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## The BAW codes of practice to ensure the bank stability of German inland waterways

Workshop on Seepage Induced Geotechnical Instability

Imperial College London, UK

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## German Federal Waterways



### Inland Waterways

total length:	7.310 km
canals:	1.740 km
ivers:	
• barrage controlled:	3.030 km
• free flowing:	2.540 km

### Embankments

total distance:	about 600 km
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### Waterway Structures:

• locks:	335
• weirs:	287
• canal bridges:	15



## Canal Embankments and Hydraulic Structures



Source: Wikipedia, Axel Hindemith



Source: WSA Uelzen

### Elbe Lateral Canal



Source: WSA Uelzen



## Embankments at Barrage Controlled Rivers

### Iffezheim Barrage Upper River Rhine



## Case of Damage at Elbe Lateral Canal (1976)

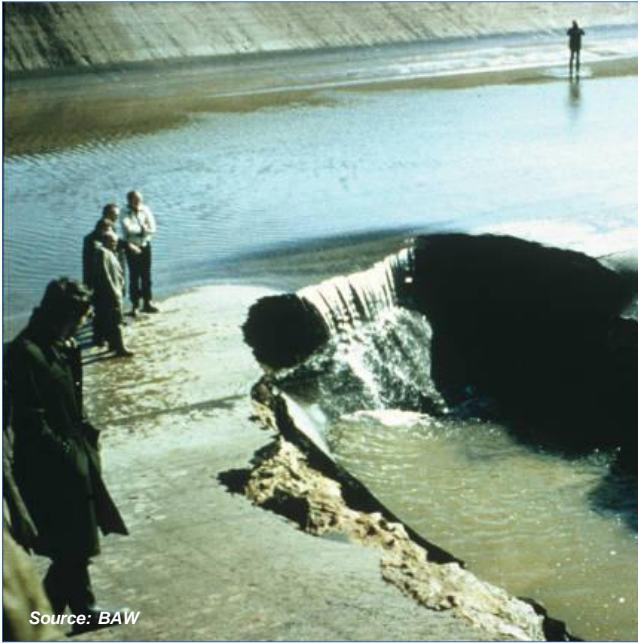


dam breach at road tunnel after  
flooding of a new canal section



Case of Damage at Main-Danube-Canal (1979)

dam breach at crossing with underlying water transport pipe after flooding of a new canal section



Case of Damage at Main-Danube-Canal (1979)

flooding of the village of Katzwang, heavy damages



## Conclusions - Impacts on Embankment Stability

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- embankments at waterways permanently loaded by water
- embankment stability reduced by seepage forces
- ∅ failure of the impervious lining of the canal bed with resulting seepage through embankments must be taken into account (accidental design situation)
- increased damage potential at junctions with structures in embankments
  - different stiffness of soil embankment and concrete structure
  - possible development of erosion channels along structures (piping) cause by seepage flow
- ∅ verification against piping for embankments with structures inside considering possible hydraulically effective joints (cavities) along structure/soil interface
- ∅ prevention of soil material losses by appropriate measures taking into account filter criteria and internal erosion processes

## Consequence of the assessment of the damages

### BAW Code of Practice Stability of Embankments at German Inland Waterways (MSD)

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**BAW Code of Practice**

**Stability of Embankments at German Inland Waterways (MSD)**

Issue 2011

- provides rules for assessing the stability of embankments, taking account of seepage through embankments
- covers the influence of structures in embankments (separate piping verification procedure taking account of possible cavities along structure/soil interfaces)

directly downloadable

[www.baw.de](http://www.baw.de)

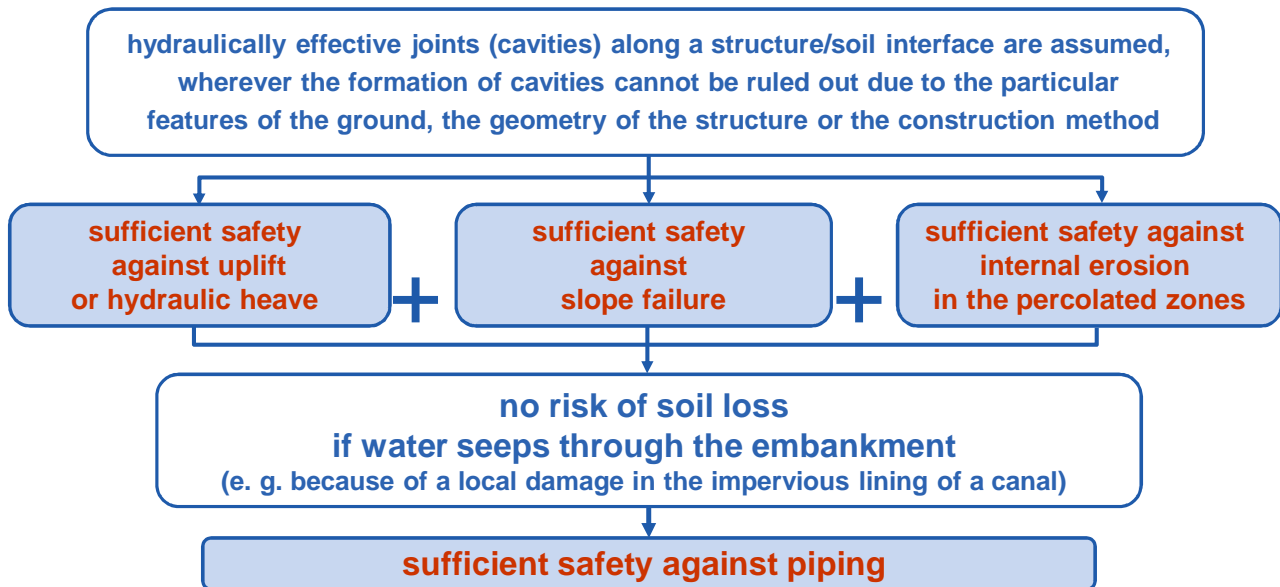
> service and knowledge

> publications

> rules and standards

> MSD (2011)

### Verification against Piping at Structures in Embankments



BAW Code of Practice

Use of Granular Filters on German Inland Waterways (MAK)

Issue 2013

covers practical advices for design and construction of granular filters used in

- embankments,
- bank and bottom protection and
- other structures on waterways

directly downloadable

[www.baw.de](http://www.baw.de)

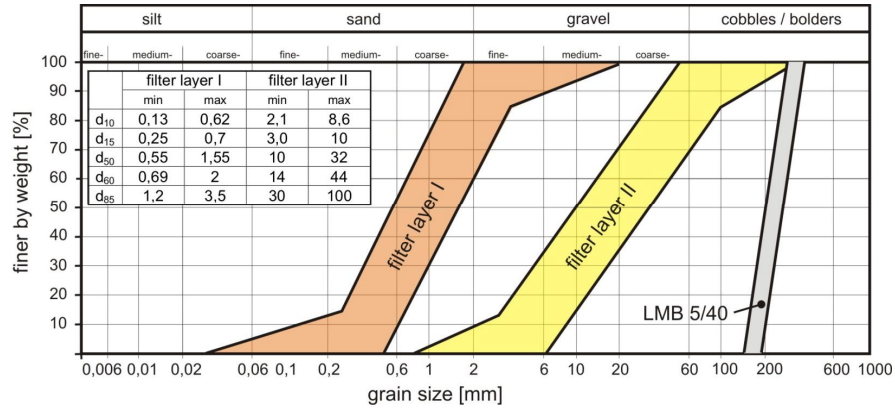
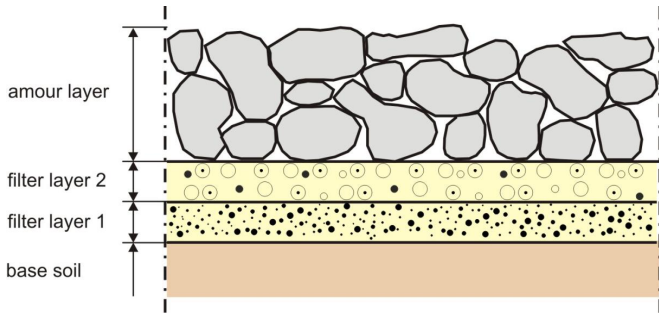
> service and knowledge

> publications

> rules and standards

> MAK (2013)

Standard two-stage filter for revetments at inland waterways



Acceptable ranges for grading curves in a standard two-stage filter

BAW Code of Practice Internal Erosion (MMB)



- describes verification methods based on geometric criteria of the soil structure
- recommended for dealing with specific hydraulic issues, e.g.
  - design of granular filters according to MAK (2013) or
  - verification of internal stability according to MSD (2011)

BAW Code of Practice:

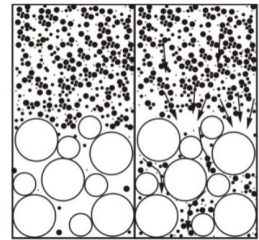
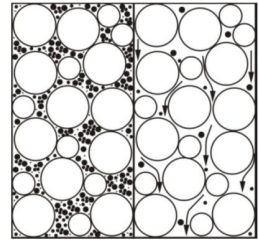
Internal Erosion (MMB)

Issue 2013

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[www.baw.de](http://www.baw.de)  
 > service and knowledge  
 > publications  
 > rules and standards  
 > MMB (2011)

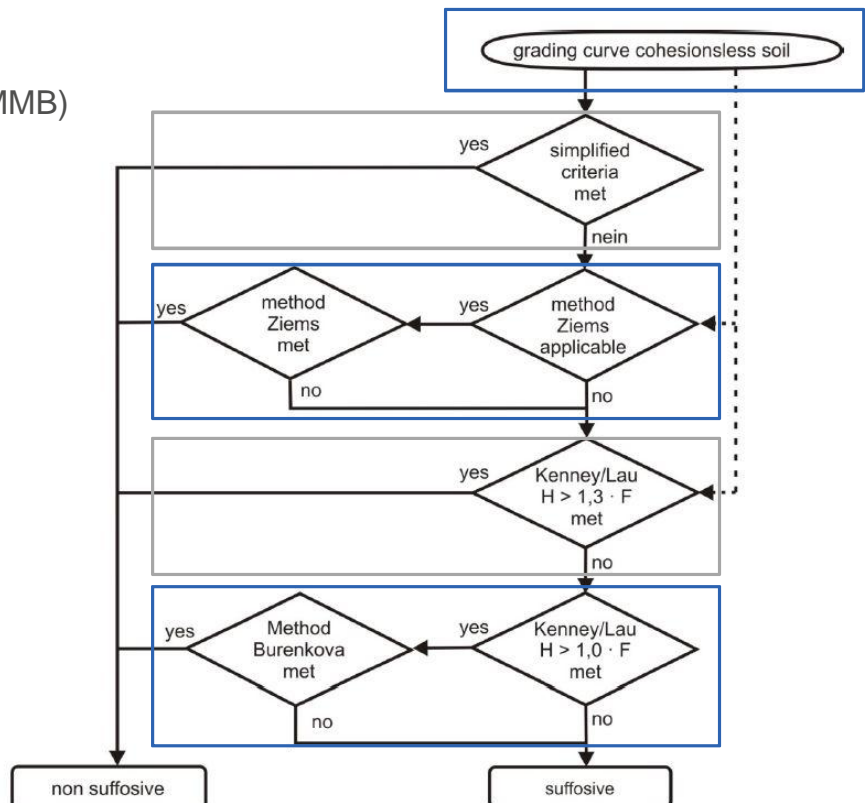
### Types of internal erosion

- Suffosion
  - migration and transport of the fine soil fractions through the pores of the granular skeleton of the coarse fractions
  
- Erosion
  - migration and transport of almost all grain size fractions of a soil caused by the flow of water
  - contact erosion
    - at the interface between two soils of different composition
  - piping
    - at the interface between solid structures and the soil or
    - between a cohesive soil and an underlying cohesionless soil layer



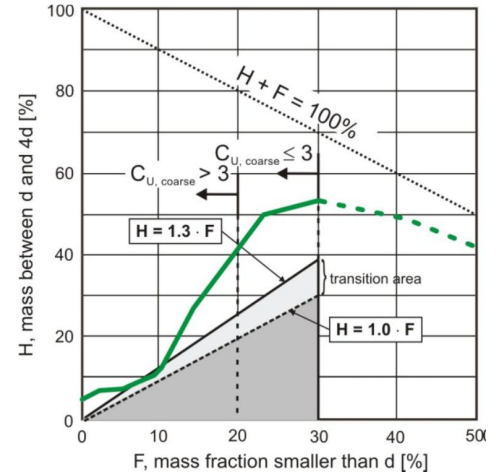
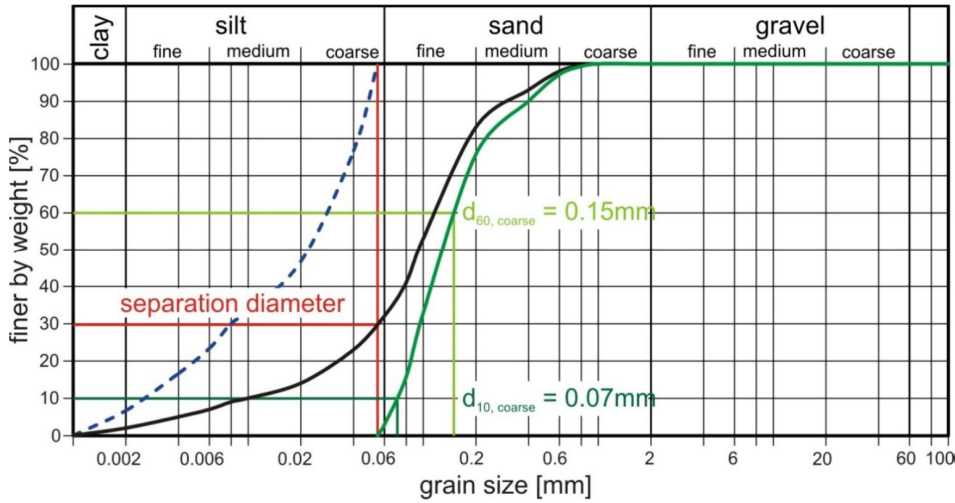
### BAW Code of Practice Internal Erosion (MMB)

**recommended procedure  
for verification of safety  
against suffusion**

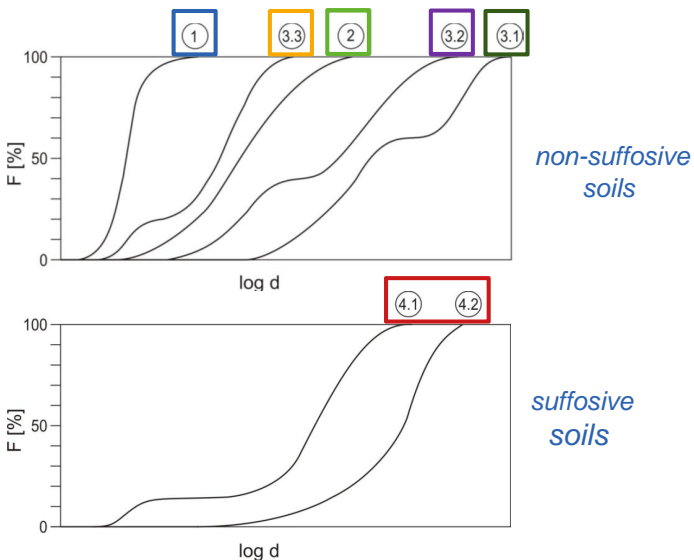




Examples of verifications of safety against suffusion  
(according to Kenney and Lau)

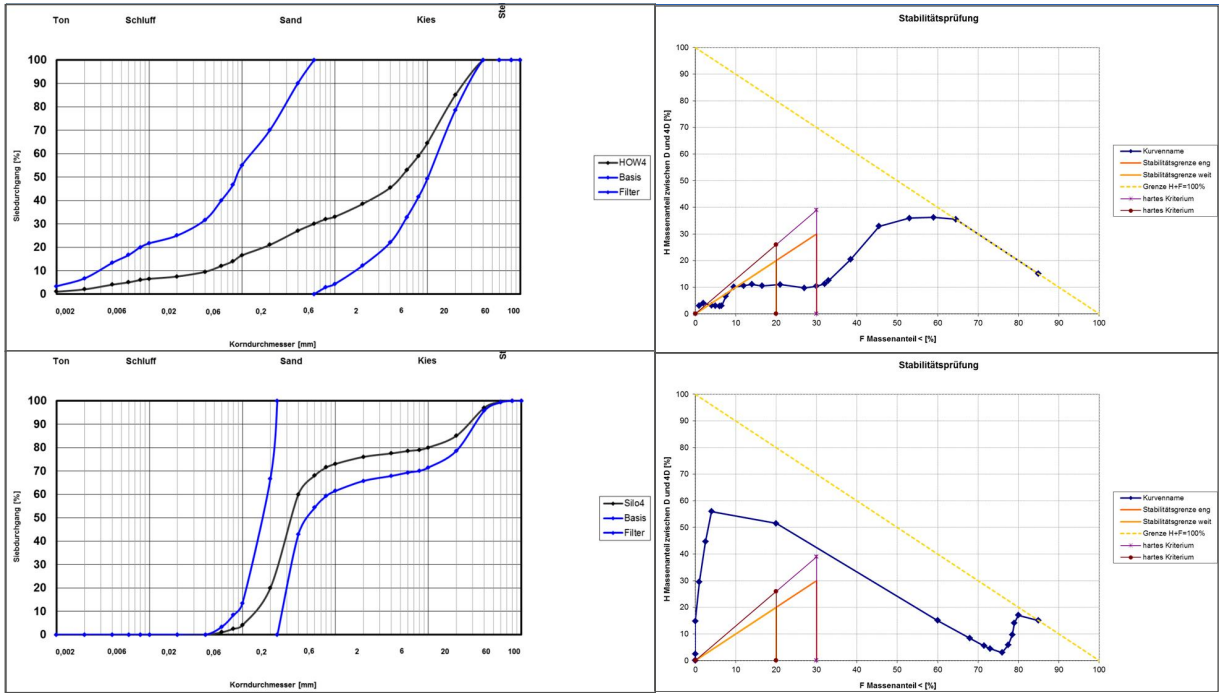


verification of safety against contact erosion  
method following Lafleur's approach



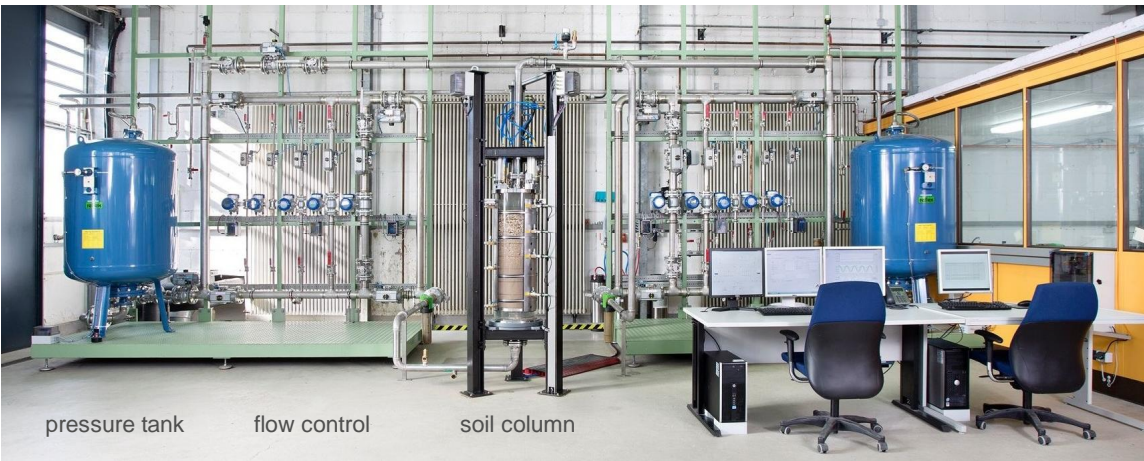


# Results of the comparison calculations



suffusive soil

non-suffusive soil



pressure tank      flow control      soil column

Alternating Flow Apparatus

Thank you for your attention

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