Chapter 13: Construction methods for granular material

cf5308 Breakwaters and Closure Dams
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Elements to consider

- Bed fixation or bed protection mattresses, etc.
- Shore connected and intermediate dam sections sand fill/quarry; execution
- Abutments sheetpile, caisson
- Breakwater core; dumped sills
- Cover layer, armour
Scour prevention

- Change of flow in course of time
- Flow distribution over the vertical
- Flow is not saturated with sediment
- Turbulence intensity increases
development of a scour hole
length
balance of material
effective scour time

Diagram showing effective scour time with time intervals marked as 0, 2 1/2 hr, 6, and 12.
development of a scour hole
mattresses or granular filters

- Limited construction height
- Applicable on steep slopes
- Difficult to remove
- Presence of structural joints
- Vulnerable to mechanical damage
- Restricted lifetime

- Self healing after minor damage
- Absence of structural joints
- Simple to remove by dredging
- No sudden change at the end; they can fade out gradually
- Absence of structural coherence
- Disintegration on steep slopes
- Considerable construction height
stability downstream of a sill

\[ K_v = \frac{u_c \text{ uniform flow}}{u_c \text{ with load increase}} \]
Shields with corrections

\[ d = \frac{K_v^2 \bar{u}_c^2}{K_s \Psi_c \Delta C^2} \]

In Cress: \( K_t = \frac{K_v - 1}{0.4} + 1 \)

Rectangular Abutments: \( K_v = 1.7 \Rightarrow K_t = 2.75 \)
example bed protection

- $Bs = 2.5 \times 20 = 50 \text{ km}^2$
- depth = 10 m
- $B = 500 \text{ m}$
- tidal difference = 3 m
## Bed protection in case of horizontal closure

<table>
<thead>
<tr>
<th>width</th>
<th>$u_0$ (max)</th>
<th>D (cm)</th>
<th>W (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>2.13</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>450</td>
<td>2.35</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>400</td>
<td>2.60</td>
<td>8</td>
<td>1</td>
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<tr>
<td>350</td>
<td>2.90</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>300</td>
<td>3.26</td>
<td>17</td>
<td>7</td>
</tr>
<tr>
<td>250</td>
<td>3.68</td>
<td>23</td>
<td>20</td>
</tr>
<tr>
<td>200</td>
<td>4.16</td>
<td>35</td>
<td>65</td>
</tr>
<tr>
<td>150</td>
<td>4.63</td>
<td>50</td>
<td>192</td>
</tr>
<tr>
<td>100</td>
<td>5.13</td>
<td>71</td>
<td>653</td>
</tr>
<tr>
<td>50</td>
<td>5.47</td>
<td>90</td>
<td>1161</td>
</tr>
<tr>
<td>25</td>
<td>5.68</td>
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<td>1794</td>
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<tr>
<td>10</td>
<td>6.27</td>
<td>158</td>
<td>6166</td>
</tr>
</tbody>
</table>
Mixing layers (from ct4310)
Jet equations (from ct4310)

Plane jets: $u_m = \frac{3.5 u_0}{\sqrt{x/B}} \quad b = 0.1 x \quad u = u_m e^{-0.693 \left( \frac{z}{b} \right)^2}$

Circular jets: $u_m = \frac{6.3 u_0}{x/D} \quad b = 0.1 x \quad u = u_m e^{-0.693 \left( \frac{R}{b} \right)^2}$

$x = \text{distance from sill} \quad B = \text{width of gap}$
## Bed protection in case of vertical closure

<table>
<thead>
<tr>
<th>depth</th>
<th>U0</th>
<th>u2</th>
<th>3*U2</th>
<th>D (cm)</th>
<th>W (kg)</th>
<th>W(kg)</th>
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<tbody>
<tr>
<td>10</td>
<td>2.13</td>
<td>2.13</td>
<td>2.13</td>
<td>5</td>
<td>0</td>
<td>80/200</td>
</tr>
<tr>
<td>9</td>
<td>2.36</td>
<td>2.15</td>
<td>2.36</td>
<td>6</td>
<td>0</td>
<td>80/200</td>
</tr>
<tr>
<td>8</td>
<td>2.64</td>
<td>2.18</td>
<td>2.64</td>
<td>8</td>
<td>1</td>
<td>80/200</td>
</tr>
<tr>
<td>7</td>
<td>2.97</td>
<td>2.20</td>
<td>2.97</td>
<td>14</td>
<td>4</td>
<td>80/200</td>
</tr>
<tr>
<td>6</td>
<td>3.38</td>
<td>2.20</td>
<td>3.38</td>
<td>21</td>
<td>14</td>
<td>10/60</td>
</tr>
<tr>
<td>5</td>
<td>3.86</td>
<td>2.18</td>
<td>3.86</td>
<td>27</td>
<td>32</td>
<td>10/60</td>
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<tr>
<td>4</td>
<td>4.33</td>
<td>2.07</td>
<td>4.33</td>
<td>39</td>
<td>97</td>
<td>60/300</td>
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<tr>
<td>3</td>
<td>4.63</td>
<td>1.81</td>
<td>4.63</td>
<td>50</td>
<td>192</td>
<td>60/300</td>
</tr>
<tr>
<td>2</td>
<td>4.64</td>
<td>1.41</td>
<td>4.24</td>
<td>37</td>
<td>79</td>
<td>60/300</td>
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<td>0.74</td>
<td>2.23</td>
<td>5</td>
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<tr>
<td>0</td>
<td>3.13</td>
<td>0.41</td>
<td>1.22</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

**Conclusion:** everywhere 60/300 is needed
providing quarry material

- by road
- by rail
- by water
- a combination
subsequent working fronts
Construction phases of the Zeebrugge Breakwater (1)

Unsustainable material in the location of the breakwater is removed by sea going cutter suction dredge
Construction phases of the Zeebrugge Breakwater (2)

Split-hopper replaces material with sea sand and sea gravel
Construction phases of the Zeebrugge Breakwater (3)

Willow mattresses are sunk with two sink pontoons and specialised stone barges
Construction phases of the Zeebrugge Breakwater (4)

Lateral berms are constructed with quarried stones of 3-6 tons with specialised stone barges.
Construction phases of the Zeebrugge Breakwater (5)

The dam core is built with quarry stone using heavy duty earth moving equipment.
Construction phases of the Zeebrugge Breakwater (6)

The stones are faces with a layer of 1-3 tons stones plus filter construction with Poclain 600
Construction phases of the Zeebrugge Breakwater (7)

The seaward side is protected by 25-30 ton concrete blocks with an American Hoist 11-310
Construction phases of the Zeebrugge Breakwater (8)

Finishing: crown block, service road, lighting
a breakwater under construction
trucks waiting on the breakwater
use of cheap local equipment
build up of profiles

line dump

horizontal layers
use of waterborne and land based equipment
# Land Based Equipment

<table>
<thead>
<tr>
<th>Type</th>
<th>Capacity (m³)</th>
<th>Weight (ton)</th>
<th>Wheel Load (ton)</th>
<th>Width (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(off highway) dump truck</td>
<td>20 - 90</td>
<td>empty: 30 - 110 loaded: 60 - 270</td>
<td>front/rear (ton) empty: 15/15 - 50/60 loaded: 20/40 - 90/180</td>
<td>wheel base 3.7 - 5.7</td>
</tr>
<tr>
<td>Articulated dump truck</td>
<td>12 - 27</td>
<td>empty: 20 - 40 loaded: 40 - 90</td>
<td>front/rear (ton) empty: 10/10 - 20/20 loaded: 14/26 - 30/60</td>
<td>wheel base 5.7 - 6.8</td>
</tr>
<tr>
<td>Wheel loader</td>
<td>2.5 - 9</td>
<td>15 - 86</td>
<td></td>
<td>bucket width 2.7 - 4.7</td>
</tr>
<tr>
<td>Track loader</td>
<td>2.5 - 3</td>
<td>25</td>
<td>60 - 90 kPa</td>
<td>bucket width 2.7</td>
</tr>
<tr>
<td>Backhoe crane</td>
<td>0.5 - 15</td>
<td>15 - 200</td>
<td>40 - 150 kPa</td>
<td>track gauge 2 - 5</td>
</tr>
<tr>
<td>Front shovel</td>
<td>2 - 15</td>
<td>40 - 200</td>
<td>70 - 190 kPa</td>
<td>track gauge 2 - 5</td>
</tr>
<tr>
<td>Bulldozer</td>
<td>blade width 2.5 - 5 m</td>
<td>10 - 80</td>
<td>50 - 100 kPa</td>
<td>track gauge 2 - 3</td>
</tr>
</tbody>
</table>
tipper truck vs. dump truck
space requirements for heavy equipment
lifting capacity of a crane
grab types

ROPE CLAMSHELL

- capacity: 1000 ltrs
- type: 2 ropes, digging
- dead weight: 1550 kg
- width: 1200 mm

HYDR. GRAB

- capacity: 1000 ltrs
- type: hydraulic grab with orange peel shells with mechanical swivel 360
- no. of shells: 5
- max. load: 8 tons
- dead weight: 1890 kg
Waterborne equipment

• Bulk
  • Pipeline
  • Floating
    • flat deck barges
    • bottom door barges
    • split barges
    • tilt barges
    • side unloading vessels
• Individual placement
closure by pumping sand
barges for dumping material

- Bottom-door barge
- Split barge
- Tilting barge
- Side-unloading barge
- Flat barge
example of combined transport and crane vessel
motion of a driven wheel

- Hard tire on solid ground, driven wheel rolls
- Granular or soft soil, wheel subsides and digs
- Low pressure tire, wheel deforms and rolls
temporary road on soft subsoil
final closure with sand only
closure with a cable car
varying construction sequence