Down Under

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In 2005, Ric-Man Construction, Inc. asked Spalding DeDecker Associates, Inc. (SDA) to provide surveying layout of the "East Side Water main Phase II" tunnel crossing beneath the Maumee River in Toledo, Ohio. The tunnel is constructed between the City of Toledo and Perrysburg Township.

This project was one of five contracts of the Phase II East Side Water Main Project. Phase I was completed in 2002 and was two miles of 96-inch diameter water line from Toledo's Water Treatment Plant to an existing river crossing. Phase II is a continuation of Phase I which takes off from a stub left in Phase I and runs approximately eight miles to the River Tunnel, then another mile from the tunnel to an existing waterline. These 11 miles of water mains are necessary to maintain safe, reliable service that will meet existing and future growth demands in the City of Toledo service area. The water mains will result in increased water pressures in the southern and western portions of Toledo's distribution system, strengthen the eastern portion of the system, increase the reliability of the system by providing an additional river crossing, and increase the overall efficiency of the system by reducing system pressure losses. Phase II included five miles of 72-inch water main, 2.6 miles of 66-inch water main, and 1.5 miles of 48-inch water main, including the Maumee River Crossing. The Phase II project was split into contracts A through E to make it more construction friendly and affordable for the City. The City was able to spread the projects out to secure funding.

The City of Toledo had a Water Distribution Study done in 1996 that reviewed and projected the population and water demands through the year 2025. These water mains were one of the improvements the study recommended. The City then sent a Request for Proposal to engineering firms for a route study for the water main followed by a Request for Proposal for the design of the watermains.

APPLICATION OF EXISTING TECHNOLOGY

In May of 2006, Spalding DeDecker Associates, Inc. (SDA) finished the initial phase of surveying layout services for a tunnel under the Maumee River. The tunnel hosts a 48-inch diameter pre-cast concrete water main between the City of Toledo and Perrysburg Township.

The Challenge

The City of Toledo's surveyor set the initial horizontal and vertical control for the construction of the tunnel. SDA set two offsets along the survey baseline and two offsets perpendicular to the baseline at the centerline of each proposed shaft. These offset control points were used to transfer the survey baseline alignment down into the tunnel. SDA utilized GPS equipment to verify the coordinates of the control and to establish an azimuth between the two points at the centerline of each shaft. The line between these two points is referred to as the survey baseline. The azimuth of this line was needed to ensure the accuracy of the gyroscope, which is explained later.

On the easterly side of the river, a 26-foot diameter vertical shaft, 90 feet deep, was constructed to access the tunnel entrance and to place the rock drilling/mining machine. Another shaft was constructed on the westerly side of the river to receive the tunnel. A laser plummet was used to project the survey baseline down 90 feet to the bottom of the shaft. To check the line, the laser plummet was inverted and again the line was projected down to the bottom of the shaft. The average location between the two sights was used. A vertical benchmark was also transferred down into the tunnel.

COMPLEXITY

Typically, as tunnel construction progresses, probe holes (small vertical shafts dug along the proposed tunnel centerline) are used to verify the location of the constructed tunnel. If the probe holes indicate that the tunnel is off center, small horizontal corrections can be made. Because the tunnel was being constructed below a river, probe holes could not be used to verify the actual horizontal location of the tunnel. Another method had to be used. Because GPS technology requires line of sight to the satellites, GPS cannot be used underground.

Complicating matters, a short back-sight creates the potential for a huge horizontal error if projected out 1600 feet. As a matter of reference, a standard survey baseline consists of a long, back-sight which can be projected forward accurately for the same length. The initial back-site at the bottom of the shaft was barely 24 feet, meaning that we could only project a line accurately another twenty-four feet into the tunnel. The survey baseline had to be projected sixteen hundred feet in order to hit the centerline of the shaft constructed on the other side of the river. A 24-foot back sight versus a 1600-foot fore-site after plumbing down a 90-foot deep shaft would normally create the potential for a huge amount of error. A one degree error in sighting could create a 28-foot horizontal error in 1600 feet. Obviously, this would neither be acceptable, nor desired.

The Solution: Surveying with "Old Technology"

To minimize any potential error, SDA used a piece of surveying equipment typically used for mining that dates back at least to the 1960's. It is called a Gyrocompass, usually referred to as a Gyroscope. The Gyrocompass is mounted on the top of a Wild T2 theodolite (shown in the adjacent picture) for measuring angles. The gyroscope spins at 22,000 revolutions per minute in the same direction as the earth. Within the gyrocompass, "the gyroscope motor is suspended on a thin tape similar to a plumb bob. The upper end of the tape is connected to the upper end of the tubular housing at the top. A cross-sectional view of the gyrocompass is shown in Figure 7-16. The moving mark oscillates with the gyroscope. This mark is projected down to a V-shaped index which is viewed through the eyepiece. Since the eyepiece index is attached to the instrument, it is fixed with respect to the alidade of the theodolite.

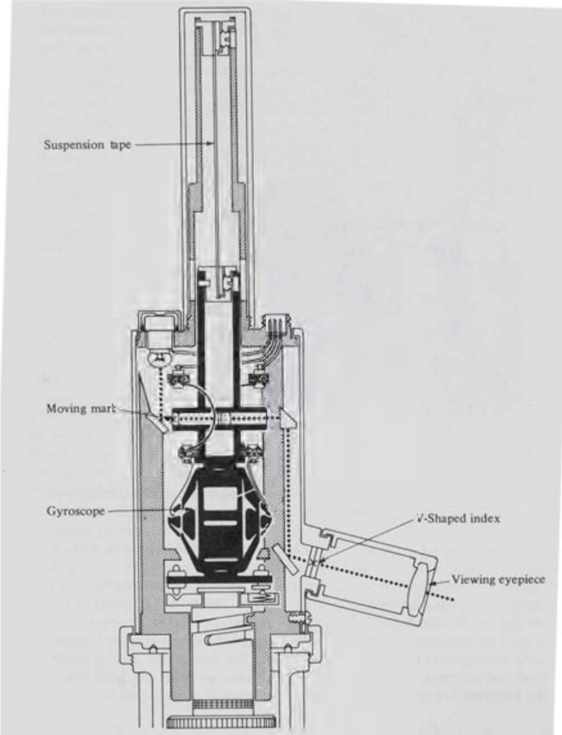

Figure 7-16. Cross section of gyrocompass

After the instrument is set up over the survey station, the theodolite telescope is aligned approximately to true north, by means of a magnetic compass (or with GPS in SDA's case). The gyrocompass is then attached to the theodolite. The gyro motor is then turned on and allowed to run up to full operating speed, after which the gyroscope is released. The projected moving mark can then be observed through the eyepiece as moving across the graduations contained in the eyepiece scale.

The Turning Point Method can be used to determine the precise direction of true north with an accuracy of thirty seconds or better. The observer follows the oscillations of the moving mark, keeping it centered in the V-shaped index by turning the horizontal motion tangent screw of the theodolite. When a turning point is reached, the moving mark will appear to remain stationary in the V-shaped index. A horizontal circle reading of the theodolite is now made and recorded. The observer then follows the movement of the mark, keeping it centered in the V-index until the opposite turning point is reached. The horizontal circle is again read and recorded. Three or more turning points are observed, from which the horizontal circle reading representing true north is computed.

The azimuth of a reference line is established by sighting on a reference mark in direct and reverse orientations, obtaining the mean of the direct and reverse readings, and comparing this circle reading with the value computed earlier." (Excerpt taken from "Surveying, Seventh Edition," by Moffitt and Bouchard).

Using this method, the angle of the tunnel measured from true north is first measured precisely on the ground surface with the Gyrocompass and T2. Patience must be exercised when using this equipment. One reading takes at least 20 minutes. Several readings must be taken at ground level to average the results even before entering the tunnel. The equipment is then taken into the shaft and the orientation process is repeated to once again point the instrument toward true north and then to the actual bearing of the survey baseline. Nails were set in the crown of the tunnel along the alignment every Saturday throughout the duration of the project, at the back of the rock drilling/mining machine. To get beyond the machine, the survey technicians had to crawl through a 90-foot long, 3'x 3' opening carrying a bag full of tools through the conveyor system.

EXCEEDING OWNER/CLIENT NEEDS

The tunnel was scheduled to hit the receiving shaft on a May 10, 2006. Jim Bilicki of Ric-Man Construction, Inc. called SDA on May 9, 2006, ahead of schedule, and notified us that they had hit right on the mark after drilling through 1600 feet of dolomite, the same type of rock that Niagara Falls is composed of. ***Jim Bilicki exclaimed, "Just heard from Ohio. They hit the exit shaft dead center, perfect line and grade. Congratulations! You guys did a hell of a job getting us across that river!"*** Everyone was crossing their fingers and holding their breath hoping that this piece of equipment worked the way that it was supposed to, taking into consideration that our initial computations were correct.

FUTURE VALUE TO THE ENGINEERING OR SURVEYING PROFESSION

This was the first time SDA had ever used this equipment and it worked flawlessly. Even though new surveying technology like GPS and Robotic instruments may improve efficiency and productivity, sometimes the old technology cannot be beat. Very few surveyors will have the chance to become familiar with this specialized niche of tunnel surveying. Surveyors graduating from college today may not even know how to use the instruments of yesterday, let alone a gyrocompass. By using the technology of yesterday successfully, SDA is preserving and promoting the historical values and techniques of the survey profession to the young surveyors of tomorrow and surveying history that helped shape America.

SOCIAL, ECONOMIC, AND SUSTAINABLE DESIGN CONSIDERATIONS

The City of Toledo's vision to continue to provide safe drinking water and reliable water service to it's surrounding communities was one of the primary requirements taken into consideration when first considering this project. The new watermains will provide increased water pressures in the southern and western portions of Toledo's distribution system, strengthen the eastern portion of the system, increase the reliability of the system by providing an additional river crossing, and increase the overall efficiency of the system by reducing system pressure losses. The City's goal of making Phase II construction friendly and affordable was accomplished by splitting the project into five separate contracts; A through E. In doing so, the City was able to more easily secure funding.

When SDA initially looked at the project to determine a layout budget, we knew that the responsibility placed on our shoulders to provide an accurate baseline was paramount. Any deviation from the survey baseline would increase the project costs astronomically. Because of the construction timeline, there was no room for error. And based upon our diligence, calculations, and proper use of equipment, SDA was able to contribute successfully to this project.