Prevention of Internal Erosion by Cut-Off Walls in River Embankments on the Upper Rhine

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Barrages in the Upper Rhine

- Barrages in the River Rhine
- Barrages in short lateral canals (canal loops)
- Barrages in long lateral canal (Grand Canal d‘Alsace)

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<tr>
<th>Number</th>
<th>Location</th>
<th>Year</th>
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<td>Iffezheim</td>
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<td>Gambsheim</td>
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<td>Vogelgrün</td>
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<td>Fessenheim</td>
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<td>Ottmarsheim</td>
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<td>Kemps</td>
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Iffezheim Barrage

weir  dam

fish pass

hydro-electric power plant

double lock

river embankment
Composition of the River Embankments (German side)

impoundments between canal loops (simplified example)
Construction (In-Place) Soil Material

- embankment shell, subsoil: sandy gravel
- embankment core, alluvial layer: silty sand (sandy silt)

- shell, subsoil: grain size gap for coarse-grained sand and fine gravel
- No filter stability between embankment core and shell or subsoil
Internal Erosion
Caused by Groundwater Flow

contact erosion:
interface between embankment core
and shell or subsoil

suffosion
inside shell or subsoil
Damages due to Internal Erosion

river Rhine  embankment  drainage canal
Embarkment Rehabilitation with Cut-Off-Walls

• **objective:** reduction of the risk of internal erosion (contact erosion and suffosion)

![Diagram of embankment rehabilitation with cut-off-walls](image)

• **measure:** reduction of seepage flow velocity at the interface embankment core / subsoil by cut-off-walls

• **conditions:** quaternary sediment aquifer, thickness several 100 m, embedment of cut-off-walls in an aquiclude not possible

• **cut-of-wall effective measure to reduce the risk of internal erosion?**
Effects of Cut-Off-Walls

isotropic aquifer ($k_v = k_h$)

anisotropic aquifer ($k_v = 0.1 \cdot k_h$)

- anisotropic ground due to alternating deposition of fine grained and coarse grained sediments
- partially fine grained layers in ground
- meanders of old Upper Rhine filled with coarse grained soil material
  - cut-off-walls effective measure to prevent internal erosion
Used Types of Cut-Off- Walls

- diaphragm wall
- jet grouting wall
- sheet pile wall
- mixed-in-place wall
- soil mixing wall
Evaluation and Inspection of Cut-Off-Walls

- sheet pile walls very robust and less sensitive to hydraulic stress, but very expensive
- soil mixing, jet grouting and particularly diaphragm walls very sensitive to hydraulic stress (depending on groundwater flow velocity, cement setting rate, suspension transport in pores of soil)
  - cut-off walls installed by using a suspension generally only suitable for ground areas with low groundwater flow velocities

- reliable method for inspection of cut-off walls: measurement of soil and/or groundwater temperature downstream wall, basic principle: different temperatures of surface water and groundwater, different conduction or convection heat transport velocities
  - to evaluate the effectiveness of a cut-off wall: temperature measurements before and after installation of the wall, sensors at relatively short distance