Colloquium on the construction of Slimes dams

The following contributions to the discussion at the above Colloquium were received for publication.

D. G. DAVIES*

This contribution is really a follow up on Mr H. E. Cross's paper on the conversion of a uranium plant to the recovery of zinc (published in the *Journal*, November 1973).

Residue and solution bleed from Zincor are discharged to what was formerly the Vogelstruisbult gold-plant residue-disposal dam. This was the original slimes-dam disposal area laid down in November 1936, and was subsequently sluiced for pumping to the uranium flotation plant. The area was again used later for slimes residue from the gold plant.

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Solids in the residue from Zincor amount to some 3000 tonnes per month made up of 1500 from treatment of Waelz-kiln oxide and 1500 from treatment of roaster calcine.

The oxide residue contains approximately 15 per cent lead and is deposited separately, with the prospect that it will be reclaimed for re-treatment and recovery of the lead.

The solids do not provide much in the way of wall-building material, and the exercise is largely one of evaporation. No solution is returned to the plant.

Walls were originally thrown up from the original gold-plant residue slime, but lapping of the solution in windy conditions did not help the maintenance of these walls. Some success was achieved by protection with old polypropylene filter cloths.

There was, and still is, a dump of excavated material and rubble from the plant site, and this has been used to establish a road wall round the perimeter of the dam and to bolster some of the inner walls. This has proved very successful, and the work, which is done departmentally, is still being carried out.

Approximately half of the slimes-dam area is used for zinc-plant effluent. In the remaining portion, walls have been bulldozed to paddock the area for evaporation of rain water. The pentstock has been sealed.

Ecological aspects of slimes-dam construction

by H. T. CLAUSEN

Published in the Journal, December 1973

C. M. VAN STADEN*

I should like to thank Mr Clausen for his paper and to congratulate the Research Laboratories and the Vegetation Unit of the Chamber of Mines on the excellent work they have done in the past, are still doing at present, and, we hope, will continue to do in future, on the testing of various methods for the covering of slimes dams and specifically on the vegetation of dams. In this same catagory, we must also congratulate the individual companies that, at great cost, have done their share to combat air and water pollution and to improve the environment.

The solid material, after gold extraction, that is deposited on dumps has various names. These include residue, tailings, slime, ground ore, ground rock, and perhaps many more. I prefer to use the term 'slime', although 'residue' may be a better word. We could then talk of residue dams. It is immaterial to me which of these two names is used. Tailings (Afrikaans 'uitskot') to me is that which remains after ground ore has been subjected to flotation or jigging. You may then well ask what I would call the material left after a leaching and flotation process. I will leave it to the language people to sort out the correct nomenclature. At least, I think we know what we are talking about.

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We do not always realize how fortunate we are that this dumped material can, with some help, support the growth of vegetation. What would have been the choice if this had not been so? There is not really a good second method. The alternative would have been to cover the dumps with rock or soil. What would the cost then have amounted to?

As a matter of interest, in a report published by the United States Environmental Protection Agency, an estimated figure of about R10 000 per hectare is given as the cost of establishing a grass cover on an abandoned refuse pile by first covering it with a 30 cm layer of soil.

As stated in the paper, the sulphide content in the milled ore is the main culprit, causing acidity, high total dissolved solids, dissolved iron, and pollution. But fortunately this pyrite content also bestows certain blessings. First of all, it cements the slime together to form a crust, which is, to a certain extent, resistant to wind and water corrosion. Secondly, it forms sulphuric acid, which decomposes any cyanide that may be present.

The work on the vegetation of slimes dams and sand dumps done by the Chamber of Mines Vegetation Unit is at times questioned, mainly on two points:

(a) whether, in the long run, the vegetation on dumps is self-supporting, and
(b) the cost of vegetating these dumps.

To find an answer to the first point, the Chamber of Mines consulted Professors Orchard and Sumner of the University of Natal. In their report, the soil and the plant cover are discussed, and recommendations for long-term maintenance are given.

The practical efforts of the Vegetation Unit have met with a fair deal of success. After having been vegetated for twelve years, the tops of certain dumps have very good coverage and are self-supporting. The sides are more difficult. After being planted, the vegetation requires a fertilizer boost periodically for the first three to four years, because the soil is at that stage deficient in nitrogen. There are dumps with eight years coverage on the sides that have not received any booster treatment over the last four years and are now self supporting. A very encouraging phenomenon is that indigenous plants and grasses are moving into the planted areas.

In an assessment of the coverage of a dump, one aspect must be borne in mind: the coverage is to prevent air and water pollution and not to yield the maximum crop per unit area.

It can therefore be assumed that, under normal circumstances, the vegetation of the dump tops is permanent. The sides are also permanent, provided the angle of slope of the sides is not steeper than 27°. A plea is made in the paper for gradients of less than 27°, various reasons being given. This is an aspect that requires further investigation to ensure that the capacity of a dam is not adversely affected by the flatter slope, despite the increased ultimate height that is claimed to be possible. The initial size of the dam at foundation level must obviously play an important role in this respect.

The cost of vegetating dumps has been mentioned. To prepare and vegetate a dump is expensive. Dumps that are severely eroded require large amounts of filling, and civil work must be done to prepare the surface before the actual planting of the grasses. The cost of preparing and planting one dump cannot be compared directly with the cost of vegetating another dump because conditions may vary. The cost of vegetating each dump must therefore be assessed on its own.

It must be realized that the vegetation of dumps is done on ground ore that comes from deep down in the earth and contains no organic plant foods. All the plant food must be provided in the form of fertilizer, and the bacterial life in this almost-dead soil must be established and stimulated. The cycle starts with fertilizer and plants, the plants die down and as a result of bacterial action form humus; this humus increases the bacterial action, which creates a suitable soil medium to sustain plant life, etc. A great deal is known about balanced fertilizers and fertilizer requirements of soil. Relatively large sums of money are spent by the mines and the Government in treating, fertilizing, and vegetating dumps. Money would be well spent on a study and investigation of the conditions required to improve the bacteriological activity that aids the vegetation on dump material.

The main hazards affecting the vegetation, especially its permanency, are as follows:

(a) the pyrite content of the slime,
(b) the slope of the dump sides, and
(c) grass fires.

The first two factors we have dealt with. I shall say a few words only about the last. During the dry winter months, the vegetation on the dumps is prone to fires. The fires destroy not only the existing vegetation but also the organic material that could provide humus to the soil and foster bacterial growth. We believe that some of these fires are started by irresponsible people, not so much as an act of sabotage but just for the fun of it or by negligence. Such a deed is deplorable and criminal.

As a member of the public and not only as a representative of one of the Mining Groups, I wish to pay tribute to the work done by the Vegetation Unit. The work beautifies our environment by establishing green hills that we believe will lessen the pollution of the life blood of the Industry and community on the Reef, namely air and water.

J. E. GROVES*

The film shown at the colloquium featured dumps grassed by the Vegetation Unit of the Chamber of Mines. These successes represent the culmination of many years of advances in both the practice and theory of vegetative reclamation.

However, these very gratifying results in no way represent the likely end point in this series of advances. Our work in the Vegetation Unit is basically to discover improved ways of establishing and maintaining the vegetation on reclamation sites. This is being done partly by a series of field fertilizer trials.

The establishment of vegetation is undergoing four trials to determine the fertilizers required to improve total grass cover and the lasting qualities of that cover. Tests are being done with nitrogen, phosphate, and potassium in amounts of up to 250 lb of each element per acre (these amounts being over the whole range of responses expected, both positive and negative). The tests include 21 treatments and 4 replicates.

Three maintenance trials are being conducted to determine what fertilizers are required for the maintenance of good vegetation on old grassed dumps and dams. These tests, which involve 67,5 lb of nitrogen and 20 lb of phosphorus per acre annually, are considered to be adequate and well within economic limits.

The problems to be faced from the 'soil' point of view during the course of vegetating sites are possibly fourfold, involving slope, acidity, salinity, and water.

These very basic problems obviously preclude the growth of good veld-type grass in most cases, and therefore reduce the rate of true-soil build-up. The build-up of true

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soil is probably the only sure way of producing an everlasting grass cover on our tailings dumps. A build-up of soil leads to cycling of plant foods and good plant/soil-moisture relations — both essential for lasting growth. However, to effect this soil formation requires the availability of a soil-type ecology — this is not present in tailings and may have to be introduced. Research on this aspect of reclamation is now under way.

Shallow slopes aid soil build-up, partly owing to their greater effective area for rainfall reception without resultant erosion. That steep slopes produce greater run-off velocity, and thence greater sheet and gulley erosion, is a fact. Erosion retards soil build-up with or without the presence of a vegetative cover.

As the film demonstrated, mine-dump reclamation is no easy task. It would aid the work greatly if, at the stage of planning a new dumping site, cognisance were taken of the environmental aspects of its subsequent reclamation and suitable measures were incorporated into the plan, as for example in the U.K., where dump slopes are *planned* to be at 1 in $7\frac{1}{2}$ when reclamation commences because local authorities prefer to grass at this slope. Drastic regrading is usually done during the reclamation of colliery spoil heaps in the U.K. The dumps are re-shaped both for purely aesthetic reasons and for the utilization of these degraded areas, usually for agricultural purposes, during the important maintenance period, and later for recreational or similar uses. Forestry also plays a large part in the reclamation of a site and the long-term landscaping of the area.

This environmental planning is now obligatory in most mining areas of the developed world, and central Governments provide large sums of money, in the form of subsidies to local authorities, to ensure that the work is done thoroughly to the benefit of the whole community.

A total commitment to environmental planning and improvement is required—from all quarters.

AUTHOR'S REPLY

Fig. 1 shows the relationship between the volume of a slimes-dam and the ground area it occupies for three conditions of side slope and permissible height. It illustrates the saving of land that can be achieved by the use of flatter side slopes, and thus greater permissible heights, in slimes-dam construction.

The diagram shows that 45×10^6 m^3 of slime (assumed residue from a mine milling 200 000 tonnes per month for 30 years) will occupy 230 ha where the permissible slimes-dam height is 20 m with a side slope of 1 in 1, but this same volume will occupy only 160 ha where the permissible height is 33 m with a side slope of 1 in 3.

However, the main reasons for the plea for flatter slopes are that they make the establishment of vegetation less costly, considerably improve growing conditions, and reduce surface erosion by water.

Because the title of my paper was 'Ecological Aspects of Slimes-dam Construction', the influence of ecological factors on construction had to be reviewed, not the details of ecology or construction. I was therefore particularly grateful to Dr Van Staden, who, in his contribution,

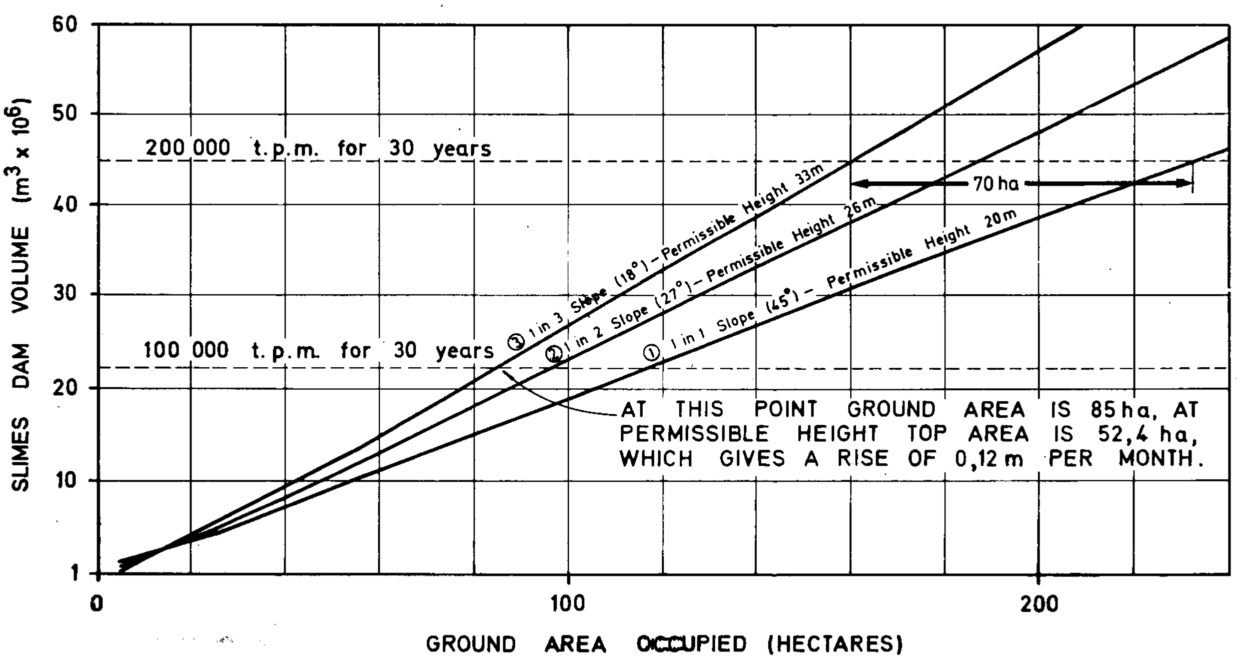

Fig. 1—Relationship of slimes-dam volume to the ground area occupied for three conditions of side slope and permissible height

enlarged on the work of the Vegetation Unit and on the many problems encountered in establishing vegetation.

I am also grateful for the contribution by Mr Flook (page 325), who gave a detailed analysis of the pros and cons for steep and flat slopes for slimes-dam walls. However, comparisons of the economic factors relating to the grassing of dams with different slopes and permissible heights should consider the cubic metres of slime under a square metre of grassed surface (including sides). This shows that, where a 1-in-3 slope and a permissible height of 33 m is used, 25 per cent more slime can be stored under a $1 m^2$ of grass on a $500 m^2$ dam, and 43 per cent more on a $1000 m^2$ dam, than where a 1-in-1 slope and a permissible height of 20 m is used. (Refer to the details of hypothetical slimes dams in the paper.) It should be noted that, for dams within this range, the maximum rate of rise will be 0,12 m (4,7 in) per month.

The purpose of the present investigations on nutrient-supply programming and the rate of soil formation being carried out by the Vegetation Unit is to establish the optimum procedure for the production, as quickly as possible, of a self-sustaining maintenance-free vegetation cover on dump surfaces. In the early stages (the first five years) of the establishment of the vegetation cover, the weak link in the nutrient cycle appears to be the rate of growth of microlife in the 'soil'.

With reference to the paper 'The Rhodesian Approach to the Vegetating of Slimes Dams' by Messrs J. R. C. Hill and W. F. Nothard (*Journal*, December 1973) and to the contribution by Mr John Groves, I should like to point out that, even if plant species tolerant to the particular residue are developed, the nutrient cycle should still be brought into being as soon as possible for plant-growth and economic reasons. The two developments, the evolution of tolerant plant species and of the nutrient cycle are complementary — not alternatives. Quite a few grasses and other plants have proved tolerant to normally neutralized gold-mine slimes (pH over 3,5).

In his paper, 'Practice and Economics of Slimes Dam Construction in the Gold Mines of the Anglo American Group' (*Journal*, February 1974), Mr Ruhmer referred to the use of cyclones to separate out sand from slime for wall construction. He also stated that, owing to the fineness of our residues, only a very small proportion of sand suitable for wall building is available. Thus, it would appear that this procedure is not applicable to local slimes-dam construction.

Mr Ray's slides of the use of mechanical equipment for the construction of slimes-dam walls showed equipment that, because of the steep outer slopes, is operated on the inner, wet surfaces. This is very costly.

Mr D. Immelman, the Chairman, in his summing up drew attention to increasing labour costs on slimes-dam construction and suggested that further thought should be given to the development of mechanical equipment for such construction in the future. Mr Moyers has pointed out that suitable flat slopes to the outer walls make it possible for conventional mechanical plant for dam construction to be operated from, and on, the comparatively dry, outer wall surfaces.

This advantage, together with the savings in land and vegetation costs, and greater structural and surface stabilities, to which should be added aesthetic considerations, makes the plea for flatter side slopes (1 in 3) in the design of new slimes dams worthy of consideration.

The impact of slimes-dam formation on water quality and pollution

by R. T. RUDD*

Published in the Journal, December 1973

C. M. VAN STADEN*

I should like to congratulate Mr Rudd on the paper he presented. Congratulations are also due to the Department of Water Affairs for the practical attitude they have taken in implementing the Water Act.

The Water Act was promulgated in 1954, the Standards in 1962, and the Permit Regulation a few years ago. At that time, there was a degree of reluctance in getting things moving. This was probably due to the normal resistance to change. It was very fortunate that the Act was promulgated in 1954 and not at some later date. Had we waited longer to get this Act passed, the more difficult and expensive it would have been to put water-pollution problems right. Deep down in our minds we have always been, and still are, pro-water saving and anti-pollution. But the interpretation and implementation of the words in the Act, written in cold, impersonal, legal language, caused some concern. Fortunately, we have all learnt a lot since 1954. By we, I mean the Department of Water Affairs, the South African Bureau of Standards, the Chamber of Mines, individual mines, etc. In the past, I have experienced very good co-operation and good-will from officials of the Department of Water Affairs and the South African Bureau of Standards.

If we look back at the results of the past twenty years, we must admit that a lot has been achieved. However, we also realize that there is still a huge task ahead. As long as we have industries, we shall always have a pollution problem.

Allow me to mention a few of the things that have been done during the last two decades.

(a) The practice of running penstock water direct into a public stream is a thing of the past. Water is now recycled between

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the disposal dam and the plant.

(b) Many dumps have cut-off drains to protect them from storm water.

(c) Many dumps have evaporation paddocks to catch run-off.

(d) Thirty per cent of total dump area on the Witwatersrand has been vegetated.

(e) Underground water is treated for the correction of pH and the removal of suspended solids. Unfortunately, nothing can be done at present about the high total dissolved solids in underground waters.

(f) A fairly large percentage of existing sewage plants have been improved, and a number of new ones have been built.

During the period when penstock water was discharged into public streams, some cyanide must have got into the streams. The misconception still exists that water from slimes dams contains cyanide. This reason was not so long ago given for fish dying in one of the dams on the Reef. I have also heard a statement that cyanide was the cause of sinkholes appearing in the Carletonville area — the cyanide was dissolving the dolomite!

Research that I feel might profitably be done includes simulated tests on the quantity and quality of run-off water while changes are made to such parameters as slope, amount and intensity of downpour, and percentage and age of vegetative cover.

In a few years' time, the major power stations in the Transvaal will be burning coal at the rate of $23{,}5 \times 10^6$ tonnes per annum. This is said to contain an average of 188 p.p.m. of fluorides expressed as F, of which about 90 per cent is volatilized. This will result in the emission of 11 tonnes of fluorine per day.

Water saving and pollution control are international problems; they will always be with us. We must work on them continuously. It is a job for life.

H. T. CLAUSEN*

I should like to thank Mr Rudd for his explicit paper, and for the open manner in which he has presented the various problems. I shall give a case in point. On page 187, where a table of the average sulphate concentrations in the Vaal Barrage waters for the years 1967 to 1972 is given, he states:

> It must also be remembered that figures taken by the Board are spot samples taken monthly, and other mechanisms may at times be operative and give a false picture.

Later on (page 188), he refers to 'masking effect'.

I should like to enlarge on his tables. For the year 1967, the average sulphate concentration was the lowest (95 p.p.m.), whereas the highest was in 1971 (170 p.p.m.). For the year 1971, the discharge from Vaal Dam—the diluting water—was approximately only one-third of that in 1967, and there were occasions when there were no discharges from Vaal Dam. I think this is the type of mechanism or masking effect to which Mr Rudd refers.

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Slimes-dam construction in the gold mines of the Anglo American Group

by W. T. RUHMER

Published in the Journal, February 1973

W. R. FLOOK*

Methods for the construction and operation of slimes dams in the gold-mining industry do not appear to have changed much for some considerable number of years. To the casual observer, these Witwatersrand landmarks must be, to all intents and purposes, identical in appearance and construction, and a detailed study of their design could fairly easily confirm this observation. The task of finding sufficient material to present a paper on the subject is therefore a formidable one, and I feel that Mr Ruhmer should be congratulated not only on succeeding in this respect but also on including some very useful information.

Individual group practice in design and operation does not appear to differ sufficiently widely from Anglo American practice to promote much constructive criticism or lively discussion on the subject. Nevertheless, apart from some remarks on wall slope, this contribution to Mr Ruhmer's paper is aimed at highlighting those small differences between Union Corporation and Anglo American practice as described in the paper.

WALL SLOPE

One very important, and sometimes controversial, aspect of design and practice of slimes-dam construction that I feel has received insufficient emphasis in the paper is that of wall slope. This is accepted as the angle between the wall surface and the horizontal, and values vary between 45° and 27° or less.

Until the end of the last decade, wall slope was discussed in terms of capacity, stability, and susceptibility to erosion, but more-recent emphasis on the prevention of atmospheric and water pollution has now included the aspect of ease and cost of grassing the slopes. We are all becoming increasingly aware of the fact that the ecological condition in which we leave a slimes dam after it has served its purpose must now be considered as part of the design and as part of the original and projected cost.

Many opinions have been expressed on the wall slopes of slimes dams, and it could almost be said that the protagonists of high and low angles vary between the repre-

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sentatives of those who have to foot the bill for design and operation, and those who have to care for the dam in its old age.

Very often both tasks fall into the sphere of responsibility of one individual or company.

The Chamber of Mines in its code of practice for the construction of slimes dams has given its recommendations for wall slopes, but, judging by the angles of current construction, there must be views that conflict with this advice.

Some opinions, theories, and facts on the advantages and disadvantages of large and small angles of slope are presented and discussed as follows. I should add that these are not based on any scientific study or research, and are not intended to supply any information, but are included rather to promote discussion by experts with firm views on the subject, which might result in guide lines for those of us who have to decide on future slimes-dam design and construction policy.

Catchment Area of Wall

All gold-mining slimes dams are in an area where precipitation, although infrequent, is very often heavy, and erosion of walls through sudden storms consequently becomes a major problem. Shallow walls present a large vertical face to rainfall and receive the maximum volume of water to erode the slimes-dam sides. A wall of 27°, for instance, has 96 per cent more catchment than a wall of 45° at the same height, and, to compensate for overall reduced dam capacity, the shallow wall may eventually be required to reach a greater height and so present even more area.

On the other hand, a steep slope will result in rivulets of higher velocity during storms, and it has been claimed that erosion increases rapidly as the velocity of water over the surface increases.

The catchment area of walls must also comply with the pending regulations in terms of the Water Act. Barrier dams and evaporation areas to contain polluted run-off from shallow walls will therefore have to be proportionately larger.

Vegetation of Sides

The Chamber of Mines Vegetation Unit have made it quite clear that slimes-dam walls of shallow slope are easier to grass than walls with steeper sides. Presumably, the unit cost varies accordingly, and the shallow slope will result in a lower cost per hectare. However, it becomes obvious once again that the shallow slope will result in more hectares to be grassed. If the same extremes of slope are used as an example, a 27° wall will require 56 per cent more surface to be grassed than that required by a 45° wall at the same vertical height.

Dam Capacity and Areas Required

The user might argue that a shallow slope will reduce his dam capacity by virtue of the fact that the deposition area diminishes rapidly as the height of the dam increases. The civil engineer constructing the dam will argue that the shallow slope strengthens the walls to the point where the safe height of the dam can be increased to compensate.

Another consideration under this heading is the fact that, because of the rapidly decreasing deposition area of a shallow-walled dam, the rate of rise for a fixed tonnage deposited may reach unacceptable proportions sooner. On the other hand, higher rates of rise are possible with the more-stable shallow walls.

In the case of a dam designed for a specific tonnage, life, and allowable rate of rise, the initial area can be calculated for any desired slope, and it is surprising what little effect the slope has on this dimension.

A simple geometric model of a square slimes-dam, designed to receive 100 000 tonnes dry weight of residue per month with a life of 15 years and a maximum wall rise of 13 cm per month, shows that the initial area required with a 27° wall will be only 8 per cent more than with a 40° wall, and the final height will be 4 per cent less.

In a case such as this, the maximum rate of wall rise fixes the final area of the dam top, which in turn dictates the other dimensions. If the slope is to be shallow, more ground must initially be set aside and, when the total 18 million tonnes has been deposited, it will have reached a height lower than that of a steep-sided dam. Thus, under these circumstances, no advantage can be taken of the fact that a greater height is now permissible.

However, if it can be safely assumed that, because of a shallower slope, the rate of wall rise may be increased, then full advantage can be taken of extra height and the initial area required for a shallow-walled dam will in most cases be less than that required by the steeper-walled dam.

In the hypothetical case quoted above, if 13 cm per month is the maximum rate of wall rise for a 40° slope, while 20 cm per month is safe for a 27° slope, then the initial ground area required for the same overall tonnage will be 20 per cent less in the latter case and the dam will rise to 30 instead of 20 m.

It would be most convenient if we all had square dams with such precise parameters to deal with. In practice, several considerations other than those mentioned interfere with our design and policy, and each dam has to be considered individually.

TERRACES OR BERMS

Under the heading 'Slopes and Berms' in the paper, the practice of stepping the wall back at regular intervals as the height increases is described. This has the effect of reducing the average slope. It is our opinion that this method has no advantage over that of constructing at the average slope without terraces. Without drainage facilities, terraces have the disadvantages of the large catchment of a shallow slope and the high velocity of water run-off of a steep slope. It is our experience that, where drainage pipes are set into terraces on a slimes-dam wall, they are very often the starting points of erosion channels.

SPECIFIC VOLUME OF DRIED SLIME

Of the several variables and physical constants to be taken into account in slimes-dam design, the mass of dried compacted slime per unit volume plays a prominent part in design. If it is accepted that this figure can vary to a small extent with particle size and compression forces, the accepted average taken from various publications appears to lie between 1300 and 1400 kg/m³. This is a convenient unit since it can also be expressed as the dry tonnes per month deposited per hectare to give a rise of 10 cm per month.

Mr Ruhmer in his paper quotes two cases: (a) the deposition of 100 000 tonnes dry weight of slime per month on 45 hectares for a 10 cm rise per month, and (b) a slime compaction of 0,625 m³/t. In terms of kg/m³, these work out to 2222 and 1600 respectively, and, apart from being contradictory, appear very high in comparison with other standards.

PRECIPITATION OF HYDROXIDES

The practice of minimizing downstream pollution by maintaining a high pH in the residue is interesting, but, as far as we are concerned, it is an entirely new concept.

However, a question that immediately arises is how this high pH affects the natural decomposition of cyanide on the dam by the acid-decomposition products of pyrite. Metal hydroxides would be preferable to residual cyanide in any stray effluent from the slimes-dam, and, in an actual case of animal poisoning in the proximity of a slimes-dam, it was strongly suspected that cyanide in the residue had been protected longer than normal by high lime strengths.

GROUND PREPARATION

The cross-section of the ground preparation to receive a new dam (Fig. 2 of the paper) could be used to describe the design of preparatory earthwork for the earlier Union Corporation slimes dams. Prompted mainly by unpleasant experiences of slimes-dam walls built on poor ground, this method has recently been considerably modified and can be briefly described as follows.

In Fig. 1 (a) of this discussion, which shows a cross-section at right angles to the future wall, the heavy line represents natural ground level, and from left to right are shown:

1. A lateral blanket drain of carefully graded material approximately 0,3 m deep placed on surface without any excavation. The width of this layer is proportional to the expected height of the wall and terminates laterally at the toe wall.
2. An earth toe wall, which is constructed of material excavated from a suitable area inside the proposed dam. This wall is approximately 1 m high and $3\frac{1}{2}$ m at the base. There is no toe trench.
3. A catchment paddock of width approximately proportional to expected wall height.
4. An earth lateral catchment paddock wall of the same dimensions as the toe wall.
5. A solution trench with spoil deposited on the side away from the new dam.

At regular intervals along the length of the blanket drains, small transverse trenches beneath the surface layers of the filter material collect solution filtered through the blanket drain (Fig. 1b). These trenches are filled with the coarser product of the blanket-drain medium, and set in this is a small-bore polyethylene pipe for each trench, perforated in this area only. The pipes serve to carry solution beneath the earth toe wall, catchment paddock, and paddock wall to discharge into the solution trench.

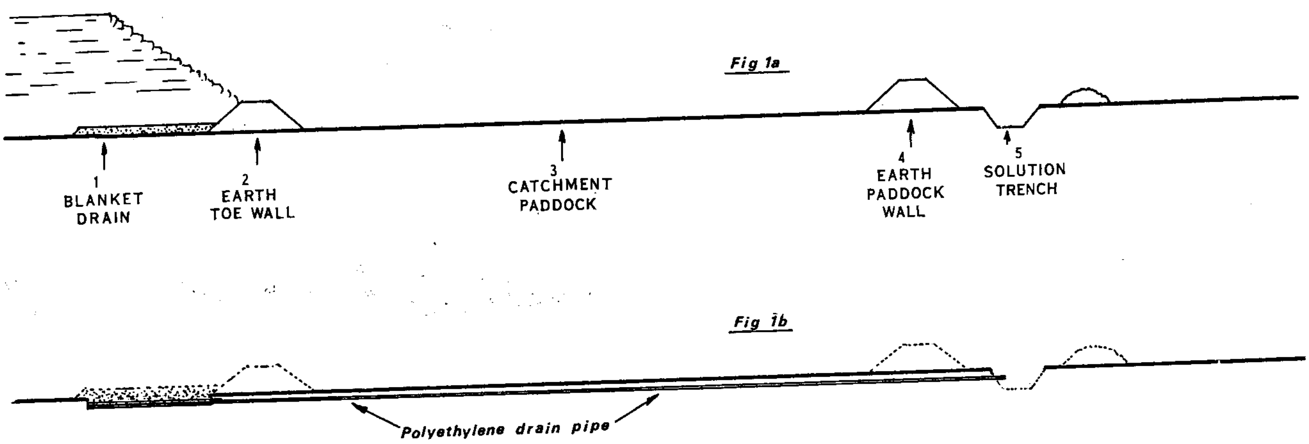

Fig. 1—Sections showing the preparation of the ground to take a new slimes-dam

J. C. THOMSON*

Mr Ruhmer in the synopsis of his paper states 'although many of the details given are either obvious or have been amply dealt with elsewhere, these have been included for the sake of completeness'. I wish to express the opinion that the inclusion of these obvious details enhances the value of the paper. We now possess a practical document containing information that can be readily digested and absorbed by mine personnel who are intimately connected with slimes dams.

The most pressing problems in slimes-dam stability and pollution stem from unsatisfactory operations in the past, when a scientific approach to slimes-dam construction was non-existent.

Slimes-dam Design

As stated by Mr Ruhmer, it is usually impossible to meet all the basic requirements for an ideal slimes-dam site. Where the areas available are not suited to the establishment of slimes dams, it is, in our opinion, imperative to obtain the services of experts in the field of

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soil mechanics before any construction work commences.

As an example, one mine in the Rand Mines Group was faced with the problem of establishing a new dam requiring an area of some 40 hectares. There was only one available site, but it was not considered suitable because there was a cross fall of 30 m and the terrain along one boundary was waterlogged. The cross fall of the site necessitated the raising of the proposed dam in a number of steps or terraces in order to create the total deposition area within one year.

The National Building Research Institute (N.B.R.I.) was requested to investigate the foundation conditions in the waterlogged area and to recommend a system of underdrainage[1]. In addition, it was asked to examine the feasibility of raising the dam in 6 to 9 m terraces.

Seven exploratory boreholes 0,76 m in diameter were drilled along the waterlogged boundary, and it was established that the water table was at a depth of 0,6 to 0,9 m below ground level. Fortunately, a highly permeable boulder layer that could be used as a natural drainage layer was encountered. To assess the permeability of the boulder layer, the rate of rise of the ground water in the exploratory holes was observed after the completion of the drilling.

Based on these observations, it was decided to excavate a main outer drainage trench. After this drain had been completed, secondary trenches were excavated at right angles to the outer drain 75 m apart and 60 m in length. These secondary trenches joined the main inner drainage trench, which ran parallel to the main outer drainage trench.

After the ground water in the trenched area had been drained, the drainage trenches were filled with successive layers of clean waste rock, crushed stone between 18 and 6 mm in size, and minus 6 mm crusher sand, and finally the trench was filled with moist, well-compacted slime.

Stability calculations by the N.B.R.I. indicated that, for a final dam height of 36 m and an average slope of 30°, the dam would be adequately safe. It was recommended that the dam wall should consist of three 12 m lifts with 35° slopes, each successive lift being set back 3 m.

The N.B.R.I.'s recommendations were strictly adhered to during the construction of the dam. To date, approximately 2,5 million tonnes of gold-plant residues have been deposited on the dam and there are no indications of any stability or pollution problems.

Slimes-dam Operation

The Rand Mines Group prefers to limit the number of slimes dams on any one mine. If possible, slime is deposited on a single dam, which could occupy an area exceeding 230 hectares. At a deposition rate of 160 000 tonnes per month, the amount of slime to be deposited is of the order of 47 million tonnes and the calculated life of the dam is 22 years. The final maximum height of the dam is 30 m. By consolidating the operation in one area, maximum supervision is ensured and the capital cost of pumping is kept at a minimum. Naturally, mines that incorporate high- and low-grade milling circuits require two dams for slime deposition.

Both the race and paddock system of dam building are used. The race system operates satisfactorily, provided the slime is fed onto the dam by means of a ring feed round the periphery of the dam. Feed points are situated approximately 300 to 400 m apart. The number of feed points required depends on local conditions, but it can be stated that more than one feed point is essential. Apart from the segregation of particle sizes, free board problems arise, and surveying usually indicates that the slope away from the slime delivery point, on the top of the dam, is aggravated.

The paddock system of dam building requires more wall building and closer supervision, but has the advantage of decreasing the possibility of malfunctions. Those in favour of the paddock system claim that a more-stable dam is created.

When a multi-point slime feed system is used, it is advisable to introduce a snorkel, or by-pass, on the delivery columns. This prevents any damage to the residue pumps if all the slime-delivery valves are inadvertently closed.

The slimes-dam operation is carried out by metallurgical personnel on some mines, while other mines prefer to operate their dams under the supervision of outside contractors. It is claimed that outside contractors have the advantage that they are intimately concerned with all the methods and conditions of slimes-dam construction.

Concrete penstocks and outlet pipes are favoured on some mines, while others report failures with this type of outlet pipe. The failures are attributed to ground movement, and these mines have resorted to timber penstocks and concrete-lined steel outlet pipes.

Pollution Control

To combat air and water pollution, the mines are taking the best practical steps to comply with the requirements of the law[2]. As this subject is dealt with in detail by Dr C. M. van Staden of Rand Mines, I shall say no more about it.

I should like to conclude by congratulating Mr Ruhmer on his paper. I am sure that, if copies of the paper are available to persons intimately connected with slimes dams, many future problems will be circumvented.

References

1. Private contract No. 5033/9831 between the National Building Research Institute and Blyvooruitzicht Gold Mining Company Limited.
2. Water Act (Act No. 54 of 1956) and Atmospheric Pollution Prevention Act, (Act No. 45 of 1965).