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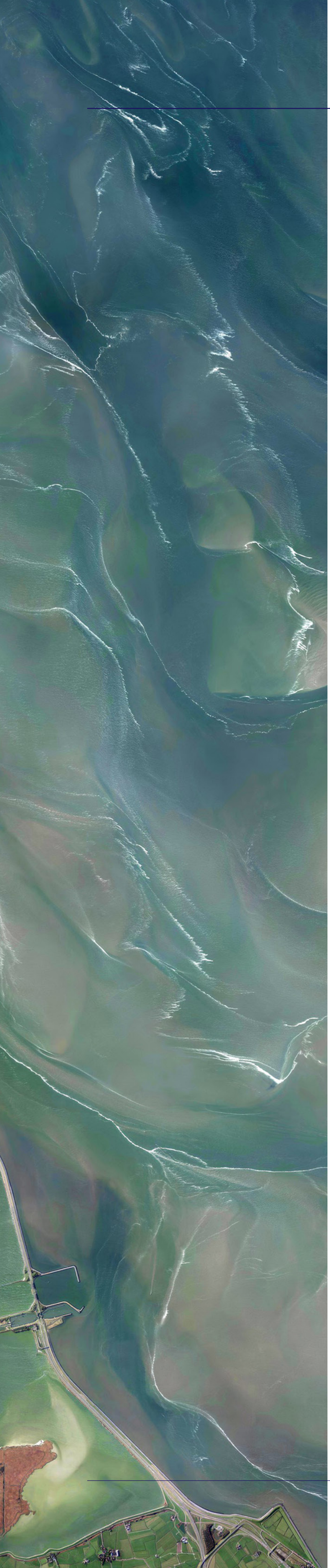


DEALING WITH COMPUTATIONAL INNOVATION IN DYKE REINFORCEMENT PROJECTS

Since 2023, the Dutch government no longer prescribes which calculation models must be used in the assessment of dykes. The water boards themselves must determine which method they use to calculate the probability of flooding. This enables the development of calculation innovations. Following various dyke assessments, the largest safety risk is caused by the failure modes of slope stability and piping, therefore substantial investment is being made to better understand these failure modes. In our research, we found a way to deal with computational innovation in dyke reinforcement projects by applying specific innovations and looking at their general implementation.

This study aims to investigate, for each project, the potential for application of two computational innovations still under development, namely shear strength of initially unsaturated soil for slope stability and bursting for piping. This investigation will show which components play a role in whether or not to include this computational innovation. The information is then incorporated into an assessment framework. The assessment framework aims to advise the water boards whether or not to apply these computational innovations in dyke reinforcement projects. Existing schematisations and semi-probabilistic analyses were used for the calculations. The main question for this study is, how can a trade-off be made for applying the computational innovations bursting and shear strength of initially unsaturated soil within dyke reinforcement projects?

Our study started with background research on the failure mode and computational innovations by reviewing the literature of research reports by the Dutch Water Board (Rijkswaterstaat), Deltares, the Flood Protection Programme (Hoogwaterbeschermingsprogramma

For the SAFE project, great returns were achieved at two of the ten locations.

(HWBP)), as well as interviews with experts in the field. Data was then obtained from contact with water boards about the specific projects, with which the application of the computational innovation to the project is calculated and a gap analysis is done. Based on these results and conversations with industry experts, an assessment framework was drawn up, substantiating the choice of whether or not to include the computational innovation. After the background research was completed, we started focussing on the computational innovations.

At first, we will take a look at the shear strength of initially unsaturated soil for slope stability. For the initial unsaturated zone, the computational innovation was applied to two projects in the Netherlands: Sprok-Sterreschans-Heteren (SSH) and Pannerdense Waard-Westervoort (Pan-Wes). From this application, it can be concluded that for both projects the computational innovation leads to a large reduction of the task by using a Su table, which determines the shear strength of soil with undrained behaviour. SSH went from 77% approved dyke sections to 91%, with three additional dyke sections. In Pan-Wes, the sections were rejected at first but after applying the computational innovations 90% were approved.

These results are considered significant but cannot yet be applied in practice because there are many uncertainties about the structure and behaviour of the dyke. Moreover, knowledge about the computational innovation is still developing in practice, which makes water boards cautious. A conservative assumption or more research is necessary, but the potential is visible.

For the computational innovation of bursting for piping, the computational innovation was applied to two projects, namely Mastenbroek-IJssel (MAIJ) and Streefkerk-Ameide-Fort Everdingen (SAFE). From this application, it can be concluded that for the MAIJ project, there is no difference between applying and not applying the computational innovation. No significant results were obtained here. However, for the SAFE project, great returns were achieved at two of the ten locations. At one of these two locations, there is certainly no more safety risk, at the other location there may be no safety risk. This means that the computational innovation produces significant results for the SAFE project because here parts of the task are dropped. These results cannot yet be applied in practice because knowledge about the computational innovation is not yet at a far enough stage.

Results

Our studies have produced results that address the probability of success for two specific computing innovations. From these results, discussions were held on what considerations should be made to substantiate the decision whether or not to include computational innovation within a project. From these conversations with experts, it can be concluded that the expected yield from the application of computational innovations is central to the choice of whether or not to include it.

On the other hand, the knowledge and information available about the innovation and the dyke are important. Little information results in high research costs and/or long waiting times, making the higher investment costs in the innovation. This assessment framework incorporates this acquired knowledge. Water boards must use the results of this assessment framework to enter into discussions (with the HWBP, for example) about which choice they will make for including the computational innovations. If, for example, the weighing framework shows that the computational innovation should be included, but they do not want to do so, they must be able to substantiate this and otherwise apply it.

By offering the weighting framework as an aid to water boards, they are provided with tools to support the choice of whether or not to include computational innovations in a project. This gives a water board or the HWBP guidelines for identifying promising projects. This reduces the chance of wrongly not including the computational innovations resulting in a chance of over-dimensioning the dyke. The social values associated with this, such as sustainability, cost savings (of tax money) and effective use of space, are in addition to this trade-off framework.

The levees are dimensioned strong enough through this flowchart because the amount of knowledge and information is included in the trade-off framework. This tests the certainty of the computational innovation tests so that the levee will meet the 2050 standard. Moreover, there is such climate action attached to the product, because over-dimensioning is prevented.

Explanation of weighting framework

The weighting framework (as shown in Figure 1) consists of four steps and is intended as an aid to the discussion about whether or not to include the computing innovation. This is often done during preliminary exploration but can also be done later in the process, because it

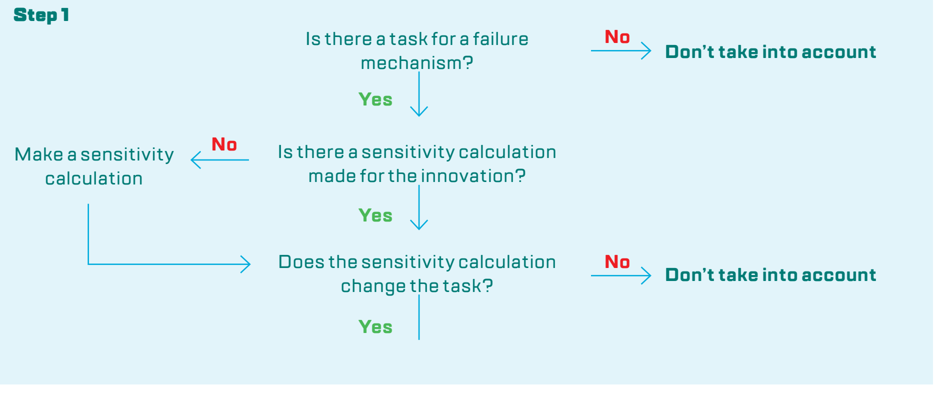
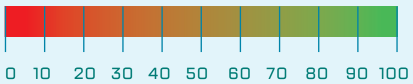


FIGURE 1

The weighting framework.

Potential

Cost and sustainability
Costs are saved by changing the task. Sustainability correlates with this change in the task, because sustainable options are predominantly cheaper but less robust.

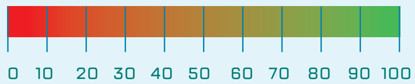


0 Task does not change
30 Optimisation measure
60 Change of measure
100 Task expired

Environment
Does the necessary measure damage the environment? If the computing innovation ensures that this is removed, there is greater motivation to include it.
Bonus score: 100

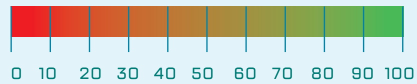
Knowledge and information

Subsurface and dyke material
Amount of information



0 Few
25 Moderate/ mediocre
50 reasonable
75 High
100 Complete

Innovation
Knowledge development stage



0 Just an idea - TRL 1
25 Hypothesis written - TRL 2
50 Laboratory and/or scale tests done and consistent with hypothesis - TRL 4
75 Practical test done and consistent with hypothesis - TRL 6
100 Innovation report delivered and validated - TRL 9

FIGURE 2
Grading scheme.

still seems promising due to possible changes in the project.

Step 1
The project determines whether it is possible to apply the computational innovation. This is done by first checking whether there is a task for the failure mechanism for which the computational innovation is intended. Then a sensitivity calculation is performed to see if the task changes when it is assumed that the computational innovation is fully functional.

Step 2
A score is given for the two components of potential and knowledge and information. This is done by filling in different part scores and based on that an average score is calculated.

For potency, there are two criteria. These are the criteria cost and sustainability, and environment. The criterion of cost and sustainability is based on the degree of change in the task. Cost and sustainability are linked here because they have a mutual correlation. When the project becomes cheaper due to the change in task, it is always also a more sustainable solution when it comes to levees. This is because cheaper often means less use of materials. The criterion environment is only included as a bonus criterion. This means that it can only raise the score and not lower it. This is done because this is about the extra motivation to apply computational innovations when the required measure damages the environment.

For knowledge and information, there are also two criteria. These are subsoil and dyke material, and computational innovation.
The subsoil and dyke material criterion deals with the amount of information that the water board has about the dyke. The score for this criterion can be increased by the water board itself by doing more research on the dyke.
The criterion of computational innovation is about the stage at which knowledge about computational innovation is now in. The stage is defined in Technology Readiness Levels (TRL). This is a widely accepted way of defining at what stage a computational innovation.

Using the results of Step 2, in which the total score of the potential and the knowledge and information are determined, a colour is assigned within a system of axes (see Figure 2). The table contains an explanation of how the line was determined.

Certainty: 0 Potency: 75 – From this limit, it becomes relevant to invest in more research, to wait for knowledge or to choose a conservative variant, because there is enough potential that can bear the risk of the large investment due to low certainty.

Certainty: 50 Potency: 30 – From this limit, it becomes relevant to invest in more research, to wait for knowledge or to choose a conservative variant, because there is a good indication by moderate certainty that the sensitivity calculation is correct and the potency covers the risk.

Certainty: 75 Potency: 100 – From this limit, it is stated that the computational innovation can be included because the potency is so high and the certainty is such that the remaining risk can be taken.

Certainty: 80 Potency: 50 – From this limit, it is stated that the computational innovation can be included because the certainty is so great and the remaining risk is carried by reasonable potential.

Certainty: 90 Potency: 15 – From this limit, it is stated that the computational innovation can be included because the certainty is so high that it can be assumed that it is correct.
Certainty: 100 Potency: 0 – At this point, it matters because you are completely certain but applying the computational innovation has no result.

Step 3

The advice was then developed for the different colours. For green, the computational innovation is promising and should be included. It is important to focus on risk management because it is still a computational innovation. For yellow, there are also opportunities for the computational innovation, but follow-up steps must still be taken to be able to implement the computational innovation, such as more research, waiting for more knowledge or making a conservative variant. Finally, for red, it is advised not to include the computational innovation, but at changes that might respond positively to the computing innovation, the flowchart should be used again from the beginning.

Conclusions

This research answers the question, how can a trade-off be made for including or excluding or not to include the computational innovations bursting and initial unsaturated zone within a dyke reinforcement project?

A decision can be made whether or not to include the calculation innovations by first looking at the dyke section at whether the sensitivity calculation changes the task, then giving a score on both the potential of the computational innovation and the knowledge and information. Based on a combination of these scores, an interim conclusion is given for the dyke section (green, yellow, orange) as shown in Figure 3.

Finally, based on the results of all dyke sections, the scope of the entire dyke section must be expanded. This involves looking at: what the outcomes mean for the complexity of the project; whether the results of other failure mechanisms play a role; and whether the effort required outweighs the benefits of the computational innovation. Using the assessment framework for the application of computational innovations helps water boards to decide whether or not to include the computational innovation. These dykes will be designed more soberly and efficiently, saving taxpayers' money and allowing more sustainable measures to be taken. Potentially more sustainable measures can be taken.

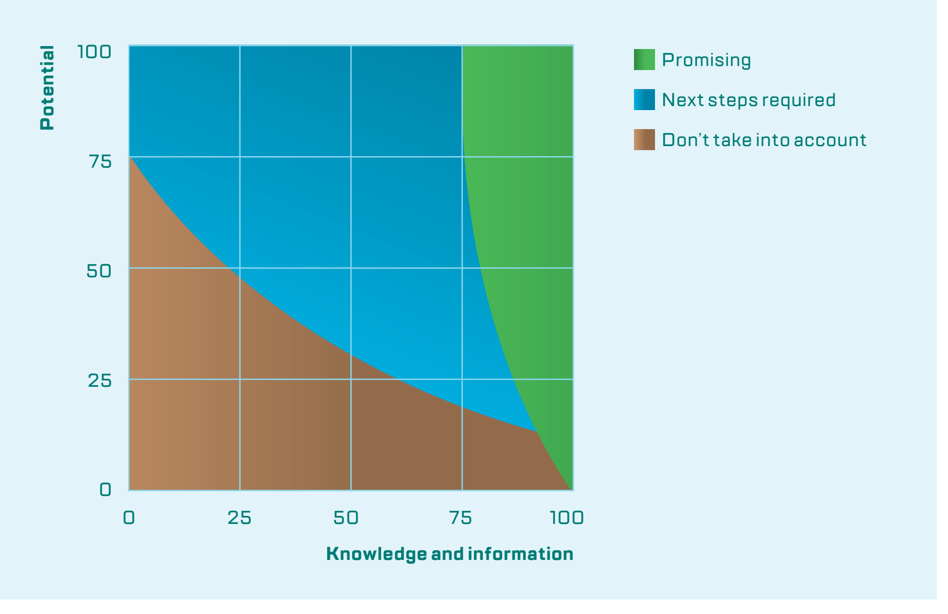


FIGURE 3

Recommendations.

Summary

This article describes our research of dealing with computational innovation in dyke reinforcement projects. Specifically, two computational innovations still under development – shear strength of initially unsaturated soil for slope stability and bursting for piping. It will describe which components play a role in whether or not to include this computational innovation. This information is incorporated into an assessment framework. The assessment framework aims to advise the water boards whether or not to apply these computational innovations in dyke reinforcement projects. The main question for our study was, how can a trade-off be made for applying the computational innovations bursting and shear strength of initially unsaturated soil within dyke reinforcement projects?

Dykes will be designed more soberly and efficiently, saving taxpayers' money and allowing more sustainable measures to be taken.

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