PRESSURE GROUT RECLAMATION PROCESSES CONDUCTED INSIDE A BUILDING[1]

by

Bruce E. Beechie[2]

ABSTRACT

The Abandoned Mine Lands Division (AML) of the North Dakota Public Service Commission implemented a pressure grouting reclamation project during the fall of 1992 that included rotary drilling and pressure grout injection inside a 12,000 square foot (1,115 square meter) building (Eagles Club) in Beulah, North Dakota.

To our knowledge, a large scale drilling and grouting project of this nature has not been documented and this reclamation project proved to be very interesting and challenging. Depth to the ten foot (3 meter) thick mined lignite seam averaged 70 feet (21.3 meters) below ground surface, however, pre-reclamation exploratory drilling indicated the unmapped mine workings were in an advanced stage of collapse and many void/rubble areas were encountered within 20 feet (6.1 meters) of surface. Normally, rotary drilling, angle drilling and grouting would have been implemented for this type of subsidence prevention, however, in consideration of the size of the structure (100 feet x 120 feet) (30.5 meters x 36.6 meters) and the close proximity to surface of the void and rubble zones, drilling and grouting inside the building was deemed necessary to stabilize the structure.

Concerns with this approach to reclamation included the potential for lifting or "jacking" the structure foundation and/or floor, monitoring of injected material into the flooded mine workings and rubble, design and monitoring of an injection sequence that would eliminate the potential for ground water discharge to surface, and sufficient spacing of injection holes to optimize infill of the grout material.

ADDITIONAL KEY WORDS: Public Health and Safety, Rotary Drilling

---

[1] Presented at the 15th Annual Meeting of the Association of Abandoned Mine Land Programs, Jackson, Wyoming, September 13-15, 1993.

[2] Bruce Beechie is AML Project Manager, State of North Dakota, Public Service Commission, Bismarck, North Dakota 58505-0480.

INTRODUCTION

Pressure grouting of abandoned underground mine workings has proven to be an accepted procedure for successful subsurface stabilization. A full-scale pressure grouting reclamation project was implemented to stabilize high-use areas of a 60 acre (24.3 hectare) underground mine located within the town of Beulah in Mercer County, North Dakota. Areas delineated for reclamation included a two block area within a trailer court, numerous roads, an electrical substation, parking lot and the Beulah Eagles Club.

Generally, rotary drilling and angle drilling are utilized to provide the means to inject a cementitious grout into abandoned mine workings and rubble zones. However, it was determined by North Dakota's AML Division that drilling and grouting from inside the 12,000 square foot (1,115 square meter) Eagles Club was deemed necessary to stabilize the structure from the collapsing mine workings. A total of 12,000 cubic yards (9,175 cubic meters) of cementitious grout was injected into the abandoned mine workings of which 500 cubic yards (382 cubic meters) was injected from inside the Eagles Club. A total of 21 holes were drilled inside the building with 7 of those being used for grout injection.

The Beulah Coal Mining Company operated the underground lignite mine from 1919 through 1922 and provided coal for sale to local residents, as well as fuel for a power plant situated adjacent to the mine site. Mining was accomplished by the room and pillar method. A pre-mining schematic design map was available, however, exhaustive exploratory drilling had proven the mine map to be inaccurate and incomplete.

Although an extensive reclamation project was completed, this paper will focus mainly on methodology leading up to and including subsidence prevention processes conducted inside the Eagles Club.

PRE-RECLAMATION INVESTIGATION

Exploratory drilling of suspected mined areas was implemented during the winter of 1991, six months prior to reclamation construction. Exploratory drilling was accomplished utilizing rotary drilling equipment. The intent of rotary drilling was to determine depth to voids and rubble zones, coal extraction methodology, size and extent of the mined workings, integrity of the abandoned mine (intact, collapsing etc.), presence or absence of ground water and site specific lithology.

Information gleaned from the exploratory drilling program was used in determining grout material flowability requirements, injection hole spacing and grout volumes required to fill the

abandoned workings. Exploratory drilling was not conducted inside the building. However, systematic drilling around the periphery of the building on 10 foot (3 meter) centers provided us the required information to extrapolate potential mining trends and room locations under the structure.

Generally, exploratory drilling indicated the abandoned mine to be in an advanced stage of collapse. The original mine elevation of 70 feet (21.3 meters) below surface had experienced substantial roof collapse and pillar failure with numerous rubble zones being located within 20 feet (6.1 meters) of surface. In areas where the mine was intact, the workings were inundated with ground water. Advanced stages of collapse are further evidenced by documented accounts of two sinkholes surfacing near the building foundation. An underground video camera was available for use, however, the flooded workings and rubblized nature of the voids thwarted extensive use of the camera equipment.

Due to the presence of ground water in the mined coal seam, six monitor wells were installed within the project boundary. The monitor wells were strategically situated to determine geochemical and hydrologic components of the aquifer. The well screens were completed in pillars of the mined coal seam. An aquifer (pump) test was conducted by AML personnel utilizing In-Situ Inc. equipment and results indicated the mining zone to be highly transmissive. One of our concerns initially was the reaction of the ground water when grout injection processes began. The monitor wells were checked frequently during injection and showed only slight water level increases. The AML staff felt confident the ground water was being displaced laterally rather than vertically during injection processes.

INTERIOR PREPARATION

Prior to reclamation activities inside the Eagles Club, arrangements were made between Eagles Club officers and AML personnel to schedule closing of the Club for nine days. It was estimated that 20-25 interior holes would be drilled and 835 cubic yards (639 cubic meters) of grout would be injected from inside the building. Nine days was considered sufficient time for reclamation activities and clean-up inside the Club.

A pre-construction survey of the Eagles Club interior and exterior was conducted prior to beginning work. The survey was conducted by the AML project manager, the contractor's superintendent and an engineer contracted by AML. A map was generated and photographs were taken of all structural flaws (cracks, settling, separation etc.) of the foundation, floor, walls and ceiling. Also, a video camera was utilized to document the pre-construction condition of the building. A pre-construction survey was considered a necessity because the

documentation would relieve the contractor and contracting agency of potential claims if unwarranted disputes arise. Additionally, this documentation provides solid evidence to the contracting agency in the event a contractor is liable for damages.

As could be expected, the inside of the Eagles Club contained a bar, dining room, large dance hall, kitchen, numerous bathrooms, offices, power room and storage rooms. Approximately one-half of the interior floor was carpeted and the other half was tiled. A suspended ceiling had been constructed eight feet above the floor level. Prior to beginning work inside, plastic sheeting was used to cover the floor, walls, bar, tables, video games and pool tables. Electronic tracing services were required to delineate sewer line locations inside the building.

RECLAMATION PROCESSES

Prior to interior drilling and interior grout injection, it was deemed necessary to have the contractor begin grouting operations in areas located outside of the Eagles Club to allow AML personnel and the contractor's grout pump operators to get a "feel" for safe and allowable injection pressures. It was determined during the pre-reclamation pump test that ground water flow was in a southeasterly direction. Grout injection was initiated approximately 100 feet (30.5 meters) west of the building and commenced in an easterly direction in an effort to displace mine water down-gradient, correlative with the pre-reclamation flow regime.

The grout material injected was composed of aggregate, powdered sodium bentonite, Portland cement and sufficient water to produce a ten inch (25.4 centimeter) slump grout. Flyash was not a consideration for use as a grout component. North Dakota's State Health Department does not allow the use of flyash as a grout material admixture in underground saturated mines because of their concern for potential toxic leachates (specifically heavy metals) from the flyash. Mine water was used as make-up water for grout formulation and was extracted from the pump well (used during the pump test) and located at the eastern limits of the project area. The well was completed and screened in the fractured coal seam and provided sufficient water to maintain four concrete mixer trucks operating continuously.

Early on, problems were encountered with "sand locking" in the injection pipe due to material separation in the grout during pumping. Numerous line-loss tests were then conducted utilizing various mix designs and material slumps until the contractor and AML personnel felt comfortable with the flowability and pumpability characteristics of the grout. Injection of grout into void and rubble zones was accomplished by emplacing a 2 inch (5.1 centimeter) diameter injection tube or "tremmie pipe" at the bottom of the drilled void and rubble zones. Nearly all drilled

holes were completed into the underclay (below the bottom of mined coal seam). Bottom-up tremmie grouting was then employed to backfill the mined workings. The tremmie pipe was secured, raised and lowered by the use of portable hydraulic lifting jacks.

During pressure grouting outside of the building, grout was injected to the bottom of the void and rubble zones until injection pressures approached what was considered to be unsafe, or until the ground began cracking noticeably, or until formation refusal and subsequent grout rejection up the annulus of the injection hole. At that point the tremmie pipe was tremmied up-hole in 2 foot (.6 meter) intervals and injection resumed until all of the void and rubble zones were filled to refusal. In the few areas where mined workings were still intact (haul tunnels), the tremmie pipe was placed at the top of the void (in the coal roof) and grouting was conducted until refusal.

The interior drilling program was designed to systematically delineate room and tunnel location. Previous exploratory drilling outside of the building indicated a northwest to southeast trend mining scheme. Room dimensions averaged 25 feet (7.6 meters) in width and up to 130 feet (39.6 meters) in length. Haul tunnels averaged 10 feet (3 meters) in width. With this in mind, a line of holes on ten foot (3 meter) centers was drilled across the entire length of the building through the bar and lounge area, dining room and dance hall. Once voids and rubble zones were encountered, the remaining portions of the rooms were "chased down" by the drilling rig to allow for a maximum spacing of 30 feet (9.1 meters) between injection holes. Carpet and tiles were cut and removed in those areas designated as drill hole sites.

Interior drilling proceeded with the use of a home-made portable rotary drilling rig. The drilling rig was over 8 feet (2.4 meters) in height, which required removal of the suspended ceiling panels directly above specific drill hole locations. Once the drilling rig was set up, four holes were drilled through openings in the rig's base plate into the concrete floor and the rig was bolted securely to the concrete floor.

Mechanically, the drilling rig was operated by hydraulics. Circulation was provided by the use of a trailer-mounted air compressor. Rotary drilling with soap and water injection was utilized to enhance circulation and bit penetration. The drill rig operator, power plant, air compressor and accessory equipment were all located outside of the building. Air lines and hydraulic hoses were extended from the outside-located equipment to the drilling rig located inside the building. A vacuum truck (also located outside) equipped with a 4 inch (10.2 centimeter) diameter flex hose was used to extract drill cuttings from the annulus during drilling operations.

Immediately after drilling a void or rubble hole, the grout injection pipe was emplaced in the hole and prepared for pressure

injection. Liquid-filled diaphragm in-line gauges were utilized to monitor pumping pressures at the injection point.

Drilling and grouting commenced inside the building concurrently. Schwing BP 750 RD Model portable trailer-mounted grout pumps were utilized. These pumps were set up outside the building and a grout supply line was routed through the building's doors to the void or rubble holes located inside and grout injection commenced. During injection, bubble levels were positioned on three sides of the grout injection hole to monitor potential surface heaving or jacking of the floor.

Grout was supplied to the pumps by the use of concrete mixer trucks. Batching of the grout was accomplished on-site by the use of a portable batch plant. The batch plant was certified to National Ready-Mixed Association requirements. Previous monitoring of injection pressures during grouting outside the building was used to gauge maximum allowable injection pressures inside the building. Numerous variables were considered in determining allowable injection pressures and back pressure, the most important being depth below surface to the void or rubble zone and competence of the overburden.

Throughout the course of injection, samples of the grout material were collected and tested for each 50 cubic yards (38.3 cubic meters) of material injected. Tests conducted on the grout included slump, temperature and yield. Samples were stored, cured and broken at appropriate times to determine actual unconfined compressive strength in pounds per square inch (kilograms per square centimeter). The grout samples were required to achieve 150 pounds per square inch (10.55 kilograms per square centimeter) compressive strength within 28 days. Material testing was contracted to an Engineering firm under the supervision of a Certified Professional Engineer.

Once drilling and grouting operations were completed inside the building, new carpet was installed with a pattern selected by the Eagles Club Officers. An attempt was made to re-use the tiles that were removed however some of the tiles had faded, chipped and warped. A different color of tile was chosen to replace the previously removed tiles and a mosaic or accent pattern was developed. A professional cleaning service was employed for the remaining clean-up items inside the Club.

POST-RECLAMATION EXAMINATION

Angle drilling technology was utilized during and after reclamation. The angle rig used was an MW-400 model truck-mounted top head drive rig with angle drilling capabilities to 40 degrees from vertical. During reclamation, numerous drill holes were angled underneath the building as far as was practicable and used as injection holes. It was our experience

that holes angled to 20 degrees or more from vertical presented numerous problems including formation collapse around the drill hole and difficulty in discriminating void and rubble conditions from those of competent overburden and intact strata. An inclinometer was used to accurately measure angles from vertical when we attempted to intercept a predetermined target zone. The angle drilling rig was also utilized to perform confirmation drilling (after injection) under portions of the building after grouting was completed.

Post-reclamation coring was attempted using conventional rotary drilling equipment. This proved to be unsuccessful. Coring of grouted mine workings has been successful in the past in areas of intact mine workings (open voids), however, in areas where substantial amounts of rubble predominate, our attempts at coring were unsuccessful. Confirmation drilling with conventional rotary drilling equipment was conducted between injection holes in selected areas located outside the building that simulated "under the building conditions" and results indicated a successful grouting project.

CONCLUSION

Large scale drilling and grouting projects from inside of buildings are the exception rather than the rule. Conventional methods of rotary drilling, angle drilling and grouting will suffice in most situations. However, as with the Beulah Eagles Club, when faced with a large structure located over a collapsing mine, conventional methods of subsidence prevention may fail to address large portions of the collapsing mine that could only be grouted from inside of the building.

ACKNOWLEDGEMENTS

Special acknowledgement is given to Mr. Robert Aberle and Mr. Bruce Gross of Northern Improvement Company of Bismarck, North Dakota.