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**Erosion Prevention and Sediment Control Handbook**

#### **4.2.6.4 Hard Armoring**



Source: TNWRRC

#### **Definition and Purpose**

Hard armoring is a structural practice that uses conventional riprap, flagstone, gabions, concrete, or paving blocks to stabilize and convey runoff in channels and swales (Section 4.2.6.1).

#### **Appropriate Applications**

This practice applies to construction sites that contain concentrated runoff in an open ditch, channel or swale. Typical locations include roadside ditches, channels at property boundaries, channels created by diversion structures, or channels and swales designed as part of a permanent storm water conveyance system for the site. Hard armoring may be more practical than vegetated or engineered products where (KTC, 2015):

- Channel slopes above five percent predominate;
- Design velocities and shear stresses exceed the capacities of vegetation;
- Prolonged high flows are anticipated;
- Soils are highly erosive and not suitable for vegetation; and
- There is insufficient time to construct, seed, and establish a vegetated lining.

#### **Limitations and Maintenance**

This measure only includes stabilizing the channel or swale. During inspections, check the channel for debris, scour, or erosion. Repair any bare areas and report insufficient stability immediately. Hard armoring techniques, while effective at reducing erosion, provide minimal



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to no environmental or wildlife benefit as well have reduced aesthetics. Generally, vegetated linings should be considered before hard armoring techniques. When used, long-term maintenance may be needed to remove vegetation growing in areas of hard armor, as this can change the hydraulic capacity and undermine the hard armoring.

#### Planning and Design Considerations

Channel stabilization is an iterative process using Manning’s Equation (Eqn 6, Section 2.1.2) and shear stress (Eqns 12-14, Section 3.3.2.1) to ensure the selected liner can withstand design velocities and shear stresses (Section 4.2.6.1). Hard armoring is most often employed as a channel liner when design flow velocities exceed the tolerance of grass, vegetated, and bioengineered linings. Manning’s n values for hard armoring material (Table 4.2.6.4-A) is presented such that the methodology in Section 4.2.6.1 (i.e., Figure 4.2.6.1-A) can be implemented.

Table 4.2.6.4-A) Manning’s n values for various hard armoring materials and by flow depth. Source: NCDEQ (2013).

Lining Category	Lining Type	Manning's n values		
		0 - 0.5 ft	0.5 - 2 ft	> 2 ft
Rigid	Concrete	0.015	0.013	0.013
	Grouted Riprap	0.04	0.03	0.028
	Flagstone	0.042	0.032	0.03
	Soil Cement	0.025	0.022	0.02
	Asphalt	0.018	0.016	0.16
Unlined	Bare Soil	0.023	0.02	0.02
	Rock Cut	0.045	0.035	0.025
Gravel	1-inch D <sub>50</sub>	0.044	0.033	0.03
Riprap	2-inch D <sub>50</sub>	0.066	0.041	0.034
Conventional	6-inch D <sub>50</sub>	0.104	0.069	0.035
Riprap	12-inch D <sub>50</sub>	-	0.078	0.04

A flexible liner, such as conventional riprap is preferred over rigid liners for several reasons (NCDEQ, 2013):

- Conventional riprap liners can be designed to withstand most flow velocities by choosing a suitable gradation;
- Soil and void-filled riprap soil bioengineering techniques (Section 3.3.2.2) can easily be incorporated into conventional riprap design;
- Conventional, soil, and void-filled riprap liners adjusts to unstable foundation conditions without failure;



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- Failure of a riprap liner is not as expensive to repair as a rigid liner would be; and
- The roughness of conventional riprap reduces outlet velocity and can reduce flow volume by allowing some infiltration.

Conventional riprap linings are best used on slopes that do not exceed 2H:1V and that are at least one and a half times the thickness of the maximum stone diameter plus the thickness of any required filter or bedding (KTC, 2015; NCDEQ, 2013). Furthermore, velocity and shear stress thresholds for conventional riprap gradations are presented in Tables 3.3.2.1-A and 3.3.2.1-C. Filters or bedding need to be used to prevent piping and should have a thickness of six inches. Additionally, non-woven geotextiles can be used between the riprap and soil surface to prevent soil particle migration. Generally, the non-woven geotextile is recommended to meet the requirements found in AASHTO M288 for a Class 2 separation geotextile (ALSWCC, 2018).

Concrete and flagstone can convey large volumes of water without eroding, are typically not limited by velocity, take up less land area, can be constructed to fit limited site conditions, and require less maintenance (NCDEQ, 2013). However, they are more expensive to design and more labor intensive. Because they have a lower roughness coefficient (Table 4.2.6.4-A), rigid linings yield higher velocities and energies that must be controlled and dissipated at the channel outlet to prevent scour and damage to receiving waterbodies or EPSC measures. Concrete and flagstone (including mortar) linings should be a minimum of four inches in thickness. Channels with rigid liners should not exceed the slopes presented in Table 4.2.6.4-B.



Table 4.2.6.4-B: Maximum allowable slopes for channels with rigid liners. Source: NCDEQ (2013).

Lining Type	Height of Lining (ft)	Maximum Permissible Slope (H:V)
Formed Concrete	≤ 1.5	Vertical
Screened Concrete or Flagstone	≤ 2	1:1
Screened Concrete or Flagstone	> 2	2:1
Slip Form Concrete	≤ 3	1:1



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Channels may have grassed side slopes and conventional riprap or paved bottoms where velocities are within allowable limits for grass lining along the channel sides, but long-duration flows, seepage, or a high velocity flow would damage vegetation in the channel bottom (NCDEQ, 2013). However, soil riprap or void-filled riprap may be more ideal in this scenario. Paving blocks and gabions have some of the same characteristics as conventional riprap and are often used instead of riprap to fit certain site conditions, such as narrow channels and loose soils.

To ensure properly implemented and stabilized channels, first, the surrounding area should be cleared of trees, stumps, roots, loose rock, and other debris (NCDEQ, 2013). Excavation is then performed to match the grades and dimensions of the channel in the plans as specified by the engineer, and excavated to account for liner and filter thickness (KTC, 2015). For rigid liners, such as concrete, the lining is placed to the required thickness, with attention to proper curing and temperature protection. Transverse contraction joints are used to prevent cracking and are recommended to be spaced approximately 20 feet apart, while expansion joints are placed at a recommended maximum of every 100 feet (NCDEQ, 2013). Conventional riprap liners involve placing either non-woven geotextile or gravel layers immediately after slope preparation. It is then followed by rock placement to form a dense, well-graded mass. Geotextiles and stone bedding are positioned to maintain proper drainage and erosion control, with fabric overlaps secured by anchor pins. Channel outlets may need to be stabilized using energy dissipators, and disturbed areas near and within the ditch should be promptly vegetated or otherwise protected to minimize erosion and reduce water pollution.

#### **Example Application**

Refer to Section 4.2.6.1.

#### **References**

- ALSWCC. (2018). *Erosion Control, Sediment Control and Stormwater Management on Construction Sites and Urban Areas*.
- KTC. (2015). *Best Management Practices (BMPs) for Controlling Erosion, Sediment, and Pollutant Runoff from Construction Sites*.
- NCDEQ. (2013). *Erosion and Sediment Control Planning and Design Manual*.