COMPRESSED AIR AIDS MINNESOTA TUNNEL PROJECT

RIGHT:
The launch of the shield was first. As the shield was advanced, the "push can" followed. A couple of rings of liner plate were then installed and the airlock was then advanced. After the airlock had been advanced into the tunnel, the entire annulus was grouted and tunneling with liner plate under pressure was begun. The rust on the pit walls shows the water level before the pit was pumped dry.

BY AL TENBUSCH

This article discusses a particularly complex tunneling project in St. Paul, Minn. The South St. Paul Force Main Improvements job required the installation of dual 30-in. diameter sewer force mains from a lift station to the Metro Plant in St. Paul. The job was challenging for several reasons:

- Existing wet ground conditions due to a high local water table.
- Proximity of the sewer line to buried utilities and inconsistent fill
- The need to tunnel under a levy (supporting two parallel rail lines) located next to the Mississippi River.
- The tunnel exited the levy into the cofferdam in the river.

The path of the sewer lines and important sections of the tunnel project are indicated in Figure 1. The two 30-in. sewer force mains were to be installed in a single tunnel built with 84-in. diameter liner plate. The tunnel installation would extend 255 ft from the installation pit, moving under the levy and two BSNF parallel railroad lines, and into the receiving pit, located within the Mississippi River. The line was then to be open cut along the river bottom. The owner of the job was the Metropolitan Council. CNA was the engineering firm for the project. The tunnel contractor was Lametti and Sons, Inc., and Tenbusch, Inc. built the tunneling shield and the airlock chamber used to complete the job.

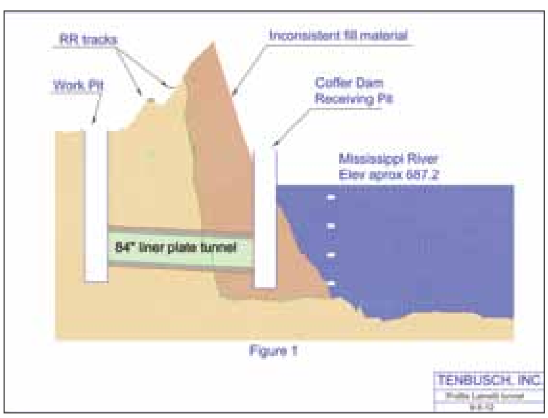

Figure 1

The most critical condition regarding the tunnel installation was the high water table present throughout the entire region of tunnel – as pictured in Figure 1. The top elevation of the levy was approximately 25 ft above the surface of the river. The tunnel invert elevation was approximately 20 ft below the river's surface. The local ground water level was approximately equal with the surface of the river.

Because the tunnel was relatively shallow and only 255 ft long, the use of compressed air was a cost-effective way of controlling the water intrusion at the face.

Normally, when the term "compressed-air tunnel" is used, there are images of a complicated and costly work site as well as slow progress. In the past, compressed air was used more frequently. Today the problem jobs that require compressed air are often performed by tunnel boring machines where the face can be pressurized and the men work in a normal atmosphere outside of the compressed air chamber. Tunneling and microtunneling equipment, using a concept called earth pressure balance, is also used. Both of these options were inappropriate for this job because of the depth and length of the tunnel.

The work pit had a finished floor approximately 25 ft deep. The owner of the levy required that all of the work be done without dewatering. This meant that the pit had to be sheet piled prior to excavation. The pit could not be pumped dry until the excavation was complete and the floor was constructed. In order to resist uplift, when the water in the pit was pumped out, the design called for a 6-ft thick concrete floor. The pit was then excavated to a depth 6 ft beyond the floor elevation and a concrete floor was poured underwater with the aid of a tremi. The work pit was then pumped using a single 5-hp, 4-in. hydraulically driven pump.

The receiving pit was cofferdamed in the river. Here again, the site conditions required that the pit be constructed without dewatering. As with the work pit, this structure could not be pumped dry until the excavation was complete and the floor was constructed. After the sheet piling was in place, the pit area was excavated to a level 8 ft below the floor elevation. The floor was poured underwater with the aid of a tremi. The floor was 8 ft thick to resist uplift when the pit was pumped out. The receiving pit was then pumped using two 5-hp, 4-in. hydraulically driven pumps.

In order to control the intrusion of water at the face of the tunnel, the owner specified that the tunnel work would be carried out using compressed air. The specifications also called for the area in the excavation zone to be grouted prior to tunneling. In addition to the grout, the specifications called for sand shelves in the leading edge of the tunnel shield.

In years past it was common to simply hand mine the ground and install liner plate one section at a time. As the excavation progressed around the circle, a full ring of liner plate would be installed. In other words the excavation progressed in increments required to install individual liner plates. (Liner plate is usually 16 in. wide and a little over 3 ft in circumferential length. It easily bolts together to form a ring of the desired tunnel diameter. It can be fitted with gaskets, however, it almost always leaks water even if gaskets are used.)

Today, most agencies require the used of a shield. Some of the advantages of using a shield are:

- Superior protection of workers as the tunnel is excavated.
- Excavation efforts can be limited to moving material at the face.
- The trimming of the excavation at its limits is accomplished by the overcut banding on the shield.
- The use of an overcut band limits the annular space created and therefore the amount of grout required to grout the annular space.
- The shield is advanced by pushing itself off of the assembled liner plate with hydraulic jacks.
- When the shield is advanced, a space is created between the pushing hydraulic cylinders and the existing liner plate to allow another ring of liner plate to be assembled.
- The installation of liner plate is carried out in a skirted area at the rear of the shield.
- Line and grade are controlled by steering the shield with the use of a laser and target. The shield is normally articulated and hydraulically steered to allow the crew to control the line and grade from within the shield.
- When control at the face is required, the shield can be fitted with sand shelves. Hand mining with sand shelves simply requires that the material is pulled in through the shelves as the shield is "crowded into the face"

This photo was taken from inside of the tunnel. As you can see there is no latch on the door. The doors were held shut by the pressure of the air. The airlock was long enough to accommodate the spoil removal equipment.

An airlock was used at the entrance to the tunnel. The outside diameter of the airlock was 84 in. to coincide with the finished diameter of the liner plate. The length was 17 ft to accommodate the muck cart train that carried out the spoil. The airlock also allowed the men to safely enter and exit the tunnel.

The process of entering and exiting the tunnel through the airlock involves:

- When a workman enters the compressed air work zone, he is required to spend a short period of time in a chamber where the air pressure is slowly increased.
- Once the workman is acclimated to the increased air pressure, he will stay in the higher pressure area for the duration of the work day.
- When the workman leaves the compressed air work zone, it is necessary to spend a short period of time in the chamber where the air pressure is slowly decreased.
- The times that the men spend getting acclimated are strictly governed by the level of compressed air pressure.

Both doors opened inward. Safety considerations precluded the use of latches on the doors. The doors were closed and held closed by the air pressure beyond the door opening. Each end of the airlock had 27 separate pipe openings (penetrations) to service the many functions listed below;

- Pressure air to the airlock
- pressure air to the tunnel work area.
- Fresh air to the tunnel face
- Exhaust air to accommodate the fresh air stream
- Telephonic communication
- Water pump discharge
- Electric cables to service lights
- Compressed air for air tools
- Control piping to allow the crew to monitor and control the different functions
- A portal "site glass" to allow the crew members to see through each door.

When the spoil removal muck cart was full, the inside door would be opened, this would be easy since the airlock and the tunnel work area were at the same elevated pressure. When the muck cart was in the airlock, the inside door would be closed and the air pressure in the airlock would be reduced. When the pressure was equal to the outside pressure, the outer door could be easily opened and the muck cart could be removed and emptied. The return trip was the same only in reverse. The workmen in the tunnel stayed in the tunnel and the workmen in the pit stayed in the pit.

As the tunnel progressed each day, the annular space around the liner plate was grouted. The crew found that by keeping the annular space grouted, less air was able to escape and also less water entered the work area.

There are very specific industry standards governing the amount of air pressure that is needed. It is based on the depth of the groundwater as well as the weight of the soil. Since this tunnel had an invert approximately 20 ft below the water surface elevation, it was expected that 8 lbs of air pressure would be required. However, the crew found that 8 lbs caused bubbling on the surface. The optimum pressure turned out to be just above 4 lbs.

When the tunnel excavation neared the receiving pit - within 4 or 5 ft - the compressed air was stopped. The area near the wall of the pit was temporarily dewatered. This allowed the sheet piling to be cut and the shield to be advance into the pit.

The job began in September 2011. The tunnel was launched in January and finished in February. The 255 ft was hand mined at approximately 6 ft per day (single shift). The receiving pit was reached in 40 days. This production was surprising, given the fact that the entire tunnel zone had been grouted because of concerns of settlement by the U.S. Army Corps of Engineers and the railroad.

Dan Banken, the project engineer for Lametti & Sons, said. "It was amazing how the presence of compressed air limited the intrusion of water at the face."

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