Use of Asphalt Emulsions in Underground Mines

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Abstract

Inco Limited operates six mines in the Sudbury area of Ontario as well as a fully integrated milling, smelting and refining complex producing nickel, copper and associated precious metals. One of the mines in production is the Coleman McCreedy East mine located about 50 km northwest of Sudbury.

The truck haul ramp within the mine extends a distance of 5 km from the 3370 ft. to the 4950 ft. level. Large Kiruna electric trucks move the ore along this ramp. At the 3370' level the ore is delivered by conveyor to the shaft and brought to the surface. The quality of the road that the trucks are running on can make or break the success of the mine. Since 1997 the surface of the ramp has been stabilized with asphalt emulsion to provide a smooth, hard and dust-free surface. There have been some issues and concerns with the current practice and a review was initiated to determine if there was a better way to rehabilitate the ramp. Based on this review it was recommended that the ramp be rehabilitated using full depth reclamation (FDR) with asphalt emulsion. The use of the FDR process would provide an improvement in the roadway smoothness and also provide greater durability.

This paper outlines the design, construction and results of the rehabilitation of the roadway ramp in the mine.

Key Words: rehabilitation, emulsion, stabilization, reclamation, recycling

Résumé

1.0 INTRODUCTION

The Coleman McCreedy East mine is located northwest of the City of Sudbury. It is one of six mines operated by Inco in the area which also includes a fully integrated milling, smelting and refining complex producing nickel, copper and associated metals.

Production from the Coleman orebody began in 1967 and ceased in 2001. Currently production of 3500 – 4000 tons per day is now concentrated from the McCreedy East Orebody and the 153 Orebody. In order to gain access to the ore a considerable distance must be traveled underground from the main access shaft. The ore must travel up to 4.5 kilometres to reach the exit shaft from an elevation of 4950 feet to 3370 feet. The mine utilizes Kiruna electric trucks (first brought into service in 1996), which can carry a payload of 53 tons and are powered by a 1000-volt overhead trolley system. The trucks haul the ore along the truck ramp to a conveyer system, which moves the ore to the shaft where the material is taken to the surface. Figure 1 shows the mine layout and the electric truck in operation on the ramp.

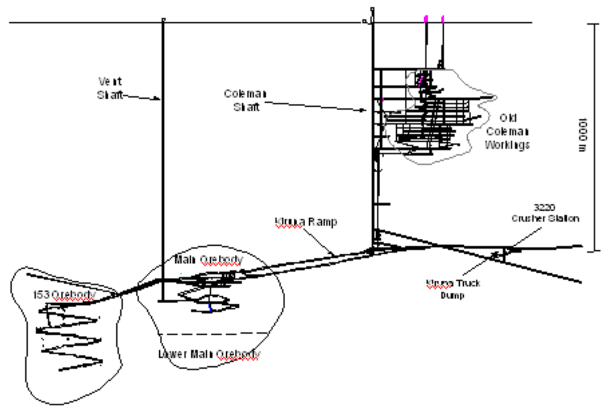

Figure 1a: Coleman/McCreedy Mine Layout

Figure 1b: Kiruna Electric Truck

Figure 1. Mine Layout and Electric Truck in Operation

The initial ramp design was a gravel road with a 250 mm sub-base layer consisting of 75 mm crushed waste rock, and a 200 mm base layer of 31 mm crushed waste rock. This provided a granular roadbed which, could be graded as required to maintain a smooth riding surface. Although this design provided a satisfactory ride it quickly became apparent that dust was a major problem. The dust issue also caused problems with the electrical controls of the trucks and created extra maintenance on the vehicles. Truck maintenance is very costly and the truck down time was seriously affecting production targets.

In efforts to control the dust, experimentation was done using a variety of products such as calcium, magnesium chlorides and lignins. All these products provided some level of success, however they tended to become slippery at times posing a safety risk because of poor traction.

In 1997 an emulsion system was utilized to improve the ride and dust situation. The road base was sprayed with a dilute SS-1 emulsion and a crusher run dust was added. This was scarified together, graded and then rolled with a steel drum. This thin layer provided some protection but the system did not allow for any fine grading to take place and the road surface deteriorated with time. The layer was susceptible to potholes when samples of rock and ore spilled from the trucks and punctured the road surface. These potholes were then susceptible to raveling into larger holes. Cold patch was used to fill the potholes and the dilute emulsion was sprayed on the walls to suppress the dust.

There were numerous problems with this process. The products being used had very poor quality control and this was reflected in the quality of the finished surface. The material was taking to long to set up and this was slowing down production in the mine.

After a site visit it was concluded that the current process method was inadequate and changes had to be made. Also based on the electric truck requirements a new rehabilitation/construction strategy had to be developed to provide a smoother and more durable riding surface. Additionally the technique had to a viable economic process and could be implemented within the narrow scheduling window available, which would have minimal affect on the production schedule.

2.0 DESIGN REVIEW

Due to the extremely high maintenance costs and poor production rates caused by truck down time as well as constant repairs to the ramp the mine was becoming an economic liability. An immediate investigation into a viable solution was started. Because of the need for a smooth road surface a solution had to be found for new sections of the ramp as well as large-scale improvements to the existing ramp. The process also had to be economically viable and cause a minimum amount of disruption to the mine operation.

A detailed investigation was conducted with regards to the road design and the surface alternatives for new construction as well as to the existing ramp rehabilitation. Opportunities were identified that could reduce the overall aggregate thickness without a reduction in structural strength. It was also concluded that improvements could be made to the asphalt stabilized layer using the latest road construction techniques and this could be done for both the new construction and the existing areas.

One area that was investigated was the superelevation of the curves in the ramp. The original granular road base had been constructed without superelevation. The flat riding surface created stresses on the trucks as well as contributing to the spillage of rock and ore pieces onto the surface. The new construction received extra granular in the curves to provide some superelevation and reduce the stresses on the truck bodies. This will reduce the lateral tire forces, the body stresses and spillage. The existing ramp areas would be regraded to provide the superelevation in the curves.

Based on the extensive study the solution chosen was Full Depth Reclamation using a CSS-1h asphalt emulsion. This process would allow the following:

- A thicker pavement layer that would provide greater durability and be less susceptible to potholing.
- Process would allow road to be reprofiled to improve smoothness and rideability.
- Reuse existing asphalt and granular material to reduce costs and maintain ceiling clearance.
- Insitu reconstruction would minimize interruptions to production.

The FDR approach to reconstruction is a well- established process in the reconstruction of roads throughout the world.

3.0 MIX DESIGN

Once the asphalt recycling construction process was established as the best alternative for the ramp rehabilitation an engineered mix design was required. Samples of the existing asphalt surface were randomly obtained as well as the granular material underneath to a depth of 100 mm. McAsphalt Industries performed a mix design on the samples of material received in the laboratory.

The asphalt slabs were crushed using a laboratory crusher and the crushed recycled asphalt pavement (RAP) was blended with the granular material in the proper proportion (40/60 split). A five-point mix design was conducted by adding additional asphalt emulsion to the combined material. The physical properties obtained on the mix design are as shown in Table 1.

Table 1. Mix Design Physical Properties

Material	**Mix**	**Aggregate**
RAP	38.60 %	40.00 %
Granular	57.90 %	60.00 %
CSS-1h	3.50 %	
Added Water	2.00 %	
Physical Properties		
Stability (Newtons @ 22º- Unsoaked	28930	
Flow Index (0.25 mm) - Unsoaked	14.5	
Stability (Newtons @ 22º- Soaked	22228	
Flow Index (0.25 mm) - Soaked	15.5	
% Retained Stability (Soaked/Unsoaked)	76.8	
Bulk Relative Density	2.384	
Maximum Relative Density	2.606	
% Air Voids	8.52	

The switch in asphalt emulsion from anionic to a cationic would help to improve retained strength as well as provide a chemical break to the system and shorten the length of time before traffic can resume running over the surface.

4.0 CONSTRUCTION PROCESS

The use of asphalt recycling has increased significantly over the last twenty-five years and with that increase the equipment has become more efficient and accurate. The recycling units are manufactured in all different shapes and sizes and due to the restrictions in size to get the machine underground a smaller unit (Caterpiller RM-250C) was chosen. The smaller machines are more

Figure 2a. Caterpiller RM-250C **Figure 2b. The Engine**

Figure 2c. The Wheel Hubs

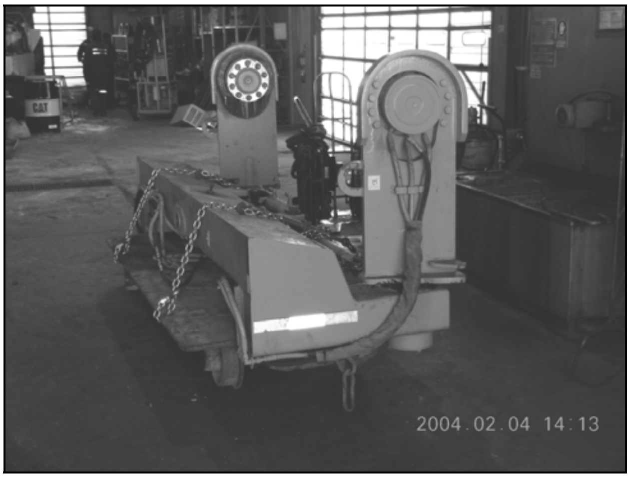

Figure 2d. Front Wheel Assembly

Figure 2. The Recycler and Its Parts

amenable to the disassembly and assembly required to get the machine underground and operational. The photographs in Figure 2 show the machine and the machine in pieces in order to get it into the mine.

The process for the ramp rehabilitation involves the following steps:

- Pulverization/Mixing
- Initial Compaction
- Grading/Shaping
- Final Compaction
- Sweeping and Sealing

4.1 Pulverization/Mixing

Pulverization and mixing is accomplished by making a pass with the recycler to break up the asphalt and blend with the underlying granular material to a maximum depth of 100 mm. The CSS-1h asphalt emulsion is mixed into the pulverized material to provide a homogeneous mixture of aggregate and asphalt. The asphalt emulsion was added at a rate of 8.5 l/m², which correlates to 3.5% addition by weight. For the new construction the emulsion addition rate would be 14 – 15 l/m², corresponding to 6.0% emulsion by weight.

4.2 Initial Compaction

Once the mixing is completed the initial compaction was done using a Bomag BW-172 single drum vibratory roller. This roller has an operating weight of 6,550 kg.

4.3 Grading/Shaping

Following the initial compaction a motor grader grades the material to provide the longitudinal and transverse profile. The profiling of the road surface is critical to obtain a smooth riding surface on the finished roadway.

4.4 Final Compaction

Following the grading the final rolling operation is performed. The final compaction was done using a Caterpiller CB-335D combination steel drum and pneumatic roller. This particular combination roller has an operating weight of 3,620 kg. The rolling process provides a smooth finished surface, while providing compaction to the top layer of recycled material, which had been disturbed by the grading operation.

4.5 Sweeping/Sealing

The final stage in the operation involved the sweeping and sealing the finished surface. The sweeping removes any loose material remaining and provides a clean surface for the sealing operation. The sealing operation involves the spraying of a dilute CSS-1h asphalt emulsion in a “fog seal” application. The emulsion is typically diluted with water at 1:1 to 1:5 ratio applied at a spray rate of 0.45 – 0.70 l/m². Both the sweeping and fog sealing were done from one to three days following the recycling operation.

Figure 3a. Placement of Recycled Material

Figure 3b. Initial Compaction

Figure 3c. Grading for Final Profile

Figure 3d. Final Compaction of Surface

Figure 3. Full Depth Reclamation Process

5.0 CONCLUSIONS

The use of asphalt recycling (the FDR process) has achieved the goals originally set by Inco management. The process has provided an economical solution by reusing the existing road materials, improved the smoothness and durability and has kept the interruptions in mine production to a minimum. The use of superelevation in the curves and the improved smoothness have reduced the down time for maintenance on the trucks thus improving the mine's productivity. The FDR process has more than satisfied the people involved and will continue to be used to upgrade the mine as well as other mines in the area.

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