Shotcrete Application in the SNOLAB

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Abstract
The SNOLAB is an expansion of the Sudbury Neutrino Observatory and is being built as an underground laboratory for research by scientists around the world. The laboratory is located in an active CVRD Inco mine about 2 km underground and the construction of the facility will be completed in 2009. The excavation walls and back are reinforced with rock bolts and a 3 inch (7.5 cm) cover of King MS-D3 Accelerated Shotcrete, (meeting ACI Gradation #1) trowelled smooth by hand. This paper provides an overview of the project and describes the shotcrete application.

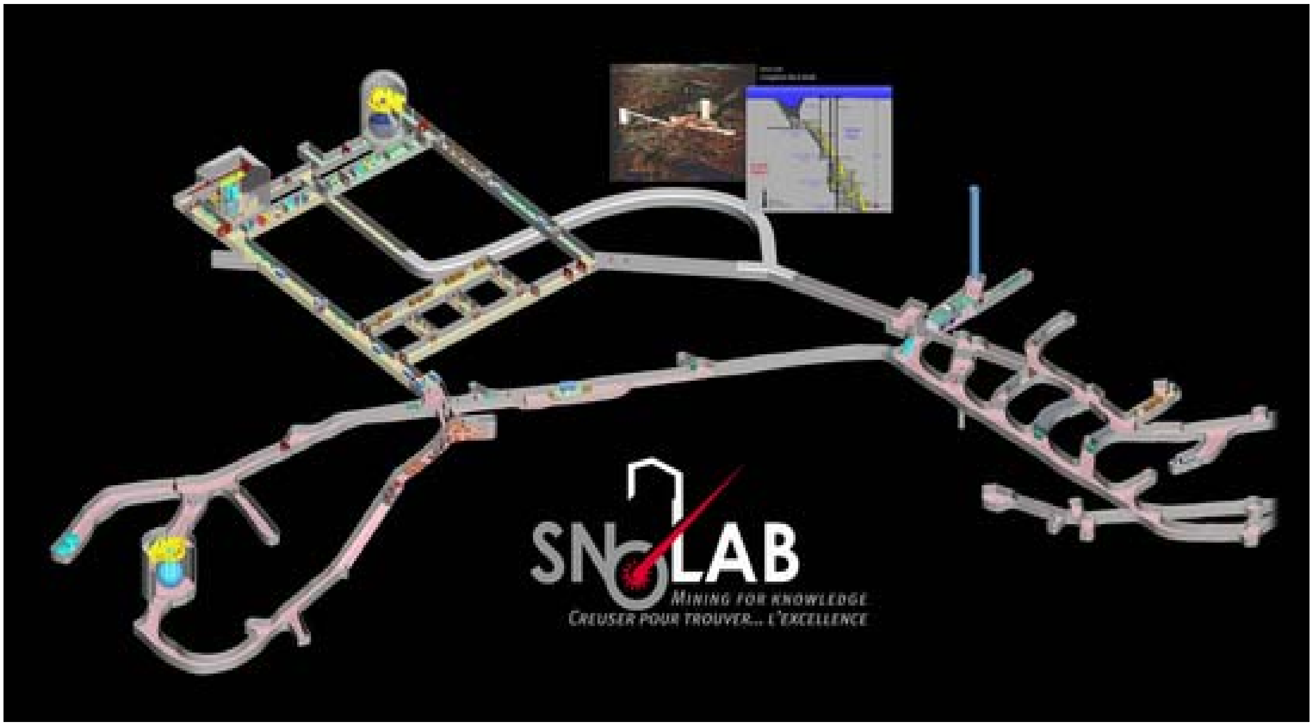
Introduction

The SNOLAB underground science laboratory is situated 6800 ft (2072 m) below surface at the CVRD-Inco Creighton Mine in Sudbury, Ontario. SNOLAB is an expansion of the existing facilities constructed for the Sudbury Neutrino Observatory (SNO) which were excavated between 1990 and 1993 and became operational in 1999. SNOLAB will have 53,000 sq ft (4924 sq m) of clean space underground for scientific experiments and the supporting infrastructure. SNOLAB is a project by a collaboration of Carleton University, Laurentian University, Queen’s University, University of Guelph, University of Montreal and the University of British Columbia. Funding is principally from the Canada Foundation for Innovation with significant contributions from the Northern, Ontario Heritage Fund, the Ontario Innovation Trust and FedNor. The primary contractor for excavation is J.S Redpath Ltd. The primary contractor for outfitting is Comstock Canada Ltd. And Project management by Hatch Energy.

SNOLAB follows on the important achievements in neutrino physics achieved by SNO and other underground physics measurements. The primary scientific goals of SNOLAB will be in the field of particle astrophysics, in which the primary topics for experiments include: low energy solar neutrino studies, neutrinoless double beta decay, cosmic dark matter searches and supernova neutrino searches. These are fields where the next generation experiments require great depths as shielding to reduce cosmic ray backgrounds produced in the Earth's atmosphere to very low levels. They also require extreme levels of cleanliness to reduce environmental radiological backgrounds to the levels necessary for these very sensitive experiments to succeed. SNOLAB achieves these goals by being located 6800 ft (2072 m) underground and by having the entire laboratory constructed as a single large clean room. The cleanliness will be maintained throughout the laboratory with a maximum particle count target of CLASS 10,000 with 10 air changes per hour with air circulation filtration capabilities.

SNOLAB Facility

The existing SNO underground laboratory consists of a large experimental cavern 72' 2’’ (22 m) in diameter and 96" (30 m) high with additional space for experiment and personnel infrastructure. To ensure that the laboratory maintains the necessary level of cleanliness, all personnel entering the laboratory must pass shower and change into clean clothing and all equipment is cleaned before entering the laboratory.
caverns and a large experimental hall and additional space for servicing these areas. The largest cavern will be 60 ft (18.3 m) long by 50 ft (15.1 m) wide and 65 ft (19.7) high to the top, the second cavern will be approximately 50 ft (15.1 m) in height and diameter, and the experimental hall will be 180 ft (54.9 m)



Artist's view of SNOLAB

The SNOLAB expansion will excavate an additional 991,000 cubic feet (28,062 m^3) of rock by adding 51,000 sq ft (4738 m^2) of space to the existing SNO facilities. The new excavations will include two large caverns and a large experimental hall and additional space for servicing these area. The largest cavern will 60 ft (18.3 m) long by 50 ft (15.1 m) wide and 65 ft (19.7m) high to the top, the second Cavern will be approximetly 50 ft (15.1 m) in the height and diameter, and the experimental hall will be 1180 ft (54.9m) long, between 20 and 25 ft (5.92 and 7.47 m) wide and between 18 and 25 ft (5.59 to 7.62 m) high. A conceptual; view of SNOWLAB is how in Figure 1.

Construction of SNOLAB

The SNOLAB exacavations are located adjacent to the existing SNO facility but far enough from it and CVRD Inco's mining activity that seismicity resulting from blasting does not harm existing and future experiments. An exploratory drilling program was carried out to finalize the location of the largest caverns. The access to the new development was planned such that the impact on existing experiment was minimal.

The excavation of the SNOLAB was started in October 2004 and the first phase which includes the rectangular cavern and the long experimental hall were completed in May 2007. The second phase which includes the cylindrical cavern has started and is expected to be completed in June 2008. The outfitting of the Phase 1 portion with services has started and is expected to be completed in February 2008. The progress on the excavation was limited by the capacity to dispose of excavated rock. Initially, the only mine skip hoist was used to haul rock to the surface. But as the metal prices started increasing in 2005, other alternatives such as disposal into mined stopes and crushing rock into road bed have been used.

The access drifts and top sill of the rectangular hall were drilled with a twin drill jumbo. The majority of the excavation will form part of the "Clean Laboratory", while the drifts outside remain as the mine side of the laboratory. The ground support specification for SNOLAB are equal or better than that in effect at the mine at this level. On the mine side it consists of # 4 galvanized screen with 8 ft long 3/4" diameter rebar bolts on a 4'x 2.5' pattern in the back and alternate rows of 6 ft long rebar bolts and 5'6" long galvanized split sets on the walls.

In the "Clean Laboratory", the ground support consists of # 4 gauge screen (not galvanized) with alternate 8 ft long modified cone bolts and rebar bolts in the back and alternate 6 ft long modified cone bolts and rebar bolts in the walls. In addition, the large caverns and large hall have 5/8" dia seven strand double cable bolts installed on a 5'x 5' pattern; the cables are 33 ft and 23 ft long in the back and the walls, respectively. A single pass of 3" minimum thickness King MS-D1 Accelerated Shotcrete is sprayed to cover screen and all protruding ground support. CVRD-Inco Creighton Mine, utilizes dry-mix shotcrete extensively throughout their mining cycle for the construction of backfill and ventilation barricades, garage and refuge station construction and ground support. Ground support applications vary. Shotcrete is used in the reconditioning of previously supported drifts, in new excavation (over bolts and screen) and also plays a crucial role while mining through paste-fill. When driving a drift through paste-fill, a two-pass Shotcrete system is used, often with steel fibre reinforced shotcrete as the first pass. Over 25,000 metric tonnes are sprayed annually and transported through various levels of the mine to be used by at least 10 construction and development crews. The mine owns and operates a fleet of Aliva rotor type Shotcrete machines used for spraying the material.

The first pass applied in SNOLAB is shot using an Aliva AL-262.1 shotcrete machine and the finish coat is applied with an ALIVA AL-246.5, fed by an Allentown pre-dampener.

Shotcrete mixing and pumping equipment

Requirement for Surface Finish
In the existing SNO laboratory the shotcrete walls are left unfinished, providing a very rough texture. In many areas, the screen and rock bolts are easily visible. The SNO detector cavern has a layer of Mineguard applied over the shotcrete which has a thickness of about 0.4” (1 cm). The Mineguard is used as both a radioactive barrier and to waterproof the shotcrete to create a large water filled cavity.

As the rock contains natural radioactive isotopes of uranium and thorium, it is very desirable to reduce the amount of their decay products which escape into the laboratory. One of the decay products of uranium is radon, which is a colorless and odourless gas at room temperatures which emates from the rock into the laboratory air. Radon is itself radioactive and decays, producing radioisotopes that create undesirable radioactive backgrounds in the clean laboratory that are very difficult to remove. In order to minimize the radon emanating from the rock, products such as Mineguard can used to seal the shotcrete and block the radon, however this is difficult if the shotcrete is extremely rough. Therefore it was desired that the new laboratory space have a smooth surface to make it easier to paint or to apply radon blocking materials. The smooth surface is also much easier to clean thus allowing a higher level of cleanliness in the laboratory space.

Shotcreting of drift walls in progress

Trowelling of finish shotcrete layer

The new underground experiments require low radioactive backgrounds, but they also require knowledge of the backgrounds that are present in the existing environment and building materials so that the appropriate shielding can be designed, if necessary, to filter out these backgrounds. Therefore samples of the rock from the walls from throughout the laboratory, and shotcrete and concrete samples were assayed by either chemical processes or through the use of gamma ray detectors to determine the uranium, thorium and potassium content, as these are the radiological materials that produce the dominant backgrounds that sensitive experiments want to avoid. The background levels measured from the rock were ~1.2 ppm uranium, ~5.5 ppm thorium and ~1% potassium, the shotcrete and concrete backgrounds were slightly higher, with ~2.6 ppm uranium, ~14 ppm thorium and ~1.6% potassium. These levels are comparable to the levels found in the materials used in the construction of the original SNO experiment. When experiments are constructed underground, most of the materials used in their construction will also be assayed for these radioactive backgrounds.

Based on the experience of the SNO detector, smooth finishes inside the clean spaces with painted walls and painted concrete floors were specified. Maximum waviness of the primary shotcrete surface was specified in the contract. The contractor was given an option to use an additional thin layer of mortar or shotcrete for trowelling the surface smooth. The contractor chose to use King MS-D1 Shotcrete, a non-accelerated shotcrete as a finishing layer and contracted the application of this material to MAH, a shotcrete contractor from XX, Quebec who specializes in this type of shotcrete application. Initially considerable effort was used to experiment with different types of primary and secondary shotcrete to obtain the desired finish acceptable to the scientists. Different types of paint were used on the finished shotcrete to obtain the desired painted surface.

Strict quality control was used to ensure that shotcrete provided adequate strength to the overall ground support. Test panels were shot regularly (every 2 to 3 days) with primary shotcrete and core samples tested for shotcrete strength. In addition core samples of the combined primary and secondary shotcrete were taken from the walls and tested for proper bond between the two layers.

Painted walls of Ladder Room

Since the first layer of Shotcrete was not finished, it had an excellent surface for allowing the transition between the first and second pass to have an excellent bond strength. Prior to applying the second pass, the area would be washed down with compressed air and water in order to saturate the surface and then all excess water is blown away with compressed air only. This leaves the accepting surface saturated but dry. This allows maximum bond between the layers. If the surface was not saturated, water from the cement paste would be absorbed into the pores of the previous layer of Shotcrete and bond strength would be reduced. Alternatively, if the area had excess water on the surface, this water would get mixed in the cement paste of the initial second pass and decrease the water coment ration and in turn decrease the bond strength.

During the excavation of the cavern, certain areas of the finished Shotcrete were damaged by fly rock. In order to repair these areas and return them to a smooth surface, King's Super Top product was used as a patching material. Ideal for both horizontal and vertical applications, Super Top brought the surface back to the specified geometric tolerance. These areas were also tested for bond strength to ensure no voids or delaminating would be present in the finished coating.