

FILPAK: GULLY SUPPORT IN BACKFILL STOPES

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Abstract

The paper describes an R&D programme carried out on Filpak, a proposed means of gully support in stopes using backfill as local and regional support. Filpaks fundamentally comprise sheets of ductile welded steel mesh fixed in horizontal array at the ends of backfill bags. Following a series of lengthy trials in strike gullies at Moab Gold Mine, the units have also been tested in dip gullies at Tau Tona Gold Mine. Further tests are scheduled at other gold mines and a platinum mine. Among several claimed beneficial features of the system can be cited the elimination of point loads at gully edges and possible savings in handling, transport and installation.

The paper also comments on mistakes made and problems encountered in management of the programme.

Introduction

During the early 1960s a French engineer, Henri Vidal, invented a new construction material he named Terre Armée (Reinforced Earth), basing the technique on formation of a composite material through association of granular fill with linear reinforcement. The system is now internationally accepted and applied in a variety of civil engineering structures, for the most part in retaining walls and bridge abutments. South Africa has followed the trend, and since 1975 Reinforced Earth (Pty) Ltd (RESA) has been actively promoting use of the technique, which is now usually referred to as MSE (Mechanically Stabilised Earth).

Further to its normal civil engineering activities however, RESA has detected possible applications for MSE technique in the South African mining industry. In this case the MSE structures act as short columns or “packs” in underground support systems in the stopes of hard-rock gold and platinum mines. Over a period of about 20 years therefore, an associated RESA company, REMS, has pursued an R&D programme that has attempted to develop such support packs that could cope with loads and physical circumstances encountered in the underground mining environment. Three new and potentially practical systems have emerged from the programme.

The object of this paper is to set down the record of research, development and practical application relating to one of the three systems, Filpak, that sets down a proposed method of protecting and supporting gullies in mines using backfill as local support.

The R&D Programmes

REMS has carried out three consecutive R&D programmes, separated in time one from the other by intervals devoted to attempts at practical implementation and promotion – a procedure that probably accounts for the rather lengthy duration of the entire innovation effort.

Results of the R&D programme have been recorded in three separate documents; termed for convenience in this paper as the Wits report (1988)¹, the COMRO report (1992)², and the Miningtek report (2002)³. Comment and opinion in this paper will therefore essentially be based on the three documents cited above, together with experience gained in subsequent underground trials. For easy reference, statements deriving from the three reports will either be summarized or quoted verbatim.

Furthermore, in order to show the manner in which the intermittent activities of “Research” on the one hand, and “Development” on the other, have exerted their influence on the management and planning of the total project, the history of the programmes and their consequences is briefly recounted:

- In 1988 the Wits Report was presented to a backfill conference held under the auspices of SAIMM. The programme had concentrated on cemented, reinforced grout packs (Cempaks) for conventional stope support, but it was thought at the time that the proposed packs could also be beneficially installed on gully edges in backfill stopes. The theory and design method set down in the Wits Report has however been found to apply to all three types of packs developed by REMS.
- As an outcome of REMS’s presentation at the conference, COMRO invited REMS to join them in a collaborative research programme with the objective of pursuing the MSE concept further.
- The COMRO research programme eventually covered grout packs (Cempaks), precast packs (later marketed under licence as Durapaks), and gully packs for backfill stopes (Filpaks). COMRO issued their report towards the end of 1992, and commented favourably on possible possibilities and prospects for Filpak.
- In the several years following the issue of the COMRO report however, REMS made scant progress in commercial development of Filpak. Their main effort was focused on establishing safe and practical methods of underground installation, a matter that had not been actively pursued during the COMRO programme. A few limited underground installations had also been attempted.
- By the year 2001 however, in a final attempt to establish the operational and economic viability of Filpak, REMS decided to enter into an IDC-sponsored R&D programme termed SPII (Support Programme for Innovation in Industry). REMS appointed Miningtek as consultants to the programme, who monitored the under-

ground trials and whose report was completed in 2002, and for the first time REMS were able to report underground performance of Filpaks, monitored by a

neutral and credible agency. The positive report from Miningtek then gave sufficient reason to persevere with the Filpak concept.

Function and Description of Filpak

Expressed simply, the Filpak comprises a collapsible steel assembly fixed into position within the end of a backfill bag or sock, either up-dip or down-dip.

Diagrammatic, longitudinal sections comparing the Filpak concept with conventional layouts are shown in Figure 1.

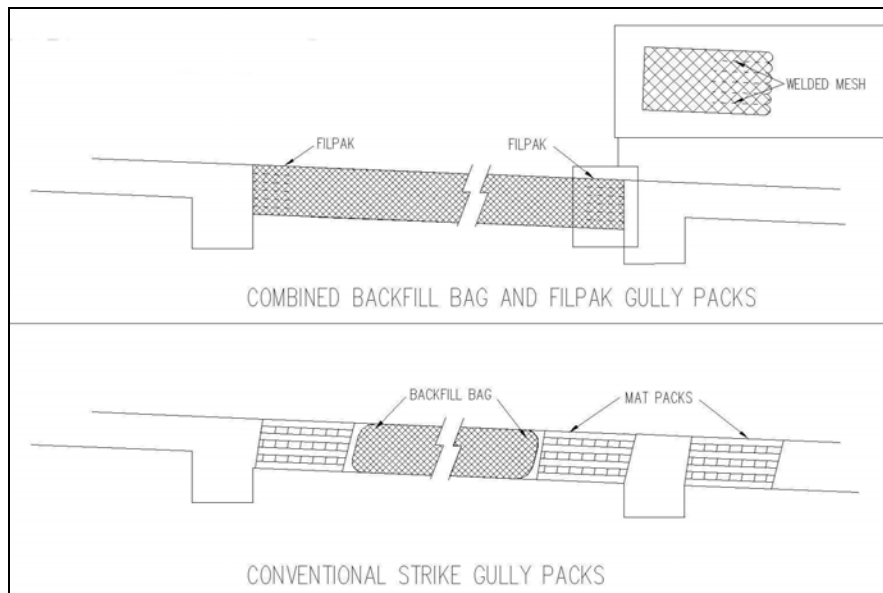


Figure 1.

Function of the Filpak is to provide gully support in stopes that use backfill as regional support, while at the same time minimising damage to the gully sidewalls by elimination of point loads. Filpak is designed to accept load initially, to continue to accept load until reaching yield point, and then accept increased load by virtue of increased “squatness”. Figure 2, taken from the COMRO Report, compares the performance under load of Filpak with unreinforced backfill and timber slab packs, and demonstrates that timber packs and Filpaks show the same degree of initial stiffness.

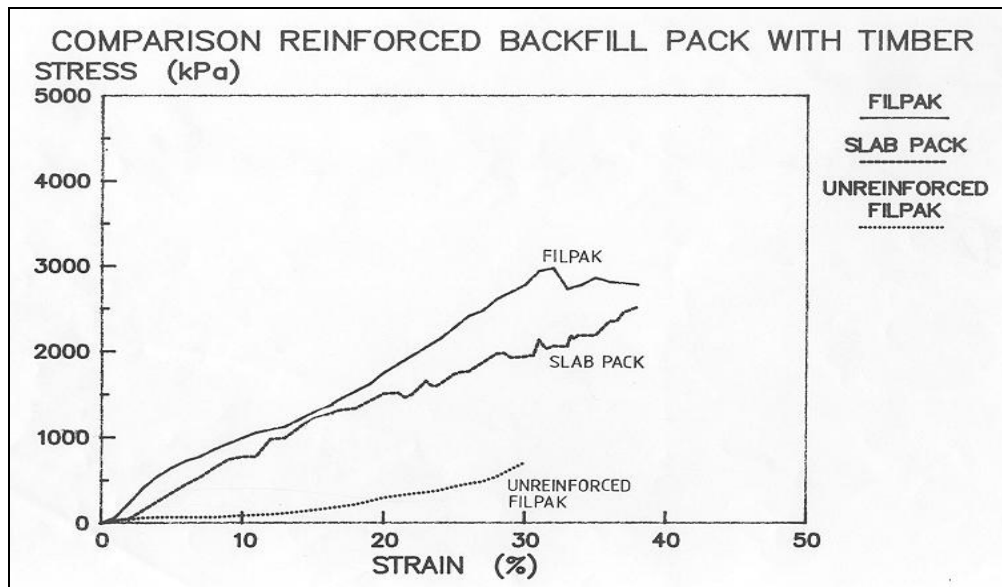


Figure 2.

Various patterns have been devised in order to enable installation to be carried out underground, and will be more fully illustrated and explained in the "Underground Trials" section of this report.

Materials

- Reinforcement, which comprises a steel assembly of parallel, square or rectangular sheets of ductile steel mesh. Commercially available low-carbon steel mesh is preferably used, after having been annealed to a ductility of about 25%. Ductility is required to provide yielding properties to the installed pack.
- Geotextile backfill bag or bags that are made up of partially pervious geotextile material designed to accommodate the nature and density of the backfill.
- Backfill material that in virtually all instances comprises mine tailings, classified in order to remove unwanted fines, and sometimes cemented - depending on Rock Engineering requirements. (In terms of MSE theory, the coarser the backfill, the better the performance; to the extent that layers of spherical rocks in contact with the reinforcement would theoretically provide an ideal backfill that would bring about immediate strength and stiffness.)

Variables affecting performance

- **Reinforcement:** Mass of steel reinforcement required would depend on assumed loads and convergence. Design would fix diameter of mesh wires, mesh spacing, size and shape (square or rectangular) of sheets. Stresses in the mining environment are measured in MPa, as distinct from KPa in civil engineering
- **Height-to-width ratio:** Squatness is always desirable, which in the case of Filpaks is assisted by the confining effect of backfill on either side of the steel assemblies.
- **Cementitious binders:** Present stipulations apparently recommend cementation of backfill in stopes wider than 1,6 metres. A weak strength of about 2 MPa would improve stiffness and not affect post-peak performance.
- **Backfill:** Mine tailings are used in most cases, with finer fractions extracted by cycloning to improve performance under load and flow characteristics. Relative densities of backfill in gold-mine practice are in the order of 1,7 to 1,8.

Other than formal design parameters, other factors - angle of dip, rate of closure, stope width and footwall conditions on the edges of gullies - affect performance, and would vary from mine to mine.

Cementation of backfill is not generally required when Filpaks are used as gully support., except for reasons determined by Rock Engineers in special cases.

Each project would however have to be designed subject to its particular requirements, and a certain amount of experimentation might be advisable in order to obtain the best combination of the various parameters affecting performance.

Design of Filpak systems

Design needs to be carried out in collaboration with Rock Engineering Departments at each mine in order to cater for specific conditions and requirements in respect of:

- rate of closure
- anticipated loads at gully edge
- angle of dip
- width of stope
- mining methods
- choice of installation system

The resultant design would then specify:

- ductility of reinforcement
- diameter and mesh spacing of mesh reinforcement sheets
- vertical spacing of reinforcement sheets
- dimensions and shape (square or rectangular) of reinforcement sheets
- spacing of Filpak along gully edges

Design would be based on Reinforced Earth theory, and also as set down in detail in the Wits Report.

Review of Filpak Test Programme at COMRO

COMRO accepted the theory and design concepts set down in the Wits Report.

Tests on Filpaks were conducted on quarter-scale packs (in area) and using uncemented classified backfill from Western Deep Levels Gold Mine. Cemented backfill packs were not tested.

Some of the principal findings of that programme are summarised in the COMRO report—those shown in quotation marks are quoted verbatim:

- “The stiffness of the backfilled pack is much lower than a cemented one, but similar to that of a timber pack. However, the strength at 20% strain, and greater, is similar to a cemented pack utilising grout with a strength of around 5 MPa”
- “The Filpak method would appear to cut usage of timber considerably, as it could replace packs in both strike and dip gullies. Transport and labour requirements would also be greatly reduced with a commensurate reduction in costs.”
- Referring again to Figure 2 (Figure 13 in Comro report), the performance of Filpak in laboratory tests is compared with that of a monitored underground slab pack, and the COMRO report states that the ultimate strengths are comparable. It also states that the Filpak curve is “remarkably similar” to that for conventional timber packs adjusted for “creep” and there is “no reason to believe that the results for reinforced backfill packs will degrade underground due to creep....”.
- COMRO conducted limited dynamic tests on mini-packs both Cempak and Filpak, and comment as follows: “the uncemented pack increased its resistance during the fast loading then settled back to the original curve. The cemented pack, on the other hand, appeared to react in a brittle manner, shedding load during the rapid load phase then building it up in a similar fashion to the uncemented pack afterwards. This suggests that the rapid loading occurred before the pack had reached its yield load, failing the cement bonds and leaving the pack in a similar state to that of the uncemented one. The fact that the load still builds after the rapid loading indicates that the steel did not fail completely”. This latter comment indicates that uncemented Filpaks might behave better than cemented Filpaks under seismic conditions.

Generally, COMRO accepted the theoretical concepts contained in the Wits Report, and commented positively on Filpak’s possible application in mines using backfill support.

COMRO also tackled the matter of practical installation underground by conducting full-scale surface tests at a trial surface stope at Western Deep Levels (WDL): (Subsequent to the COMRO programme REMS installed a few Filpaks underground using the WDL method, but found it somewhat cumbersome, as did underground mine personnel).

Review of the SPII Programme

The SPII R&D programmes are sponsored by IDC to cater for development rather than research ('D' rather than 'R'), and so underground testing became a prime requirement. For technical opinion and advice, REMS appointed Miningtek as consultants to the programme.

Miningtek chose Savuka Gold Mine as target mine because its policy of using backfill as local and regional support in much of its mining area. A single Filpak was thereupon installed in a stope at close to 3000m depth, and monitored for stress, deflection and general performance over a period of about 6 months. Figure 7 illustrates the layout, and Figures 8 and 9 the performances respectively of unreinforced and reinforced backfill bags.

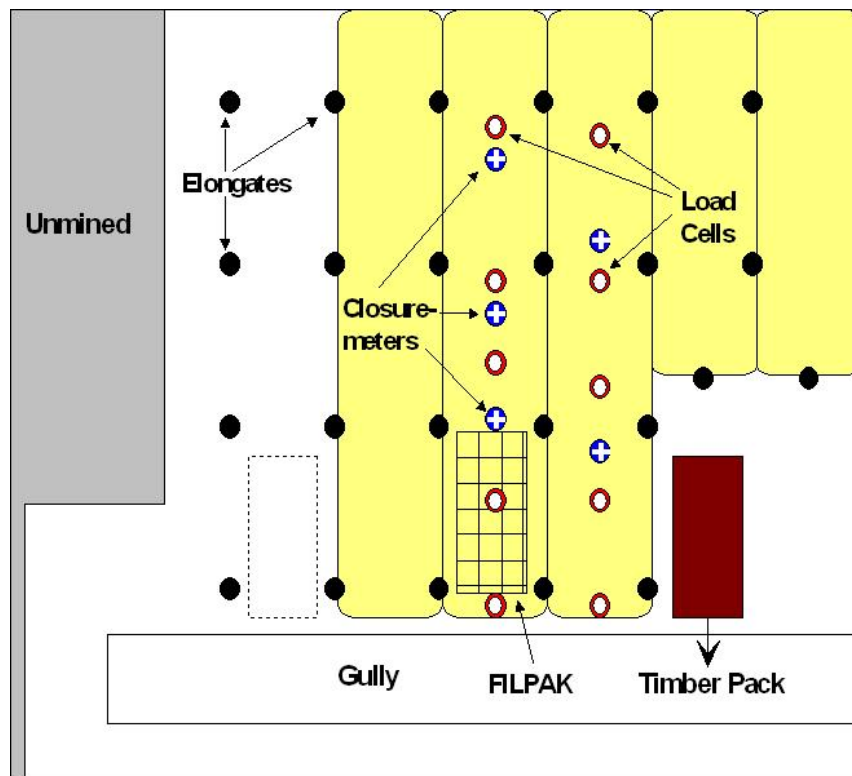


Figure 7. Instrumentation layout (not to scale)

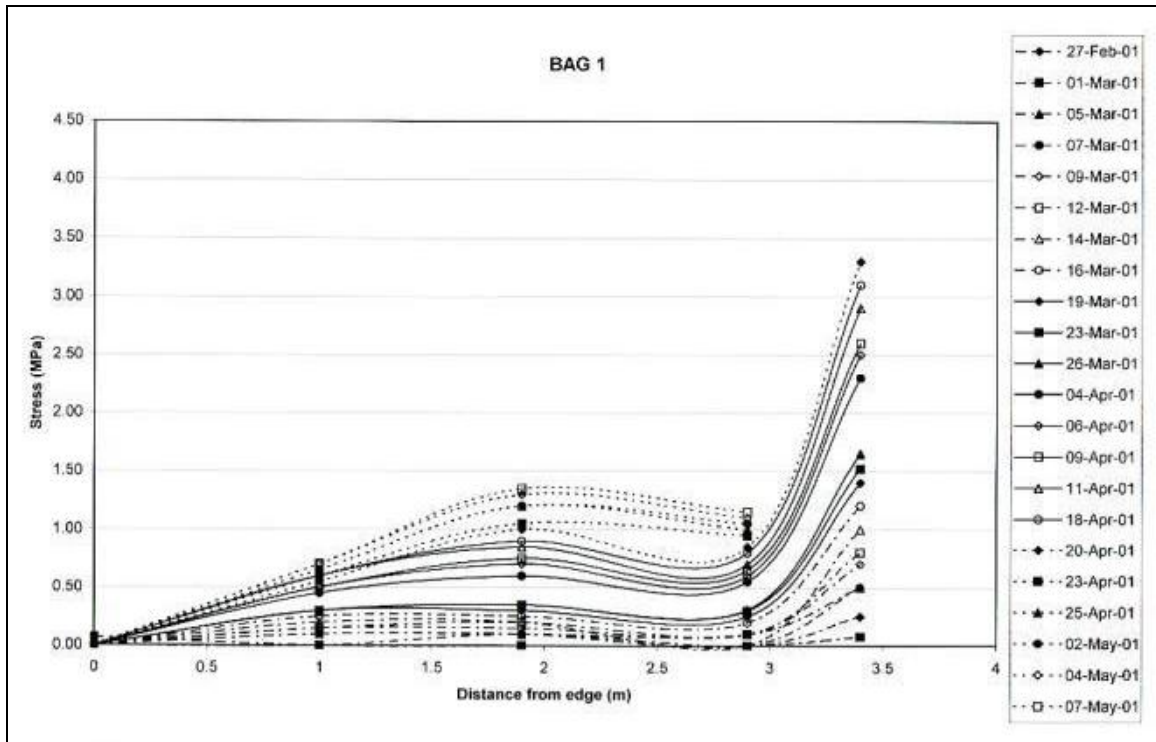


Figure 8

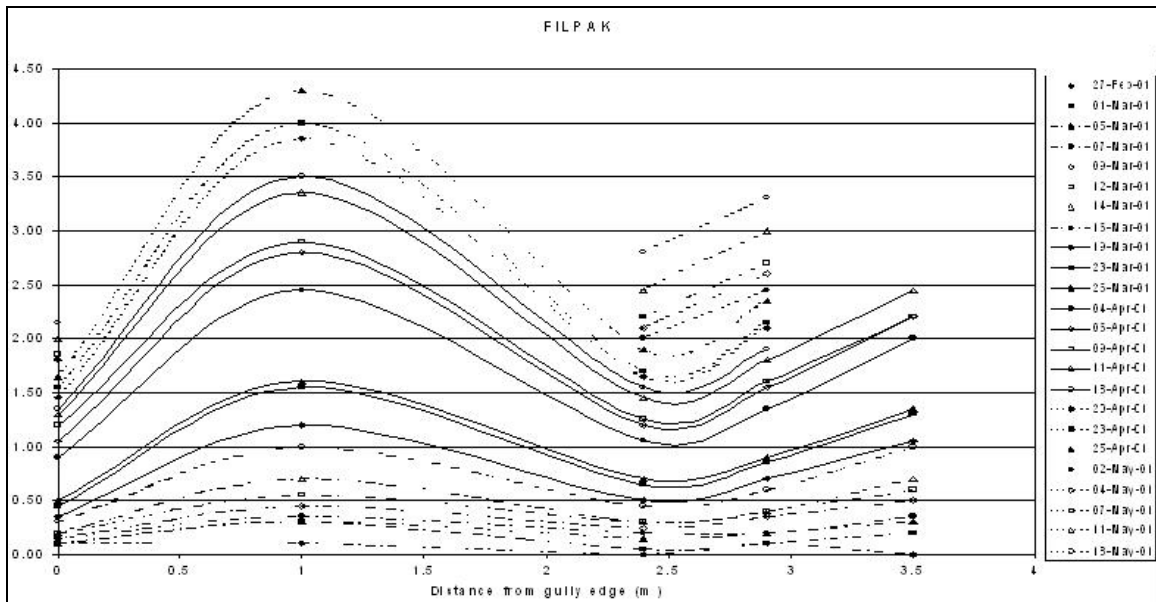


Figure 9

In their report to REMS on the trial, Miningtek state:

“The comparison of results has shown that when an internal reinforcement (Filpak) is used there is a significant improvement in support characteristics of backfill in the vicinity of gullies. The studies show that this is more pronounced closer to the gully edge (ie 0,1 – 1 m from the gully edge) where the reinforcement is placed and it gradually decreases away from the gully edge. For example, Filpak generates over 4 MPa vertical stress at 1 m from the gully edge at 4% strain (Closure / Stopping width) whilst a normal backfill generates only 0,6 MPa. Although the internally reinforced backfill (Filpak) generated relatively higher support resistance, the observations at about six months after the installation indicated that there was no additional fracturing on the gully sidewalls and no deterioration on the gully hanging wall. In the light of the above results, it is considered that Filpak has proven itself as a very effective gully support”.

(REMS would comment further that the graphs show a stress of 1,0 MPa having developed at the gully edge after about a month, compared to zero stress for the adjacent unreinforced backfill).

REMS were obviously encouraged by the above comments. Clearly, it now remained to be determined whether the system could be implemented on an operational scale.

Underground Trials

The positive report from COMRO had led REMS to move from laboratory testing to underground installation. The idea of separate reinforced packs not connected to the backfill bags was considered impractical and undesirable, and a method (or methods) consequently had to be devised to fit steel assemblies into the backfill socks, normally 30m in length from up-dip gully to down-dip gully.

Several methods have been evolved over the years:

“**Fingers**” method: Only two Filpaks were installed (Blyvooruitzicht and Libanon) and were not received with much enthusiasm by underground management on account of their somewhat difficult and cumbersome installation procedure.
(Figure 3A)

“**Paddock**” method: A few packs were installed at Vaal Reefs No. 9 Shaft, Elandsrand and South Deep (Figure 3B). Photograph of the Vaal Reefs paddock pack some days after installation is shown in Figure 4. Installation procedures presented only minor difficulties.

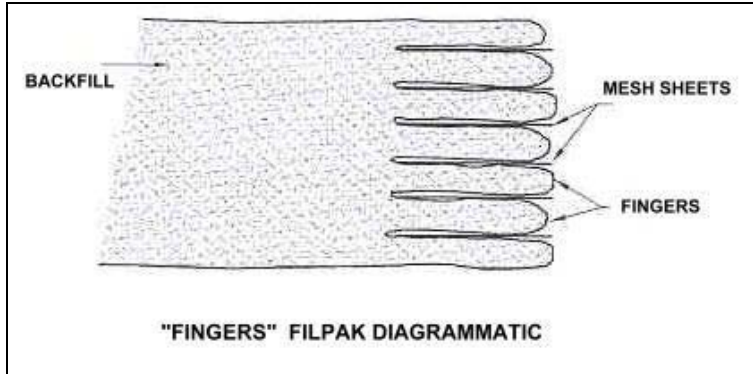


Figure 3A.

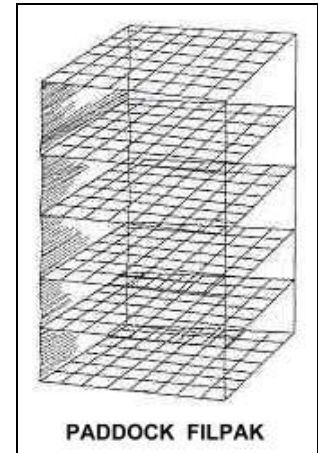


Figure 3B.



Figure 4. Note bulging of backfill between layers of reinforcement, indicating that the FILPAK is accepting the stress.

“**Prop-Up**” method: Incorporates the reinforcement with the backfill bag. Only one has been installed to date (at Savuka), and could possibly be suitable for narrow stopes. It requires additional development however. (Figure 5)

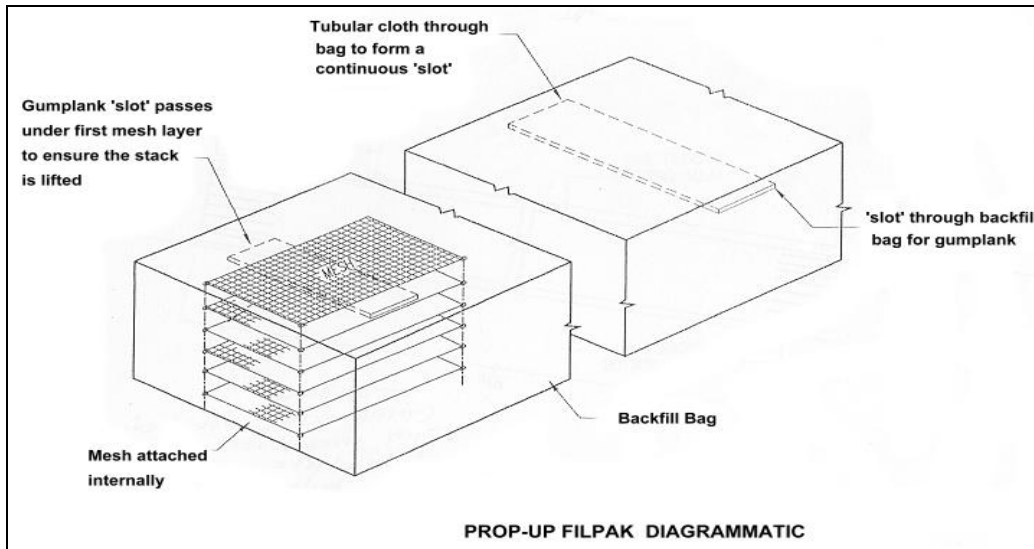


Figure 5.

“**Short Filpak**” method: Incorporates a separate short bag to contain steel assembly. This method should be suitable for both wide and narrow stopes and for heavy-grade geotextile materials. It appears to be the most practical method and was used for the first time in trials at Moab Gold Mine. (Figure 6)

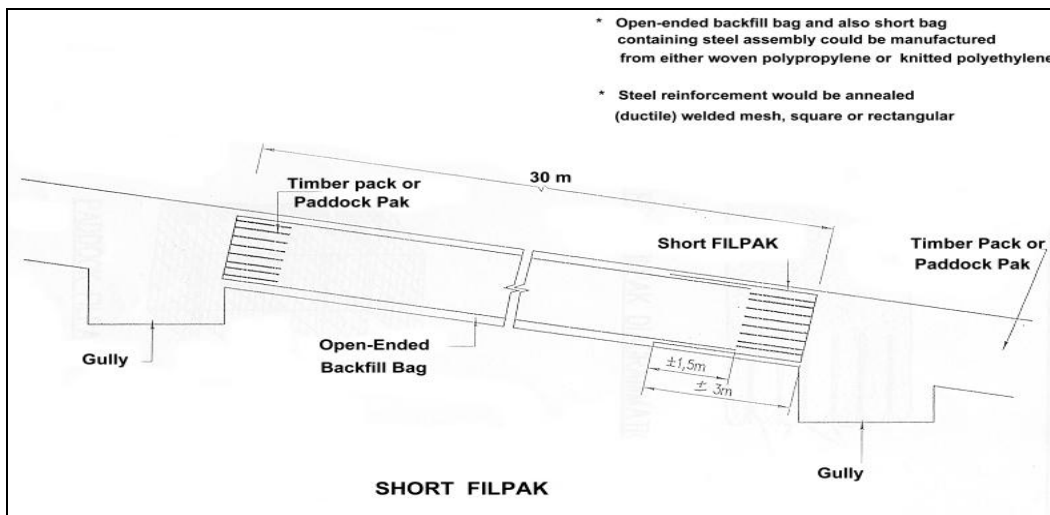


Figure 6.

Comment on Installation Systems

Before the advent of the Miningtek Report, underground installation of Filpaks had been conducted on a limited scale only, and Paddock packs had proved to be the most successful. Short Filpak is now favoured, while “Fingers” and “Prop-up” methods have been temporarily shelved but not yet discarded.

At Elandsrand, although the Paddock Pack had been approved before installation by their risk assessment team, the trial was brought to a close after installation of 40 to 50 packs, because miners found handling and installation awkward and laborious. Nevertheless, the Filpaks performed acceptably once in place, and were in fact still protecting the gullies several years after installation.

In wider stopes, the South Reef trial showed that Paddock Pack could be carried into the stope in collapsed condition to its required location, within the already-placed backfill bag. The steel assembly is then extended and fixed into position, up-dip or down-dip of the gully. The backfill bag plus steel assembly is then ready to accept backfill.

The “Short Filpak” has proved to be adaptable to both wide and narrow stopes, and, having been used for some time at Moab, is at present the favoured system.

Recent Progress

On the advice of Miningtek, subsequent to completion of their report, REMS approached South Deep Mine and received their approval to install a limited number of Filpaks in an operational backfill stope. Performance was observed visually and as a result South Deep decided to commission a more comprehensive trial. They insisted however that the trial be monitored on the same lines as at Savuka, and Miningtek were again appointed consultants to the proposed trial. Problems at the mine however created a constant stream of delays, and the trial had to be cancelled.

In the meantime, through the good offices of a progressive, newly-appointed appointed licensee, Moab Gold Mine agreed to conduct a Filpak trial that has now been running for close to two years in certain of their backfilled stopes. All Filpaks have been installed on the Short Filpak system and on strike gullies, and Filpak has recently been accepted as a “stock item” in the mines of the Anglo-Gold group.

At the time of writing, and in addition to the Moab trial, and again due to the efforts of REMS’s licensees:

- Elandsrand Gold Mine has agreed to conduct Filpak trials, which will probably start in 2008
- Tau Tona Gold Mine is conducting trials, in dip gullies as well as strike gullies.

- Northern Platinum Mine is contemplating an underground trial, which will probably also be initiated in 2008
- South Deep, under new management, has agreed to further trials

It is not within REMS's province, and possibly premature, to report or comment on the results of trials (past, present or future) without approval of the respective mines. No doubt such reports will be issued or published at some future date as between the mines themselves, the licensees and REMS itself. In the meantime, REMS hopes to continue promotion and close co-operation with the principal participants in the process.

Comment on Planning and Administration of the Project

To quite a considerable extent, the somewhat inordinate length of time it has taken REMS to reach its present stage is due to its original lack of understanding of the manner in which the mining industry operates. RESA, REMS's civil engineering parent company, had achieved rather swift success in promoting MSE in the construction industry, and REMS hoped (optimistically) that similar success could be repeated in mining. They failed however to realise the difficulties of product promotion in an industry with which they were unfamiliar.

Civil engineering operates through hundreds of projects, large and small. Personnel in RESA had gathered through the years an intimate acquaintance with the civil industry and its network, and therefore found little difficulty in gaining access to- and obtaining decisions from senior designers and constructors in both the private and public sectors. Initial projects might have been relatively small, but provided a quick start.

The mining industry however required a different approach. It comprises giant underground "factories", obliged to work to a fixed set of rules – especially those relating to safety – and cannot quickly be diverted from its path at the drop of a hat. Formal processes are in place for testing and authorisation of experimental support systems and REMS took some time to fathom the decision-making hierarchy, and the company now realises that safety procedures on the mines are simply not altered for the benefit of an aspirant innovator, no matter how great the predicted benefits.

In their civil engineering effort moreover, RESA were carrying out technology transfer. The new construction material had been tested and approved by authorities in both Europe and the USA and was being applied on a reasonable scale in many countries, and no reason could be found for MSE not to work successfully in South Africa. On the other hand, in order to persuade the mining industry on the possible merits of their proposed systems, REMS became obliged to undertake the triple tasks of original research, development of models and real-life testing underground.

Finally it also took RESA some time to realise that they should promote their products through licensees, who possessed not only resources for promotion, production and training but also an intimate knowledge of the industry. Present increased hopes for the application of Filpak can be attributed to the present policy of “division of labour”.

Discussion and Conclusions:

- Laboratory and underground trials, and specifically the monitored Savuka trial, indicate that Filpak could satisfy the performance required for gully packs in backfill stopes.
- The reinforcement system is based on an accepted design procedure, and designs could speedily be verified by underground trials and measurements.
- When underground performance shows that increased or decreased load-bearing capacity is required, modification of design of steel assemblies, could be achieved speedily by adjustment of wire diameters, mesh spacing, vertical intervals between sheets of reinforcement, area and shape of reinforcement sheets
- Practical and safe methods of installation, the most important original barrier to acceptance of the system, have been evolved. Methods of installation will however have to be adapted to specific conditions at each mine. Installation methods need continued and continual attention and research, in particular in narrow- and steep stopes. “Short Filpak” appears now to be the most practical and user-friendly system.
- Costs appear to be competitive, in particular in relation to underground transport and handling.
- Filpaks could be installed both up-dip and down-dip of gullies, and for both strike and dip gullies.
- On the basis of mini-pack tests, Filpaks appear to be able to resist seismic events (COMRO report).
- Wide-stope mines, South Deep for example, tend to use cemented backfill in their support operations. This policy does not affect the post-yield performance of Filpaks, and cementation would produce a stiffer initial resistance before yield, which might in some cases be advantageous. Where cementation of backfill takes place however, grout strengths are in any event of a low order, about 2 MPa at 28 days.
- Filpaks will not create point loads at the gully edges.
- Mild steel was chosen as the reinforcing medium because of its availability, strength, modulus of elasticity and resistance to creep. Furthermore, mild steel does not lose those properties at temperatures generated underground. Alternative reinforcing media are however not ruled out, if able to provide similar properties.
- Filpak raises the ratio of total area backfilled to total area mined, and would therefore enhance the safety of operations in stopes using backfill as local and regional support.

Acknowledgements

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