install the section.

(b) Excavator: compared to the wire crane it is different for the excavator. As the barge can freely move the x-range in the load chart is of non-importance. If any mass on the y-levels suffices for both the top and the bottom of the section, construction is possible.

2. Figure 3.9: in this case the barge should keep some distance from the construction due to safety constraints. Therefore the location of the equipment mounted on the barge is given by:

$$x_{equip} = x_{top} - (y_{end} - y_{waterlvl} - \text{draft}) \cdot H/V - margin_x - \text{offset}$$

$$y_{equip} = y_{waterlvl} - \text{draft} + \text{height}$$

For both the crane and the excavator, the installation must then be evaluated based on the location of the section in relation to the location of the equipment, together with the loading chart.

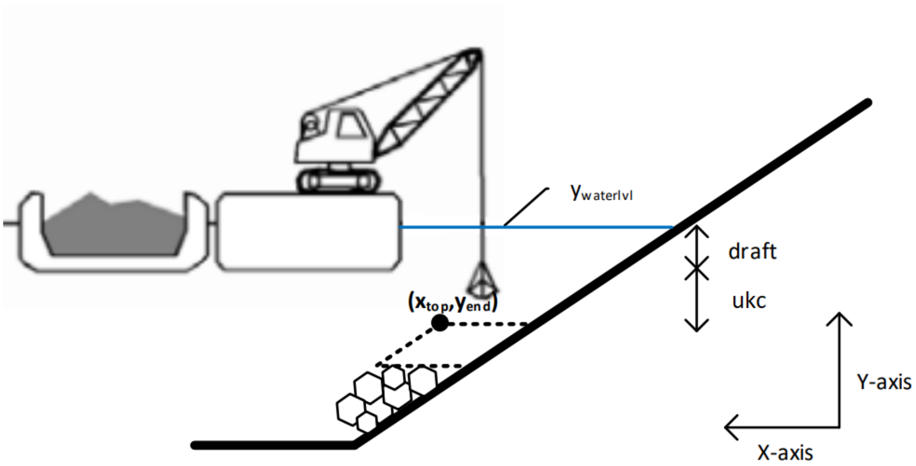


Figure 3.8: First case in which a barge combined with land based equipment can construct a section. There is no depth limitation.

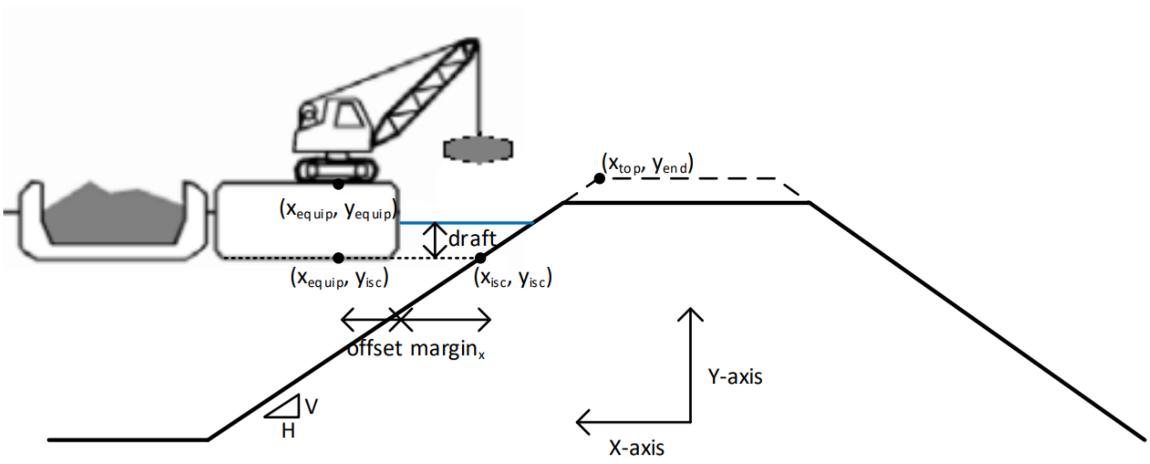


Figure 3.9: Second case in which a barge combined with land based equipment can construct a section. There is depth limitation so the barge locates itself the closest as possible to the section.

3.2.3. INSTALLATION ALGORITHM

Now the different construction methods are schematized, the conditions for installation are set and the structure is divided into smaller sections, an algorithm is created to examine whether a set of equipment can install the structure. This algorithm investigates for a section which equipment are capable of constructing it and at what cost, with what CO_2 emission and within what time.

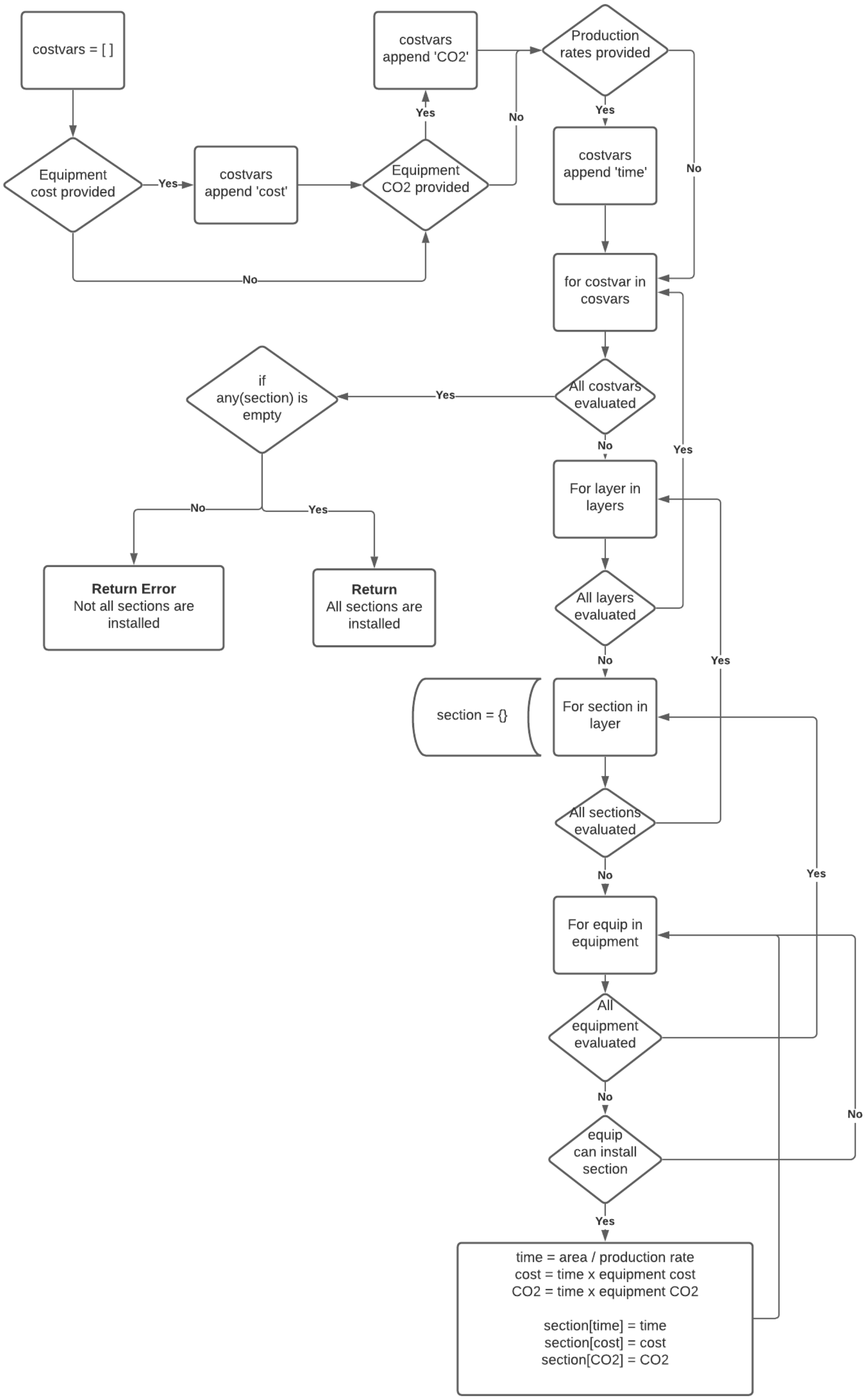


Figure 3.10: Algorithm to estimate if the construction can be build given a set of equipment and what the installation cost is for a section per equipment. The cost can be calculated in terms of either CO_2 emission, monetary values or both.

The algorithm in Figure 3.10 raises an error if there remain sections which can not be installed by a single installation method.

```
EquipmentError: variant 'a' can't be installed completely
```

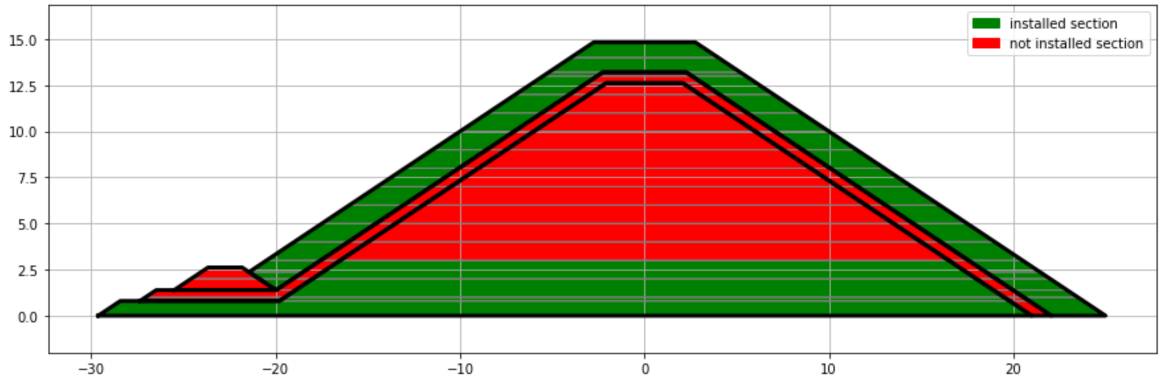


Figure 3.11: Equipment error

With the help of the error from Figure 3.11, the user can determine which construction method should be added to construct the remaining sections.

3.2.4. THE OPTIMAL EQUIPMENT SET

The algorithm from Figure 3.10 determines which equipment can install which section. The next step in the process is to determine which combination of equipment is the optimal one to construct the section. Three options to determine possible combinations of equipment are evaluated:

1. Brute Force Combinations: create all possible combinations of equipment using combinations with replacement.

$$\# \, combinations = \frac{(n+r-1)!}{r!(n-1)!} \tag{3.1}$$

   Then for each combination check if the entire structure can be installed and at what cost.

   (a) Advantage:
      i. Advantage: all combinations are evaluated.

   (b) Disadvantage:
      i. Computational inefficient: for 5 different equipment (n=5) types and 40 sections (r = 40), there are:

$$\# \, combinations = \frac{(5+40-1)!}{40!(5-1)!} = 135.751$$

      If this is done for multiple structure variants or more equipment will be added, this method will become computationally inefficient. There are also combinations evaluated which are not able to install the entire structure so are useless beforehand.

2. Cheapest Combinations: the cheapest equipment is estimated for each section. In the end, a combination is made with all these construction methods.

   (a) Advantages:
      i. Computational very efficient
      ii. Not complex

   (b) Disadvantages:
      i. Might give a combination where each section is construction by a different type of equipment. This is not realistic.

3. Smart Combinations: Each equipment will be given the opportunity to install the sections to which it is capable. Next, the construction method that is able to install the most new sections will take over, and so on. Land based installation is preferred to installation from the sea side. In other words, the equipment are first ordered by land or marine based type and second to the amount of new layers they can add to its predecessor, see Figure 3.12. When installation is complete no new construction methods will be added to the set

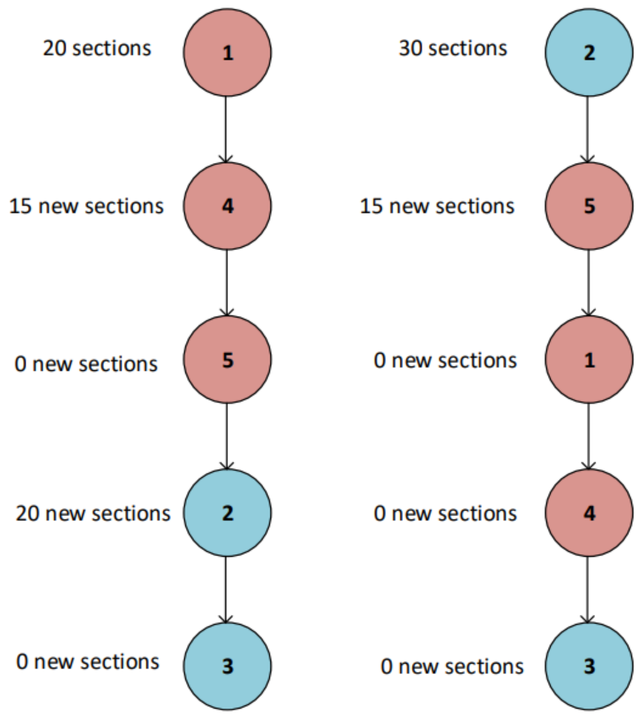


Figure 3.12: Smart equipment combinations. Land based equipment have a brown color and marine based equipment a blue color.

The construction methods used with equipment 1 on the level 0 node are:

1 - 4 - 2

The construction methods used with equipment 2 on the level 0 node are:

2 - 5

Important to notice is thus that the sorting is done on how much new sections a construction method can add to the already installed sections.

(a) Advantages:
  i. Computational efficient with respect to Brute Force.
  ii. Less equipment used than Cheapest Combinations
(b) Disadvantages:
  i. More complex than the Brute Force algorithm.
  ii. Does not evaluate all combinations.

Due to its computational inefficiency the Brute Force method is disregarded. For a small number of installation methods, the cheapest combinations method is preferred over the smart combinations method, because it will yield the cheapest combination of installation methods with little equipment. On the other hand, if the input is a large number of construction methods, this will lead to an unrealistic number of used methods. Since parametric design desires optimisation for a large design space, thus also a large equipment input, the

best method is Smart Combination.
Finally, for each of the (relevant) combinations, the costs can be expressed in monetary value, CO_2 emissions and construction time. When this has been estimated for all combinations, the most optimal one can be chosen.
Unfortunately, Van Oord doesn not have a complete data set containing CO2 emissions of all installation methods. As far as optimisation on CO_2 is concerned, this is therefore only possible on the emissions resulting from extraction and processing of the material.

3.3. DESIGN OPTIMIZATION

Now the cost of installation and the cost of material is calculated, the total cost of the structure can be estimated. Besides that it is also possible to get an estimate of the duration of installation.

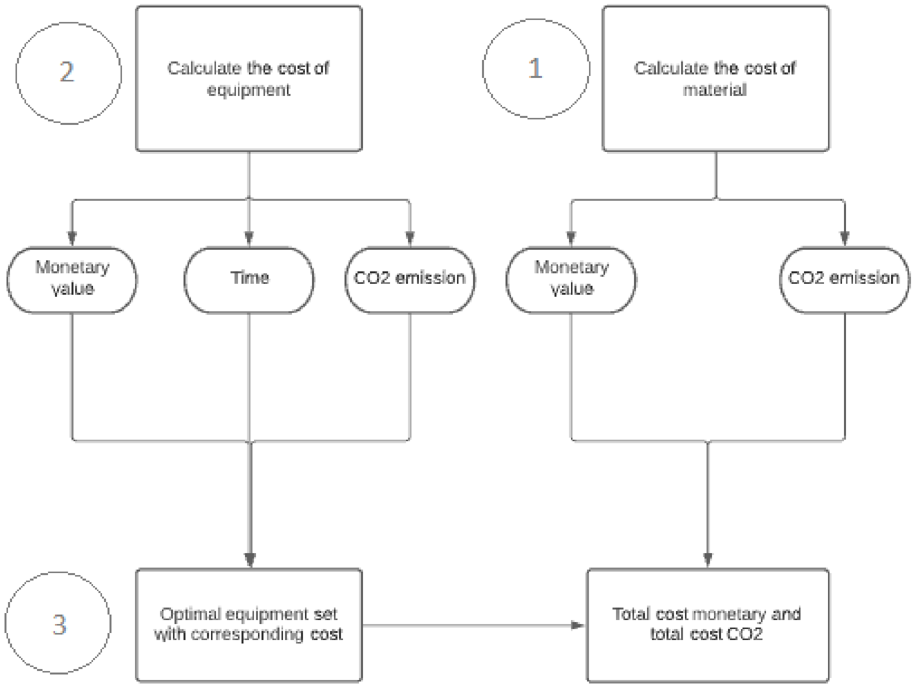


Figure 3.13: The three parts of the cost calculation algorithm

Instead of just one variable, the cost of materials, there are now three variables to which we can optimize our designs:

1. Total cost = cost of material + installation cost
2. Total CO_2 = CO_2 of material + CO_2 installation
3. Installation time

4

Results of Test Case

4.1. Design Input

Input Parameters

An overview of the inputs to the test case is given below.

1. hydraulic conditions:
   (a) h = 27 m
   (b) Design high water = 0.2 m
   (c) H_{m0} = 9 m
   (d) T_p = 11.8 s
   (e) slope foreshore = 1:100
2. damage levels:
   (a) S_d = 4
   (b) N_{od} = 3
   (c) q = 100 l/s/m
3. densities:
   (a) $\rho_w = 1025\ kg/m^3$
   (b) $\rho_s = 2650\ kg/m^3$
   (c) $\rho_c = 2400\ kg/m^3$

Due to the severe wave conditions, a concrete armour layer with Cubipods is chosen; see Figure A.1 for the armour unit specifications.
The design space (see Section 2.1) is as follows:

1. slope = (1:3, 2:3, 5).
2. crest width = (5, 25, 20). Minimum at $3D_{n50}$.

CONSTRUCTION METHODS

The following construction methods are used to investigate the outcomes of the tool.

1. Land based
   (a) Dump truck
   (b) Caterpillar 385 excavator
   (c) Hitachi 1200 excavator
   (d) Hitachi 1900 excavator
   (e) Liebherr 300t crane
   (f) Liebherr 700t crane
2. Marine based
   (a) Fall pipe vessel storness
   (b) Fall pipe vessel braveness
   (c) Side stone dumper resolution
   (d) Side stone dumper HAM602
   (e) Barge with Hitachi 1900 excavator
   (f) Barge with Liebherr 300t crane
   (g) Barge with Liebherr 700t crane
   (h) Barge with Platefeeder

4.2. OPTIMIZED DESIGNS

MATERIAL COST

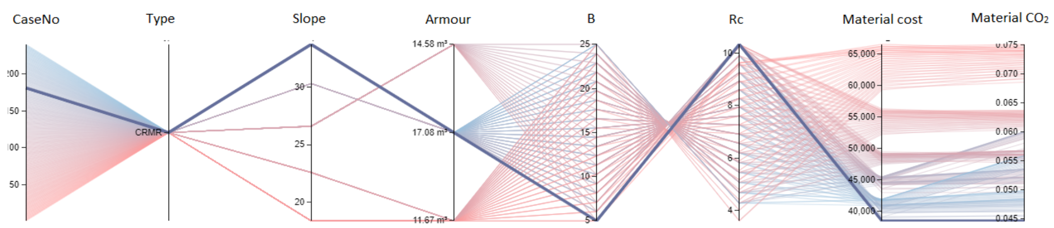


Figure 4.1: Design Explorer with case with lowest material cost highlighted

The highlighted case in 4.1 shows the design with the lowest material cost and CO_2 emission. Below the specifications of this design are summarized.

Optimization variable	**Value**
Material cost	38.505,96 EUR/m
Material CO_2	0.0447 kge/m

Table 4.1: Material cost and material CO_2 for the design optimized on minimum material cost

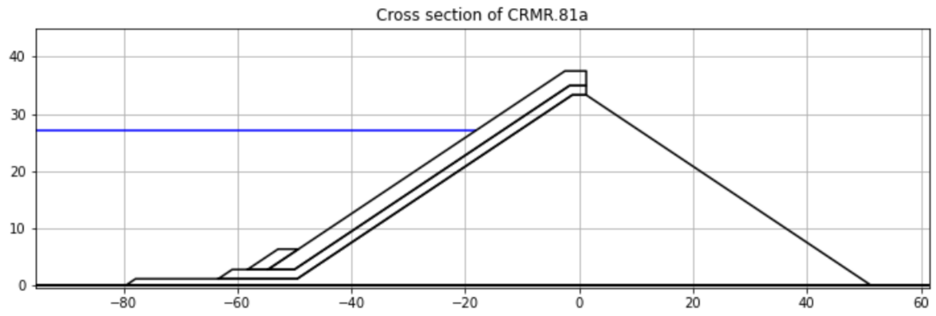


Figure 4.2: Design with lowest material costs

Structure part	Specification
Armour	Cubipod 41t (A = 164 m^2)
Underlayer	1-3t (A = 119 m^2)
Toe	3-6t (A = 13 m^2)
Core	quarry run 1-1000kg (A = 1781 m^2)
Crest width	5 m
Freeboard	10.4 m
Slope	2:3

Table 4.2: Structure details of the design optimized on material cost. The total area of the structure is 2077 m^2.

TOTAL COST

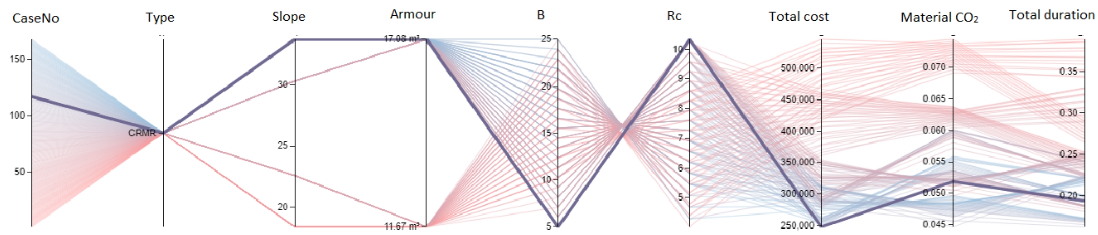


Figure 4.3: Design Explorer with case with lowest total cost highlighted

The highlighted case in Figure 4.3 shows the design with the lowest total cost. Below the specifications of this design are summarized.

Optimization variable	Value
Total cost	248.264,60 EUR/m
Material CO_2	0.0519 kge/m
Installation time	0.1941 wk/m

Table 4.3: Total cost, material CO_2 and installation time for the design optimized on total cost

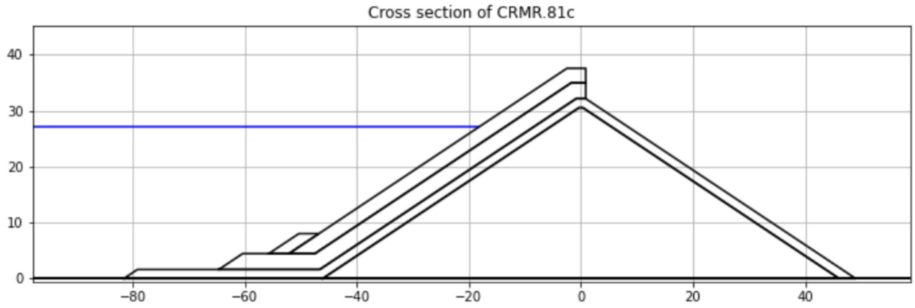


Figure 4.4: Design with lowest material costs

Structure part	**Specification**
Armour	Cubipod 41t (A = 155 m^2)
Underlayer 1	8-12t (A = 205 m^2)
Underlayer 2	1-3t (A = 239 m^2)
Toe	3-6t (A = 13 m^2)
Core	quarry run 1-1000kg (A = 1417 m^2)
Crest width	5 m
Freeboard	10.4 m
Slope	2:3

Table 4.4: Structure details of the design optimized on total cost. The total area of the structure is 2029 m^2.

Equipment	**Layers**
Hitachi 1900 excavator	Underlayer 1, Underlayer 2
Liebherr 300 ton crane	Armour
Liebherr 700 ton crane	Armour
Dumptruck	Core
Side stone dumper	Toe, Underlayer 1, Underlayer 2
Barge with Liebherr 300 ton crane	Armour
Barge with platefeeder	Core

Table 4.5: Overview of the used equipment for the optimized design

INSTALLATION TIME

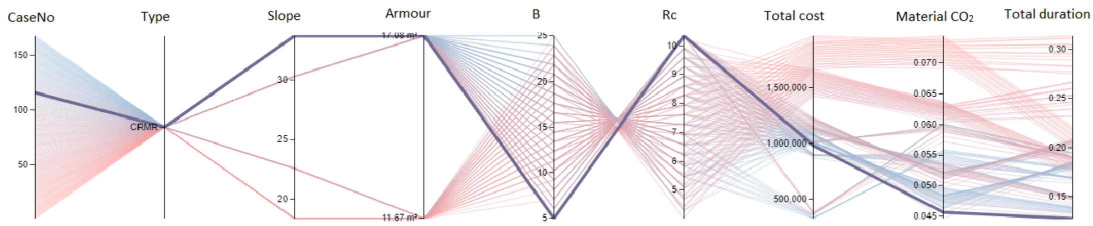


Figure 4.5: Design Explorer with case with minimum installation time highlighted

The highlighted case in 4.5 shows the design with the shortest time of installation. Below the specifications of this design are summarized.

Optimization variable	Value
Total cost	979.874,77 EUR/m
Material CO_2	0.0457 kge/m
Installation time	0.1277 wk/m

Table 4.6: Total cost, material CO_2 and installation time for the design optimized on time of installation

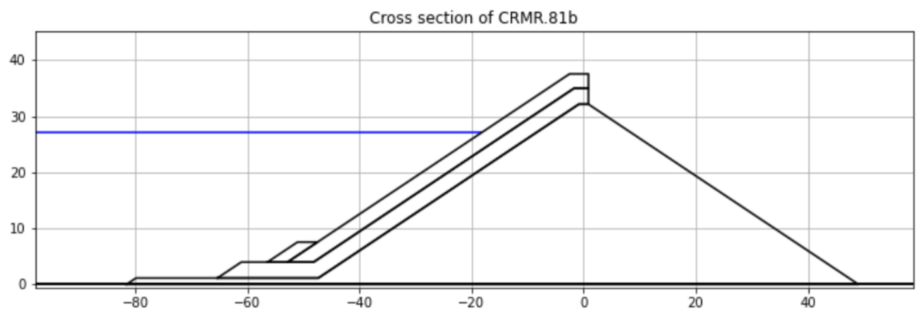


Figure 4.6: Cross-section of design with minimum installation time

Structure part	Specification
Armour	Cubipod 41t (A = 157.5 m^2)
Underlayer	8-12t (A = 208 m^2)
Toe	3-6t (A = 13 m^2)
Core	quarry run 1-1000kg (A = 1641 m^2)
Crest width	5 m
Freeboard	10.4 m
Slope	2:3

Table 4.7: Structure details of the design optimized on installation time. The total area of the structure is 2020 m^2.

Equipment	Layers
Hitachi 1900 excavator	Underlayer
Liebherr 700 ton crane	Armour
Side stone dumper	Toe, Underlayer
Barge with Liebherr 300 ton crane	Armour
Barge with platefeeder	Core

Table 4.8: Overview of the used equipment for optimization on installation duration

5 CONCLUSIONS

This work has demonstrated the added value of adding modules for evaluating construction methods, installation and CO2 costs to the parametric design tool for coastal structures developed by Winkel (2020). To begin, in the expanded tool, designs can be optimised not only on material procurement cost, but on three other variables: total cost, CO_2 emissions and installation time. Total costs now consist of material costs, transport costs and installation costs. Based on the variable to be optimised, not only is a cross-section of the structure designed, but an estimate is also made of the equipment required to install the structure.

Thus, a more complete cost estimate of the construction is obtained. After adding the construction methods, the price of the design with minimum cost increased by a factor 5 [1] compared to the old tool that only took the material cost into account. This is a significant difference. Moreover, compared to the optimised design based on the cost of materials alone, the design with lowest total cost has an additional underlayer.

Finally, compared to optimisation based on cost, a design optimised on the duration of the installation not only led to a different cross section, but also to the use of other installation methods. This did lead to a significant increase, a factor 3 [2], of the total cost. With this knowledge the user can make a trade-off between cost, CO_2 emission and duration of installation and then come to the best design.

The results clearly show that the implementation of construction and CO_2 emission in the parametric design has added value for the preliminary design phase. An estimate of the required equipment can be made, a more complete price of the construction is assessed and the optimal design can not be chosen on material procurement costs only, but on a trade-off between costs, CO_2 emissions and installation time.

1
$$\frac{248264.60 - 38505.96}{38505.96} \cdot 100\% \approx 545\%$$

2
$$\frac{979874.77 - 248264.60}{248264.60} \cdot 100\% \approx 295\%$$

6

DISCUSSION

DATA AVAILABILITY

The development of a new tool also requires the availability of more data. The results were obtained on the basis of rough indications from cost estimators. Exact information was not available, leading to questionable results of the test case. More specifically, the design with the lowest total cost consists of an additional underlay compared to the design with the lowest installation time, but is almost three times cheaper. Part of this can be explained by a different use of installation methods. But why not use the "cheaper" equipment to install the design with only one underlayer? Shouldn't that result in even lower costs? Possible reasons for this could be that the extra underlayer resulted in a smaller quantity of the expensive armour or simply an inaccurate input for the installation methods.
Moreover, no data was available within Van Oord on the CO_2 emissions of construction methods. Although the method is present in the new tool, nothing can be said about its added value.

OPTIMAL EQUIPMENT ALGORITHM

The algorithm used to estimate the optimal equipment set is the so-called "smart combinations" algorithm. This is based on installation with a preference for land-based equipment and equipment that can install the most new sections. When comparing a large and a small excavator, it is clear that the large excavator can reach deeper and thus install more new layers than the small excavator. The "smart combinations" algorithm will therefore give preference to the large excavator. The algorithm ignores the fact that the small excavator has a higher production speed and therefore lower installation costs. The algorithm thus misses certain combinations of equipment that could be cheaper.

EQUIPMENT SIZE AND MASS

When determining whether a construction method can install a section, the tool does not take into account the methods size and mass. For land-based equipment, this is very relevant. If an excavator is working down the slope of the structure, the top layer on which it stands must have a considerable length in relation to the size of the machine. Also, the geotechnical stability must be sufficient to carry the load of heavy cranes.

7 Recommendations

Input automation and data availability

The purpose of parametric design is to speed up the preliminary design phase. If all design inputs, costs and equipment have to be entered into the code by hand, it is time inefficient and prone to errors. Therefore, databases for design inputs, costs per quarry and equipment should be created. Suitable quarries and equipment can then be selected depending on the project.

Optimal equipment algorithm

As mentioned in the discussion, the "smart combinations" algorithm misses some combinations that could lead to cheaper designs. One solution could be to allow the user to also apply the "cheapest combinations" algorithm and let the user decide whether the number of installation methods used is acceptable. Another solution could be to set a threshold for the number of installation methods used in the "cheapest combinations" algorithm. The number of installation methods would then be reduced to the threshold by removing equipment with the highest marginal cost.

3D structure shape

The design optimisation is performed on one wave condition, resulting in a design for only one section of the breakwater, and a cost and time estimate per running metre. A structure is not constant over it's entire length, think of the roundhead or irregular shapes. Therefore the 2D design can not be accepted over the entire length of the structure. An optimal equipment set for a 2D section is therefore not automatically the optimal set for the entire structure. Implementing a 3D shape for the design and corresponding wave conditions per section will result in a cost and time estimate for the entire structure.

Site conditions

The production rate must be determined using another, non-coupled, tool and put in manually. A good improvement would be to link the equipment to this tool so that the production rate is estimated automatically.

Geotechnical stability

The structure and the equipment on the structure are not assessed for geotechnical stability. Therefore, an instrument that examines this geotechnical stability should be coupled to the package.

Multiple quarries

With the current tool, only one quarry can be included. The inclusion of multiple quarries gives the opportunity to select a certain amount of material per quarry based on cost, CO2 emissions and transport time. Suppose quarry A has higher material costs, but is closer to the construction site. This has a negative effect on the total cost in monetary terms, but a positive effect on CO2 emissions and transport time. On the other hand, quarry B has low material costs, but is located far away from the construction site. With this information a certain amount of material per quarry can be calculated to optimise costs and transport time.

Bibliography

Cubipod brochure. (n.d.). https://www.cubipod.com/en/documentation/brochures/

Durakovic, A. (2021). Van oord orders mega jack-up for 20 mw offshore wind turbines. https://www.offshorewind.biz/2021/10/01/van-oord-orders-mega-jack-up-for-20-mw-offshore-wind-turbines/

Ellis, L. D., Badel, A. F., Chiang, M. L., Park, R. J.-Y., & Chiang, Y.-M. (2020). Toward electrochemical synthesis of cement—an electrolyzer-based process for decarbonating caco3 while producing useful gas streams. *Proceedings of the National Academy of Sciences*, *117*(23), 12584–12591.

Hitachi ex1900-6 brochure. (n.d.). https://www.hitachiconstruction.com/wp-content/uploads/2016/02/DKEX1900HT_16-01.pdf

Klein Breteler, M., Ockeloen, W., Boerma, E., & Kuiper, C. (2019). Design verification of afsluitdijk renovation with large scale tests. *Coastal Structures 2019*, 180–189.

Ltm 1100-4.2 brochure. (n.d.). https://www.liebherr.com/external/products/products-assets/806197/liebherr-187-ltm-1100-4-2-td-187-01-defisr10-2018.pdf

Luna, E. (n.d.). Liebherr crane autocad. https://cadbull.com/detail/127712/Liebherr-crane-vehicle-side-elevation-cad-block-details-dwg-file

Mankelow, J., Oyo-Ita, D., & Birkin, M. (2010). Assessing the carbon footprint of transporting primary aggregates.

Ramanathan, V., & Feng, Y. (2009). Air pollution, greenhouse gases and climate change: Global and regional perspectives. *Atmospheric environment*, *43*(1), 37–50.

Schiereck, G. J., & Verhagen, H. (2019). *Introduction to bed, bank and shore protection*. Delft Academic Press / VSSD.

Tomasetti, T. (n.d.). Design explorer 2. https://tt-acm.github.io/DesignExplorer/

van der Meer, J., Allsop, W., Bruce, T., Rouck, J., Kortenhaus, A., Pullen, T., Schüttrumpf, H., Troch, P., & Zanuttigh, B. (2018). *Eurotop: Manual on wave overtopping of sea defences and related sturctures - an overtopping manual largely based on european research, but for worlwide application (2nd edition).*

van der Meer, J. W. (1988). Deterministic and probabilistic design of breakwater armor layers. *Journal of waterway, port, coastal, and ocean engineering*, *114*(1), 66–80.

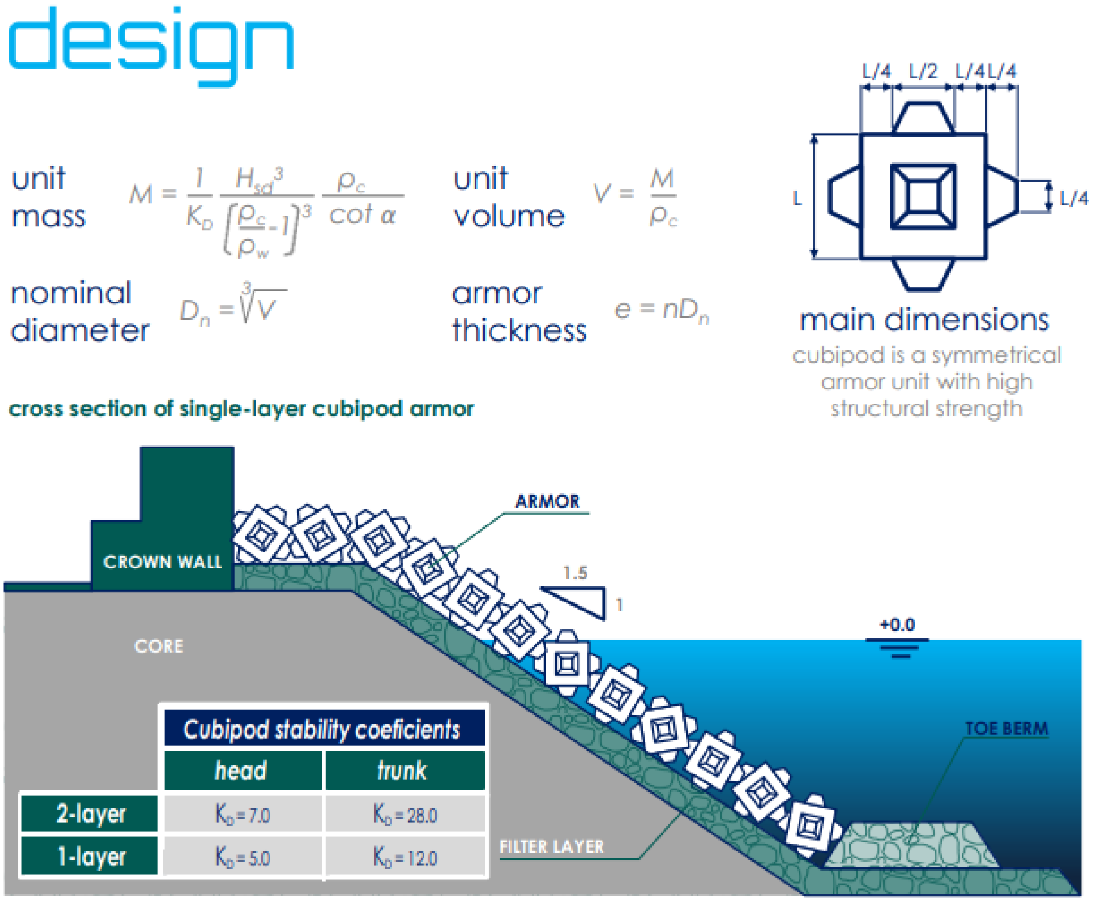
Verhagen, H. (2002). *Kennisbank waterbouw*. Delft University of Technology.

Winkel, S. (2020). Improving the breakwater design process by using a design automation tool.

Zaalberg, P., Ockeloen, W., Hofland, B., Antonini, A., & Smith, G. (2020). The relation between sand and overtopping for cobble revetments: A numerical approach with openfoam. *Coastal Engineering Proceedings*, (36v), 14–14.

A

SPECIFICATIONS CUBIPOD



Based on the generalized Hudson's Formula for an armor slope 3H:2V, in trunk section (non-breaking and non-overtopping) with $K_D[n=1]=12$ and $K_D[n=2]=28$. $\rho_{concrete}[t/m^3]=2.400$ and $\rho_{sea\ water}[t/m^3]=1.030$. Note: If $\rho_{concrete}[t/m^3]=2.300$, armor unit weight increases 20% and concrete consumption 8%.

design wave height Hs [m]	unit mass M [t]		unit volume V [m3]		equivalent cube size Dn [m]		armor layer thickness e [m]		armor layer porosity p [%]		packing density φ [-]		placing density φ [u/100m3]		concrete consumption φ*V/100 m3/m2	
	1-layer	2-layer	1-layer	2-layers	1-layer	2-layer	1-layer	2-layers	1-layer	2-layer	1-layer	2-layers	1-layer	2-layer	1-layer	2-layers
3,50	2,40	1,00	1,00	0,40	1,00	0,76	1,00	1,50	41,00	42,00	0,59	1,16	59,00	200,00	0,59	0,88
4,00	3,60	1,60	1,50	0,60	1,15	0,87	1,10	1,70	41,00	42,00	0,59	1,16	45,00	155,00	0,68	1,00
5,00	7,10	3,00	3,00	1,30	1,43	1,08	1,40	2,20	41,00	42,00	0,59	1,16	29,00	99,00	0,85	1,25
6,00	12,20	5,20	5,10	2,20	1,72	1,30	1,70	2,60	41,00	42,00	0,59	1,16	20,00	69,00	1,02	1,51
7,00	19,40	8,30	8,10	3,50	2,01	1,51	2,00	3,00	41,00	42,00	0,59	1,16	15,00	51,00	1,18	1,76
8,00	29,00	12,40	12,10	5,20	2,29	1,73	2,30	3,50	41,00	42,00	0,59	1,16	11,00	39,00	1,35	2,01
10,00	56,70	24,30	23,60	10,10	2,87	2,16	2,90	4,30	41,00	42,00	0,59	1,16	7,00	25,00	1,69	2,51
12,50	110,70	47,40	46,10	19,80	3,59	2,70	3,60	5,40	41,00	42,00	0,59	1,16	5,00	16,00	2,12	3,14
15,00	191,20	82,00	79,70	34,10	4,30	3,24	4,30	6,50	41,00	42,00	0,59	1,16	3,00	11,00	2,54	3,76

Before using this table please contact SATO at www.cubipod.com

Figure A.1: Cubipod specifications "Cubipod Brochure", n.d.

B

THE COMPANY

B.1. VAN OORD N.V.

FORMAL ORGANISATION

Van Oord was founded in 1868 and is an N.V. The family Van Oord holds 78.5% of the shares. The remaining shares are equally divided to Ulran S.A. and ConsOord B.V.
The Executive Committee is responsible for managing Van Oord. The C.E.O of Van Oord is Pieter van Oord. Furthermore, the company has a supervisory board which is responsible for supervising the strategical planning and the company's policy. The supervisory board also oversees the executive committee. Van Oord has four business units:

1. Dredging
2. Offshore wind
3. Offshore
4. The Netherlands

Besides the business units, Van Oord is divided into several departments. Some examples of departments are; engineering and estimating, finance and control and ship management. Van Oord has two offices in the Netherlands. One in Gorinchem were mainly the offshore departments are located. The head office is located in Rotterdam.

PROJECT MANAGEMENT

Van Oord uses the following overview of the processes from acquisition of a project untill the finall product:

1. Acquisition. An Area director starts the acquisition in line with the approved annual plan. The area managers executes acquisition in compliance with applicable sanctions. Then is decided if there will be participated in pre-qualification of the tender. If Van Oord is invited to the tender the next step is to analyze and either accept or decline the tender.

2. Tendering. If the tender is accepted, a tender manager is appointed which will analyse the tender documents and the available data. The tender manager organizes brainstorm sessions and reviews. From the Engineering and Estimating and other relevant departments input is provided. The tender manager selects the design solutions, an execution plan and needed equipment. This will have to be run by the area director. Dependent on the level of the bid, different levels on the organization will have to approve the tender. The higher the bid, the more levels will have to accept the tender. If all the levels in the organization accept the tender, the tender manager hands over the files to the area director who will start negotiations. After this the area director decides whether to sign the contract.

3. Realisation.
    (a) Prepare: a project manager appoints a team and executes and monitors the procurement.
    (b) Execute.
    (c) Test commission: the project manager hands over the work to the client.
    (d) Maintain warrant.

STAKEHOLDERS

There are several stakeholders which are affected by activities executed by Van Oord. Below the most important ones are listed:

1. Clients: should be delivered with good quality, price and services.
2. End user: design should meet the demands. For example with respect to: flood safety, accessibility, space and energy.
3. Shareholders: sufficient return on investment.
4. Employees: good working environment, safety.
5. Society: minimum undesired side effects and sufficient safety.

STRENGTHS AND WEAKNESSES

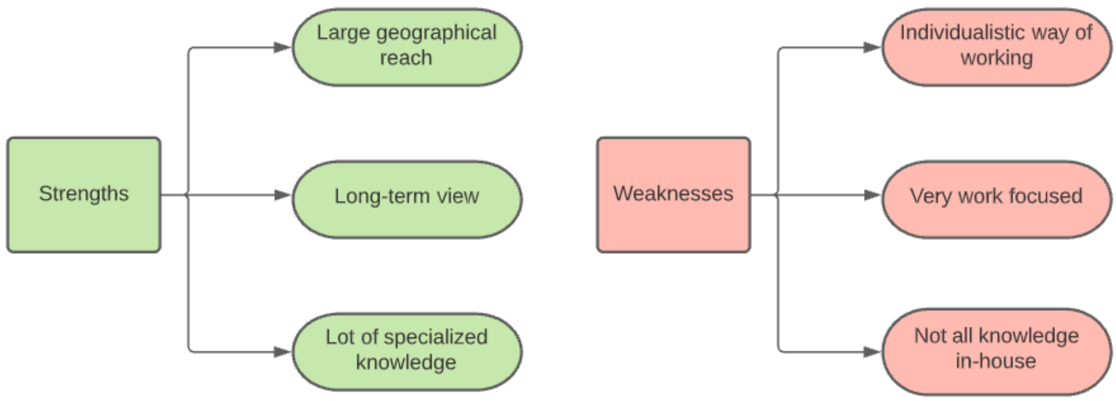


Figure B.1: Van Oord strengths and weaknesses

During my internship, a number of strong but also weak points within the company emerged.

1. Strengths
    (a) Large geographical reach. Being one of the oldest contractors in the world, Van Oord has executed works around the entire world. By maintaining good connections with the locals and providing them work Van Oord has expanded their reach throughout the world. Especially South-Asia, Africa and South America have a lot of business opportunities for Van Oord.
    (b) Long-term view. The world is shifting towards sustainability. A concept in which Van Oord is not lacking behind. They participated in the Climate Adaptation Summit in January 2021 and presented here their global tool: the Climate Risk Overview. With this map it becomes clear where to take actions to create a better world for future generations. Furthermore, Van Oord has it's sustainability themes closely linked to the 17 UN Sustainability Development Goals. Van Oord is also investing a lot in Offshore wind as being one of the most rapidly growing markets. Van Oord has recently announced that an order has been made for a vessel to install wind turbines up to 20MW (Durakovic, 2021). Current vessels are only able to install up to 12MW.

(c) Lot of specialized knowledge. Van Oord has been specialized in marine works since 1868. Van Oord is specialized in dredging and coastal structures, offshore works and offshore wind. Over the last 150 years the company has gathered knowledge within these specializations.

2. Weaknesses

   (a) Individualistic way of working. I noticed that the people within the company do not work together much. I noticed this especially within the coastal engineering department and can imagine that this also applies to the rest of the company. The Coastal Engineering department does not have any shared work spaces and the employees of this department all work on different projects. Especially for starters, this might give less opportunities to learn from your fellow coastal engineers. In this way, you are really on your own and figuring things out. I think this is a missed opportunity.

   (b) Very work focused. Of course, a company exists to work and should focus primarily on providing a good working environment and delivering good work. On the other hand, what I missed at Van Oord were activities aimed at creating non-work relationships between colleagues. I think that this way you create a working environment in which everyone feels more comfortable and there is more discussion about the work.

   (c) Not all knowledge in-house. Due to specialized knowledge there are also lots of disciplines which are not available within Van Oord. Within the coastal department I noticed that there was not much knowledge on sedimentation or modelling. Things I think that are also important to take into account when for example designing a breakwater. On the other hand, Van Oord has to make a decision where to specialize on and which disciplines to outsource.

B.2. ENGINEERING AND ESTIMATING DEPARTMENT

INTERNAL ORGANIZATION ANALYSIS

The internal organization of the department of Engineering and Estimating (E&E) is analysed using the method provided by Meyer, Hofstede and Belbin. This is a framework used to analyse the different group role within this department at Van Oord. This method uses six categories to define a culture. Below for the E&E department at Van Oord these six categories are evaluated.

1. Power Distance Index. This index considers to which extent inequality and power are tolerated. Within the E&E department there are of course different levels in organization. Nevertheless besides some people taking the decision, this is always done in consultation with others from the department. There is not a single person making final decisions. Everybody who has an opinion on something is heard.

2. Collectivism vs. Individualism. This considers to which extend the department is integrated into groups and dependence on groups. The E&E department is subdivided into groups such as coastal engineering, geo-engineering, cost estimating etc. There is not really importance on attaining personal goals as people work together on projects.

3. Uncertainty Avoidance Index. This index estimates to which extent uncertainty and ambiguity are tolerated. Within engineering of course risks can be accepted. But before they can accepted all risks should be know with their probabilities. I don't think that uncertainty and risk-taking have a high tolerance as is case of failure it can have high consequences. In engineering, ambiguity is very undesired as it might lead to errors which have great consequences.

4. Femininity vs. Masculinity. Although within Van Oord mostly men work, the company's goal is not to focus on material achievements and wealth-building but more on improving the quality of life. The latter corresponding more to feminine characteristics.

5. Short-term vs. Long-term Orientation. Van Oord has a very well long-term orientation. Examples from this are already mentioned and are their sustainability goals and investments in future prospects such as the growing offshore wind business.

6. Restraint vs. Indulgence. This considers the extent and tendency for a society to fulfill its desires. The working atmosphere at Van Oord is very relaxed. Everybody is trusted to finish their work in time. As long you comply with this you can work your own hours.

THE ACADEMIC CIVIL ENGINEER

There are several roles the civil engineer has within the E&E department:

1. Create designs. One of the roles for example from a coastal engineer is to create designs for a tender. This is done in different stages of the project and also results in different designs. The engineer receives input data and constraints and from this creates a design. This is done with the use of specific subject knowledge. Also important is the documentation and possible presentation of designs. So besides creating a design it is important to convince people in a structured manner why the design is the best.

2. Manage. In construction phases, the engineer has to make sure the design is executed correctly. Communication with the constructors is therefore importance. Also knowledge of equipment and construction phases is required.

3. Create business. Engineers can also be assertive and create business themselves. A good example from this is the global climate adaptation tool Van Oord has. Using data analysis and statistical skills the engineer can estimate whether business can be generated at a certain location.

4. Do research. Besides applying already known knowledge, engineers at Van Oord also contribute to new knowledge. Together with engineers from the TU Delft or other universities they conduct researches and write papers to document their findings. Some examples of researches in which engineers at Van Oord where involved are: Zaalberg et al., 2020 and Klein Breteler et al., 2019.

C

Personal Reflection

Below the personal learning objectives are listed which I put for myself before the start of the internship:

1. Get more insight in the design steps of coastal structures by talking to engineers about their personal experiences in the field.
2. Working in a professional environment. Having an active role in meetings, making decisions and sharing (intermediate) results.
3. Being a sociable colleague. Besides contributing to the professional working environment also participating in non-work related conservations.
4. If possible, visit a project site and see construction works is done.
5. Get to know more about careers at Van Oord (or large contractors in general).

I would like to reflect on these objectives to what extent I have met them.

More insight in the design steps of coastal structures

By actively participating in the Energy Island tender, I have gained much more insight into the design steps of coastal structures. I had already acquired some knowledge in this area during the course on breakwaters and closure dams that I took last April. Since this course mainly focused on a preliminary design, I was also interested in how the next steps were taken to arrive at a final design. Especially the opportunity to be physically present in the office and work with coastal engineers gave me the chance to learn more about these steps. Whenever I met new people from the coastal department, I always showed interest in their work and projects, and in this way I learned not only more about the design phases, but also about how the construction was carried out after the designs were finished. Something that really intrigued me was the cooperation with other nationalities. Someone told me about working on a project in Poland and how difficult it was to work with the locals because of differences in regulations and education. Another anecdote was about a project in Dubai on how to work with Arab people. Most of the Arab people involved in the projects did not like to be contradicted. You had to find a 'clever' way to show them that another solution might be better. I enjoyed these stories and it is good to realise that there is more to the profession than just coming up with a good design.

While working on the developments for the parametric design tool, I also got more grasp on the input parameters. Especially a small mini-lecture of Wouter Ockeloen gave me more insight into what value to choose for armour damage levels and toe damage levels. Parameters that were difficult for me to understand in the beginning.

Cost estimators have helped me more in understanding the constructability of a structure and how certain equipment can be used.

Altogether, I am happy to say that I've met this objective.

Have an active role in a professional environment

Every week I worked two days a week at the office to get the know colleagues from the coastal department. This contributed to a better professional and personal relation between me and the colleagues. I had two meetings a week, one with Arthur Zoon and Piet Zaalberg to talk about my progress and how the internship in general is going at Van Oord. If possible we did the meeting in real life instead of a teams meeting. Which I found much nicer as it is much easier to communicate to people face to face instead over a teams meeting. The other meeting I had was more specific on the Energy Island tender. Also here we tried to do it in real life with everybody who was at the office. I really enjoyed here showing everybody my results and see how enthusiastic everybody was about it.

During the start of my internship Arthur was still working a lot on the Twente channel project so I was mostly involved with Piet. After two weeks Piet also went on a two weeks holiday so I was pretty much working by myself. In some reason it gave me also a lot of opportunities to meet other people in the office and have an active role and reach out to other people if I was stuck on something. Everybody was always happy to help me and to see on how I was doing on the parametric design. When Piet returned from it's holiday he was impressed by all the work I had done.

Before meeting I sometimes created a small powerpoint slide to better let people understand on what I was working on. I noticed that by using powerpoint slides and figures or sketches people better understand what I was doing than just telling them.

At a certain point when I was getting familiar with the parametric design and it's possibilities I even started to come up with ideas my self on how the tool could be improved. Besides goals from Piet and Arthur I also implemented for construction methods things I came up with myself. A good example of this is the implementation of the loading charts for excavators and cranes as an installation requirement.

At the end of my internship I planned to presentations at Van Oord to show my results. One to the department of engineering and estimated in general and one for the Energy Island tender team. I really enjoyed showing my end results to the colleagues who helped me the last few weeks or other who where just interested. As parametric design is a promising development within Van Oord it was nice to see there were a lot of attendees who also where all very enthusiastic about the end results.

Being a sociable colleague

Besides going to the office two days a week to learn more about the profession of coastal engineer, I also got to know more people in the field. Besides the work, I really enjoyed talking to colleagues and hearing about their experiences of working for Van Oord abroad. The stories about Dubai, Indonesia and the Maldives particularly caught my attention. When I was at the office, I always went for lunch with a few colleagues from the coastal department or other interns/graduates. Especially the lunches at the end of the summer when the weather was nice along the river Maas were very pleasant.

Twice I attended the last Thursday of the month meeting where Pieter van Oord gave an update on upcoming business. During this meeting there were beers and snacks which I enjoyed with the younger colleagues. One of my last days there were drinks organised by Dennis at Bokaal. It was a nice way to end my internship with the team. We drank some Weizen Paulaners together and ate the famous patatje stoofvlees. One of Dennis' favourites ;).

After my internship, I can conclude that I got to know more people than I thought beforehand and that I will miss working with them. I especially enjoyed working with Piet, who put me at ease during my first days in the office and gave me tips on how everything works.

Visit a project

Unfortunately, I did not find an opportunity to visit a project.

Careers at Van Oord

I am really excited about the possibility of a traineeship at Van Oord. During the traineeship, you will work on three projects with a duration of nine weeks. I especially like the prospect of starting out at the company with a group of young people, the other trainees. In addition to the project, you will receive all kinds of training focused on self and personal development. After the traineeship, you can start working in a department of your choice.

Besides the traineeship, it is also possible to apply directly for a vacancy. I have also spoken to people who did not see the added value of the traineeship because they already knew what they wanted to do and therefore applied directly.

Working as a coastal/data engineer at Van Oord

Especially the combination of solving programming problems together with a coastal background is something I would like to continue doing. I think that this has also become clear to Piet, Arthur and Wouter and they have therefore offered me the opportunity to continue working at Van Oord for two days a week until February. In that period I will continue to develop the parametric design tool. What I particularly liked about working for a large contractor is that, in addition to the design itself, the company also carries out the construction. Also the possibility to go abroad and get to know other cultures besides working on projects is something that really appeals to me. Still, I am not sure whether I want to specialise in designing 'hard' solutions or more in 'soft' solutions. Therefore, I want to do a thesis that focuses more on sedimentation and these 'soft' solutions. I think this is a good way to find out for myself where my interests lie most. This could also be a good opportunity to find out more about a more consultancy like RoyalHaskoningDHV. To get started as a coastal engineer, there are a number of things I need to complete before I graduate.

1. Get to now more on equations such as the Vd Meer equations and other stability equations and its applicability. This can of course be done by completing the course Bed, Bank and Shore protection.
2. Choose a specialization in coastal engineering.
3. More knowledge about different companies. Difference between working between consultancies and contractors.
4. More knowledge on modelling of sediments.