Marine ingenuity

3D Parametric Design

Installation, Cost and Optimization

By: Dante van der Heijden
Department: Engineering and Estimating
Group: Coastal Engineering & Datalab
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Contents

1 Objective

Within Van Oord, the coastal engineering group is working together with the Datalab team to create a parametric design tool for coastal structures. This tool is an expansion of the python module 'breakwater' created by Winkel (2020) as a graduate at BAM. This tool allowed the user to create designs for rock rubble mound breakwaters, concrete rubble mound breakwaters and caissons based on known stability formulas such as the Van der Meer equation, the Hudson equation etc. By providing cost of the material this tool was also able to estimate the material cost for the entire section. Based on this total material cost the most optimal design can be chosen.

Besides material costs, costs also arise due to the installation of the structure and the transportation of the material. The way of transportation is also dependent on the installation methods so it is essential to expand the breakwater module with the construction of a cross-section. This was done at Van Oord in the period from August till November. After this implementation of construction methods it could be estimated which set of equipment could install a cross-section the cheapest and with the least installation time. Furthermore, besides costs in terms of monetary values it was also made possible to express the costs in terms of CO_2 emission. See the technical report of Dante van der Heijden for more information about the construction methods and CO_2 emission in the breakwater package.

As for now, designs and cost-estimations have been calculated for single cross-sections. The next step is to take the designs and cost-estimations to the 3D space taking into account a certain wave climate. This will lead to an estimation of the costs, duration of installation and CO_2 emission of the entire structure.

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Classes and Functions

2.1. 3D Battjes and Limitstates

Just as in the 2D space it possible to estimate the wave height distribution based on the method of Battjes and Groenendijk (2000). The only difference that there is no a wave climate instead of a single wave. This also holds for the limit state which is now defined for a wave climate.

2.2. Structure

A new class is created named 'structure_3D'. Same as in the 2-D space the slope, berm width, number of waves, densities and a grading must be provided. In the 2D-space the waves we're assumed to be always normally incident, in the 3D-space obliqueness will also play a role. Therefore also the wave climate must be provided. The last important parameter is a file containing the shape of the structure. Below some important things are summarized with regard to the design in 3D:

1. The file should be a keyhole markup language (kml) file
2. The shape is automatically divided into different sections. As it is not possible to draw circular shapes in the kml files these are small lines. For now, if the length of a single line is less than 10 meter it is considered to be part of a circular shape. It is therefore not possible to consider an entire circular shape as it will identified as a single section.

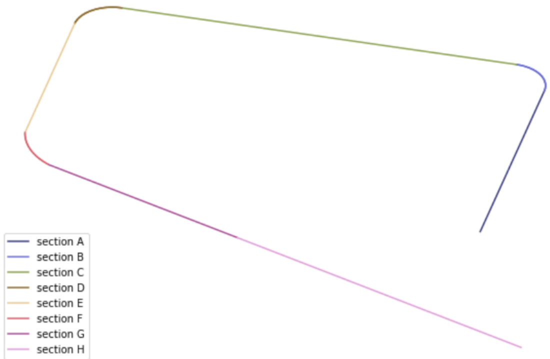


Figure 2.1: Sections in the top view

3. The shape can be a Polygon or a Linearring. In this case a Polygon is a closed shape and a Linearring is an open shape. This can be defined in the argument 'shape' which default value is set to Linearring. Figure 3.1 is an example of a Linearring.
4. To estimate the obliqueness of the waves a wave climate should be provided in stead of a single wave. Therefore also a wave direction should be provided. This can be done with the argument 'wavedirection'. This argument can be set to 'left' or 'right' and is 'right' by default. 'Right' means that when one

walks in counter-clockwise direction along the structure the waves are coming from the right.

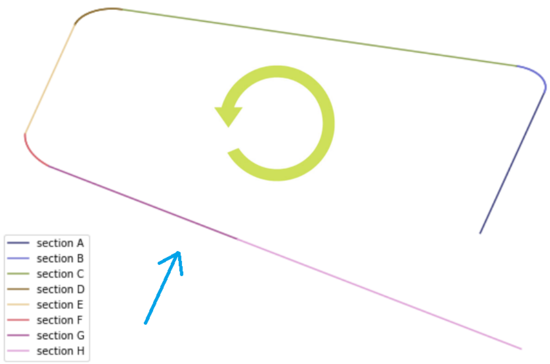


Figure 2.2: Wave direction from the right

5. A reduction of the nominal diameter due to wave obliqueness is only taken into account for the rock armour based on a research from van Gent (2014). Due to the lack of research on armour units there is no reduction factor applied which might lead to a conservative design.
   The reduction on the crest height due to wave obliqueness is taken into account.
6. For each section the design is chosen from the governing wave direction. This is thus the design with the largest D_{n50} and the highest crest height.

Functions of the class 'structure' are:

- plot_topview: plot the top view of the structure
- plot_section: plot the variant(s) of a certain section
- print_section: print the detail of the variant(s) of a certain section
- totalcost_3D: calculate the cost on either material cost, installation cost, CO_2 emission or combinations of them.

2.3. 3D DESIGN

For the 3D shape it will also be possible to create design within a certain design space for the crest width and the slope of the structure in a class name configurations_3D. This will be possible with the class 'Configurations3D' with the same inputs as structure_3D only now the crest width and slope can be defined as a design range in stead of a single value. The following functions are available for the configurations_3D:

- add_cost: compute cost, installation duration and CO_2 emission for all the generated designs.
- to_design_expolorer: this function has two different arguments with respect to the 2D variant. As one can imagine in 2D, N variants are created, in 3D there are $\sum_{Section=A}^{Section=n} N_i$ variants created. When combining all these variants to estimate all possible design this will result in $\prod_{Section=A}^{Section=n} N_i$ possibilities. For 8 sections with each 10 designs this will already lead to:

  $$8^{10} = 1073741824 \text{ designs}$$

  This is way too much to evaluate in the Design Explorer. Therefore two additional arguments are added: 1. reduce_on: on which cost estimate should the number of designs be reduced, either cost, CO_2 or install_duration 2. keep: this should be an integer, for example 3. Then the 3 designs with the lowest value on the reduce_on argument will be kept.

The images and csv-file generated for the DesignExplorer will also be similar. Combinations from sections will have different crest widths, slopes and crest heights. These variables are then not suitable anymore to adjust in the DesignExplorer. Only the variables cost, CO_2 and install_duration remain then.

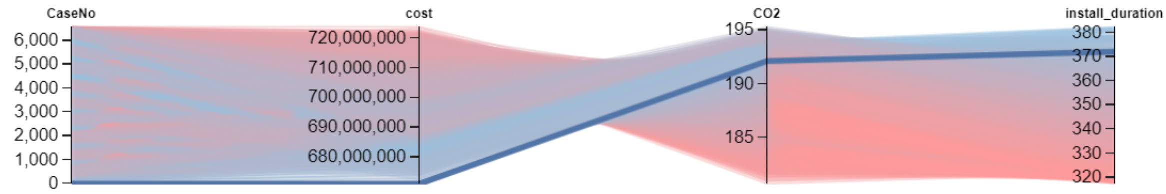
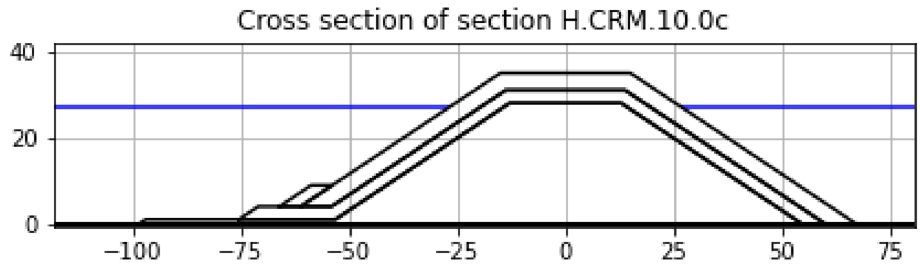


Figure 2.3: DesignExplorer for 3D Design. There are no CO_2 emission here added due to installations so the results are questionable.

As variables as the crest width, slope and crest height are no longer visible in the interface from Figure 2.3, this information is added to the images.



parameter	value
B	30.0
Rc	7.906
slope	33.7
class armour	62.5
class underlayer	10-13t
class filter	None

equipment
Hit1900
Liebherr300
SSD_resolution
Barge_Liebherr300
Barge_platefeeder

Figure 2.4: Design for a certain section with the information of the design

There is a Jupyter Notebook on the Van Oord Github available where all functions for the 3D design are demonstrated. If you are interested, reach out to Luc Kroon.

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FUTURE IMPLEMENTATIONS

3.1. INPUT AUTOMATION

A first start has been made to automate the input from a central server. Together with Carina Wierda from cost estimation relevant data has been put into this location and an API has been set up.

```
import requests
import pandas as pd


host = "https://sharepointproxy.data.vanoord.com"
api_key = "OJZFUDkPTy1oIgSwlgPFOkIjf6mrAlcT"
lst = "lists/b0afef99-aad4-4c73-b487-db1e6ea834f1"


url = f"{host}/{lst}/get.json"


res = requests.get(url,headers = {
"X-API-KEY":api_key
})

df_rocksupply = pd.DataFrame(res.json())



df_rocksupply
```

	id	Cost	Unit	Currency	Quantity	Supplier
0	1	72.0	mt	NOK	1.0	Skipavika Næringspark,, Sandevegen 631, N-5977...
1	2	70.5	mt	NOK	1.0	Dalsøyra 5960 Slovag
2	4	75.0	mt	NOK	1.0	Stema Shipping A/S Sydhavn 4, 1tv DK–6200 Aabenra
3	5	75.0	mt	NOK	1.0	Stema Shipping A/S Sydhavn 4, 1tv DK–6200 Aabenra

Figure 3.1: Rock procurement from the Van Oord sharepoint proxy

This information has yet to be specified in line with the required input for the tool. If necessary the tool has to be altered to match with the input provided from cost estimating. The latter mostly applies to the input automation for installation methods.

3.2. GEOTECHNICAL STABILITY

This part of the tool is currently being developed by Luc Kroon. Interesting would be to not only take into account the weight of the structure but also additional mass due to installation methods on top of the structure.

3.3. INSTALLATION METHODS

Dependent on the type of equipment conditions are based whether it can install a certain part of the structure or not. Figure 3.2 shows how an equipment object can be created. For the current tool it must thus be specified which layers it is capable of of installation, at what cost and what rate.

```
SSD_res = bw.Vessel(name = 'SSD_resolution',
                    layer_cost = {'0-200mm': {'cost': 59, 'CO2': None, 'production_rate': 14928.19},
                                  '0-300mm': {'cost': 55, 'CO2': None, 'production_rate': 15504.36},
                                  'QR 1-1000kg': {'cost': 57, 'CO2': None, 'production_rate': 14793.61},
                                  '60-300kg': {'cost': 58, 'CO2': None, 'production_rate': 14483.83},
                                  '300-1000kg': {'cost': 58, 'CO2': None, 'production_rate': 14483.83},
                                  '1-3t': {'cost': 74, 'CO2': None, 'production_rate': 1141.06},
                                  '3-6t': {'cost': 79, 'CO2': None, 'production_rate': 10528.30},
                                  '8-12t': {'cost': 65, 'CO2': None, 'production_rate': 13090.75},
                                  '10-13t': {'cost': 65, 'CO2': None, 'production_rate': 13202.16}},
                    waterlvl = MLW,
                    installation_waterdepth = 5,
)
```

Figure 3.2: Equipment object of a side stone dumper

A good improvement would be to replace this argument layer_cost to a reach of masses for which the equipment can be used. Then dependent on the mass and the location of the installed part of the breakwater the tool estimates costs and productions rates itself. Also the argument waterlvl contributes to this as the water level can cause downtime due to wave run-up, for land based equipment, or low water levels, for waterborne equipment. Taking tidal variations and the wave climate is also a good implementation with respect to the duration of installation.

3.4. 3D IMPLEMENTATIONS

Some implementations which can be made now the shift is made from a 2D to a 3D space:

- water depths are for now assumed constant in the entire reach of the structure. One can think of enough situations in which this is not the case. This might also lead to the choice for a different type of structure. When one part of the reach has a water depth it might be more viable to chose for a caisson at this part. The possibility to provide different structure types, water depths etc per section could be thus a good improvement.
- 3D movements of the equipment. Equipment is not only able to move back and forward but also to the right and the left.
- The amount of equipment working. Now it assumed that on each section, one set of equipment works. But most preferable would be to search for an optimum in cost and duration of installation.

Bibliography

Battjes, J. A., & Groenendijk, H. W. (2000). Wave height distributions on shallow foreshores. *Coastal engineering*, *40*(3), 161–182.

van Gent, M. R. (2014). Oblique wave attack on rubble mound breakwaters. *Coastal Engineering*, *88*, 43–54.

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