FLEXMAT™

MARECON

MARINE ENVIRONMENTAL AND CONSTRUCTION CONSULTANTS

Flexmat Flexible Concrete Block Mattresses

Flexmats are flexible concrete block mattresses with a guaranteed operational life time of at least 50 years in the most adverse environmental conditions, both onshore and offshore.
The Flexmat system has been applied in Australia (and occasionally overseas) on many projects since 1984.
It is highly competitive - both in terms of its performance and relatively low cost - in comparison to more traditional systems such as rip-rap, rock linings, grout fill- or reno mattresses and sealed linings (shotcrete, bitumen, concrete slabs or pavers)

Key Features of the system are summarised as follows:

- Fast installation rate (normally exceeding 75 sqm per hour)
- long-term durability in (sea)water with maximum UV protection;
- Environmentally and visually attractive, especially if dyed;
- Broom-finish anti-slip roughness (minimising public liability risk in boat ramp and waterway embankment applications)
- Hydraulically smooth lining face, ensuring that visual pollutants such as weeds, plastics and other rubbish will not be trapped or stick to it.
- Retrievable and re-deployable in seasonal or temporary applications such as beach ramps, access roadways etc.
- Not sensitive to vandalism and virtually maintenance free;
- Excellent resistance against chemical and biological degradation;

Finalist

2008 WA Engineering Excellence Awards

Seawall revetment at Anderson Point, Port Hedland



MARECON Pty Ltd

Marine Environmental & Construction Consultants

The company was established in 1983 by P J (Jan) deGeeter, after he had completed a two-year assignment as senior pipeline engineer at Woodside's Rankin project on the North West Shelf of Australia.

He graduated as a coastal engineer at Delft University of Technology in the Netherlands in 1961 and has more than 60 years of design and offshore experience, in the service of Royal Dutch / Shell and leading international marine pipeline Consultants R J Brown and Associates.

Marecon is the sole owner of the Flexmat technology, IP rights and Trade Mark.

The company commenced operation in 1984, initially supplying a large number of concrete block mattresses to Woodside Energy from supplementary stabilisation and free span control at various locations along the Rankin trunkline and for scour prevention around the base of the Rankin offshore platform and flare structure.

Flexmats are currently produced in all States of Australia for onshore and offshore application by regional Licensees. (reputable precasting companies)

Using specially developed and certified software, Marecon produces tailored designs for the prospective customers as part of an overall support package which also includes installation directives. If necessary, on-site support and advice can be provided by the company's installation specialist.

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Information Document for Onshore and Coastal Applications

(1) INTRODUCTION

This document provides detailed DESIGN- and INSTALLATION Guidelines for professional engineers wishing to determine whether the Flexmat™ system could be applied at the project under consideration and pre-select the most suitable Flexmat™ version.

The contents of this document are based on conservative design and engineering practice, in compliance with relevant Australian Standards and Codes.

However, due to lack of specific information pertaining to the project site, the advice and figures provided in this document should be treated as advisory only. As a consequence, Marecon cannot accept responsibility for the manner in which the contents of this document are interpreted nor for its consequences. However, if called upon, Marecon would be available to provide professional –sites specific- advice at a nominal fee.

(2) GENERAL

The concept of regular concrete block patterns, precast on permeable geotextile matting was developed more than fifty years ago in Western Europe. In these early mattresses the blocks were bonded to the matting by means of synthetic pins. After introduction of the system into Australia, more than forty years ago, the pins were replaced by a dense pattern of stiff loops tufted into the matting.

During the concrete casting- and vibrating process the loops penetrate into the base of the liquefied concrete, providing superior bonding between blocks and matting at significantly reduced labour cost.
As a consequence the all-in cost of an installed Flexmat lining is highly competitive in comparison to more traditional systems such as armour rock, rip-rap and grout fill mattresses.

The principal merits of the FLEXMAT system are summarised as follows:

- Assured long-term durability (of more than 50 years) under any conceivable site conditions;
- Virtually maintenance free;
- Environmentally attractive, particularly if dyed;
- Broom-finish surface roughness, minimizing the risk of pedestrians losing their footing;
- Hydraulically smooth, preventing plastic bags or other rubbish from sticking to the lining;
- Easily retrievable and redeployable;
- Highly resistant to vandalism.

(3) PRODUCT INFORMATION

Standard Flexmats consist of a uniform rectangular pattern of square concrete blocks cast onto durable woven polypropylene fabric, called loopmatting. Mattress dimensions and other parameters are presented in the standard drawings shown in Attachment 1.

Concrete durability is assured by adopting the right type of cement and aggregates for the anticipated environmental conditions. The matting has excellent durability, both in marine environment and on land, containing special long-life additives to prevent degradation by UV light and loss of strength in seawater.

The matting also has excellent resistance to wear and tear, bio-organisms, most chemicals and abrasion. More information and the results of extensive testing programmes are contained in a detailed technical document. (which can be provided on request)

Notes:

1. The flexmats can be supplied in different widths and lengths, with our without side skirts, at insignificant additional cost per sqm.(the number of blocks per row and the number of rows would be varied)

2. In the absence of side skirts the gap between adjoining flexmats can be sealed by means of a strip of non-woven fabric (Bidim A14 or equivalent) placed centrally below the jointline. The required width of the strips roughly equals the height of the design wave. (with a minimum of 0.6 m and a maximum of 1.5 m for a design wave height higher than 1.5 m)

(4) ONSHORE AND COASTAL APPLICATIONS

Recommended standard FLEXMAT versions are as follows:

FLEXMAT FM 65 for:

- Bicycle tracks
- Pedestrian passage ways, malls, walkways in parks, jogging tracks, beach/dune crossings
- Terrain cover in utility areas (requiring occasional access to buried drains/cables)
- Farm applications (cattle feed areas, pens and other hardstand areas)
- Lining of lakes, ponds, sewage reservoirs and sumps
- Speed control humps in roads, access driveways to garages and carports
- Boat Ramps

FLEXMAT FM 100 for:

- Temporary road way for 4WD vehicles, light trucks up to a loaded weight of 5T

FLEXMAT FM 150 for:

- Vehicles up to a loaded wight of approximately 15 tonne

(5) HYDRAULIC APPLICATIONS

Required flexmat mass (Mf) in kg/m2 follows from Mf = 3.0 * v2 / cos(α) (1)
in which "α" is the slope angle of the lining (in degrees) and "v" is the main (over)flow velocity in m/s defined as the channel's discharge in m3/s divided by its flow cross section in m2.

Notes:

1. The above expression (1) is conservative, based on extensive full-scale overflow trials on concrete block mat systems undertaken by CIRIA in the UK.
2. In the event of wave action in, for example, wide rivers or estuaries the above expression can still be applied as long as the maximum wave height (in m) does not exceed the dry weight of the flexmat (in /m2) by more than a factor 5.

Example: in case of flexmat FM65 with a weight of around 0.14 T/m2, maximum wave height should not exceed 5 * 0.14 = 0.7 m. (approximately)

(6) FORESHORE APPLICATIONS

(a) On straight embankments without berm (as schematically shown below)

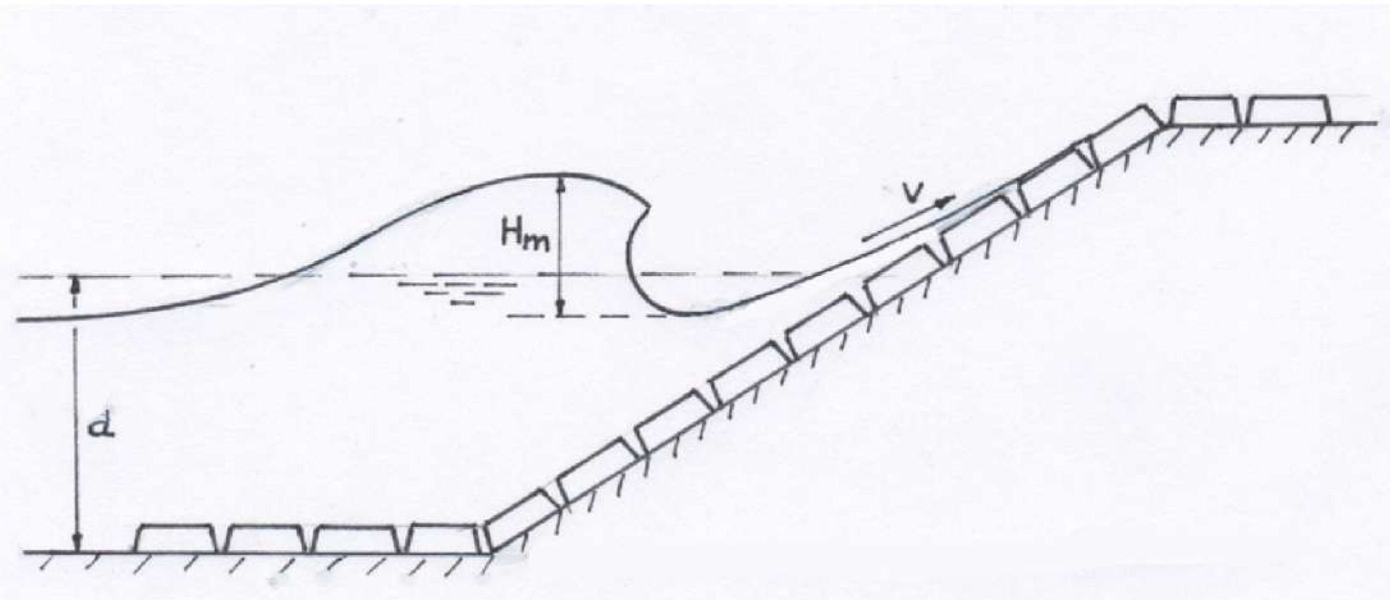


figure 1. On straight embankments without berm schematic diagram

Extensive field and flume trials by Delft Hydraulics and other hydraulic research Institutes have shown that there is an approximately linear relationship between wave height and required mattress weight as a function of the so-called “breaker parameter”.

The relationship is graphically represented in figure 2, right

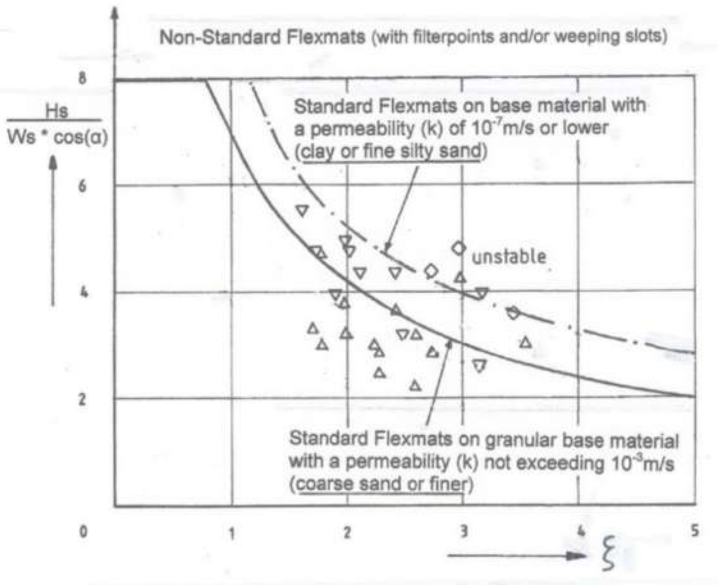


figure 2. Breaker Parameter schematic diagram

in which Hs is the significant wave height (in m), Ws is submerged mattress weight (in T/m2) and ξ is the breaker parameter which equals tan(α) * (Lw/Hs)0.5 in which “Lw” is the wave length (in m) and “α” is the slope angle of the embankment. (in degrees)

The wave length can be derived from its period “T” (in sec.) according to: Lw = c * T in which “c” is the wave celerity (in m/s) which follows from: c = (g * (d + Hs))0.5 (2)
in which “d” is the water depth in front of the embankment at design (storm surge) water level and “g” is the constant of gravitational acceleration.

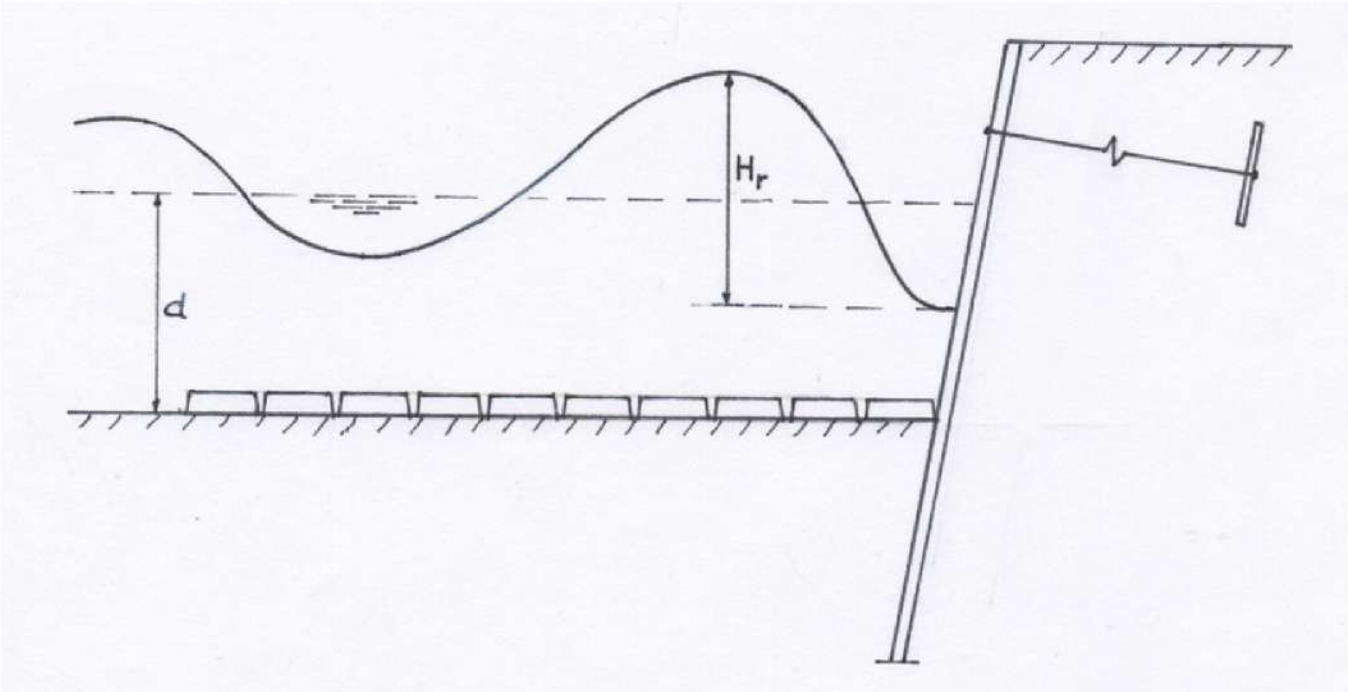
Example 1:
For a foreshore or straight embankment with a gradient of (say) 1 : 4 (a slope angle of 14 degrees) consisting of coarse sand, at a significant wave height of 1.5 m with a period of 3.5 seconds and a water depth of 2.5 m. one finds:
c = (9.81*(2.5+1.5))0.5 = 6.3 m/s, Lw = 6.3 * 3.5 = 22 m, ξ = tan(14)*(22/1.5)0.5 = 0.95
From the lower graph in figure 1 one finds: Hs/(Ws * cos(α)) = 7 (approx.)
This renders: Ws = Hs/(7 * cos(14)) = 1.5/(7 * 0.97) = 0.22 T/m2
At a concrete density of (say) 2.4 T/m3 and a seawater density of 1.025 T/m3 required flexmat weight follows from Wf = Ws * 2.4/(2.4 – 1.025) = 0.38 T/m2

Example 2:
In the case of a flexmat lining on clay the upper graph applies. For unchanged slope angle, wave parameters (and ξ value) one finds that the value of Hs/(Ws * cos(α)) would be larger than 8. Adopting this as a safe upper limit one finds: Ws = Hs/(8 * cos(14) = 0.19 T/m2 and Wf = 0.34 T/m2

Notes:

1. the Flexmat system can also be safely applied in cases of granular bank material with high permeability. (fines or rock up to a D50 of roughly 100 mm). Such cases require the application of non-standard flexmats with a dense array of filterpoints and/or weeping slots. (At little additional cost in comparison to the standard flexmats). This would keep the -wave induced- overpressure below the lining relatively low, falling well short of the so-called "Morison" lift force generated by the run-up velocity of the breaking maximum wave. Required flexmat weight per m2 can then be found by the application of expression (2) on page.....of this document. Example: at a bank gradient of (say) 2:3 and a maximum wave height "Hm" of 2 m at a water depth "d" of 3 m in front of the embankment (without berm) one finds according to expression (2):
v = (g * (d+Hm))0.5 = (9.81 * (3 + 2))0.5 = 7.0 m/s.
Required flexmat mass (Mf) in kg/m2 then follows from expression (1):
Mf = 3 * v2 / cos(α) = 3 * (7)2 / cos(34o) = 177 kg/m2

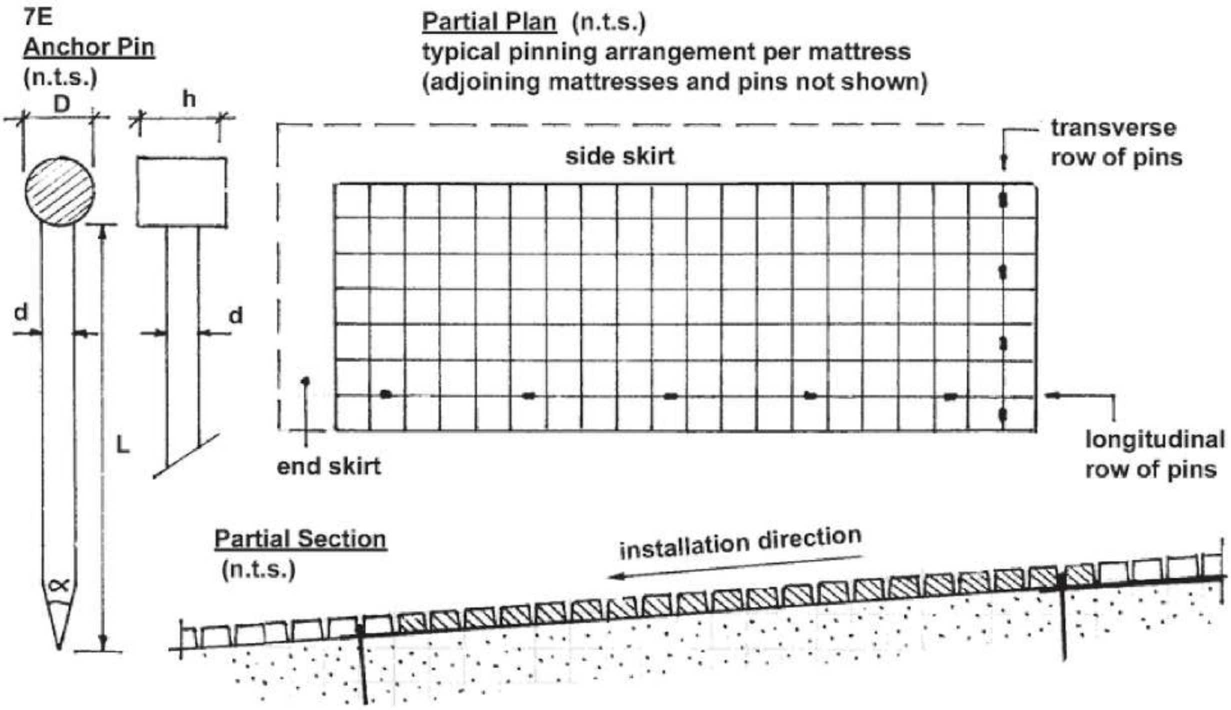
2. In the extreme case of the "slope" becoming 90 degrees or close to it (as indicated in below sketch of an anchored wall) the graphs in figure 1 would still apply. However the breaker parameter should be calculated for the reflected wave height "Hr" (which in the worst-case scenario -at 100% reflection- could become twice as high as the incident wave height Ho)



3. in case of weak bank material with low internal friction the presence of a cover layer (whether flexmat or rock) would not substantially enhance its internal stability and, as a consequence, would not reduce the risk of deformation failure during the worst-case scenario. (a high water level with concurrent severe wave pounding) In such case a slipcircle failure analysis must be performed.

(6) ANCHORING

Normally, the FLEXMATS would require anchoring to prevent creep or slippage caused by vehicle motion or wave dynamics. For this purpose standard steel anchor pins are most often used. The short pins are used for type FM40 whilst the long pins are used for all heavier Flexmat versions.



pin dimensions: (mm)	D	d	h	l
- short pins (for FM40 mattresses)	16	12	40	500
- long pins (for FM65 and heavier)	24	16	60	750

material: steel (D-bar, galvanized or epoxy coated)
point angle ( ) not to exceed 30 degrees

At each mattress, the transverse pins are placed between the upper edge block rows 1 and 2, as shown. In case of vehicle loading this is the edge facing the main traffic flow.

The pins are driven down until wedged between the blocks. During the final stage, when the pin head approaches the block surface, a steel extension rod is used in order to prevent hammer impact (chipping) damage to the block's edges. Pin driving is halted as soon as the pin head become wedged between the blocks, preventing contact with the matting.

The number of anchor pins required to prevent creep, slippage or hydrodynamic lifting of blocks is established as follows:

(a) for Flexmat lining of flow channels, water courses, open drains etc. without significant wave action:

At the section of the lining that would be permanently or occasionally submerged (during floods) the upstream edge row of blocks facing the flow direction is anchored by 1 pin every 2rd block (this is necessary to counter the additional lift force generated if the edges of the upstream blocks protrude above the mean lining surface.)

For the more elevated, permanently 'dry', section of the lining, at gradients steeper than 1 in 3, anchor pins may be required transversely (as calculated according to expression 2 below) to prevent downward mattress slippage.

(b) for Flexmats on embankments exposed to wave action:

np1 =Wmat*(sin(a)-0.33*cos(a))/Fa (1)

(c) for Flexmats exposed to vehicle traffic:

np2 =(0.15*Wveh*cos(a)+Wmat*(sin(a)-0.65*cos(a)))/Fa (2)

in which- np is number of transverse pins required per Flexmat (section) (*) with weight Wmat (in T)
- Wveh is predominant vehicle weight in T.
- Fa is minimum lateral holding power per pin. (for long pin: .25 T. For short pin: .125 T.)
- (a) is slope angle of embankment

(*) in cases of slow or sporadic traffic (e.g. maintenance vehicles) the calculated number of pins can be halved.

Note: for Flexmats subject to wave action and traffic loading (at different points in time) the highest calculated np value should be adopted. (values of np1 and np2 not to be added up)

Note: a negative np value indicates that there is sufficient base friction against slippage. Consequently no pins would be required, up to a positive np value of 2 (due to the generous safety margin in above expressions) For np values between 2 and 3.5 the number of pins should be rounded up to one installed pin every second block transversely and one pin every fourth block longitudinally. These figures are also the minimum required transverse and longitudinal spacings in permanent roadway applications. to avoid gradual lateral mattress separation over time.

Normally, longitudinal pins are spaced twice as wide as the transverse pins (without exceeding 1 pin every 4th block)

Note: if anchoring is required it is important that, on embankments steeper than 1 in 3, one ensures that:

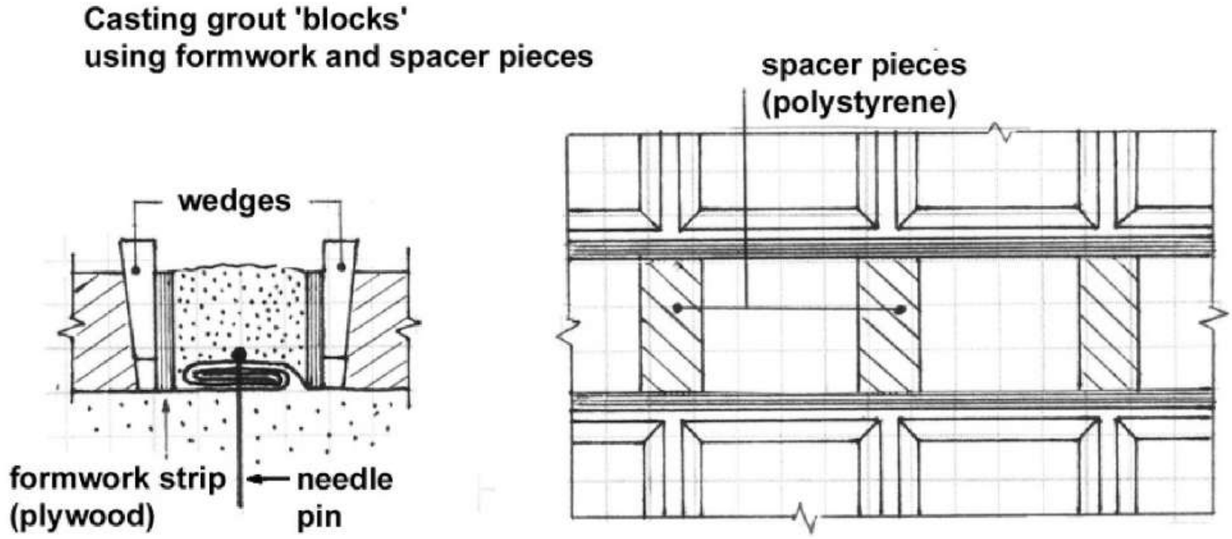
- (a) proper anchoring occurs at all joint lines to ensure that all mats are interconnected, acting as one large assembly.
- (b) the top edge of the upper mats to be well fixed in order to eliminate any risk of the entire Flexmat assembly sliding downslope. (with reference to the alternative fixation methods described in par. 9)

Note: by interconnecting all Flexmats in downslope direction, the slippage force is not primarily absorbed by the holding power (*) of the pins in the base material but, rather, by the tensile strength of the interconnected matting.

(*) which may be low in soft base material

(7) ALTERNATIVE FIXATION METHODS

(a) by means of grouting

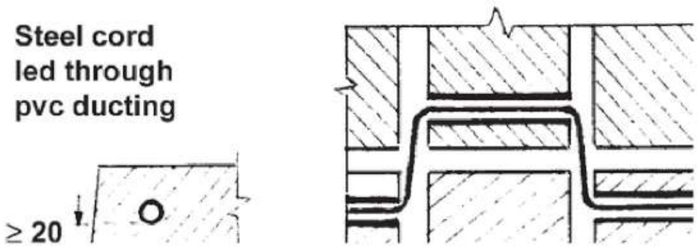


Mattress block rows would need to be cast centrally, with equal skirt width at either side.

After installation, the skirts of adjoining mats are tightly rolled up and firmly pinned down by means of knitting-type needles, placed at at approximately 0.5 m. intervals.

The gap (roughly one block wide) is then filled by means of a grout pump/hose system. This method is economical and preferable if visual appearance is irrelevant. (e.g. under water)

(b) by means of steel cords

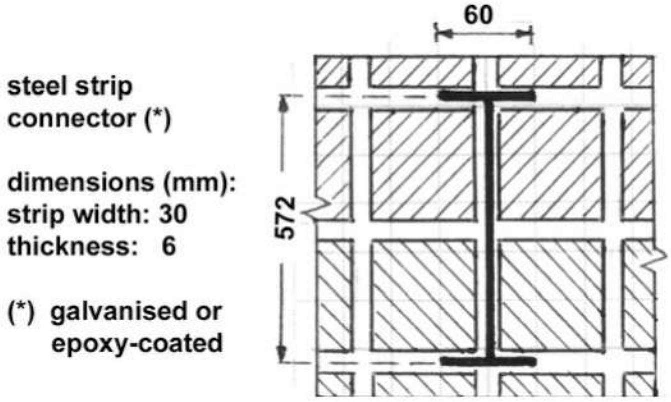


This method is advantageous if there is the prospect that mattresses may, at some point in future, need to be lifted and repositioned. (in such situation it would be easy to disengage the cord system)

After installation of the mattresses the flexible stainless steel cords are directed through small diameter pvc tubes, precast in every second edge block.

This 'shoe lacing' method was successfully applied at the Thevenard project mentioned in par. 5C of this document.

(c) by means of steel strip connectors (or pins driven into pre-drilled holes)



In case of hard base material such as rock or limestone the Flexmats are to be placed on a bedding layer of sand, fines or roadbase. Such layer would normally be thin, with just sufficient thickness to fill the depressions between the base materials protrusions. Consequently anchor pins would not penetrate deep enough to render sufficient holding power.

In such situation one could use steel strip connectors as shown above. The number of connectors required would be half of the required number of anchor pins, subject to spacings not exceeding specified upper limits.

In areas accessible to the general public it is recommended (if the block grooves are left unfilled) to 'fix' each connector by means of small lumps of grout.

Alternatively it is possible to use anchor pins after having drilled holes at the pin's intended locations, with hole diameter equal to anchor pin diameter.

The pointed pins, reduced to roughly half length, are then hammered in, providing adequate holding power as a result of tight fit. By using a drill with elongated stem, holes can be drilled to considerable depth under water, for adequate pinning of fully submerged mattress sections.

This method was found to be effective during upgrading of the Leeuwin Barracks ramp in the Swan River (W.A) where a Flexmat lining was placed directly on top of a degraded (cracked) concrete ramp. (using pins at one third of standard length)

(8) GROOVE FILLING

In traffic applications it is beneficial to fill the grooves to, roughly, half block height with a lean mix of blue metal, sand (10%) and cement (5%)

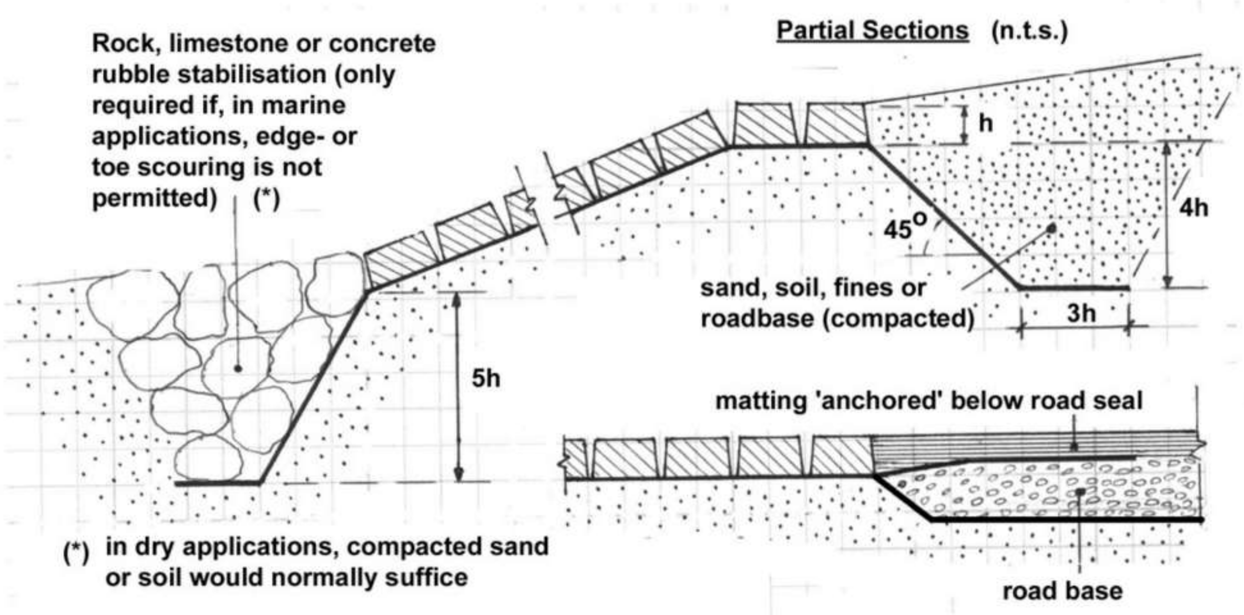
The mix is then brushed into the grooves and its adhesion, after curing, will prevent any substantial dislodging of particles from the grooves.

Such measure eliminates potential mattress slippage or creep. As a result the required number of anchor pins can be halved by doubling the pin spacings.

In addition, groove filling prevents the growth of weeds and effectively shields the matting from UV light.

(9) EDGE STABILIZATION

If the mattress' edges could be undermined by scour or if there is a perceived risk of vandalism in areas accessible to the general public it is recommended to bury the edge skirts as well as any exposed head skirts or toe skirts.



Note: in water courses with erodable bed material the toe of the lining needs to be extended to cope with possible descent of the mean bed level during the lining's design life.

CAUTION: in the case of boatramps the toe skirt should be cut off to prevent the exposed, buoyant, skirt from getting hooked by the under-carriage of trailers or the skeg of outboard engines.
Also and most importantly, the toe row of blocks should be at least 1 m. (*) below the lowest possible water level, to prevent lifting of blocks by the hydrodynamic lift force generated by propeller wash.
(*) for typical conditions

If necessary, at low water, the toe row of blocks could be lowered by manual excavation along its edge (using spades or rakes), creating a trench into which the undermined toe block row would collapse.
In marine applications the fill material used for the burial and weighing down of skirts would be concrete rubble, rock or limestone pieces with average particle weight at least three times the weight of a single Flexmat block.

In dry applications the side skirts could be stabilised by any low-cost granular material as may be available such as (compacted) sand, soil, clay, fines, blue metal or road base.

Note: in boatramp applications it would be beneficial to cover the top skirt by extending the bitumen- or concrete seal of the access road onto the fully stretched, skirt up to the first (upper) row of blocks.
If the road seal material has sufficient tensile strength, the penetration of loops into the seal would effectively prevent the upper mattresses from sliding downslope and, as a consequence, would eliminate need to anchor the upper mats by pinning.
In dry applications accessible to the general public one may consider to bury the edge row of blocks.
It would eliminate the risk of vandalism by making it virtually impossible to manually dislodge the edge blocks.

(10) CURVED ALIGNMENTS

In non-straight alignments, tapered mats would be required. These could be precast.

A more flexible option would be to cut the lighter Flexmat versions, up to FM100, to the required shape on site. A portable disk grinder is used to cut through the blocks at the intended cut line.

Mats would also be cut to fit the outline of adjoining structures. Any gaps remaining would then be grouted up if there is a risk of the base material escaping, using a grout pump with pressure hose in underwater applications.

(11) ENVIRONMENTAL ENHANCEMENT

In environmentally sensitive areas it would be beneficial to dye the concrete grout during manufacture or to spray the blocks after curing, using UV-resistant paint, in order to ensure the the lining would blend in well with surrounding natural materials such as limestone or grass.

In regions with sufficient rainfall the visual appearance of embankment Flexmats could be further enhanced by filling the grooves with grass-seeded soil.

(12) FLEXMAT INSTALLATION

Flexmats can be swiftly installed, using a tubulars/slings/hooks assembly as shown in Attachment 3. The squeezing arrangement, as shown ensures that the suspended mattress can not dislodge prematurely.

The mats are normally lifted by mobile crane from one end. However, for short mats with reduced number of block rows, a front-end loader or back-hoe could be used.

No special installation expertise is required except for normal care to be exercised by machine operator and supervisor, in accordance with detailed instructions as summarized in attachment 2.

Note: heavy non-standard Flexmats, including those for marine pipeline stabilisation and scour control, are provided with swiftlift points at every second block and installed by means of a parallel beam installation frame.

Installation directives can be summarised as follows:

- (a) base material to be well-smoothed by means of transverse skimmer beam (supported at its ends by longitudinal ‘runner’ beams) followed by mechanical compacting.

- (b) in marine application: mats to be installed at the lowest possible water level. It may be feasible to install the Flexmats ‘in the dry’ by constructing a temporary bund wall of sand or soil. (e.g. in case of boatramps)

- (c) during mattress suspension the lifting tubulars must be kept perfectly horizontal, to avoid progressively worsening misalignment (skewing) of successive mattresses.

- (d) special care should be taken that the side skirt is fully stretched (not dislodged by wind) at the moment the blocks of the following Flexmat touch down on it. (to ensure that effective overlap width is not reduced)

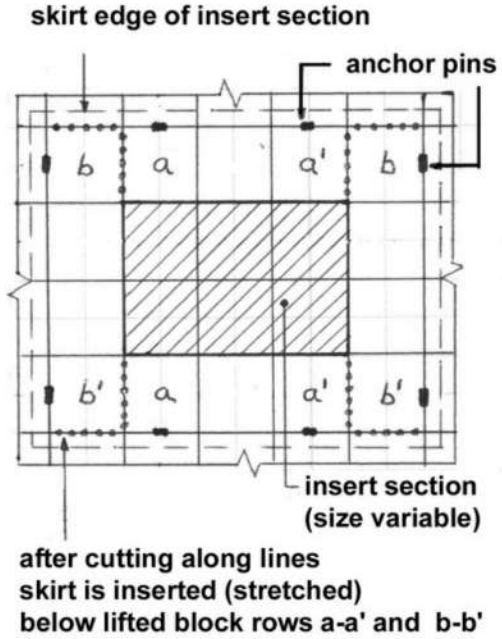
The installation directives are condensed in attached summary sheet. It is crucial that it is handed to the installation supervisor on site, well before the work commences.

(13) MAINTENANCE

Over time, some cracking or chipping of blocks could occur, caused by excessive wheel loads, dropped objects etc. At a certain stage of cumulative damage the affected blocks should be cut out and replaced by a precast insert section.

Its skirt, at least 800 mm wide in all directions, is then pushed sideways below the surrounding blocks until fully stretched and then secured by pins as shown.

Single damaged or crushed blocks can be replaced by chipping away the concrete residue without damaging the base matting and then perform an in-situ recast, using a portable (single or double) block mould, made out of steel or plywood.



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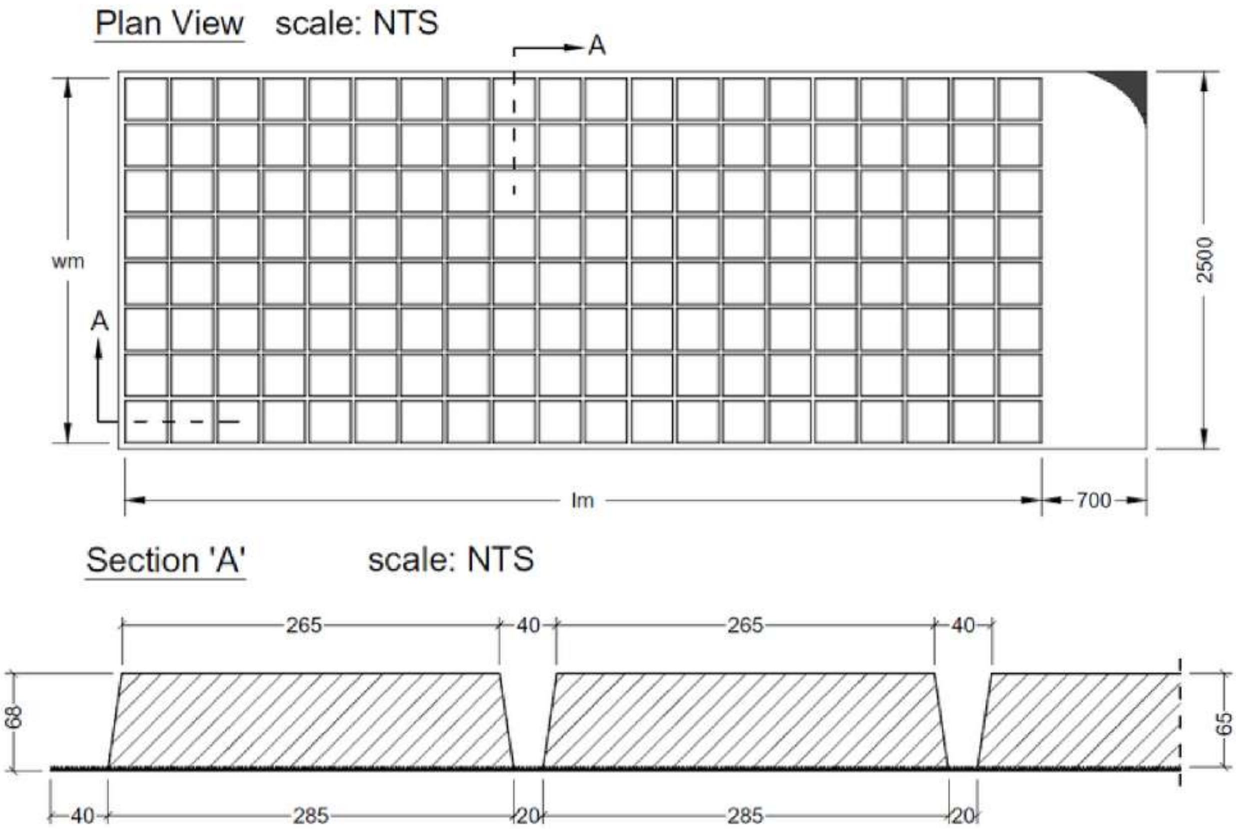
ATTACHMENT 1

DRAWING OF STANDARD FLEXMAT FM 65



FLEXMAT WEIGHT (in T) at concrete (*) density of 2.35 T/m3

number of block rows	lm (cm)	number of block rows				
		4	5	6	7	8
		wm (cm)				
		120	151	181	212	242
11	334	0.52	0.66	0.79	0.92	1.05
12	364	0.57	0.72	0.86	1.01	1.15
13	395	0.62	0.77	0.93	1.08	1.24
14	425	0.67	0.82	1.00	1.17	1.33
15	456	0.71	0.89	1.07	1.25	1.43
16	486	0.76	0.95	1.14	1.33	1.52
17	517	0.81	1.01	1.21	1.42	1.62
18	547	0.86	1.07	1.28	1.51	1.72
19	578	0.91	1.13	1.36	1.58	1.81
20	608	0.95	1.19	1.43	1.67	1.91

(*) unconfined compressive strength after 28 days curing: 32 MPa

ATTACHMENT 2

INSTALLATION SUMMARY SHEET

TIMING: other construction activities nearby (if any) such as installation of piles for walkways or jet- ties etc. must have been completed before the Flexmats are installed! Under no circumstance should the Flexmat lining be used as a 'workfloor' for such activities. (severe damage would almost certainly result)

SITE PREPARATION and **COMPACTING**: protruding objects (boulders, roots etc) need to be removed. Proper smoothing is most important as any -hardly visible- unevenness becomes very conspicuous once the mats are in place! A scraper beam on parallel runner beams should be deployed. The material should then be mechanically compacted. After installation of the Flexmats, the compactor (on plywood separation board) is to be deployed again, to accomplish proper bedding of the blocks onto the supporting material.

INSTALLATION DIRECTION: in marine applications it is important to install the mats in opposite direction to the current- or wave approach direction, in order to enhance hydrodynamic stability of the mat joints. On long embankments the upper mats are installed first, followed by the second (lower) layer of mats etc. The Flexmats are to be installed with their length axis running downslope. (if installed parallel to the shoreline it is difficult to avoid, progressively worsening, skewness)

UNDERWATER INSTALLATION: this should ideally be undertaken at the lowest possible tide level or, in non-tidal waters, at the lowest seasonal water level. This would, normally, eliminate the need to use diving gear. Where possible, installation work should be carried out 'in the dry' by first pushing out a sand- or soil bund.

MAT LOWERING: for accurate positioning and to avoid skewness, the side edge of each fringe mat should be lowered alongside a pre-pegged wire and the suspended mat should be perfectly vertical when lowered alongside the preceding mattress. The edge row of blocks should be lightly lowered onto the **FULLY STRETCHED** side skirt of the preceding mat. (this must be closely watched to ensure that the skirt is not blown back by the wind just before touchdown of the following mattress)

LIFT HEIGHT LIMITATION: if headroom is restricted (e.g. below overpasses etc.) or if reach of crane is limited, the mats could be lifted at both ends (in hammock mode) or cut into halves, for one-sided lifting. This would require skirts at both ends of the full-length mat, unless the tubulars/slings system is used. Safe working load of the crane must be at least twice the weight of the Flexmats. Hoisting should be smooth without jerking after checking that proper closure of the clamps is not prevented by debris or wrinkled (unstretched) matting.

EDGE STABILISATION, ANCHORING (*) and **GROOVE FILLING**: to be carried out in strict accord- ance with the projects specifications and as directed in the Flexmat Licencee's Guidelines document.

(*) a steel extension rod must be used as soon as the head of the anchor pins approaches the concrete blocks surface. (to avoid chipping damage to the blocks)

ATTACHMENT 3

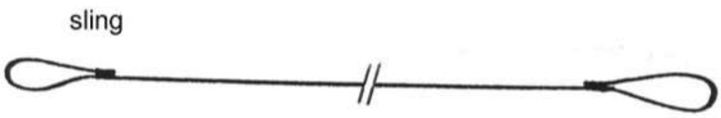
TUBULARS LIFTING ASSEMBLY SPECIFICATION FOR STANDARD FLEXMATS

(1) ACCESSORIES:

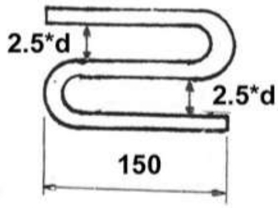
- 2 Tubulars (ERW electronic resistance welded linepipe, grade 350) Length: 2800 mm each
- 2 Wire rope slings with end loops, as shown below
- 2 Hooks (mild steel) as shown below. (to prevent slippage of slings along tubular)

Allowable mattress weights as a function of pipe diameter and wall thickness are as follows: (for a lifting angle of slings at least 45 degrees, as shown below)

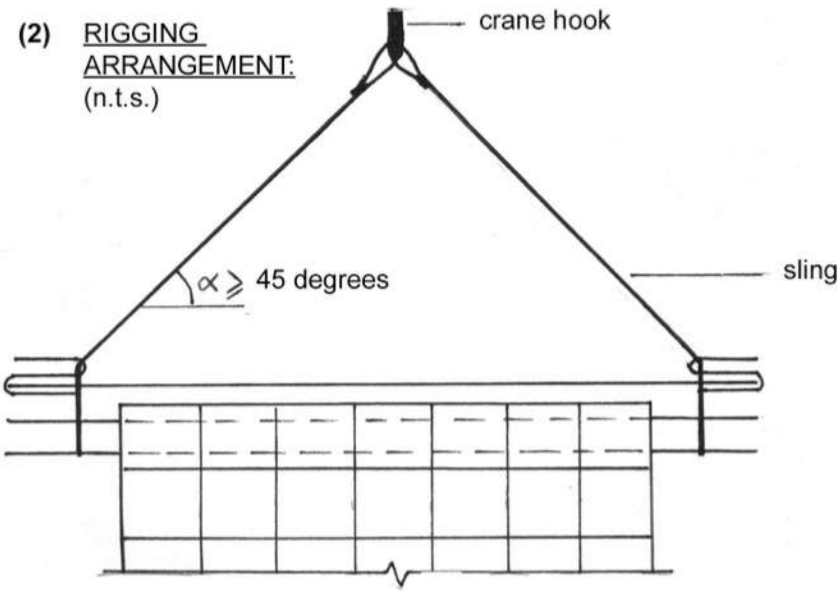
Tubulars: OD (mm)	wall thickness (mm)	Hooks rod diam. d in mm:	Allowable mat weight in metric Tonnes
88.9	5.5	12	1.0
114.3	6.0	14	1.7
141.3	6.5	16	2.4
168.3	6.4	18	3.4

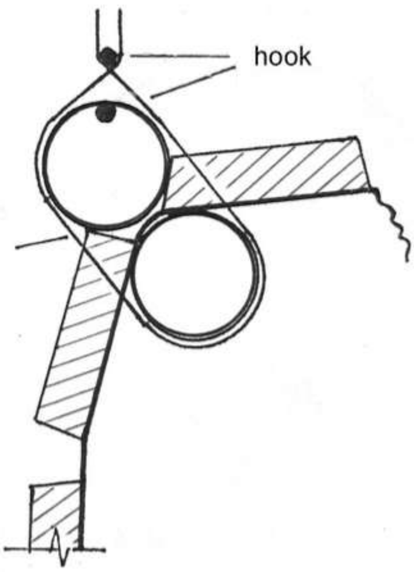


Hooks bent from TEMPCORE deformed bar (AS 1302, grade 410Y) or mill/cut from strips (AS 1205, grade WR350) with bend radius not smaller than 2.5*d



(2) RIGGING ARRANGEMENT: (n.t.s.)



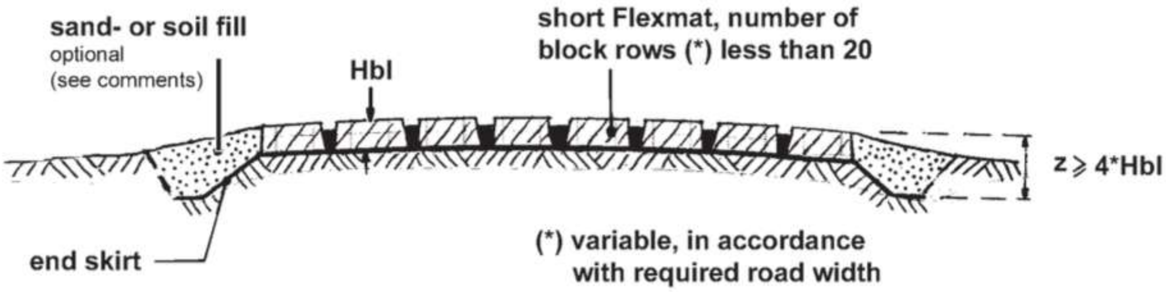


ATTACHMENT 4

Design Example 1

ROADWAY (Either permanent, for example to farm building or temporary, for example to construction site)

cross section (n.t.s.)

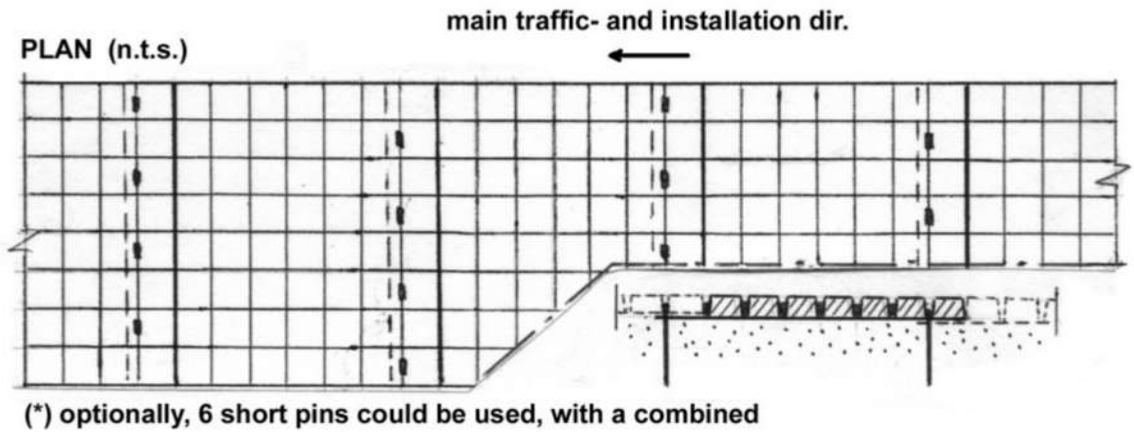


Assumed traffic: 4WD vehicles and light trucks.

According to table 7: mattress version FM65 is required Mattress weight, for 8 block rows (as shown):
From table 1: Wmat = (8/20)*1.65 = 0.66 T.

From par. 8, expression (2) for -say- level road and assumed predominant laden vehicle weight of -say- 7.5 T: np=0.15*Wveh*cos(a)+0.66*cos(a)+Wmat*((sin(a)-0.65*cos(a)))/Fa so that, for sin(a)=0, cos(a)=1 and Fa=0.25 T: np=(0.15*7.5*1.0+0.66*(0-0.65*1.0))/0.25=2.8 (*)

This is larger than 2.0 so that number of pins needs to be rounded up to one pin every second block, as shown below:

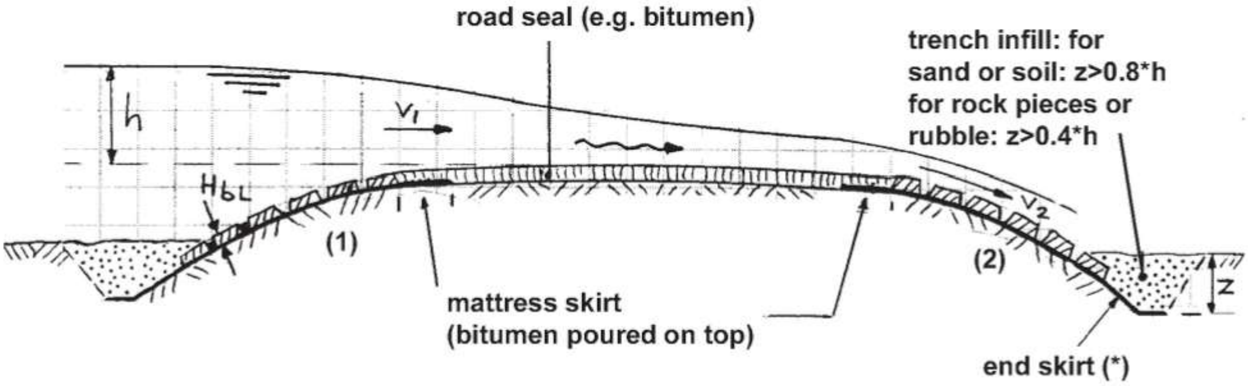


Comments: in the case of field roads inaccessible to the public the mat's edges would not normally be buried. Full length (or overlength) mats, or blocks wide, could then be installed lengthwise, reducing the number of joints and pins required.
Also: grouting of the grooves would eliminate any risk of creep.

DESIGN EXAMPLE 2

ROADWAY LEVEE (scour protection at the shoulders of occasionally overflowing roadway sections)

cross section (n.t.s.)



Design overflow velocity:

- for upstream area (1): $v1 \approx 3.2*h^{0.5}$ (1)
- for downstream area (2): $v1 \approx 5.5*h^{0.5}$ (2)

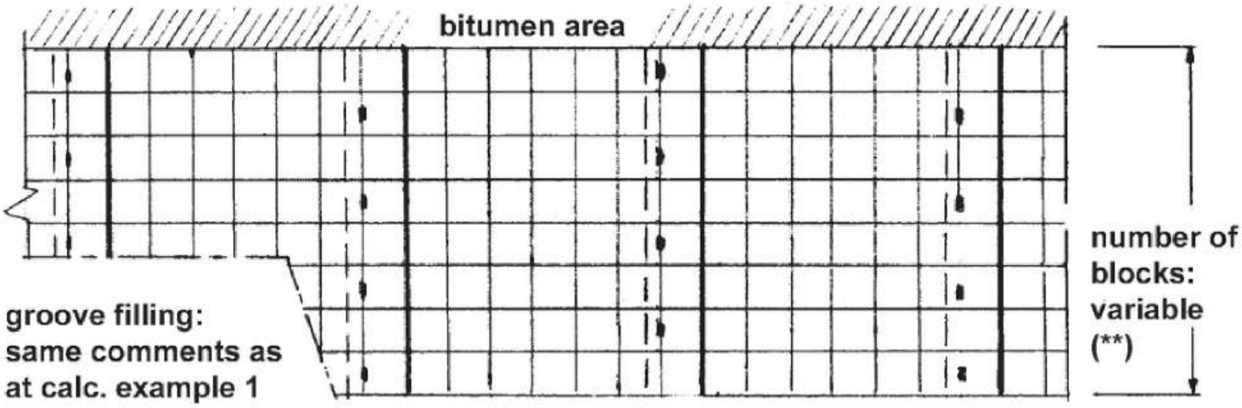
For an assumed head (h) of -say- 1.0 m above expressions render flow velocities v1 and v2 of 3.4 m/s and 5.5 m/s respectively.

According to expression (1) this renders:

For v : required dry mass M = $3.0\,(3.2)^2$ = 31kg. Adopt Flexmat FM40
For v : required dry mass M = $3.0\,(5.5)^2$ = 90kg. Adopt Flexmat FM65

Note: if the road shoulders also would need to cope with (temporarily) parked vehicles and/or operation of maintenance vehicles heavier than -say- 5T: from table 7: adopt FM100 This implies that, in such situation, mattress version FM100 would be required in both areas (1 and 2)

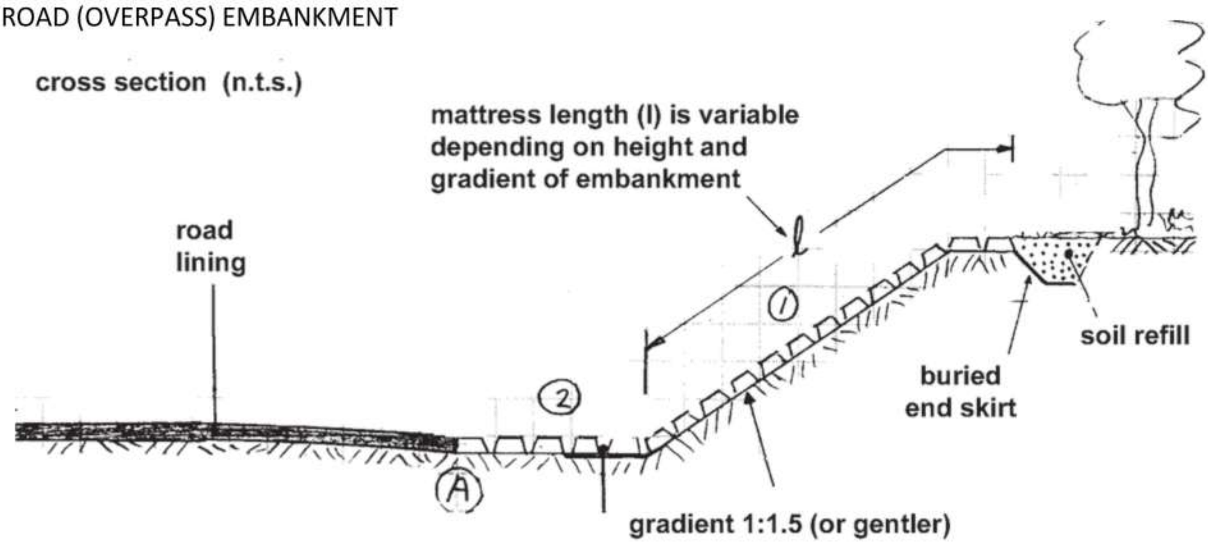
Anchor pin requirement and spacing: similar to cale. example 1



(*) minimum skirt length: at least 1.5 times head drop (h)
(**) as required by customer

DESIGN EXAMPLE 3

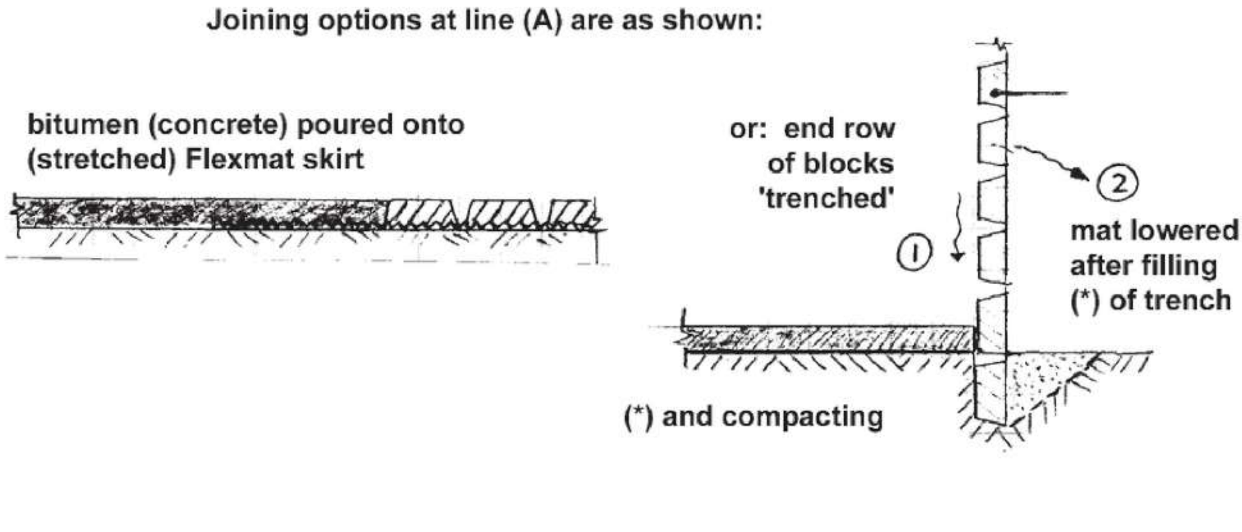
ROAD (OVERPASS) EMBANKMENT



In regard to area (1), no vehicle traffic is possible because of the steepness of the bank: mattress version FM40 would suffice. Anchor pins are not required, provided that the upper skirt of the mats is adequately buried under compacted sand or soil fill.

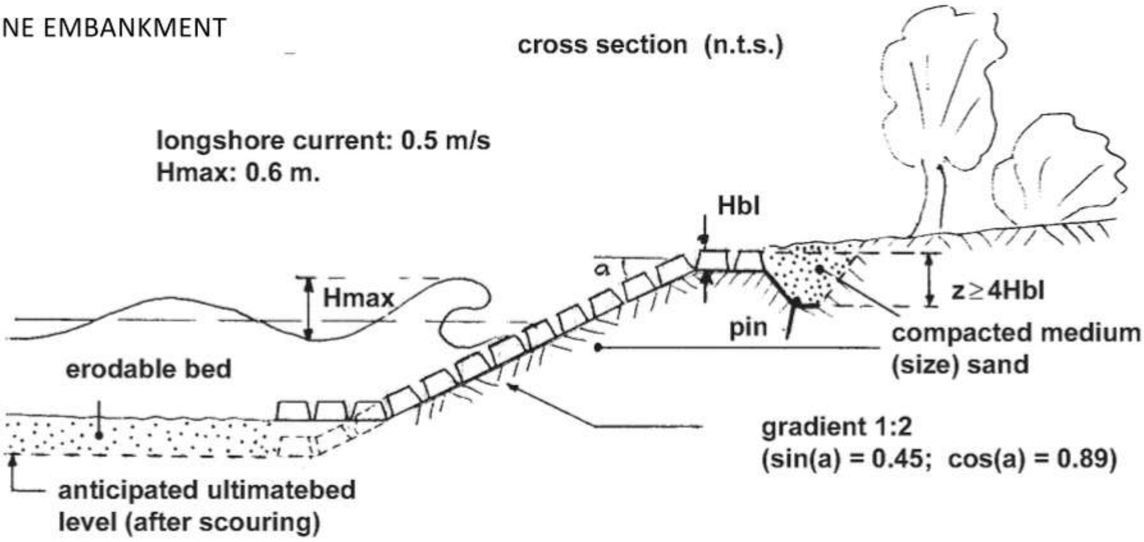
In regard to area (2), for medium weight (maintenance) traffic up to vehicle weight of -say- 4T. acc. to table 7, required mattress version would be FM65. Anchor pin requirement, ace. to par.8 , expression 2, would be minimal, with reference to calculation examples 1 and 2.

Mattresses (1) would be installed first, after which the upper block rows of each mattress (2) are lowered onto the end skirt of mattress (1), as shown above.



DESIGN EXAMPLE 4

MARINE EMBANKMENT



From tables 4A and 5A (by linear interpolation): required Flexmat version is FM100

Required no. of anchor pins for mattress of -say- 16 block rows and 7 blocks per row:

From table : Wmat=(16/20)* 2.35 = 1.88 T. From par. 8, expression (1):
np= Wmat*sin(a)-0.33*cos(a))/Fa= (1.88*0.45-0.33*0.89)/0.25=2.2 This is larger than 2 so number of pins to be rounded up to 3.5 (one pin every second block: pin spacing 572mm)

Note 3: instead of driving the pins between block rows 1 and 2 it is preferable to drive the pins into the upper skirt, as shown above, at the same (572mm) spacings.

Note 2: if light (maint.) vehicles would traverse the lining, expression (2) renders, for a vehicle weight of-- say- 3.0 T. np= (0.15*Wveh*cos(a)+Wmat*(sin(a)-0.65*cos(a)))/Fa
or
np= (0.15*3.0*0.89+1.88*(0.45*-0.65*0.89)))/0.251-0.6

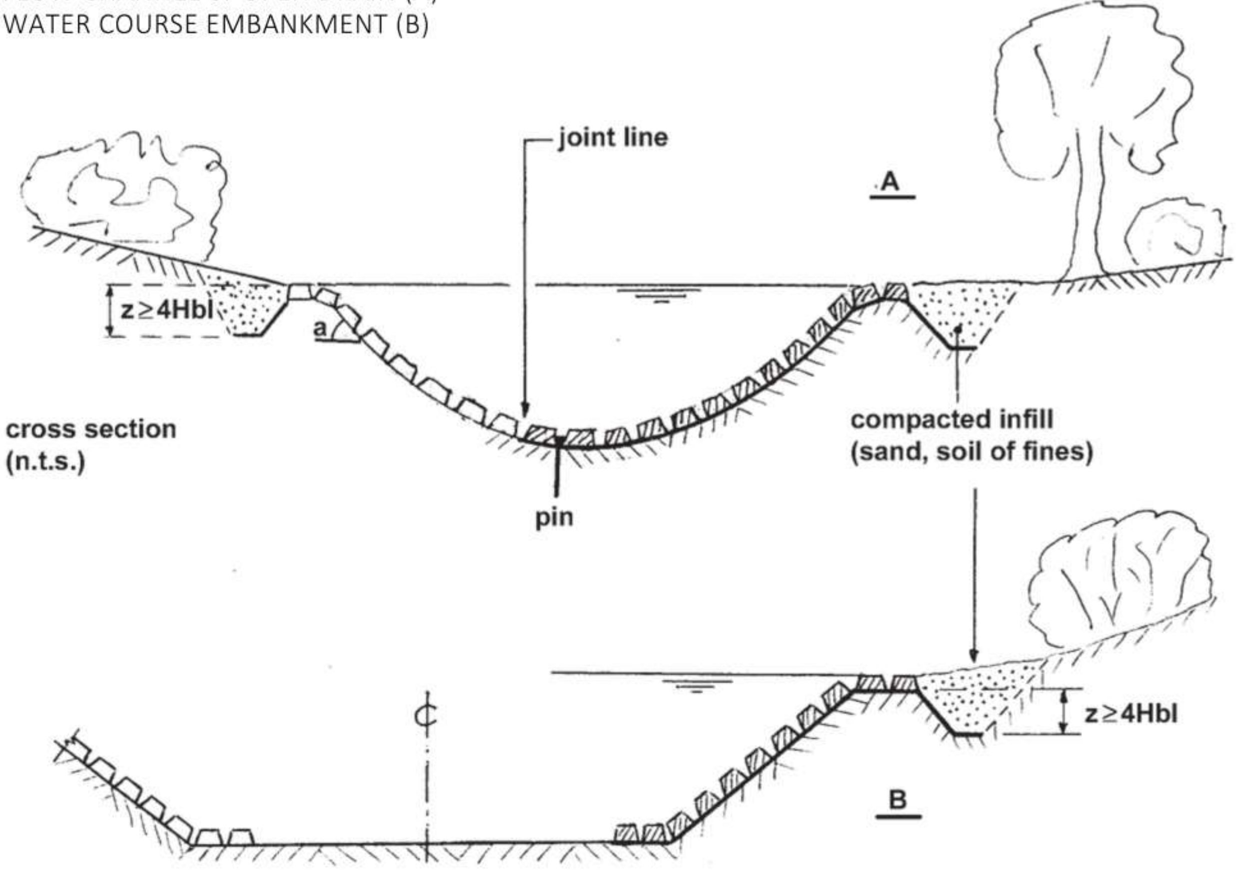
This value is smaller than 2.0 so that no pins would be required at the top. However, the above requirement against wave action (1 pin required every 2nd block) would prevail.

Note 3: if there is a 'split' mattress situation, as shown in calculation example 5, the lower inats would need to be pinned as shown, to prevent downslope creep of the upper row of blocks. Longitudinal pins are required at the (usual) double spacing of the transverse pins at a (max) spacing of 1 pin every 4th block.

Note 4: for Flexmat FM100, table 3 shows that allowable peak vel. is 3.8 m/s, 50% of which far exceeds the design current (0.5 m/s). Consequently, the use of tables 4A/5A was permitted.

DESIGN EXAMPLE 5

FLOW CHANNEL or OPEN DRAIN (A)
WATER COURSE EMBANKMENT (B)



For a given channel gradient (I) the flow velocity can be determined by means of the well-proven Chezy expression for open channel flow as follows: $v = C*(I*Ac/Lc)^{0.5}$ in which C is the roughness coefficient which, for flexmats, is around 60 whilst Ac (in m^2) and Lc (in m) are the flow cross section and its wet circumference respectively. For Ac is $3m^2$ and Lc is 5 m and a realist channel gradient (I) of 1:100 (an angle of 0.57 deg.) one finds: $v = 60 * (3/(5* 100)^2 = 4.6m/s$.
According to expression (1) on page ..... of this document this velocity renders a required flexmat mass of $3* (5.5)^2 / \cos(0.57) = 91 kg/m^2$

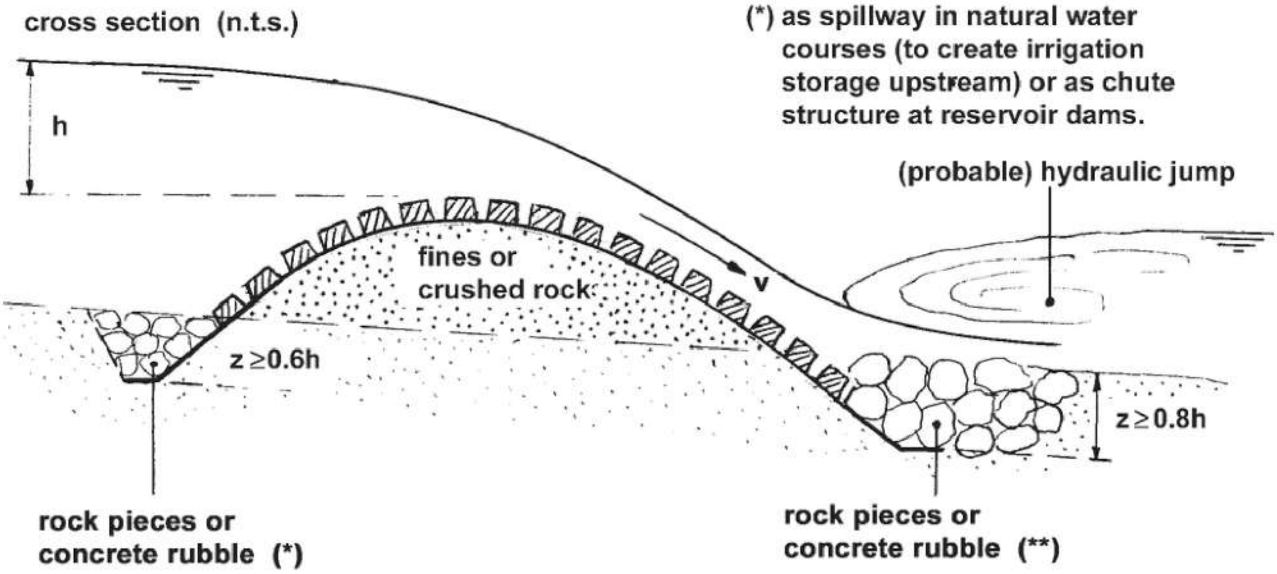
In the absence of significant wave action, only the upstream mattress edges would require minimum anchor- ing: 1 short pin every 2nd block. (this is to counter additional hydrodynamic lift force which occurs in areas where the upstream edge blocks protrude above the mean lining surface)

Note: if the channel or drain seasonally 'dries out', enabling maintenance (cleaning) vehicles to operate down the channels centre line it is necessary to check adopted mattress version. For example, for a vehicle weight up to -say- 4Tonne, table 7 indicates that Flexmat version FM65 should be adopted unless some degree of block cracking could be accepted. (in which case FM40 would suffice)

Required number of anchor pins would be calculated in the same manner as undertaken in the roadway examples.

Design Example 6

SPILLWAY



For maximum head (h) during flood runoff the peak velocity (v) follows from Bernoulli's expression $v^2/(2*g) = 1.5\ h$. This renders $v = 5.5 * h^{0.5}$
At a head (h) of -say- 1m this renders a flow velocity of 5.5m/s.
According to expression (1) of this document and for a gradient of (say) 1:2 (an angle of 26.5 deg.) this renders a required flexmat weight (mass) of $3* (5.5)^2 / \cos(26.6) = 101\ kg/m^2$

This implies that flexmat version FM 0 would be too light and that, instead, FM would need to be adopted.

In wide cross sections, covered by two (or more) mattresses the joint line(s) need to be secured by anchor pins, spaced every second block. In such case the concave profile does not generate additional stability. Consequently mattress weight can not be reduced. (FM150 to be adopted as previously calculated)

In all cases, skirt overlap with the next (adjoining) row of mattresses needs to be at least 0.5 m, to be secured by one longitudinal pin every second block.

(*) average particle weight to be twice as heavy as the Flexmat's individual block weight.

(**) average particle weight: four times block weight.