Delta dikes

Delta Dikes are designed to withstand the limited overtopping of flood volumes expected to occur as a result of extreme weather events linked to the projected impacts of climate change to 2100-2200.

1. Introduction

status: this topic is still under discussion

"Delta Dikes are designed to withstand the limited overtopping of flood volumes expected to occur as a result of extreme weather events linked to the projected impacts of climate change to 2100-2200. (NWP, 2009)" The essential difference between delta dikes and existing dike systems can be described as follows: Existing dikes are of such towering height that they cannot be overtopped during 'normative' conditions. The dike height is proportional to its strength and width. When normative conditions are exceeded, water overtops the dike crest. More importantly however, this increases the probability of sudden dike failure due to compromised structural integrity. This type of sudden failure can result in a flood event that will claim many casualties and cause great damage.

A delta dike is so massive and stable in structure that the probability of dike failure in extreme weather events is virtually zero. With a similar height, but wider and stronger structure than existing dikes, flood waves can overtop delta dikes in extreme - above-normative - conditions without compromising their structural integrity. This may create some water hazard, but not to the magnitude that would occur if the dike were to fail in a flood event. The images that exist about delta dikes do not always capture their essence. Multi-functionality, for instance, is often a characteristic associated with delta dikes. Now, there are still discussions underway about what a delta dike is or is not.

2. Related topics and Delta Facts

Keywords: Multifunctional dikes

Delta Facts: Building in and on flood defences

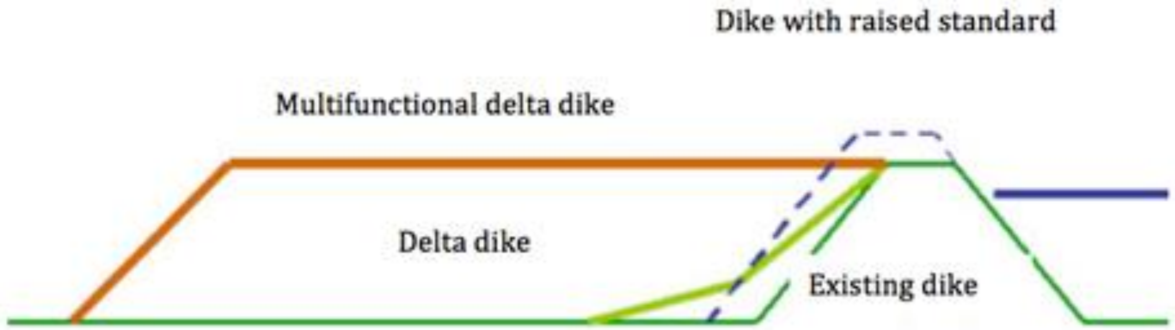
3. Multilayer safety strategy

Multilayer safety can be categorised into three main areas:

1 Prevention, 2 Spatial Planning, 3 Crisis Management

Delta dike falls under the first layer, prevention, but it is also inherently linked to the concept of mitigating consequences in the second and third layer. A characteristic typical of delta dikes is their resilience to overflowing and overtopping events, which means that the risk of water hazard occurring in the areas behind the dikes must also be taken into account. Delta dike falls under the topic dikes.

4. Schematic



In this fact sheet a distinction is made between 'delta dikes' and 'multifunctional delta dikes' in analogy to the on-going study "Exploring Delta Dikes":

- Delta dike: a dike that is of such structural integrity that it is highly unlikely to fail and lose its flood defence function in above-normative conditions.
- Multifunctional delta dike: an extremely strong or wide delta dike which, in addition to its flood defence purpose also offers room for other functions, such as residential development.

These types of dikes are referred to by other names in publications and the media: overflow dike, overtopping dike, climate dike and ‘unbreachable’ dike. The term delta dike was introduced by the Delta Committee (2008). The difference between the Multifunctional Delta Dike and the Delta Dike is that the latter is primarily a flood defence. In theory, a multifunctional delta dike can also serve as a place that can accommodate residential and landscape development or built-in tunnels, all located outside the free space profile of the flood defence zones of the Multifunctional Delta Dike. Multifunctional Delta Dike is often viewed as a desirable solution to combining other functions with the flood defence function in areas with high spatial density.

5. Technical specifications

As indicated above, there is no one type of delta dike. An example of how a delta dike can be designed is described in Silva and van Velzen (2008):

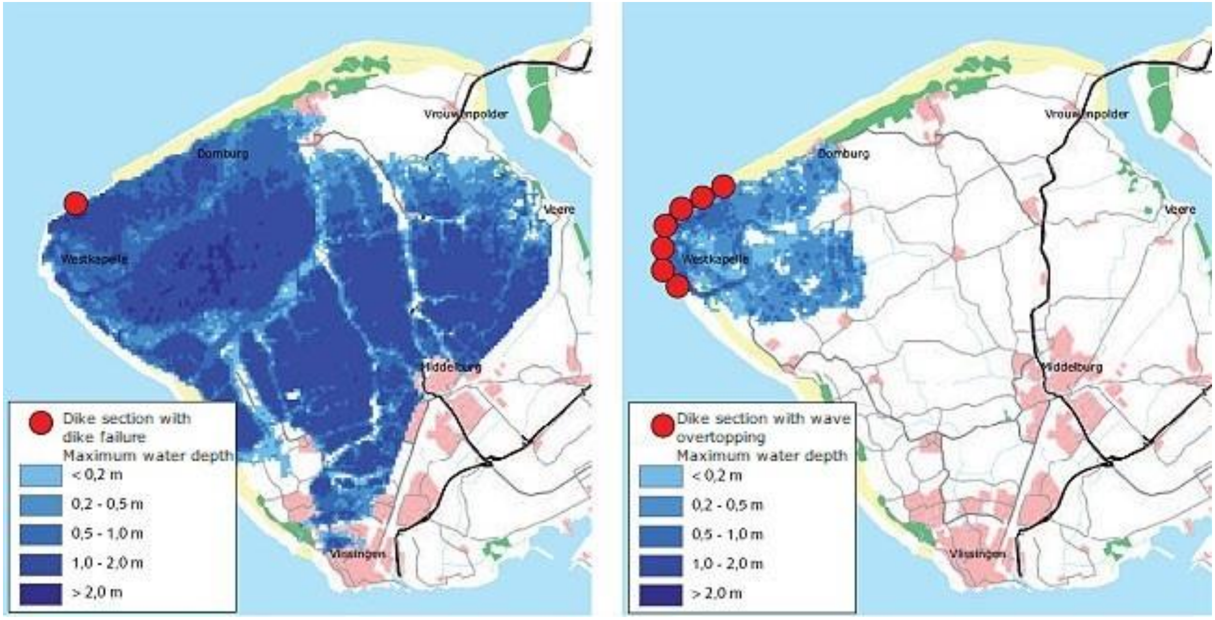
- The dike will not fail if water overtops or overflows the crest; the discharges defined for river dikes with a grass cover is 10 l/m/s and 30 l/m/s for sea, lake and estuary dikes (Silva and Van Velzen, 2008). This is in contrast to the standard overtop flow rate that is maintained between 0.1 - 1 l/m/s. (Guidelines for designing River Dikes and Guidelines for Sea and Lake Dikes)
- A delta dike has an inner slope of at least 1:3 (Silva and Van Velzen, 2008).
- The probability of dike failure is 100 times smaller than the current protection standard (Silva and Van Velzen, 2008). A factor of 100 has been applied to calculate the dike concept with a virtually zero failure probability.

The possible adjustments and reinforcement options are (Knoeff, van der Meij and Schelfhout, 2011):

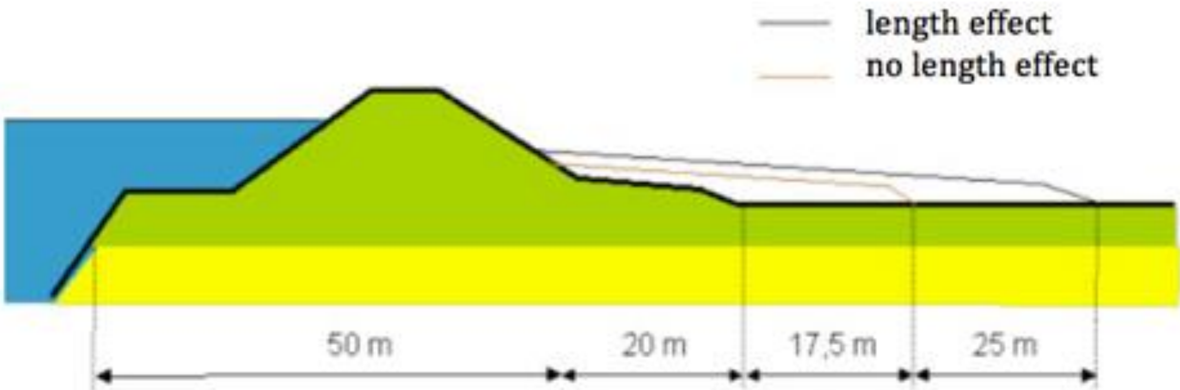
- Reduction of the inner slope
- Inner slope (hard/soft) revetment
- Widening of the dike
- Raising the crest (if the 10 or 30 l/m per second is exceeded)
- Building a verge, only if the dike is widened

Design/operation

Delta dike is custom-designed for specific locations, where it leads to a substantial reduction of water inflow.



The figures above show water hazard resulting from dike failure (figure on the left) and wave overtopping the delta dikes (figure on the right) in the dike ring area Walcheren (Silva and Van Velzen, 2008). The maps show the consequences of extreme water levels in existing/traditional dikes and delta dikes, respectively. Traditional dikes typically fail in above-normative conditions, causing a large section behind the dike ring area to flood in a very short time. The damage is significant and casualties are inevitable. Delta dikes, on the other hand, will continue to provide protection against sea or river water. The dikes remain standing. Water, however, will still wash over the dikes and create some degree of water hazard. Significantly less water flows into the dike ring and the water rises much less rapidly, giving people more time to seek a safe haven.



If the delta dike is situated along a riverbank, a 17.5 metre verge will be needed to reduce the failure probability of piping by a factor of 100 (no length effect). To achieve this flood probability factor at dike ring level, the verge should be extended by 25 metres (length effect). (Knoeff, van der Meij and Schelfhout, 2011)

6. Delta Dike positioning

The delta dike can be either an A, B or C-type flood defence, whereby some difference will also occur as a result of the (structural) solution chosen. In other words, it does not involve only one type of delta dike. The entire concept is based on the principle that delta dikes will be able to withstand higher volumes of overtopping/overflow waves as greater strength is guaranteed. In that context, the Delta Dike focuses mainly on the prevention of the following failure mechanisms (Knoeff, van der Meij and Schelfhout, 2011):

- inner slope erosion by wave overtopping
- outer slope erosion by wave attack
- inner slope displacement by piping and macro-stability

Based on the use of delta dikes, the following arguments can be made

Arguments for	**Arguments against**
If investment is made in a multifunctional delta dike, the dike construction could be financed by developing other spatial functions (Hartog, 2009)	Delta dikes involve significant additional costs. These costs, which are needed for oversizing the dike, may not be funded by the HWBP.
Sudden failure mechanisms (especially piping and macro-stability) are prevented where possible, resulting in a potential reduction in casualties (Calle, 2011)	Why suffer wet feet if you can build a higher dike?

7. Governance

Some focus areas from an administrative/legal perspective (Delta Programme; area pilot study, 2011, yet to be published):

- Laws and regulations will not prohibit the construction of delta dikes.
- Conversion of a part of a dike ring into a delta dike will create different safety levels within the dike ring, which is permissible in practice, but requires compelling reasons based on hydraulic engineering arguments, casualty risks and costs.
- Construction of delta dikes requires new design, management, maintenance and testing guidelines.

- It is advisable to communicate clearly about the water hazard that could occur in delta dikes in conditions above the existing normative conditions. It should be noted that this 'water hazard' only occurs in delta dikes if an existing dike has already failed.
- Administrators will need to pay close attention to social acceptance of delta dikes, given the higher costs involved and the amount of space they occupy.

8. Lessons learned and on-going study

No delta dikes have been built as of yet, but there are dikes and initiatives that can be considered a delta dike. A number of initiatives/dikes are described below, arranged per type of dike adjustment (Klijn & Bos, 2010).

- Reinforcement behind the dike (slope adjustment or verge). Examples in developed areas are the Nieuw Mathenesse Dike, the Stadionpark in Rotterdam and the Pettemer Zeewering. In rural areas, the Hondsbossche Zeewering is an example. Three generic concepts are associated with this form of dike adjustment: i.e. the terrace town, the mound dike and the overflow dike.
- Reinforcement outside the dike (slope reduction or foreshore). An example in urban areas is Tiel-Oost, in rural areas Hoorn-Edam.
- Reinforcement behind and outside the dike. This dike adjustment has the highest shape variation. Examples of bilateral reinforcement are Corlijnsplaat, Yerseke, and various MER alternatives for Hoorn-Edam and the concept of Dike City (shape concept) in Den Helder.
- Wide flood defence zone. This concerns two or more parallel dikes, a low quay situated in front of a high band dike or nearby artificial or natural (beaches, salt marshes) breakwaters in front of a dike. Examples are Perkpolder, Hondsbossche and Pettemer Zeewering and the shape concepts Sea City, Wieringerrandmeer and Tripledijk.
- Camouflaged dikes. In this situation, the dike is not or is poorly recognisable as a separate landscape element. Different functions are combined with the flood defence function, obscuring the height difference. Examples are Rotterdam Boompjes, boulevard in Noordwijk, Scheveningen and Vlissingen.

In other countries, such as Germany (Nordrhein-Westfalen), United States (New Orleans) and Japan (Tokyo), dikes have also been or are being constructed which share many similarities with delta dikes (Silva and van Velzen, 2008) (for the example in Japan, click here).

The study Exploring Delta Dikes (conducted by Deltares for the Rijkswaterstaat Waterdienst as part of the safety sub-programme of the Delta Programme) is expected to be released in the second half of 2011. The first insights in relation to assessment and design aspects of delta dikes are also discussed briefly in a separate memo (Calle and Knoeff, 2011, yet to be published). The costs depend on the specific design chosen and therefore vary for each type of delta dike. The costs are currently being assessed within the study.

On-going initiatives/pilots involve the following areas (Delta Programme; area pilot study, 2011, yet to be published):

- Dike ring 43: Delta dikes are used to provide additional protection for urban concentrations behind the flood defences (KAN area, Tiel, Culemborg).
- Dike ring 36: Developed strategies based on integral application of delta dikes along the Meuse and as a consequence, to a lesser extent in the other layers.
- Dike ring 22 (Dordrecht municipality): This area presents a high casualty risk from dike failure, in which case use of delta dikes appears to offer perspective.

9. Knowledge gaps

The delta dike is still in the early stages of development. The current study therefore aligns closely with the knowledge gaps. The consequences of measures such as the delta dike design and assessment of the dikes still need to be studied. In addition, the cost-benefit ratio is subject to study.

10. References & links

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11. Example

Deltares internal study report

Japanese example of a multifunctional delta dike

Both types provide adequate protection against the failure mechanisms overtopping and piping. The rolling out of the super levees in Japan is a long-term process; approximately 50 km of super levees have been developed since 1987. The dikes are built in phases, combining urban redevelopment with work on water safety. The biggest challenges in that respect are land ownership issues and local integration of the super levee.

The main differences with respect to the situation in the Netherlands are that super levees are also built to withstand earthquake impacts, which is not relevant for the Netherlands. There are also great differences in the water safety standards. The standard in Japan is 1/200 while a standard for the Netherlands in a similar situation is at least 1/1250.

12. Disclaimer