Construction Surveying using GPS and Robotics

By: Milton Denny
Copyright Jan. 2009

What is Different About Construction Surveying?

- Increased Liability
- Starting the Project
- Dependence on Plans by Others
- Difficult Site Conditions
- Safety Considerations
- Special Contracts

Project Management

- Must Have Contracts
- Timely Collection of Accounts
- Negotiate The Right Fee
- Compare Final Product With Scope
- Monitor Every Project
- Scope “Creep”
- Use Deadlines To Control Cost
Estimating A Job

- **Loan Plats** - Minimum Technical Standards
- **Boundary Survey** -
  - Lump Sum, Cost Per Acre, Cost Per Foot, Hourly Rate
  - Per Cent of Value
- **Topographic Survey** -
  - Per Acre, Economies of Scale, Contour Interval
  - Data Collectors
- **ALTA Surveys** -
  - Increased Liability?, Flood Maps, Special Certificate

Estimating A Job

- **Hazardous Site Survey** -
  - Special Equipment, Training, High Liability, Special Survey Methods
- **Special Surveys** - Market Will Absorb
- **Items In An Estimate** -
  - Field Crew Time, Office Staff, Professional Time, Reports & Meetings, Vehicle Expenses, Rental Equipment, Per Diem, Consultants, Company Overhead

Understanding What's Important

- Perpendicular & Parallel
- Required Accuracy
- Tenths Vs. Inches
- Scheduling the Work
- Reference Points
- Permanent Bench Marks
- Checking the Equipment
- Metric in Construction
Getting Started

- Site Visit
- Project Cost Estimate
- Safety Equipment
- Special Training
- Verifying the Boundary and Topo
- OSHA – Occupational Safety and Health Act (Title 29 Labor Code Chapter XVII, Part 126)
Equipment

- Robotic Total Station
- Total Station
- Optical Plumbing Instruments
- 200 Foot Steel Tape
- Levels and Rods
- Reference Targets
- Data Collector or Laptop
- Radio or Cell Phone

Modern Total Station

- Is A Computer
- Data Collection
- Liquid Dual Axis Compensator
- Affected By Heat
- EDM Check Line
- Log Book For Each Instrument
- Diagnostic Read Out For Calibration

Robotic Total Stations

- Growing New Technology
- Does Not Need Telescope
- Allows Two People to Do Work Of Two Crews
- Steep Learning Curve
- Sent Off To Get Repaired
- Read The Factory Manual
- High Original Cost
Geodesy and GPS

- Clarke Spheroid 1866
- North American Datum of 1927 (NAD27)
- North American Vertical Datum of 1929 (NAVD29)
- GRS80 Spheroid / WGS 1984 Spheroid
- North American Datum of 1983 (NAD83)
- North American Vertical Datum of 1988 (NAVD88)
- NAD83/NSRS 2007
- NAD88/NSVRS 2009
- NSRS = National Spatial Reference System

Satellites Constellations

- Global Positioning System – GPS 24 in operation / 3 extra in reserve
- Global Navigation Satellite System/Glonass 21 satellites in 3 orbital planes / 3 spares
- European Satellite Navigation System/ Galileo 30 satellites / 3 currently in orbit
- Total of 72 satellites available by 2010
- Buy only units with 72 satellite compatibility

Ellipsoid, Geoid, and Orthometric Heights

\[ h = H + N \]

- \( h \) (Ellipsoid Height) = Distance along ellipsoid normal (Q) to P
- \( N \) (Geoid Height) = Distance along ellipsoid normal (Q to \( \gamma \))
- \( H \) (Orthometric Height) = Distance along plumb line (P to \( \gamma \))
What About Elevation?

- Leveling-Derived Orthometric Heights
- GPS-Derived Ellipsoid Heights
- Geoid Heights

Expected Accuracies

- GPS-Derived Ellipsoid Heights
  - 2 centimeters
- Geoid Heights (GEOD99)
  - 2.5 cm correlated error (randomizing at 40 km)
  - Relative differences typically less than 1 cm in 10 km
  - 4.6 cm RMS about the mean
- Leveling-Derived Heights
  - Less than 1 cm in 10 km for third-order leveling

GPS Mission Planning (daily)
Mission Planning (Continued)
- Horizon Mask
- Point Specific
- Obstruction diagram

Scope (Continued)
- Right tools for the right job
Leveling

Level Surface
A level surface, as the term is used in surveying, means an approximately spherical surface concentric with the surface of a body of still water, in other words, following the curvature of the earth. The tangent to such a surface at any point is at right angles to the direction of the force of gravity, or to a plumb-bob line. A level surface is therefore not a plane, but is curved to fit the shape of the earth.

Elevations are generally referred to sea level. When we say that a certain point has a certain elevation, we mean, unless specified to the contrary, that the point is a certain distance above sea level. Sea level usually signifies for means obtained by averaging high and low tides over at least a lunar month, and longer for precise results. In many locations there may be several level surface datums, sometimes including different so-called sea-level datums. Since many of these have been used in different leveling operations, it may be necessary to specify the datum to which any particular elevation or set of elevations is referred.

Automatic Compensator

Quick Peg Check Procedure - Step 1
Find two stationary objects (utility pole, fence, building, etc.) that are 200'-300' apart with a clear line of sight between them, in this case, the light pole and the building.
Step 2

Set up the level at the midpoint between the objects, and mark the line of sight on both objects. The mark should be permanent for later use. Hint: this instrument setup should be a foot or two below your normal setup height.

Step 3

Move the instrument to the proximity of one of the objects and set up as closely as possible to it. Make sure you can see both points from this setup.

Step 4

Have a person hold an engineer’s rule on the mark on the near object and read the rule.
Step 5

Construction Surveying
Tribrach Adjustment Procedure:

Step 1. Mount one Tribrach on tripod, with adjusting
adapter in place, in a tree under a point on
existing. This can be done under a tree limb or any
overhead structure.

Step 2. Place GIF on Tribrach on adjusting adapter in an
inverted position.

Step 3. Adjust lower Tribrach (the one attached to tripod)
until optical plummet crosses are on an
identifiable point.

Step 4. Rotate upper Tribrach (the one to be adjusted)
180 degrees. Adjust 1/2 of the cross with the
planner adjusting screws, the other 1/2 of cross
adjusted with the lower Tribrach adjusting screws,
checking in that direction.

Note: The latter adjustment screws are opposing each
other. The forward and backward adjusting screw is
going forward.

TRUE PLUMB

TEST AND
ADJUST
YOUR ROD
IN SECONDS!
Radial Stakeout

- Data Collector/Radial Stakeout
- Coordinate Files
- Point Numbers
- Two Instrument Setups
- Stake Files/Design Files
- Stakeout Analysis
- Tolerance Check
- Horizontal

Good Data Collection

Make sure batteries are charged and cables in good working order before going to the field.

On a larger project, run survey control separate from the data collection.

Always shoot the distance when taking a backsight.

When finishing your work each day leave at least two points in the area you are going to continue work the following day. Bring a print out of the data and field check the points before continuing work the next day.

Keep a secure raw data file on each day's work.

If you are working in the same area for a long period of time, establish coordinates on local radio station towers as an azimuth check.

If you are doing vertical elevations make sure you are doing the check of your vertical compensator.

In extreme hot weather conditions try to shield your data collector from the direct sun.

For best results use a prism pole that is in good condition and has had its level bubble checked. When not in use keep the prism pole in a padded case.
Good Data Collection

Have your instrument mounted on a tripod that is in good condition. A good check on your tripod is to take a site on a survey station. After tightening the clamping screws, take the tripod where the instrument is attached and twist it until the cross hairs leave the target. When your grip is released the cross hairs should return to the original point.

Building Layout

- Checking the Plans
- Exterior Building Lines
- Squaring the Building
- Checking the Diagonals
- Offsets and Batten Boards
- Column Lines and Bolt Locations
- Plumbing the Forms/Pre-fab Units
- Plumbing Structural Steel and Columns
- Multi-Story Buildings
- As Built Survey
Other Considerations

- Understanding the Superintendent
- Site Housekeeping
- Dealing with Union Conflicts
- Archaeological Preservation
- Environmental Problems
- Fast Track Projects
- Vibration-Noise-Weather
- Prevailing Wages
- Labor Recruitment
- Arbitration
- Collection of Fee

Seeing the Future: STAKELESS!

As GPS machine control makes its way onto more surveying and construction sites, who will provide the data and how?

All data is not created equal.

Does this technology benefit the contractor more than the surveyor or engineer?

Communicating between the surveyor and contractor.

Is there a place for my company in machine control construction?
All Grading Plans ARE NOT Created Equal

In soil work, a "final" grading plan is a contract document plan that shows the existing terrain that is to be built out to, or to a certain standard, the engineering plans. It shows the material that is to be removed or added to, the equipment that is to be utilized, and the time frame in which it is to be completed. The plans may also include an estimate of the cost of the work. The grading plan is a contract plan that is used by the contractor to plan and budget the work.

The grading plan is a contract plan that is used by the contractor to plan and budget the work. The grading plan is a contract plan that is used by the contractor to plan and budget the work. The grading plan is a contract plan that is used by the contractor to plan and budget the work. The grading plan is a contract plan that is used by the contractor to plan and budget the work. The grading plan is a contract plan that is used by the contractor to plan and budget the work.
The Making of the Model

Raw data reduction

Proposed DTM

Proposed DTM for design

Proposed DTM for construction

A special thanks for use of his material appearing in SitePrep Magazine to:

Michael M. Slusarski

Slusarski Excavating and Paving, Inc.

Adrian, Michigan

mms@slusarski.com
X, Y and Z data converted to pixels to form an elevation image

Thanks for the e-mail. It came at a good time as I am working on those issues to validate my construction schedule. I wanted to be sure the data is yours but the court system may hold the final answer. The issue are becoming more urgent these days. These issues are not going to go away anytime soon.

Contractors are getting more and more into tracking controls and want the surveying and engineer data. The problem is no one has control or who will see the data. You can bet if something goes wrong the contractor will be knocking on your door.

This is a huge issue you may want to hire a lawyer to write the contractor to write a letter to the contractor. Be ready it could get messy.

Milton Cherry
Keep me informed.
Practice of Engineering

Practice of engineering is the performance of services in connection with the design, development, or supervision of engineering projects or systems, for hire, that utilize and apply professional training, scientific principles, and mathematical calculations to produce a professional result. The practice of engineering is limited to those activities for which the services of a licensed professional engineer are required by law, or are needed to protect the safety, health, or welfare of the public.

The practice of engineering includes the following activities:

1. Investigation and analysis of the problem or issues.
2. Development of a solution design.
3. Preparation of drawings, specifications, and other professional services.
5. Coordination with other professionals and regulatory agencies.
6. Supervision of the construction process.
7. Preparation of reports and other documents.
8. Preparation of plans and specifications.
9. Preparation of reports and other documents.
10. Coordination with other professionals and regulatory agencies.

The practice of engineering requires a high level of education, training, experience, and continuing professional development. It also requires adherence to ethical and professional standards, as well as an understanding of the laws and regulations that govern the practice of engineering.

For the practice of engineering in the United States, it is typically performed by a licensed professional engineer (PE) who has passed the Fundamentals of Engineering (FE) exam and has achieved at least two years of relevant work experience. The practice of engineering in other countries may have different requirements, but similar principles apply.

In summary, the practice of engineering is a professional activity that requires the application of scientific principles, mathematical calculations, and professional judgment to produce a professional result. It is governed by ethical and professional standards, as well as laws and regulations that protect the safety, health, and welfare of the public.
Where does this leave the Surveyor/Engineer?

- Collection of the original data
- Design DTMs
- Site control
- Construction site inspections
- Final site surveys

Companies Designing Machine Control Files:
- API - www.apisurvey.com
- TOPS - www.takeoffpros.com
- Terrain Modeling Services - www.terrainmodeling.com

Construction Safety
- Safety Roadway
- OSHA - PL 91-5596, PL 101-552
- Employee Workplace Rights - 3021-1989
- Permit-Required Confined Space - 3138-1993
- Sling Safety - 3072-1988
- OSHA Publications & Audiovisual Programs - 202/219-4667 Fax 202/219-9266
What Is Confined Space?

Confined Spaces have the following elements:

- Limited Opening for Entry and Exit
- Unfavorable Natural Ventilation
- Not Designed for Continuous Worker Occupancy

Considerations Before Entering A Confined Space

- Trained Personnel and Advanced Preparation - This includes first aid and CPR training, and a respiratory protection program featuring equipment selection, fit test, medical certification and respiratory training
- Hazard Assessment - This includes atmospheric testing; means of entry and exit; ventilation; hidden physical hazards and hazards resulting from work being conducted

Confined Space

- Personal Protective Equipment - This includes boots, gloves, raingear, hardhats, respiratory protection, harness equipment
- Required Tools and Other Equipment - This includes low voltage lighting system, battery, and explosion proof lighting, communications system; tools, gauges, ventilation and other miscellaneous equipment
- Rescue Equipment - This includes hoisting equipment, first aid supplies, backboards, self-contained breathing apparatus SCBA and other rescue devices
**Hazardous Situation Criteria**

- Oxygen Deficient or Asphyxiating Atmosphere
- Combustible - Explosive
- Corrosive - Acidic/Caustic
- Toxic - Exposure May Lead To Immediate Or Eventual Illness

---

**Oxygen Levels**

- **Normal, Safe Oxygen Levels:** 19.5% to 21% of the air in space
- At 16%, you’ll start developing symptoms like fast breathing and heartbeat, drowsiness, and nausea
- At 12%, you’ll be unconscious
- At 6%, you’ll be **dead**

---

**Toxics**

- Carbon Monoxide - is a colorless, tasteless chemical created by internal combustion
- **Carbon Dioxide** - is a natural by-product of fermentation
- Sulfur Dioxide - is colorless, but has a heavy smell. It is toxic even in small amounts
- **Hydrogen Sulfide** - is produced in petroleum and sewage treatment and other industrial processes
Six Contractors in Texas Cited for OSHA Construction Site Hazards

Construction sites in Texas are the latest to be cited for work hazards in noise, ionizing, by the Occupational Safety and Health Administration (OSHA), according to a news release issued last week by the Department of Labor from Fort Worth.

Six contractors were cited for allegedly failing to provide adequate fall protection for workers at one apartment construction site.

"Strong enforcement is a key part of this Administration's efforts to reduce worker fatalities, injuries and illnesses," said Labor Secretary Elaine Chao. "The significant penalty of $151,200 in this case demonstrates our commitment to protecting the health and safety of American workers."

One general contractor was issued citations and proposed penalties of $91,000 for allegedly failing to ensure that workers operating high reach forklifts were trained, failing to train workers on the hazards of falls from roofs and unguarded balconies and failing to properly erect and maintain scaffolds.

Safety videos, software and resources for OSHA compliance!

Construction Safety

These videos are $99.95 each
OR
Choose Any 15 for $695.00

The End
Thank You

Milton Denny
Denny Enterprise, LLC
P O Box 2242
Tuscaloosa, AL 35403
205/553 4448
mdenny5541@aol.com