EXERCISE BREAKWATER DESIGN
GENERAL DESCRIPTION

1. INTRODUCTION

Welcome to the Breakwater Design Exercise. This document describes the details of your assignment and the required content of your report. In this exercise, you will design a breakwater for a port located somewhere in the world. The exercise is always linked to an actual, real-life breakwater design project. Upon completing the exercise, we will provide you with information about the actual project, allowing you to compare your results.

At the beginning of the exercise, you will receive a second document titled "*Case Description*". This document will disclose the location selected for this year, provide site-specific background information about the area, and specify the type of breakwater, the kind of armour material to be used, and the required technical lifetime of the structure. You will also be provided with the boundary conditions necessary for the design. However, you may need to perform additional nearshore wave transformations as part of your work.

2. GROUPS

The assignment will be carried out in groups of three students, where possible. This General Description is the same for all groups, and all groups will work on the same location. However, the details provided in the Case Description will vary for each group.

3. QUESTIONS

You are required to make a design of your breakwater section and describe how you would construct this section. You will have noticed that at the beginning of the exercise, you will have very little information, except for a location, a type, a lifetime and some limited background information. This means you will need to go through the entire design process and make numerous decisions yourself. The questions for your assignment are formulated specifically to help you through this process. They are listed below and elaborated in the following paragraphs.

Q1: List the failure modes that you want to include in your design. Select an appropriate design criterion for each of these failure modes. Also, specify the associated return period of the design hydraulic boundary conditions for each of these criteria. Describe your methods, support your choices and report your results in a table (See section 4.1)

Q2: Analyse the extreme wave data provided to you in the *Case Description* and determine the design wave condition(s) that correspond to your selected return period(s). If necessary, transform this (these) wave condition(s) from offshore to nearshore. Also, select appropriate values for the water levels and other hydraulic boundary conditions that you think are necessary, (See section 4.2).

Q3: Design a cross-section for your breakwater using the conventional (deterministic) design method. Perform the necessary calculations and determine the primary dimensions of your breakwater section for each of the failure mechanisms (and return periods) listed in question Q1. Ensure that you translate all results into practical numbers, e.g., using standard rock classes and so on. Report on your methods and results in the main text of your report. Provide the details of your calculation in an appendix, but please do provide the minimum explanation/equations/values needed to understand what you did in the main text (See section 4.3).

Q4 (only for HOS students CIEM4220): Make a calculation of the actual safety factor and/or failure probability of your design using a probabilistic method of your choice, and comment on the results. You only have to do this for one of your failure modes. (See section 4.4).

Q5: Work out your design into a to-scale technical drawing (See section 4.5).

Q6 (only for HOS students CIEM4220): Make an elementary project execution plan for the construction phase of your breakwater. This should contain at least a description of the construction phases, the logistics of the most important materials and an estimate of the total project duration. In this exercise, we do not consider construction costs. (See section 4.6). **This question should also be answered by Groups HE3.**

Q7: Describe the required laboratory setup to validate your conceptual design of the cross-section.

Q8: Give an overview of the most important risks and uncertainties for the project after this design stage, including proposed mitigating measures. (See section 4.7).

4. DETAILS

4.1. FAILURE MODES AND RETURN PERIODS

In this context, we loosely define failure modes as "all the things you want to make a design calculation for". Armour stability (how large should the rocks / concrete blocks / caisson of your breakwater be?) and overtopping (how high should the crest of your breakwater be?) are the two most obvious ones, but there could be more. Or maybe overtoppig is not important, but transmission is. You could consider factors such as reflection, toe stability, rear side armour stability, and so on. Some of these will be relevant, others may not. That depends on the actual situation for your location. You will have to make your own selection, but limit yourselves to failure mechanisms that were discussed in the lectures and/or lecture notes.

For each of these failure modes you can define one or more design criteria. For example, this could be "an allowable mean overtopping rate $Q = 1l/sm$", or "N_{od} = 0.5". You will need to consider which criterion is most appropriate in your situation. Each of these criteria should be coupled to a design return period and a limit state, e.g. " for the SLS we allow Q = 1l/sm for the R = 5y condition".

It is important to realize that, in most cases, it is useful to define more than one criterion/return level per failure mode, for instance by specifying both SLS and ULS levels. For example, it might be appropriate to allow a relatively large overtopping volume in extreme events, but limit the overtopping to smaller values for more frequent conditions. How large and how frequent is up to you to decide.

For some failure modes, the design criteria and/or return periods may be specified by the infrastructure owner; in such cases, you will find this information in the Case Description. In other cases, you will have to derive your own criteria and return periods, for instance, from an estimate of the allowable failure probability in the lifetime of the structure, or from some kind of design lifetime cost optimization analysis.

Table 1 Example table failure modes and design criteria. Replace by your own choices and numbers.

Failure mechanism	Limit state	Criterion		Return period
Overtopping	ULS	No damage to infrastructure	Q = 10 l/sm	Once per 50 years
	SLS	No inconvenience to pedestrians	Q = 1 l/sm	Once every year
Armour stability	…	Start of damage	…	…
	…	…	…	…
…	…	…	…	…

Your report should include a table that specifies your failure modes, along with the associated criteria and return periods. Provide your criteria both as a short description and as a numerical design value. You can use Table 1 as a reference. Please note that the values provided here are for illustration purposes only. You have to replace them with your own values and complete the table with the other failure modes that you have selected.

Note: Some failure mechanisms (such as filter stability) will not be dependent on the return period of the boundary conditions. In that case, just mention "N/A" in your table.

4.2. WAVE STUDY AND BOUNDARY CONDITIONS

We will provide you with enough information so you do not have to make an EVA yourself. However, the provided information cannot be used directly; you may have to analyse it in a little bit more detail before you can start your design. For instance, you will have to select the required direction or return period etc.

The provided information might be offshore, so you must transform your extreme offshore conditions to the breakwater site using one of the available methods (e.g. Swan, Goda, etc…). You might need to make your own depth profile based on the information in the case description. Describe your method and your choices in the report and illustrate these where necessary.

List your results in a table, as shown in Table 2. This table should contain the details of the wave boundary conditions for each return period that you have specified, both offshore and nearshore, if needed. Include the associated water level for each return period. If the wave period and wave direction are relevant to your design, include them as well. Consider which wave period metric (T_m, T_p, $T_{m-1,0}$, etc) is relevant in your case.

Table 2 Example table of hydraulic boundary conditions. Replace with your own choices and numbers.

Return period	Water level	Offshore				Nearshore			
		H_s [m]	Tp [s]	T_m [s]	Dir [°N]	H_s [m]	Tp [s]	T_m [s]	Dir [°N]
1 year	…	…	…	…	…	…	…	…	…
10 years	…	…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…	…	…

4.3. DESIGN CALCULATIONS

Provide a short description of the calculation that was applied for each requirement and related failure mode, and the conclusion that is derived from it. Give the name of the formula/design method and provide the proper reference. N.B. The Lecture Note(s) are not proper references; they collect equations and formulae developed and presented somewhere else.

Provide calculation details in an appendix if necessary. These calculations must be made using the conventional deterministic design approach. Make your own decisions related to what you consider to be safe values for the coefficients in your design formula.

Work out the entire cross-section, including armour size (front and rear), crest level, toe material and dimensions, underlayers, filter layers, scour protection, and core material (as relevant). If you decide that the structure should have a crown element or other superstructure, you must include that in your drawing and provide the hydraulic stability calculations.

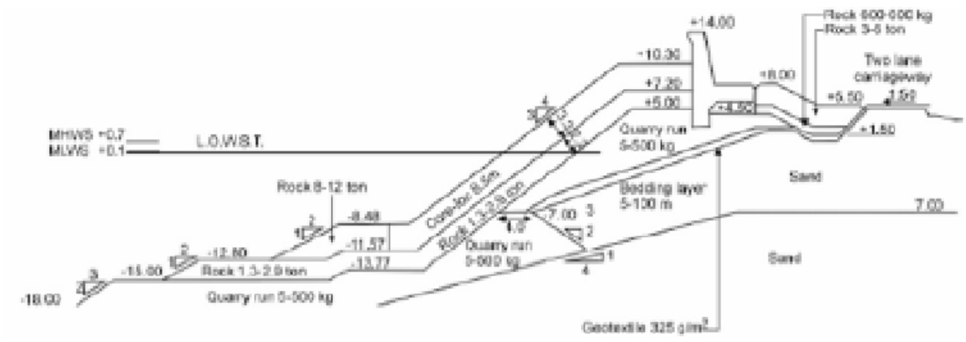

Figure 1: Example of technical drawing

If you use rock material, specify your rock sizes using the NEN-EN 13383 system. You do not have to specify rock quality parameters (such as compressive strength or water absorption) for this exercise, other than sizes/grading and density. If you decide to use non-standard gradings, provide a graph of the grading curve as well.

4.4. RELIABILITY ANALYSIS (only for HOS students CIEM4220)

You have made a decision about a return period, which should be based on a consideration regarding one or more allowable probabilities of failure ("target reliability"). In the deterministic calculation this probability of failure is no longer explicitly present; the actual reliability of your structure may have changed as a result of e.g. the coefficient values in the design formulas that you have chosen. In this part of the assignment we ask you to make a probabilistic assessment for one failure mode and one return period only (for instance, only for overtopping in SLS. Or only for toe stability in ULS. Make your own choice.)

Make a probabilistic assessment of the actual failure probability of this part of your design, using either a level II or level III method of your choice, and comment on the differences with the original target reliability on which you have based your return period. Describe potential optimizations (or areas that need improvement) in your design, but do not work these out in detail. You can use software packages like Prob2B or others to make these calculations.

4.5. DRAWING

Your report should contain a technical drawing of your designed section. This drawing should be to scale, and should contain sufficient details for a contractor to understand your design and make a cost proposal without having to read the report for further information. This means that at least all important dimensions and materials should be included.

You may use a CAD program to make the drawing, but if you are not familiar with such programs you can also use any other method as long as the result meets these criteria.

See Figure 1 for an example. You will find more examples in appendix H of the Breakwater design lecture notes.

4.6. PROJECT EXECUTION PLAN (only for HOS students CIEM4220)

Describe the construction method. Your report should contain the following:

- Make sketches of the most important construction stages, like the ones shown in Figure 2. Show the equipment used in each stage and give a very brief explanation (in one or two lines) of what happens in that stage. You do not have to work out your sketches as detailed and 'professionally looking' as in Figure 2, it is allowed to make sketches by hand. Additionally, you do not need to write lengthy descriptions of your construction method; simply providing sketches with a brief explanation will suffice.

- Make a table of all materials used in your cross-section and calculate the required volume for each material using the dimensions of your drawing; measure the length of your breakwater section from the drawings in the Case Description and assume that it has a constant depth. Tip: If you draw your cross-section at the average seabed level of your section, you will get a very accurate estimate of the total volume. Round off your numbers to practical values and ensure you use practical units, so rock in tons, concrete armour in number of units (“pieces” or pc). Describe the source of your material (e.g "local quarry", provide location) and the equipment you want to use to transport this to the project site. See Figure 2 as an example.

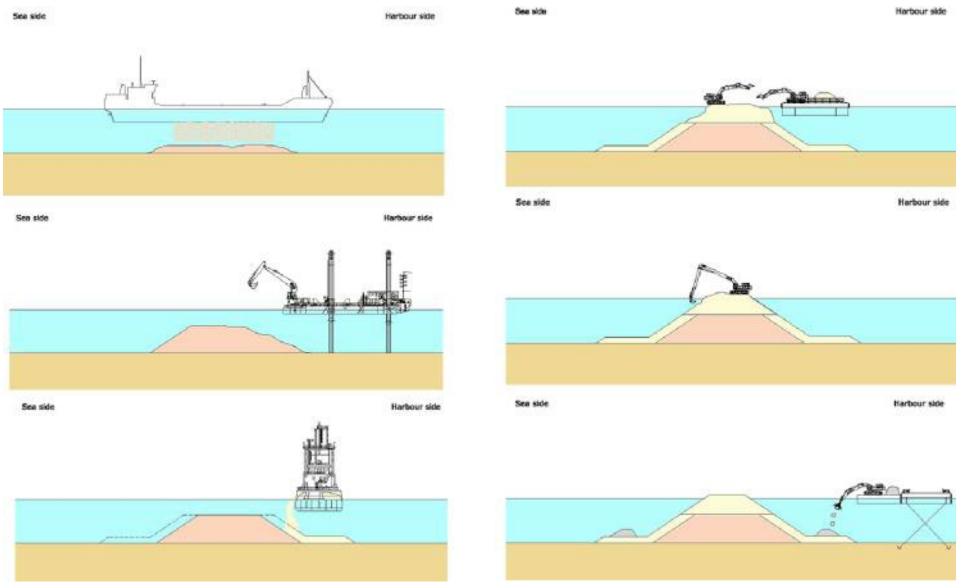

Figure 2 Example of construction stage sketches

Table 3 Example table material logistic

Material		Quantity	Source	Transport
Core	1-500 kg	500,000 t	Quarry ’The old Rocker’, Delft	Flat top barge
Underlayer	HMB300/1000	45,000 t	...	...
...	...	...	...	...
Armour	Accropode 4 m^3	2000 pc	Produced on site	N/A
...	...	...	...	...

- Select one activity (e.g. "core placement by split barge") at your own choice and make a production calculation for this activity. Estimate the volume/amount of material that can be placed per Nett Operational Hour (NOH) using the methods explained in the lecture. Estimate the workability (percentage of downtime due to wave conditions) for this activity and use this to estimate the number of NOH required per week. Estimate the total duration for this activity. To estimate the workability you may have to analyse (or estimate) the operational wave climate near your project site.
- Show the sequence of activities in a bar chart. Use the construction stages you identified in the previous step and add the most important project preparation activities. For the duration of the activities, use the calculated duration for the activity you used in the previous step, and make very rough estimates for the other activities.

4.7. MODEL TEST

A flume with maximum wave height of H_s = 20 cm and water depth at the wavemaker of 80 cm is available. Describe the required test setup to validate your conceptual design of the cross-section. Quantify the main dimensions of the test setup, like foreshore dimension, H_s offshore, T_p, h, armour size, Δ, and test duration. Discuss which risks under 4.8 can be mitigated, and which uncertainties (scale effects) remain.

4.8. RISKS AND UNCERTAINTIES

Now that you have completed your design and prepared your project execution plan, you should have a good idea about the risks and uncertainties that remain for the following stages of the project. Make a list of the top 5 risks that you see at this stage. For each risk, describe both the probability that the risk occurs (you can say "high", "medium", or "low") and describe the potential effects on the design or construction if the risk occurs.

Table 4 Example table risk register

Risk	Description	Probability	Effect	Mitigation
1	...	...	...	...
2	...	...	...	...
3	...	...	...	...
4	...	...	...	...
5	...	...	...	...

Try to be as quantitative as you can (on the basis of estimates, without making elaborate calculations). Also, provide a short idea on how this risk could be dealt with (mitigated), i.e. as a suggestion for the contractor or for your fellow designers in the next stage. In your list, include at least one design risk and one construction risk.

5. SOIL CONDITIONS

In this exercise, you will not address geotechnical issues. You may assume that the subsoil has sufficient bearing capacity and shear resistance, unless stated otherwise in your Case Description.

Note: This is an important simplification of real-world practice. In many breakwater projects, geotechnical failure modes are as critical as hydraulic ones.

6. REPORTING

You have to write a report to complete the assignment. There has to be one report per group. There is no requirement for individual reports per student. Your report should be concise and to the point. The main body of the report (excluding the table of contents, appendices, etc.) should not exceed **11 pages for HE students (CIEM3210) and 13 pages for HOS students (CIEM4220) in length**, including figures, and should be formatted with a standard font size (e.g., 10 to 12 points) and margins. If required, substantiating calculations and drawings can be added in appendices. However, the main **text should be understandable without reading these appendices**. The report should contain the items listed under Section 4, in a clearly recognizable way.

The report has to be sent to (a.antonini@tudelft.nl and b.hofland@tudelft.nl) in a digital copy by the deadline specified in the Course structure and dates. For the submission email please **put all the group members in Cc** and specify whether you are HOS or HE students!

7. PRESENTATION (only for HE students CIEM3210)

The design must be presented in a PowerPoint (or similar) presentation with **a maximum duration of 15 minutes, followed by 15 minutes of discussion, including questions from both peers and professors**. All members of the project team must be present during the session, but it is acceptable if only one member actually presents. The presentations are followed by a discussion, during which questions can be asked of all project members. Questions can be asked by the course supervisors, but also by members of other groups. In fact, active participation in these discussions is compulsory.

The presentations final schedule will be made available on Brightspace. The attendance is compulsory for the entire session, not just for your own presentation.

8. ASSESSMENT CRITERIA

Python, MATLAB, R, and similar tools do not “think”; they simply execute the instructions we give them. Therefore, we will not consider any code you provide as part of your evaluation. In fact, submitting code used for your analysis will be viewed negatively.

We will mark your performance on this assignment based on:

8.1. HOS - CIEM 4220

- The completeness of your report. If any of the items listed under Section 4 are missing, you will not get a final mark before you complete your report.
- The quality of your assessment of design criteria and return periods (20%), determination of boundary conditions (10%), design calculations and associated choices (20%), discussion of reliability (15%), drawing (10%), project execution plan (10%), model test (5%) and risk register (5%).
- The overall quality of your report (5%).

8.2. HE - CIEM 3210

- The completeness of your report. If any of the items listed under Section 4 is missing you will not get a final mark before you complete your report.
- The quality of your assessment of design criteria and return periods (25%), determination of boundary conditions (15%), design calculations and associated choices (20%), drawing (15%), model test (5%) and risk register (5%).
- The overall quality of your report, your presentation and your participation in the discussion sessions (15%).

9. FINAL RECOMMENDATIONS

The prospect of completing this assignment within the allocated time slot may seem daunting at first. However, it has proven to be very manageable (and usually also enjoyable) year after year — and sometimes even achievable in less time. We will conclude this document with a few words of advice to help improve your chances of success:

First of all, keep it simple. If you need to choose between various methods of analysis, or decide on the level of detail, be pragmatic. You will not earn extra points for unnecessary complexity — you will be evaluated on your ability to select the appropriate method for the given circumstances and to defend and explain your choices.

Remember that there are at least three people in your group. You will be able to deliver your report on time if you work collaboratively and divide the tasks where appropriate. If you feel overwhelmed by the amount of information and are unsure where to start, follow the steps outlined above and discussed in the lectures. Make good use of the calculation examples provided in the textbook and the supplementary reading materials.

Be concise and to the point in your reporting. There is no need to include a detailed description of the assignment or of the project location, nor to explain, for example, what the Van der Meer formula is. You can assume that the person reading and assessing your report is already familiar with this background. Instead, focus your report on the methods you applied, the calculation results you obtained, and most importantly, your conclusions and the rationale behind your choices.

Good luck

Alessandro