A New Materials Handling Technique for Cemented Rockfill Distribution in VBM Mining

S Peterson[1] and J Szymanski[2]

ABSTRACT

Although efforts towards producing a 'total quality rockfill product' have allowed cemented rockfill costs to be reduced considerably, there is still tremendous potential for further cost reductions.

Cemented rockfill costs range from approximately $7 to $12 (US) per tonne of fill placed. Approximately 50 per cent of the rockfill costs are associated with cement costs. A large portion of the remaining 50 per cent is associated with labour and materials handling costs.

Several Canadian underground mines utilise haulage trucks and/or conventional belt conveyors to distribute the rockfill. However, due to the restrictive nature of the underground environment, these current materials handling systems have limitations (ie spillage from trucks, dust from conveyors). The Sicon conveyor system (developed in Sweden) has considerable potential for replacing these current methods. The Sicon conveyor utilises a revolutionary approach — the conveyor belt is folded over upon itself (forming a tear drop shape) so that the transported material is completely encased within the belt. The Sicon conveyor's ability to negotiate very tight corners (without transfer points) makes the conveyor very appealing for underground mining applications. An analysis comparing the pros and cons associated with the Sicon conveyor system versus conventional materials handling systems will be presented in this paper.

CEMENTED ROCKFILL SYSTEM

Cemented rockfill is used to replace ore that has been removed during the mining cycle. Cemented rockfill consists of cement slurry (usually normal portland cement and/or flyash or slag) added to crushed aggregate. Typically, the slurry is mixed at a surface batch plant and then sent underground through piping and/or boreholes until it reaches an underground storage tank at the desired filling level. The aggregate material is often crushed, quarried rock which is sent underground through a raise-borehole to the desired filling level. The aggregate material can also be waste-rock obtained while developing the underground mining tunnels.

1. If the underground haulage truck method is being used to transport the cemented rockfill, the cement slurry is sprayed directly onto the crushed aggregate as the aggregate is dumped from the main rockfill raise into the haulage trucks. Then the haulage trucks will dump the material into the mined-out blocks.
2. With the conveyor method, the aggregate is transported from the main rockfill raise to the mined-out blocks via conveyor belts. Then the cement slurry is sprayed onto the conveyed aggregate as the rock exits the belt and enters the mined-out block.

The cemented rockfill is allowed to cure for several weeks before adjacent mining commences. The cemented rockfill must remain strong and competent even after blasting and removing the adjacent ore blocks. If the rockfill sloughs-off while mining these adjacent blocks, costly dilution will be the result. However, by creating competent rockfill, dilution will be kept to a minimum. The materials handling method can assist in creating a strong product.

When utilising the conveyor method, the aggregate and slurry are usually mixed effectively at the discharge end of the conveyor. Few unmixed areas will develop while filling the block. However, unmixed areas can occur while using the haulage truck method. Unless the aggregate and slurry are added to the truck box with extreme care, the two generally don't receive a proper mixing until the truck is dumped. When the truck is dumped, the aggregate and slurry may mix together while tumbling into the block being rock-filled.

ADVANTAGES OF CONVEYOR SYSTEMS OVER HAULAGE TRUCK SYSTEMS

Transport of bulk materials can often be economically achieved using a continuous conveying technique. A continuous conveying technique can allow the following:

1. high productivity;
2. the potential for less manpower;
3. no lost time at the loading and unloading stations;
4. no maintenance to haulage equipment due to poor haulage road conditions (eg tire costs);
5. no frequent grading or repairs to haulage routes;
6. potential for fully automated system (with lineside safety equipment installed); and
7. predictability of final product (better mixing between the slurry and the aggregate).

GENERAL ADVANTAGES OF HAULAGE TRUCKS OVER CONVEYOR SYSTEMS

1. Flexibility of the system (re-routing to different locations is simple with haulage trucks).
2. Less prolonged down-times due to relocating conveyors to different filling locations.
3. Less prolonged down-times due to major repairs (eg belt replacement or splicing). There is often more than one haulage truck, allowing the backfilling operation to continue if one of the trucks breaks down.
4. Less potential for fires (conveyor belts have more potential to ignite and emit dangerous gases and smoke into the mine airways).
5. Haulage trucks are often used for additional purposes (ie ore haulage) and may still be utilised even when the rockfilling cycle is not being performed.

THE SICON CONVEYOR SYSTEM

The Sicon conveyor system was designed by the Swedish company Scaniainventor Conveyor Sicon AB. Innovative thinking was necessary when solving several of the problems associated with conventional conveyor systems and their limitations in the underground environment. The Sicon conveyor

1. Graduate Student in Mining Engineering, 606 Chemical-Mineral Building, Department of Mining, Metallurgical and Petroleum Engineering, University of Alberta, Edmonton, Alberta, Canada T6G 2G6.

2. Professor of Mining Engineering, 606 Chemical-Mineral Building, Department of Mining, Metallurgical and Petroleum Engineering, University of Alberta, Edmonton, Alberta, Canada T6G 2G6.

utilises a revolutionary approach — the conveyor belt is folded over upon itself (forming a tear drop shape) so that the transported material is completely encased within the belt.

CURRENT SICON CONVEYOR USES

The Sicon conveyor systems have been used for a wide range of applications, throughout several different industries (some examples are listed below):

1. AVEBE TAK (Holland) conveys potato residue;
2. Boliden Mineral (Sweden) conveys grinding pebbles,
3. Cementa AB (Sweden) conveys cement clinker;
4. LKAB (Sweden) conveys iron ore concentrate;
5. Hydro Supra (Sweden) conveys potassium nitrate; and
6. Beatson Clark (UK) conveys glass batch mix (Johansson, 1989).

The list of examples indicates that a wide variety of solids can be transported by the Sicon Conveyor. Therefore, provided the maximum aggregate size is not too large, transporting rockfill should be an ideal application for the Sicon Conveyor.

DESCRIPTION OF THE SYSTEM

Conveyor belt

The conveyor belt has three main functions: to support the transported material, to provide a track for the idlers and pulleys and to take up the tension from the drive machinery (Johansson, 1989). Figure 1 shows a cross-section of the Sicon conveyor belt. The steel reinforced profiles serve as tracks for rollers.

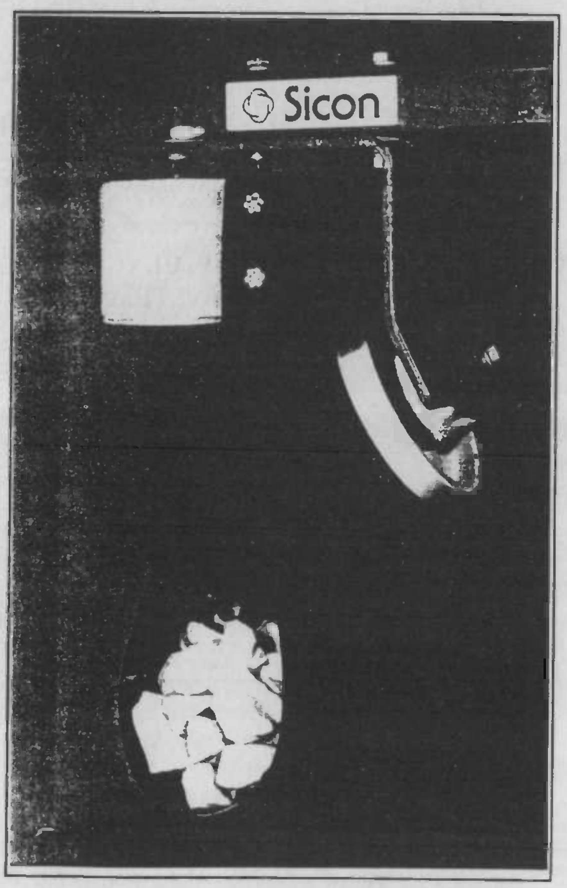


FIG 1 - The Sicon Conveyor.

The profiles are vulcanised onto the belting, which is manufactured from wear-resistant, flexible rubber. The qualities of the rubber allow the belt to easily negotiate tight horizontal turns (Johansson, 1989).

Drive units

Multiple drive units can be installed with the Sicon system. By installing multiple drives on long conveyors, the belt tension can be greatly reduced. The drive units can be installed wherever the conveyor makes a minimum turn of ninety degrees. Because underground mining contains numerous ninety degree corners (drifts and drawpoint intersections), the Sicon Conveyor could be easily integrated into the underground environment. Whereas, the integration of conventional belt conveyors would involve large excavations and/or transfer points at every 90 degree corner.

The energy consumption associated with the Sicon Conveyor is similar to that of conventional belt conveyors and less than for screw, chain and pneumatic conveyors (Johansson, 1989).

Mountings and supports

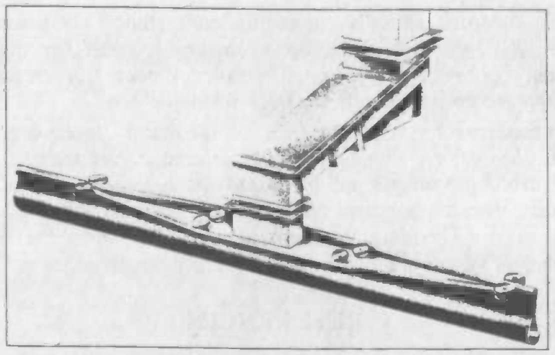
Because the Sicon conveyor requires less space than conventional conveyors, supporting the system can be achieved in several different manners. The conveyor can be hung from the roof, the walls, or can be floor mounted. Because the conveyor can be mounted in several different manners, the potential for successfully implementing the system into the underground environment is greatly increased. The tremendous flexibility in support techniques will enable the conveyor to be erected regardless of the local rock conditions within the area. Another valuable aspect of this system is that the supports do not have to be perfectly aligned. Because of the uneven roof and wall rock surfaces underground, this lack of necessary accuracy allows for easy installation of the Sicon conveyor. Rock-bolts could be used to fasten the main conveyor to the roof or walls of the mining drifts.

Loading possibilities

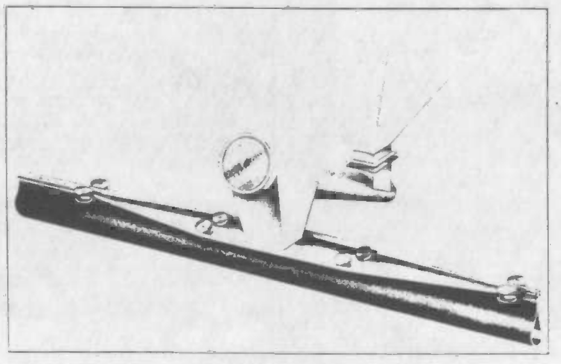
Loading of the belt can take place anywhere along the length of the conveyor. Vibrating feeders or screw feeders are recommended to ensure that even loading of the belt occurs (Johansson, 1989). At the loading station the belt is opened into a U-shape to allow for the loading chute (see Figure 2). Because the loading chute can be situated within the U-shaped opening, there is very little spillage at the loading station. Special safety devices can be fitted at the loading station to prevent the belt from being overfilled (Johansson, 1989). Aggregate lumps as large as 15 cm can be handled by the Sicon conveyor (provided the material is a blend of all fractions and the percentage of large lumps is small). Due to attrition while travelling through the rockfill raises, the maximum aggregate size arriving underground is typically less than this 15 cm limit.

Discharge possibilities

The material can be discharged vertically, where the belt opens into a flat vertical orientation. Once the material is discharged from the belt using the vertical method, the belt returns directly back to its original pear-shape. The second option is horizontal discharging, where the belt opens into a flat horizontal orientation (similar to conventional belt conveyors). With the horizontal discharge method, the belt closes and then must twist back to its original position (Johansson, 1989).



Vibration feeder from the bottom of a silo.



Hopper with screw feeder.

FIG 2 - Loading the Sicon.

SICON ADVANTAGES

In the past designers have attempted to solve the problems associated with conventional conveying systems and the underground environment. Problems such as negotiating tight horizontal turns, dust pollution, size constraints, inclination problems and belt cleaning problems are minimised when using the Sicon conveyor system.

Negotiating tight turns

Solutions have been developed to permit conventional belt conveyors to negotiate horizontal turns. However, these conveyor systems have been extremely costly, complicated and still do not deliver the desired results that the Sicon conveyor system produces. Large radii are still required for the horizontal turns when considering standard conveyor belt systems. The Sicon conveyor can travel around sharp corners with minimum curve radii of 0.7 metres (Johansson, 1989). Due to this ability to negotiate tight turns, the Sicon has a definite advantage over the conventional belt conveyors. There are often tight 90 degree turns (eg mining drawpoints) which have to be considered in the underground environment. By avoiding transfer points, dust problems and spillage will be reduced significantly.

Controlling dust pollution

Different designs of covered belt conveyors have been developed, but none have conquered the problem of eliminating dust due to spillage at the transfer points or during the return of the empty belt. However, the Sicon conveyor's ability to negotiate tight turns has eliminated the need for transfer points along the length of the conveyor. Also, because the empty belt returns to the loading pocket in a closed state, no dust is permitted to escape during the entire length of the conveyor (Johansson, 1989). Note, the transported material is protected within the belt during the entire length of the conveyor, reducing the possibility of contaminants mixing with the transported material.

Providing sufficient ventilation to the underground mining environment can be costly and complicated. Dust pollution from conventional belt conveyors can quickly contaminate the underground environment. However, the immediate environment surrounding the Sicon Conveyor would be much improved due to the enclosed belt system and the absence of transfer points.

Solution to size constraints

Because the Sicon conveyor belt is folded upon itself (tear drop shape), the necessary width required to house this conveyor is greatly reduced. This allows the Sicon conveyor to be integrated more easily into the current mining system than conventional conveyors. The total width of the conveyor system is less than 500 mm (not even as wide as the ventilation tubing currently being used underground) and could be easily rock-bolted to the roof of the mining drift. Occasionally the drifts would have to be enlarged slightly, but in most cases interference with the conveyor could be avoided if reasonable caution is used. Under most circumstances, the conveyor haulage ways could still be utilised by the mining crews. Therefore, the regular mining activities could continue, uninterrupted by the backfilling cycle.

Solution to steep inclination problems

There have been efforts to add troughs and/or rubber cleats to the belt so that steeper inclinations can be attempted, but this has caused belt cleaning problems. Other conveyors have developed hoods for there conveyor belts, but none as effectively as the Sicon system. The Sicon system can transport effectively along vertical grades as steep as 35 degrees (Johansson, 1989). Therefore, typical underground mining grades of ten to 20 per cent will not cause problems for the Sicon conveyor.

Two-way conveying possibilities

Because the Sicon conveyor belt returns closed, the conveyor has the capability of conveying a second material, which could be loaded at the discharge end of the conveyor, back to the original loading station — two-way conveying! For example, ore from a chute could be transported on the return side of the conveyor.

Increased transport speed

Because the belt is covered, the acceleration and transport speed can be increased. The material is trapped inside the belt and therefore cannot escape into the environment even at high speeds of transport (this can increase your handling rate — more tonnes per hour).

FEASIBILITY STUDY FINDINGS

A feasibility study was performed comparing the underground truck haulage method against the Sicon Conveyor method. The study indicated that the total operating costs per ton of rockfill placed would be $0.86 less with the Sicon Conveyor method ($8.56/tonne for the Sicon Conveyor method compared to $9.42/tonne for the haulage truck method). Therefore, by using the Sicon Conveyor, considerable savings could be realised. For example, with a planned production of 250 000 tonnes rockfill per year, annual savings of $215 000 (US) could be generated. Note, when considering the operating costs associated strictly with the underground transport of the rockfill product (neglecting surface plant and cement costs etc), the Sicon Conveyor operating costs were approximately 50 per cent of those associated with the haulage truck method. These figures are similar to those found by Krefting and Bennett (1984), who indicate that operating costs associated with conveyor systems at Cyprus Anvil Mining Corporation are approximately 50 per cent of those associated with truck haulage.

DISCUSSION OF RESULTS

Consistency of the final cemented rockfill product is a major advantage associated with the conveyor methods. Because the cement slurry is sprayed onto the aggregate evenly, the final product would be strong and predictable, with fewer 'weak' or unmixed zones than with the haulage truck method. However, long delays associated with belt splicing and/or conveyor relocation could cause 'bottle-necks' in the filing cycle that would not be present with the haulage truck method.

The higher filling rates associated with the Sicon Conveyor method make it an ideal method for filling large voids (ie blocks requiring 100 000 tonnes or greater). Once the conveyor has been routed into the block to be filled, high tonnages can be placed and the block can be filled at a faster rate than with the truck option. The conveyor system allows continuous filling with little or no interruptions. However, the Sicon conveyor method may prove to be inefficient when filling small voids. For smaller voids, the truck option is a more efficient method. The flexibility associated with the truck option makes it ideal for moving quickly between the different smaller blocks (no relocating hassles are associated with the truck method).

If a conveyor system is to be used, the Sicon Conveyor seems like the obvious choice for the underground environment. There are several advantages and few disadvantages (perhaps a lack of North American empirical mining data) associated with the Sicon Conveyor. Therefore, for back-filling large voids, the Sicon Conveyor system should be considered as a possible option.

REFERENCES

Krefting, D V and Bennett, D R, 1984. Alternative ore transport systems at Cyprus Anvil Mining Corporation, *The CIM Bulletin*, February:49-55.

Johansson, R, 1989. The Sicon Conveyor System, A new closed conveyor system, *Bulk Solids Handling*, October.