Montana Tech Research Interests
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Homestake DUSEL Letter of Interest

Both the Departments of Geological Engineering and Mining Engineering at Montana Tech of the University of Montana have recently conducted rock mechanics research in the following areas: (1) rock stress determination, (2) instrumented rock bolts, and (3) backfill stability when used in the cut-and-fill mining method. The first two were conducted in concert with NIOSH's Spokane Research Laboratory and Mary MacLaughlin was the principal investigator. The third research topic was conducted by Rich McNearny and was funded through a variety of sources. The funding was limited, but the Department of Mining Engineering was able to produce one graduate student with this research program. Mary MacLaughlin produced numerous graduate students with the first two research topics. All three areas of research involved an extensive numerical modeling component using all of the Itasca discrete element codes.

We would like to continue and extend all three areas of research into the DUSEL program so that we would be conducting our research investigations at deeper depths and in a higher stress environment. We feel that this is essential as future mining in the U.S. will eventually have to exploit much deeper mineral deposits if it is to maintain any semblance of mineral independence.

In addition to an extensive collection of commercial numerical modeling software packages, Montana Tech also has state-of-the-art rock triaxial shear testing equipment. The original load frame was delivered in 1993 by TerraTek of Salt Lake City and was recently upgraded to the latest in data acquisition software and instrumentation, high temperature measurement capability, pore pressure measurement and permeability testing capability. The maximum confining pressure is 20 000 psi with an axial load capacity of 330 000 lbs. This equipment would be available for use by other researchers at the Homestake DUSEL site.

Thus, Montana Tech would like to see the following research investigations at the Homestake DUSEL site: (1) an extensive rock bolt research program that would test instrumented rock bolts at higher *in situ* stresses provided by the Homestake DUSEL site (2) a backfill testing program at greater depth than is currently available at conventional mining locations, and (3) a large diameter excavation research program. It should be noted that since numerical modeling is becoming more and more important, an extensive numerical modeling program, involving the Itasca codes, DDA and finite element codes available on the Montana Tech campus, should accompany each of the proposed research programs. Since the experiments would be at great depth, rock temperature measurements will be made as part of the data collection routine.

The rock bolt research program would attempt to define the actual stress distribution and deformation (both axial and shear) along the entire length of the bolt at high *in situ* stress levels. The bolts would be installed into varying rock types at the deepest levels of the Homestake site. In addition, the bolts would be installed through more than one rock type to evaluate bolt performance when crossing rock type boundaries. Determination of the *in situ* stress distribution would be necessary and perhaps could be conducted with another investigator at the Homestake site. Similar to the procedure defined in earlier research at Montana Tech, DDA, FLAC and PFC numerical models would be constructed and calibrated to the performance of the bolts. The models could be used to test additional loading and rock type variations that would not be available within a limited budget. An estimated schedule of 2 to 3 years and an approximate budget of $250 000 would be needed.

The backfill research program would follow from the cemented rockfill research program currently underway at Montana Tech. Past studies have evaluated how gradation of the rockfill, cement content and curing times would affect backfill performance relative to how well cemented rockfill would resist blasting stresses and stresses induced by draw of the adjacent broken ore. This type of work would be continued at the Homestake site, except with the addition of the higher *in situ* stresses that would occur at this site. Past work at Montana Tech has indicated a significant negative influence on backfill performance by increased *in situ* stress. Again, an extensive numerical modeling program would also be performed. This research program would take 3 to 5 years and would have a budget of $350 000.

Physicists who are interested in the DUSEL site have expressed a desire to have exceptionally large openings be excavated at the Homestake DUSEL site, such as a 60-m diameter by 50-m high opening located at a depth of 2150 m for the proposed liquid argon detector. To investigate whether or not such large openings are feasible, a research program should be conducted that would evaluate rock performance under these extreme excavation conditions. A depth will be chosen, based on previous geological investigations, where an excavation will be located for a selected opening size. An extensive instrumentation program, to include *in situ* stress measurement, deformation measurement with extensometers, and other instrumentation, would be installed prior to excavation. Monitoring of the changes in the rock by the instrumentation during excavation should provide valuable information on rock behavior as it reacts to the mining sequence. Monitoring of the excavation for many years after the project could continue as the opening is used for physics experiments. A series of numerical models would again be constructed in an attempt to predict behavior of the opening and the surrounding rock. The schedule for this research program would be one to two years to install the instrumentation, one to two years for the excavation, and up to 10 years for the long-term performance phase. The budget would be $1 000 000 to $2 000 000.

An extensive research program, such as the last one proposed, will likely involve multiple investigators from numerous academic institutions, government research laboratories and private companies. This type of research program will need to be submitted as a cooperative effort by interested Homestake DUSEL investigators.

A more detailed example of a rock mechanics experiment follows:

Large Scale True Triaxial Test Apparatus

An *in situ* test apparatus that will utilize a pillar-sized test specimen at the Homestake DUSEL site is proposed. This large-scale experiment would be useful to the rock mechanics research community as a way of overcoming the common concern that smaller laboratory test specimen are too small to evaluate the influence of large-scale discontinuities of a rock mass, especially with regard to changes in stress path of the rock during excavation (Andersson, et al., 2004).

Information needed prior to construction that would influence the location and orientation of the rock pillar test specimen are the following:

1. rock mass classification,
2. a thorough characterization of the spacing and orientation of local discontinuities, as the size of the isolated pillar specimen will be determined by them, and the
3. initial *in situ* stress field.

The construction sequence is relatively straightforward: 1) drive two parallel drifts that would define one dimension of the pillar specimen, 2) drive two parallel crosscuts perpendicular to the first two drifts to define a second dimension, 3) scale loose rock and trim faces of the pillar flat, 4) apply an "impermeable membrane," such as a sprayed epoxy, which will prevent seepage from the test specimen and will isolate the rock specimen from the mine environment, 5) install loading plates and loading rams, 6) drill holes in the rock specimen and the adjacent country rock for instrumentation probes and install the probes, 7) after applying a low level of load to the loading rams, separate the test specimen from the roof and floor of the drifts by cutting through with a wire rope so that shear stresses will not develop at these locations during testing , 8) after releasing the loads in the loading rams, install flat jacks at the top and bottom of the rock specimen, and 9) attach leads to the instrumentation cart.

Instrumentation that would be utilized include directional borehole strain gages, stress cells, extensometers, heaters and temperature gages, geophones and other geophysical instrumentation, and piezometers.

Possible experiments could include:

1. load/unload cycling with pore pressure measurement,
2. permeability testing with the possibility of injecting different fluids,
3. creep testing,
4. acoustic emissions experiments under varying load conditions,
5. geophysical measurements under varying load scenarios,

6. verification of numerical modeling codes against a tightly controlled physical experiment, and finally,
7. loading of the pillar specimen to failure if one is willing to destroy the specimen.

Properties that would be measured include:

1. large scale directional stiffness of the jointed rock mass,
2. permeability of the rock mass under variable stresses and pressure gradients,
3. pore pressure response under variable stresses and pressure gradients
4. changes in rock mass properties influenced by variable thermal gradients, and
5. strength of the rock mass.

In addition to addressing unanswered basic scientific questions about rock masses properties and rock mass response under tightly controlled experimental conditions, this particular test arrangement will also provide essential design information for the large caverns that will be excavated at the Homestake DUSEL site.

Reference:
Andersson, J. C., C. D. Martin and R. Christiansson. (2004) "SKB's Äspö Pillar Stability Experiment, Sweden," in Gulf Rocks 2004: Rock Mechanics Across Borders & Disciplines. Proceedings of the 6th NARMS Conference, Houston, June 2004, D. P. Yale, S. M. Willson, and A. S. Abou-Sayed, Eds. Paper no. ARMA/NARMS 04-503.