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BACKFILLING: NEW TRENDS AND TECHNOLOGY

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BACKFILLING: NEW TRENDS AND TECHNOLOGY

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ABSTRACT: Backfill behaviour and its impact on regional ground stability must be well understood if mining of deep ore deposits is to succeed.

Several backfill research projects are being carried out under the Canada/Ontario Mineral Development Agreements (MDA) to provide additional information on this increasingly important subject. The results of the MDA projects are expected to benefit the mining industry by leading to improved ground control in deep mines and in areas of high stress. The introduction of new mining methods could also result from this work.

Paste fill is presently the state-of-the-art in backfill technology. Further research is required, however, before it is accepted for use in bulk mining in Canada.

CANMET has recently established a laboratory in Sudbury for mine backfill studies. The laboratory will investigate the engineering properties of backfill materials and the cost of their application. The laboratory will become fully operational during 1988.

New trends in backfill technology and the changing objectives of backfill usage in bulk mining are discussed in this report as well as the engineering research initiatives to ensure the objectives are met.

RÉSUMÉ:

INTRODUCTION

Ground control related to mining is one of CANMET's major research activities. An integral and important part of this activity has been the investigation of artificial support methods and systems for better understanding of their support characteristic in surface and underground situations. Recent research efforts to develop an improve understanding has included several research projects being carried out under the Canada/Ontario Mineral Development agreements (MDA) (1,2). In addition, CANMET has recently established a research laboratory in Sudbury to provide technical support to the MDA research projects on backfill presently underway and listed in Table 1.

Backfilling with classified mill tailings, sand, rockfill etc. are common methods of achieving local support and ground control in mines. For hard rock mines operating at shallow to medium depth, the performance characteristics of backfill are well understood. However, where mines are operating at great depth or in areas of high stress, backfill characteristics and its contributions to support are not well understood. These aspects of backfill are the subject of several research projects. The target objectives of these projects are the following:

- to improve ground control in deep mines;
- to improve ground control in stressed areas;
- to establish new mining methods.

This paper discusses some of the changes forseen for backfill use in mining as a primary support system, and the engineering initiatives required to meet these changes.

The scope of this report includes the following:

- evolution of backfill use in mines;
- requirements for backfill in bulk mining;
- some new trends in backfill practice and technology;
- future innovations in backfill technology;
- the role of CANMET's Sudbury laboratory in mine backfill research;
- conclusions and recommendations.

TABLE 1

CANADA/ONTARIO MDA BACKFILL PROJECTS

1. In-situ determination of dewatered fill properties - 2 parts
2. In-situ monitoring and modelling of a sill mat
3. Use of cemented fill to control pillar failure
4. Backfill alternatives
5. Liquefaction potential of dense fill

EVOLUTION OF BACKFILL USE IN MINES

The use of backfill for primary support in mines has evolved over the years. Originally, backfill provided working floors for mines operating at shallow depths, and also provided a means of disposing of waste rock underground. It was part of the selective mining sequence which involved drilling, blasting, mucking and backfilling. To more effectively carry out its function, cement was often added to the fill in order to provide an improved operating surface for rubber tired equipment. The addition of cement has also helped to reduce ore dilution by scoops and scrapers working on "loose" fill during the mucking cycle.

Stopes were generally small and fill placement was usually carried out in lifts. Stope preparation was very labour intensive with this method of placement, however, this process did minimize some of the common problems associated with modern day bulk fill placement such as segregation. It also ensured some degree of compaction, thus eliminating large voids in fill.

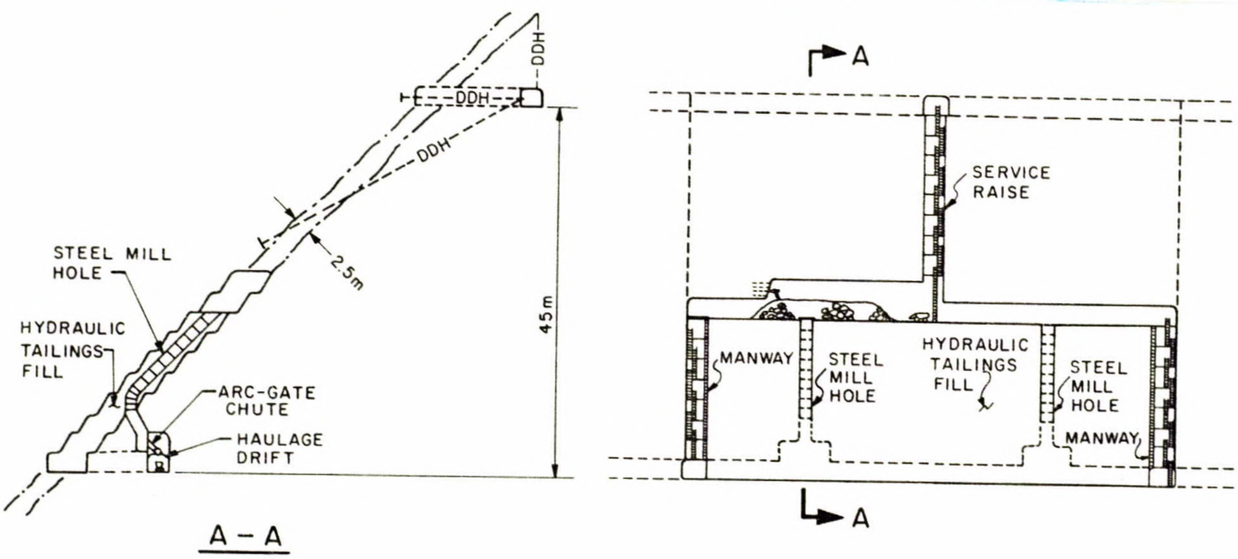

Fig. 1 - Conventional Cut-and-Fill Stope Sections

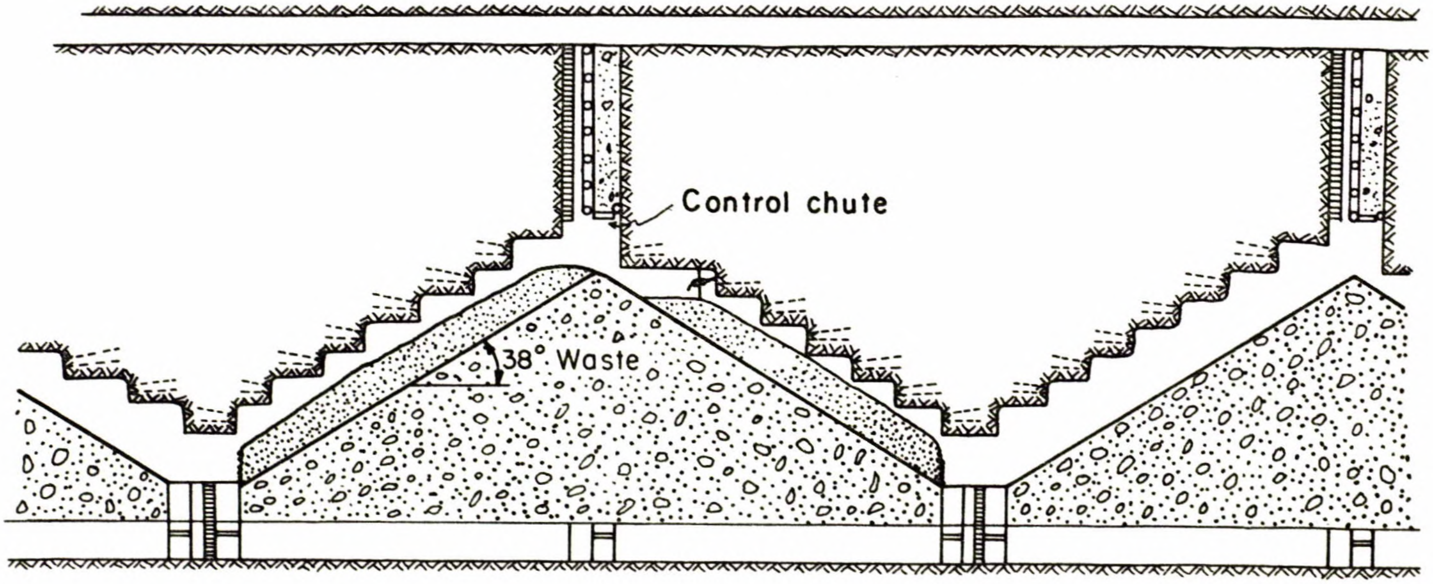

Fig. 2 - Rill Cut-and-Fill Stope

Over the years various cut-and-fill mining techniques have been developed and used, including these conventional cut-and-fill stoping technique, Figure 1, and the rill-cut-and-fill stoping method, Figure 2 (5). With the latter method, the angle of repose of the waste fill is used advantageously to convey the ore to the ore chutes.

As an effective method of controlling ground, hydraulic fill has often been used to "tighten" stopes previously filled with rock; to fill empty shrinkage stopes; or to provide fill for cut-and-fill stopes (4). Rock, and other high modulus fills have since been introduced.

Backfill has also been used to provide artificial support in the recovery of mine pillars.

An essential criterion for fill materials used in shallow to medium depth mines is that they should satisfy a gradational requirement for acceptable percolation rates. Material strength and deformation properties are not generally included in the criteria for fill selection and use.

SOME NEW TRENDS IN BACKFILLING PRACTICES AND TECHNOLOGY

With the introduction of bulk mining methods, stopes have become larger and fill must often be placed by remote means. In some cases stope sizes are so large that in situ stress patterns are modified. Such changes have led to ground control problems, including the bursting of pillars.

Remote placement of great quantities of fill can cause particle segregation, resulting in variable properties within the fill and the occurrence of large voids in filled stopes. The effectiveness of the fill in controlling ground can, as a result, sometimes be reduced.

In terms of bulk mining applications, the performance functions of backfill have been expanded to include the following (6):

- (i) to control subsidence;
- (ii) to provide pillar support;
- (iii) to improve regional stability;
- (iv) to provide an adequate mining floor and to reduce induced streses in the mining zones;
- (v) to improve ventilation;
- (vi) to increase productivity by controlling dilution.

Existing backfill technology must therefore be expanded to meet new requirements imposed by the growing use of these relatively new mining methods. Greater application of engineering principles for fill design, its transportation and placement is also required.

Backfill as a Building Material

Current backfill requirements in bulk mining demand a new look at the functions of backfill. From an engineering perspective it has become necessary to view backfill as a building material, which must be employed advantageously for resource recovery.

In this regard, the material properties and parameters required for sound engineering analysis and design must be identified, studied and evaluated. There is also a need to institute some form of quality control to ensure uniformity in its material properties. The parameters of interest include the physical, chemical and mechanical properties of fill.

Backfill transportation and placement techniques must also be investigated. Additionally, modelling, programs and laboratory and field studies are required to evaluate engineering designs and to validate in situ support capabilities.

Physical and numerical models must be developed for predictive purposes and to evaluate the limits of in situ fill behaviour. Laboratory investigations must provide data for engineering design and analysis and input parameters for predictive models. The developed models must also be validated by field observations.

Some Material Properties and their Effects on Backfill Behaviour

Some physical properties of interest, in terms of engineering analysis and design of backfill, are:

(i) mineralogy of the fill materials;
(ii) particle size and gradation;
(iii) relative density of solids;
(iv) void ratio and moisture content.

These parameters can have a direct influence on the mechanical and chemical properties of the backfill. For example, particle sizes and gradations often have a direct effect on the percolation rate, strength and compressibility of the in situ backfill. Additionally, backfill strength and stiffness are influenced by the chemical properties of the backfill materials involved, the chemistry of the binder additives and the chemistry of transport medium. If mill tailings are used for backfill, the chemistry of the mill effluent can affect the proportion of cement needed for proper curing and can affect the fill material's ability to reach the required strength.

Mechanical properties, such as: the unconfined compressive strength; the angle of internal friction; and the cohesion and modulus of deformation; control the free standing height and consolidation characteristics of backfill. Percolation rates can also affect overall fill stability.

SOME CURRENT BACKFILL PRACTICES TRENDS AND SPECIALIZED REQUIREMENTS

High Modulus Fills (Paste Fill)

In the past, new developments in backfill technology usually occured with changes in market and mining conditions. In the future, as mines get deeper, the technology of dense fills will be used to provide adequate ground support.

Unlike conventional hydraulic fill, high modulus or dense fills are dewatered to more than 80% solids by weight before placement in a stope. Also, unlike conventional hydraulic fill, high modulus fills do not need to be made from the coarser mill tailing particles. If produced in surface plants, high modulus fills must be pumped; if produced underground, the high modulus fill can be fed by gravity but the excess water must then be pumped to surface.

Although the use of dense fill offers potential economic benefits over the use of other types of backfill, dewatering and handling costs for large volume production and placement may not make its use cost effective at the present time. Further development of dense fill technology is required before it can become economical for widespread application in Canadian mines.

Hydraulic Fill

In a 1986 survey of backfill practices in Ontario mines, cemented mill tailings were found to be the most popular fill type in use (7). Hydraulic filling is a fully developed technology and it will continue to be used by small mines because of its ease of application.

Problems with in situ fill segregation still persists. Transportation and fill placement techniques to minimize fill segregation, require further development.

Cementing Agents

The current trend seems to be to use as little binder in fill as possible in bulk mining applications. The use of normal Portland cement as a binder is gradually being replaced by much cheaper binders such as fly ash and blast furnace slags, with lime as an activator.

A mixture of normal Portland cement and granulated slag is gaining increasing acceptance as a cost effective binder alternative in Ontario mines.

Modelling & Backfill Monitoring

Computer models have been developed for simulating backfill behaviour, however user costs need to be brought down in order to gain wider acceptance by individual mines (7).

The accuracy of the models in predicting in situ fill behaviour depends on the availability of reliable input data. The data must come from physical property tests in the laboratory and in situ monitoring instrumentation. At the present time, there is a lack of standardization for physical properties testing of fills in the mining industry. Additionally, more reliable instrumentation has yet to be developed for in situ backfill monitoring purposes.

FUTURE INNOVATIONS IN MINING WITH BACKFILL

In the past, the development of more efficient mining methods generally depended on the availability of, amongst other things, better types of backfill and improved support systems. If the material properties of backfill can be determined with some degree of confidence, and the engineering design parameters can be clearly defined, it will be possible to develop new innovative mining methods with backfill as the principal support medium. The following examples illustrate some of the elements involved in current mining practices when hydraulic fill is used, as well as some possible innovations in mine design when dense fill is used.

Conventional Cut and Fill Stoping

The backfilling cycle for cut-and-fill stoping consists of several component activities, Figure 3 (4):

- erecting fill fences;
- raising manways;
- raising mill holes;
- installing drains;
- placing fill;
- waiting for water to drain.

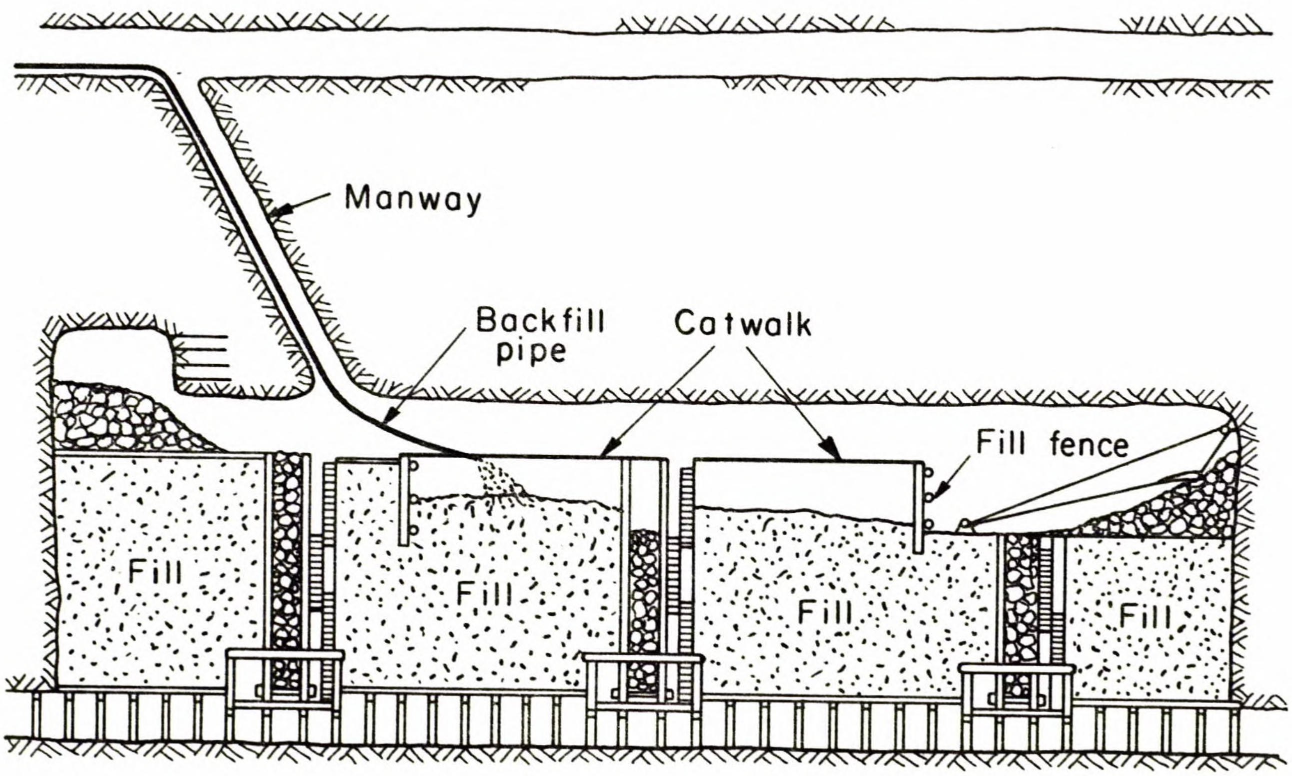

Fig. 3 - Typical Activities in a Conventional Cut-and-Fill Stope

These activities are not only time consumming and slow but must be repeated every 8 to 12 feet of stope height. In effect, the backfill cycle requires that the mines have almost twice as many cut and fill stopes as required to meet their daily tonnage requirements.

Dense fill could eliminate many of the backfill cycle component activities if its anticipated properties are realized. Fill fences and drains would no longer be necessary, nor would 2 to 3 days be required for water to drain out of the backfill. Manway and millhole extensions would be simpler to construct as they would not need to be sealed.

Dense fill can be prepared from unclassified mill tailings. This could eliminate the backfill shortages many mines periodically suffer, and reduce the number of standby stopes needed to maintain production. It could also reduce the necessity of relying on backfill made from low grade or uneconomic development muck.

Conventional Bulk Stopes With Delayed Fill

Dense fill will eliminate the need for backfill bulkheads in bulk stope drawpoints. Since these installations can cost up to $25,000 and a drawpoint is needed under every 25,000 tons of ore, potential savings could be substantial.

Mine Maintenance With Hydraulic Fill

Mines using hydraulic backfill have one common problem whether selective cut and fill or bulk stoping methods are being used - dirty water must be handled. In some cases, about 100 gallons of water must be pumped out of a mine for every 18 cubic feet of void filled. Typical costs associated with the pumping of dirty water or slurry has been a subject of investigation (8). Their findings are illustrated by Figure 4. In this example, a horizontal slurry pump with a pumping rate of 3,000 l/min. (793 gal/min) and a pulp with a specific gravity of 1.3 was assumed to be operating under the conditions outlined in Table 2 below:

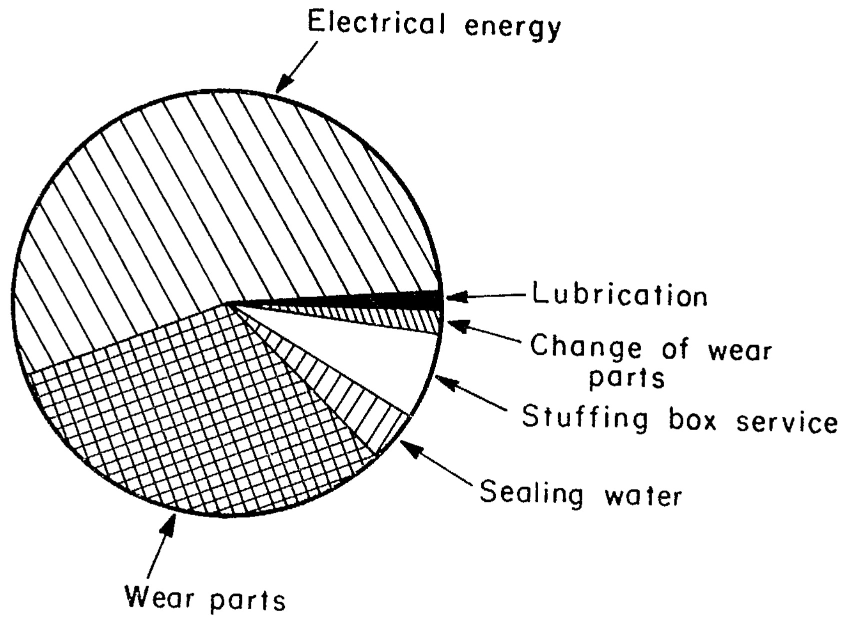

Fig. 4 - Slurry Pump Operating Cost Breakdown

TABLE 2

ASSUMPTIONS FOR A SLURRY PUMP OPERATION

Total discharge head	20 m (65.6 ft)
Pump efficiency	60%
Costs of electrical energy	1.2 US cents/kw (1.62 Cdn cents/kw)
One set of wear parts	$280 US (x1.35 = $378 Cdn)
Life of wear parts	2,000 hr

Change of wear parts	2 man-hrs @ $6 US/hr ($8.10 Cdn/hr)
Sealing water consumption	8 l/min
Cost of sealing water	13 US cents/1000 litres (18 Cdn cents/1000 litres)

It was concluded, on the basis of the above assumptions, that the frequency of worn parts would increase with slurry abrasiveness, which would result in higher maintenance costs. The above cost factors are often appreciable in hydraulic backfill operations.

The slimes associated with drainage of backfill also clogs ditches, fills sumps, and can spread to roads and road beds. The fine materials involved destroy brake shoes and bearings of mine equipment and machines. It is envisaged that most of these maintenance cost items will be eliminated with the introduction and use of dense fill.

Vertical Cut And Fill Stoping

The concept of vertical cut and fill stoping shown as Figure 5, will only be realized with the well designed use of backfill. Work to date on dense fill indicates that it might have the necessary behavioural characteristics to permit the use of such a mining method. Dense fill is stiff, stands up at 75°, does not flow under normal circumstances, and does not require drainage or decantation. If research work still to be concluded verifies that dense fill has a very low potential to liquify as a result of nearby blasting operations, then we are a step closer to introducing a new stoping method.

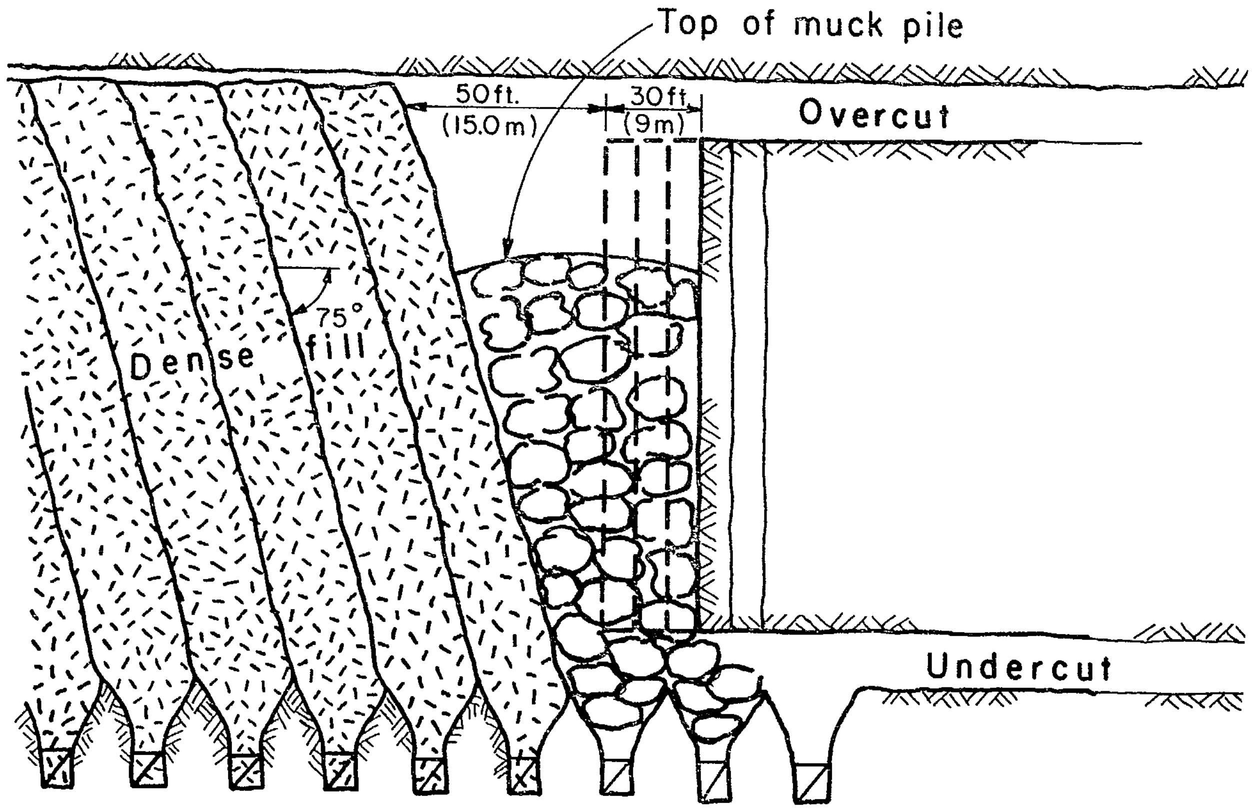

Fig. 5 - Vertical Cut-and-Fill Stoping Using Paste Fill

Vertical cut and fill stopes will eliminate the many repetitious tasks required by VBM such as cleaning holes; profiling hole bottom breakthroughs; plugging holes; and moving in to load holes. All of these tasks will be done only once for each hole. With vertical cut-and-fill mining, they are repeated for every 10 to 15 feet of blasthole length.

The method would theoretically eliminate the need for pillars. In an ore body with an ideal configuration, mining would start at one end and retreat along strike to the other end. All ore blasted would be immediately available and could be drawn as fast as possible. Some of the obvious advantages of such a system are listed below.

1. Eliminates need for pillars, pillar losses, pillar salvaging;
2. Eliminates need for slot winze;
3. Eliminates repeated cleaning of same holes;
4. Eliminates need for profile measurements;
5. Eliminates danger of holes needed for repeated blasts and hole closing between blasts;
6. Provides a continuous ore source;
7. Eliminates need for drawpoint bulkheads;
8. Reduces broken ore inventory.

As with all new concepts, there are many technical questions which must be answers before its practical use. Some of the more obvious questions which must be answered before this new mining method can be used are the following:

1. What is the optimum rate of placing dense fill to prevent fill slumping to less than a 75° angle of repose?

2. What is the liquefaction potential of dense fill?

3. Will stope geometry affect dense fill placement, liquefaction, angle of repose, drawpoint spacing and ore drawdown angle?

4. What Blasting design will minimize vibration damage to walls, back, dense fill and still produce optimum fragmentation?

5. Optimum method of placing dense fill with the following options possible:
   - install beam in stope back and use crawl to pull delivery pipe across void;
   - use shotcrete type delivery system;
   - use Radmark type delivery system;
   - use concrete pump.

6. Drill bit trajectory monitor and control device needed.

It is expected that the results of the current MDA projects on dense fill will provide answers to some of the above questions.

THE ROLE OF CANMET'S SUDBURY LABORATORY IN MINE BACKFILL RESEARCH

The Sudbury Laboratory was established in 1987 as a field office of the Mining Research Laboratories of CANMET. The purpose of the Laboratory is to carry out laboratory and field investigations in support of the MDA research projects on backfill. The Sudbury Laboratory is expected to be fully operational by January 1989, and will be devoted to the study of the physical and engineering properties of backfill materials as well as costs associated with their use underground.

Included in the laboratory planned projects are the investigation of economical mix design techniques and the development of quality control methods for various types of backfill. A compilation of a summary report on typical backfill practices currently used in Canadian mines, complete with quality control methods, in situ instrumentation and monitoring techniques, is a short term objective of the laboratory.

In accordance with CANMET's present cost recovery objectives emphasis will be given to research project on backfill which are sponsored and have support by the mining industry.

CONCLUSIONS & RECOMMENDATIONS

Paste fill is presently the state-of-the-art in backfill technology. The use of hydraulic mill tailings for backfilling is expected to continue because of the developments in this technology.

The application of backfill for ground control and local support in mines operating in deep deposits and high stress areas indicates some promise, especially considering the recent advancements in dense fill technology. More work remains to be done however, in terms of accurately defining the engineering properties of the fill, and its behaviour under in situ conditions.

A new approach is required in terms of how backfill is perceived in the mining cycle. A recommended engineering approach, would be to view backfill as a structural material which must be applied advantageously for resource recovery. In this regard, backfill design, transportation, placement and monitoring must incorporate numerical, laboratory and field components into engineering design studies, to ensure safe and economical operations.

More economical binder alternatives such as blast furnace slag and fly ash are being used in backfill to partially replace Portland cement. The present trend is to reduce cement content in backfill used for bulk mining purposes. Further research is required for finding more economical binder alternatives to Portland cement.

CANMET's Sudbury Laboratory is dedicated to the study of the physical and engineering properties of backfill materials, and the costs associated with their use underground. A short term goal of the laboratory is to compile a summary report on typical backfill practices presently used in Canadian mines, including quality control methods, in situ instrumentation and monitoring techniques.

It is expected that the proposed research activities at the Sudbury Laboratory, in conjunction with the results of the Canada/Ontario MDA research projects on backfill, will contribute to the eventual development of guidelines which will assist an expanded, safe and more economical use of backfill by the mining industry.

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