

## Reinforced Earth™ in the Lesotho Highlands water scheme

G.M. Bentel & A.C.S. Smith  
Reinforced Earth (Pty) Ltd

**ABSTRACT:** Reinforced Earth was used for the construction of several structures on the Northern Access Road from Pitseng to Katse Dam.

High retaining walls carry the road across precipitous terrain at virtually the top of the Maluti Mountain range, while Reinforced Earth 'caps' are used to limit the extent of massive fills which will eventually be partially submerged in the Katse Dam.

Reinforced Earth with grid cladding elements is particularly well suited to geotechnical applications in developing countries. A cost effective solution is achieved by combining a simple labour-intensive facing with the well-proven advantages of a Reinforced Earth mass gravity structure.

This paper covers the design and construction of Reinforced Earth retaining walls in the Lesotho Highlands Development Project.

### 1 REINFORCED EARTH - BASIC PRINCIPLES

Reinforced Earth is a composite construction material consisting of a compacted granular fill reinforced with steel strips (Figure 1). As a result of the interaction between the strips and the soil, all the soil is restrained to some degree, resulting in a reinforced soil block with a width dimension equal to the length of the reinforcing strips.

The density and length of the strips are dependent on the height of the structure, the applied loads, the intended purpose and service life of the structure, and the properties of the backfill. The strip length may however be increased relative to the length required for internal stability to guard against potential slip surfaces.

To ensure uniform corrosion of the strips and the connections, the strips, nuts and bolts are all

hot dip galvanised to SABS 763 with a minimum zinc coating thickness of 80  $\mu\text{m}$ .

A protective 'skin' prevents the erosion of material at the face. Two type of facing were used on the Lesotho Highlands structures

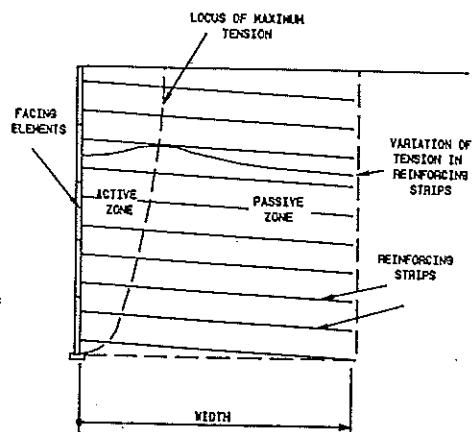


Figure 1. Reinforced Earth - definition of basic components

namely precast concrete panels, and a grid cladding (Figure 2) backed by rock. The grid cladding elements are manufactured from 6,3 mm diameter hot dip galvanised weldmesh.

## 2 MOUNTAIN RETAINING WALLS WITH PRECAST CONCRETE CLADDING

The Northern access road traverses the steep Mafika Lisiu mountain pass which rises 1 000 m in 10 km to an altitude of 3 059 m. The road is carved into the basalt rock which has a weathered surface zone 1 to 2 m deep.

Although the road was aligned mainly in cut, it was not possible to avoid the use of retaining structures along two curved sections of the road.

Excavation for Wall 1 (km 25,3) along the original alignment revealed a near vertical fault running almost parallel to the road. During blasting, the rock broke away allowing the road to be realigned, with a significant reduction in the length of the wall. Wall 1 (Figure 3) is 65 m long with a maximum height of 10 m on a curve of radius 45 m (to outside face of wall).

Near the top of the pass, the alignment follows an S-shape, the road placed entirely in fill, with a hairpin bend allowing the road to top out at a reasonable grade.

Wall 2, situated on the hairpin bend at km 26,6 is 145 m long with a maximum height of 18 m (Figure 4).

### 2.1 Design

Both walls are designed as mass gravity structures with precast concrete cladding. The strip cross-sectional dimensions and length at each height in the structure were determined in accordance with the recommendations of Terre Armee Internationale.

The design calculations examine the internal stability of the Reinforced Earth mass, namely sliding on the base, stresses in the strips, adherence (soil/strip interaction), and stresses at the connections.

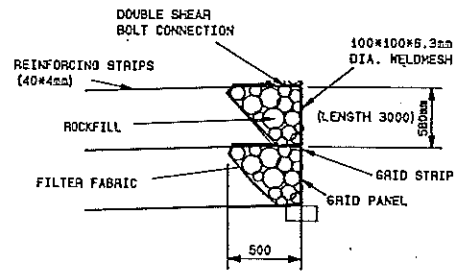


Figure 2. Reinforced Earth with grid facing



Figure 3. Wall 1

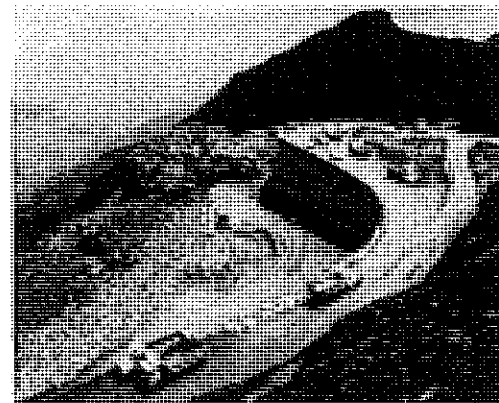


Figure 4. Wall 2

To minimise rock excavation, Wall 1 was designed with a trapezoidal cross-section (Figure 5a). However blasting of the rock to these lines proved to be time consuming and unjustified according to the scale and

inaccessibility of the works. To simplify construction Wall 2 was designed with a rectangular cross-section (Figure 5b). Both walls were faced with interlocking precast concrete panels 140 mm thick. Over a considerable portion of its length, Wall 2 is 18 m high and has a radius of curvature of 22 m. The flexibility of the facing decreases with increasing height and with decreasing radius of curvature. Wall 2 was thus split into 2 tiers in order to ensure sufficient flexibility (Figure 5b).

## 2.2 Construction

After considerable investigation and debate, it was decided not to use the weathered basalt from nearby borrow pits for the Reinforced Earth backfill in the two mountain walls.

Although this material met Reinforced Earth specifications, it was fairly impermeable ( $10^{-6}$  cm/sec) and problems were envisaged regarding compaction and drainage. The remote position of the site, the inclement weather conditions and time constraints determined that a free draining material be used.

A crushed doleritic basalt from a borrow pit at km 2 was used as the Reinforced Earth backfill in both mountain walls. This material was considered to be sufficiently free draining to eliminate additional drainage which would otherwise have been substantial since ground water flows abundantly from fracture planes in the rock excavation.

The facing panels for Walls 1 and 2 were precast by the Contractor on site at km 15 and transported up the pass to km 26.

Construction of Wall 1 started on 1 August 1990, while Wall 2 was started in October 1990. A construction rate of approximately  $25 \text{ m}^2$  per working day was achieved and as a result of the good quality of the backfill used, construction proceeded smoothly with no problems being encountered. Wall 2 was completed by the middle of February 1991.

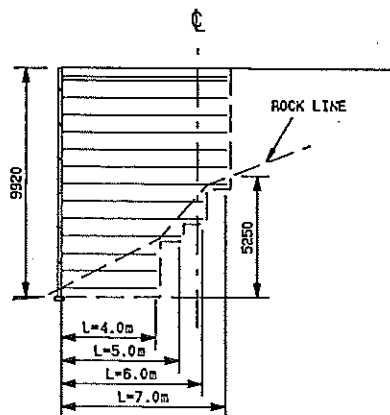


Figure 5a. Typical cross-section through Wall 1

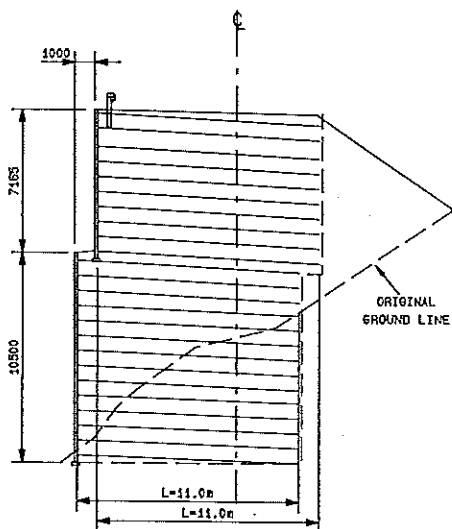


Figure 5b. Typical cross-section through Wall 2

## 3 EMBANKMENT FILL CAPS

In the upper reaches of the Malibatso River Valley, the access roads cross deep valleys. Large embankment fills in combination with bridges carry the roads across these valleys. Some of these fills are exceptionally high, namely:

- \* A 40 m high approach fill to the Malibatso bridge from the Pitseng side (Figure 6).

- \* The Mokhoulane fill, a 30 m

high fill over a large culvert at km 2,0 on the Pelaneng Adit Road.

\* The approaches to the Pelaneng River bridge at km 5,0 on the Pelaneng Adit Road. These approaches are 10 m and 20 m high respectively.

The fills were originally designed and specified as rockfills with slopes of 1:1,5 or 1:1,75. However, re-appraisal of these slopes was necessary since:

- i. the embankments would be partially submerged by the backwater of the Katse Dam,
- ii. there is a scarcity of good quality rockfill in these areas,
- iii. the freshly blasted basalt showed signs of fairly rapid degradation.

Thus a redesign of the embankments using weathered basalt was carried out. Slope stability analyses conducted by Messrs Highlands Infrastructure Consultants using the new fill parameters showed that embankment slopes of 1:2,5 would be required. The flatter slopes would result in an enormous increase in the volume of fill, which in turn would increase the construction period and the project cost.

Various cost saving alternatives were considered, bearing in mind that it was also desirable to maintain the original toe lines since construction had already started on the Malibamatso fill, while at the Mokhoulane site, a massive Armco arch culvert had already been constructed.

The most economical and practical solution was to 'cap' the 1:2,5 sloped embankments with Reinforced Earth with grid cladding (Figures 7 and 8).

### 3.1 Design

The Reinforced Earth caps were again designed in accordance with the recommendations of Terre Arme International.

Early proposals attempted to achieve higher cost savings by using Reinforced Earth below the full supply level. However fears were expressed that the soft Lesotho Highlands water would accelerate the corrosion of the strips.

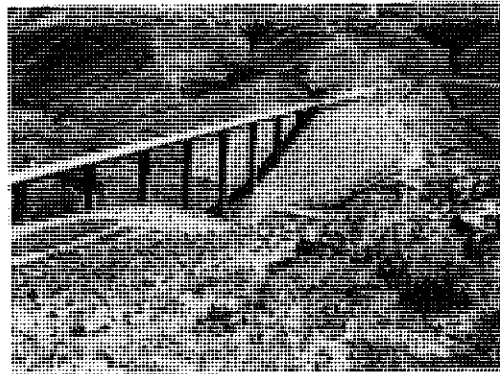


Figure 6. Malibamatso bridge and approach

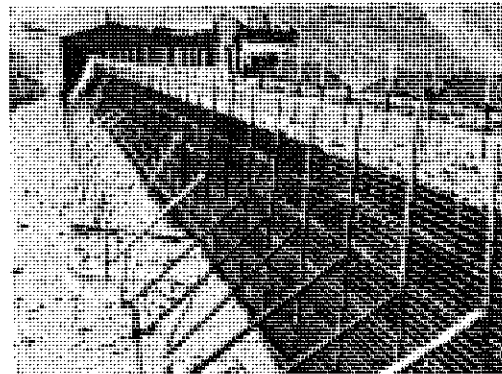


Figure 7. Typical cross-section through embankment (Mokhoulane) showing Reinforced Earth cap



Figure 8. Reinforced Earth with grid cladding

Since there was insufficient time to complete an evaluation of the rate of the corrosion of galvanised steel strips in soft water, the Reinforced Earth was restricted to use above water. A sacrificial thickness of 1,5 mm (normally 1,0 mm in 'dry' structures) was allowed to account for the possible presence of soft water through capillary action or seepage. Laboratory electro-chemical tests using water and backfill taken from the site are underway and indicate that the corrosion rate is not excessive.

The load imparted by the cap is not necessarily detrimental to the stability of the underlying embankment. The overall stability may in fact be improved by the cap, since for a failure surface to pass through the cap, the reinforcing strips must either be broken or pulled out. Slope stability analyses were carried out using Tarupt, a program developed by the Reinforced Earth Group. The critical case was a rapid 6 m drawdown corresponding to an emergency lowering of the level of the Katse dam.

Messrs Highlands Infrastructure Consultants, the design engineers, also carried out slope stability analyses and found that the caps and the embankments were stable without any additional drainage measures.

### 3.2 Construction

The grid cladding is ideal for retaining structures in remote areas since it is light and easy to transport. It is placed by hand and thus provides an economical labour-intensive construction method which was mooted as being desirable in Lesotho (Figure 9).

A total area of some 7 000 m<sup>2</sup> of Reinforced Earth with grid cladding is being erected on the large embankment fills. Weathered basalt taken from locally situated borrow pits proved suitable for use as the Reinforced Earth backfill, while competent non-degradable rock was used to provide a 500 mm 'filter' behind the cladding. A sheet of non-woven polyester geofabric is placed behind the rock to prevent leaching out of fines from the Reinforced Earth backfill.

Construction is undertaken by teams comprising 40 female and 12 male labourers allowing an average construction rate of 150 m<sup>2</sup> per team to be achieved daily.

### 4 CONCLUSIONS

Reinforced Earth is a versatile construction material which, as demonstrated by its successful use in the Lesotho Highlands is very well suited to geostructural

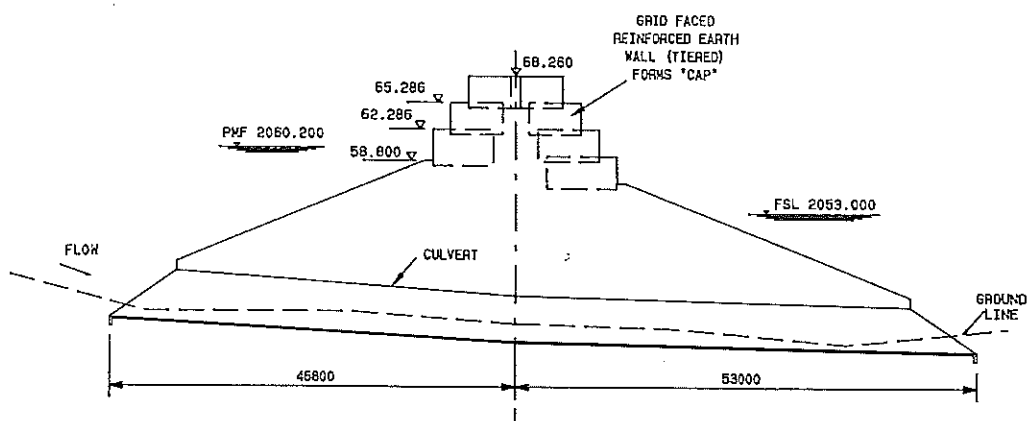


Figure 9. Erection of grid cladding

applications in the African environment. The construction of large earth retaining structures under difficult conditions in remote and inhospitable terrain is greatly simplified by the use of Reinforced Earth, particularly when faced with lightweight grid cladding.

#### ACKNOWLEDGEMENTS

Highlands Infrastructure  
Consultants (HIC) - Design  
Engineers

O'Dwyer Jeffares & Green -  
Supervising Engineers

Lesotho Highlands Development  
Authority - Client

LTA Construction - Contractor