C.R. Coll. Int. Renforcement des Sols. Paris 1979.

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Reinforced earth in the mining industry in southern Africa

La terre armée dans l'industrie minière en Afrique Australe

RESUME

Cet exposé décrit les applications de la terre armée dans l'industrie minière en Afrique Australe et discute les aspects les plus intéressants d'un certain nombre de projets. On explique pourquoi le matériau a trouvé un bon développement qui devrait se poursuivre.

INTRODUCTION:

Reinforced earth was introduced into Southern Africa in late 1975 and the first structure erected near Cape Town in March 1976. At the time of writing (October 1978) a variety of structures with face area totalling some 25 000m^2 have been completed and a further 10 000m^2 are currently under construction. The material has found particular application in the mining industry of Southern Africa. This industry accounts for 45% of the projects undertaken; 39% of the total square metres constructed and 51% of the total costs of the reinforced earth materials (excluding backfill) which have been supplied.

SUMMARY OF MINING PROJECTS IN SOUTHERN AFRICA:

MINE:		DESCRIPTION:
Consolidated Diamond Mines of South West Africa (Pty) Ltd.	-	21m high L-shaped wall for the 50G Clay Sampling Plant.
	-	13m high tip wall for the No. 3 Conglomerate Plant.
Silicon Smelters Mine, Northern Transvaal.	-	A two-tiered tip wall to screen out clay from the ore.
Beestekraal Mine, Western Transvaal.	-	8,25m high tip wall to the primary crusher building.
Koingnaas Diamond Mine N.W. Cape Province.	-	Terracing to various levels of a 20m high gravity feed plant.
Kimberley Diamond Mine N.E. Cape Province	-	7m high tip wall using metallic facing elements.
Jwaneng Diamond Mine - Botswana	-	7m high wall using metallic facing elements.
Tweepad Diamond Mine - Cape Province.	-	Wingwalls and terracing to a 41m high gravity feed plant.
Stilfontein Uranium Mine Transvaal	-	Ore storage facility for coal and pyrolusite.

APPLICATIONS:

The uses of reinforced earth in the mining industry of Southern Africa can be classified into 3 categories:

i) *Tip Walls and associated Wingwalls:*

A requirement of virtually all open cast mines is that ore-loaded construction plant such as trucks, front end loaders or scrapers are obliged to tip their loads into receiving bins of some sort. The vertical grade separation required for this purpose is termed a "tip wall". If the ore is processed at the mine in any way then this tip wall will be situated at the first point of processing, usually the primary crushing facility.

If rear dump trucks or front end loaders carry the ore then the tip wall required will be a retaining wall. If the ore is carried by bottom dump trucks or scrapers then this plant must travel over an open grid through which the ore is dumped. This grid is supported by abutments and both the retaining wall and these abutments provide applications for reinforced earth.

If the tip is situated in rock then the application obviously, does not exist. It is also apparent that the application becomes favourable to a reinforced earth solution when the tip is above ground level and even more so with increase in height of the tip.

The tip might lead into a box type structure and if the structure is above ground level wingwalls are often required to prevent the earth from spilling around the sides. Reinforced earth could be used to advantage for both the box structure and the wingwalls.

All but three of the projects undertaken in Southern Africa to date have been of this type.

ii) *Ore Storage Facilities*:

It is usually imperative to have some sort of "buffer" between the mining operation and the load-out operation on a mine. This stockpile could take on a number of forms.

a) A common stockpile in which material is tipped onto the ground and then reloaded.

b) A stockpile in which a mechanical stacker-reclaimer is used to stack and reclaim the ore.

c) A silo in which conveyors are used to load the silo and from beneath which the ore is reclaimed.

d) A stockpile in which recovery is made by means of a reclaim tunnel running beneath the entire length of the stockpile.

If the ore is coal then it is necessary to prevent the build up of "dead" material which could initiate self combustion of stockpile. A slot storage facility is one similar to that described in (ii) (d) above but which has sloping sidewalls to ensure that the entire stockpile is "live"

If the slot is in rock then it is only necessary to line the sides of the excavation. If the slot is in soft material or is situated above ground level then it is necessary to provide a structure with the required sloping sides. (The angle of these sides is normally between 50° and 55° from the horizontal). Traditionally the slots have been constructed in reinforced concrete or by stabilizing the earth embankment before trimming to the correct angle and guniting the face.

Reinforced earth employing sloping facing panels is now also used to construct these steep sloping side walls.

iii) *Gravity Feed Plants*:

On South Africa's West Coast diamonds are found in a matrix of sands, clays, shales and conglomerates. The material must first be crushed and then made to pass through scalpers to get rid of large flakes and later through scrubbers. Water and gravity are required to remove the clay and to wash the ore from one area to the next.

Considerable earthworks are required to form a stepped or terraced formation to allow the ore to cascade from one level to the next. Reinforced earth is used to provide the vertical faced terraces which also allow access to various levels of the plant to install and maintain mechanical equipment. The structures at Koingnaas and Tweepad are designed for this application.

NOTES ON SPECIFIC APPLICATIONS:

Consolidated Diamond Mines (C.D.M) - 21m High Tip Wall for 50G Clay Sampling Plant

The L-shaped tip wall at 50G Sampling Plant C.D.M. at the time of construction was the highest reinforced earth structure in the world using precast concrete facing elements (Fig.1). The 50G wall together with the tip wall at No. 3 plant in the same mine are thought to be the only structures protected by an impressed cathodic protection system.

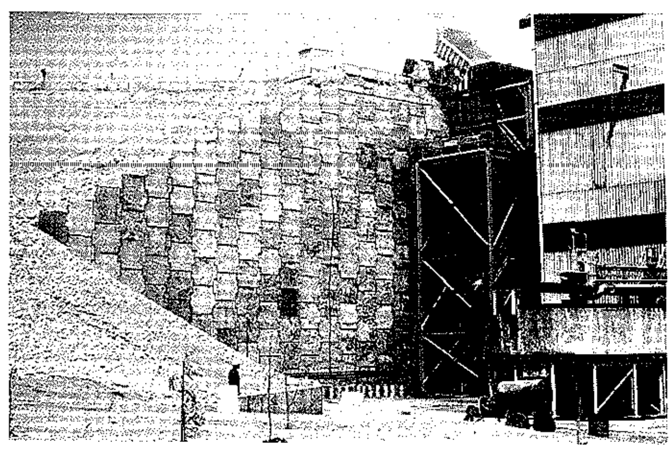

FIG. 1. : *THE 50G CLAY SAMPLING PLANT AT C.D.M.*

C.D.M. is situated on marine terraces stretching Northwards from the mouth of the Orange River along the coastline and into the Namib Desert. The only available backfill materials are clean marine sands with very high chloride contents ($>$ 500 p.p.m.) and associated low resistivities. ($<$ 1000 ohm.cm.)

After comparison with the use of various thicknesses of black and galvanized steel for the reinforcing strips it was decided to use cathodic protection on 3mm thick black steel reinforcing strips. A sacrificial thickness of 0.5mm was used to allow for extreme atmospheric corrosion rates experienced by steel in this area before the strips could be placed in the structure.

Cathodic protection was chosen for the following reasons:

a) This was the most economical way of protecting the reinforcing strips from corrosion.
b) A ready source of electric power was available at the plant.
c) Maintenance crews would be constantly in attendance.
d) Sea water ponds, situated nearby, were suitable for installation of the anode groundbed.
e) The low resistivity of the surrounding in-situ materials ensured an efficient return path to the anode groundbed.

Electric power was introduced into the system through a transformer-rectifier housed in the mechanical plant building. Negative cabling leads to 8 drainage points on the structure face. The electrical continuity of all the reinforcing strips was ensured by welding all tie strips of each panel together inside the concrete and by bolting continuity strips from one tie strip to the next. (Fig.2) Testing of all continuity bonding was carried out using resistance meters on all bonding strips at all levels of construction. The positive cabling leads to platinised titanium and high silicon iron anodes some 200 metres distant from the plant. The anodes are suspended in a sea water pond to reduce the total anode resistance.

Potential measuring points have been installed into the structure to permit the potential of the reinforcing strips to be measured at any future time. Each test point consists of a pair of cables, one connected to a selected reinforcing strip and the other to a small block of high purity zinc buried in the structure near the selected reinforcing strip. Ten such test points have been provided and the potential of the reinforcing strip can be measured against the zinc reference at any time to ensure that full cathodic protection is being achieved.

It was necessary to bond the structural steelwork of the Reception Building directly to the reinforced earth wall at two of the cathodic protection points to prevent adverse electrical interference on the plant steelwork by the ground currents of the cathodic protection system.

The first maintenance inspection was conducted 9 months after installation of the system and the report indicates that the system is operating satisfactorily at 200 A 40 V and is fulfilling its design function.

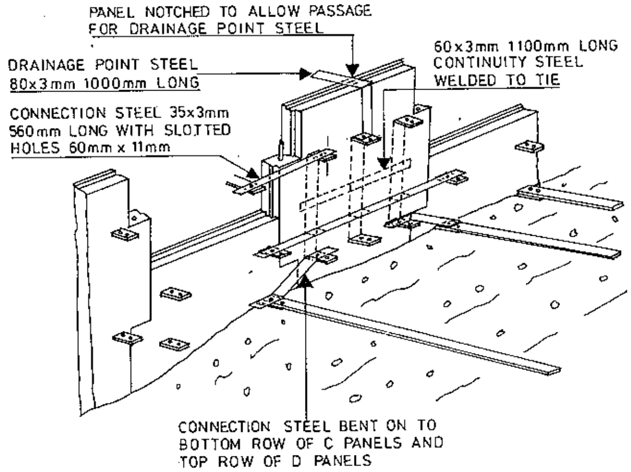

FIG. 2 : *ISOMETRIC VIEW OF CONTINUITY STEEL*

Beestekraal Tip Wall:

At Beestekraal the mine had for many years used a crushing plant where the limestone was tipped into a receiving bin at ground level and then taken up to the crusher by conveyor. This system proved unsatisfactory and a decision was taken to stop production and to replace the bin conveyor system with an eight metre high tip wall from which ore could be tipped directly into the crusher. Speed of erection was critical and reinforced earth was chosen for the work. Due to the time element a precast slab was provided at the top of the structure in place of an insitu slab which would have taken too long to cure.

The entire construction of the wall and slab was completed within 10 days. A photograph of this work is shown in Fig. 3.

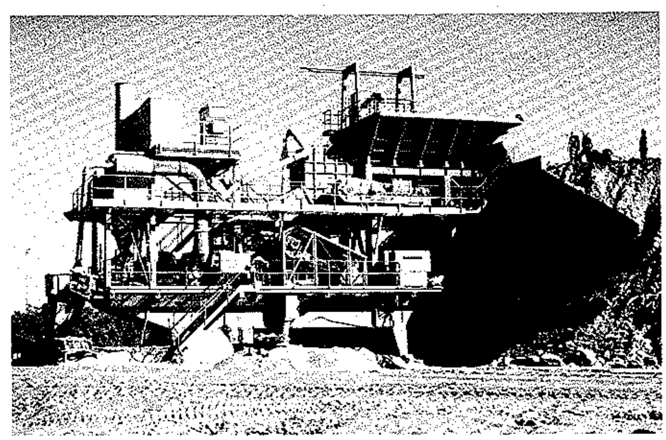

FIG.3 : *THE BEESTEKRAAL TIP WALL*

Impact and Point Loads:

An important design aspect of most of the tip walls constructed in Southern Africa is the detailing of a reinforced concrete slab at the top of the structure to absorb the impact loads uniformly. These slabs are usually 500mm thick and have sufficient plan area to ensure that all wheels of truck or front-end loader will actually be on the slab while tipping.

To take these supposedly high impact loads some slabs have been anchored back to a "dead man" while others have relied on a concrete key at the back. These latter slabs have performed adequately to date.

Horizontal Loads:

Many tip walls which are designed in reinforced concrete are also designed to take horizontal loads from the mechanical plant. Reinforced earth cannot take these loads on the panels. Either extra bracing must be introduced into the mechanical structural steelwork or special design arrangements must be devised.

At the Silicon Smelters Mine the upper tier of this two-tiered structure was erected using special panels with holes to allow for the passage of 4 steel universal beams to pass through the reinforced earth mass. A concrete pipe 3m long was placed behind the panels and the beams were placed through these pipes and concreted into a ground beam placed behind the reinforced earth mass. (Fig.4)

Although it is realised that considerable movements are required to mobilize passive earth pressures the structure is operating satisfactorily.

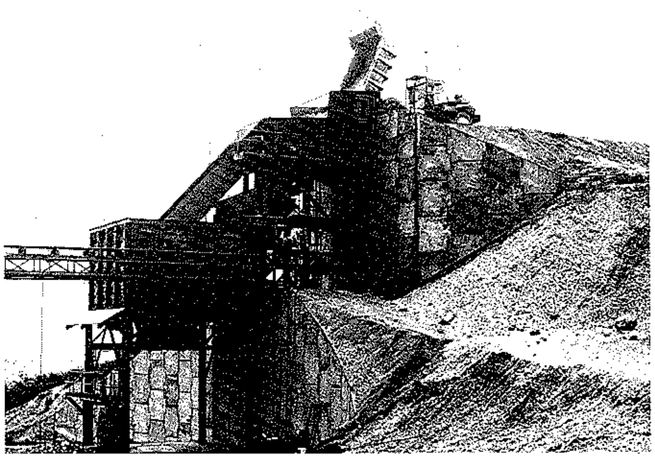

FIG. 4 : *THE STRUCTURE AT SILICON SMELTERS MINE*

Ore Storage Facilities:

The first slot storage facility in Southern Africa was approved for Stilfontein Mine in the Western Transvaal in mid 1978. This slot combines the use of both sloping sidewalls and vertical reinforced earth end walls. (FIG.5)

An attempt has been made to provide the same vertical interval between the reinforcing strips on both sloping panels and on vertical panels. This has been done by using 3 buttresses on the back of each sloping panel with 2 tie strips cast into each buttress. This speed of erection of this structure is critical and it is programmed to be completed within the months of December 1978 and January 1979. The reclaim tunnel should be completed by the time construction of the reinforced earth is due to start.

The storage facility is for 10 000 T of coal and 10 000 T of pyrolusite. The coal consists of - 25mm fines and will be reclaimed by means of a plough feeder at the rate of 120 T/hour. The pyrolusite with specific gravity twice that of the coal will be reclaimed at 240 T/hour, by means of vibrating screen feeders.

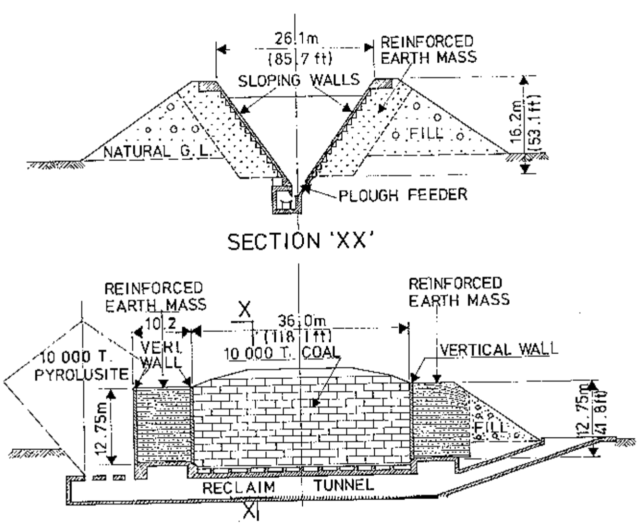

FIG. 5 : *STILFONTEIN ORE STORAGE FACILITY*

High Gravity Feed Plants:

The structures at the Koingnaas and Tweepad Mine fall into this bracket. A cross-section of the Koingnaas plant is shown FIG.6 and a sketch drawn to scale of the Tweepad plant is shown in FIG.7. A photograph of the completed Koingnaas structure is shown in FIG.8.

The advantage of reinforced earth is that the mass can be founded in fill and be constructed simultaneously with the bulk earthworks.

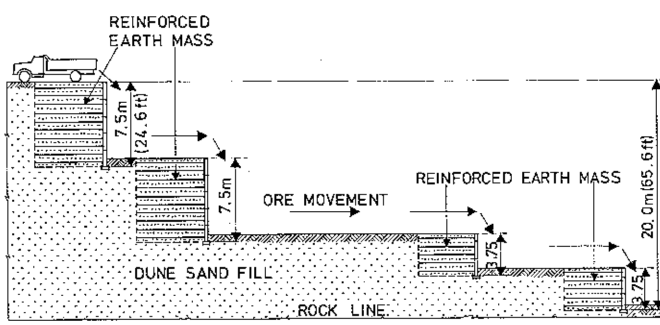

FIG. 6 : *KOINGNAAS GRAVITY FLOW PLANT*

The Tweepad structure is extremely high. One of the walls (wall K) is 27m high and is thought that this will be the highest continuous wall ever constructed.

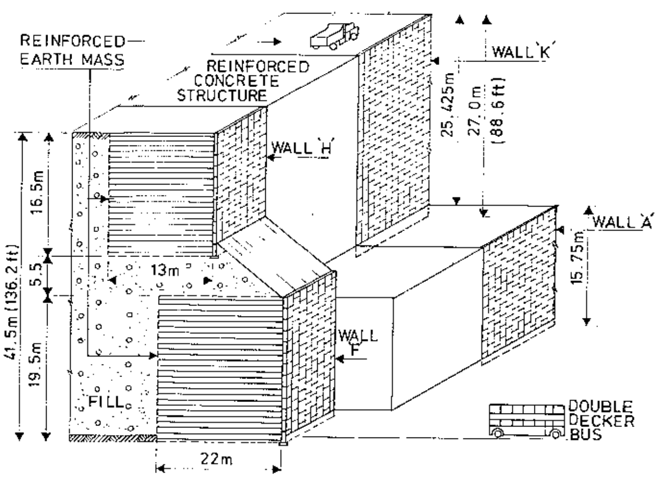

FIG.7 : *TWEEPAD GRAVITY FLOW PLANT*

It is difficult to imagine what alternative form of construction could have been used for the structures at Tweepad. The whole concept of the plant has evolved from the ability of reinforced earth to meet the requirements of such large structures economically and practically. Once again it should be remembered that the massive structures founded in fill have no special foundation preparations although steps have been taken to improve the local bearing capacity of the sand fill near the face of the structures.

If reinforced earth had not been considered then in all probability the plant would either have been lowered deep into the rock or else would have been split up into 2 plants, i.e. one for the crushing and scalper areas and one for the scrubber and screening areas. It could also possibly have become 3 different plants.

It is technically difficult to pump the ore efficiently, consisting as it does, of clay, sand, shale and conglomerate with particle size upto 150mm and consequently if 2 or 3 plants had been used it would have been necessary to dewater the ore at the bottom of each plant and raise it again to the top of the next plant by conveyors. The most economical solution is the single high gravity feed plant as shown in FIG.7.

The retaining walls required to prevent the earth from enveloping this plant and to provide access to various levels are massive. These structures must be founded on fill and must be flexible to adjust to differential settlements. Reinforced earth has removed certain civil engineering constraints from the mining and mechanical design criteria in this application.

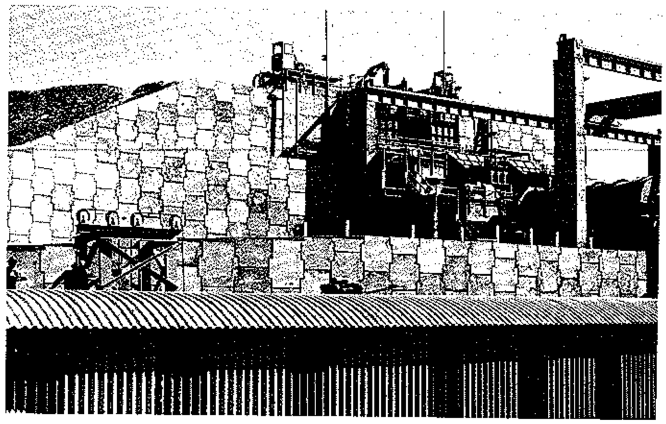

FIG. 8 : *A VIEW OF THE KOINGNAAS GRAVITY FLOW PLANT*

REASONS FOR ACCEPTANCE OF REINFORCED EARTH BY THE MINING INDUSTRY :

i) The mining industry in South Africa is developing rapidly and consequently is ready to accept innovation and change which might expedite progress.

ii) An important factor in the choice of reinforced earth is that of service life. In the mining industry the service life of any particular structure can be fairly accurately defined, depending on the working life of the mine. In fact the required service life of all structures in Southern Africa with the exception of the Stilfontein Ore Storage has been only 30 years. This has not only been a psychological reassurance to the client, but has also enabled the sacrificial thickness of reinforcing strips to be reduced with associated cost savings.

iii) The ability to erect a reinforced earth structure without any special technical skills has also been a consideration. The establishment costs for a Contractor to move onto site for small civil works such as an 8m high tip wall would be high. Mine personnel themselves erected the walls at Silicon Smelters, Beestekraal and the Kimberley Mines.

iv) The tip wall at Beestekraal illustrates the value of speed to the mining industry, where cost of downtime can be accurately estimated.

vi) The use of metallic facing elements with associated low transport costs has proved useful for small projects in remote areas.

CONCLUSION:

i) Vertical reinforced earth walls have already proved their potential in the Southern African mining industry and indications point to their continuing and expanding use.

ii) Sloping walls have a distinct application for bunkers used in coal mining. This development has potential but is still to be proved to be competitive with other forms of construction.

iii) The advantages of reinforced earth should be made known to mining authorities so that investigations can be undertaken at an early stage in the study and development plans for new mines.

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