CONCRETE RIPRAP VERSUS STONE PROTECTION RIPRAP

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WHAT TYPE OF BANK PROTECTION SHOULD BE USED IN RIVER/WATER ENVIRONMENTS?
BANK PROTECTION

RIGID
- Impermeable
- Does not conform to changes in the supporting surface

FLEXIBLE
- Permeable
- Conforms to changes in the supporting surface
TxDOT’S TYPICAL SELECTION FOR BANK PROTECTION

BANK PROTECTION

RIGID
- CONCRETE
- RIPRAP

FLEXIBLE
- STONE PROTECTION
- RIPRAP
CONCRETE RIPRAP
RIGID PROTECTION: CONCRETE RIPRAP

CONCRETE RIPRAP
SOME PROBLEMS OBSERVED WITH CONCRETE RIPRAP
RIGID PROTECTION: CONCRETE RIPRAP

Problems:
- Erosion at the toe
- Undermined
- Settled
- Cracked
- Voids
RIGID PROTECTION: CONCRETE RIPRAP

Problems
- Cracks/Separation
- Loss of Material
- Undermined/Voided
- Settles
RIGID PROTECTION: CONCRETE RIPRAP
RIGID PROTECTION: CONCRETE RIPRAP
RIGID PROTECTION: CONCRETE RIPRAP

ADVANTAGES
- Long history of use
- Impermeable
- Resists impact damage
- There is a TxDOT Standard
- Contractor’s are familiar with it
- Construction is not complicated and does not require specialty equipment

DISADVANTAGES
- Smooth surface
- Erosion at the perimeters
- Susceptible to undermining
- Susceptible to movement and cracking due to removal of support
- Hydrostatic pressures can build up behind the protection
- Problems are not always visible and are not easily repaired
STONE PROTECTION RIPRAP
A flexible facing of graded rock, usually dumped or hand-placed, which provides protection against erosion and scour.
FLEXIBLE PROTECTION: STONE PROTECTION RIPRAP
SOME PROBLEMS OBSERVED WITH STONE PROTECTION
FLEXIBLE PROTECTION: STONE PROTECTION RIPRAP

Problems:
- Nearly uniform gradation
- Poor placement
- Lack of filter fabric
FLEXIBLE PROTECTION: STONE PROTECTION RIPRAP

Problems:

• Erosion at the toe
• Rock slide down slope
Problems:

• Erosion at the toe
• Rock slide down slope
ADVANTAGES

- Rough surface
- Adjusts to distortions and local displacement of the foundation soil
- Design is adaptable
- Construction is not complicated and does not require specialty equipment
- Has a natural appearance
- Movements can often occur without complete failure and protection is still functional
- Failures are easily identified and can be fixed

DISADVANTAGES

- Needs to be designed
- In some areas of Texas rock can be hard to obtain
IN RIVER/WATER ENVIRONMENTS FLEXIBLE BANK PROTECTION IS RECOMMENDED

- it can be used in a wide variety of conditions
- it adapts to movements of the soil
- it is easily inspected
- it is easily repaired
HOW WOULD ONE DESIGN STONE PROTECTION RIPRAP?

MANUALS FOR USE IN DESIGN OF STONE PROTECTION RIPRAP

- FHWA Hydraulic Engineering Circular 23 (HEC-23) – Bridge Scour and Stream Instability Countermeasures: Experience, Selection, and Design Guidance

- NCHRP Report 587 – Countermeasures to Protect Bridge Abutments from Scour
  (http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_587.pdf)

- NCHRP Report 568 – Riprap Design Criteria, Recommended Specifications, and Quality Control
  (http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_568.pdf)
HOW WOULD ONE DESIGN STONE PROTECTION RIPRAP?

FHWA HYDRAULIC TOOLBOX

- Contains stone protection calculations for a variety of conditions.

FLEXIBLE PROTECTION: STONE PROTECTION RIPRAP

FHWA HYDRAULIC TOOLBOX

Stone Protection

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FLEXIBLE PROTECTION: STONE PROTECTION RIPRAP

- Default value is set to 2.650
- This should be changed to 2.500 to be consistent with Item 432.

- The appropriate size can be selected using the D50 value determined from Table 2 in Item 432 Riprap.
FLEXIBLE PROTECTION: STONE PROTECTION RIPRAPP

**Note:**

XX in = Size in Item 432  
Thickness = YY in (~ 1.5 x XX)

**FIGURE 5 ~ PROTECTION STONE RIPRAPP**
Acceptable Alternatives to the Toe Trench Shown on the TxDOT Standard

Buried Toe

Extended Rock Filled Trench

Mounded Toe

Acceptable Alternatives to the Toe Trench Shown on the TxDOT Standard – Adapted from FHWA Hydraulic Engineering Circular 23 (HEC -23) – Bridge Scour and Stream Instability Countermeasures: Experience, Selection, and Design Guidance
FLEXIBLE PROTECTION: STONE PROTECTION RIPRAP

IF THE STONE PROTECTION RIPRAP SIZE IS EXCESSIVE

- Verify Hydrology/Hydraulics
- Check the Hydraulic Modeling
- Select a different flexible protection system
FLEXIBLE BANK PROTECTION

INCREASING FLEXIBILITY

STONE PROTECTION

GABION MATTRESS

INTERLOCKING ARTICULATED CONCRETE BLOCKS

DECREASING FLEXIBILITY

GABIONS

CONCRETE ARMOR UNITS
IN RIVER ENVIRONMENTS FLEXIBLE BANK PROTECTION IS RECOMMENDED

- it can be used in a wide variety of conditions
- it adapts to movements of the soil
- it is easily inspected
- it is easily repaired
Under what conditions can Stone Protection Riprap be used?  

Are these conditions comparable with those for Concrete Riprap?

<table>
<thead>
<tr>
<th>Bank Protection Type</th>
<th>Suitable River Environment</th>
<th>River Type</th>
<th>Stream Size</th>
<th>Velocity</th>
<th>Bed Material</th>
<th>Debris Load</th>
<th>Bank Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>B- braided</td>
<td>W-wide</td>
<td>H-high</td>
<td>C-coarse</td>
<td>H-high</td>
<td>V-vertical</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M-meander</td>
<td>M-moderate</td>
<td>M-moderate</td>
<td>S-sand</td>
<td>M-moderate</td>
<td>S-steep</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S-straight</td>
<td>S-small</td>
<td>L-low</td>
<td>F-fine</td>
<td>L-low</td>
<td>F-flat</td>
</tr>
<tr>
<td></td>
<td></td>
<td>X- all conditions</td>
<td>X- all conditions</td>
<td>X- all conditions</td>
<td>X- all conditions</td>
<td>X- all conditions</td>
<td>X- all conditions</td>
</tr>
</tbody>
</table>

- **Rigid**
  - Concrete Riprap
  - X
  - X
  - X
  - X
  - X
  - X
  - S,F

- **Flexible**
  - Stone Protection Riprap
  - X
  - X
  - X
  - X
  - X
  - X
  - S,F

Modified from Table 2.1 of HEC-23
## How Much Does Each Cost?

<table>
<thead>
<tr>
<th>Bank Protection Type</th>
<th>Typical Bid Price</th>
<th>Normalized Typical Bid Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete Riprap (5 in thick)</td>
<td>$431/CY</td>
<td>$6.65/SF</td>
</tr>
<tr>
<td>Stone Protection (18 in size, 27 in thickness)</td>
<td>$97/CY</td>
<td>$8.08/SF</td>
</tr>
</tbody>
</table>

Based on TxDOT current Average Low Bid Prices for Construction and Maintenance
CONCLUSIONS

• Historically, concrete riprap (rigid bank protection) has been used.

• Concrete Riprap:
  - is rigid;
  - is impermeable;
  - is susceptible to erosion along its edges;
  - is susceptible to undermining;
  - obscures the identification of problems;
  - when problems occur it is no longer functional in protecting the embankment;
  - problems are costly to repair and the repair options are limited.
• Stone Protection Riprap (flexible bank protection) is recommended for use in river/water environments, because:
  - it can be used in wide variety of conditions;
  - it is effective in preventing erosion/scour;
  - it is permeable;
  - it is flexible to adapt to ground movements;
  - it is easy to identify problems; and
  - if a failure occurs it is readily visible and can be easily repaired.
QUESTIONS?
## COST COMPARISON

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<td>$8.08/SF</td>
</tr>
<tr>
<td>Interlocking Articulated Concrete Blocks (4 in min.)</td>
<td>$10/SF*</td>
<td>$10/SF*</td>
</tr>
<tr>
<td>Gabion Mattresses (Galvanized)(12 in)</td>
<td>$148/SY</td>
<td>$16.44/SF</td>
</tr>
<tr>
<td>Gabions (Galvanized) (3ft x 3ft x 3ft)</td>
<td>$230/CY</td>
<td>$25.56/SF</td>
</tr>
</tbody>
</table>

* - These are rough estimates due to insufficient use to obtain accurate bid prices, as it has been only used once.

** - This is typically a structure and is not used as surface treatment.

Based on TxDOT current Average Low Bid Prices for Construction and Maintenance.
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