Rock Mattress Linings

DRAINAGE CONTROL TECHNIQUE

Low Gradient		Velocity Control		Short Term	
Steep Gradient	✓	Channel Lining	✓	Medium-Long Term	✓
Outlet Control	✓	Soil Treatment		Permanent	✓

Symbol

Photo 1 – Rock mattress-lined drainage chute

Photo 2 – Rock mattress-lined table drain (stormwater infiltration pit)

Key Principles

1. The principal hydraulic design parameter is either the allowable flow velocity or allowable shear stress.
2. The key operational issues include provision of appropriate anchorage to adjacent fixed structures (critical if displacement of the mattresses is to be avoided), good anchorage of mattresses to the soil (critical when placed on steep slopes such as shown in Photo 2), and establishment of appropriate vegetative cover (not required for short-term operations).
3. Longevity is usually reliant on the establishment and retention of appropriate vegetation across the mattresses.
4. The key to successful revegetation is selection of appropriate, low maintenance species, especially where such vegetation can reduce the structures hydraulic capacity. Inappropriate plant selection can result in ongoing maintenance issues.

Design Information

Good design information is generally available from most manufacturers and suppliers.

Rock mattresses:

- Typically available in thicknesses of 170, 230, 300 and 500mm at a length of 6 metres and width of 2 metres.
- Heavily galvanised, PVC coated cages should be used within hydraulic structures.
- Mattresses should be laid over a filter fabric or properly designed gravel filter.

Rock-fill:

- Rock-fill should be angular and block-shaped.
- Nominal rock size as specified in Table 1.
- Minimum rock size around 1/3 the basket depth.
- Maximum rock size around 2/3 the basket depth.
- The rock should be uniformly graded with 80% by number greater than 100mm in size.
- Nominal rock size should be 200-300mm when used within the splash zone of weirs and drop structures.

Mattresses can be anchored to adjoining fixed structures with the use of I-bolts set into the wall, and galvanised rods threaded through the I-bolts after installing of the mattress cages (Photo 5).

When used as the lining of embankment chutes, filter cloth and a subsoil drain should be laid under the mattress.

When used within the splash zone of weirs and drop structures, at least two layers of minimum 300mm thick mattresses should be used.

On slopes, the mattress should generally be laid with the diaphragm across the slope rather than up and down the slope (ie. the 2m wide cells placed parallel to the slope contour).

On chutes and stream beds, the mattress should generally be laid with the diaphragm at right angles to the main direction of water flow (i.e. the 2m wide cells are transverse to the flow direction).

Photo 3 – Rock gabion and mattress channel stabilisation (during construction)

Photo 4 – Gabion structure during vegetation establishment phase – note; vegetation density can become excessive unless appropriate species are selected

Photo 5 – Anchorage of gabions and rock mattresses to fixed objects using I-bolts set into the concrete and galvanised tie rods

Photo 6 – Displacement of the rock can occur in areas of high shear stress (such a condition does not necessarily represent a structural failure)

Table 1 – Recommended rock size for rock mattresses and gabions [1]

Type	Thickness (m)	Rock size		Allowable flow velocity (m/s)
		Range (mm)	d_{50} (mm)	
Rock mattress	0.15–0.17	70–100	85	3.5
		70–150	110	4.2
	0.23–0.25	70–100	85	3.6
		70–150	120	4.5
	0.30	70–120	100	4.2
		100–150	125	5.0
Gabion	0.50	100–200	150	5.8
		120–250	190	6.4

[1] Sourced from Maccaferri (1988) *"Flexible gabion and Reno mattress structures in river and stream training works".*

Manning's roughness:

Manning's roughness of rock mattresses can be based on the equivalent roughness of loose rock assuming a rock size distribution of d_{50}/d_{90} = 0.8. Table 2 provides typical Manning's (n) roughness values for various rock sizes and flow conditions.

Table 2 – Manning's roughness of rock mattress lined chutes and channels [1]

R_h	Nominal mean rock diameter (d_{50})						
	85 mm	**100 mm**	**110 mm**	**120 mm**	**125 mm**	**150 mm**	**190 mm**
0.1m	0.047	0.052	0.055	0.058	0.060	0.068	0.080
0.15m	0.039	0.043	0.046	0.048	0.049	0.055	0.064
0.20m	0.036	0.039	0.041	0.043	0.044	0.049	0.056
0.25m	0.033	0.036	0.038	0.039	0.040	0.044	0.051
0.30m	0.032	0.034	0.035	0.037	0.038	0.041	0.047
0.40m	0.030	0.032	0.033	0.034	0.035	0.038	0.042
0.50m	0.030	0.030	0.031	0.032	0.033	0.035	0.039
1.00m	0.030	0.030	0.030	0.030	0.030	0.031	0.033
>1.00m	0.030	0.030	0.030	0.030	0.030	0.030	0.030

[1] Manning's roughness based on distribution of rock size represented by d_{50}/d_{90} = 0.8

The roughness values presented in Table 2 have been developed from Equation 1 (Witheridge, 2002). In circumstance where laboratory-based Manning's roughness values exist, then such values should be used in preference to Equation 1. It must be noted that Manning's roughness is depth related, thus any laboratory result must report the associated flow depth.

$$n = \frac{(d_{90})^{1/6}}{26(1 - 0.3593^{(x)^{0.7}})} \qquad \text{(Eqn 1)}$$

where:
- X = $(R/d_{90})(d_{50}/d_{90})$
- R = Hydraulic radius of flow over rocks [m]
- d_{50} = mean rock size for which 50% of rocks are smaller [m]
- d_{90} = mean rock size for which 90% of rocks are smaller [m]

For rock obtained from watercourses the factor d_{50}/d_{90} is typically in the range 0.2 to 0.5, for imported, quarried, rock the ratio is more likely to be in the range 0.5 to 0.8.

Description

Rock-filled mattresses consist of multi-celled, rectangular, PVC coated, heavily galvanised wire cages filled with well-graded rock. PVC coated cages should be used in all watercourse situations.

Purpose

Used as a channel liner in high flow velocity locations such as sediment basin spillways, permanent drainage chutes, and energy dissipaters.

Limitations

If poorly constructed, they can be expensive to rectify.

Water-transported sediment (sand and gravel) can reduce the service life of the wire. The turbulent transportation of such bed load material can break the wire through a hammering action.

In hydraulic environments, longevity is normally related to the establishment of an appropriate vegetative cover. The plant roots anchor the rocks thus decreasing the reliance on the wire mesh.

Advantages

Rock-filled cages are a well-proven protection measure.

Gabions and rock-filled mattresses are very useful for small localised drainage problems where immediate lining and/or protection is required.

When integrated with appropriate vegetation the structures can be both aesthetically pleasing and durable.

Disadvantages

If inappropriately vegetated, the structures can lose their aesthetic appeal and experience durability and maintenance problems.

Unsightly weed infestation can be a maintenance problem in some environments.

Sediment is difficult to remove from the cages without causing damage to the wire, especially if the location or shape of the structure is difficult to distinguish under the sediment load.

Some rock mattress and gabion structures have experienced durability problems caused by trickle flows, high sediment loads, and woody debris.

Special Requirements

Labour intensive construction requiring good supervision.

Prior to installation, the cages should be labelled and stockpiled separately according to cage size and thickness.

Site Inspection

Cages should be inspected annually for damage.

Check that inflows can freely enter the channel or chute.

Check for rill erosion along the up-slope edge of the mattresses.

Damaged cages should be repaired as soon as possible.

Materials

- Rock infill: hard, angular, durable, weather resistant and evenly graded with 50% by weight larger than the specified nominal rock size. The diameter of the largest rock size should be no larger than 1.5 times the nominal rock size.
- Geotextile fabric: heavy-duty, needle-punched, non-woven filter cloth, minimum bidim A24 or equivalent.

Installation

Installation procedures should be provided by the manufacturer or distributor of the product. A typical installation procedure is described below, but should be confirmed with the product manufacturer or distributor.

1. Refer to approved plans for location, extent and installation details. If there are questions or problems with the location, extent, or method of installation contact the engineer or responsible on-site officer for assistance.
2. Mattresses of different thicknesses should be stored on-site in separate piles and clearly labelled.
3. Clear the proposed channel area of trees, stumps, roots, loose rock, and other objectionable materials.
4. Excavate the treatment area to the lines and grades as shown on the plans. Over-cut the area to a depth equal to the specified mattress thickness such that the finished surface will be at the elevation of the surrounding land.

5. Place filter fabric directly on the prepared foundation. If more than one sheet of filter cloth is required to over the area, overlap the edge of each sheet at least 300mm and place anchor pins at minimum 1m spacing along the overlap.
6. Ensure the filter cloth is protected from punching or tearing during installation of the mattresses. Repair any damage by removing the rock and placing with another piece of filter cloth over the damaged area overlapping the existing fabric a minimum of 300mm.
7. Flatten out each mattress on a hard, flat surface, and stamp out any unnecessary creases. Edge creases will need to be stamped into the bottom of the 2nd and 4th internal diaphragms.
8. Ensure that each diaphragm is vertical and the correct height. Fold the sides and ends of the mattress to meet the top of the diaphragms. Fold the side panel flaps to lie adjacent to the diaphragms. Tack temporarily either by using short lengths of binding wire, or alternatively by twisting the top diaphragm wire over the flap selvedge wire.
9. The ends of the diaphragms must now be permanently laced to the sides of the mattress. At the four corners, bend the projected lengths of the end panels to overlap the sides, and lace up with binding wire.
10. When the mattress is placed over a geotextile, care must be taken to ensure that projecting ends of wire are bent upwards to avoid puncturing or tearing the cloth. Geotextile should be placed according to specifications.
11. Carry the wired-up mattress to its final position, and wire it securely to the adjacent mattresses. Mattresses should be placed and wired together empty as it is difficult to wire mattresses together when both are full of stone.
12. On slopes, the mattress should generally be laid with the diaphragm across the slope rather than up and down the slope. On chute and stream beds, the mattress should generally be laid with the diaphragm at right angles to the main direction of water flow.
13. All hand wiring must be done as a continuous lacing operation. Begin wiring by securing the binding wire to the corner of the panels to be joined by looping it through and twisting it together. Then lace with single loops and double loops in turn at 100mm intervals. Finally poke the loose end inside the mattress. Tightness of the mesh and wiring is essential at all times.
14. Place the fill material, by hand or mechanically, in the compartments, starting at the bottom if on a slope. The fill should be a hard, durable stone, in size between 80mm and two-thirds the thickness of the mattress, but generally no greater than 200mm.
15. Filling can be done unit by unit, but several units should be ready for filling at any one time.
16. For units with PVC coated wire mesh, particular care shall be taken to ensure that sharp edges of quarry stone are not placed against the mesh in order to avoid causing unnecessary abrasion.
17. Slightly overfill each mattress to allow for settlement. Tack the lid to the corners of the mattress, and then securely wire it to the tops of the sides, ends and diaphragms, using alternate single and double loops as specified above.
18. With more than one mattress filled, the edges of adjacent lids can be wired down in the same operation, saving both time and binding wire.
19. When the mattress is laid on a slope steeper than 1.5:1(H:V), it should be secured by star pickets or hardwood pegs driven into the ground just inside the upper end panel at 2m centres or as necessary.
20. On soft or sandy slopes, pegs may be used to hold the mattress in position during filling.
21. Mattresses maybe shortened where necessary, by cutting along the fold at the top of a diaphragm and removing the bottom spiral connections.
22. Always consult manufacturer's specifications and assembly instructions before modifying the shape of the mattress or wiring deformed mattress shapes.

23. Immediately upon completion of the channel, vegetate all disturbed areas or otherwise protect them against soil erosion.
24. Where specified, fill all voids with soil and vegetate in accordance with the approved plan.

Maintenance

1. Rock mattress channels should be inspected periodically and after significant storm events. Repair damaged areas immediately.
2. Closely inspect the outer edges of the treated area. Ensure water entry into the channel or chute is not causing erosion along the edge of the mattresses.
3. Check for piping failure, scour holes, or bank failures.