# CONCRETE MATTRESS FOR EROSION CONTROL IN CHANNEL APPLICATIONS

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**ABSTRACT**

This paper discusses the use of geotextile containment concrete mattress for erosion control works in channel applications. The system of geotextile contained concrete mattress is economical, easy to install, gives a durable revetment finish and is aesthetically pleasing. The unfilled concrete mattress is a geotextile formwork product that allows micro concrete to be pumped in. Two layers of high strength woven geotextiles are internally connected at regular conjoined filter points or with binding yarns which created the internal space to allow filling with micro concrete. When filled with micro concrete a durable surface that acts as an erosion protection surface results. Various types of concrete mattress in the market and typical applicability are described. Certain product designs result in a continuous concrete lining that effectively acts as a water barrier as well. This paper also details the use of such concrete mattress in the construction of drainage channels for the Kuala Lumpur International Airport 2 Project in Malaysia.

*Keywords: Concrete mattress, installation, micro concrete, pumping*

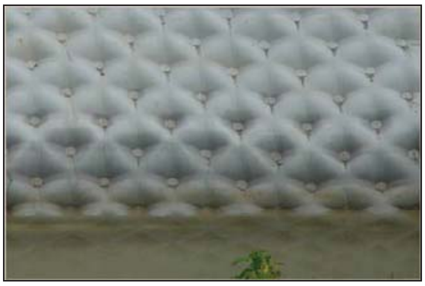
## INTRODUCTION

Along the coast, and in waterways and impoundments, revetments are used to provide protection against erosion of fine material or fill materials. Common systems used for construction of such revetments include rip-rap, rock armour, gabion mattress, concrete blocks and geotextile containment concrete mattress (referred simply as concrete mattress in this paper).

## CONCRETE MATTRESS PRODUCTS

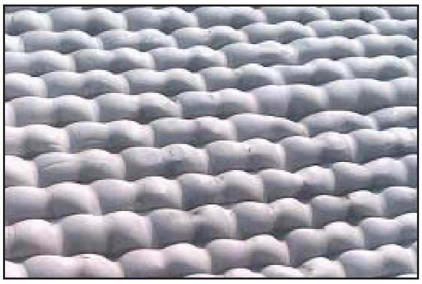
Concrete mattress is a double geotextile layer mattress forming product. The two layers of geotextiles are systematically linked either by conjoined woven filter points or through connecting internal thread. The internal space created between the two fabric layers are filled with micro concrete to form a robust and durable concrete mattress and used for erosion control in hydraulic environment. The concrete mattress reduces seepage across the product. For continuous concrete mattress seepage across the mattress is effectively eliminated. The width of the concrete mattress will shrink as the filling compartments are filled with micro concrete. The filled height of the concrete mattress and the amount of width shrinkage will depend on the specific type of concrete mattress used.

Concrete mattress design generally falls under the category of conventional filter point type (see Fig. 1a), flexible block type (see Fig. 1b) and continuous concrete section type (see Fig. 1c).



(a)

(b)



(c)

Fig. 1 Concrete mattress design (a) conventional filter point type (b) flexible block type (c) continuous concrete section type

Some of the attributes of concrete mattress include the following:

- cost effective
- ideal candidate when rock is in scarcity or expensive
- rapid installation (up to 500 $m^2$/day)
- does not require heavy machinery for installation
- provides a hard, durable and aesthetic surface finish (micro concrete compressive strength can reach up to 18 MPa)
- can conform to slight undulating ground (although profiling may be required in many cases)
- may be installed in water if required

## MICRO CONCRETE

The specification for micro concrete mix to fill concrete mattress (McConnell, 1998) is recommended. The mix should have a water:cement ratio of 0.7:1 and a sand:cement ratio of 2:1. The sand used in the micro concrete mix should be a well-graded and within Zone F as defined in BS 882, BSI (1992). Washed river or sea sand is preferable as it is more rounded in nature. The sand should be in accordance with the grading requirement specified in Table 1.

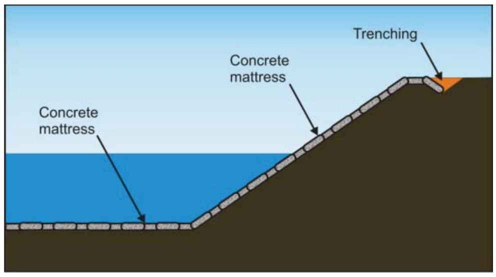
Table 1 Sand grading specification for micro concrete mix

| Size | Percentage passing (%) |
|---|---|
| 5 mm | 100 |
| 2.36 mm | 80-100 |
| 1.18 mm | 70-100 |
| 600 μm | 55-100 |
| 300 μm | 5-70 |
| 150 μm | 0-15 |
| 75 μm | 0-5 |

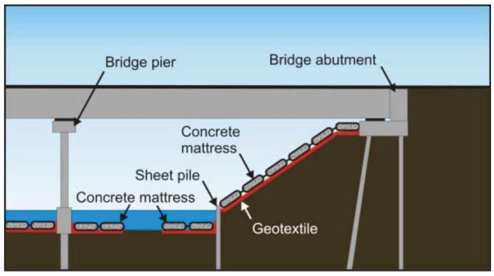
The cement used to produce the micro concrete shall be ordinary Portland cement according to BS 12, BSI (1996). The water used to produce the micro concrete shall be fresh and potable according to BS 3148, BSI (1990). The equipment for mixing and placing shall be a colloidal mixer and a low pressure pumping system.

## APPLICATIONS

Typical applications of concrete mattress are described by McConnell (1998), Pilarczyk (1990, 2000) and Sprague and Koutsourais (1992). The main application of concrete mattress is erosion protection in hydraulic environment. This includes channel revetment and bed lining (see Fig. 2a); impoundment lining (see Fig. 2a); bridge abutment, pier and toe erosion protection (see Fig. 2b); hydraulic structure outfall erosion protection (see Fig. 2c).




(a)

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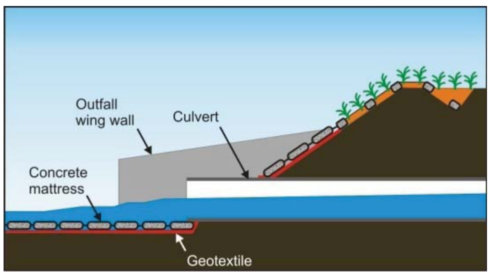


(c)

Fig. 2 Concrete mattress applications (a) channel revetment and bed lining (b) bridge abutment, pier and toe erosion protection (c) hydraulic structure outfall erosion protection

## STABILITY UNDER FLOW ATTACK

The stability criterion of concrete mattress revetment under longitudinal flow attack is as follows (Pilarczyk, 1990):

$$\Delta D_e \geq 0.035 \frac{\Phi}{\Psi} \frac{K_T K_h}{K_s} \frac{(u_{cr})^2}{2g} \qquad (1)$$

Where;

$\Delta$ = buoyant relative density of structural unit [-];
$D_e$ = effective thickness of revetment [m];
$\Phi$ = stability parameter [-];
$\Psi$ = Shields parameter [-];
$K_T$ = turbulence factor [-];
$K_h$ = depth parameter [-];
$K_s$ = slope parameter [-];
$u_{cr}$ = critical flow velocity along the structure [m/s];
g = gravitational acceleration [m/s$^2$].

For the micro concrete used to fill the mattress, a value of 1.4 may be adopted for $\Delta$. For concrete mattress revetment, the value of $\Psi$ is 0.07. For concrete mattress anchored at the top of slope in a trench, the value of $K_s$ is 1. The value of $\Phi$ is generally 1 except for design at edges when a value of 1.5 is adopted. The value of $K_T$ represents a safety factor applied to cater for different turbulence conditions in design. The value of $K_T$ is 1 for normal turbulence in rivers but may be as high as 3 to 4 in extreme conditions. Pilarczyk (1990) provided guidance on the value of $K_T$ to adopt in design as well as determining the value of $K_h$.

## DETAILING

### Toe Protection Details

Toe protection will provide some sliding resistance to revetment and help to prevent failure of revetment from scour. Typical forms of toe protection are:

(a) *buried toe* – the revetment cover layer is extended beneath the bed level to beyond the predicted scour depth (see Fig. 3a);
(b) *sheet piling* – this may be used alone or with a concrete toe beam (see Fig. 3b);
(c) *toe retaining structure* – this may be in the form mini-wall (see Fig. 3c);
(d) *extension of cover layer along bed* – the cover layer may be extended along the bed in front of the structure(see Fig. 3d); if scour occurs, then this extra length of revetment will drop into the scour hole providing protection (therefore this extra length of revetment should be flexible such that it can deflect; alternatively if this length extends over the entire channel bed then scour will not develop).

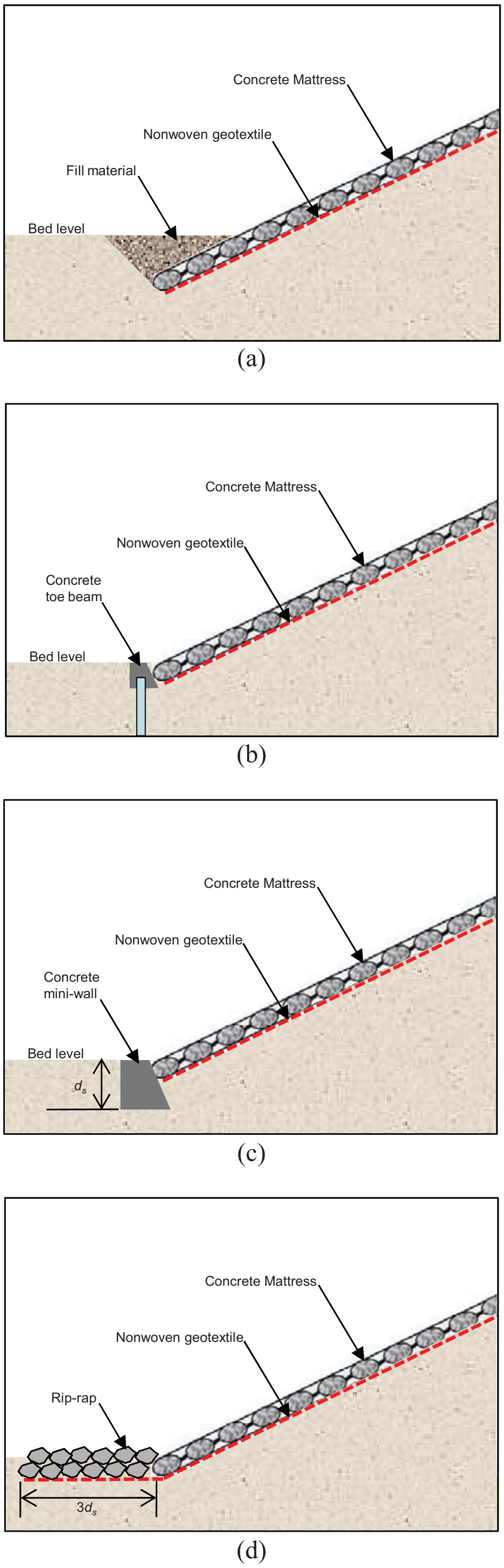


Fig. 3 Toe protection details (a) buried toe (b) sheet piling (c) toe retaining structure (d) extension of cover layer along bed

### Trenching Details

The top of concrete mattress revetment is generally anchored in a trench. The trenching and anchoring details may differ from case to case. Overtopping and overflow of the structure are seldom a major risk event with concrete mattress revetments because either the hydraulic events concerned are not as aggressive or the revetments tend to be extended to the top of slope. When there is a possibility of significant overtopping or overflow of the structure, erosion protection of the back face may need to be provided for.

### Termination Details

Appropriate termination details should be adopted at the ends of the structure to prevent undermining at the end of the structure. Such details are usually very much site-specific. The termination details may involve butting against a solid structure; e.g. concrete walls, wing walls of culvert openings, concrete discharge drains along the bank slopes, etc. or involve the revetment curving back in plan into the bank slopes.

## INSTALLATION METHODOLOGY

Some pre-installation planning may be necessary, which includes estimation of panel sizes and tailoring to suit a site situation. Slope preparation, trenching and other profiling may be needed before the product is laid out. When the product is laid out in position and properly anchored, micro concrete is then injected into the internal space created in-between the two fabric layers.

The filling of the concrete mattress is done by compartments in a selective order sequence. It may be necessary to prepare for these compartments during the pre-installation planning, taking into account the layout, the concrete batch size and the anticipated rate of filling. Any spillage of concrete slurry over the concrete mattress surface during filling shall be washed away to provide an aesthetic finish. When the filling of the mattress with micro concrete is complete, the trench at the top of slope is backfilled with soil.

## KLIA 2 PROJECT CASE STUDY

The Kuala Lumpur International Airport (KLIA) Phase 2 Project is an extension project to KLIA. KLIA 2 is slated to be the largest purpose-built and dedicated terminal for low-cost carriers in the world. This new project site is located less than 2 km away from the KLIA main terminal building. KLIA 2 is designed to accommodate up to 30 million passengers annually, and could be upgraded to serve 45 million passengers a year.

The KLIA 2 project involves the construction of an integrated complex that includes infrastructural works e.g. earthworks, road works, drainage works, etc. At the aircraft parking apron area, for drainage channels, concrete mattress was used as the revetment and lining system. This choice was due to economics, ease of installation and aesthetics.

The selected concrete mattress system has a dimpled square block motif and the geotextile form to allow the filling with micro concrete also acts as an articulating backing. As a result, a flexible revetment system is created. The use of a flexible revetment system was important at this site because the subsoil was soft and differential ground settlement was to be expected with time.

Two sizes of concrete mattress were specified, depending on site design conditions. One has a filled nominal block thickness of 120 mm while the other has a filled nominal block thickness of 180 mm. Figure 4 shows the typical cross section of the channel lined with concrete mattress for the KLIA 2 project.

The concrete mattress was anchored into a top trench which was later backfilled with suitable soil. A layer of topsoil was placed at the top of the revetment slope prior to turfing. The channel depth varied up to 2.7 m with revetment side slopes of between 1:2.5 to 1:3.

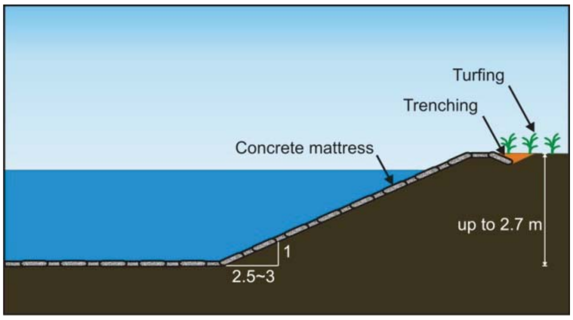


Fig. 4 Typical cross section of the channel lined with concrete mattress for the KLIA 2 project

Figure 5a shows the general installation works; in the background slope is prepared for the laying of concrete mattress, in the foreground concrete mattress has been laid out, and in-between certain sections of concrete mattress has been filled with micro concrete. Adjacent panels of concrete mattress were linked by seaming with a hand held sewing machine. Figure 5b shows the filling of compartments of concrete mattress with micro concrete. Figure 5c shows the completed concrete mattress prior to impoundment. Figure 5d shows the impounded channel lined with concrete mattress.

(a)

(b)

(c)

(d)

Fig. 5 Concrete mattress for drainage channel revetment and bed lining at KLIA 2 (a) overall construction showing prepared slope, mattress prior and after filling with micro concrete (b) filling of mattress with micro concrete (c) completed channel prior to impoundment (d) impounded channel

## CONCLUSIONS

The design, detailing and installation methodology of concrete mattress for erosion control in channel applications were discussed. A specification for micro concrete for the filling of the mattress was provided. A case study involving the use of concrete mattress for the erosion control of the drainage channels of the KLIA 2 project was described.

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