

5.1 Total Station:

Basic Principle

Although taping and theodolites are used regularly on site - total stations are also used extensively in surveying, civil engineering and construction because they can measure both distances and angles.

A typical total station is shown in the figure below



Fig 3.1 Total Station

(https://www.brainkart.com/article/Total-Station--Basic-Principle_4649/)

Because the instrument combines both angle and distance measurement in the same unit, it is known as an integrated total station which can measure horizontal and vertical angles as well as slope distances. Using the vertical angle, the total station can calculate the horizontal and vertical distance components of the measured slope distance.

As well as basic functions, total stations are able to perform a number of different

survey tasks and associated calculations and can store large amounts of data. As with the electronic theodolite, all the functions of a total station are controlled by its microprocessor, which is accessed through a keyboard and display. To use the total station, it is set over one end of the line to be measured and some reflector is positioned at the other end such that the line of sight between the instrument and the reflector is unobstructed (as seen in the figure below).

- The reflector is a prism attached to a detail pole
- The telescope is aligned and pointed at the prism
- The measuring sequence is initiated and a signal is sent to the reflector and a part of this signal is returned to the total station
- This signal is then analysed to calculate the slope distance together with the horizontal and vertical angles.
- Total stations can also be used without reflectors and the telescope is pointed at the point that needs to be measured
- Some instruments have motorized drivers and can be used with automatic target recognition to search and lock into a prism - this is a fully automated process and does not require an operator.

Some total stations can be controlled from the detail pole, enabling surveys to be conducted by one person.



Measuring with a total station



Robotic total station

Fig 3.2 Measuring with a Total Station

(https://www.brainkart.com/article/Total-Station--Basic-Principle_4649/)

Most total stations have a distance measuring range of up to a few kilometers, when using a prism, and a range of at least 100m in reflector less mode and an accuracy of 2-3mm at short ranges, which will decrease to about 4-5mm at 1km.

Although angles and distances can be measured and used separately, the most common applications for total stations occur when these are combined to define position in control surveys.

As well as the total station, site surveying is increasingly being carried out using GPS equipment. Some predictions have been made that this trend will continue, and in the long run GPS methods may replace other methods.

Although the use of GPS is increasing, total stations are one of the predominant instruments used on site for surveying and will be for some time. Developments in both technologies will find a point where devices can be made that complement both methods.

CLASSIFICATION OF TOTAL STATIONS

1. Electro- Optical System
2. Distance Measurement

When a distance is measured with a total station, an electromagnetic wave or pulse is used for the measurement - this is propagated through the atmosphere from the instrument to reflector or target and back during the measurement.

Distances are measured using two methods:

- ➔ the phase shift method, and
- ➔ the pulsed laser method.

This technique uses continuous electromagnetic waves for distance measurement

although these are complex in nature, electromagnetic waves can be represented in their simplest form as periodic waves.

The wave completes a cycle when moving between identical points on the wave and the number of times in one second the wave completes the cycle is called the frequency of the wave. The speed of the wave is then used to estimate the distance.

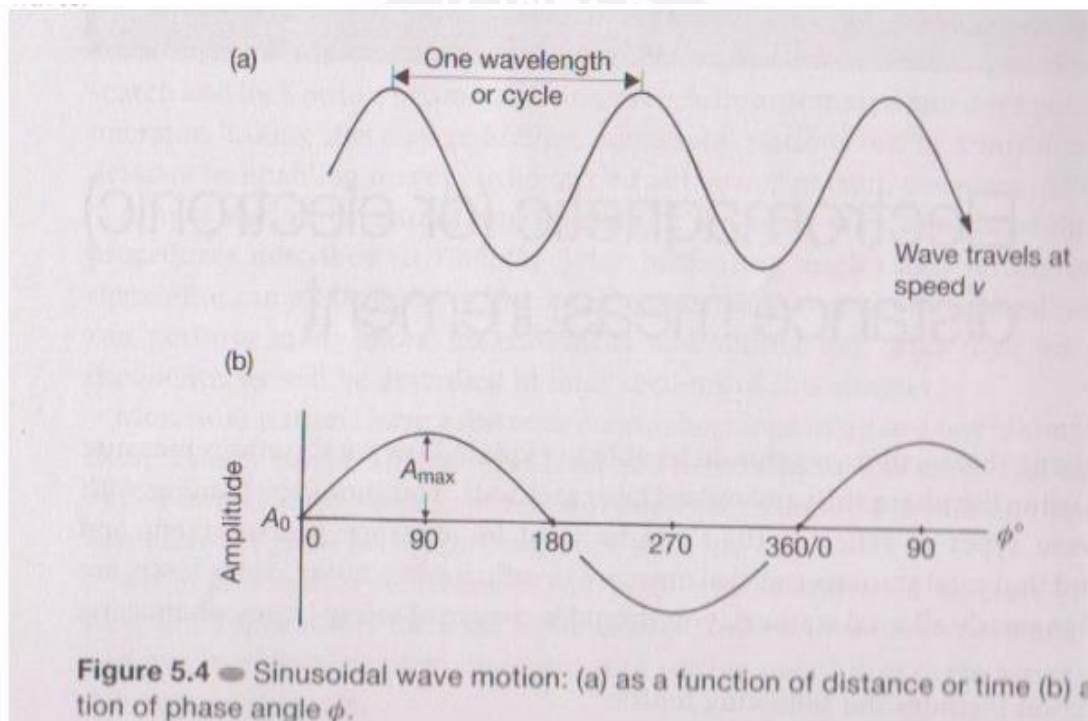


Fig 3.3 Sinusoidal wave motion

(https://www.brainkart.com/article/Classification-of-Total-Stations_4650/)

2 Laser Distance Measurement

In many total stations, distances are obtained by measuring the time taken for a pulse of laser radiation to travel from the instrument to a prism (or target) and back. As in the phase shift method, the pulses are derived from an infrared or visible laser diode and they are

transmitted through the telescope towards the remote end of the distance being measured, where they are reflected and returned to the instrument.

Since the velocity v of the pulses can be accurately determined, the distance D can be obtained using $2D = vt$, where t is the time taken for a single pulse to travel from instrument - target - instrument. This is also known as the timed-pulse or time-of-flight measurement technique. The *transit time* t is measured using electronic signal processing techniques. Although only a single pulse is necessary to obtain a distance, the accuracy obtained would be poor. To improve this, a large number of pulses (typically 20,000 every second) are analysed during each measurement to give a more accurate distance.

The pulse laser method is a much simpler approach to distance measurement than the phase shift method, which was originally developed about 50 years ago.

Slope and Horizontal Distances

Both the phase shift and pulsed laser methods will measure a slope distance L from the total station along the line of sight to a reflector or target. For most surveys the horizontal distance D is required as well as the vertical component V of the slope distance.

$$\text{Horizontal distance } D = L \cos \Theta = L \sin z$$

$$\text{Vertical distance } = V = L \sin \Theta = L \cos z$$

Where Θ is the vertical angle and

z is the is the zenith angle.

As far as the user is concerned, these calculations are seldom done because the total station will either display D and V automatically or will display L first and then D and V after pressing buttons

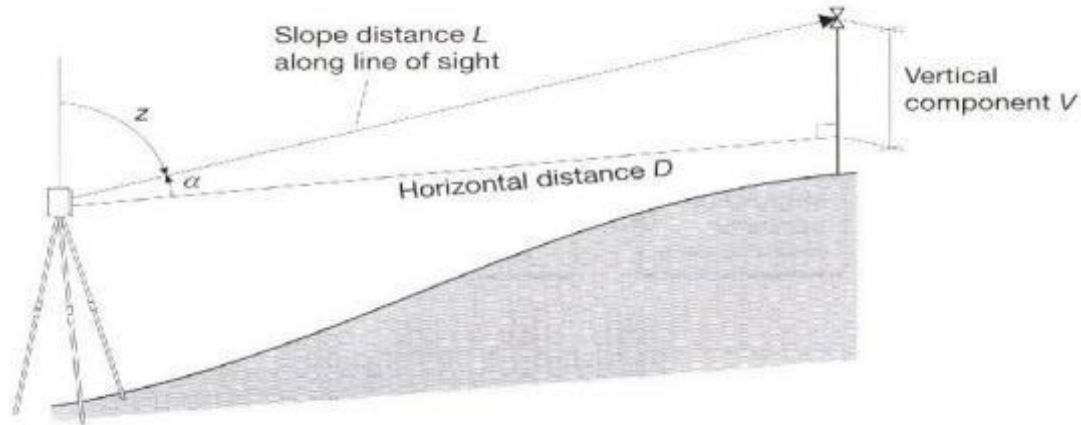


Fig 3.4 Slope and Distance Measured

(https://www.brainkart.com/article/Classification-of-Total-Stations_4650/)

How accuracy of distance measurement is specified All total stations have a linear accuracy quoted in the form (a mm + b ppm) The constant a is independent of the length being measured and is made up of internal sources within the instrument that are normally beyond the control of the user. It is an estimate of the individual errors caused by such phenomena as unwanted phase shifts in electronic components, errors in phase and transit time measurements.

The systematic error b is proportional to the distance being measured, where 1 ppm (part per million) is equivalent to an additional error of 1mm for every kilometer measured. Typical specifications for a total station vary from (2mm + 2ppm) to (5mm+ 5 p.m.).

For example:

(2mm + 2ppm), at 100m the error in distance measurement will be 2mm but at 1.5km, the error will be (2mm + [2mm/km * 1.5km]) = 5m m

Reflectors used in distance measurement

Since the waves or pulses transmitted by a total station are either visible or infrared,

a plane mirror could be used to reflect them. This would require a very accurate alignment of the mirror, because the transmitted wave or pulses have a narrow spread. To get around this problem special mirror prisms are used as shown below.

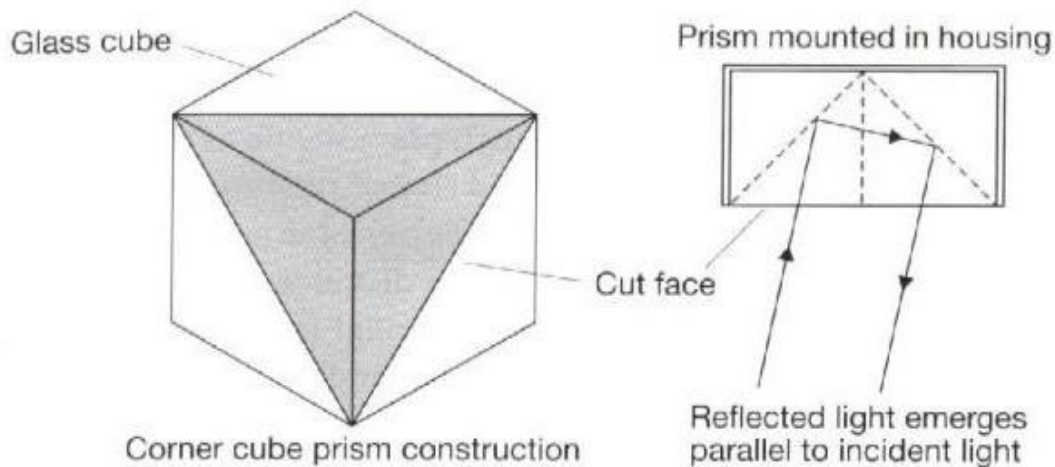


Fig 3.5 Reflector used in total station

(https://www.brainkart.com/article/Classification-of-Total-Stations_4651/)

Features Of Total Stations

Total stations are capable of measuring angles and distances simultaneously and combine an electronic theodolite with a distance measuring system and a microprocessor.

Angle Measurement

All the components of the electronic theodolite described in the previous lectures are found total stations. The axis configuration is identical and comprises the vertical axis, the tilting axis and line of sight (or collimation). The other components include the tribatch with levelling foot screws, the keyboard with display and the telescope which is mounted on the standards and which rotates around the tilting axis.

Levelling is carried out in the same way as for a theodolite by adjusting to centralize a plate level or electronic bubble. The telescope can be transited and used in the face left (or face I) and face right (or face II) positions. Horizontal rotation of the total station about the vertical axis is controlled by a horizontal clamp and tangent screw and rotation of the telescope about the tilting axis. The total station is used to measure angles in the same way as the electronic theodolite.

Distance measurement

All total stations will measure a slope distance which the onboard computer uses, together with the zenith angle recorded by the line of sight to calculate the horizontal distance. For distances taken to a prism or reflecting foil, the most accurate is precise measurement.

For phase shift system, a typical specification for this is a measurement time of about 1-2s, an accuracy of $(2\text{mm} + 2\text{ppm})$ and a range of 3-5km to a single prism.

Although all manufacturers quote ranges of several kilometers to a single prism. For those construction projects where, long distances are required to be measured, GPS methods are used in preference to total stations. There is no standard difference at which the change from one to the other occurs, as this will depend on a number of factors, including the accuracy required and the site topography.

Rapid measurement reduces the measurement time to a prism to between 0.5 and 1's for both phase shift and pulsed systems, but the accuracy for both may degrade slightly.

Tracking measurements are taken extensively when setting out or for machine control, since readings are updated very quickly and vary in response to movements of the prism

which is usually pole-mounted. In this mode, the distance measurement is repeated automatically at intervals of less than 0.5s. For reflector less measurements taken with a phase shift system, the range that can be obtained is about 100m, with a similar accuracy to that obtained when using a prism or foil.

KEYBOARD AND DISPLAY

A total station is activated through its control panel, which consists of a keyboard and multiple line LCD. A number of instruments have two control panels, one on each face, which makes them easier to use. In addition to controlling the total station, the keyboard is often used to code data generated by the instrument - this code will be used to identify the object being measured.

On some total stations it is possible to detach the keyboard and interchange them with other total stations and with GPS receivers. This is called integrated surveying.



Fig 3.6 Key Board and Display

(https://www.brainkart.com/article/Classification-of-Total-Stations_4652/)

Software Applications

The microprocessor built into the total station is a small computer and its main function is controlling the measurement of angles and distances. The LCD screen guides the operator

while taking these measurements. The built in computer can be used for the operator to carry out calibration checks on the instrument.

The software applications available on many total stations include the following:
Slope corrections and reduced levels
Horizontal circle orientation
Coordinate Measurement
Traverse Measurements
Resection (or free stationing)
Missing line measurement
Remote elevation measurement areas
Setting out.

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Sources Of Error For Total Stations

Calibration Of Total Stations

To maintain the high level of accuracy offered by modern total stations, there is now

much more emphasis on monitoring instrumental errors, and with this in mind, some construction sites require all instruments to be checked on a regular basis using procedures outlined in the quality manuals.

Some instrumental errors are eliminated by observing on two faces of the total station and averaging, but because one face measurements are the preferred method on site, it is important to determine the magnitude of instrumental errors and correct for them.

For total stations, instrumental errors are measured and corrected using electronic calibration procedures that are carried out at any time and can be applied to the instrument on site. These are preferred to the mechanical adjustments that used to be done in labs by technician.

Since calibration parameters can change because of mechanical shock, temperature changes and rough handling of what is a high-precision instrument, an electronic calibration should be carried out on a total station as follows:

Before using the instrument for the first time After long storage periods. After rough or long transportation After long periods of work. Following big changes in temperature Regularly for precision surveys. Before each calibration, it is essential to allow the total station enough to reach the ambient temperature.

Horizontal Collimation (Or Line Of Sight Error)

This axial error is caused when the line of sight is not perpendicular to the tilting axis. It affects all horizontal circle readings and increases with steep sightings, but this is eliminated by observing on two faces. For single face measurements, an on-board calibration function is used to determine c , the deviation between the actual line of sight and a line perpendicular to the tilting axis. A correction is then applied automatically for this to all

horizontal circle readings

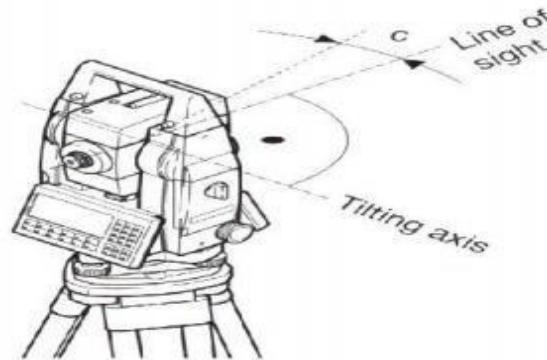


Fig 3.7 Line of Sight error

(https://www.brainkart.com/article/Sources-of-Error-for-Total-Stations_4653/)

Tilting Axis Error

This axial errors occur when the tilting axis of the total station is not perpendicular to its vertical axis. This has no effect on sightings taken when the telescope is horizontal, but introduces errors into horizontal circle readings when the telescope is tilted, especially for steep sightings. As with horizontal collimation error, this error is eliminated by two face measurements, or the tilting axis error a is measured in a calibration procedure and a correction applied for this to all horizontal circle readings - as before if a is too big, the instrument should be returned to the manufacture

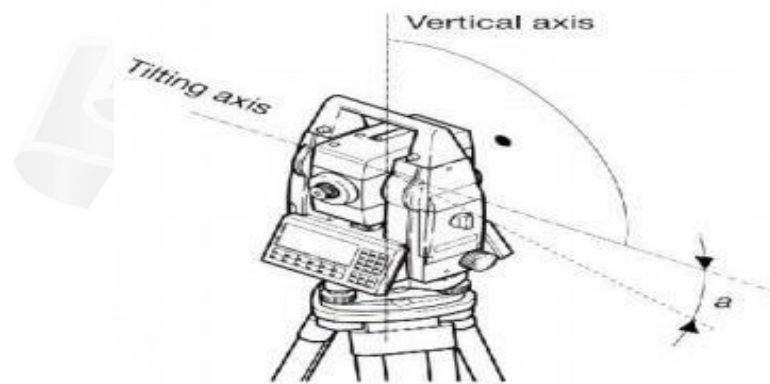


Fig tilting axis error

(https://www.brainkart.com/article/Sources-of-Error-for-Total-Stations_4653/)

Compensator Index Error

Errors caused by not levelling a theodolite or total station carefully cannot be eliminated by taking face left and face right readings. If the total station is fitted with a compensator it will measure residual tilts of the instrument and will apply corrections to the horizontal and vertical angles for these.

However, all compensators will have a longitudinal error l and traverse error t known as zero-point errors. These are averaged using face left and face right readings but for single face readings must be determined by the calibration function of the total station.

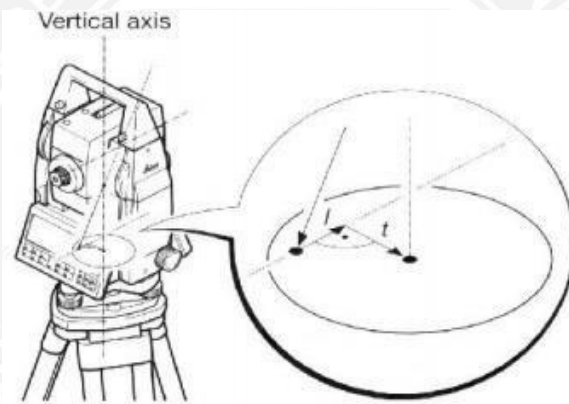


Fig 3.8 Compensator Index Error

(https://www.brainkart.com/article/Sources-of-Error-for-Total-Stations_4653/)

A vertical collimation error exists on a total station if the 0° to 180° line in the vertical circle does not coincide with its vertical axis. This zero-point error is present in all vertical circle readings and like the horizontal collimation error, it is eliminated by taking FL and FR readings or by determining i

For all of the above total station errors (horizontal and vertical collimation, tilting axis and compensator) the total station is calibrated using an in-built function. Here the function is activated and a measurement to a target is taken as shown below. Following the first

measurement the total station and the telescope are each rotated through 180° and the reading is repeated.

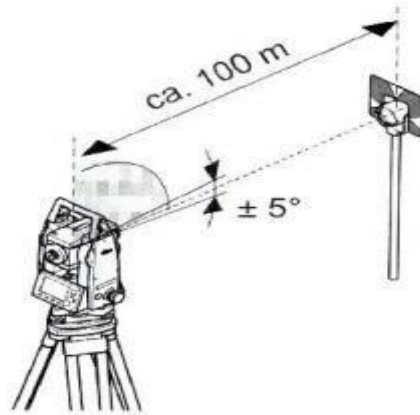


Fig 3.9 Compensator Index Error

(https://www.brainkart.com/article/Sources-of-Error-for-Total-Stations_4653/)

Any difference between the measured horizontal and vertical angles is then quantified as an instrumental error and applied to all subsequent readings automatically. The total station is thus calibrated and the procedure is the same for all of the above error type.

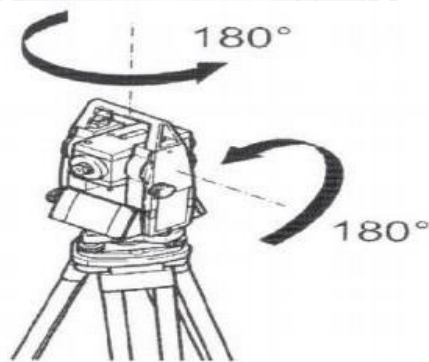


Fig 3.9 Compensator Index Error

(https://www.brainkart.com/article/Sources-of-Error-for-Total-Stations_4653/)