Optimization of the as-placed properties of hydraulic backfill

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Synopsis

The use of hydraulically placed backfill in the deep gold mines of South Africa has increased rapidly over the past decade. The backfill that is delivered to the placement areas has a relatively high moisture content, and it is therefore pumped into geotextile containment bags that allow excess water to drain out but retain solid particles. The specific problems associated with this process that are addressed in this paper include the loss of solid particles entrained in the excess water, the rate of strength gain of the backfill, and the post-placement shrinkage of the backfill. The results of laboratory, surface stope, and underground tests are described. The parameters that were varied included the slurry density, the particle-size distribution, and the feed rate of the slurry; the

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Introduction

Increasing use is being made internationally of backfill in underground mining operations. It may be in the form of large aggregate or finely ground rock flour, or any grading of material between these two extremes. The milled waste material is usually mixed with water to form a slurry, and then pumped underground to fill previously excavated areas.

The conditions under which backfill is used in South African mines differs in certain respects from current international practices. Extensive international experience with backfilling has been gained in the use of cemented backfill[1,2] principally because the backfill is placed in large underground caverns (with exposed vertical faces of up to 180 m at Mount Isa Mines in Australia[3]), and the backfill is required to be self-supporting, i.e. it should have sufficient shear strength to support its own weight. Furthermore, although many operations in South Africa utilize cemented backfill, much of the hydraulic backfill that is currently being placed is uncemented. Most of the stopes in underground gold mines are of the order of 1 to 1,4 m high and between 200 and 2000 m long. This, coupled with the fact that mining is currently taking place at depths in excess of 3000 m (with planned depths of up to 4500 m[4]), means that the self-weight of the backfill is neglible in comparison with the stresses that are induced by closure of these narrow, deep excavations. For example, Gürtunca *et al.*[5] report measured vertical stresses of 50 MPa in a backfill paddock of classified tailings. In addition, compared with the stress conditions in a high, backfilled stope, where very large shear stresses may develop, most of the backfill in an underground paddock is undergoing confined compression[6]. Thus, the shear strength of the backfill is not of overriding concern, and far more important is the compressibility of the backfill.

Rockbursts and rockfalls remain one of the greatest hazards facing the South African gold-mining industry[7]. Cook *et al.*[8] proposed that the severity of the rockburst problem could be alleviated by the use of mining layouts designed to minimize volumetric convergence of a mined stope[9]. Placement of backfill in a stope can help to alleviate the rockburst problem since the backfill resists closure of the stope. In view of the fact that closure rates can be as high as 5 mm per day, it is clear that the backfill in a mined-out area should be placed as soon after the excavation has been completed as possible. As mentioned earlier, during placement the backfill has the consistency of a slurry. A common technique is therefore to pump it into large geotextile bags, which retain the slurry, thus preventing it from flowing uncontrollably into existing mine workings. A typical operation is illustrated in Figure 1.

The primary function of the geotextile is therefore one of containment, i.e. it must retain solid particles. In doing this, however, it must allow water to drain as rapidly as possible from the backfill. This is necessary since the backfill must become self-supporting prior to subsequent underground blasts. This blasting, which can take place as soon as eight hours after the filling of a backfill paddock, inevitably results in severe damage to the geotextile containment bag; thus, the requirement for self-support.

Problems Associated with the Placement of Backfill

The use of hydraulically placed backfill in South African gold mines is relatively new, and there were a number of problem areas that the current study attempted to address, particularly the problems of solids losses, 'instability', and shrinkage.

- **Solids Losses.** This involves the washing of solid particles through the geotextile bag during the placement of the slurry. Mud accumulates in the working areas of the stope, creating hazardous working conditions and blocking drains.

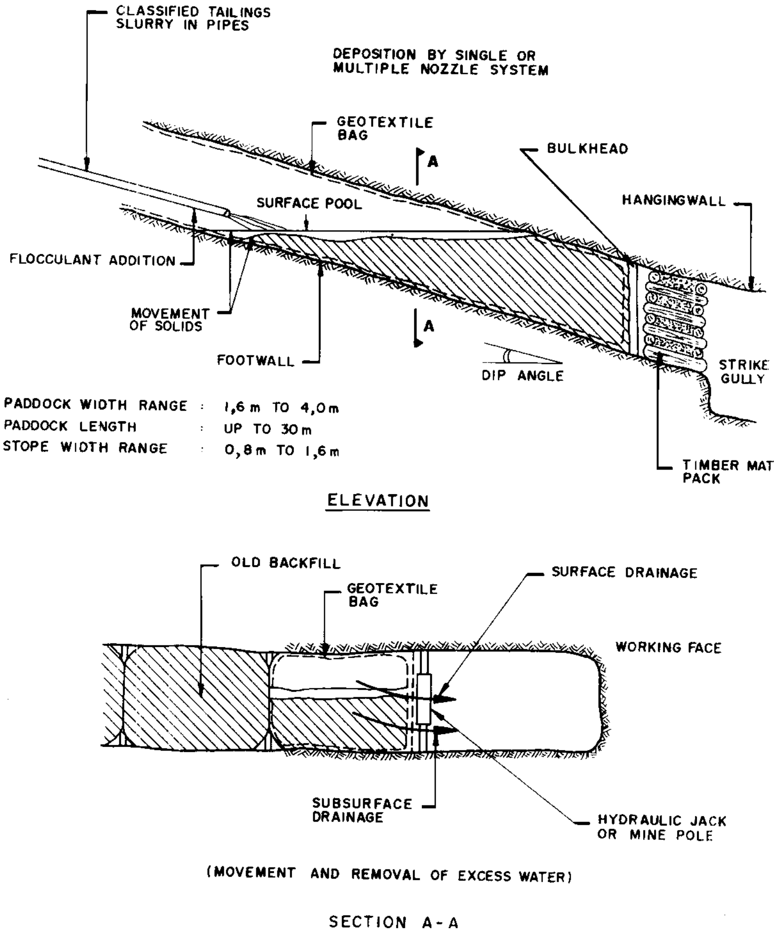

Figure 1—Structure for the containment of geotextile bags

concentration of added flocculant; and the type of geotextile used as containment. Suggestions are given for the optimization of the placement properties of backfill.

- **Instability.** As already discussed, this refers to the inability of the backfill to support its own weight. While the backfill remains in an unconsolidated state, damage to the geotextile bag can be severe: the backfill may liquefy, particularly as a result of nearby blasting of the stope face, gullies, and adjacent panels, thus creating extremely hazardous conditions.
- **Shrinkage.** Since the prime function of backfill is to resist closure of a mined-out stope, it is desirable for the backfill to be in intimate contact with the hangingwall at all times. However, the drainage of water from hydraulically placed backfill results in consolidation of the backfill under its own weight, and thus a decrease in volume. A gap between the backfill and the hangingwall results.

A prime objective of this study was to find ways of minimizing the loss of solids during backfill deposition, whilst also reducing both the time required for the backfill to become self-supporting and the amount of post-depositional shrinkage. The following six variables had previously been identified by the Chamber of Mines Research Organization (COMRO) as having a major influence on the performance of backfill: the slurry density, particle-size distribution, type of geotextile, stope geometry, filling rate and method, and addition of a flocculant. The magnitude of the effects of these variables is discussed later.

Material Tested

Since approximately 90 per cent of the backfill placed underground in narrow stopes in South Africa consists of classified tailings[5], this was the only backfill considered in the present study. Classified tailings, to produce a backfill that is relatively free draining, require the reduction of the minus 38 μm particle-size fraction from 50 per cent to approximately 10 per cent. This is illustrated in Figure 2, in which the curves marked A, B, and C represent the backfill samples that featured in the present study.

Three general types of geotextiles were considered for use as containment bags: woven, non-woven, and knitted geotextiles. The only available non-woven material was a needle-punched polyester, and it soon became evident that this geotextile resulted in such slow drainage times (accompanied by a solids retention of almost 100 per cent) that it was not worth further evaluation. The geotextiles that were tested comprehensively were therefore a woven and a knitted geotextile. The woven product was a polypropylene fabric with a mass per unit area of 282 g/m^2, and tensile strengths in the warp and weft directions of 55 and 33 kN per metre width respectively. The high-density polyethylene knitted product had a mass per unit area of 200 g/m^2, and strengths of approximately 0,5 and 1,0 kN/m.

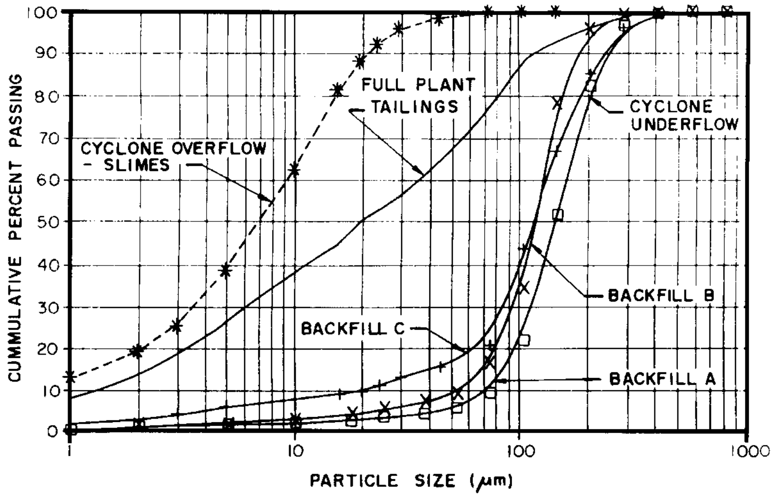

Figure 2—Particle-size distribution of the three backfills that featured in the study (also shown are the original full plant tailings product and the cyclone overflow)

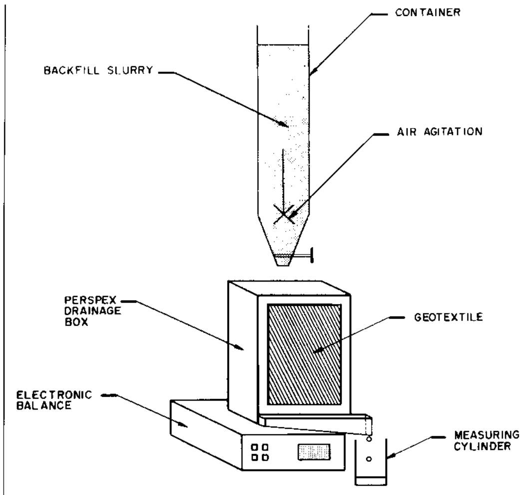

Figure 3—Drainage box used in the investigation of the retention and filtration characteristics of various geotextiles

Experimental Procedure

Although there are many criteria for the determination of the filtration and drainage characteristics of geotextiles[10], they are not necessarily applicable to the containment of hydraulically placed backfill. This is because the flow of water through the geotextile is transient, and the functionable requirement is not necessarily that no solid particles whatsoever should pass through the geotextile (i.e. some loss of solids may be acceptable). It was therefore necessary to develop testing equipment that was appropriate for the application under consideration.

The following four types of experimental apparatus were used in this study.

- **Drainage Box.** This consisted of a 3-litre Perspex box, with one vertical side fitted with a sheet of the geotextile under consideration, as shown in Figure 3. The backfill slurry was prepared in an air-agitated container that was suspended above the box and, when required, it was discharged into the box under gravity. The quantity of water and suspended solids (solids loss) that passed through the geotextile was monitored.
- **Drainage Cylinder.** This consisted of a cylinder 0,1 m in diameter and 1 m in length, half of which was Perspex and the other half the geotextile under consideration (Figure 4). Once again, the backfill slurry was discharged into the cylinder from an air-agitated container, and the quantities of discharged water and suspended solids were monitored.

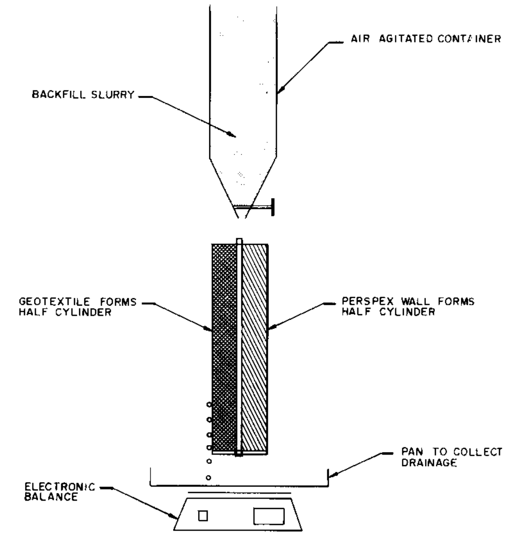

Figure 4—Drainage cylinder used in the laboratory investigation of the retention and filtration characteristics of various geotextiles

- **Surface Stope.** The surface stope test facility, which is located at the Western Deep Levels Gold Mine, is shown in Figure 5. It was used to simulate the underground backfilling operation, and had a fixed dip angle of 20 degrees, with the stope dimensions fixed at 1 m high and 9 m long. As shown in Figure 5, the backfill slurry was pumped into the geotextile bag at the highest point, and flowed under gravity to the lowest end. Aside from the measurement of the discharged water and suspended solids, measurements were taken of the variation with time of the pore pressure, shear strength, and moisture content in the backfill.

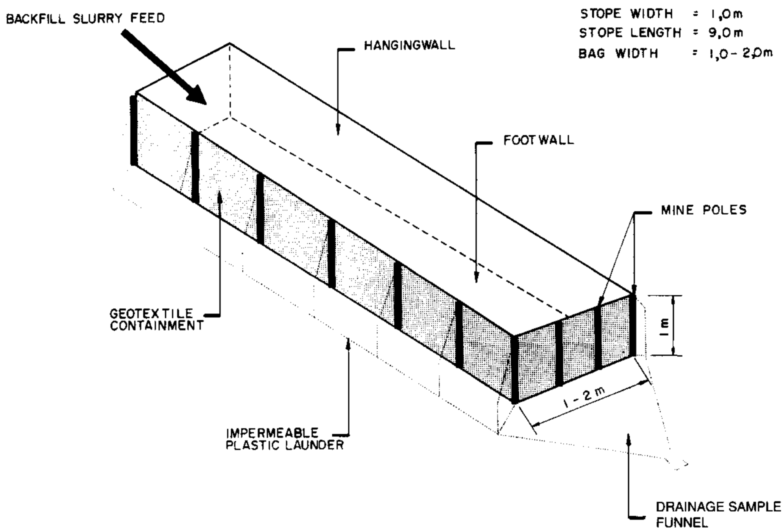

Figure 5—Surface stope testing facility for the full-scale testing of various backfill–geotextile combinations

- **Underground Tests.** These were full-scale production backfilling operations, which were monitored as a check on the validity of the previous three procedures, as well as a direct measure of the underground performance of various combinations of geotextile and backfill. Figure 6 shows a typical underground stope in which measurements were made. The control of this backfilling operation, as well as the measurement of the water and solids discharged, was of course more difficult than in the surface stope tests. These measurements are therefore likely to be less accurate than the surface measurements. Measurements of pore pressure, shear strength, and moisture content were again made.

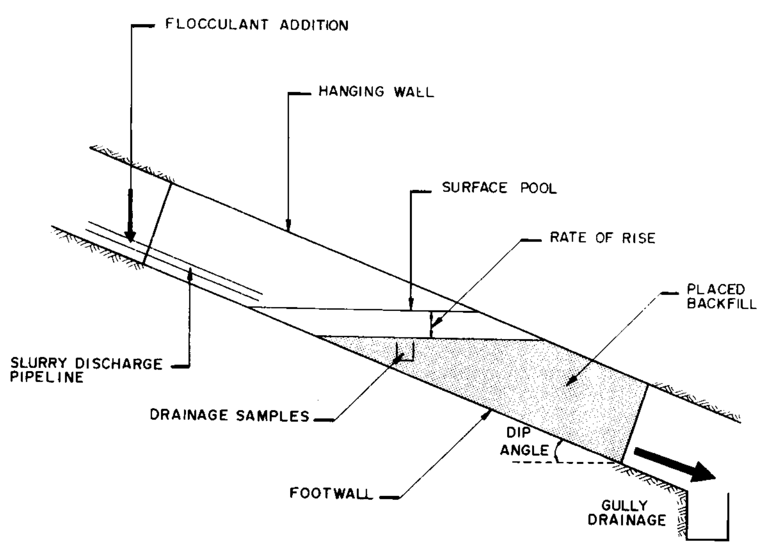

Figure 6—Typical underground testing arrangement for the testing of various backfill–geotextile combinations

Complete details of the measurement techniques mentioned here are given by Copeland[11]. For present purposes, the techniques used are briefly as follows.

- **Pore Pressure.** Measurements were made with simple standpipe piezometers. As illustrated in Figure 7, these consisted of a plastic pipe connected via a nylon tube to a manometer board that was located outside the backfill paddock. A non-woven geotextile was wrapped round the piezometer cap to prevent the ingress of solid particles.

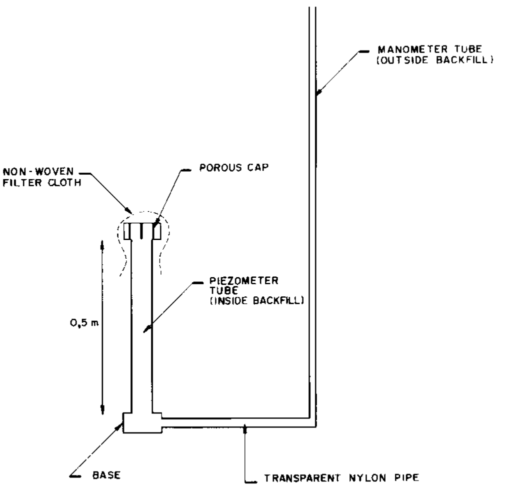

Figure 7—Standpipe piezometer for the measurement of pore pressures inside a backfill paddock

- **Backfill Strength.** A conventional hand-held shear vane was used as an indicator of the strength of the backfill in the surface and underground tests. Measurements were made near the edge of the bag, and up to 1 m inside the fill.
- **Moisture Contents and Porosities.** These were measured with steel tubes and constant-volume cylindrical piston samplers respectively, which were pushed into the backfill at the required positions to extract samples.

Experimental Results

Solids Losses

Slurry Density and Particle-size Distribution

These two factors have been combined for the purposes of this discussion. As a first estimate of the effect of these parameters, a study was carried out using the drainage box. Figure 8 shows the effect of the slurry density and particle-size distribution on the quantity of solids lost through the geotextile in question. At this point, it is necessary to explain some of the terminology used in this diagram.

A technique known as cycloning can be used to divide a tailings sample into coarse and fine fractions (where these terms are used relatively). The term 'cut size' refers to the size of the particles in the selectively classified material that have a 50 per cent chance of being recovered in the underflow (Svarosky[12] gives more information on hydrocyclone characteristics). The 'bypass' fraction refers to the quantity of material that is inadvertently entrained with the coarse fraction (i.e. particles that are smaller than the cut size and are separated into the coarse-fraction stream). Although a bypass of zero per cent is impossible in a production environment, it can be produced in the laboratory to represent a perfectly classified product.

Although, as will be discussed later, the laboratory box did not provide a direct quantitative correlation with the surface and underground stope tests, it did accurately reflect the relative behaviour of the parameters under consideration. As can be seen from Figure 8, the larger the cut size (i.e. the smaller the percentage of fine particles in the backfill), the smaller the percentage of solids that are lost. As can be expected, an increase in slurry density has a similar effect. It should be noted that, at a slurry density of 1,85 t/m^3, the backfill has the consistency of a paste, and problems of pumping and placement are experienced underground[13].

A comparison of these results with those obtained from the surface and underground stope tests is shown in Figure 9. These results were obtained from more than one backfill product, as well as from slightly different feed rates (complete details of the tests are given in Table I), and the results therefore indicate only trends in behaviour. Nevertheless, the very strong influence of slurry density on solids losses is emphasized. Two points regarding the results in Figure 9 are worth noting. The percentage of solids that are lost tends to be larger than measured in the laboratory box tests, and the type of geotextile used as containment has a marked effect on the solids that are lost (which is also evident in Figure 8).

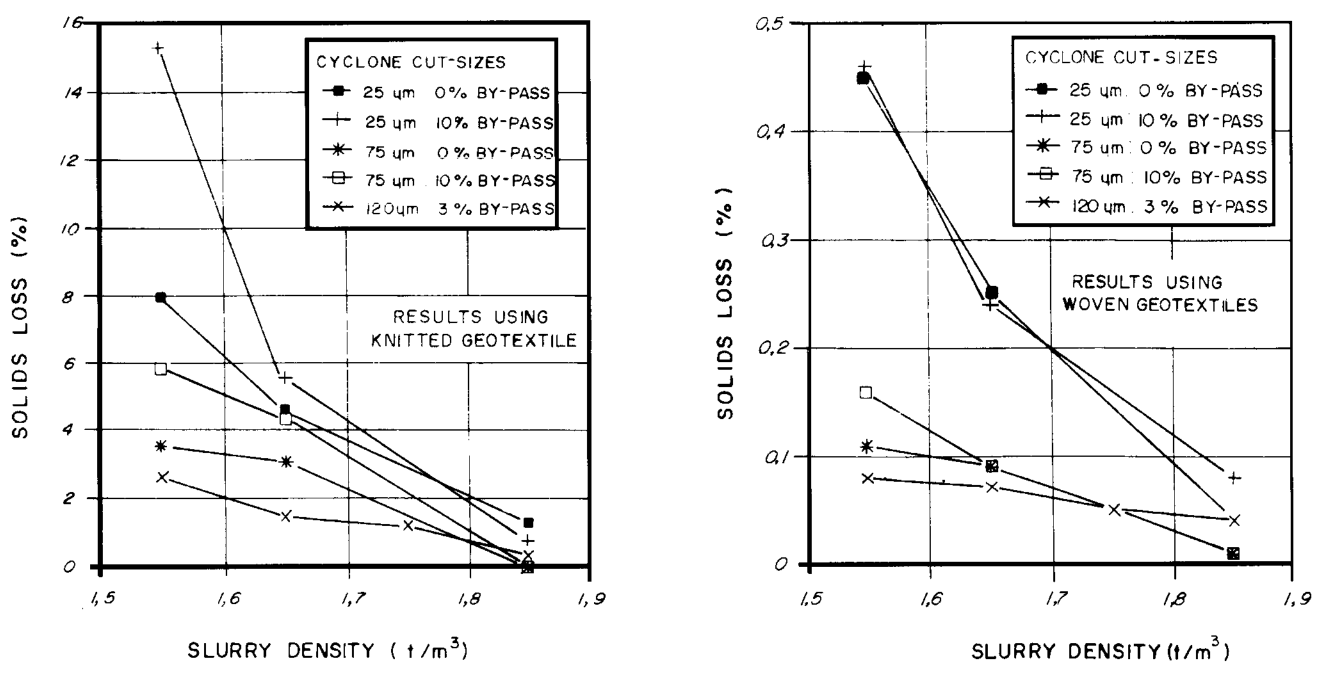

Figure 8—Effect of the slurry density and particle-size distribution on the loss of solids through a geotextile containment bag (results obtained from the drainage box)

Table I

Details of stope tests

Test*	Solids losses %	Backfill type	Slurry density t/m³	Geotextile type	Feed rate m³/h
1	1,3–1,9	A	1,75	Knitted	20
2	2,7–3,3	A	1,73	Knitted	12
3	1,0–1,4	A	1,72	Woven	20
4	1,3–,17	B	1,66	Woven	19
5	1,5–1,9	B	1,67	Woven	24
6	0,3–,07	B	1,75	Woven	22
7	15–16	B	1,64	Knitted	20
8	1,8–2,2	C	1,69	Woven	21
9	4,4–4,8	C	1,72	Knitted	20
10	12–13	C	1,70	Knitted	24
11	3,5–4,5	A	1,75	Knitted	40
12	1,5–2,5	A	1,75	Woven	40
13	4,5–5,5	B	1,60	Woven	23
14	3,0–4,0	B	1,65	Woven	23
15	5,5–6,5	B	1,67	Knitted	18

* Tests 1–10 refer to surface stope tests, and tests 11–15 refer to underground tests

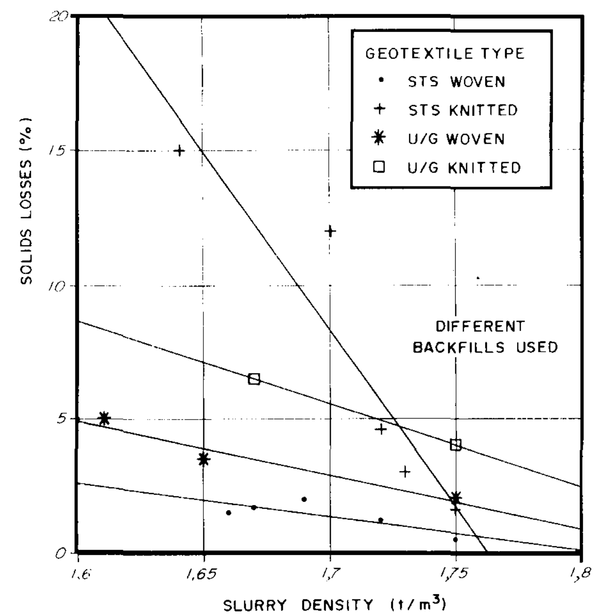

Figure 9—Effect of slurry density on the loss of solids through geotextile containment bags in the surface stope (STS) and underground (U/G) tests

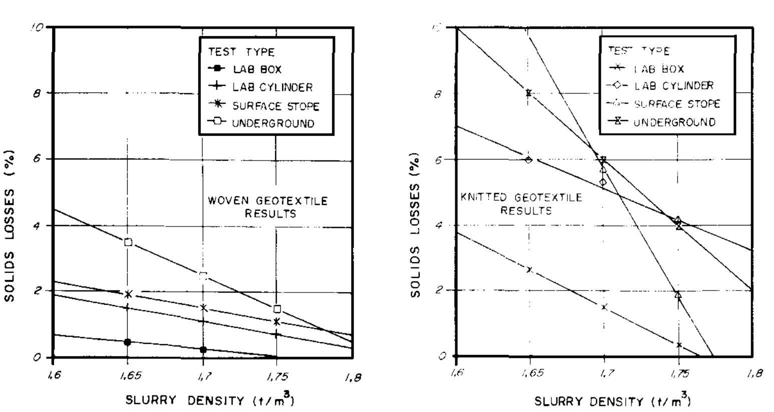

Figure 10—Relationship between solids losses and slurry density obtained from various testing apparatus

The difference in the measured solids losses that were obtained from the four test methods discussed earlier is shown in Figure 10. The laboratory cylinder test can be seen to have provided a much better correlation with the surface and underground stope tests than the laboratory box test. Possible reasons for this are discussed later.

The results presented in this section clearly show the importance of both the particle-size distribution and the slurry density of the backfill on the quantity of solid particles that are lost through a geotextile containment bag. A coarser backfill results in a smaller loss of solid particles and, the greater the feed slurry density, the lower the solids losses. Whilst both of these trends were not unexpected, it is important to quantify their magnitude in the optimization of backfill placement parameters. Aside from its beneficial effect on solids losses, an increase in slurry density results in a smaller volume of water draining into the stope area, and requires less time for the filling of a geotextile bag than a mixture of lower density. Clearly, therefore, within the constraints of pumpability, it is desirable for the slurry to have as high a density as possible.

Type of Geotextile

The effect of the type of geotextile on the quantity of solids that are lost has already been summarized in Figures 8 to 10. It is clear that, all other things being equal, there is a far greater loss of solid particles through the knitted fabrics than through the woven. This is not surprising considering the difference in structure between the two types of geotextile. The woven geotextiles have a criss-cross lattice of single or fibrillated tapes, which results in a fabric with a relatively small open area, whereas the knitted geotextiles consist of monofilaments in the weft direction interlaced with tapes in the warp direction, thus giving a more open structure than the woven geotextiles.

Acknowledgement

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As mentioned earlier, the laboratory box produced some anomalous results. It appeared to under-predict the underground solids losses by a factor of 3 to 4. To remedy this situation, the laboratory cylinder apparatus was developed, which, as can be seen from Figure 10, gave much more representative results for the woven geotextile, although there was still a poor correlation for the knitted geotextile. In the laboratory cylinder, the geotextile is subjected to larger tensile stresses than in the box apparatus (as a result of the less rigid boundary conditions and the greater volume of slurry that is being retained). There is thus a greater tendency for openings to expand, allowing the passage of more solid particles. Despite the fact that some of the solids losses were not measured (owing to spillage), this could also explain the greater degree of solids losses that occur underground, where geotextiles are subjected to tensile stresses by the retained hydraulic fill.

The above hypothesis is purely speculative. Reference to the literature revealed no information on the effect of different stress regimes on the filtration and retention characteristics of geotextiles. Work is currently under way at the University of the Witwatersrand to address this problem.

The Effect of a Flocculant on Backfill

The reason for adding a flocculant to the backfill was to increase the rate of drainage, and thus consolidation. This was desirable in order to produce self-supporting backfill as soon after placement as possible. It has been reported[11] that in some instances the use of flocculants provides no increase whatsoever in the rate of backfill consolidation.

Figure 11, shows the time taken for the backfill-slurry interface to settle in a measuring cylinder. It is clear that the addition of a flocculant can speed up the settlement process quite substantially, but that the use of too much flocculant is detrimental (as shown, for example, by the slow settlement rate when 100 g/t of flocculant at a concentration of 0,1 per cent was added). The reduction in solids losses that occurs due to the addition of a flocculant is shown in Figure 12. It can be seen that, provided over-dosing does not occur, there is a marked reduction in the solids losses, particularly when a knitted geotextile is used. Although not investigated in this study, the effect of a flocculant would also depend on the characteristics of the backfill, e.g. its particle-size distribution.

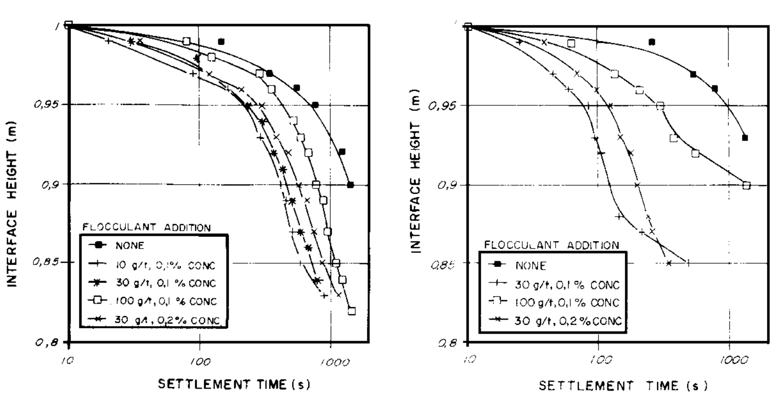

Figure 11—Effect of flocculant concentration on the settling time of backfill slurries

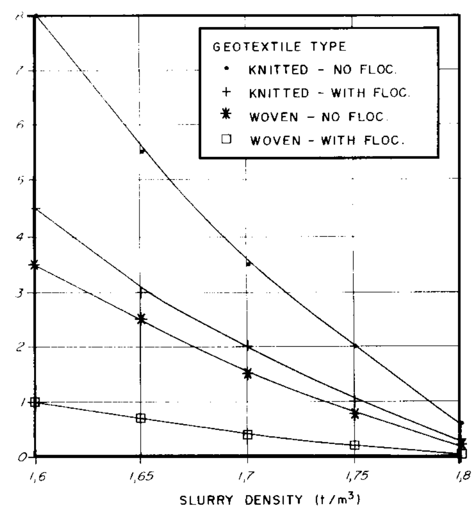

Figure 12—Effect of flocculant on the loss of solids through a geotextile containment bag

Rate of Rise

The results of a series of tests in the surface stope on the effect of the rate of rise (i.e. the rate at which the geotextile bag is filled) on the solids losses are summarized in Figure 13. These tests had the somewhat unexpected outcome that the solids losses decreased as the rate of rise increased. This finding was verified by a limited number of tests in the underground stope. A possible explanation for this result is that, with more rapid filling, there is less opportunity for a significant height of supernatant water to accumulate above the backfill. Visual observations underground have indicated that a significant proportion of the solids loss actually occurs in this zone of turbulent, supernatant water. This hypothesis is borne out by the observation that the reduction in solids losses that occurs with an increase in rate of rise was most pronounced for the slurry of lowest density.

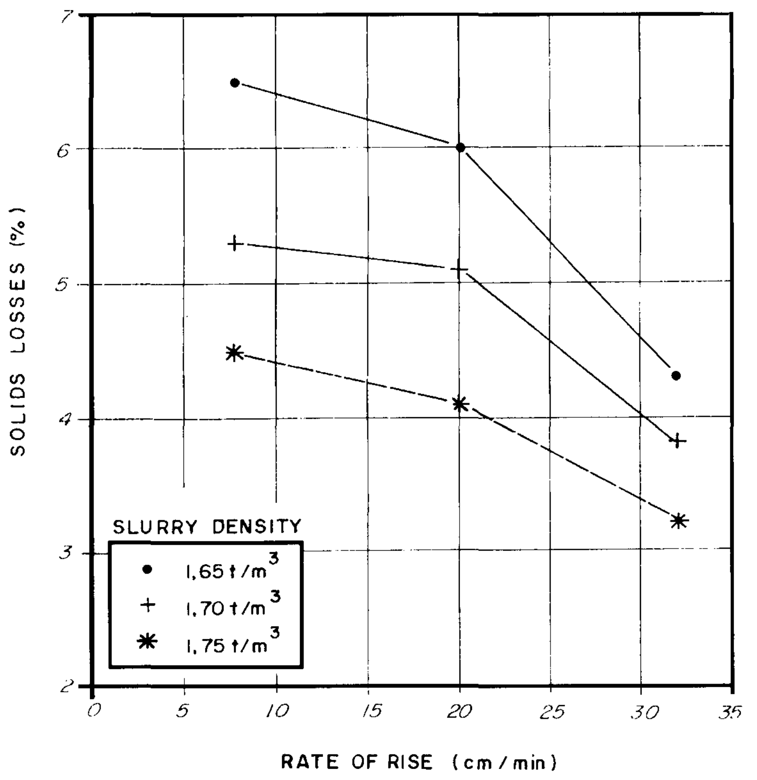

Figure 13—Effect of rate of deposition on the loss of solids through a geotextile containment bag

Tests to determine the effects of backfill composition on the rate of strength gain and of drainage were conducted in both the surface stope and underground. The relationship between shear strength, as measured with the vane, and the moisture content for both sets of tests is given in Figure 14. The solid line is a best-fit straight line to the data. It is clear that there is very little strength gain until the water:solids ratio drops to below about 0,23. Thereafter, there is a rapid gain in strength. This transition point corresponds to the moisture content at about which the calculated degree of saturation of the backfill drops below unity (for a final as-placed porosity of 38 to 40 per cent). Monitoring the shear resistance gives a very useful indication of when the backfill has become self-supporting (which, for the very narrow stope heights in question, corresponded to approximately 5 kPa undrained shear strength).

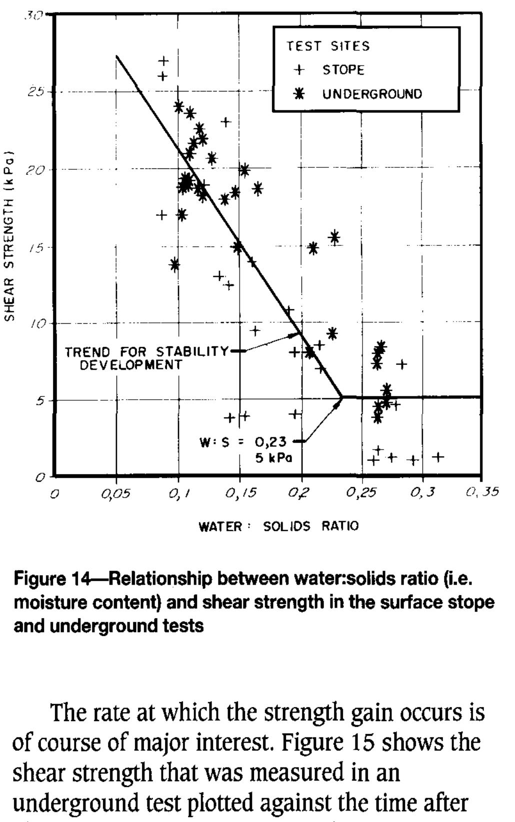

Figure 14—Relationship between water:solids ratio (i.e. moisture content) and shear strength in the surface stope and underground tests

The rate at which the strength gain occurs is of course of major interest. Figure 15 shows the shear strength that was measured in an underground test plotted against the time after placement. As would be expected, there is not a uniform rate of strength gain throughout the height of the backfilled stope. The closer the measurement point to the footwall, the slower the rate of strength gain. This is simply because, as gravity-induced drainage occurs, the highest point in the backfill paddock becomes desaturated first. The results in Figure 15 show that, for the backfill in question, a shear strength of 5 kPa is achieved in less than one hour, which was regarded as satisfactory for the reason stated above.

Summary of Results

In summary, the foregoing results show that the backfill slurry density and particle-size distribution, the type of geotextile, the addition (and quantity) of flocculant, and the rate of rise can all have significant effects on the amount of solids that are lost during the placement of a particular backfill. The results presented so far illustrate effective means of reducing solids losses during placement but, before an optimal system could be chosen, the issues of instability and shrinkage needed to be addressed.

Instability

As discussed earlier, concerns of stability relate to the ability of hydraulically placed backfill to support its own weight. Drainage of excess water from the backfill results in an increased shear strength because of an increase in the mean effective stress. It is essential that the required strength gain occurs as rapidly as possible after placement has been completed. The rate of drainage of excess water from the backfill is thus of major importance. The rate of strength gain was monitored with a shear vane, while the drainage rate was inferred from measurements made with the standpipe piezometers.

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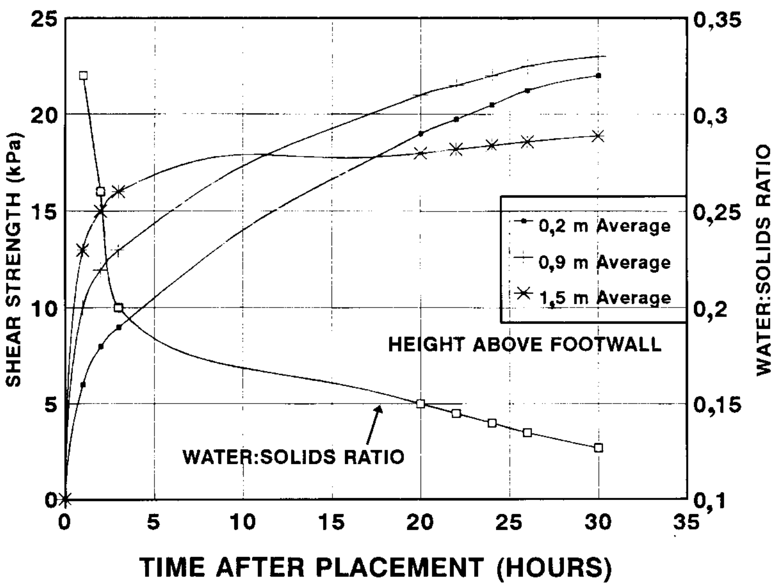

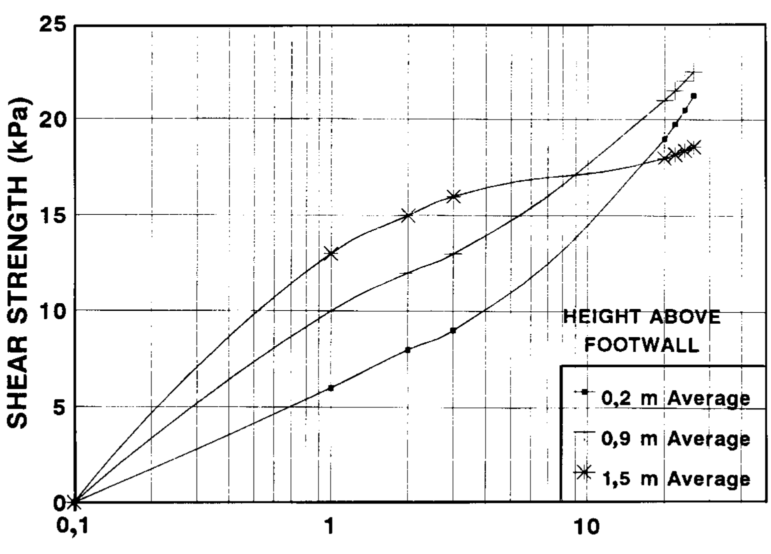

Figure 15—Rate of gain of shear strength at various positions in a backfill paddock

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Whilst monitoring the vane shear strength is a useful method of evaluating the stability of a newly placed backfill paddock, it is time-consuming and does not provide a continuous indicator of stability improvement. This was achieved by the monitoring of a number of standpipe piezometers. Figure 16 shows a plot of pore pressure against time (from the start of hydraulic deposition) for a test in the surface stope. Firstly, it should be noted that the piezometer readings start from non-zero values. This is because the piezometers are filled with water prior to the start of a test in order to provide an instantaneous response when the water level in the backfill rises above the piezometer tip. It can be seen that, as the water level rose above the piezometer tips (as indicated by the line marked 'surface pool level'), there was an immediate rise in the piezometric levels, indicating that the backfill was relatively permeable. Once backfill deposition had ceased, there was a very rapid drop in the piezometric levels, with the pore pressures decreasing below the ambient value. These negative pore pressures result from the development of suction in the backfill as it becomes desaturated. However, the relatively coarse nature of the backfill means that, at a very low displacement pressure (about 5 kPa), air is able to enter the voids, thus breaking the suction.

Since the vane measurements of shear strength illustrated that a strength in excess of 5 kPa was achieved when the calculated degree of saturation dropped below unity, piezometer results such as those shown in Figure 16 were used in estimations of when a newly placed backfill had reached a 'stable' condition.

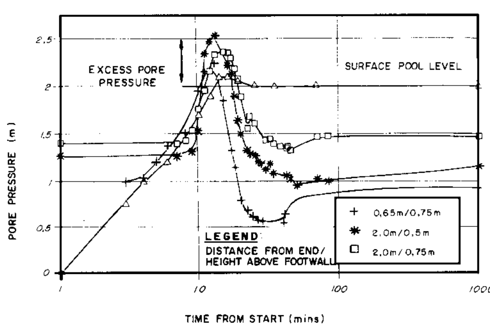

Figure 16—Variation of pore pressure with time at various positions in backfill, measured in the surface stope

Shrinkage

It is obviously of little use selecting placement parameters so that solids losses are reduced and stability is achieved very rapidly, if the post-deposition shrinkage of the backfill is large. It is essential that the initial gap between the backfill and the hangingwall is minimized (preferably eliminated) to provide support to the rockmass surrounding the stope as soon after excavation as possible.

The reason a gap develops between the hangingwall and the backfill is that, as the backfill drains and consolidates under its own weight, it decreases in volume. This decrease in volume can be reduced by, *inter alia*, depositing the backfill at as high a density as possible, or depositing it at a slow rate in order to achieve as much consolidation during the filling process as possible.

13. KRAMERS, C.P., RUSSELL, P.M., and BILLINGSLEY, I. Hydraulic transportation of high density backfill. *Proc. 4th Int. Symp. on Mining with Backfill.* Montreal (Canada), 1989. pp. 387–394.

From the three backfills illustrated in Figure 2, field observations showed that problems of shrinkage did not occur if the dip angle of the stope exceeded about 15 degrees. This was because, for larger dip angles, the backfill tended to slump into any gap that may have formed, as illustrated in Figure 17, irrespective of the slurry density. For dip angles of less than 15 degrees, no slumping occurred, and the gaps that did open tended to remain open. The problem of shrinkage was further exacerbated in shallow stopes by the use of geotextile containment bags. It was extremely difficult to maintain complete contact between the geotextile and the hangingwall during filling, and the backfill was therefore not in contact with the hangingwall even immediately after the deposition had been completed.

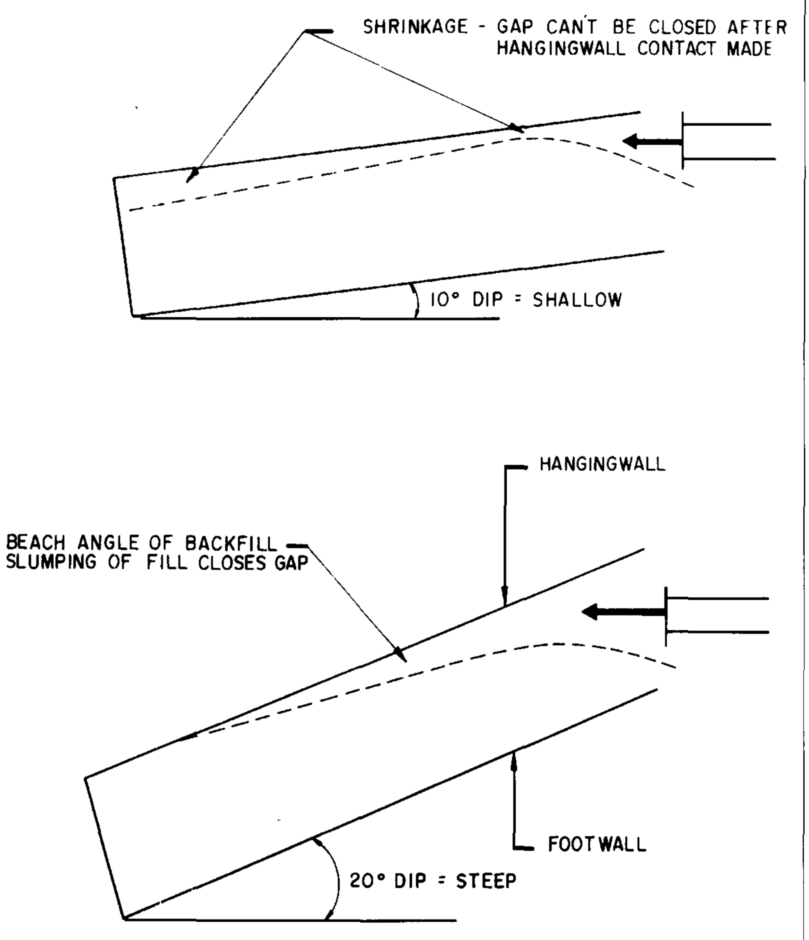

Figure 17—Effect of the stope dip angle on the shrinkage behaviour of backfill

A system was therefore adopted for shallow dip angles, as illustrated in Figure 18. In this 'paddock' containment system, the geotextile is glued to the hangingwall and folded into the paddock along the footwall. The weight of the backfill holds the geotextile in place on the footwall. Welded wire mesh, which is attached to vertical timber props, forms the lateral support to the geotextile. With the paddock system, it was found possible to achieve almost complete contact between the backfill and the hangingwall during deposition (however, the problem of post-depositional shrinkage persisted).

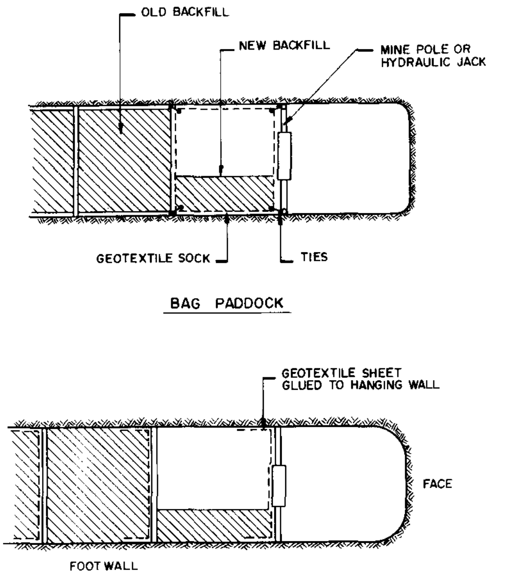

Figure 18—Alternative system of backfill containment for shallow-dipping stopes

Conclusions

As can be seen from the foregoing discussion, there is a range of parameters that influence the effectiveness of hydraulically placed backfill as a medium of support in deep-level mines. Based on the results of this study, a set of preliminary guidelines for the optimal placement of hydraulically placed backfill was prepared. Table II summarizes the guidelines that have been provided to those mining companies currently making use of hydraulically placed backfill.

Table II

Guidelines for the optimal use of backfill

Parameter	Optimal range
Slurry density	1,70–1,75 t/m^3 (as high as possible)
Particle-size distribution	< 5% – 10 µm
Geotextile type	Woven 0_{95} = 450 µm Knitted 0_{95} = 350 µm
Flocculant	Unnecessary (unless zero solids losses required)
Filling method: Bag Paddock	Stope dip angle > 15° Stope dip angle < 15°

Essential components of a suitable backfill are therefore that as high a slurry density as possible be used, and that the fines content be kept as low as possible. These requirements may, however, contradict those relating to the transportation of slurry to the paddock to be filled; for example, as the slurry density is increased, so too is the viscosity. Other difficulties that may be encountered include increased pipe abrasion due to the predominantly coarse particles, and a greater chance of pipe blockages since a well-classified backfill will settle very rapidly if the pumping operation is interrupted[13]. Therefore, although optimal placement parameters can be suggested to minimize the problems of solids losses, instability, and shrinkage, the final decision on the backfill to be used must take account of operational considerations. ◆

Book Review

Rock support

*Reviewer: A.J.S. Spearing**

This is an excellent state-of-the-art collection of papers on rock support (mainly in tunnels). The papers were presented at the International Symposium on Rock Support, which was held in Sudbury, Canada, in June 1992.

The papers are divided into the following five sections:

- support design, analysis, and applications
- case histories
- cable bolting and anchorage
- rock reinforcement and support
- support in burst-prone ground.

The authors represent some of the world's most eminent experts in the field of rock support, and most of the papers are directly relevant to the South African mining industry. Of particular relevance are the papers on shotcrete (a system being used more and more in South African mines) and the support of burst-prone tunnels (a unique challenge in South African deep, hard-rock tabular mines).

I highly recommend the publication and have requested the AAC library to purchase its own copy. ◆

* *Anglo American Corporation of South Africa Limited, P.O. Box 61587, Marshalltown 2107.*

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