



Work instruction / guide

How to use sandbags as flood emergency response measure?



Background information document

Workgroup 'Professionalizing Levee Guarding'  
( 'Professionalisering Dijkbewaking' ) together with the Dutch  
WIKI Flood Emergency Response community

Version: **06-02-2023**





# Work instruction: how to use sandbags?

## Background information

**Author** Jaap Bronsveld, Water Authority Rivierenland  
**With support of** Ulrich Förster, Deltares  
 Adrie Kraaijeveld and Arjan Krikke, Water Authority Rivierenland and member of the working group '*Professionalizing Levee Guarding*'  
 Members of the '*Crisis Expert Team Water Defenses*' (CTW)

**Status** : Final

**Date** : 06-02-2023

### Version management

Version	Date	Changes
0.1	15-06-2022	First draft
0.2	05-09-2022	Second draft with Förster and Kraaijeveld
0.3	12-09-2022	Third draft concept before meeting CTW
0.4	13-10-2022	Slide order adjusted after try-out VHR-GZ
0.5	01-11-2022	Content adjustments after meeting sandbag science CTW
0.6	18-01-2023	Text adjustments
1.0	06-02-2023	Final by authors
1.0.1	14-02-2023	English translation



## Table of Contents

Introduction.....	4
1. Materials and general instructions.....	5
a. Personal safety .....	5
b. Size and filling.....	5
c. Shear resistance .....	5
2. How to stack sandbags.....	7
a. Passing on.....	7
b. 'Bottom on top' .....	7
c. Run-up and leakage.....	7
d. Half-brick and cross-stacking.....	7
e. Subsurface bearing capacity.....	8
3. Vertical stacking of sandbags .....	9
a. The height.....	9
b. Overflow and overtopping .....	10
c. Sealing with geotextile .....	10
4. Sand boils .....	12
5. Special situations.....	13
a. Ditch .....	13
b. Wall.....	13
6. Don'ts .....	14
7. Real-life aspects.....	15
Bibliography.....	16
Links.....	17



## Introduction

At high water, sandbags are an important tool for the use in emergency situations. Water Authorities use this material/emergency measure for various purposes. But there is a lack of good (English) working instructions on how sandbags can be used in certain situations.

The Working Group Professionalizing Levee Guarding wants to offer well-supported instructions to water authorities and other organizations. This background document provides the justification for choices made in this instruction.

This instruction is limited only to the actions required to use sandbags during a flood crisis. It does not address a choice of sandbag type or use in other situations.

Included with this background document are:

1. A "train the trainer" presentation with the operations illustrated step by step, to be used in an office instruction (PowerPoint + text booklet).
2. A field instruction with a collection of images including brief instructional text (PowerPoint, also to be used as a booklet).

### **Reading Guide**

This document and instruction cover general instructions and basic operations for sandbags. This is followed by the operations to be applied for sand boils and for a vertical stack. Then we cover the application at a ditch and a wall. We conclude with what not to do. The numbers in the presentation, the field sheet, and this background document correspond.

Research questions appear as red text in the document.



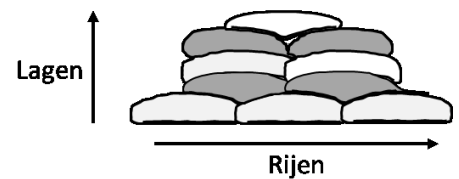
## 1. Materials and general instructions

Layers = the number of sandbags forming the height of the stack.

Rows = the number of sandbags that form the width of the stack.

Bottom = the bottom of the bag.

Top = the side of the closure or the side that remains empty.



### a. Personal safety

Always follow the regulation regarding personal safety. Take enough rest and drink and eat sufficiently.

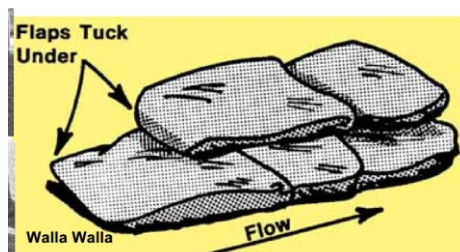
### b. Size and filling

- Sandbags have an average size of 30-35 by 55-70 cm. We choose 40x60 cm as a standard.
- Fill them max. 2/3 with sand. Bags that you have filled completely are not good for shaping or lifting.
- The resulting thickness when used in a stack is 8 cm.
- Not more than 15 kg sand in a bag. A heavy mass results faster in fatigue and exhaustion when handed over to someone else.
- The loose/empty end of the bag, the top, is needed to stack bags correctly.

Found on Wiki Emergency Measures: "How to handle sandbags" and in Koppe (2018)

#### [WIKI How to handle sandbags \(Dutch\)](#)

- The filling rate is 2/3 of the bag (Schmidt, 2014; USACE, 2007) and Wiki Emergency Measures.
- Tie or sew up the bags so that sand cannot wash out. Do not use open bags. Wave action can wash the sand out of the bags and wash it away due to reduced weight (USACE, 2007; p.45).
- As a rule of thumb, use two fist-widths of void in the bag, one above and one below the tie wrap binding (Koppe, 2018; p. 25).
- A test in Polder2Cs showed that modern sandbags lose material at the stitched filler seam. Probably due to the stitching gap that provides an opening. We recommend flipping the pocket edge first, before stitching.
- If sealing materials are missing, as a fallback, you can flip the open top and put it under another pocket (Koppe, 2018, p.25; TOHSEP). The folding edge reduces the chance of sand leaching out.
  - <http://www.tohsep.com/SandbagLocations>
- According to these sources, an open top should be placed against the current. However, we strongly advise against an open top.



### c. Shear resistance

Internal and external shear resistance of stacking is necessary for sufficient stability. Jute traditionally shows good frictional resistance and scores better than plastic bags. The work instruction 'How to



Handle Sandbags' on the WIKI 'Noodmaatregelen' advises against plastic bags because of sliding. De Vries conducted a comparative study of materials (De Vries, 2020; p. 13-17) and showed that jute is more suitable than plastic bags.

The water authority De Stichtse Rijnlanden solved this by making bags rough on one side (transverse to the bag) using a particular sort of weave. That method has not yet been studied (De Vries, 2020), but has indeed turned out to be rougher in practice.

Jute and some types of plastic bags have a crosswise fiber that gives crosswise resistance. Therefore, you can stack those crosswise in layers.

The modern type of bag with a handle ("purse") provides resistance in one direction. Those have to be stacked all in the same direction.



## 2. How to stack sandbags

### a. Passing on

When handing over sandbags in a chain, stand alternately facing each other. This leads to the least rotational strain on your back. Furthermore, you can look each other in the face.

Line up the people in the chain by length. This saves energy when lifting by short people.

Also, carry the bag close to your body.

Bags can be carried on the forearm, like a forklift. This results in less strain on your hands.

Allow for 1 person per meter of the passing chain (Schmidt, 2014) p.7.

A "chief of the chain" is needed, who provides **RVP**:

1. **Resting moments:** let the chain rest and eat/drink sufficiently.
2. **Variety of tasks.** Picking up and laying down sandbags are tough tasks, rotate them.
3. **Proactively manage the chain:**
  - Signal what is happening and act accordingly. The helpers should not have to wait all the time with bags in their hands. Give timely signals for this. The chain should be deflated during instructions.
  - Determine the proper pace of passing: the person at the end of the chain must be able to handle the supply for proper stacking.

### b. 'Bottom on top'

All sources consulted recommend 'bottom on top' for a better interconnection and protecting the fastener. Loose tops are fragile.

Do not let the bag drop on the ground but place the bottom first and hold the top longest.

### c. Run-up and leakage

For a firm packing of the sandbags, a good connection to each other and to the surface or the side of an object, it is necessary to tread the sandbags by walking on them (Wiki Emergency Measures), (Nottawasaga Valley Conservation Authority, n.d.), (Koppe, 2018).

During the tests at Flood Proof Holland, participants observed that the sandbags deformed due to internal sand flow (oral med. U. Förster, Deltares and A. Kraaijeveld, WSRL). We assume that firmer packing and less space in the bag reduce this risk.

American research shows that even a well-tightened stack can leak under laboratory conditions: at first load with water up to 8.7 liters/meter/minute, decreasing to 6 l/m/min at a water height of almost 90 cm as the packing of the sand improves (Wibowo & Ward, 2016).

We explicitly do not use the word 'pounding' in this instruction because it is too intense and prolonged pounding poses health risks.

For a better effect of "bottom on top," do not touch the last placed bag in the growing row: the sand will move into the empty top.

### d. Half-brick and cross-stacking

Literature does not always agree with the figures of the examples. But most of them explain that the strength of stacking is increased by half-stone and cross-stacking:

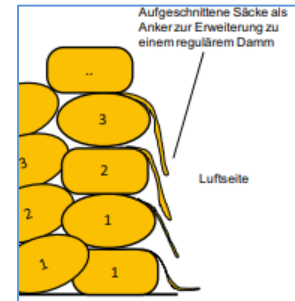
- When two rows are side by side, then stagger the bags by half so that the bottoms are not side by side. This decreases the chance of leakage under the bottom.



- When stacking two layers on top of each other, do this crosswise. This increases the interconnectivity.

This effect depends on the type of fabric of the bag. Jute and some types of plastic have a crosswise fiber that gives crosswise resistance. Thus, the weaving of the wires in both directions generates sufficient frictional resistance. You can stack those bags crosswise in layers. The modern type of bag with a handle ("purse") provides resistance in only one direction. In that case you have to stack those bags all in the same direction.

**Rule of thumb: "Friction crosswise, then layers built up crosswise. Friction one direction, layers in one direction".**



Another source (Schmidt, 2014) mentions suggests to put loose burlap bags between the layers on the inside as a measure to make any possible enlargement fit better, see Figure 1.

*Figure 1 Loose bags as coupling.*

#### e. Subsurface bearing capacity

If the subsoil as a whole has a sufficient load-bearing capacity, it may still be weak in some places. The total load of the stack of sandbags must not lead to the deformation of the subsoil. Here we follow the general principles of soil mechanics. This is site-specific and we suffice with a general warning that the executor must take this into account.

The question remains whether a geotextile or non-woven fabric leads to a higher bearing capacity of the subsoil. The CTW believes that it offers no benefits. A geotextile introduces a sliding surface and a non-woven fabric introduces a leakage path.

- Geotextile used to wrap a stack is slippery by itself and there is a risk that the wet stack on a pad of geotextile will shift as a whole due to water pressure. De Vries has not examined the coefficients of friction between sandbags and geotextile. However, he does conclude that a geotextile under the structure is providing a lower shear force (De Vries, 2020; p. 42).
- Road fabric has a higher frictional resistance, however, no studies of this are known.
- According to Ulrich Förster, a fleece or non-woven fabric can have even higher frictional resistance, but again no studies have been done on this. Therefore, it is important to look at the specifications of the supplier of these materials. The effect of weight on the non-woven, a water film that forms in the non-woven with possible leakage path and water stress: this has not been tested yet.





### 3. Vertical stacking of sandbags

#### a. The height

For the aspect "height", we consider the following factors:

1. stability stacking
2. effect of internal sand flow during overflow/overtopping
3. required freeboard
4. shortage of sandbags

#### Stability

All sources recommend stacking in the form of a blunt pyramid, starting with a height of three bags or two feet of water depth. The Wiki Emergency Measures recommends laying a double row at the base so that you can expand it when raised.

Sources differ on the aspect ratio of the entire stack, thus the amount of sandbags horizontally in respect to the height.

Manitoba (n.d.) suggests directions for a fairly steep stack:

- Base is height + "two feet" (60 cm).
- The crest of the stack must be at least 60 cm wide (= two rows of sandbags).
- Additional advice is needed for stacks higher than 'six feet' (= 1.80 m.).
- Include a 5% latch due to saturation bags.

Nottawasaga Valley Conservation Authority (n.d.) recommends a base of three times the height. This is a very stable ratio that requires many pockets.

TOHSEP recommends a base of 2x the height with a maximum of 1.50 m high.

- <http://www.tohsep.com/SandbagLocations>

Koppe (2018) recommends a base of 2x the height + 1 bag.

De Vries (2020) calculates different stacks without concluding about the number of layers of the same width or the height-to-width ratio. However, he does reason that the stacking "alternative" with 2 layers of the same width is many times more stable than those with three layers of the same width.

Förster via email:

"The sensitivity to imperfections (in stacking, size and fill rate of the bags, run-up) will increase with the size of the stacking."

#### Internal sand flow

Förster and Kraaijeveld describe an observation at Flood Proof Holland of the internal flow of sand in the sandbag. This occurs under the influence of overflowing or overtopping. Particularly at the top row of three-high-sandbags, this caused overhang and loss of stability (Figure 2). They, therefore, recommend a maximum of two layers high of the same width.

**Research:**

**The phenomenon of internal sand flow in sandbags has not yet been researched and described.**

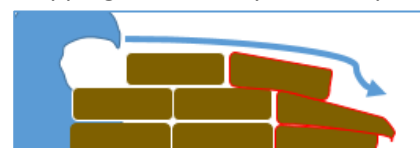


Figure 2 Schematic representation of the sand flow



**Freeboard** > see 3.b overflow and transshipment

### **Shortage of sandbags**

If there is a shortage of sandbags, we recommend first to achieve the required height and then extending the stability. Indeed, overflow and overtopping are important failure mechanisms for the stack of sandbags.

### **Conclusion:**

In the instruction, we recommend:

- max. 2 layers of the same row width;
- the foundation layer is always 1 bag wider so that staggered expansion is possible;
- the top layer should be at least 2 bags wide to prevent blowing away in case of overburden. Make the stack so high that this risk does not exist.
- Use sufficient freeboard to limit overburden.

### **b. Overflow and overtopping**

De Vries (2020) shows that freeboard "is important and plays a significant role in stability calculations" (p. 42). In the calculation, it is 15 cm.

Sources give differing opinions on the height of the freeboard, which makes sense because wave height conditions vary. The executor should make the freeboard high enough to limit larger amounts of overtopping. U.S. research shows that overtopping leads to stack failure due to several mechanisms (USACE, 2007). Failure began after only half an hour (Wibowo & Ward, 2016) in a stack with a single sandbag on top.

### **c. Sealing with geotextile**

Sources also differ concerning the usefulness and method of sealing with geotextile.

#### **Front 'waterproof'**

We found no source that demonstrates that a geotextile in front/around the stack provides a watertight seal. However, all sources do recommend its use to reduce permeability. We assume this is expert judgment.

American research describes that retrofitting a geotextile on the outside did not reduce leakage (USACE, 2007; p.208).

Packing a stack of sandbags is substantially different from an outer embankment for which the Wiki mentions that packing with geotextile does not help to counteract permeability.

- [WIKI Crest protection and outer bank with geotextile or geotextile \(Dutch\)](#)

**Discussion:** sources point out the risk of damage to the geotextile and protect it by stacking another row of sandbags against the geotextile on the waterside. Could a geotextile (woven) be an alternative?

#### **Protect inside from overflow/overflow**

All sources prescribe covering of the outside, the crest, and possibly a piece of inside-top with geotextile, but to leave the bottom of the inside of the stack largely free of geotextile. The reason is that geotextile under the stack is providing a sliding surface. Furthermore, complete wrapping can lead to saturation in the stack. This is because there is a good chance that the geotextile will not make it completely watertight.

Given these sources, coupled with the observation of internal sand flotation during transfer (Mouth. Förster and Kraaijeveld), we opt for packing the crest and upper layers of the interior with geotextile.

Weight the geotextile on top with a sandbag to reduce movement by water or wind. Most sources show at least one row, without further explanation.

**Discussion:** are two rows of sandbags on top necessary to prevent the bags from washing away when overflowing over the geotextile? Or is one row sufficient? No research is known about water entrapment in the stack either.

### Water confinement inside

To avoid trapped water inside the stack, the bottom layers inside must remain free of geotextile.

### Geotextile underneath

Do not apply geotextile under the stack due to the risk of sliding (De Vries, 2020; Koppe, 2018). Geotextile has a lower shear resistance due to its smooth nature. This introduces two forms of deformation of your row of sandbags with the same effect.

1. Geotextile begins to slide on the surface. Very low resistance because it creates a layer of water between the geotextile and substrate.
2. Sandbags are pushed off the geotextile by the water against it and water gets between the sandbags and the geotextile.

Geotextile underneath the entire stack can trap water in the substrate.

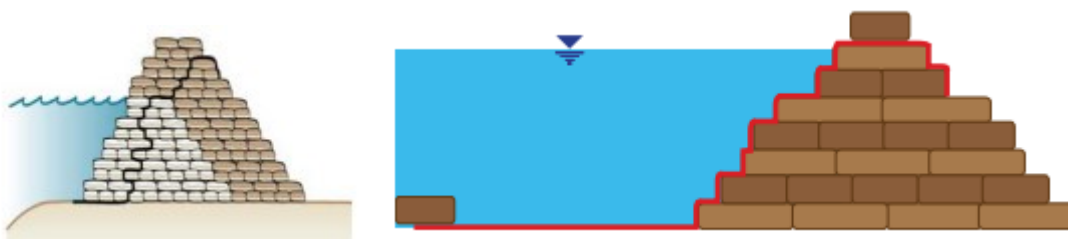
### Roofing

Lay the front of the film in a tile-like manner so that the flow can pass it and does not get behind an overlap.

### Anchoring film

To anchor the geotextile, you can place it under the front two rows of sandbags and then fold it forward and upward like a hood. On the inside of the stack, put the geotextile back under a sandbag to prevent it from blowing away. No source provides an example of this.

**Discussion:** how best to fix geotextile on the inside?



### Cut-out (notch)

The Nottawasaga Valley Conservation Authority (n.d.) describes a variant with an cut-out of the ground surface under the stack. We do not consider this advisable due to soil excavation, the time required, and the possible presence of obstacles, cables and pipes, etc.

### Material

Polyethylene **thickness??** with plenty of overlap on connecting rolls.



### **Workability**

Feasibility is a point of concern. The wind is a strong determinant of success. Lay out as little film as possible.

## 4. Sand boils

Based on Wiki Emergency Measures: encase sand boils with a ring levee according to the WIKI ([WIKI ring levee and sand boils \(Dutch\)](#))

There is no complete agreement within the CTW on the use of a water-permeable fabric over the sand boils.

The majority has the following arguments against the use of a fabric:

1. You cover the sand boil and can no longer clearly see what is going on.
2. Outflowing sand can push up the fabric.
3. There is a chance that the fabric will become less permeable in time and thus hinder the discharge too much. This may increase the pressure and cause a blow out at different location.





## 5. Special situations

### a. Ditch

In this, we follow the approach we described earlier.

Wear a wading suit and a life jacket.

Walk on the bags also underwater and also well against the ditch slope.

### b. Wall

Pack the wall, at least over a distance equivalent to half the width ( $1/2 W$ ) of the stack ( $W$ ) (Koppe, 2018).



## 6. Don'ts

- 1) Do not stack sandbags on clutter or sand. There is a risk of leakage. Advice based on Wiki Emergency Measures.

[https://v-web002.deltares.nl/sterktenoodmaatregelen/index.php/Hoe\\_om\\_te\\_gaan\\_met\\_zandzakken](https://v-web002.deltares.nl/sterktenoodmaatregelen/index.php/Hoe_om_te_gaan_met_zandzakken)

- 2) Do not place the top towards the water. This increases the risk of washing loose.

On this topic, sources are divided and there is also discussion within the CTW. Consideration:

- Koppe (2018) shows in drawing that the bottom is always towards the water and direction of flow.
- Manitoba (n.d.) places the bottom on the upstream side or waterside.
- The Wiki Emergency Measures comes up with conflicting advice.

**Discussion:** The chance of internal sand flow increases if there is more space in the pocket. This argues for putting the bottom where the packing is usually the largest, on the waterside, the downstream side, and on the inside of the stack. The rule of thumb then remains: no top part in free space.

- 3) Do not stack the bags sloppily and loosely. There is a risk of sinking of the stack. This is mentioned by almost all sources.
- 4) Do not alternate sandbags with bigbags. Any transition between sandbag and bigbag is a weakness.
  - a. Using bigbags does not add value to the stability of a long row of sandbags. If you want to stabilize, stack the sandbags out backward.



## 7. Real-life aspects

The work instruction comes from the assumption of an ideal situation. In practice and training, therefore, give attention to the following:

- Use of alternating types of bags as is done during high water: jute, plastic, nylon, big shoppers and shopping bags, fuller, and army.
- Apply to a rough surface: reeds, forest material, etc.
- Extending a previously made stack that is scuffed and skewed.



## Bibliography

- De Vries, P. (2020). *De inzet van zandzakken als noodmaatregel tegen dreigende overstromingen*. Rotterdam: Hogeschool Rotterdam.
- Koppe, B. (2018). Hochwasserschutz und Deichverteidigung. Hochwasserschutzfibel. Bremen, Deutschland: Institut für Wasserbau (Herausgeber).
- Manitoba. (n.d.). Sandbag Dike Construction. Winipeg, Manitoba, USA: Manitoba, Transportation and Infrastructure - Emergency Measures Organization.
- Nottawasaga Valley Conservation Authority. (n.d.). Temporary Flood Protection Using Sandbag Dikes and Walls. Essa Township, USA: Nottawasaga Valley Conservation Authority.
- Schmidt, K. (2014). *Einsatztaktik für die Feuerwehr. Hinweise zum Einsatz von Sandsäcken bei Hochwasser. Grundlagen*. Bruchsal: Landesfeuerwehrschule Baden-Württemberg.





## Links

### Wiki Flood Emergency Response

[https://v-web002.deltares.nl/sterktenoodmaatregelen/images/d/d7/De inzet van zandzakken als noodmaatregel tegen dreigende overstroming %28Pieter de Vries Afstudeerrapport%29.pdf](https://v-web002.deltares.nl/sterktenoodmaatregelen/images/d/d7/De_inzet_van_zandzakken_als_noodmaatregel_tegen_dreigende overstroming_%28Pieter_de_Vries_Afstudeerrapport%29.pdf)

- [https://v-web002.deltares.nl/sterktenoodmaatregelen/index.php/Hoe\\_om\\_te\\_gaan\\_met\\_zandzakken](https://v-web002.deltares.nl/sterktenoodmaatregelen/index.php/Hoe_om_te_gaan_met_zandzakken)
- [https://v-web002.deltares.nl/sterktenoodmaatregelen/index.php/Verhogen\\_dijkkruin\\_met\\_zandzakken](https://v-web002.deltares.nl/sterktenoodmaatregelen/index.php/Verhogen_dijkkruin_met_zandzakken)
- [Zandzakken vullen oefening Aa en Maas: https://v-web002.deltares.nl/sterktenoodmaatregelen/images/f/fa/Zandzakken\\_Vullen\\_V3\\_720P.mp4](https://v-web002.deltares.nl/sterktenoodmaatregelen/images/f/fa/Zandzakken_Vullen_V3_720P.mp4)
- [https://v-web002.deltares.nl/sterktenoodmaatregelen/images/9/93/HO702\\_wel\\_opkisten.pdf](https://v-web002.deltares.nl/sterktenoodmaatregelen/images/9/93/HO702_wel_opkisten.pdf)
- [https://v-web002.deltares.nl/sterktenoodmaatregelen/images/7/77/Werkinstructie stabiliseren zandmeevoerende\\_wel.pdf](https://v-web002.deltares.nl/sterktenoodmaatregelen/images/7/77/Werkinstructie_stabiliseren_zandmeevoerende_wel.pdf)

### International information:

- [https://v-web002.deltares.nl/sterktenoodmaatregelen/images/8/84/Hinweise\\_Sandsackverbau.pdf](https://v-web002.deltares.nl/sterktenoodmaatregelen/images/8/84/Hinweise_Sandsackverbau.pdf)
- <https://www.gov.mb.ca/emo/pdfs/sandbag.pdf>
- [https://www.nvca.on.ca/Shared%20Documents/Temporary Flood Protection Using Sandbags.pdf](https://www.nvca.on.ca/Shared%20Documents/Temporary_Flood_Protection_Using_Sandbags.pdf)
- <http://www.tohsep.com/SandbagLocations>
- [https://v-web002.deltares.nl/sterktenoodmaatregelen/images/c/c9/20180904\\_a4\\_handzettel\\_web.pdf](https://v-web002.deltares.nl/sterktenoodmaatregelen/images/c/c9/20180904_a4_handzettel_web.pdf)
- [https://v-web002.deltares.nl/sterktenoodmaatregelen/images/e/ec/20180904a6heft\\_einzelseiten.pdf](https://v-web002.deltares.nl/sterktenoodmaatregelen/images/e/ec/20180904a6heft_einzelseiten.pdf)
- [https://v-web002.deltares.nl/sterktenoodmaatregelen/images/3/3a/Paletten\\_packen\\_THW\\_Ortsverband Emden.pdf](https://v-web002.deltares.nl/sterktenoodmaatregelen/images/3/3a/Paletten_packen_THW_Ortsverband_Emden.pdf)

### Youtube videos (Dutch)

- [Video WSRL ophogen kade 1'51" – 2'54"](https://www.youtube.com/watch?v=bCII5AaiQA) <https://www.youtube.com/watch?v=bCII5AaiQA>
  - [Video WSRL stabiliseren wel in sloot 2'30" - 3'40"](https://www.youtube.com/watch?v=gWwblulasZk) <https://www.youtube.com/watch?v=gWwblulasZk>
- Preventive stacking sandbags <https://www.youtube.com/watch?v=ace4kHMrYDo>

### Sandbag filling machines:

Hydraulic sandbag filling machine <https://youtu.be/2JMfmCFnmmI>

Machine Delfland: [Zandzak vulmachine Mammut Nederland - YouTube](#)

Spiessens: <https://www.youtube.com/watch?v=WSJeIFRV4v0>

[The Sandbag Store® Ultimate Bagger - Mobile Sandbag Factory Filling Machine - YouTube](#)