Shotcrete Application in SNOLAB

by Satish Bhan, Fraser Duncan, Ian Lawson, and Craig McDonald

The SNOLAB underground science laboratory is situated 6800 ft (2072 m) below ground at the CVRD-Inco Creighton Mine in Sudbury, ON, Canada. SNOLAB is an expansion of the existing facilities constructed for the Sudbury Neutrino Observatory (SNO) that were excavated between 1990 and 1993 and became operational in 1999. SNOLAB will have 53,000 ft^2 (4924 m^2) of clean space underground for scientific experiments and the supporting infrastructure. SNOLAB is a project constructed by a collaboration of Carleton University, Laurentian University, Queen's University, University of Guelph, Université de 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 is 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 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 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.

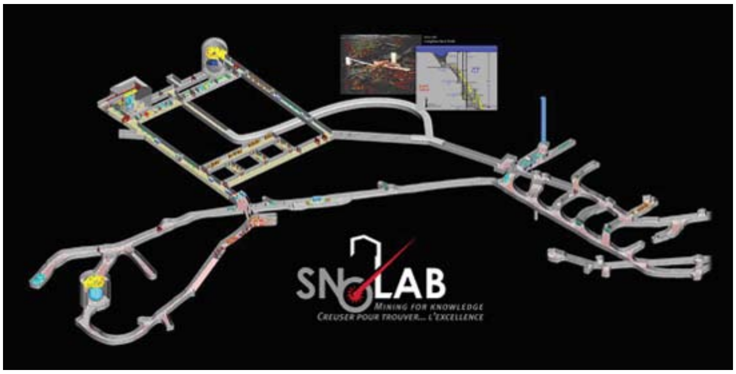

Fig. 1: Artist's view of the SNOLAB

SNOLAB Facility

The existing SNO underground laboratory consists of a large experimental cavern 72 ft (22 m) in diameter and 96 ft (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 shower and change into clean clothing and all equipment is cleaned before entering the laboratory.

The SNOLAB expansion will excavate an additional 991,000 ft^3 (28,062 m^3) of rock adding 51,000 ft^2 (4738 m^2) of space to the existing SNO facilities. The new excavations will include two large caverns, 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 m) 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) 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 SNOLAB is shown in Fig. 1.

Construction of SNOLAB

The new SNOLAB excavations 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 experiments was minimal.

The excavation of SNOLAB was started in October 2004 and the first phase, which includes

Fig. 2: Process of shotcreting in cavern

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 beds 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 whereas the drifts outside remain as the mine side of the laboratory. The ground support specifications for SNOLAB are equal to or better than that in effect at the mine at this level. On the mine side, it consists of No. 4 galvanized screens with 8 ft (2.4 m) long, 0.75 in. (19 mm) diameter rock bolts.

In the Clean Laboratory, the ground support consists of No. 4 gauge screen (not galvanized) with alternate 8 ft (2.4 m) long modified cone bolts and resin bolts in the back and alternate 6 ft (1.8 m) long modified cone bolts and resin bolts in the walls. In addition, the large caverns and large hall has 5/8 in. (16 mm) diameter seven-strand double cable bolts installed on a 5 x 5 ft (1.5 x 1.5 m) pattern; the cables are 33 ft (10 m) and 23 ft (7 m) long in the back and the walls, respectively. A single pass of 3 in. (75 mm) minimum thickness King MS-D3 Accelerated Shotcrete is sprayed to cover the screen and all protruding ground support. CVRD-Inco Creighton Mine uses 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 excavations (over bolts and screen), and also plays a crucial role when mining through paste-fill. When driving a drift through paste-fill, a two-pass shotcrete system is used, often with steel fiber-reinforced shotcrete as the first pass. Over 27,500 tons (25,000 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 predampener.

Requirement for Surface Finish

In the existing SNO laboratory, the shotcrete walls have been 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 that has a thickness of about 0.4 in. (10 mm). 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 that escape into the laboratory. One of the decay products of uranium is radon, which is a colorless and odorless gas at room temperature that emanates 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. To minimize the radon emanating from the rock, products such as Mineguard can be used to seal the shotcrete and block the radon. This is difficult, however, if the shotcrete is very 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.

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 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 with 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 with the SNO experiment, 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 troweling the surface smooth. The contractor chose to use King MS-D1 Shotcrete, a nonaccelerated shotcrete, as a finishing layer and contracted the application of this material to Béton Projeté MAH, a specialty shotcrete contractor from Beaupré, QC, Canada, 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.

Fig. 3: Shotcreting of drift walls in progress

Fig. 4: Trowelling of finish shotcrete layer

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.

Because the first layer of shotcrete was not finished, it had a good surface texture for allowing the transition between the first and second pass to have excellent bond strength. Before applying the second pass, the area would be cleaned with compressed air and water to saturate the surface and then all excess water is blown away with compressed air only. This leaves the accepting surface saturated but dry (the so-called SSD condition) and 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-cement ratio and in turn decrease the bond strength.

During the excavation of the cavern, certain areas of the finished shotcrete were damaged by fly rock from blasting. To repair these areas and return them to a smooth surface, King's Super Top HV Polymer-Modified Patching Material 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 delaminations would be present in the finished coating.

To summarize, shotcrete plays a vital role in the construction and performance of the SNOLAB at the Sudbury Neutrino Observatory.

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Craig McDonald *is Sales Manager for the Mining Markets Division of King Packaged Materials Co. Equipment for both the wet- and dry-mix shotcrete process as well as the mixing and placing of dry-mix concrete and grout products are his areas of expertise. He is a graduate of the Mechanical Engineering Technology program at Canadore College, North Bay, ON, Canada.*

Fig. 5: Painted walls of Ladder Room