Case Study on Student Competence in Construction Surveying and Layout

Dejah Hilliard
California Polytechnic State University
San Luis Obispo, California

The Cal Poly San Luis Obispo Construction Management (CM) curriculum requires its students to enroll in BRAE 239, a course that educates students on field surveying using equipment such as a total station and an automatic optical level (builder's level). The class focuses on how to use the specified equipment to calculate distances, heights, and angles over fixed benchmarks to create labeled contour maps and land plot diagrams. The information and methods of calculation are taught in a classroom, and the physical surveying with the provided equipment is done in the agricultural field on campus. The course does touch on procedures and tips to minimize error, however it does not spend a great deal of time explaining how to correct errors already made, let alone identify errors during the process. The course is also limited to calculating data resulting from preset benchmarks, whereas CM students need experience creating points, lines, and benchmarks. Large commercial construction companies, like the one I interned for this past summer, complete a sizable amount of self-perform work, and their field engineers, or recent college graduates, prepare the layout. The Cal Poly CM curriculum would significantly benefit from a course that focused on jobsite surveying utilizing updated equipment, with a section dedicated to identifying errors and correcting them during the layout process.

Key Words: Surveying, Layout, Total Station, Trimble

Introduction

The purpose of this senior project paper is to evaluate student competence in construction surveying and layout based on a single case study. The case study I chose to focus on was a hospital tower I worked on that is being built from the ground up. A unique aspect of this large commercial project was the large amount of self-perform work done on the project. I arrived to the jobsite when excavation was finished and they were in the middle of grading. They needed to mark elevations on the surrounding shoring as well as place stakes in the dirt for column placement. The equipment used to mark elevations based on previously placed benchmarks included a builder's level and an engineering rod, and a total station with a prism was used for gridlines and centering columns.

A total station or TST (total station theodolite) is an optical instrument used for surveying and building construction. The total station is an electronic theodolite integrated with an electronic distance measurement to read slope distances from the instrument to a particular point, and an on-board computer to collect data and perform advanced coordinate based calculations. For the purpose of this project in particular, the total station would set up on an existing benchmark and use another benchmark as the back sight to locate new points at 90º. Another employee on the field team would be set up along that new line at 90º with a walkie-talkie and the prism while the person looking through the total station could guide them to a spot at the correct distance away from the original point. This process would continue until all gridlines were laid out and each of the 70 column centers was located.

Leica Total Station

Discrepancies were discovered after laying out gridlines “1-14” and it was up to the field team in charge of the layout to figure out the cause of these issues. The causes could have been the equipment used, the processes undertaken, the experience level of the field engineers, or unseen quantitative errors. The necessity for college graduates to be able to utilize this equipment became apparent to me during my time on this project because gridline and column layout for the foundation of a working hospital is a crucial part of construction. If the individuals performing this work are under qualified, it is more likely that mistakes will be made.

Subcontracting vs. Self-Perform

An increasing number of commercial construction companies such as Hensel Phelps Construction, DPR Construction, Clark Construction, Turner, Sundt, Layton, and several others self-perform work on their projects as of 2017. Self-perform work includes pouring concrete, and building up all of the formwork necessary to pour. In my experience on this particular jobsite, labor and carpenter crews are hired by said general contracting company and build up formwork based on lift drawings created by the field engineers. This method of getting work done allows the general contractor to have control over the work done and how quickly it gets done. When the carpenters and laborers work directly for the general contractor managing the project, they have more motivation to finish unlike a subcontractor who is less attached to the project. Cutting back on time spent also cuts back on the labor cost. There is also a specific method of work that ensures safety on the jobsite when the laborers work directly for a company. Subcontracted companies may be safe, however their policies may not align with the policies of the general contractor managing the project; the difference in methods may create a problem between the sub and GC.

Methodology

The first step to this senior project was to pick a topic interesting to me as well as relevant to other students in my major that may benefit from industry knowledge. The second step was to choose a project to utilize as the case study relevant to the topic. Once I chose that project, I collected the specific data that pertained to my project topic. Included in that data are interviews with a couple members of the project team that utilized the total stations and Trimble used to lay out the site. These interviews will give an insight into the process used for layout, the mistakes discovered along the way, and the ways in which the mistakes were resolved.

Research will be focused on the equipment used on the jobsite, such as the two different total stations and the Trimble. Product data should give specific information on proper techniques as well as margin of error. They should also give suggestions to decrease error using the equipment, and proper maintenance procedures that may have affected their use during layout.

Case Study

During the Summer of 2017, I interned with a major general contracting company, specializing in commercial construction. The particular project I worked on was a seven-story, 170,000 sq. ft. hospital tower that began construction in January 2017. When I arrived in June, the parking lot that existed previously had been torn out, and the shoring was in place. The site was undergoing excavation for the mat foundation, however there were several steps to be taken before that foundation could be poured. As soon as excavation and grading was complete, the field engineers in charge of the mat foundation had to lead during the layout process for gridlines and columns.

On the existing road that surrounded the Northern and Eastern sides of the site, dime-sized steel benchmarks that marked the site's given gridlines were placed by an outsourced surveying company. This company came in with their expensive surveying equipment when the project first began, and placed these large nails along the road, parallel to each other so it would be very clear where gridlines "1-14" and perpendicular gridlines, "A-G" were. These pre-existing benchmarks were the authority during the entire layout process.

We utilized two total stations to layout points on the freshly excavated and graded dirt. The total station would be set up on one benchmark and operated by one field engineer while another member of the team would be holding a target card on the back sight benchmark. A third field engineer would hold the prism down on the dirt at a 90º angle from the back sight parallel to the total station. The team member operating the total station would direct the person with the prism to move left or right to mark at least two points along that line. This process was repeated in both directions until all of the gridlines were laid out.

Once the gridlines and columns were laid out, we went back to check that the line stayed consistent from gridline "1" to "14" along gridline "D" but it turned out to be off by a small distance. By this time, gridlines had been setup and column foundation formwork had been built and put in place. At first, it was easy to panic due to a mistake we couldn't pinpoint. When you don't know the source of a mistake, it becomes very difficult to fix it. After going back and forth about possible causes of the issue, the team came up with a few possibilities:

- Too short of a back sight,
- Utilizing two different total stations to do the same work,
- Recording data when the instrument wasn't completely level.

In response to the issues that arose, we set up the Trimble to check and redo the points created with the total stations. The Trimble Optical Plummet has the ability to locate specific points on a line on the jobsite utilizing geographic points uploaded onto the Trimble mobile computer. The points uploaded correlate exactly with the actual site and gridline endpoints are clearly defined in the system. The Trimble allows you to create points in the mobile computer based on the location of the Trimble Target Prism. This advanced equipment corrected all errors previously made in a very short amount of time and saved us the headache of setting up and taking down one total station several times over.

Trimble Optical Plummet and Target Prism

Interviews

Superintendent

Have you worked on a jobsite with no self-perform work, or significantly less? How did they differ in cost and scheduling and what was your preference?

> "Yes, my last job was a non self-performing job. Cost on that job was a little different then most jobs out there. The five big subcontractors (Electrician, Plumbers, Mechanical, Fire Protection and Framers/Drywall) were CRS subs (Cost Reimbursable Sub). Essentially they were T&M paid, so they would turn in time cards and invoices and get directly reimbursed for those items. At the end, if we finished under budget and before schedule, there was a large bonus to be had. I like the self-performed jobs just because we have a lot of control of the work, which essentially affects the overall schedule and cost."

In your experience with surveying, what are the initial steps you would take to identify errors with layout? What are the steps you'd take to correct them?

> "Sometimes it is as simple as taking a step back for a second and just looking at your layout and visually verifying it. So many times we get wrapped up in our work that a curb can be laid out wrong (inside face vs. outside face) and a lot of times it can be caught visually. Another set of eyes and different piece of equipment should be utilized. A different set of eyes is simply another FE (field engineer) doing the same layout and checking to see if it's right. Different equipment could be as simple as a tape measure, steel chain, 3,4,5 triangle or a total station vs Trimble."

Field Engineer

How important do you think is it to be knowledgeable about surveying equipment (total station and level at minimum)?

> "We are still strong in the industry with self-performing our own work along with surveying/quality control of others' work. We have a great training program (Field Engineer Bootcamp) that takes FE's from all skill levels (from people that have never touched survey equipment to some that have used it for years)."

Do you feel that new hires (college graduates) know enough about surveying/layout upon being hired?

> "With the FE Bootcamp and majority of the other field staff on the jobsites that have gone through Bootcamp, the need for college courses of surveying is not required, but obviously it would be helpful."

Looking back on the layout for this particular project, how do you think things could have gone faster and more accurate?

> "The site is very tight not allowing us to get our long back sights, as we should have. We should've realized that earlier in the process and did away with the total stations and stuck to the Trimble (Robotic Total Station). Luckily we knew our MEP subs were going to utilize them on the decks for the tower so we had primary control setup for them already; it was an easy transition to a Trimble."

Conclusion

The amount of self-perform work being done in the commercial construction industry is increasing with every project. Project managers are realizing the advantages of self-performing work, such as time consistencies, cost savings, and increased control over the project flow. For that work to be done, project team members in-house must do construction surveying and layout, and it only makes sense that the field engineers at the bottom of the ladder would do that work. As college graduates, only taking BRAE 239, the agricultural surveying class already required, is not enough to prepare us for performing building layout with all of the necessary equipment knowledge. BRAE 239 offers a class that teaches us how to use the total station to set up on an existing benchmark and locate another existing benchmark in an open field. Although this does teach us basic skills as far as using the total station, the setting and goals of this class don't exactly align with what we will be expected to

do in the real world on a commercial jobsite. College students going straight to work in the construction industry should be better prepared to perform construction surveying and layout.

New Knowledge

As a result of this case study, there should be a CM class implemented at Cal Poly SLO that is focused on Construction Surveying and Layout. Although this class is underway already by Professor Paul Redden, I am suggesting that it have a specific section on identifying and correcting errors with a total station as well as including the use of a Trimble. The holdback to a Trimble Optical Plummet with the prism and mobile computer to go with it is the cost, however with our large, well known CAED Department, we should be making an effort to either raise funds for this necessary equipment, or make connections to receive a donation. After experiencing the use of such advanced equipment on a jobsite as large as the hospital building referenced in this paper, I believe it id imperative for our curriculum to invest in what it takes to stay up to date with industry standards.

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