A LOOK AT NEW TECHNOLOGIES

State-of-the-art Total Stations

In the last few years, the computer revolution has brought about a different approach to engineering and construction projects. Thanks to automated processes, engineers can now produce a much higher level of detail and accuracy in their projects. These changes have significantly increased the level of responsibility within the role of land surveyor in particular. Surveyors nowadays have more data and information to handle while facing ever-increasing demands for high-quality topographic products such as construction site surveys, land ownership and utility management. One of the most important tools surveyors use is the total station which, having been used for decades merely for the storage of observations, coordinates and simple mathematical calculations, has recently evolved into a powerful, integrated field computer. This article will review the newest total station technologies for performing land surveys, and how they are being used by surveyors.

Â@

When looking back over the past fifty years of total station development, from when theodolites started to work with distance meters to the latest high-tech total stations, it is impressive to realise that the basic working principle has remained the same: measuring two angles and one distance.

Angle Measurements

Early land surveys were carried out using simple instruments that essentially consisted of an aiming sight on top of a plate that had angle readings engraved on it. The surveyor could measure the angle between two sighted points, aided by a survey helper holding a vertical pole on the point, and subsequently perform trigonometric calculations to determine plane coordinates. With the help of compasses, topographic maps could be created. The logical development was to have plates with horizontal angle readings enclosed in a metal body, whereby a vertical plate was added in order to also be able to measure the vertical angle, and an optical sight was quickly adopted in favour of the sight lines. The main survey tool was born: the theodolite.

It was only in the 1920s - the decade that also brought us highly accurate clocks and photographic cameras - that theodolites became accurate measuring tools, with the Wild T2 being one of the best-known of this generation.

Although it is possible to calculate coordinates using angle measurements only, it is much easier if you measure the distance to the sight point. So with only mechanical means at their disposal, early surveyors measured distances using known-length cables of usually approximately 20 metres. The cables were set out repeatedly from the station point to the sight point, the number of cable positions was counted and the total distance calculated. Setting out the cable repeatedly through rough terrain was a daunting task, and on slope terrains the situation was considerably worse: measuring a few kilometres could take several days or even weeks.

Distance Measurements

Once radio waves had been utilised as a means of communication, it did not take long for them to be used to measure distances too. The principle was based on transmitting a radio beam signal which would reflect on a reflector surface and return back to the instrument. By comparing wavelength phases at different frequencies over time, a distance could be calculated. Such instruments were called distance meters.

Early distance meters, such as the well-known Rangemaster III, became the main tools for calculating geodetic networks. They were oversized and heavy, and would be unsuitable for land surveys nowadays. Refinements resulted in the distance meter becoming small enough to be portable, and then ultimately to being attached to a theodolite. Surveyors could now not only measure two angles to the sight point (horizontal and vertical), but also measure the distance with a coupled distance meter.

Total Station

By the 1980s, digital technology had introduced simple calculators to the general public, allowing surveyors an easier calculation and record of angular measurements in the field. Not long after, the field calculator and the distance meter were integrated in the theodolite itself, thus becoming a ‘total station' - a device that was able to perform all necessary measurements (total) by using different techniques in one single device (station).

Servo and Automatic Stations

One significant upgrade implemented by manufacturers of total stations in recent years has been the addition of mechanical motors allowing motorised angle movements both in the vertical and horizontal axis. Such total stations are called servo stations and, while not especially beneficial in common surveys, they are particularly useful when staking out coordinates.

Whereas, in common surveys, the assistant places the reflector prism on the point and the surveyor then has to manually move the axis to aim the sight at the prism, the opposite situation occurs when staking out coordinates. This makes the servo station very useful in such a scenario, since it will rotate itself to the correct aim for the coordinates.

When a servo station is able to recognise a reflector prism, it is called an Automatic station. Some manufacturers use different names for this technique: Trimble calls it Autolock, for instance, while Leica refers to it as Automatic Target Recognition. In order to recognise a reflector prism, total station s have to be capable of detecting the position of the target, using either radio waves or imaging technologies.

Using radio technology, the station's distance meter emits a signal that is very weak yet strong enough to reflect the prism signal. If the station receives the signal back, it means that the prism is within the distance meter's sight area. The closer it gets to the centre of the sight area, the stronger the reflected signal is.

Once the target has been recognised, the station can then automatically use the axis motors to move around and find the angles that pinpoint where the target is located. The advantage is that as the prism moves, the station detects that movement (the reflected signal offset from centre) and it moves the sight to follow the prism. Since the surveyor does not need to manually aim at the target, it considerably speeds up point recording, which represents a significant benefit in survey situations.

Robotic Stations

In the case of a servo station, the surveyor is only using the onboard controller rather than the station's optical controls. When an external controller is added which is identical to the onboard controller but instead communicates with the station via radio link, it becomes possible to cut the physical connection between the controller and the servo station. Since such a station will operate without a manual interface, it is known as a robotic station. The major benefit is that surveys can be performed by just one person, eliminating the need for the common two-person team.

While the axis motors previously comprised mechanical geared motors, the latest total stations use stepless magnetic motors that provide near-silent operation and very fast angular speeds. Current developments are in progress to speed up the prism search, which can be affected by obstacles and other reflecting surfaces.

Monitoring stations

The capability of automated total stations to feature motorised axis movements combined with the development of monitoring software led to an innovative geotechnology concept: monitoring stations. When designing a construction project, it is essential to include the need for periodic position controls. Every year, losses are caused by landslides, rock falls and structural failures. In applications such as the construction of bridges, tunnels, mines, high-rise buildings and dams, it is crucial to monitor positional changes over time, observing any

small movements and emitting early warnings to alert one to the potential danger of structural failure.

Monitoring stations systematically survey the control points located on a monitored structure, without the need of an operator. The effective monitoring of projects involves statistical analysis of several epochs of observations of the control points to millimetre-level accuracy. Manufacturers such as Leica, Sokkia, Trimble and Topcon offer total stations designed specifically with the requirements of survey monitoring in mind, namely:

- very high angular accuracy, usually 1" or better

- very high distance accuracy, usually 1mm + 1ppm or better

- servo-equipped, with software that allows for repeated measurements of control points at a set interval

- highly accurate prism finder

- ability to receive external power, allowing the station to operate 24/7

- ability to communicate the measurements to a remote computer, allowing the station to function in remote locations without the need of an operator.

Imaging Stations

The availability of affordable and high-quality photographic cameras in the last few years has contributed to the development of total stations with integrated imaging capabilities. Such total stations have coaxial digital camera sensors built into the telescope. While the compact camera continues to be the surveyor's best friend when the need arises for documenting the site, the total station with onboard camera has opened up new possibilities; it has proven to be very useful in taking quick notes, for instance. After measuring a point, the surveyor can immediately take a photo, write a note on the touchscreen and save it. The photo is automatically referenced to the station point and measured point. Even more interesting is the possibility to create ortho-rectified images by taking several photos in horizontal/vertical directions and combining them to form one single image of the surveyed object. If the same object is surveyed using grid-scanning, it is bot only possible to get a set of ortho-rectified images that cover the measured object, but also a detailed 3D CAD model.

The photo capability has also proven to be very useful in robotic surveying, as the total station can lose lock on the reflector target due to moving obstacles. By using the remote controller, the surveyor can check the images from the total station and manually realign it. Some stations even feature video capture. Manufacturers such as Trimble, Leica and Topcon are currently offering total stations using imaging solutions.

Grid Scanning

The very latest total stations offer several functionalities that benefit standard surveying, but the two most significant improvements to the quality of land surveys have been grid scanning and GPS-robotic integrated surveying.

The servo total station combined with a reflector-less distance meter brought a new concept to surveyors: grid scanning. If the total station can move by itself and does not need a reflector target, then the surveyor can programme the station to measure points by specifying a view window area and setting the horizontal and vertical intervals of the points to be measured. This functionality is commonly known as grid scanning. Rather than needing to aim at each individual point, the surveyor only needs to decide the optimum point interval (grid interval) in order to represent the object with sufficient accuracy. Naturally, the higher the number of points, the longer the survey takes. The technology is proving so useful that we are now seeing total stations that have been built with grid scanning in mind, usually with imaging capabilities as well.

These latest total stations can achieve exceptional measuring speeds of several points per second, allowing the surveyor to set much smaller grid intervals for a more detailed survey. There is, however, still a big gap between grid scanning in total stations and laser scanners. While a total station measures at a rate of max. 20 pts/sec, a laser scanner can perform at up to 500,000 pts/sec!

Integrated GPS

The use of GPS has become so widespread in land surveying these days that it is common for a survey team to carry both a total station and a GPS unit with them. In recent years, the first total stations have become available that can integrate conventional robotic surveying with GPS. In this case, a GPS unit is mounted above the reflector prism in addition to the remote controller operating the total station. Since both operate on the same software, the surveyor can now opt to measure points either using the total station or using the GPS, which offers enormous advantages on sites with poor or inconsistent GPS coverage (e.g. because of the proximity of buildings or trees). This setup combines the best of both worlds: on open sites, the surveyor can measure using the GPS in order to take advantage of its superior speed in collecting points and without needing to struggle to keep the total station in the line of sight. When moving into covered areas where the GPS fails, the surveyor can simply transfer control to the total station and continue measuring points from where the GPS

stopped, barely slowing down in the process. Providing the surveyor carefully positions the total station so that it can sight the area where the GPS will have insufficient coverage, such complex surveys can be carried out with improved efficiency.

Software and Data Management

Ever since the first total stations were built, they have had onboard controllers; these were specifically designed firmwares for each station that allowed the management of measurements and user interfaces. The controllers had sufficient internal memory to store several thousand point measurements and could perform standard survey methods (set station point, resection, etc.).

In the past decade, the PDA (Personal Data Assistant) has evolved from a small, severely limited computer into a sophisticated machine capable of running countless applications, and the ‘smartphone' has gained widespread acceptance and popularity on the mobile phone market.

In this same period, manufacturers have started to offer total stations in which the standard onboard controller has been replaced by a mobile device unit. These are based on the same technology as PDAs and also run an independent operating system, with the total station being controlled by a software application running in the controller's operating system. Since controllers now have the same standards as computers, they can use the same technologies such as Bluetooth, USB, GSM and wireless, which offers tremendous benefits. With these stations, surveyors can now connect the total station to a computer without needing special software, for instance; they can save their job on a pen-drive that connects directly to the station's USB port, or they can use a Bluetooth-enabled mobile phone to send an e-mail with the job attached. Through the adoption of such hardware standards, the surveyor has also gained access to almost limitless memory capacity: a 1GB controller can store literally millions of point measurements. The software application that controls the total station also offers total data management in a Windows-style interface that allows the surveyor to analyse the job being done at any time, even while out in the field.
