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24/7 Structural Monitoring

Keeps Detroit Lakes Roadway Reconstruction Steady

>> By Vicki Speed

Mn/DOT surveyors installed backsite prisms on buried steel posts for stability and visibility.

Not long ago, residents of Detroit Lakes, Minnesota would have advised visitors to stay clear of Roosevelt Avenue, a major thoroughfare that carries travelers from one side of town to the other. They would have noted the growing traffic congestion, the danger in crossing the always busy U.S. Highway 10, and the chances of getting stopped for seemingly endless minutes at the highly active railway crossing.

That will change with the construction of the Roosevelt Avenue Underpass, an integral part of the $42 million Highway 10/Connect Detroit Lakes Project. First initiated in 2006, the Highway 10/ Connect Detroit Lakes Project is jointly managed by the Minnesota Department of Transportation (Mn/DOT), the City of Detroit Lakes, and the Burlington Northern Santa Fe (BNSF) railroad. The goal of the project is to improve safety at railroad crossings and intersections and provide mobility for travelers on Highway 10 without obstructing access for local motorists.

Besides the construction of a Roosevelt Avenue Underpass of Highway 10 and the BNSF railroad, the three-year project includes reconstruction and realignment of approximately three miles of Highway 10, realignment of the BNSF railroad tracks, reconstruction of approximately one-half mile of Highway 59 between Highway 10 and Highway 34, and the construction of a frontage road around

Surveyors relied on brackets that 'squeeze' the top of the wall to provide support for the total station and eliminate the need to drill holes in the building.

The Roosevelt Avenue Underpass infrastructure includes a storm water surge storage structure that is located beneath the new street level. The engineers called this the "boat section."

Big Detroit Lake from East Shore Drive to downtown Detroit Lakes.

As Trains Go By

The Roosevelt Avenue Underpass construction calls for construction crews to drop Roosevelt Avenue by approximately 25 feet so that it runs underneath Highway 10 and the existing railway crossings. This will require the lowering the area groundwater tables by about 5 feet and the construction of two large bridges, one for Highway 10 and the one for the railway.

Keeping this project on target and safe for surrounding residents, as well as for the many trains that must remain operational during construction, requires Mn/DOT surveyors and engineers to carefully monitor the area for ground settlement that might be caused by the ongoing de-watering process or the vibration effects from nearby construction of the bridges and underpass infrastructure. Any settlement could cause the railways to sink or shift, thereby causing derailments.

This need for near continuous monitoring of the construction zone set the stage for Mn/DOT's first opportunity to implement a fully automated, on-site geodetic monitoring system – one that could track the slightest shift in settlement in near real-time for an area that spanned well over 1,000 feet.

Tom Harper, principal land surveyor with Mn/DOT, explains, "As part of our agreement with BNSF, we need to monitor the movement of tracks throughout the construction zone at least once per hour over the course of six months. Whenever crews are working on sight, we need to know that the areas surrounding the construction zone are not unduly impacted by the equipment and processes. There was no reasonable cost- or time-effective way to do this 24/7 with the manpower available. We really only had one option and that was automated geodetic monitoring system."

The Automated Alternative

Mn/DOT's geodetic monitoring system consists of a Leica GeoMoS geodetic monitoring system and Leica TCRP1201 total station, along with 56 prisms, yagi radio antennas on portable stands, and a radio communication link. An additional 12 prisms were added for extra coverage while extensive pile-driving operations took place during a two-week period. The system also has flexible power options and can be deployed with wired, battery or solar options.

In 2006, Mn/DOT surveyed the area to establish control using conventional survey techniques, and set coordinates and elevations for the prisms. Mn/DOT looked to use the network of prisms as the framework to control the GeoMoS monitoring system. They installed the prisms at the desired points and provided an ASCII file containing the coordinates of these prisms for import into the GeoMoS. Prisms were grouped within the software according to tolerances, and measurement cycles were set up to establish the data collection rates.

The TCRP1201 total station was mounted on top rooftop ledge of a nearby

A yagi-antenna and a 900 MHz spread spectrum radio provided a clear communication link between the total station and the project computer located in a nearby project trailer.

grocery store, a location that affords good line-of-sight for the radio link connection back to the project trailer where the computer running the GeoMoS server is located. A 900 MHz spread spectrum radio was mounted and a yagi-antenna was erected and directed toward the project trailer where the project computer was located. Since AC power was available to this installation site, both the total station and the radio were powered via drop cords and power supplies. The total station was positioned to point at one of the known control points and then left in a stand-by mode until the computer and software was set up and configured. The monitoring system, intended to be portable from one area of the project to another, was placed on one control and back-sighted to another.

At the project trailer, surveyors imported the control file to the GeoMoS software running on the laptop computer and established point groups. They also established measurement cycles, which define which points and how often the total station will measure. The survey team also installed a companion radio/antenna to create the communication bridge between the GeoMoS software and the total station. Once these preliminary settings and configurations were made, the software did an initial orientation of the total station pointing at the known control point. The system was now ready to begin monitoring. The system was up and running the first day on site, including the initial site reconnaissance, hardware installation, and software install/configuration.

Timing and Training

Mn/DOT spent the second day after initial installation of the geodetic monitoring system building a baseline dataset that would provide them a clear understanding of the land's typical shifts and settling activities, assure data accuracy, and gain some additional training on the GeoMoS system hardware and software settings/configurations and data interpretation and analysis. GeoMoS software includes two main applications, Monitor and Analyzer. The Monitor module is the application that controls the sensors, collects the data and manages notification events.

The Analyzer software is the post-processing application. Mn/DOT relied on the Analyzer module of the software to track movement in the X, Y, and Z components and then plotted the results over defined time periods. "These plots provided an instant image of the shifting landscape throughout the construction zone and particularly around the railroad tracks. We could quickly spot any movements that might occur," says Harper. The software was also configured with tolerances for each point with defined triggers to take action should tolerances be exceeded. These triggers included sending e-mails and text messages to concerned parties.

Harper adds, "The rails were allowed to settle a quarter of an inch in 39 feet. They normally deflect about five-sixteenths of an inch as the train passes over, so we set the initial alarm tolerance at seven hundredths of a foot. We tried tighter tolerances, but got too many false alarms. As the track settled, we could adjust the baseline to prevent alarms if it was settling in a gradual sine wave form. We set the lateral tolerances a little tighter as there was no normal side-to-side deflection."

Once this initial set-up was complete, the system started the automated monitoring of the prism points. Measurement data is captured on an ongoing basis and stored in an SQL database. If tolerance levels are exceeded, an e-mail alert is sent directly to the project manager. Analysis is made in real-time to determine settlement values and posted to the web for collaboration.

"The trigger action is critical to the success of the underpass construction and our ability to protect the trains from potential derailment. We have implemented a complete solution that is as accurate and reliable as a full-time on-site survey team," says Harper. "In most cases, movement can be detected within thirty minutes."

Signaling Change – Preventing Disaster

The GeoMoS monitoring system has been in place and operational at the Roosevelt Avenue Underpass project since the project began in 2006 and will stay in place until project completion in Fall 2007 when construction should be complete. Already, the benefits of this system have paid off. Just recently, construction crews worked to drive sheet piles as part of the support structure for the underpass. The work, done some 14 feet away from the westbound train tracks, caused some lateral shift and sinking to these tracks. Harper recalls, "The GeoMoS system sent an immediate e-mail and text message warning to me and the railroad representative. The railroad representative was then able to visually inspect the tracks and advise the trainmaster to slow the trains to eliminate the risk of derailment." Throughout that particular sheet pile construction effort, the tracks were re-leveled two or three times due to shifting.

Building Bridges

With Underpass construction well underway, other construction crews have also begun reconstruction of the nearby Highway 59 Bridge, located on about a mile away. Two lanes of the bridge are currently under construction adjacent to the existing bridge, which also crosses active railroad tracks. During pile driving operations on this project, Mn/DOT surveyors shifted the GeoMoS monitoring system to a nearby bridge abutment and bolted the yagi antennae to a guardrail post. With no access to AC or solar power, the

The Roosevelt Avenue Underpass sheet pile installation, located adjacent to the westbound rail, caused the most shift in the railroad track alignment. The monitoring system would send out an alarm if the shift exceeded .07 feet.

The mobile framework of the geodetic monitoring system allowed surveyors to set up even in areas with no power. This total station, located at Pelican River, is powered by a solar panel.

Mn/DOT surveyors and engineers relied on geodetic monitoring to track ground settlement during the excavation of the Roosevelt Avenue Underpass.

surveyors run the monitoring system off a 12- volt battery that is changed once a week.

Once at the new location, Harper and his team fabricated a mount for the new location, surveyed in three control points to do a resect, placed the total station in the mount and connected it to the laptop, oriented the total station, then placed and recorded the positions of the prisms and added them to a new project database. They disconnected the laptop, connected up the radio, antennae and power supply, traveled to the office where they restarted the computer, connected it to the radio and antennae, set the measurement cycles and alarm thresholds and let it go.

Harper recalls, "That's why we implemented a mobile monitoring system – on a project this size, we need the ability to shift our capabilities to follow the overall project construction. We've also learned how to make this move quickly. It took us less then one-half day using three people to set the prisms and start monitoring twenty-eight prisms. We had one person with the total station and laptop computer, one to set the prisms, and one as a safety lookout. It took longer to determine a protected location and fabricate a mount for the total station than any other part of the setup. This methodology saved us time and exposure to trains."

The Mn/DOT teams will go back and forth between the Underpass and the Highway 59 Bridge as needed until both projects are complete in Fall 2007. "This has been a valuable learning experience for our entire team. I can definitely see this geodetic monitoring system put in place on future construction projects adjacent to other rail lines, or possibly to monitor buildings when there is excavation nearby," Harper concludes. "For now, the system is a big part of keeping the construction crews, trains and surrounding communities as safe as possible."

Overall, the entire Highway 10/ Connect Detroit Lakes Project is expected to finish in Fall 2008. When completed, residents and visitors will benefit from fewer at-grade railroad crossings, improved traffic flow, reduced congestion on highways, and safer and alternate routes into downtown.

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