GRASSCRETE®

CAST INSITU PAVING SYSTEM

PAVING DESIGN FOR RIVER AND STORM WATER CHANNELS

GRASS CONCRETE LIMITED

PART OF THE GC GROUP OF COMPANIES

INTRODUCTION

Engineers worldwide now face increasing pressure in the design of infrastructure projects. The detrimental effects of creeping urbanisation on the environment have been well catalogued, particularly in tropical and sub-tropical climatic zones.

Increasing emphasis is being placed on the use of either “natural” or “re-cycled” solutions in construction to the extent that we now see them as compliant requirements in many design briefs.

This document examines the increasing environmental role played in the design of river re-training and storm channel schemes. Traditional concrete channels, once the mainstay of design, are now being rejected in favour of more environmentally friendly, socially and aesthetically pleasing solutions.

Grass and concrete is perceived as an ideal means of providing necessary functional stability with the ability to maintain the environmental equilibrium within a wet lands type culture. Care needs to be taken, however, in the establishment of a correct specification for these products which, though similar in visual effect, vary widely in practical capability.

GRASSCRETE has become synonymous as the generic name for grass and concrete. In truth, it is our trade name for a particular type of system which in many respects is very different from other types available. It provides unique advantages to engineers in both design and management of water environment schemes. We feel that it is important to explore these benefits and to hopefully provide you with guidelines for effective design.

R E HOWDEN
Managing Director

WHAT IS GRASSCRETE?

GRASSCRETE can essentially be described as a cellular reinforced concrete paving layer.

It is created by site pouring concrete around re-cycled plastic former upstands (see Fig 1) and steel mesh reinforcement. After casting and initial curing the tops of the formers are removed to leave voids through to the formation. Topsoil is then infilled to the voids prior to grass seeding.

Fig. 1

Such a structure is not inter-reliant upon grass cover for stability. As a result it does not suffer from seasonal variations in capability and enables a consistent design to be achieved with hydraulic flow rate capability proven at over 8 metres/second (limit of test).

In addition to its use as a revetment armour layer, the system is also widely used for vehicular applications. It can accept, subject to type, vehicle loads up to 40 tonnes gross vehicle weight. This ability enables the system to be used for the substantial lining of channels even where vehicular maintenance access is required along the invert bed (see Fig 2).

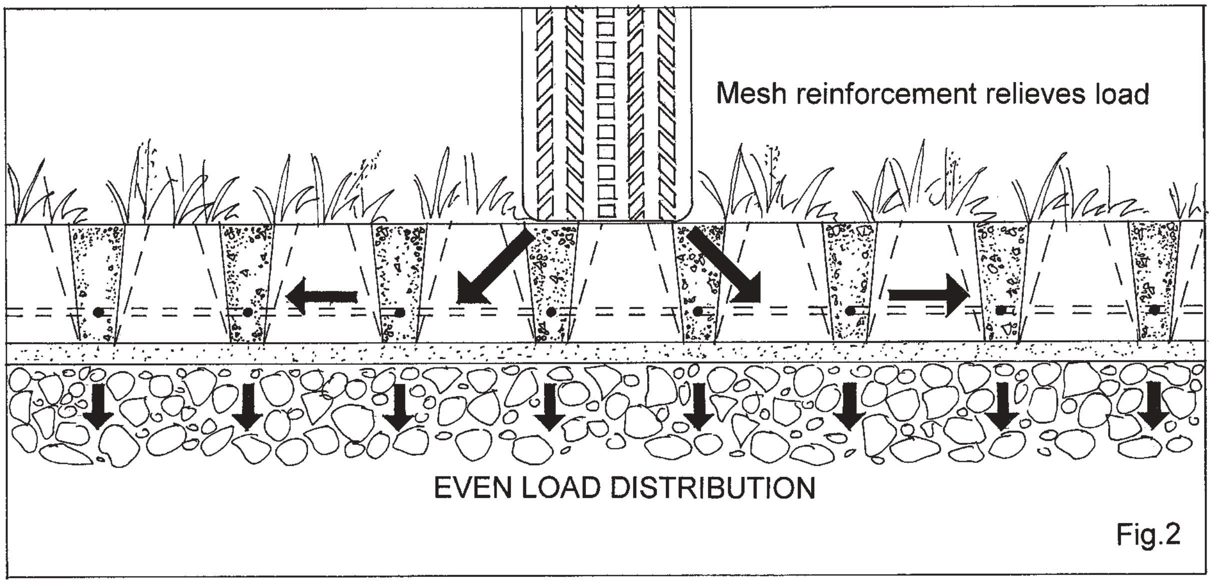


Fig.2

With structural integrity ensured by the mesh reinforcement, the paving layer resists differential settlement. As a consequence, the surface level remains even throughout, eliminating the turbulent effect that can result from settled block systems.

Being cast on site, GRASSCRETE is unique in having a soil pocket section of greater width at formation level than at the surface. This conical profile enables optimum root colonisation providing increased binding resistance against washout (see Fig 3).

Please note that illustrations throughout this publication relate to our GC2 system. For cross sections of other types please refer to page 17.

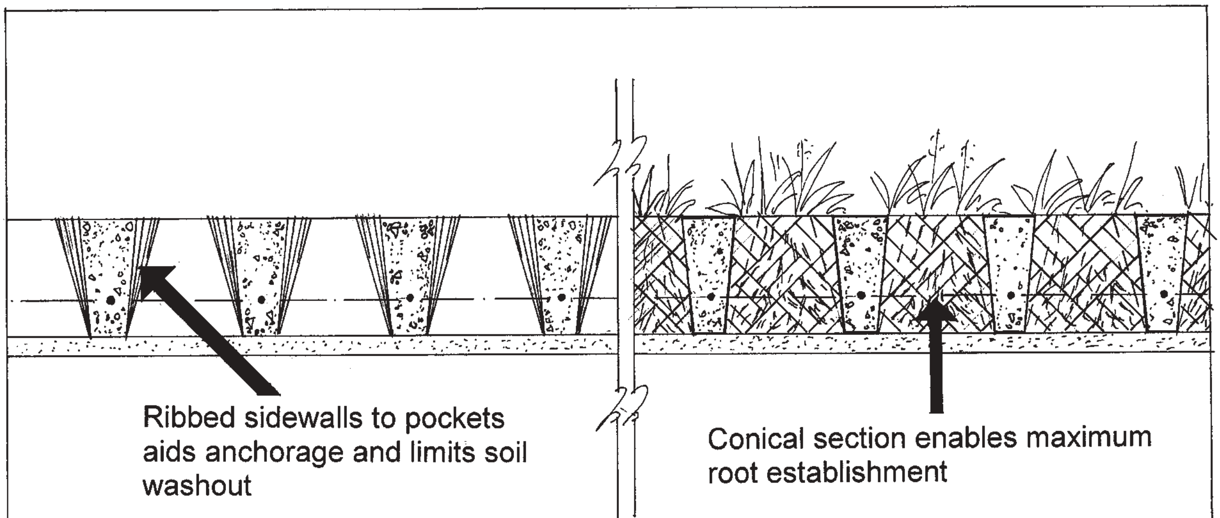


Fig.3

Cellular paving provides long established benefits in the ability to balance hydrostatic pressures behind a revetment layer. This is particularly important in wave run down or rapid lowering of water levels where residual pressure in the sub-grade could otherwise cause an armour layer to buckle.

The conical profile of GRASSCRETE enables significant volumes of water to be retained within the surface whilst at the same time providing an effective venting of the sub-grade (see Fig 4).

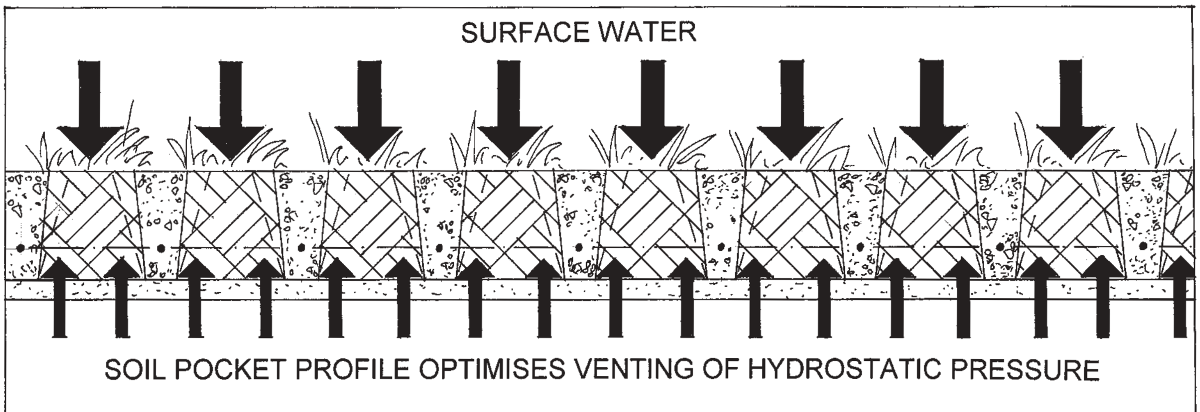


Fig.4

THIS IS NOT GRASSCRETE

BUT IT IS A PRECAST GRASS BLOCK!

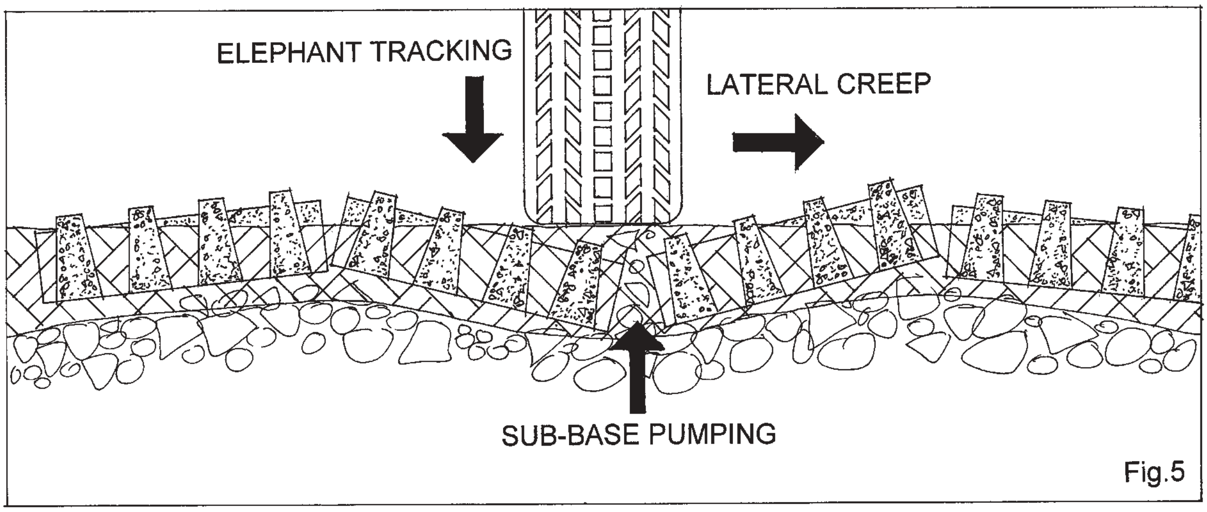


Fig.5

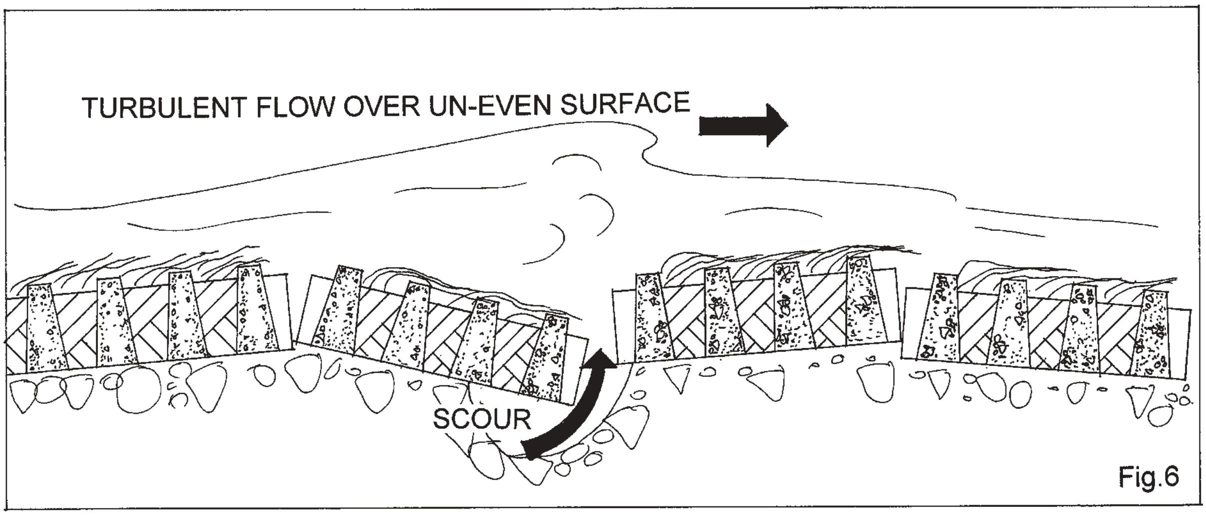


Fig.6

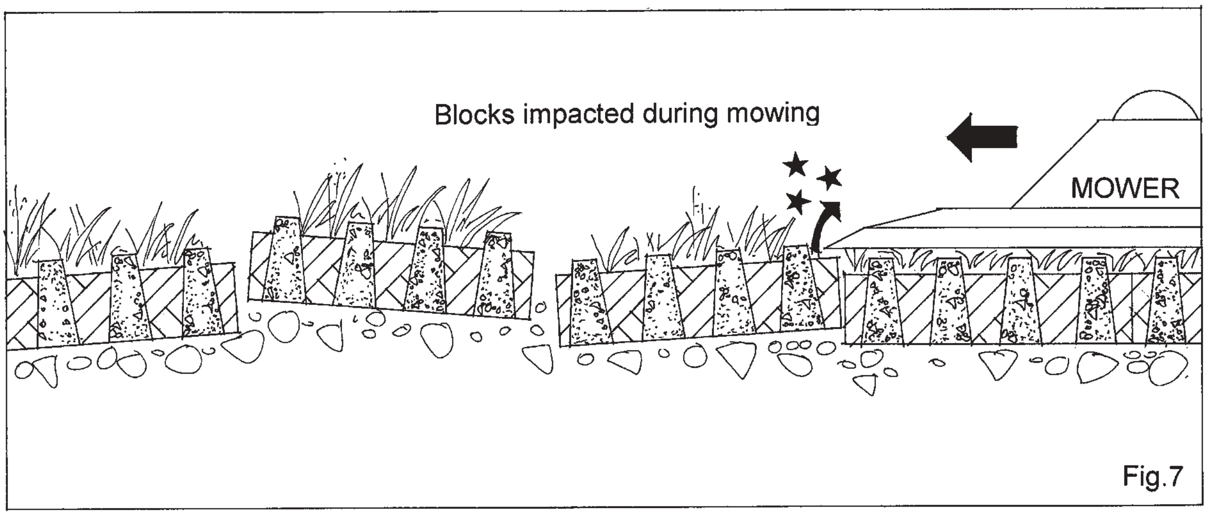


Fig.7

Often termed GRASSCRETE, a precast block performs a totally different function. As a provider of a range of all types of systems in the UK, we have studied in depth the suitability of precast blocks for such applications and we feel that this places us in a unique position to advise on the merits of GRASSCRETE v precast grass blocks.

In terms of structural stability under both hydraulic flow and vehicular use, un-tied blocks are, at best, of an intermediate classification for flow rates up to 4 metres/second. Their stability is created by a combination of frictional binding of grass between joints and root penetration to the sub-grade. In practice, however, this suggests a number of problems.

a. Whether by seasonal growth pattern or stress caused by water flow, grass growth can never be of a guaranteed uniform consistency. As a consequence, some blocks will inevitably move under load and a progressive failure by wider scale is, therefore, likely to result. Whilst some mitigation can be provided by shear pins penetrating into the revetment, this may only serve to slow down the process.

b. The reliance upon root anchorage can be a tenuous one. Most roots do not penetrate to a sufficient depth to anchor and those that do may then fail to penetrate underlying geotextiles.

c. Continuity at changes of direction or detail cannot be provided with a precast block (see Fig. 8). To provide re-tolerancing of the rigid block module, unzipped joints will be required to changes of embankment profile. These can be a focal point for erosive forces as they are likely to occur in areas of greatest turbulence.

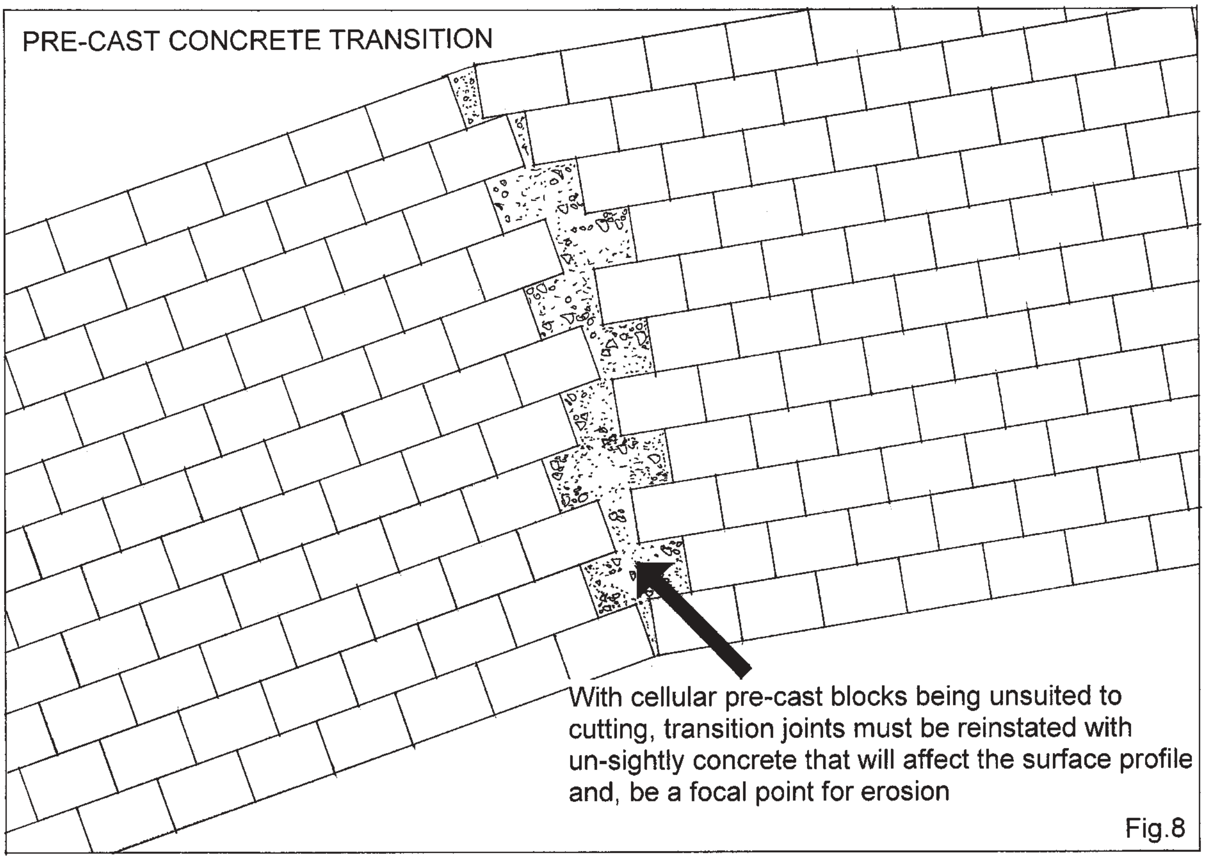


Fig.8

In contrast to his, GRASSCRETE provides an even surface profile throughout with integrity maintained at changes of direction by monolithically tapered infills (see Fig. 9).

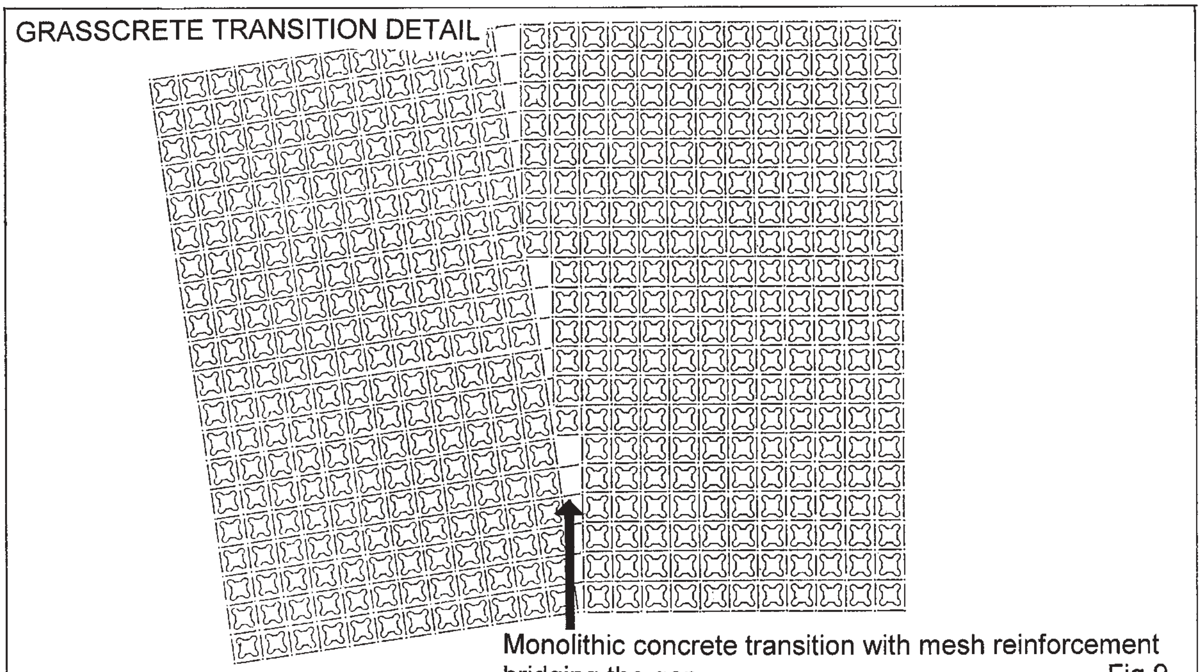


Fig.9

PROJECT DESIGN

In a typical trapezoidal channel the velocity contours, secondary currents and shear stress distribution can be seen in Fig. 10.

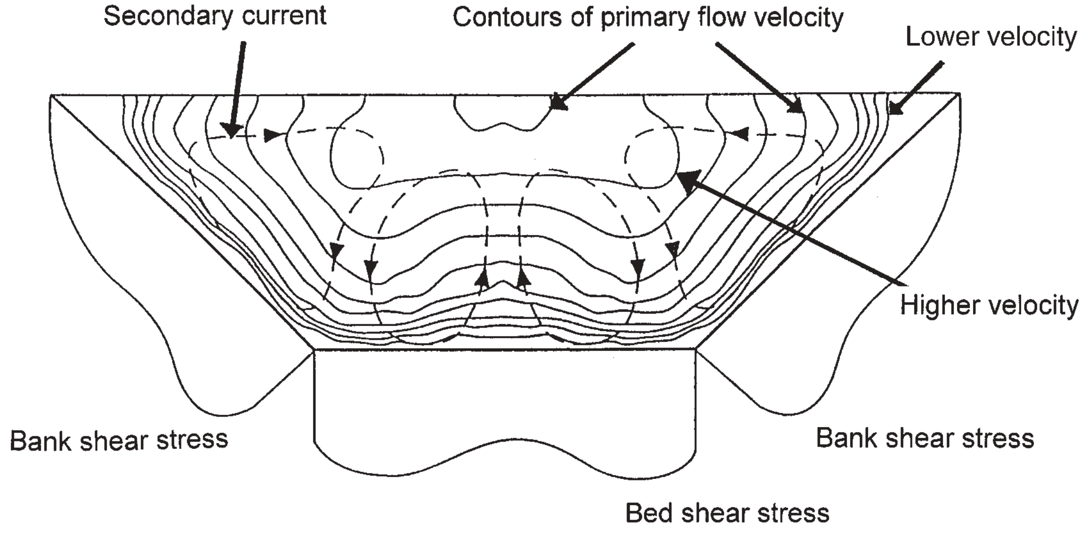


Fig.10

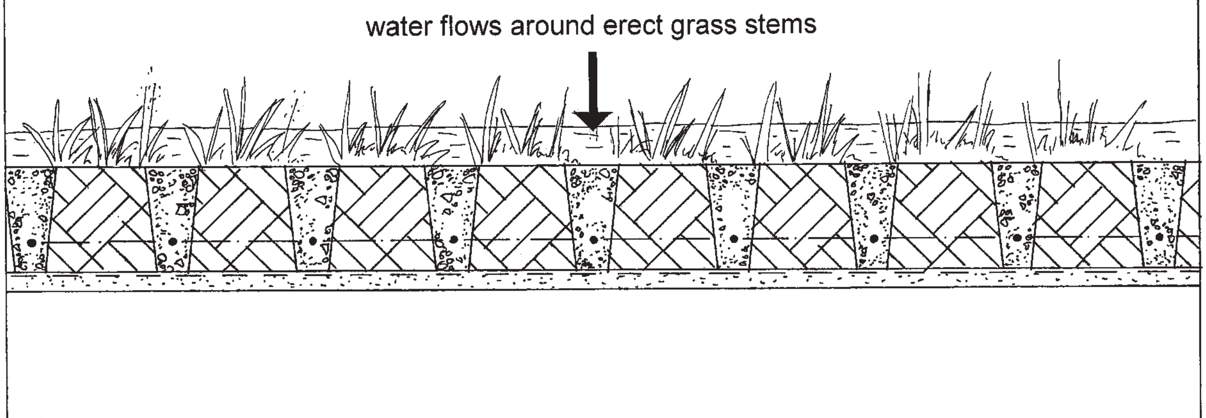
For a solid concrete revetment application, it is normal to construct with side slopes at 1 in 2, this generally being the limit of stability during the casting process. GRASSCRETE can, however, be cast to a steeper gradient of 1 in 1? and in certain instances 1 in 1. This enables a proportionally greater volume to be catered for in the channel facilitating a reduction in the overall channel width.

Hydraulic Roughness

A common mis-conception is that the cross section of a grass and concrete channel needs to be larger than that of a solid concrete design due to an increased hydraulic roughness and a resulting slower flow rate. To counter this argument, it is important to consider two stages of water flow:

a. Sub-critical flow

At this stage water flow may be contained within the stem height of the grass cover. As a consequence, the flow rate is likely to be limited by grass. In this scenario, however, the low volume makes no demands upon the design limits of the channel as a whole. Indeed, during this phase, the channel would provide the natural wetlands culture (see Fig 11) often desired by environmentalists.

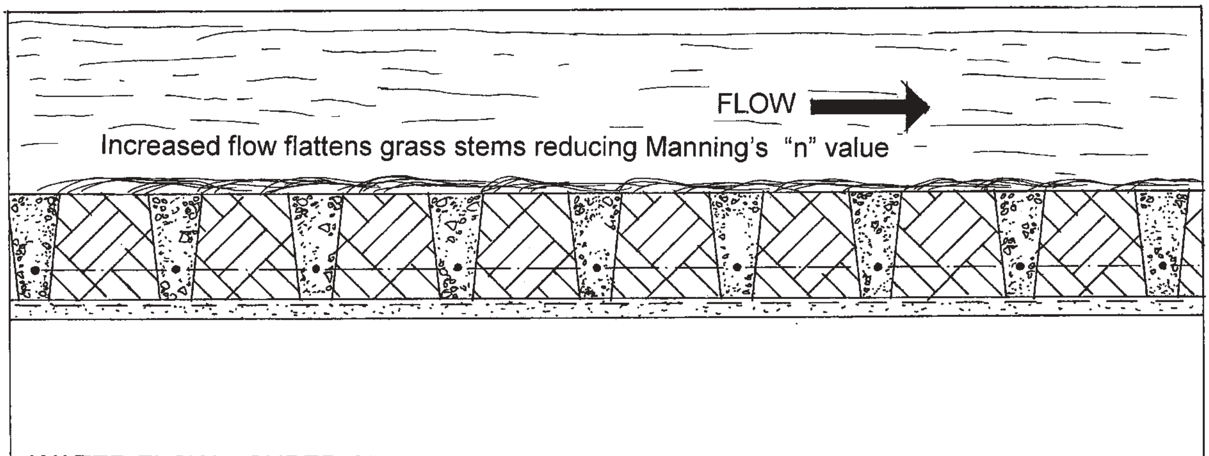


WATER FLOW – SUB CRITICAL

Fig.11

b. Super-critical flow

From critical to super critical flow characteristics, long stem grass will flatten under hydraulic load to effectively thatch over the surface (see Fig 12). The implication of this is a potential low Mannings ‘n’ value of 0.03, dependent upon grass type.



WATER FLOW – SUPER CRITICAL

Fig.12

It is easy to generalise in determining flow rates for solid concrete slabs. Practical aspects of construction dictate, however, that the 'n' value can vary throughout a given channel profile. Steep revetment faces require the placement of a lower concrete slump to hold the poured concrete in position. Combine this with a "low slip" finish requirement and it must be expected that the side slopes of solid channels could be potentially more textured than the invert bed, ie with a greater 'n' value.

A further factor is vegetation intrusion. Whether intended or not, growth will take place in the channels (see Fig. 13). Whether it be in joints or cracks, coarse grass or even shrubs will prosper. Such features will inevitably cause turbulence in the flow and may result in the build up of silt bars in the channel.

Fig. 13

Earthworks

It must be stressed that this publication refers to the use of GRASSCRETE as an armour layer. As with any revetment system, it is designed to stabilise the surface layer only.

For a design to be stable, consideration should be given to the nature of the sub-grade. Assessment should be made for the potential internal failure of a slope which would call for a retaining rather than a stabilisation solution.
The type of soil will influence the programme of works. A cohesionless granular soil will act by mass energy with relatively high angles of internal friction. It is likely, however, in the temporary works stage to be susceptible to surface erosion and slip. This may call for a two stage excavation programme with a final face steepening cut undertaken immediately prior to placing the armour layer.

A cohesive soil, whilst potentially lower in friction angle, will enable a steeper cut face. Care should be taken, however, to maintain the normal plasticity of the soil during the temporary works phase. Excessive moisture loss can cause fissures to form within the sub-grade which can result in subsequent pockets of high pore pressure behind the armour layer.

With all waterflow applications, we recommend the use of an underlying geotextile which should serve the function of:

a. Maintaining the equilibrium of water pore pressure.
b. Limiting the “piping” of fine particles of granular sub-grades through the cellular armour layer particularly in run down situations.

The positioning of the geotextile and its type is often a matter of some conjecture amongst engineers. Our own recommendations for use with GRASSCRETE would be to adopt the following principles of construction for vehicular (see Fig 14) and non-vehicular (see Fig 15) applications.

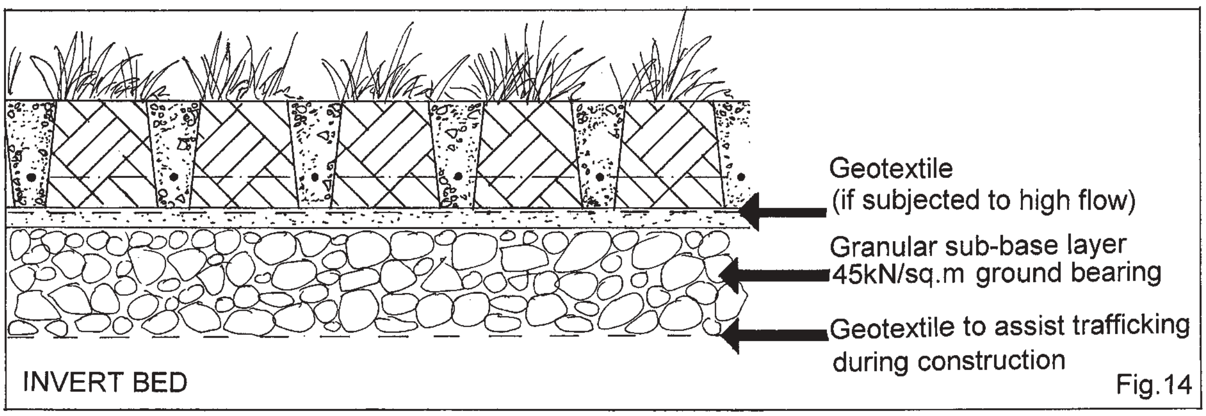


Fig.14

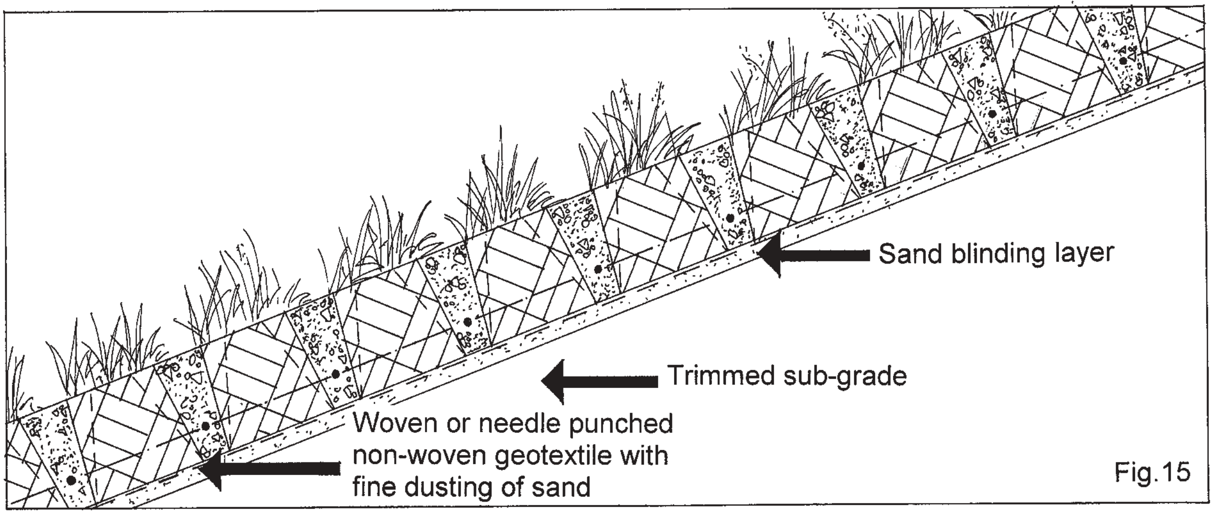


Fig.15

In revetment applications where potential for sub-grade washout is greater, we recommend the positioning of the geotextile as close to the paving interface as possible. To prevent damage to the geotextile during the burning of the plastic formers, we would suggest placing a fine dusting of sand over the geotextile prior to positioning the formers. The prevention of clogging would suggest the use of either a needle punched non-woven or woven geotextile.

Unlike precast block applications, the geotextile will not be called upon to provide mechanical strength to the works except in the temporary haul scenario. With this in mind, a somewhat lower specification of geotextile can be adopted with GRASSCRETE.

Earthworks Settlement

In applications where fill materials are used to create formation profiles, settlement will inevitably occur. In such situations, the settlement can be accommodated by the slab "re-bedding" as a whole. To enable this we would recommend that the expansion joint centres be reduced to 5 metres to permit vertical face sliding at the joints. In these applications, we would not recommend the use of dowel joints which would tend to limit such movement.

Although GRASSCRETE is often perceived as a rigid structure, its' use on resevoir and dam projects has clearly shown its ability to cater for underlying settlement.

DESIGN DETAILS

Expansion joints

As previously stated, the use of dowels in areas susceptible to settlement is not recommended. Indeed, in most applications their use is necessary only when extreme load transfer is required.

With the gridded nature of the paving layer, expansion forces will tend to move in line with the interstices surrounding the pockets. In curved channels, there is the possibility therefore that a transverse dowelled joint may limit movement by creating a wedging effect if the joint is not at right angles to the grid.

A typical detail will be a simple filler with the joint acting in both expansion and contraction (see Fig 16).

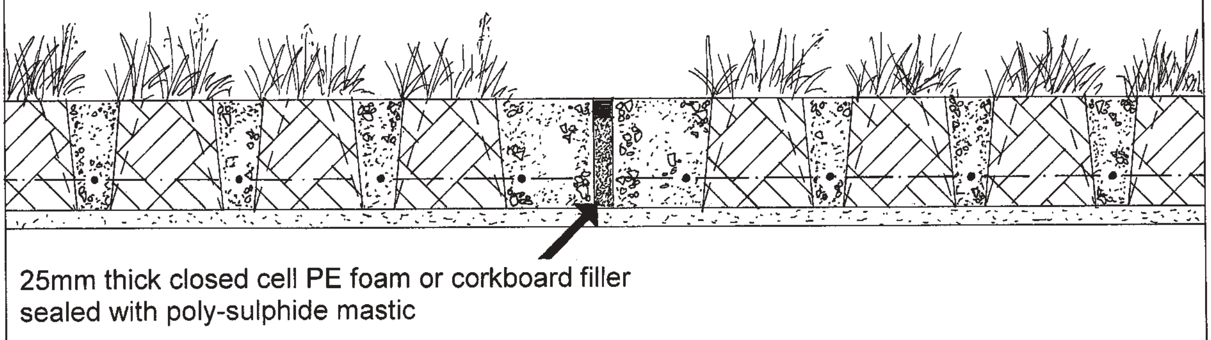


Fig.16

Toe Support

GRASSCRETE, as a reinforced concrete mass structure, provides uniform frictional resistance with its sub-grade. The need for a toe beam to revetments is, therefore, limited to providing a barrier for the migration of sub-grade materials and to providing a profile edge for the sub-base preparation to the invert bed (see Fig 17).

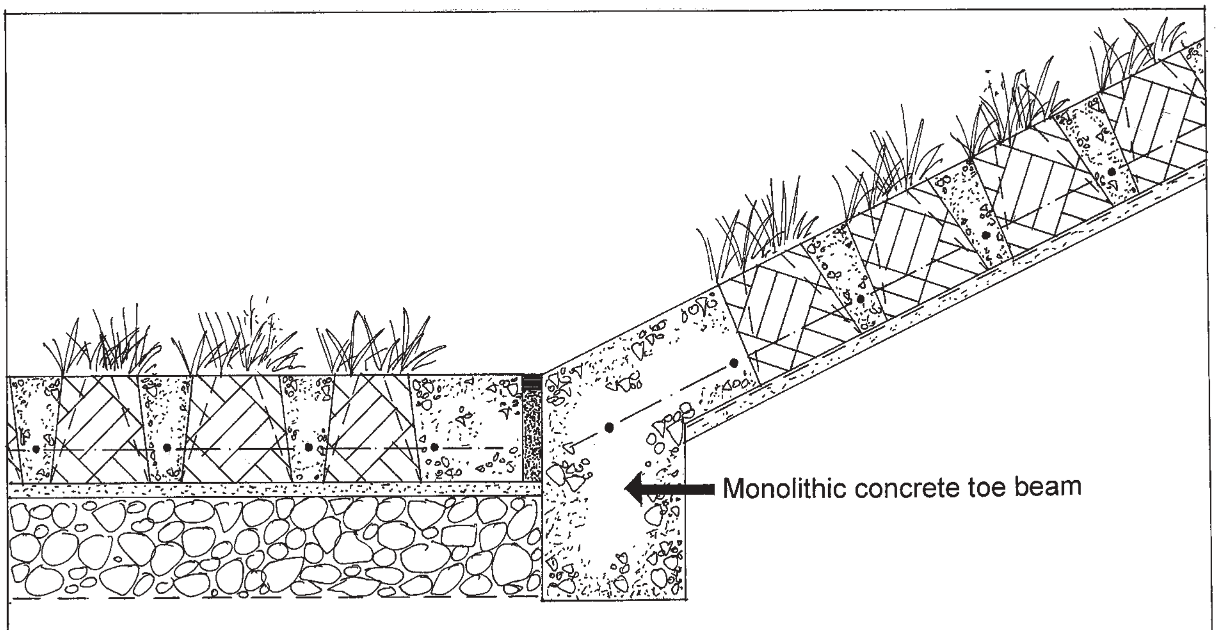


Fig.17

Low Flow Channels

A common design feature is the use of a central low flow channel within the invert bed. This enables the significant remainder of the invert to be maintained during dry seasons (see Fig 18).

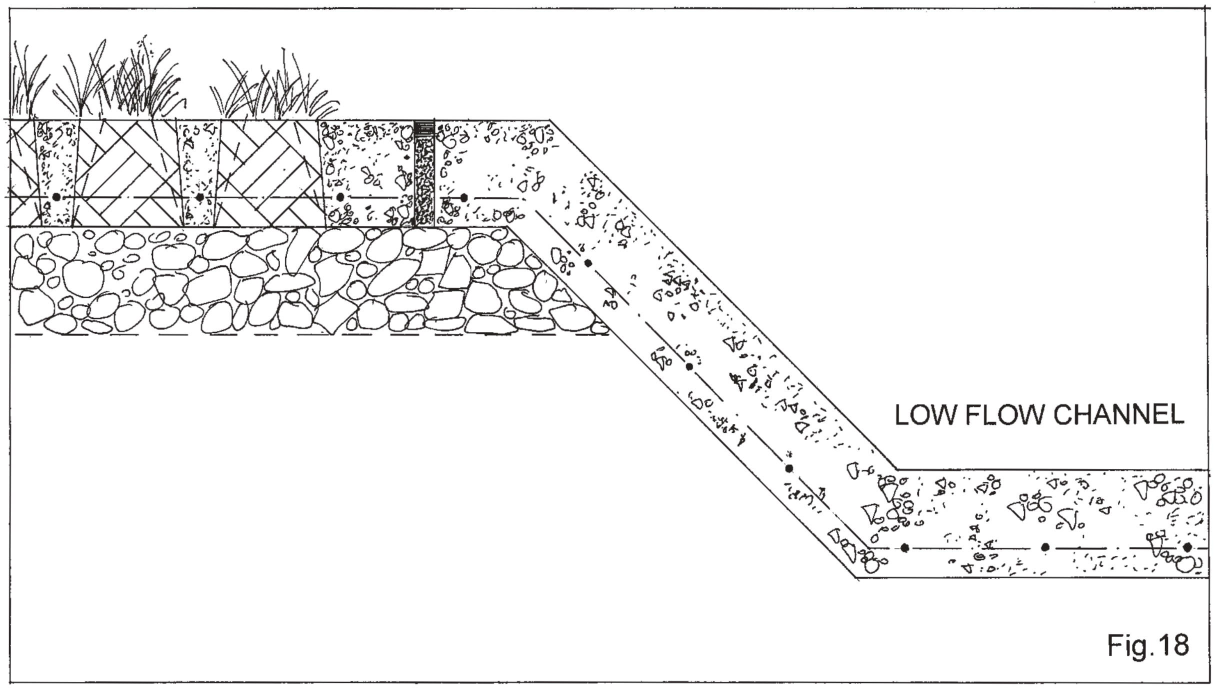


Fig.18

Inlet Pipes

To limit turbulence at the entry point, we would recommend the section of revetment below the inlet pipe to be constructed in solid concrete (see Fig 19). This can be cast monolithically with the GRASSCRETE thereby offering a continuous structure. We would not recommend the use of precast masonry units at this point which are likely to fail due to build-up of pore pressure as water passes through the structure (see Fig 20).

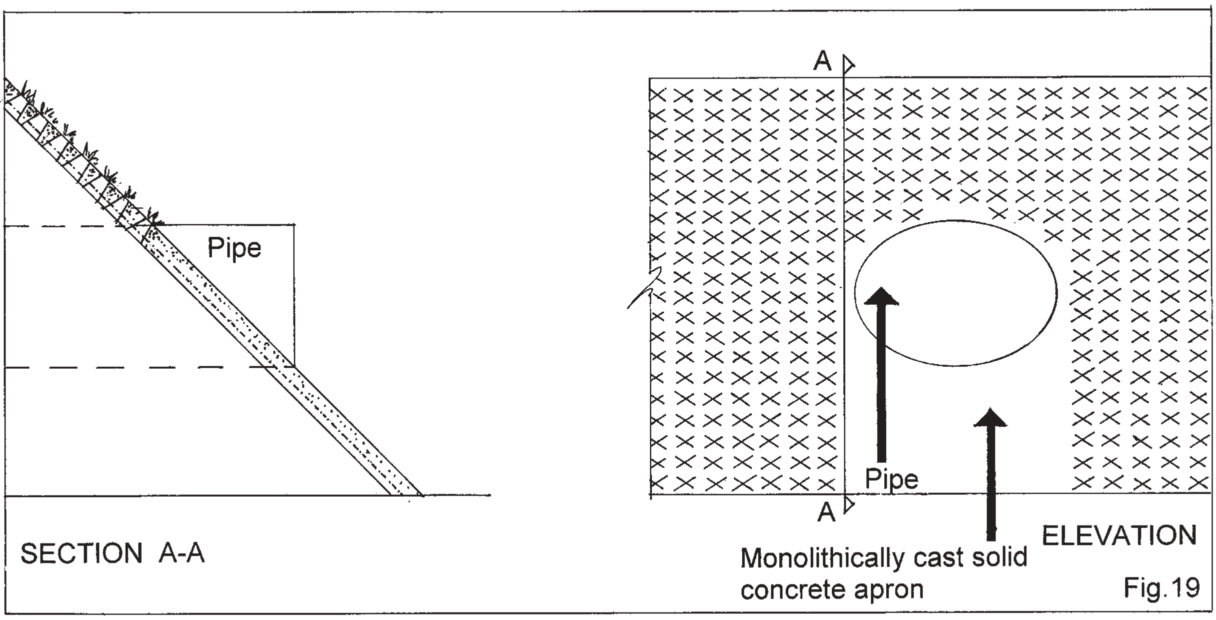


Fig.19

Fig.20

Scour Panels

During the peak rainy season, waterflow will carry with it significant quantities of sediment and debris. Dependent upon the profile of the channel, the points of highest velocity contact may call for an anti-scour detail of solid construction. As with the inlet pipe detail, we recommend that this be monolithically cast concrete with reinforcing integrity maintained with the GRASSCRETE (see Fig 21). The use of precast masonry units at this point could potentially offer a weakening rather than a stabilising influence.

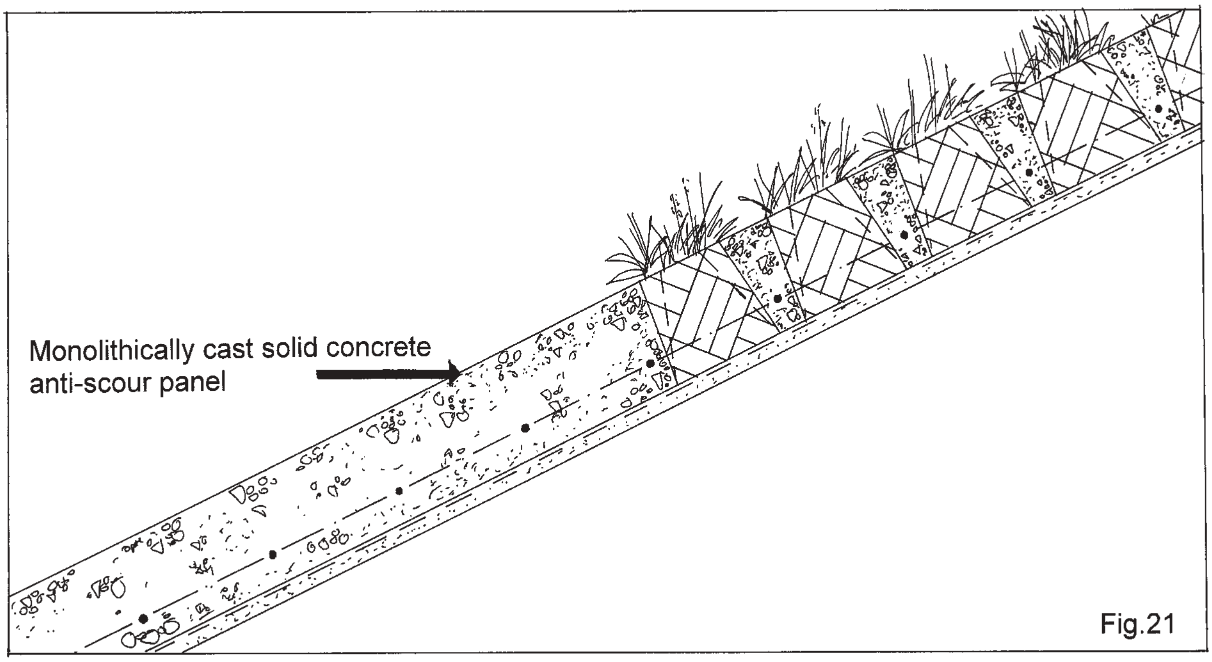


Fig.21

GRASSCRETE SPECIFICATION

SELECTION OF TYPE

	GC3 76mm thick	**GC1** 100mm thick	**GC2** 150mm thick
Weight (inc soil)	170kg/m² ave	234kg/m² ave	325kg/m?
APPLICATION			
REVETMENT			
Water flow rate:			
< 4m/sec	✓		
< 6m/sec		✓	
< 10m/sec			✓
INVERT BED			
Traffic load*			
< 4.3 tonnes GVW	✓7mm Ø mesh		
< 10.00 tonnes GVW		✓7mm Ø mesh	
< 13.3 tonnes GVW		✓8mm Ø mesh	
< 30.0 tonnes GVW			✓8mm Ø mesh
< 40 tonnes GVW			✓10mm Ø mesh
* *assumes an allowable ground bearing of 45kN/m?*			

MODEL PREAMBLE

* delete where appropriate

The paving to revetments*/invert bed* shall be a cellular reinforced cast on site system as per the type known as GRASSCRETE.

600 x 600 x 76*, 100*, 150mm* re-cycled plastic formers shall be laid edge to edge on a prepared base and 200 x 200 x 7*, 8*, 10mm* diameter mesh reinforcement shall be positioned on integrally moulded spacers within the plastic former troughs.

C30/10 concrete (see separate specification) shall be carefuly poured over the plastic formers finishing level to the tops of the upstands. After 48 hours, melt the top and side walls of the formers by LPG burners. Fill resulting voids with fine friable topsoil and sow grass seed.

Concrete Specification

Compressive strength	30N/mm^2 @ 28 days
Cement type	Ordinary Portland
Minimum cement content	350kg/m^3
Maximum water/cement ratio	0.55
Maximum aggregate size	10mm
Sand/aggregate ratio	0.45
Air entrainment	3%
Control slump	50mm (revetments)
	100mm (invert)
Placement slump*	75mm (revetments)
	Flowing (invert)

* achieved by addition of a proprietary superplasticiser, the actual dosage to be determined by laboratory/site testing.

CONSTRUCTION PRACTICE NOTES

GRASSCRETE formers

The re-cycled plastic formers are provided to order from the UK, direct to clients or via our licensees where appropriate. The low weight of the formers enables economical shipment throughout the world.

Grass Concrete Limited provide a full service of technical advice to clients for all types of applications.

During construction, only sufficient formers shall be laid in position to enable one days casting. Formers should be stored away from strong sunlight when not in position.

On all but the steepest slopes, ie greater than 1 in 2, concrete can be positioned without compaction by use of flowing concrete as the upstands of the formers throat the head of flow. Where compaction is to be used, this should be undertaken using small diameter vibrating tremies with care being taken to prevent damage to the plastic formers.

Under normal circumstances the self weight of mesh reinforcement acting upon the formers will prevent the former from moving unduly during casting. On the steepest slopes we recommend that temporary stop boards are positioned longitudinally between the former upstands at 1.80m centres pinned through to the sub-grade. These would be removed as the work proceeds (see Fig 22).

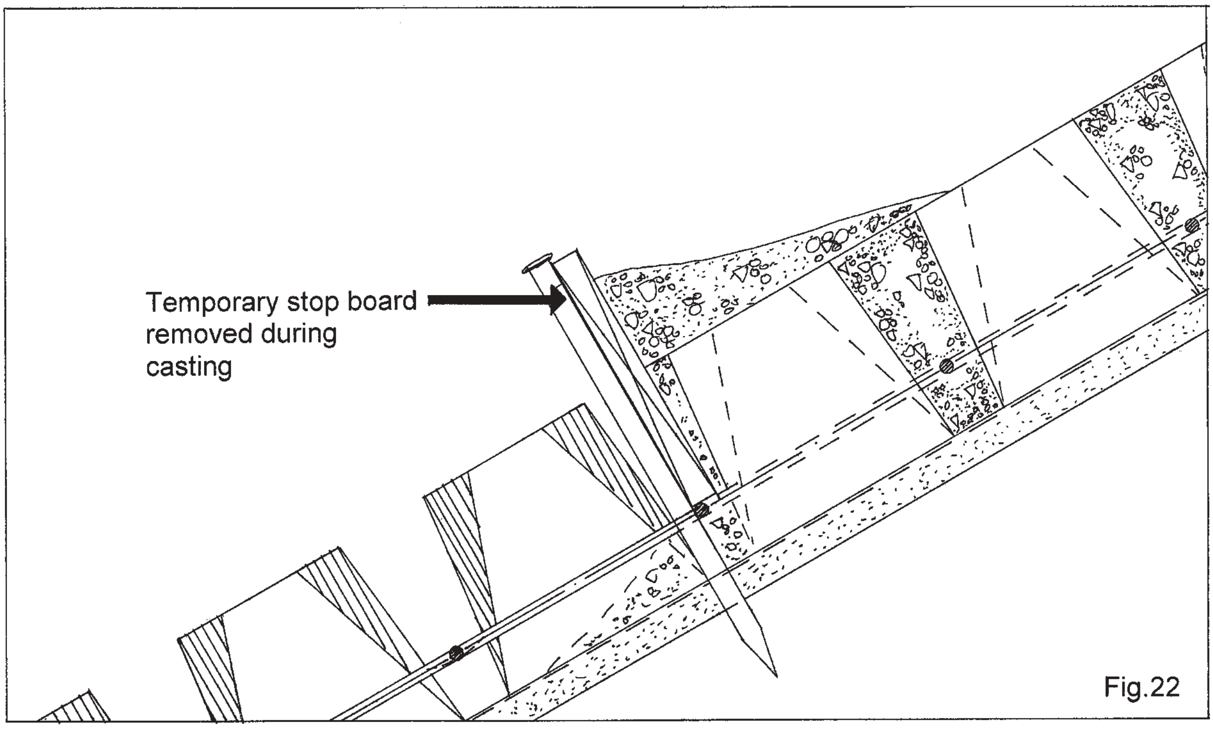


Fig.22

Concrete should be discharged over timber staging boards to prevent damage to the formers. On steep slopes, benefit can be gained from constructing a working platform to gain greater access over the revetment face (see Fig 23).

Fig. 23

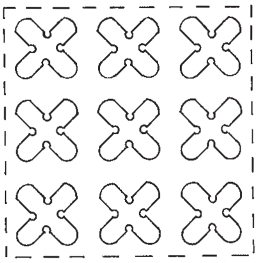
The effects of melting the plastic formers with LPG burners should be qualified. This process does not involve flame spread across the surface with the formers readily melting under short contact.

The melting process does not emit CFC gases and equates to low CO_2 emission similar to that associated with small scale wood burning.

The construction process for GRASSCRETE is typically much quicker than for hand laid precast blocks, particularly when considering the reduced labour to edge details, etc. On UK projects, using same gang sizes, typical output increases for GRASSCRETE against precast blocks can be:

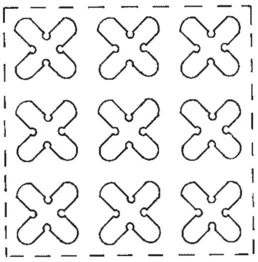
Invert beds	120-150%
Revetments	75-100%

GRASSCRETE TYPES



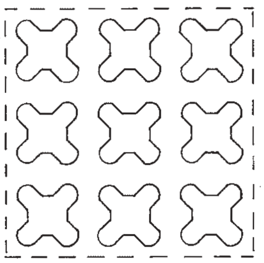
GC3

Void former size:	600 x 600 x 76mm
Paving depth:	76mm
Reinforcement:	A142 or A193
Concrete coverage:	22m²/m³
Topsoil coverage:	24m²/m³



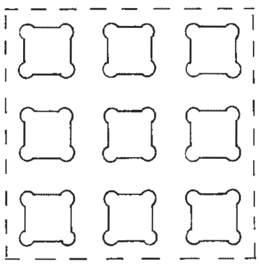
GC1

Void former size:	600 x 600 x 100mm
Paving depth:	100mm
Reinforcement:	A193 or A252
Concrete coverage:	15.50m²/m³
Topsoil coverage:	18m²/m³



GC2

Void former size:	600 x 600 x 150mm
Paving depth:	150mm
Reinforcement:	A252
Concrete coverage:	11.50m²/m³
Topsoil coverage:	12m²/m³



GC2sc

Void former size:	600 x 600 x 150mm
Paving depth:	150mm
Reinforcement:	A393
Concrete coverage:	10.50m²/m³
Topsoil coverage:	14m²/m³

For projects around the world, even though the formers are supplied from the UK, the low weight enables cost effective shipping and sound economy in construction. The lightweight nature of the material enables one container load to equal in area laid, forty loads of precast blocks. In most cases the transport costs to site are, therefore, less than locally produced precast blocks.

We hope that this publication has provided you with a greater insight into what is GRASSCRETE and that it is of benefit in the design and specification of future projects.

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