CIVE 413 - Riprap Design

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Beginning of Motion

• Critical Shields Parameter ($\tau_{cs}$)
  – beginning of motion ($\tau_0 = \tau_c$)

\[
\tau_{cs} = \frac{\tau_c}{(\gamma_s - \gamma) d_s}
\]

![Figure 7.8. Modified Shields diagram](image)

$D_s = d_{50} \left( \frac{(G - 1) g}{v^2} \right)^{1/3}$

- Data from Shields
- Data from others
Calculating Critical Shear Stress

Figure 7.9. Critical shear stress on a horizontal surface
Riprap Failure

There are four main types of riprap failure: particle erosion, transitional slide, riprap slump, and sideslope failure.

The four types of riprap failure are shown in the figure to the right.

The most common failure type is particle erosion from flow.
Riprap Design

Velocity Method

\[ V_c = K_c \sqrt{2(G - 1)gd_s} \]

\[ K_c = \log \left( \frac{4h}{d_s} \right) \sqrt{\tan \phi} \]
Riprap Thickness
US Army Corp of Engineers

- 30 cm for practical placement
- At least the diameter of the upper limit of $d_{100}$ stone
- At least 1.5 times the diameter of upper limit $d_{50}$ stone, whichever is greater.
- If riprap is placed under water, the thickness should be increased by 50%.
- If it is subject to attack by large floating debris or wave action it should be increased 15 to 30 cm.

Gradation of Riprap

- Well graded riprap scours less than uniform size riprap due to the process of armoring
- Suggested Riprap gradation from USACE is shown to the right
- Riprap with poor gradation may be used, but a “filter” layer is required

<table>
<thead>
<tr>
<th>Percent finer by weight</th>
<th>Sieve diameter ($\times d_{50}$)</th>
<th>Stone diameter ($\times d_{50}$)</th>
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<tr>
<td>0</td>
<td>0.25</td>
<td>—</td>
</tr>
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</tr>
<tr>
<td>100</td>
<td>2.00</td>
<td>1.90</td>
</tr>
</tbody>
</table>
Riprap Design

Gravel Filters

- Gravel filters should not be less than 15 to 23 cm
- \( \frac{d_{50}(\text{filter})}{d_{50}(\text{bank})} < 40 \)
- \( \frac{5}{d_{15}(\text{filter})} < \frac{d_{15}(\text{bank})}{40} \)
- \( \frac{d_{15}(\text{filter})}{d_{85}(\text{bank})} < 5 \)
- \( \frac{1}{2} \) thickness of Riprap layer is a good guideline
- Suggested gravel filter gradation equations are shown to the right