TERRAFORCE®
The original, reversible, hollow core retaining block

Feasibility Study (abr.) into the Hydraulic Applications of Terraforce "G" 150 & "HD" blocks.

Note! Terraforce G is now called the Terrafix 150. HD blocks are made to special order.

Compiled by the Division of Earth, Marine and Atmospheric Science and Technology of CSIR. *

Terraforce (Pty) Limited, requested the Division of Earth, Marine and Atmospheric Science and Technology to investigate two types of its hollow concrete blocks, the Terraforce "G" 150 and the Terraforce "HD", for use in hydraulic applications.

This preliminary study looks at the feasibility & limitations of the blocks when used for canal, river bank, estuary bank & coastal protection works. The work was carried out & the report written by Mr K R K Blake under the guidance of Mr J Moes and Mr J A Zwamborn.

## INTRODUCTION

Owing to the present rapid urbanization and residential development, rivers have to cope with an increased peak runoff whilst at the same time, more and more are canalized. This required increased and improved bank protection systems to safeguard people and property.

Outside urban areas, reliable bank and bed protection is also required, for example in the case of estuaries, spillways and irrigation canals.

Hollow concrete blocks, which are increasingly used for slope protection, are now also being used for bank and bed protection in hydraulic structures. However, a number of hydraulic aspects should be investigated before such blocks can be used with confidence.

This report gives an overview of the various relevant hydraulic aspects, especially related to the Terraforce "G" and Terraforce "HD" blocks, to evaluate their applicability in areas where water flow and wave action are present.

The aim of the report is to provide preliminary design criteria for the use of Terraforce blocks in hydraulic and coastal structures and to identify the need for and extent of further studies or model tests.

## GENERAL CHARACTERISTICS OF TERRAFORCE BLOCKS

Two types of Terraforce hollow blocks, the Terraforce "G" 150 and the Terraforce "HD", have been investigated for suitability as bank protection of canals, spillways and estuaries. The two blocks are of similar geometric shape (see Figure 1), the "G" type having a mass of 19 kg and the "HD" a mass of 48 kg.

The blocks interlock laterally due to their shape, but there is no mechanical interlocking either laterally or vertically. They can be laid in an interlocking flat layer or can be stacked on top of each other to form a steep slope.

Dimensions and specifications subject to change without notice and TERRAFORCE "HD" is only available in the Cape Province. TERRAFORCE "G" is now known as TERRAFIX 150.

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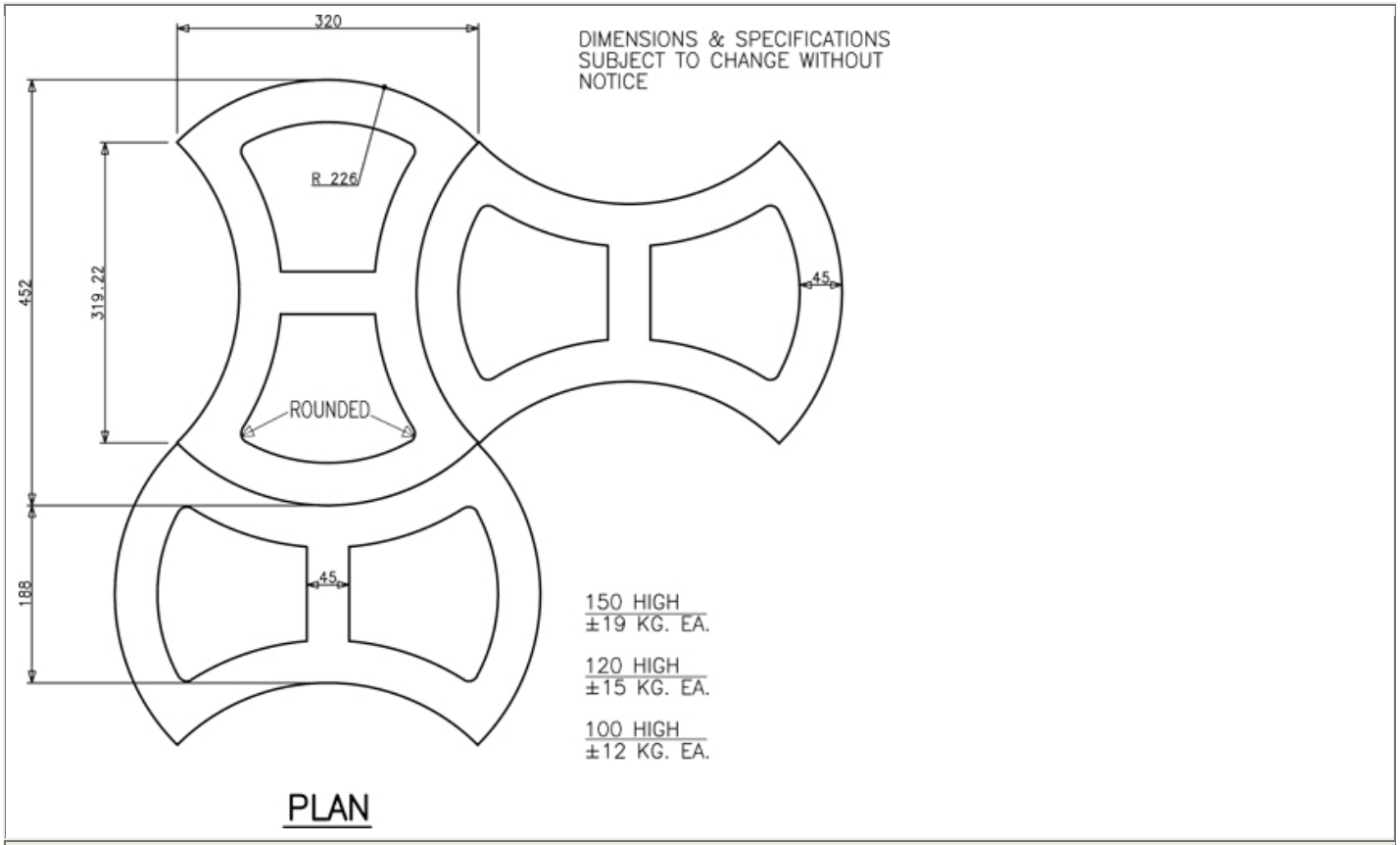
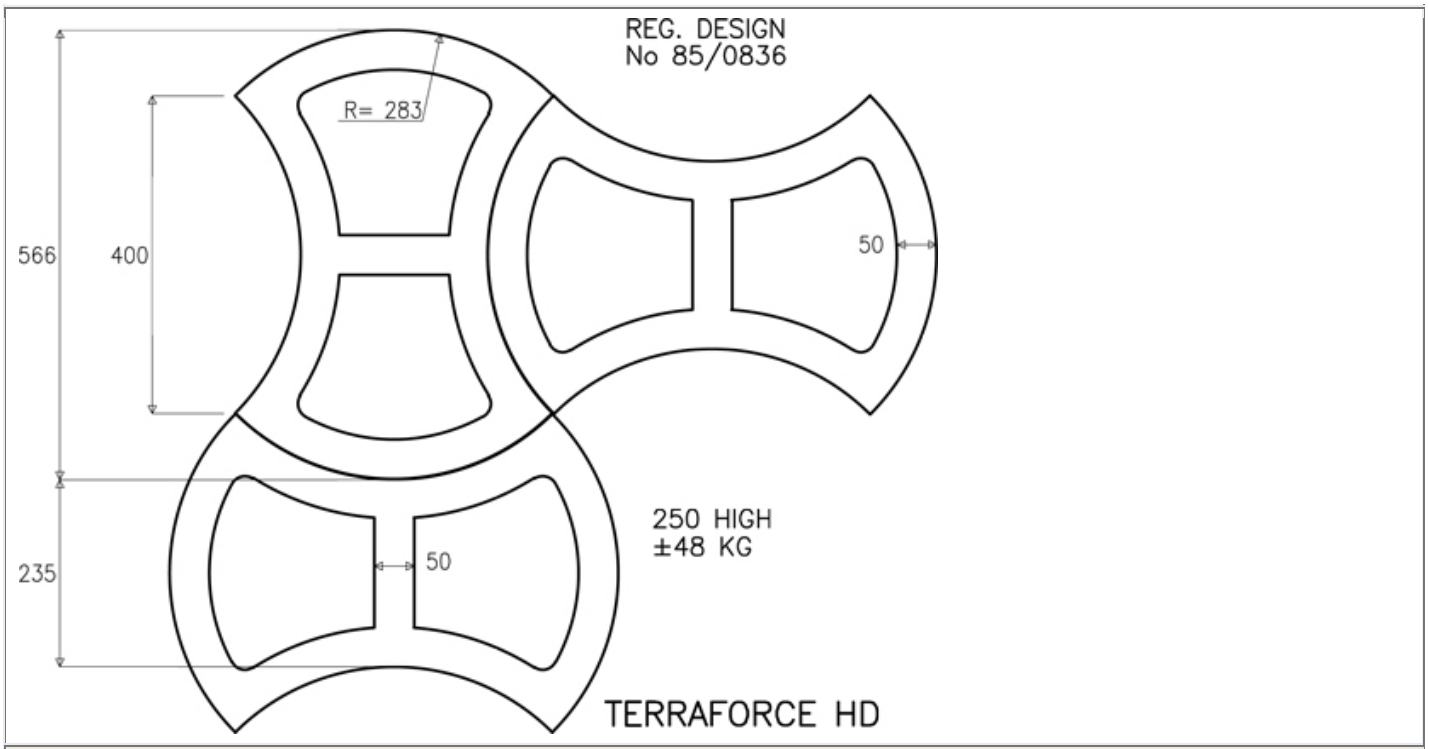



**Block infill volume = 0.006m³**




**Block infill volume = 0.022m³**

## PROTECTION AGAINST STEADY FLOW

Steady flow refers to flow in estuaries, rivers, canals and over dam spillways where there is a fairly steady flow of water. In many cases such flow occurs through alluvial soil conditions, with consequent dangers of erosion. To prevent this erosion of the bed and banks of these structures, it is necessary to protect them with some form of lining such as concrete elements. Two main aspects have been dealt with, namely block layer stability due to direct flow forces and stability related to the foundation on which the blocks are placed.

## MAXIMUM FLOW VELOCITIES FOR TERRAFORCE BLOCKS

Based on the theoretical considerations, the following critical allowable flow velocities have been calculated for varying flow depths.

| Flow Depth | | 1.0m | | | | 2.0m | | | | 5.0m | | | | 10.0m | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Slope of Side | | 0 | 11.3 | 26.6 | 33.7 | 0 | 11.3 | 26.6 | 33.7 | 0 | 11.3 | 26.6 | 33.7 | 0 | 11.3 | 26.6 | 33.7 |
| | Ratio | 1:inf | 1:5 | 1:2 | 1:1.5 | 1:inf | 1:5 | 1:2 | 1:1.5 | 1:inf | 1:5 | 1:2 | 1:1.5 | 1:inf | 1:5 | 1:2 | 1:1.5 |
| Critical flow Velocity | Type "G" 150 | 1.8 | 1.7 | 1.7 | 1.6 | 2.1 | 2.1 | 2.0 | 1.9 | 2.5 | 2.5 | 2.4 | 2.3 | 2.9 | 2.8 | 2.7 | 2.6 |
| | Type "HD | 1.9 | 1.9 | 1.8 | 1.7 | 2.3 | 2.2 | 2.2 | 2.1 | 2.8 | 2.8 | 2.6 | 2.6 | 3.2 | 3.1 | 3.0 | 2.9 |

It can be seen from this table that the Terraforce blocks can withstand relatively high flow velocities. This means that the potential for erosion will also be high, especially since the Terraforce blocks have a high porosity. To prevent erosion of the subsoil, some form of filter will have to be provided underneath or behind the blocks.

It would therefore appear from these theoretical considerations that as long as precautions are taken to prevent the erosion of the subsoil, both the Terraforce "G" and the Terraforce "HD" blocks would be suitable for steady flow protection systems if the maximum allowable velocity given is not exceeded.

## FILTER LAYER DESIGN

Erosion of the subsoil, leading to the collapse of the revetment, can occur either by turbulence or by ground water flowing out through the armour layer. The latter case may occur after a period where the water in the canal has been elevated for some time and has dropped quickly, for example after the peak of a flood.

The ground water level will have increased during the high flow condition and will need time to adjust to the lower level. This loss of subsoil has to be prevented to ensure the stability of the structure as a whole. This is achieved by the construction of a "filter" behind the protection layer, consisting of graded layers of granular material and/or geofabrics.

Geotextiles are favoured over granular filters due to their ease of placement and general convenience. A two-dimensional woven fabric is preferred with a lower-limit opening size greater than 0,5 mm. This ensures that, after the root growth has taken place through the geotextile, the fabric permeability is still at least ten times that of the subsoil.

## PROTECTION AGAINST INFREQUENT FLOW

### Grass covered Block Revetments

Sometimes, surfaces above the normal water level are also exposed to flow conditions and may need protection. Terraforce blocks may be used in conjunction with grass for the protection of such areas subject to occasional extreme flow, floods or infrequent usage.

If grass is submerged for several days, it starts to die, reducing the effective bonding that its root structure gave to the soil and thus reducing its protective function. Areas where protection against infrequent flow may be required are:

- the downstream face of embankments that are at risk of overtopping during flood events, such as earth dams, flood storage embankments and flood embankments along low lying rivers; and
- purpose-made overflow channels that convey occasional high-velocity flow, such as auxiliary spillways on dams, flood relief channels and bypass channels.

**General Requirements**

Interlinked concrete blocks covered with an established grass layer have been shown to withstand a water flow velocity of 8 m/s (Hewlett et al., 1987), provided that :

- there is minimal downslope seepage below the concrete blocks that could undermine the blocks' foundation;
- surface irregularities are avoided;
- lateral restraint is provided between adjacent blocks, there is more than 75 % face contact between blocks; alternatively, the lateral restraint is provided by grass root structures between the blocks; and
- substantial anchorage exists between the block and the subsoil, as provided by the root structure of the grass or, where necessary, mechanical anchors.

Hewlett et al (1987) also recommend a number of restrictions to maintain hydraulic stability of the blocks.

**Recommended restrictions to retain hydraulic stability**

| Requirements | Terrafix 150 | Terrafix "HD" |
|---|---|---|
| Minimum mass: 135 kg/m² | 181 kg/m² (9.5 blocks/m²) | 294 kg/m² (6.1 blocks/m²) |
| Minimum block mass:15 kg | 19 kg | 48 kg |
| Minimum thickness: 85 mm | 150 mm | 250 mm |
| Minimum block width: 255 mm | 188 mm | 235 mm |

From a comparison of the characteristics of the Terraforce blocks, it appears that, except for the minimum block width, they meet the requirements in the table.

**Suitability of Terraforce Blocks**

The anchorage of the concrete blocks to the subsoil is dependent on the root structure of the grass. It has been found that in general only 10 % of the roots exceed a depth of 200 mm (Hewlett et al, 1987). This means that the Terraforce "HD" block will have reduced anchorage to the subsoil, possibly even inadequate anchorage.

The Terraforce "G" and "HD" blocks do not mechanically interlock and can rely only on interblock contact for lateral and rotational restraints.

Hewlett et al., 1987 maintain that reduced face-to-face contact down to 40 % reduced the maximum permitted flow velocity to 6 m/s. Hence the Terraforce "G" can be used for grassed waterway banks with a flow velocity not exceeding 6 m/s.

## PROTECTION AGAINST WAVE ACTION

Concrete block armour has been used successfully in bank protection subject to wave action. The significant wave height of the area would dictate the suitability of the Terraforce "G" and "HD" blocks for similar use.

Considering the weight of the Terraforce blocks, typical applications would be in lagoons, marinas, the upstream sides of earth embankments and river banks subject to boat-generated waves.

### Significant wave heights

Assuming a Hudson stability factor of the Terraforce "G" 150 Blocks of 15 (CERC, 1984), maximum significant wave heights were calculated for the two types of Terraforce blocks.

| Slope | | Significant Wave Height (m) | |
|---|---|---|---|
| 0° | Ratio | Type "G" 150 | Type "HD |
| 11,3 | 1:5 | 1,2 | 1,6 |
| 18,4 | 1:3 | 1,0 | 1,3 |
| 26,6 | 1:2 | 0,9 | 1,2 |
| 33,7 | 1:1,5 | 0,8 | 1,1 |

These maximum significant wave heights are relatively large for inland waterways and could be generated over a fairly long fetch or by large and/or high-speed vessels.

Thus, for the average river bank or lagoon, waves would not present too much of a structural problem, although due to the cyclic loading of wave action, some kind of filter is essential to prevent erosion of the subsoil. The filter may also have to be protected against damage due to wave action.

### Filter Layer Design

Wave action on a revetment causes some of the highest forces on the subsoil below the armour layer, making a well-designed filter layer essential to the stability of the structure.

In particular the filter should prevent migration of the soil particles through the concrete block armour whilst still being porous enough to prevent a high pressure build-up within the subsoil.

For more information or to contact Terrasafe, the design service dedicated to Terraforce retaining wall projects, please visit www.terraforce.com.