Exploratory Tunnel for the Mill Creek Project

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ABSTRACT: A 1,216 -ft long, (9-ft diameter) exploratory tunnel was bored as part of the Mill Creek Project to investigate ground conditions underneath a buried glacial valley. The tunnel crown was supported with fiberglass dowels to allow unobstructed over-boring of a 24-ft. diameter (excavated) Mill Creek Phase 3 Tunnel. A comprehensive program of probe hole drilling, core sampling and seismic tomography was conducted to better define the location and condition of the soil/rock interface. The Mill Creek Tunnel is utilized to convey and store combined storm and sanitary sewage collected from the member communities in the southeast portion of Cleveland Ohio. This paper will provide an overview of design objectives and explain how an exploratory tunnel was used to provide clarity of underground conditions.

1 PROJECT BRIEF

The Mill Creek Tunnel Project is located in the southeast portion of the Greater Cleveland area and serves 134,000 people in eleven communities. A three-phase construction program encompasses fourteen (14) shafts and three (3) tunnels, totaling approximately 42,000 feet of tunnel length. The final phase of the project, Mill Creek Tunnel Phase 3, is currently under construction with planned completion in 2008. The total contract cost for the three phase development will be about $150,000,000.

2 GEOLOGY

An exploratory drilling program identified the presence of a deep soil valley within the alignment of the Mill Creek Tunnel. Using conventional subsurface investigation methods, the design team was unable to sufficiently define the depth and configuration of the valley in relation to the Mill Creek Tunnel. To further complicate this issue, Interstate 480 was located directly above the tunnel where it crossed beneath the buried valley. The bulk of the valley soils can be classified as cohesionless, predominantly dense fine sand and silty sand, with a groundwater table located within a few feet below the ground surface. Schematics of the buried valley are shown in Figure 1.

The exploratory tunnel horizon is situated within the Chagrin Shale rock formation at a depth of 250 feet. Initial core samples indicated that the top 30 feet of shale was weathered. The shale is classified as medium strong rock with thin to massive bedding. Thin interbeds of closely spaced shale and calcareous siltstone are commonly encountered in the tunnel. Such interbeds cause loosening of rock mass, mostly in the crown of the tunnel.

3 RATIONALE FOR EXPLORATORY TUNNEL

Tunneling below the buried valley presented risks that could not be mitigated effectively from the ground surface. Furthermore, encountering an incized part of the buried valley in the tunnel horizon could result in an expensive claim and remediation effort. A tomography survey preceded the exploratory tunnel investigations. The information that was obtained from this survey suggested that unfavorable geological features along the tunnel would be encountered. This finding provided the project team with more incentive to launch the exploratory tunnel program.

The following paragraphs summarize the risks and concerns related to the construction of the Mill Creek Tunnel under the buried valley:

3.1 *Mixed-face soil-rock tunneling*

If the tunnel encounters soft ground in the crown and rock in the rest of the tunnel face, sand and water will flow rapidly and uncontrollably into the tunnel, unless preventative measures are taken. This could vary from troublesome to catastrophic with

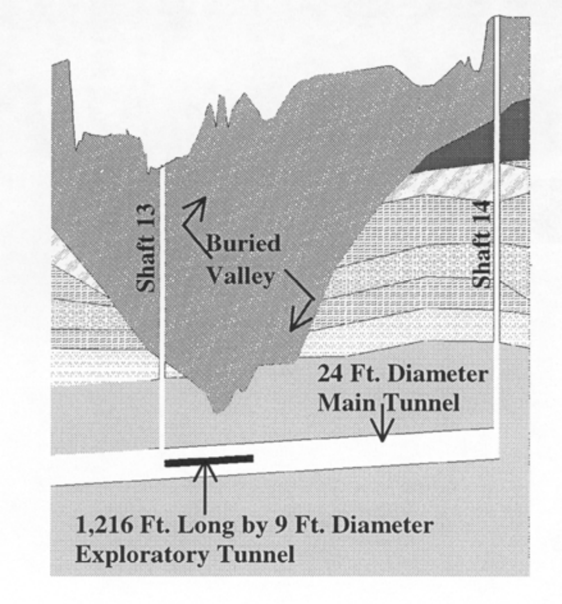

Figure 1. Schematics of buried valley.

possible loss of the tunnel and damage to structures adjacent to the tunnel.

3.2 *Blocky ground in tunnel face*

In the areas of low rock cover where the ground is weathered and blocky, rock fragments could ravel from the face and crown leading to development of voids above and around the tunnel-boring machine (TBM). This occurrence would impair the TBM's ability to use side grippers as a means of propulsion. In such cases, extensive pre/post grouting of the rock mass and voids would be required. In addition, significant zones of soft material could reduce production rates or worse, stall the machine due to irregular TBM face configuration.

3.3 *High water pressures*

Early investigations revealed the ground water table to be near the ground surface (or 240 feet above the tunnel). Mining in blocky-seamy ground and mixed face tunneling conditions could be extremely difficult should excessive groundwater inflow be encountered. As such, determining the valley depth and rock contact became critical to understanding groundwater impacts.

4 REMEDIAL OPTIONS TO MITIGATE RISKS

In the event of encountering soft ground and water in the Mill Creek Tunnel, while mining beneath the buried valley, the following remedial options were considered:

4.1 *Remedial options from ground surface*

Grouting from the ground surface was considered an option. However, its success was considered limited due to the close proximity of major roads and interstate access ramps directly above the tunnel. Holes would require close spacing, minimum 3 to 5 foot centers. This option would require angle holes, directional drilling and tight survey controls. Grouting from the surface would only be used as a supplemental method for ground treatment in the event of sudden water ingress in the tunnel.

Dewatering the soil immediately above the rock was examined. This was rejected, because some subsidence of the ground surface due to the removal of water and fines could potentially occur.

4.2 *Remedial options from the tunnel*

Possible remedial options included cement-grouting, chemical grouting, and ground freezing. These are briefly outlined as follows:

- Ground freezing was considered to be one of the methods to stop flows of sands and silts from entering the tunnel. However, it would require an access gallery around the TBM to facilitate equipment installation and use. A major drawback to freezing the holes drilled through the TBM face is the interruption in freeze circulation to advance the machine. Ground freezing would be expensive and slow.
- The use of chemical grouting was also considered but determined not to be feasible in silts, clays and silty sands with more than 20% fines passing the number 200 sieve.
- Cement grouting was considered the best option in coarse gravel, clean sands, and fractured rock. However, to be effective, chemical grouting must follow cement grouting. This technique is most effective in grouting joints in rock as opposed to sealing off flows in soil. Any grouting from the tunnel (into soil) to control soil and water flows would be difficult. This operation was considered high risk, leading to potential blowouts under high grout pressures. In order to implement this measure, a time consuming trial and error approach would be necessary to get optimal grouting performance. In contractual terms, it would be difficult to price TBM standbys while executing grouting operations.

5 EXPLORATORY TUNNEL

5.1 *Objectives*

In order to completely define and evaluate the potential risks associated with tunneling underneath the buried valley, proper definition and evaluation of such risks was required with as much certainty as possible. The use of an elaborate exploratory program was prudent for finalization of TBM design and other contractual issues. The project team, jointly with a Technical Review Board determined that an exploratory tunnel including core drilling and probing would be most effective in achieving two key objectives:

- Investigate the impact of the buried valley on construction of the main tunnel; and
- Determine the adequacy (quality and thickness) of rock cover above the crown of the main tunnel. The design criteria for minimum rock cover was 24 feet or one tunnel diameter.

5.2 *Location in relation to main tunnel*

One of the questions related to the layout of the exploratory tunnel was its location in relation to the main tunnel. Initially, construction of a side-drift gallery was considered beneficial because it would provide the means to explore rock, provide a platform for grouting, facilitate drainage and reduce ground water pressure on the crown of the main tunnel. This arrangement is shown in Figure 2. It would also allow the TBM to advance with minimal stops and delays. It was thought that by reducing groundwater pressure the use of an EPB machine could be avoided. A side-drift would also provide a gallery for freezing under emergency condition as well as provide the Contractor the necessary flexibility to employ multiple ground treatments if required.

In the final analysis it was determined that a centrally located exploratory tunnel would be the most beneficial alternative. This arrangement provides direct evidence of ground conditions in the domain of the main tunnel. A concentrically located exploratory tunnel was selected to minimize complications when overboring the Mill Creek Tunnel. Additionally, the tunnel could be used for potential advanced treatment of the ground. Its arrangement and configuration in relation to the main tunnel is shown in Figures 1 and 3.

5.3 *Tunnel excavation and support*

Excavation of the exploratory tunnel was conducted between April and July 2000, using a full-face TBM that employed open spoke cutting wheel and carbide tipped drag teeth. The tunnel excavation was initiated from the bottom of Shaft 13 and then driven horizontally along the main tunnel alignment to a distance of 1,216 feet, see Figure 1.

The tunnel crown support consisted of fiberglass rock dowels furnished with plastic washers, plywood pressure plates and straps. The rock dowels were set between 10:00 and 2:00 o’clock and were grouted into place with an epoxy grout. The plywood straps were set between the tunnel wall and rock dowel bearing plates. An example of the tunnel support is shown in Figures 3 and 4. The Contractor was able to complete the excavation without having to take any extra remedial action related to geological conditions. The shale behaved in a uniform (stable) fashion, displaying dry condition throughout the tunnel.

5.4 *Probing ahead of TBM*

Concurrent with mining, angle percussion probe holes were drilled to provide information concerning the thickness and quality of the overlying rock. The probe holes were drilled on 20-foot centers through the centerline of the tunnel crown. A set of five (5) additional vertical probe holes were drilled following the completion of the exploratory tunnel.

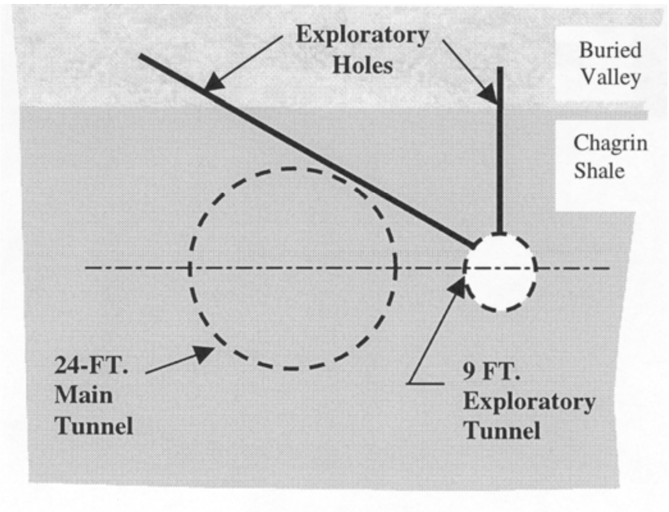

Figure 2. Side drift tunnel arrangement.

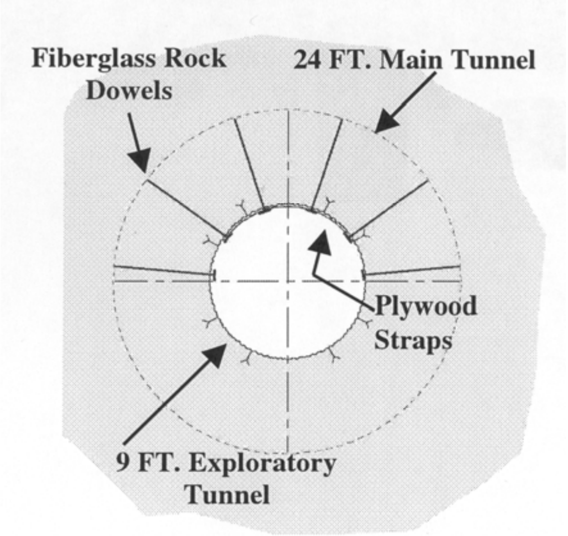

Figure 3. Tunnel configuration.

Figure 4. Exploratory tunnel excavation and support.

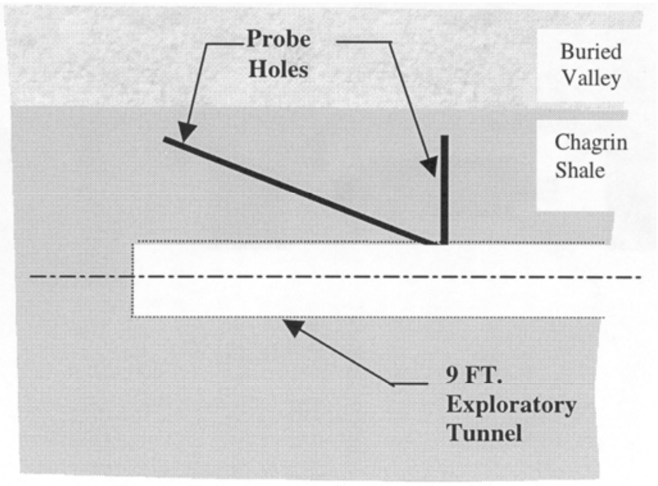

Figure 5. Probe-hole arrangements.

The holes were drilled to a height of 32 feet with the purpose of providing additional information on rock quality immediately above the tunnel. Probe holes were completed using a model G250-3, Alminco Roof Bolting Drill that utilized 1.125-inch hexagonal drill steel and a 1.75-inch pilot bit. A typical probe hole arrangement is shown in Figure 5.

5.5 *Core drilling*

Rock core drilling operations were also conducted constituting the third and final phase of the geotechnical exploration. A total of fifteen (15) rock cores were extracted using a Boart Longyear Model LM-37 electro-hydraulic drill. To accommodate the tunnel's confined space, the LM-37 was fitted with a short feed frame that provided a 1-meter stroke.

Two overhead core holes were drilled in each of five galleries cut in the exploratory tunnel. These core holes were drilled 18 degrees left and right of the tunnel centerline and were drilled to a minimum depth of 37 feet for the purpose of gathering samples to visually classify the rock quality immediately overhead of the Mill Creek Tunnel crown. The layout of drilling is shown in Figure 6. At each location, the tunnel invert was squared out to accommodate drilling equipment.

In an attempt to locate a vertical geologic feature identified in the tomographic investigation, five additional cores were drilled horizontally into the tunnel face. Each core was 150 feet in length.

5.6 *Tunnel mapping*

Tunnel mapping was performed concurrently with the mining operations. The tunnel was mapped with particular emphasis on structural geology, hydrogeology, and rock quality. The results of mapping concluded that no evidence of adverse geological features was present in the tunnel excavation. Bedding planes were observed as major structural features, occurring between shale layers.

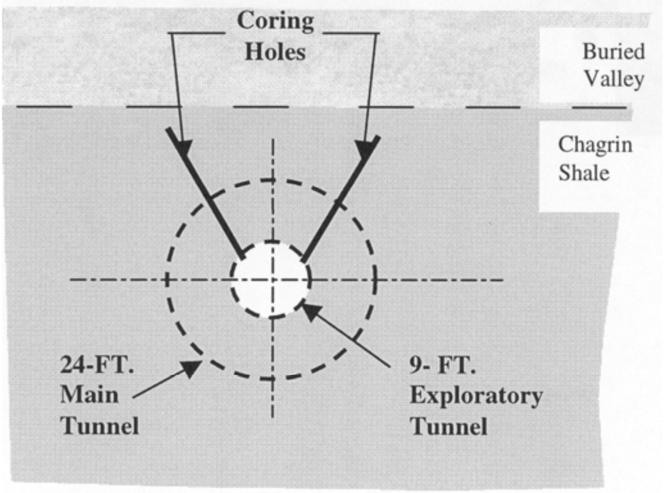

Figure 6. Typical core-hole arrangement.

5.7 *Key findings*

The most significant findings of the exploratory tunnel investigations were that the required minimum 24-foot rock cover above the main tunnel crown, consisting of good quality rock was confirmed to exist. It was also confirmed that no evidence of a buried valley protrusion existed within the main tunnel domain. Furthermore, the presence of the vertical geologic feature identified in the tomographic investigation was not substantiated.

6 CONCLUSIONS

Although no adverse geological condition was encountered in the exploratory tunnel, MWH's recommendation and the owner's decision to construct the exploratory tunnel was correct considering the potential risks identified initially. The required minimum thickness of good quality rock cover (24-feet) was confirmed to exist above the main tunnel crown. Furthermore, use of this information allowed the bidders for the Mill Creek Tunnel Phase 3 to price the project accordingly, without assuming unknown risks.

The tomography survey provided somewhat misleading information and its findings were inconclusive. Future application of such technique should be selectively used with caution.

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