Qualifications of the robotic total station construction monitoring professional

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Introduction

The use of robotic total stations (RTS), also referred to as automated motorized total stations (AMTS), has become more and more prevalent in modern construction related monitoring programs. This increase comes from realization by practitioners to the cost and efficiency benefits over manually survey monitoring as well as through contract specifications from owners and engineers to provide tighter tolerances and quicker response times. With the gap closing (or widening) between North American Professional Land Surveyors and Professional Engineers regarding the use of RTS units, questions arise as the necessary background and experience required for practitioners to effectively design, as well as run these systems and manage the data they create. Although this article should be of interest to all professionals involved in RTS technology and usage, it is particularly intended to guide owners, engineers and specification writers tasked with the preparation of specifications on projects where RTS technology will be utilized.

RTS for construction monitoring

In the early twenty-first century the improvements in telecommunications along with integration of robotics into the total station brought about the possibility of using these RTS units for remote monitoring. A total station that normally required a survey technician or transit man to run could now be controlled remotely and data sent to a remote location for plotting and analysis. With hardline communication and power connections an RTS unit could be installed in a location possibly inaccessible to a survey crew and no longer require untimely access in order to provide 3D survey monitoring information, see Figure 1. In addition to the access issues this system overcame, it introduced a level of high accuracy/high volume measurements not previously available. Measurement cycles were completed and data returned for review within short minutes and the process completed electronically heavily limiting the human error side of survey monitoring. Continuous changes in technology have led to the wireless alternative of the RTS where a wireless cellular modem is used to maintain communications and solar panels are used to power the system.

As the technology of RTS has become more accessible the use of the instruments in monitoring for construction large and small has increased. When initially introduced the cost of these systems was prohibitive to the point that only large scale "mega" projects could find the improvement outweighing the cost. Today the RTS monitoring solution is prolific in many construction venues from tunnels and bridges to high rise sky scrapers and dams to even residential construction in urban environments.

Recent contract specification requirements

As the value of RTS monitoring was evident and the desire for increased monitoring data found appeal with owners and engineers, some modifications to contract specifications were expected. Specifications regarding frequency of measurements and expectations of data delivery timelines were updated. No longer was there a one day turn around for a survey crew to complete field measurements, return

Figure 1. Typical RTS installation.

to an office environment and complete calculations and produce deformation results. Now the process was specified to be more streamlined and provide same day turn around and include forms of automated notification to stakeholders of deformations above limits.

In order to assure that quality data were to be provided per specification the language was changed to incorporate RTS measurements with other geotechnical monitoring data under what is often referred to as the Geotechnical Instrumentation Engineer (GIE). This engineer, typically required to be a Professional Engineer in the state/province that the work is undertaken is specified to have many years of experience with the installation, use and interpretation of data from all of the monitoring instruments to be installed per the contract including the RTS. Beyond this general qualification for the GIE there is little requirement for the experience of technicians or the GIE for reduction of RTS data for use in deformation monitoring as it relates to the statistical or realistic reliability of the monitoring data. There have been a small number of specifications that include a requirement for an AMTS (RTS) Specialist. These specifications generally require that this position be filled by a person with two to three years of experience with and having successfully completed some number of similar projects involving RTS monitoring.

Relevant experience for practitioners

The practice of land surveying is often defined by 50 United State and one district boards and similarly in the remainder of North America as that practice which includes special knowledge and application of mathematics to measuring, plotting and layout of dimensions, areas and volumes on and above the earth or of/on man-made structures. It also includes the location, layout, measurement of the lengths and directions of boundary lines (property lines), monumentation thereof and the application of legal rules and regulations for legal descriptions and conveyance of real property. The Professional Land Surveyor (PLS) is entrusted with taking measurements of the earth and structures and applying mathematical and regulatory principals to determine positions and elevations.

Figure 2. Prisms monitoring large crack in a building.

Professional Engineering is often defined by 50 United State boards and similarly in the remainder of North America as that practice which includes the planning, designing, composing, evaluating, advising, reporting, directing or supervising that requires the application of engineering principles which concerns the safeguarding of life, health, property, economic interests, the public welfare or the environment, see Figure 2.

Professional Engineers (PEs) work to guarantee the public's safety and promote its interest where engineering matters are concerned. They must also ensure that provincial laws adequately and properly serve and protect the public, and participate in the establishment and maintenance of engineering standards while adhering to a code of ethics.

Now every state and province regulates the practice of engineering to ensure public safety by granting only PEs the authority to sign and seal engineering plans and offer their services to the public.

PEs are defined by various disciplines, (Civil, Structural, Mechanical, Electrical, Nuclear, etc.) by various state and provincial boards, typically with different testing and experience requirements. Often the state and provincial boards for both PEs and PLSs are under the same administrative arm. Important to this discussion is that PE and PLS standards of care require that they shall only undertake assignments when qualified by education or experience in the specific technical fields involved.

This goes to the heart of this discussion. Is a Professional Engineer, licensed in the state/province where work is being performed, or any other state/providence for that matter, qualified to administer a RTS program? To answer that lets first discuss the process of the design and implementa-

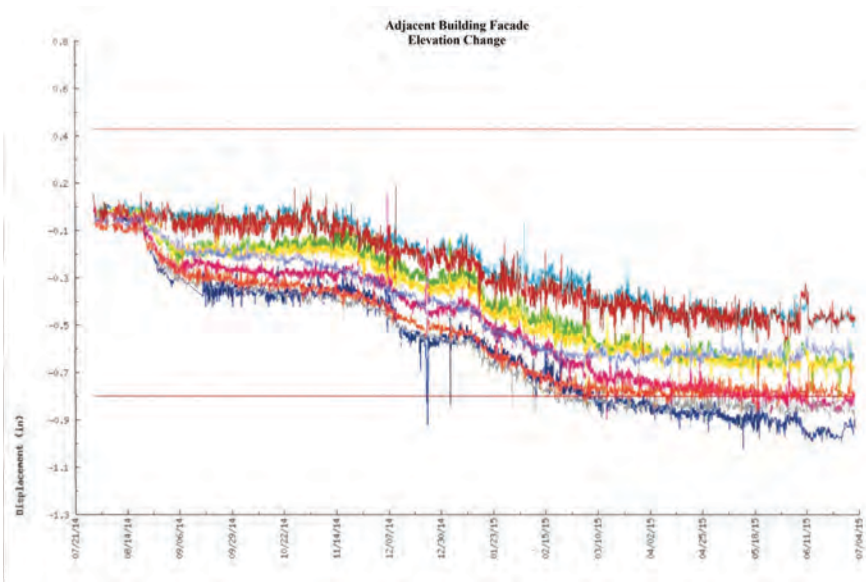

Figure 3. Long term monitoring data from a RTS system showing settlement of a building façade.

tion of a RTS program based on five distinct steps.

- Design the layout of RTS locations to maintain stability, reduce environmental errors and incorporate sufficient stable control to evaluate movement of the RTS and may also include the design of the specific locations to be monitored
- Proceed with the installation and testing of the system to verify functionality and adherence to designed criteria for accuracy and precision
- Data processing is setup to compile and reduce the measurements using appropriate methods of calculation
- Review of the data for quality assurance and identification of movements and trends as well as properly identifying possible data spikes due to transient factors, see Figure 3.
- Use information from the data review to refine and adjust the processing model as needed for changed conditions in the control reference frame or environmental factors.

The direct measurement, taken with a RTS would be the same whether programed by a PLS or PE. Much different then in previous generations where each measurement was made in the field by a two man survey crew, one of which was often the PLS.

Where the Professional (Professional Engineer or Professional Land Surveyor) is needed involves how this resulting measurement is processed, refined and used within an instrumentation data base. Given the advancements in data processing and database manipulations that are undertaken using the least square programs (see Figure 4), the initial phases of data base processing of the direct survey data are more akin to that a professional mathematician or computer software engineer. But key to the Professionals input is the installed RTS location(s) and layout to the reflective monitoring points, confirming that the measurements between these two points will give the best quality data, how corrections to data is undertaken to correct for various error types, and of most important how to address trends or direct movement of points. In this evaluation the Professional must also consider the structure being monitored, its ambient movement as a result of thermal expansion, the impact of the movement to the structure and some of the reasons that movement may be occurring, such as the excavation or tunnel construction.

RTS construction monitoring does not include the definition and layout of boundary lines (property lines), nor the legal description and conveyance of real property. Whereas it does include the use of highly precise instruments for the measurements of

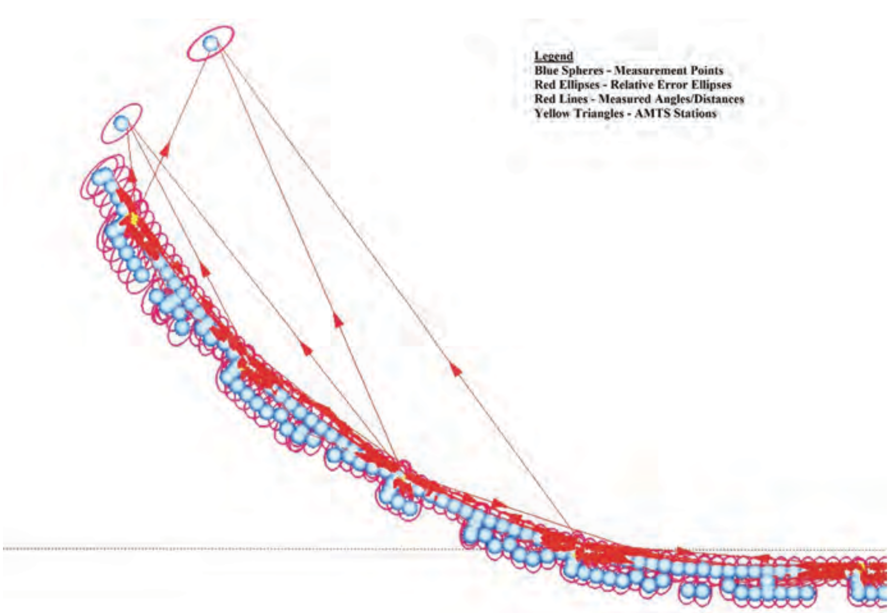

Figure 4. Least squares adjustment plot showing relative error ellipses.

the earth and structures and applying mathematical and regulatory principals to determine positions and elevations of points on structures or the ground surface where the change in position of such points are a concern for safeguarding of life, health, property, economic interests, the public welfare or the environment.

Clearly both the PE and PLS standard of conduct requires that the Professional only undertake assignments when qualified by education or experience in the specific technical fields. The difficulty in the RTS implementation is that neither a PLS nor PE is formally trained on all these issues. On projects without formal specification, the Professional typically decides if he or she has the qualifications required to perform the work.

Until such time that the relatively new field of RTS monitoring advances to influence the state or provincial registration boards, this "mix" of Professionals involved in RTS construction monitoring will likely continue.

It is these writers' opinion that both a PE and PLS can be qualified to undertake a RTS program, and that other degrees and experience may also qualify. The argument of who should be qualified as the GIE, will not be debated here.

Recommendations for contract specification language

The frustration with RTS program specifications has been prevalent in the North American industry for more than a decade, and discussed well in the September 2009 GIN article by Dail and Volterra.

It is these authors' recommendation, as representatives for both PEs and PLSs that the need for a separate AMTS (RTS) specialist is well suited and generally the best for the project, especially in the cases where there is a large amount of "in ground" instrumentation being addressed by the GIE.

We would anticipate that such a specification would generally outline as follows:

Robotic Total Station (RTS) Specialist who shall have previous experience in installation, monitoring, and data interpretation of at least two RTS systems in applications similar to those specified herein. The RTS Specialist shall perform the following tasks:

- Design and detail the overall configuration and appurtenant hardware and installation procedures for the entire RTS system, including final locations of the components.
- Perform pre-installation and post-installation acceptance tests and supervise installation of the system in its entirety.
- Collect, reduce, process and plot RTS data.
- Review RTS system data for quality assurance, identification of erroneous data and identification of movement trends.
- Incorporate information from data review, changed site conditions and/or unanticipated changes to system design into the RTS system processing model.
- Be a PE or PLS in the state or province where the project is located

We hope to see additional attention paid to the details and qualifications of this specialty as the use of RTS monitoring continues to grow.

References

Emily B. Dail, and Joel L. Volterra, "Instrumentation and Monitoring Trends in New York City and Beyond", Geotechnical News, September 2009. www.geotechnicalnews.com/pdf/GeoTechNews/2009/GIN%202703.pdf

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