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DOE/AL/31950--T8

ANNUAL STABILITY EVALUATION OF

WASTE ISOLATION PILOT PLAN

PREPARED BY

U. S. BUREAU OF MINES

JUNE, 1993

DISCLAIMER

EXECUTIVE SUMMARY

A stability evaluation of the underground workings of the Waste Isolation Pilot Plant (WIPP) was completed by the U.S. Bureau of Mines' WIPP evaluation committee. This work included a critical evaluation of the processes employed at WIPP to ensure stability, an extensive review of available deformation measurements, a 3-day site visit, and interviews with the Department of Energy (DOE) and Westinghouse staff.

General ground control processes are in place at WIPP to minimize the likelihood that major stability problems will go undetected. To increase confidence in both short- and long-term stability throughout the site (underground openings and shafts), ground stability monitoring systems, mine layout design, support systems and data analyses must be continuously improved. Such processes appear to be in place at WIPP.

INTRODUCTION

Public Law 102-579, the Waste Isolation Pilot Plan (WIPP) Land Withdrawal Act of 1992, states that "the Bureau of Mines of the Department of the Interior shall prepare an annual evaluation of the safety of WIPP." The U. S. Bureau of Mines (USBM), a mineral research and information agency, interprets this charge to be an annual evaluation of the stability of the underground workings of WIPP. The objective of the evaluation is to validate the ground control processes employed at WIPP that will lead to stable roof (ceiling), rib (walls), and floor (mine bottom) of the underground facility.

The first annual evaluation under the Public Law was conducted by three USBM engineers who have extensive professional experience in the application of ground control principles in evaporite and other mineral deposits in both the United States, Canada, and Australia. The site visit was conducted April 26-28, 1993.

Ground control processes that influence stability include the structural mine design, the stability monitoring plan, and the opening maintenance program. The processes involved were evaluated on the basis of available mining engineering reports, geotechnical data, maps of underground structures, extensive underground surveys, interviews with DOE/Westinghouse personnel, and comparisons with pertinent geotechnical data from selected evaporite mines.

STRUCTURAL MINE DESIGN

The structural design of the underground layout at WIPP has been an iterative process in which a transition from the preliminary design to a detailed design was accomplished between 1978 and 1984. Initially, empirical methods, local mining experience, analytical solutions, and numerical modeling techniques were used. A detailed design was completed in 1984 by integrating 1) information on lithologic variations from underground maps and 2) geotechnical data from an experimental site and preliminary design validation program (SPDV, Plate 1). This iterative process is common in mining engineering practices when designing underground structures in geologic material where deformation behavior is difficult to characterize on the basis of small-scale laboratory tests of drill core.

Information obtained from short-term measurements (1982-1984) in the area of the SPDV formed the basis for the final design of the waste storage area. Between 1986 and 1988, a seven-entry waste panel was excavated using geometries and stratigraphic positions similar to those tested in the SPDV rooms; this panel was originally designed to operate for 5 years. Because of evolving experimental design conditions, the panel's experimental life has been extended beyond the 5-year design period. Extensive supplementary support has been added in key rooms 1 and 2 to accommodate the longer service life of the panel (Plate 1).

Long-term measurements have provided informative data into the behavior of salt, indicating that several geologic, geometric, and support factors may need to be re-evaluated to ensure long-term stability at WIPP. These factors are: 1) opening geometry and shape, 2) opening position with respect to lithologic interfaces (clay seams), 3) opening age, 4) supplementary support, 5) pillar dimensions, and 6) mining sequence.

To evaluate the effectiveness of supplementary support in extending the life of an opening having unfavorable geometric and lithologic conditions, a supplementary support system was designed by Westinghouse (operators of the WIPP facility) and is being monitored in room 1, panel 1. The effectiveness of this support system in controlling roof movements is critical to ensuring long-term stability. A final design incorporating optimum geologic, geometric, and support systems needs to be completed if panel life is to exceed the current estimate of 5- to 8-years.

Long-term stability is important in waste handling and storage. The Department of Energy has determined the main access openings should have an estimated life of 40 years, Waste panel 1 should be accessible for a minimum of 11 years, and other waste panels should be operable for a minimum of 5 years. As the openings age, their structural integrity will generally be deteriorated, requiring support and maintenance. Instrumentation and monitoring are key processes in place at WIPP to identify unstable ground conditions so that supplementary support can be allocated on a timely basis.

STABILITY MONITORING PLAN

Rock mechanics instruments can provide two important functions. First, they can monitor the performance of openings and pillars of different dimensions; this is important for developing optimum structural design to ensure the long-term stability of the underground workings. Second, they are routinely used to assess structural stability of the mine roof at specific locations. Existing measurements, underground observations, and engineering judgement are used to determine if there is a need for additional instruments or if maintenance of the opening should be initiated.

Structural stability of the underground workings is influenced by roof, floor, and pillar behavior and the interaction of these elements. Roof deformation measurements are most suitable for monitoring roof stability. Roof-to-floor convergence measurements include total deformation of the roof and the floor. Measuring total deformation makes it difficult to segregate roof movements from floor movements, but in practice it is a common engineering technique used in the mining industry to detect roof stability problems. Measurements of horizontal convergence of ribs and lateral movements of pillars are useful when monitoring rib and pillar stability.

Plate 1 shows the location of roof deformation and roof-to-floor convergence measurements that were both available and up-to-date; additional convergence data exist but were not available in a format suitable for inclusion in this evaluation. Deformation measurements obtained from the instruments shown in Plate 1 have been analyzed and form the basis for this evaluation. Lateral pillar movements and floor movements were also reviewed.

The following procedures are used at WIPP for assessing roof stability. The convergence measurements are obtained on a bimonthly basis. The results are compared to predicted values using site-specific equations, the relation of closure rates and room dimensions, and the age of the excavation. In areas where closure rates exceed predicted limits in a consistent manner, the frequency of monitoring is increased unless the rate increase could be related to other factors, such as instrument damage or nearby mining. In addition, access to the area is limited to persons taking convergence measurements when the convergence rate reaches a critical limit of 4.5 in/yr. and is restricted to all underground persons when the convergence rate reaches 6 in/yr.

A WIPP report is completed every 3 months by Westinghouse which contains the geotechnical data and observations. The report is circulated to their technical staff. A summary of roof bolt failures during the reporting period is also included. Other weekly underground inspections are performed routinely by Westinghouse; these are local assessments and are not effective for addressing overall structural stability of WIPP.

Instruments to monitor convergence are adequate for minimizing the potential for the occurrence of undetected roof failure at instrument locations. Improvements in real-time monitoring, in the type of instrument (i.e., those that measure roof deformation versus convergence), instrument spacings, and predictive equations should be implemented to ensure roof stability of the underground workings. Most of these improvements are either being considered or implemented by WIPP's operator.

Unlike predictive models of roof stability, there are no criteria for pillar stability. Pillar behavior influences roof movements and support effectiveness and is important when designing future access openings and waste storage panels. There is a need to re-examine pillar dimensions and the mining sequence using the geotechnical data and the experience in WIPP and evaporite mines.

Floor movements have been monitored by Westinghouse using a few floor extensometers, extensive observation holes, and level surveys. These observations are useful in identifying the interaction among roof, pillar, and floor structural members. Floor movements have been mostly gradual and not a significant concern (approximately 1 in per year).

OPENING MAINTENANCE

Opening maintenance is used routinely to remedy roof, floor, and rib conditions (movement and fracturing) that might create hazards. Maintenance consists of milling the floor, repairing damaged floor areas with compacted salt, removing fractured slabs by manual or mechanical means, and installing supplementary support to reinforce the roof and the ribs.

When ground conditions deteriorate at WIPP, remedial actions include: 1) installing supplementary support, 2) mining the fractured rock salt, or 3) restricting access. There is a need to verify the effectiveness of different supplementary support systems to ensure structural stability and to minimize the likelihood for roof bolt support elements to fail and fall to the floor. In addition, mining the roof, floor, and ribs may need to be re-evaluated because such mining influences opening geometry and opening position with respect to lithological interfaces and may unfavorably influence long-term stability.

ANNUAL STABILITY EVALUATION

The criterion used for this evaluation was influenced by the existing geotechnical data base at WIPP and the stability criterion used in selected evaporite mines. Since roof-to-floor convergence instruments were generally extensive in WIPP, the rate of convergence was chosen as the most appropriate criterion for this annual evaluation. Using the rate of convergence is common in the mining industry and the critical rates used by WIPP are in general lower than those used in selected evaporite deposits (Table 1). To increase confidence in detecting stability problems, it would be useful to measure roof deformation. Roof deformation was analyzed, but could not be effectively used because of the limited numbers of instruments at WIPP. This information was supplemented by personal experiences of the evaluation committee.

TABLE 1-CONVERGENCE RATE CRITERIA FOR SELECTIVE EVAPORITE MINES AND FOR WIPP

	MINE 1	MINE 2	WIPP
CONVERGENCE RATE (IN/YR)	14.6-18.2	9.1	4.5

Total amount of roof deformation, roof deformation rate, amount of roof-to-floor convergence, and convergence rate were calculated for all the instruments shown in Plate 1 (actual data Plates 2-5). The convergence measurements were compared with WIPP closure rate criteria and to that used in selected trona and salt mines. All convergence rates were below the critical limit of 4.5 in/yr, indicating little likelihood of short-term roof stability problems at the instrument locations. WIPP's bimonthly convergence measurements provide a larger base than that shown in Plate 1; there are 17 locations where measured convergence rates are higher than the predicted rate, but lower than the critical rate. Assuming that there will be no human error interpreting the data, WIPP operators should be able to assess opening stability and provide stable roof until the next evaluation.

Mine floor and pillar ribs have deformed and fractured. These deformations are gradual and moderate in magnitude (less than 1 ft). Timely reinforcement and meshing of the ribs has been effective in minimizing the potential for major rib instabilities. Floor deformation is not considered a major stability concern.

CONCLUDING REMARKS

Compared to general ground conditions in evaporite mines, those at WIPP are better due to gradual strata deformations, extensive monitoring, conservative stability criteria, and planned opening maintenance activities. Conditions will not be as problematic as producing evaporite mines. To minimize the potential for stability problems, there is a need to continuously improve ground stability monitoring systems, both in underground workings and the shafts at WIPP, and to enhance opening stability through improved mine layout design and support systems. This is to minimize reliance on judgment for decision making. Such processes appear to be in place at WIPP.

Since the life of the facility openings and waste storage panels may extend significantly beyond the original design life, it is increasingly important to generate additional geotechnical data for optimizing stability and for improving facility design. In addition, considerations should also be given to more extensive use of proper type of instruments such as extensometers and roof and pillar deformation data to improve predictive models. Existing predictive models incorporate floor movements and are based on information from a limited number of roof falls. Since actual roof fall data from the area subjected to previous thermo-mechanical loading tests are scarce, it is important to increase instrument coverage immediately in this area and facilitate remedial actions (roof and pillar support) in all those areas influenced by past thermal experiments until more confidence is gained in the predictive model.

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