CHAPTER 15 - GABIONS, EROSION PROTECTION

GW Els

15.1  INTRODUCTION

The focus of this chapter is the practical aspects of the more commonly used bank protection and erosion protection techniques. For design principles and more detailed applications reference should be made to the appropriate manuals, brochures and the websites of manufacturers and suppliers.

The products to be discussed are gabions and mattresses, riprap, stone pitching, block paving and concrete paving.

15.2  MATERIALS

15.2.1  Gabion Boxes and Mattresses

Gabions are baskets made of hexagonal woven wire mesh. They are filled with rock at the project site to form flexible, permeable and monolithic structures such as retaining walls, channels and weirs for erosion control projects. In order to reinforce the structure, all mesh panel edges are selvedged with a wire having a greater diameter than the mesh wire. The gabion is divided into cells by means of diaphragms positioned at approximately 1 m centres.

The wire is heavily zinc coated and for added protection can also be PVC coated. Stainless steel wire is also available on special order. The gabions boxes are supplied in various sizes, 2 m long by 1 m wide by 1 m high being the most popular size. The diameter of the wire used can also be varied within limits.

Photo 15.1: Gabion boxes with mattresses for scour protection along embankment
The gabion mattresses, also known as reno mattresses, are of similar construction.

As their name suggests they are used to cover large areas and are primarily used for river bank and scour protection as well as channel linings for erosion control. The gabion mattresses are supplied in various sizes, 6 m long by 2 m wide by 0,3 m high being the most popular size.

PVC coated gabions will normally be specified in applications requiring additional protection against corrosion for example in the tidal zone of rivers, or when additional wear and tear protection is required against boulders transported by flood waters. It is important to be aware that transported cobbles and boulders can cause severe damage to the mesh and its coatings, reducing the life of the gabion considerably. For more severe exposure to sea water, stainless steel wire should be considered.

The rock to be used for filling the gabion boxes and mattresses are normally obtained from sources on or near the site and should be durable and of sound quality ranging in size between 100 mm and 250 mm for boxes and between 75 mm and 150 mm for mattresses. A well packed gabion can have a very neat appearance.

For a complete specification and the various sizes available, reference should be made to the literature published by the various manufacturers and suppliers.

A geotextile filter layer of non-woven fabrication is normally required at the interface of the gabion boxes and the native soil or backfilled embankment. Its purpose is to release any water pressure without leaching or washing out of the soil from behind or below the gabions. Depending on the application, a geotextile layer may also be required below mattresses. The geotextile specified will normally have a minimum mass of 210 g/m² which is equivalent to a grade A5.

**NOTE**

In river courses it is recommended that 2,7 mm diameter mesh be used in order to provide improved durability.
15.2.2 Riprap

Riprap is an alternative method for providing river bank and scour protection. It consists of sized and graded rock placed in a layer or in the shape of a berm.

To be effective the riprap needs to be designed for a particular application. In simplistic terms the design theory is based on a fundamental force balance. At equilibrium, or incipient motion, the drag force which the flow exerts on a riprap particle, is balanced by a component of the particle’s mass which is dependent on the natural angle of repose of the riprap material. Factors which are taken into consideration include the bank angle, the natural angle of repose of the riprap, the flow depth, the hydraulic energy slope, the size of the riprap and the relative density thereof.

For river bank protection a typical critical mass for dumped riprap is 250 kg.

Rock suitable for riprap can be sourced from quarries, from screening oversized rock from earth borrowpits or from collecting rock from fields. Screening borrowpit material and collecting field rocks present different problems such as rocks too large or with unsatisfactory length to width ratios for riprap. Quarry stones are generally the best source for obtaining large rock for riprap.

![Photo 15.3: Rip rap combined with grouted stone pitching, gabion mattresses on the slope and a gabion box cut-off along toe line](image)

15.2.3 Stone Pitching

Stone pitching as it applies to road and bridge construction is in essence uniform sized stone placed shoulder to shoulder on a prepared surface. The stones used must be sound, tough, durable and clean and are normally sourced from rock quarries. Rounded river boulders may also be suitable although they tend to have a more cobbled appearance. The stone should have a minimum dimension of 200 mm.
Depending on the particular application the stone pitching can be laid in a number of ways, viz:

(a) Laid directly on the soil surface and firmly bedded into it and using stone fragments or topsoil to fill in the spaces between the larger stone (plain stone pitching). Typical applications would be on slopes not subjected to water erosion and where re-establishment of vegetation is desirable.

(b) Laid on a cement mortar bed with the spaces between stones filled with cement grout of the same composition as the mortar (grouted stone pitching). Stone pitching laid in this manner is not flexible and typical applications would therefore be on stable slopes requiring protection where vegetation is not likely to establish such as at spill through abutments (not river crossings).

(c) Laid on a concrete bed of at least 75 mm thick with a light steel mesh reinforcement to provide structural continuity. The spaces between stones are filled with cement grout as before (reinforced grouted stone pitching). This application is suitable for approach fill protection subjected to flooding in combination with deep cut-off walls and other measures to prevent undermining of the stone pitching. It is also suitable for the lining of side drains and for erosion protection at down pipe and down chute outlets.

(d) The stones may be laid with a flat side facing up to form a reasonably smooth and pleasing in appearance surface. On the other hand, when used to line a channel or at outlet structures a rough surface may be advantageous to assist with energy dissipation.
15.2.4 Block Paving

Segmental block paving of the interlocking type consisting of class 25 concrete paving blocks, are commonly used in applications similar to that described in paragraph 15.2.3(b), i.e. approach fill slopes at spill through abutments on road over road or road over rail structures.

The main advantage of block paving is the fact that the paving blocks are:

- readily available from commercial sources
- uniform in shape and size resulting in an aesthetically pleasing appearance for some, but others may find it to be unnatural and dull.
- skilled teams are readily available to lay them to the required specification.

A significant and annoying disadvantage is the fact that they are prone to theft and their use is now discouraged by many employers. Furthermore, their relative smooth surface can be slippery, presenting a danger to inspectors.

15.2.5 Concrete paving

Concrete paving as a means of bank and fill slope protection against erosion is limited to canal crossings having controlled water flow characteristics. For river crossings with its highly variable flow characteristics and difficult to predict scour potential, the more flexible and easier to maintain techniques mentioned above are preferred.

Concrete paving for erosion control is thus limited to paved side drains the paving of which extends up to the edge of the surfaced roadway as is commonly found on major roads.

15.3 PRINCIPLES & TECHNIQUES

15.3.1 General

The principles and techniques described below are by no means comprehensive and the monitoring staff should refer to other literature, text books and manuals to gain a complete understanding of the complexities of erosion and scour protection.

This is particularly true in the case of river crossings where the bridge structure and its approach fill may be subjected to unprecedented flood levels and forces. The whole science and art of constructing hydraulically successful roadworks rests heavily with the designer but the engineer’s representative has his part to play and if he plays it badly success cannot be achieved. The following are of great importance:

- The engineer’s representative must have a clear understanding of the intent of the designer and the principles on which the design was based and hence the details shown on the drawings and associated specifications.
- An understanding of the design parameters will enable him to recognise site conditions which may be at variance to that known or assumed at the time of the design and consequently to seek advice from the designer with regard to possible adjustment of the layout and details of the erosion protection works.
- The engineer’s representative must ensure that the contractor strictly adheres to all aspects of the specifications for protection works. The stability of riprap for example, is sensitive to small changes in the slope of the embankment on which it is placed.
15.3.2 Good Practices

The monitoring staff should pay special attention to the following:

15.3.2.1 Gabion boxes and mattresses

(a) The proper technique for erecting gabion boxes and mattresses are clearly shown on the appropriate standard drawings and should be studied. Being a labour intensive operation, the contractor may well subcontract this work to an emerging subcontractor with limited previous experience of gabion work not to mention the local labour that may be employed for this purpose. The engineer’s representative is strongly advised to instruct that a trial gabion box and mattress be assembled and packed at a convenient location before starting with the permanent works. In this manner off site training can be done until the engineer’s representative is satisfied with the end product. The trial assembly should remain to serve as the norm for all subsequent work.

(b) A group of assembled gabion boxes should be stretched to their proper length, width and height as described on the standard drawings. A sturdy frame should be used along the open side (the side not attached to an already packed box) to maintain the required height. In applications where not only the functionality but also the aesthetic appearance is important, it is highly recommended that the frame be faced with a solid board. This will go a long way to ensure an exposed gabion face with minimal bulging and unevenness’s in its alignment.

(c) To prevent bulging of the visible side of a box bracing wires must be used as shown on the drawings. This is particularly important when rounded stone is used which results in less internal friction. Although not called for on the standard drawing, it is good practice to brace all boxes, exposed or not, in this manner because it will assist them in maintaining their shape in case of flood damage or settlement.

Photo 15.5: Gabion mattress construction – note protruding bracing wires
(d) The exposed side of a box should be lined with stone of near equal size neatly packed with a flat side up against the mesh. If rounded river stone is being used a special effort will be required to select flat faced stone for this purpose.

(e) Gabion boxes should not be filled with mechanical equipment. The functionality of a gabion box is inter alia dependent on its mass which must be maximised by hand packing the stone in a manner that will minimise the voids. Smaller size stones should therefore be packed in between the larger stones. When working with rounded stone it has been found that oval shaped stone works better than spherical shaped stone in general.

(f) The structural integrity of a gabion wall is dependent on its ability to function as a unit. The weakest link in this unit is the lacing together of the individual boxes and special attention needs to be given to this aspect.

(g) Gabion mattresses on a slope must be laid with the 1 m spaced diaphragms parallel to the slope even though this may result in more cutting and lacing having to be done. In this manner there is less chance for the stone to be displaced by gravity and water forces towards the lower side. For similar reasons mattresses laid flat should be laid with the diaphragms square to the direction of flow.

(h) For mattresses the normal spacing of the brace wires is one brace per 1 m$^2$. When working with rounded stone it is recommended that the brace spacing be halved.
Where gabion mattresses are laid on a slope and the top edges are to be fixed to a concrete element e.g. slope protection for a low level river structure, a detail will have been provided on the drawings for the manner in which the mattresses are to be fixed to the concrete element. The mattresses should be fixed to the concrete element in the manner specified before they are filled with stone because once they are filled they will tend to slump slightly and an undesirable gap will develop between the top edge and the concrete which cannot easily be rectified.

![Photo 15.7: Gabion mattresses. Note displacement of rock due to inadequate brace wires and too small rock sizes used.](image)

For added protection against wear and tear caused by boulders transported by flood waters, a concrete screed on top of the gabion mattresses may be specified. A dry mix which will not unnecessarily penetrate into the mattress and placed to a thickness of 50 mm above the wire mesh, works well. Dry joints should be formed at 1 meter intervals to maintain some measure of flexibility and to allow for seepage water to escape. This technique applied to small patches (say 300 mm by 300 mm) in a regular pattern will also discourage theft of the wire mesh.

### 15.3.2.2 Riprap

- Not all quarries can produce large stone because of rock formation characteristics. Because quarrying generally uses blasting to fracture the formation into rock suitable for riprap, cracking of the large stones may only become evident after loading, transporting and dumping at the construction site.

- The stone shape is important and riprap should be blocky rather than elongated, platy, or round.

- Onsite inspection of riprap is necessary both at the quarry and at the construction site to ensure proper gradation and material that does not contain excessive amounts of fines.
(d) The objectives of construction of a good riprap structure are (1) to obtain a rock mixture from the quarry that meets the design specifications and (2) to place the mixture on the slope of the bank in a well keyed, compact, and uniform layer without segregation of the mixture. The best time to control the gradation of the riprap mixture is during the quarrying operation. Sorting and mixing later in stockpiles or at the construction site is not satisfactory.

(e) Inspection must ensure that a dense, rough surface of well keyed graded rock of the specified quality and sizes is obtained, that the layers are placed such that voids are minimised, and that the layers are the specified thickness. Typically, the project specifications will call for a 50% increase in layer thickness if the riprap is to be placed underwater.

(f) Because most riprap failure results from scour or undermining at the toe of the slope, the filter layer and riprap must extend below the anticipated scour depth. In situations where riprap can not be installed below the bed level, then sufficient riprap must be stockpiled at the toe to be available to be launched into the scour hole as it develops.

(g) Where a geotextile is used as filter layer, the dumping of riprap should be limited to drop heights of less than 300 mm to prevent tearing of the geotextile fabric.

(h) Along the bankline, the geotextile should be placed so that the upstream strips of fabric overlap downstream strips, and so that upslope strips overlap downslope strips. The overlap should be at least 300 mm when working on dry ground, and twice that amount when placement is under water.

(i) Dumped riprap means placing each sequential lift immediately on the previous lift with relatively little rearrangement of the rocks to avoid segregation. Dumping rocks at the top of the slope and pushing down the slope with a dozer or front-end loader is not acceptable and the dump trucks should be lowered down the slope with a cable attached to a tractor winch. In other cases, riprap may be dumped at the toe and a dozer used to push it up the slope. The procedure would depend on the quality of the rock and whether the continuous traffic of the dozers would break down the rock. If the rock is hard and not affected by the traffic, the riprap may be consolidated into a more tightly interlocked mass.

(j) For packed riprap backhoes or cranes equipped with clamshells or orange-peel grapples, are preferred to achieve precise placement of individual stones.

15.3.2.3 Stone pitching

(a) As in the case of gabions, stone pitching is labour intensive and thus lends itself to done by an emerging subcontractor. However, the laying of stone pitching in an aesthetically pleasing manner is a craft which is not readily available. The engineer’s representative therefore should instruct that a trial section first be done to master the technique.

(b) The advantage of stone pitching over block paving if done skilfully with the right type (colour) of stone lies in its more natural appearance and its ability to blend in with the natural environment.
INDEX TO APPENDICES

15A - EROSION PROTECTION CHECKLIST
## CONSTRUCTION MONITORING CHECKLIST

**PROJECT NO. / NAME:** ........................................................................................................

**INSPECTOR’S NAME(S):** ........................................................................................................

**STRUCTURE:** ...............................................................  **ELEMENT:** .................................................................

### ACTIVITY AND DETAILS

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<thead>
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<th>APPROVAL</th>
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<th>DATE</th>
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<tbody>
<tr>
<td><strong>1. GABIONS</strong></td>
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<tr>
<td>1.1 Verify the scope of the works</td>
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<tr>
<td>1.2 Verify specifications e.g. wire thicknesses and protective coatings</td>
<td>Y/N</td>
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<td>1.3 Verify layout and orientation of mattresses</td>
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<td>1.4 Verify stone sizes, shape and quality thereof</td>
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<td>1.5 Construct trial box to verify packing technique, bracing and shape control</td>
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<td>1.6 Verify founding conditions for gabion walls</td>
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<td>1.7 Verify stretching of assembled boxes to their proper dimensions</td>
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<td>1.8 Verify adequacy of lacing</td>
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<td>1.9 Verify technique and methodology of tying to structure where applicable</td>
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<td>1.10 Verify concrete mix and methodology for concrete screeds where specified</td>
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<td><strong>2. RIP RAP</strong></td>
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<td>2.1 Confirm scope of work</td>
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<td>2.2 Verify stone mass, shape and quality</td>
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<td>2.3 Agree method statement for handling and placing technique</td>
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<td><strong>3. STONE PITCHING</strong></td>
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<tr>
<td>3.1 Confirm scope of work</td>
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<tr>
<td>3.2 Verify size, colour, shape and quality of stone</td>
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<tr>
<td>3.3 Verify trimming, shaping and preparation of area to be paved</td>
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<tr>
<td>3.4 Agree method statement with regard to stone orientation, bedding, grouting and finishing</td>
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<tr>
<td>3.5 Construct trial section to verify technique and workmanship</td>
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### Erosion Protection Check List (2/2)

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<td>4. BLOCK PAVING</td>
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<td>4.1 Verify scope of works</td>
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<td>4.3 Verify trimming, shaping and preparation of area to be paved</td>
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<td>4.4 Verify layout, dimensions and specifications of edge beams</td>
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<td>4.5 Construct trial section to confirm workmanship</td>
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