

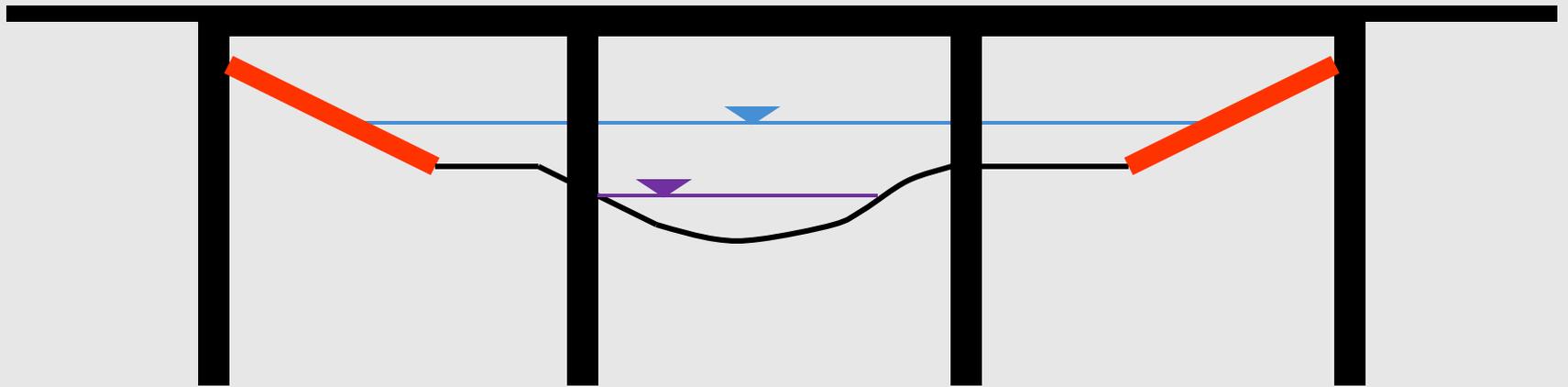


CONCRETE RIPRAP VERSUS STONE PROTECTION RIPRAP

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TxDOT Bridge Division Geotechnical Branch

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



BANK PROTECTION

BANK PROTECTION

```
graph TD; A[BANK PROTECTION] --> B[RIGID]; A --> C[FLEXIBLE]; B --> D["- Impermeable<br/>- Does not conform to changes in the supporting surface"]; C --> E["- Permeable<br/>- Conforms to changes in the supporting surface"];
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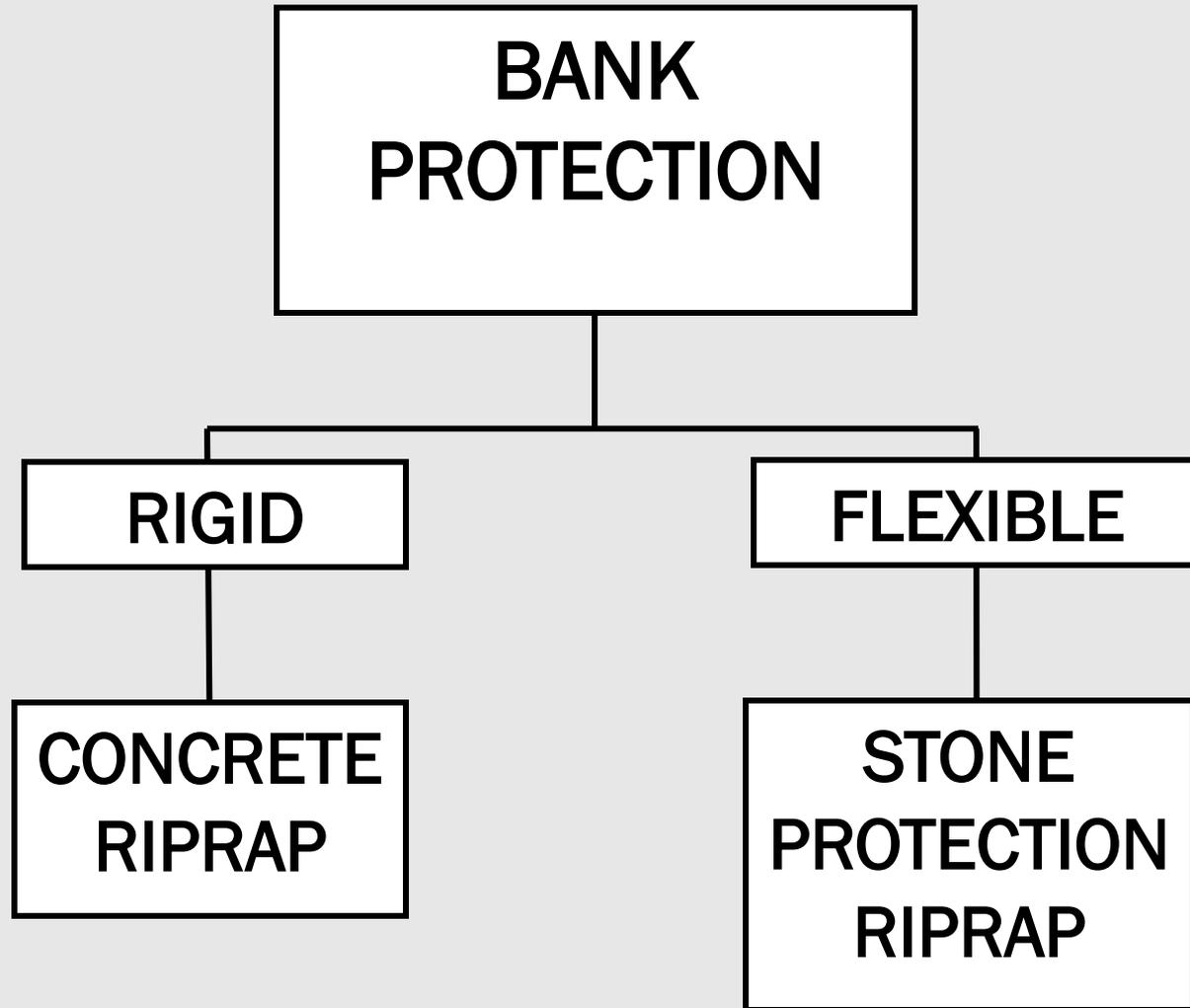
RIGID

- 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



CONCRETE RIPRAP

CONCRETE RIPRAP

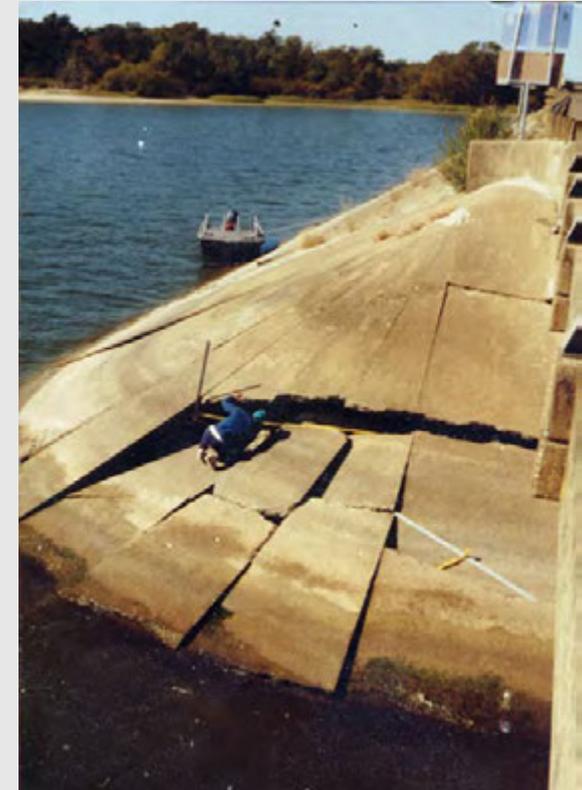


**SOME PROBLEMS
OBSERVED WITH
CONCRETE RIPRAP**

RIGID PROTECTION: CONCRETE RIPRAP

Problems:

- Erosion at the toe
- Undermined
- Settled
- Cracked
- Voids

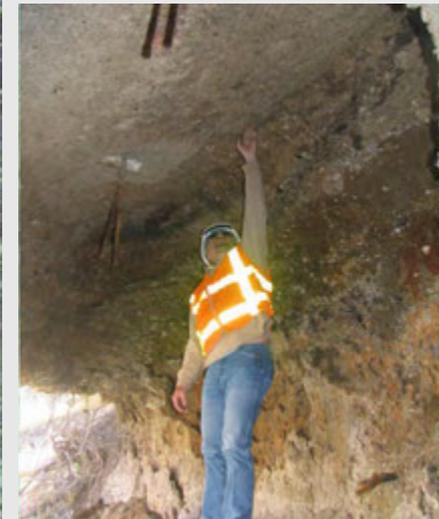


RIGID PROTECTION: CONCRETE RIPRAP



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

FLEXIBLE PROTECTION: 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



FLEXIBLE PROTECTION: STONE PROTECTION RIPRAP

Problems:

- Erosion at the toe
- Rock slide down slope



FLEXIBLE PROTECTION: STONE PROTECTION RIPRAP

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
(<https://www.fhwa.dot.gov/engineering/hydraulics/pubs/09111/09112.pdf>)
- **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)

FLEXIBLE PROTECTION: STONE PROTECTION RIPRAP

HOW WOULD ONE DESIGN STONE PROTECTION RIPRAP?

FHWA HYDRAULIC TOOLBOX

The screenshot shows the FHWA Hydraulic Toolbox website. At the top, it features the U.S. Department of Transportation Federal Highway Administration logo and navigation links for About, Programs, Resources, Briefing Room, Contact, and Search FHWA. Below this is a 'Bridges & Structures' header with sub-navigation for Structures, Geotech, Hydraulics, and Safety. Under Hydraulics, there are links for Hydrology, Highway Drainage, Culvert Hydraulics, Bridge Hydraulics, Scour, and Coastal Highways. The main content area is titled 'FHWA Hydraulic Toolbox, Version 4.20' with a date of 08/18/2014. It includes a paragraph of improvements, a link to a Desktop Reference Guide, and a 'Download Agreement' section. On the right side, there are three sidebar boxes: 'Email Notifications' with a sign-up link, 'More Information' with links to HDS 4, HDS 2, HEC 15, and HEC 23, and 'Contact' with contact information for Dave Henderson.

FHWA HYDRAULIC TOOLBOX

- Contains stone protection calculations for a variety of conditions.

<https://www.fhwa.dot.gov/engineering/hydraulics/software/toolbox404.cfm>

FLEXIBLE PROTECTION: STONE PROTECTION RIPRAP

FHWA HYDRAULIC TOOLBOX

Hydraulic Toolbox - [Hydraulic Toolbox Project]

File Display Calculators Profile Help

U.S. Customary U

FHWA Profile (read-only)

Project Explorer

Project - Untitled

Riprap Analysis

Stone Protection

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FHWA Hydraulic Toolbox

iv

FLEXIBLE PROTECTION: STONE PROTECTION RIPRAP

The screenshot shows the 'Riprap Analysis' software interface. On the left, a dropdown menu for 'Structure type' is open, with 'Revetment (channel slopes 2% or less)' selected. A red arrow points from this menu to the 'Structure type' field in the main window, which is set to 'Pier'. Below this, the 'Input Parameters' table is visible, with 'Specific Gravity of Riprap' highlighted in blue and set to 2.500. Another red arrow points from this value to the 'Table 2' below. The 'Results' table on the right shows 'D50' as 9.50 in. A red arrow points from this value to the 'Table 2' below. A text box on the right contains the following text:

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

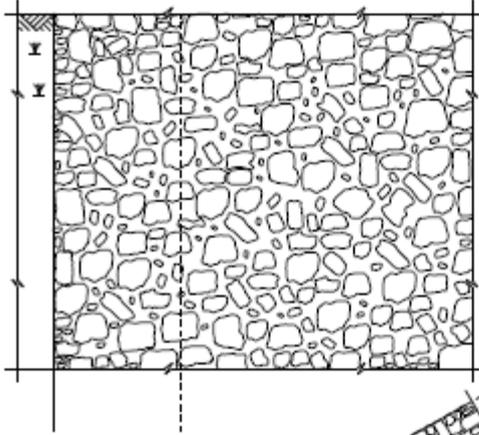
Table 2
Protection Riprap Stone Size¹

Size	Dmax (in.)	D90 (in.)	D50 (in.)	D8 (in.)
12 in.	13.76	10.14–13.29	7.31–9.92	3.39
15 in.	16.10	13.04–15.75	9.21–12.91	6.39
18 in.	19.04	15.58–18.36	11.10–14.21	6.59
21 in.	21.85	18.17–21.09	13.16–15.75	6.88
24 in.	23.53	19.28–22.29	13.76–16.18	7.31
30 in.	32.36	24.65–30.84	17.34–22.72	8.05

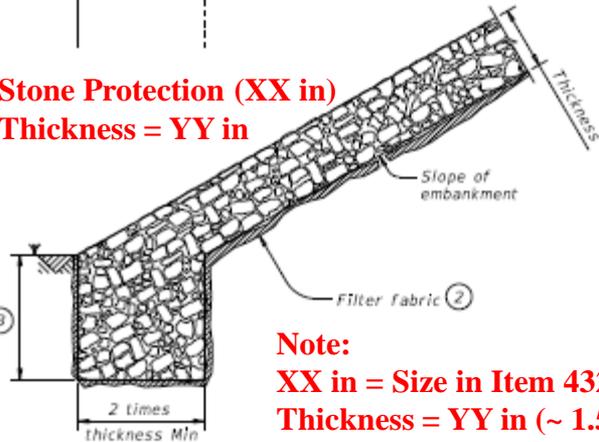
- The appropriate size can be selected using the D50 value determined from Table 2 in Item 432 Riprap

FLEXIBLE PROTECTION: STONE PROTECTION RIPRAP

TxDOT Standard – SRR



**Stone Protection (XX in)
Thickness = YY in**



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

FIGURE 5 ~ PROTECTION STONE RIPRAP



FIGURE 4 ~ COMMON STONE RIPRAP
dry or grouted



- ② Provide bedding material instead of filter fabric if shown elsewhere in plans. See Layout for thickness of bedding material.
- ③ Minimum toe depth is the larger of the maximum scour depth or 2 times the riprap thickness.



FIGURE 2 ~ TYPE F STONE RIPRAP
dry or grouted

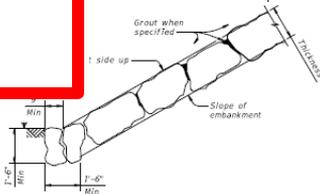


FIGURE 3 ~ TYPE F STONE RIPRAP
grouted

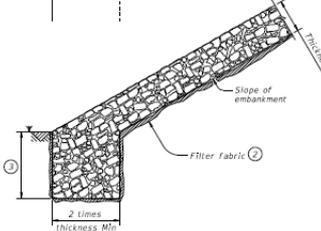
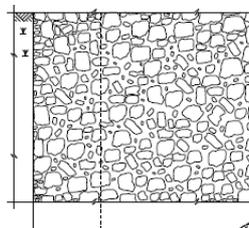


FIGURE 5 ~ PROTECTION STONE RIPRAP

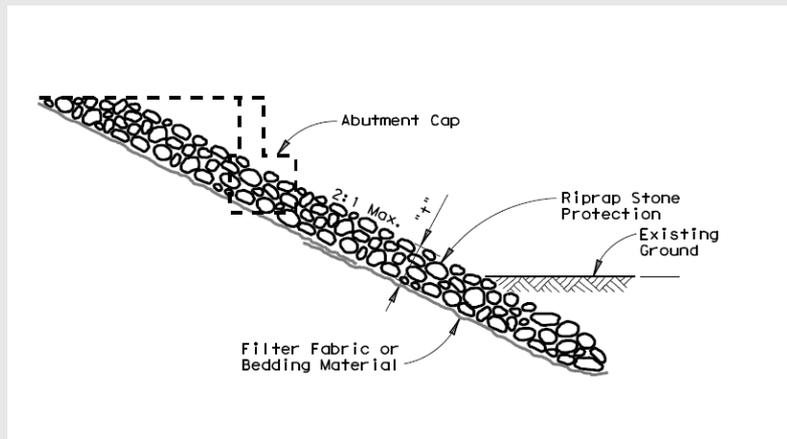
- ② Provide bedding material instead of filter fabric if shown elsewhere in plans. See Layout for thickness of bedding material.
- ③ Minimum toe depth is the larger of the maximum scour depth or 2 times the riprap thickness.

SHEET 2 OF 2

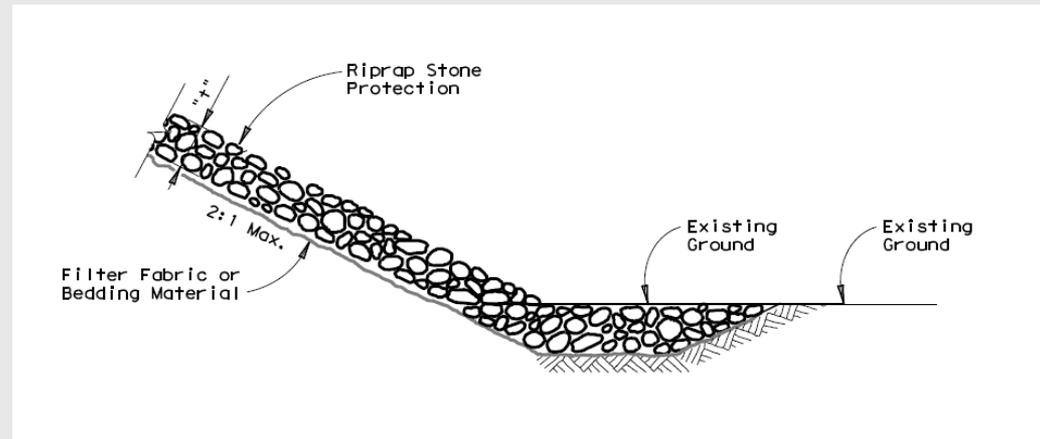
		Bridge Division Standard	
SRR			
Item: 811001.000	Unit: ACS	Unit: ACS	Unit: ACS
Date: January 2015	Code: 1000	Code: 1000	Code: 1000
Division:	County:	District:	Sheet No:

FLEXIBLE PROTECTION: STONE PROTECTION RIPRAP

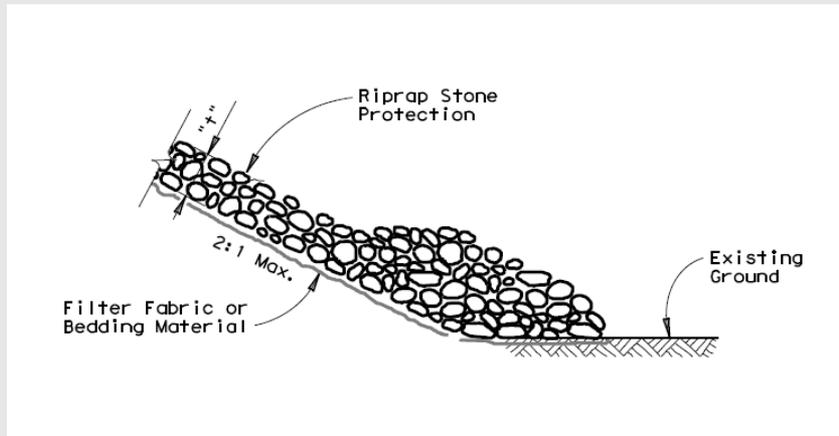
Acceptable Alternatives to the Toe Trench Shown on the TxDOT Standard



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

IF THE STONE PROTECTIN RIPRAP SIZE IS EXCESSIVE

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

0-6654 Empirical Flow Parameters – A Tool for Hydraulic Model Validity Assessment

Texas Tech Center for Multidisciplinary Research in Transportation (TechMRT)
Texas Tech University, Lubbock, Texas

Research Project: 0-6654
Research Report: 0-6654-1 Final Report

Final Report
Texas Department of Transportation
Research Project Number 0-6654

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

CONCRETE RIPRAP VERSUS STONE PROTECTION RIPRAP

Under what conditions can Stone Protection Riprap be used?

Are these conditions comparable with those for Concrete Riprap?

Bank Protection Type	Suitable River Environment					
	River Type	Stream Size	Velocity	Bed Material	Debris Load	Bank Condition
	B- braided	W-wide	H-high	C-coarse	H-high	V-vertical
	M-meander	M-moderate	M-moderate	S-sand	M-moderate	S-steep
	S -straight	S-small	L-low	F-fine	L-low	F-flat
	X- all conditions	X- all conditions	X- all conditions	X- all conditions	X- all conditions	X- all conditions
Rigid						
Concrete Riprap	X	X	X	X	X	S,F
Flexible						
Stone Protection Riprap	X	X	X	X	X	S,F

Modified from Table 2.1 of HEC-23

CONCRETE RIPRAP VERSUS STONE PROTECTION RIPRAP

How Much Does Each Cost?

Bank Protection Type	Typical Bid Price	Normalized Typical Bid Price
Concrete Riprap (5 in thick)	\$431/CY	<u>\$6.65/SF</u>
Stone Protection (18 in size, 27 in thickness)	\$97/CY	<u>\$8.08/SF</u>

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.**

CONCLUSIONS

- **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

Bank Protection Type	Typical Bid Price	Normalized Typical Bid Price
Concrete Riprap (5 in thick)	\$431/CY	<u>\$6.65/SF</u>
Stone Protection (18 in size, 27 in thickness)	\$97/CY	<u>\$8.08/SF</u>
Interlocking Articulated Concrete Blocks (4 in min.)	\$10/SF*	\$10/SF *
Gabion Mattresses (Galvanized)(12 in)	\$148/SY	<u>\$16.44/SF</u>
Gabions (Galvanized) (3ft x 3ft x 3ft)	\$230/CY	<u>\$25.56/SF **</u>

* - 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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