Armorflex®

GUIDELINES ON THE APPLICATION OF ARMORFLEX **EROSION PROTECTION SYSTEM**

This document is produced to assist the Engineer in the preparation of design details and must not be used as a definitive document.

Designers of waterways, highways and general construction projects are constantly faced with designing channels and protective channel linings. Channels range from small roadside drainage ditches to major rivers. These channels will generally experience erosion of banks and scour of the bottom. Therefore, they require the construction of a protective liner. Armorflex provides a flexible protective liner that is a functional and economical alternative to dumped stone rip-rap, gabions and poured concrete.

FORCES ACTING ON ARMORFLEX IN A FLOWING CHANNEL

Armorflex is an interlocking matrix of precast concrete grids, of uniform size, shape and weight, that when placed in a water course forms an erosion resistant boundary. When Armorflex is exposed to flowing water, certain forces are generated on the system. Figure 1 - 1 illustrates these forces as they might be applied to Armorflex blocks, along with characteristic velocity profile at the boundary surface. Because of Armorflex's no-slip condition, the flow velocity decreases as it approaches the boundary. Also shown in Figure 1-1 are the turbulent eddies in the zone of separation, or wake region. As the flow passes over the Armorflex, the streamlines are slightly deflected. However, due to Armorflex's relatively uniform boundary surface, the streamline deflections are less than those that might be expected with rip-rap.

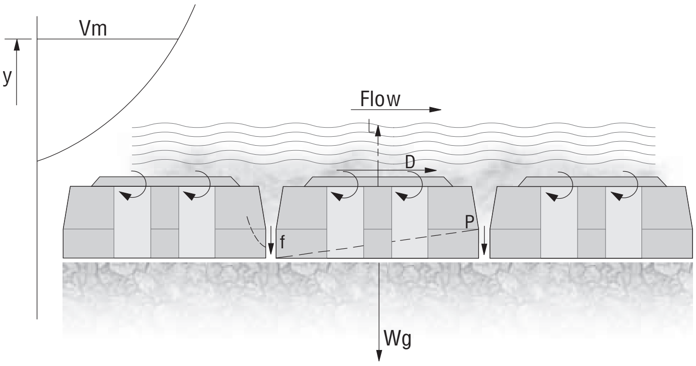


Figure 1 – 1;
Diagrammatic description of forces on Armorflex in a flowing channel.

As a result of the flow velocities over the Armorflex, forces are generated on the blocks which may be separated into drag forces in the direction of the flow and lift forces perpendicular to the direction of the flow.

The drag force is composed of skin friction drag and a form drag. Since Armorflex has a uniform surface, when laid correctly, the form drag is reduced leaving only the skin friction component to act along the top of the blocks. The lift force is the resultant of the pressure difference between the top and bottom sides of the Armorflex blocks. The top side pressure is reduced below the static pressure by the curve of the streamlines and resulting increase in flow velocity. On the bottom side where flow velocity is small, the pressure approaches the static pressure.

The forces resisting motion of the Armorflex blocks are their submerged weight, the downward force components of friction caused by contact with adjacent blocks and the system's interlocking features. This friction force is a result of small gravel and soil particles that are lodged between adjacent blocks. In addition, the degree of exposure to the forces of flowing water depends on the relative position of the blocks, which in the case of Armorflex, can be considered to be level with the channel bed.

Consequently, the movement of the individual Armorflex blocks will depend on the relative magnitudes of the forces acting on their upper surfaces. If the moment of the resultant of the lift and drag about the top of a block is greater than the moment of the submerged weight about the same point, the block will be rolled from its initial position to some point downstream.

If the lift force becomes greater than the submerged weight, the block will be lifted bodily from the channel bed and carried upward. The drag force acting on the block at this point will also tend to move the block downstream. At the edges and ends of an Armorflex protected area, the system is highly susceptible to uplift due to a) velocity energy acting on the exposed sides of the elements, and, b) velocity flow "shooting" under the protection causing uplift through pressure build-up from below the Armorflex. These edges and ends require suitable anchoring to protect the system.

ARMORFLEX BLOCKS

The unique shape factors of Armorflex contribute to the stability of the blocks by assuring that they perform as an integral system as opposed to a group of separate elements. Interlocking grooves and projections key adjacent Armorflex blocks together to form a continuous matrix of stable blocks.

This interlocking matrix assures that each row of blocks works in conjunction with subsequent rows, thus assuring that progressive rows of blocks cannot be laterally displaced. After the Armorflex has settled into the channels contour, the taper of the vertical side walls of the blocks add to the stability of the system by encouraging the build-up of binding soil and other particles between abutting blocks.

The Armorflex system, with vertical open cells, provides for hydraulic relief, velocity dissipation, soil retention and vegetative growth. Water is free to pass through the Armorflex system, thereby relieving the damaging hydrostatic pressures that can form behind the structure. As flow water passes over the open cells, the water will form eddy currents within the cells. These currents are energy dissipaters and will reduce the erosive velocity of the water. When non-cohesive material is placed in the open cells and subjected to flowing water, the material will be removed to depth A, Figure 1-2. The forces at this depth will be inadequate to remove more material from the cells. The maximum scour depth, A, is approximately equal to the open cell width, L.

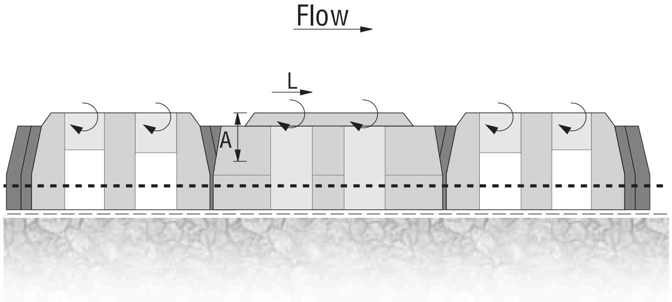


Figure 1 – 2;
Action of open cells in bank-stabilization

Since Armorflex with open cells filled with gravel or soil will retain a portion of the material, it provides the perfect environment for the establishment of vegetation. Vegetation unitizes the fill material by the formation of a root system. The root and fill material system forms a plug effect, opposing the uplifting of the Armorflex. Vegetation will give hydraulic smoothness.

Vegetation will eventually establish between blocks and within the open cells and extend over the top of the blocks to provide a complete cover to the system. Such vegetation contributes to the stability as well as to the ecological and aesthetic value of the areas lined by Armorflex. However, it is important to note that the effect of vegetation is not taken into account when determining the stability of Armorflex.

The Armorflex system also incorporates the use of cables passing through parallel, horizontal cable tunnels in each block to effectively interconnect blocks into an integral mat.Thus, an articulated mat is constructed that provides for ease of placement, even under water, of the Armorflex system and contributes an additional order of stability to the already stable features of the system. Once again, it is important to note that the contribution of the cables is not taken into account when determining the stability of Armorflex.

ERODIBLE OR NON-ERODIBLE CHANNELS

The stability of a channel is dependent mainly on the properties of the material forming the channel boundary. Unlined channels are generally erodible, except those excavated in firm foundations such as bedrock. Only after a stable section is obtained, can the designer be assured that the channel will not be subject to erosion. Most lined channels can withstand erosion satisfactorily and are therefore considered non-erodible.

The purpose of lining a channel is to prevent erosion. In lined channels, the maximum permissible flow velocity i.e. the maximum that will not cause erosion can be ignored, provided that the water does not carry sand, gravel or stone. If there are to be very high velocities over a lining, however, it should be remembered that there is a tendency for the rapidly moving water to pick up the lining material and push it out of position. Accordingly, the lining should be designed against such possibilities.

CHANNEL SLOPES

The side slopes of a channel depend mainly on the type of material comprising the channel banks. Under no circumstances should the side slope be greater than the natural angle of repose of the soil forming the channel-bank under the dynamic conditions of attack expected. Other factors to be considered in determining slopes are method of construction, climatic changes, channel size, etc. Generally, side slopes may be made as steep as practicable and should be designed for high hydraulic efficiency and stability. For lined channels of Armorflex, slopes of 1:3 to 1:1.5 are suggested where practicable.

NON-UNIFORM SETTLEMENT

Non-uniform settlement, due to soft channel body soils, can lead to cracking of paved or solid linings and to undesirable movement of the individual particles of rip-rap. With Armorflex, the liner is flexible and inter-connected, therefore it is able to withstand a normal amount of settlement. However, in areas where settlement is expected to be severe due to extremely unstable foundation soil, the designer should take steps to remove these soils and replace them with selected material having a proper stability.

WAVE ACTION

In wide rivers, lakes and dams, all or most of the erosion by water results from wave action. For main bodies of water, wave heights can be estimated, if the wind velocity and fetch are known. Wind velocities and direction can be obtained from observations made at the nearest weather station. The fetch can be scaled from a plan of the project.

LINED CHANNELS

The function of protective linings is to prevent the erosion of underlying soils when conditions leading to erosion cannot be eliminated. In order to perform this function, the lining has to be designed and constructed so as to:

1. be able to resist the forces exerted by flowing water on the lining
2. have an adequate extent along the watercourse so that erosion adjacent to the lining will not cause its failure by undermining
3. prevent the leaching of underlying materials through openings in the lining.

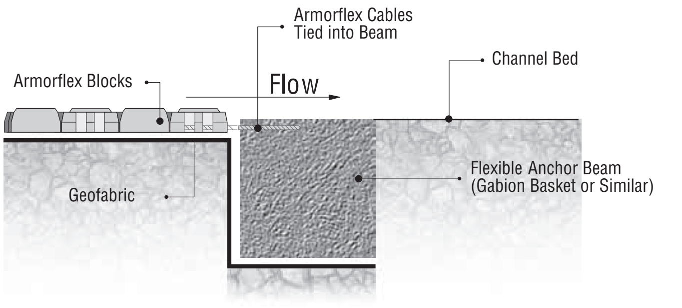


Figure 2 – 1;
Flexible cut-off beam at terminals of Armorflex

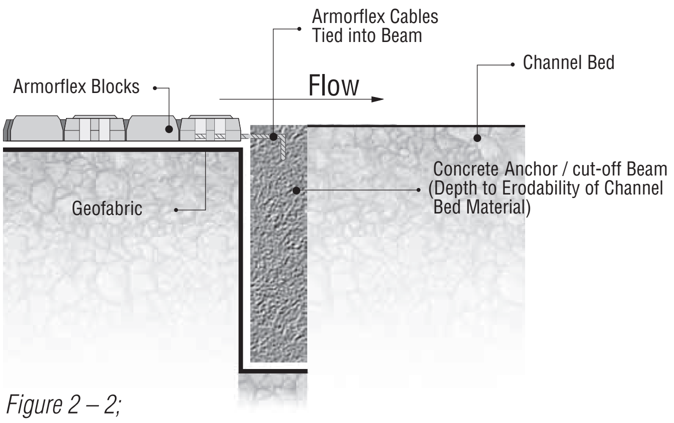


Figure 2 – 2;
Rigid cut-off beam at terminals of Armorflex

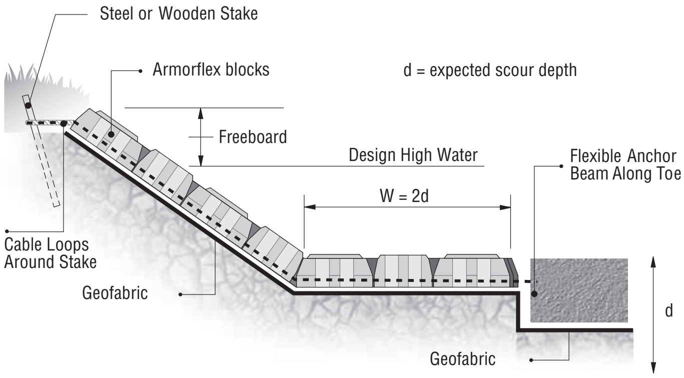


Figure 3 – 1;
Armorflex protection lining and apron detail

Armorflex Lining

Armorflex has uniformity of weight, size, shape and composition assuring the construction of an efficient lining. Unlike rip-rap linings, the Armorflex uniformity allows consistency in design calculations. Each Armorflex block in an installation has exactly the same stability potential as the adjacent blocks, thus forming an effective lining with the most conservative use of material weight. Even more important is the interconnection of the Armorflex blocks allowing the entire system to work homogeneously and thus preventing one or more blocks from being removed independently from the system.

EXTENT OF PROTECTIVE LINING

The majority of protective lining failures can be attributed to inadequate anchoring of the edges and ends and subsequent undermining of the terminations.

1. Upper Bank Protection

The lining should be extended above design water height. The allowance for freeboard depends upon the velocities near the lining and at same locations, upon the height of waves that might be generated on the water surface fig 3-2. Vegetative cover established above the lining will provide considerable protection from floods, which may overtop the lining.

The lining should be extended both upstream and downstream from the points of reverse curvature and should begin and end at a stable feature in the channel, if practicable. Such features might be outcroppings of bedrock, natural slopes deriving erosion resistance from well established vegetation or headwalls etc. In all circumstances cut-off beams should be provided at the upstream and downstream terminations of the lining (see Examples Figure 2). If the protective lining is long, intermediate cut-offs might be required to reduce the hazard of total lining failure.

2. Toe Trenches and Aprons

Protection against erosion at the toe of a bank is obtained by constructing a longitudinal anchor beam or continuing the lining into a toe trench extending to bedrock or other erosion resistant stratum. Where the channel is composed of sand or silt, the Armorflex should be buried to at least a depth of 0,5m below any expected erosion of the channel bed material (see Figure 3). On the outside of curves or sharp bends, where scour is particularly severe, the toe of the bank should be placed deeper than in straight reaches. At locations where it is not practicable to excavate a toe trench and continue the protection below the channel bottom, a longitudinal edge beam should be constructed.

The edge beam should be founded well below the expected scour depth and should key into the Armorflex blocks to ensure stability and protection.

For light duty applications where scour of the bed material is expected, a flexible Armorflex apron can be used to settle without fracture and to adhere to the ground as scour occurs. The length of the apron in front of the structure is generally 1.5 to 2 times the estimated scour depth, Figure 3-1.

This depth may be estimated relying on past experience or by other empirical methods. As with excavated toes on the outside of curves or sharp bends, the toe of the lining protected by a wider apron. The ends of the apron, when exposed on the channel bed, are subject to uplift if high velocities occur. In all circumstances it is recommended that a flexible edge beam is constructed (see Figure 3.1).

When constructing an apron, the bed is levelled or sloped taking care to fill large cavities with material from the channel bottom itself so that scour will occur as uniformly as possible.

For relatively narrow channels with erodible channel bottoms, the entire width of the channel should be lined (see Figure 4).

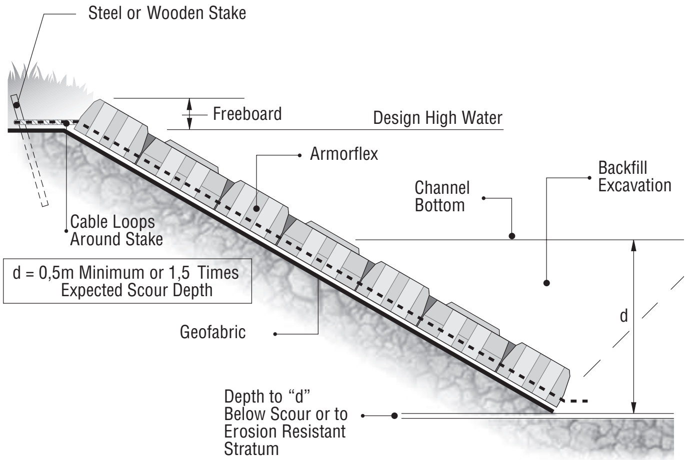


Figure 3 – 2;

Armorflex protection lining and toe trench details

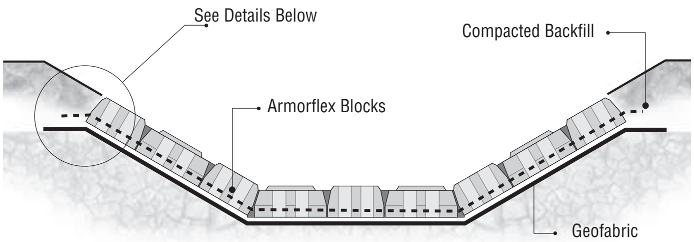


Figure 4 – 1;

Typical channel lining

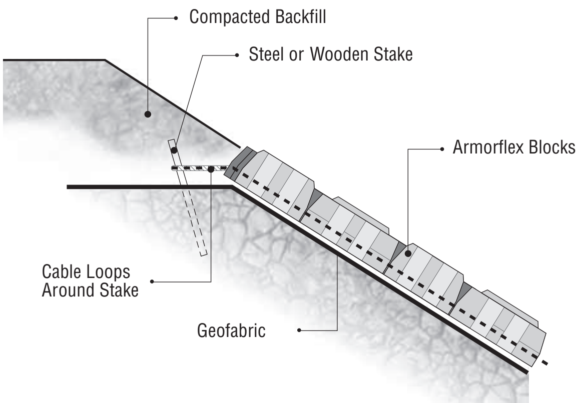


Figure 4 – 2;

Alternative edge detail with cables stakes

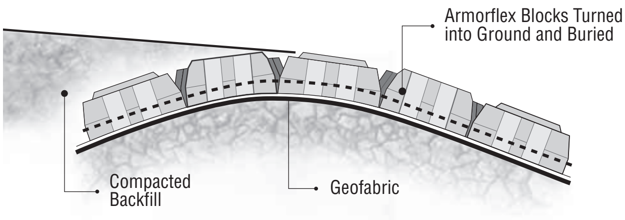


Figure 4 – 3;

Alternative edge detail with blocks buried

BACKFILL AND VEGETATION

Armorflex has an aesthetic advantage over other protective linings. Armorflex enhances the appearance of the protection through its ability to encourage the re-establishment of natural vegetation.

Armorflex's open cells should be backfilled with gravel or crushed stone in areas below the water line and with soil in areas above the water line. Do not overfill the cells with soil; the best results are obtained when the soil level is kept 10-18mm below the top of the grids. The vegetation will provide additional stability to Armorflex by consolidating the soil. Eventually the vegetative growth will completely cover the Armorflex.

However, vegetation will not take a permanent hold below a point on the side slope of the channel where water flows for an extended period of time, or where the flow velocity exceeds the permissible velocity for the vegetation.

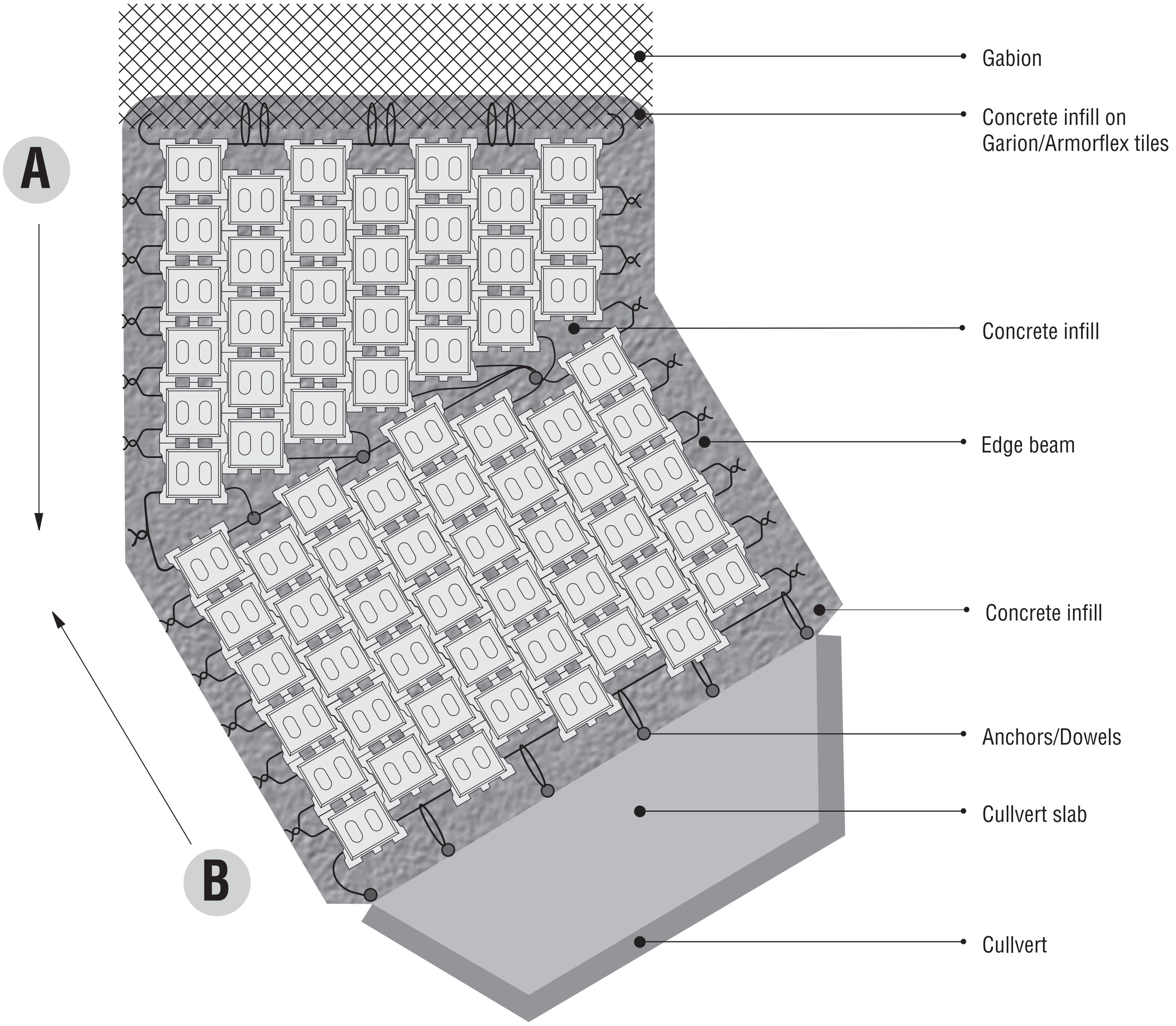
FILTER FABRIC

It is recommended that a suitable geofabric is used between the Armorflex blocks and the base material. The geofabric selected for use in conjunction with Armorflex should have a low initial modulus and be determined by assessing the soil-geofabric compatibility utilising, where possible, a full soil sieve and hydrometer analysis. Two factors should be considered, piping and permeability. Pore spaces of the fabric in contact with the soil must be small enough to prevent particles being washed through and at the same time, large enough to impact sufficient permeability to permit seepage to occur freely.

When considering critical flow gradients in a system such as Armorflex, it is important to note that flow parallel to the geotextile is considerably more critical to the soil-filter system than flow perpendicular to the system. Depending on the nature of the in-situ soil and the covering layer, the thickness and pore structure of the geotextile can decisively influence the stability of the soil-geofabric interface.

Before selecting a geofabric advise may be sought from specialist suppliers of these products.

CHANGE IN DIRECTION OF CHANNEL



Note: All wire shown before concrete

Concrete in fill where whole blocks do not fit

Fix wire first, then concrete

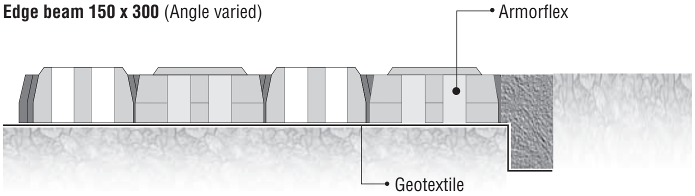
A. Laid first in direction of arrow

B. Laid second in direction of arrow.

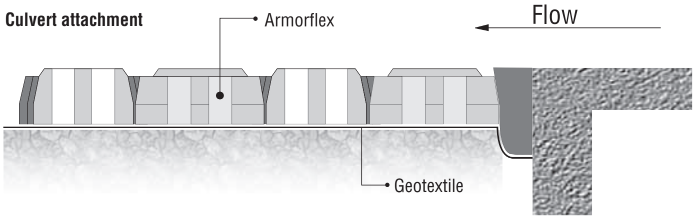
Armorflex wire across channel

EDGE DETAILS AND TERMINATIONS OF LINING

Edge beam 150 x 300 (Angle varied)



Culvert attachment



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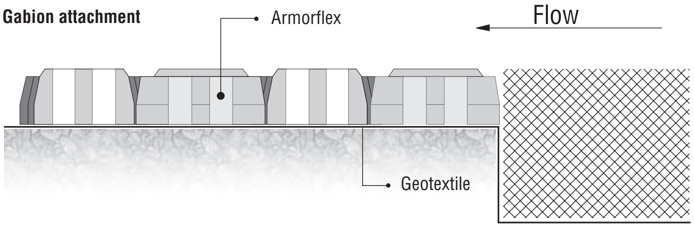
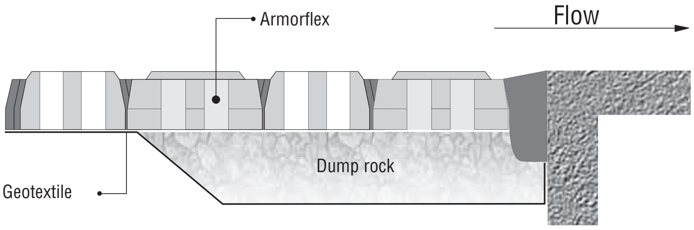


EDGE DETAILS AND TERMINATIONS OF LINING



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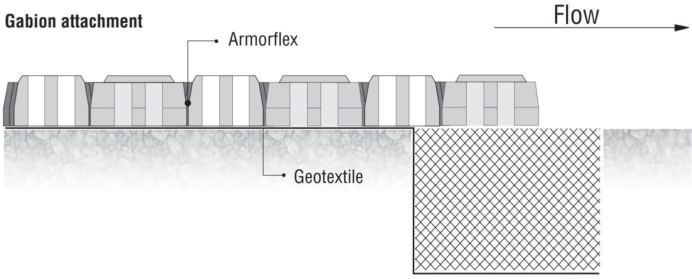
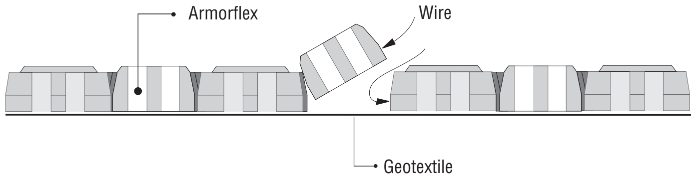


Note: Whether Armorflex 180 is wired across or longitudinally is indifferent. As the block is approx. 300 x 300. The greatest length should be in direction of flow.



A longitudinal tie.

- Lay blocks
- Lift one row
- Wire up
- Replace lifted block after wiring up.

NOTES

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