Guided Tour

CHAPTER 7 **Theodolites and total stations**

In this chapter you will learn about:

- the component parts of a theodolite
- the categories of instruments
- the procedure to measure horizontal and vertical angles
- the possible sources of error and how to minimise them
- the component parts of a total station
- the principles of electronic distance measurement (EDM)
- the factors affecting the accuracy of measurement
- the categories of total station instruments and their features
- the common applications of total stations.

In the succeeding chapters of this book, the topics of traversing, radial positioning and setting out will be considered in detail. In these topics, it is essential that the surveyor has a sound knowledge of the instruments and methods used in the measurement of horizontal and vertical angles.

For two centuries the theodolite has been the workhorse of the surveyor for the measurement of horizontal angles. In 1791 Jesse(sic) 24 inch brass circle transit theodolite was used for the first national triangulation network in the UK. Sadly, British manufacturers such as Watts and Cooke Troughton and Simms had closed down by the 1960s. In Europe the first optical theodolite using a glass circle was developed by Heinrich Wild in Switzerland in the 1920s. Manufacturers such as Wild and Kern in Switzerland and Zeiss in Germany dominated the market.

In the late 1950s a South African company developed the first electronic distance measuring (EDM) with the Tellurometer, which used microwaves. This was followed in the 1960s by the Swedish company AGA, which developed the Geodimeter, the first EDM to use light waves. These were very bulky instruments which were powered by car batteries. Most compact EDM units using light waves were introduced which attached on top of the theodolite. Topcon developed the EDM unit integrated within the telescope.

Electronic theodolites were developed in the late 1970s by Kern and Wild.

Today Leica, which absorbed Wild and Kern, and Trimble, a US company, which has incorporated Geodimeter, dominate the high-end market. Japanese manufacturers, who originally offered low-cost solutions, are catching up and companies such as Topcon and Sokkia offer increasingly sophisticated total stations as well as optical and electronic theodolites. No doubt Chinese companies will eventually appear on the European market.

THEODOLITES

1. Classification

A theodolite is generally classified according to the method used to read the circles. There are two methods commonly in use today:

(a) optical micrometer;
(b) opto-electronic.

Figure 7.1 shows some examples of these two types of instrument.

Both systems are based on a graduated glass protractor.

(a) In optical micrometer instruments the circle is graduated clockwise from 0° to 360°. It is read by projecting daylight reflected by a mirror internally through the glass scale via a system of prisms and lenses to a reading telescope.

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Learning Objectives

Each chapter opens with a set of learning objectives, summarising what readers should learn from each chapter.

Figures and Tables

Each chapter provides a number of detailed and practical figures and tables to help you to visualise the various methods and to illustrate and summarise important concepts.

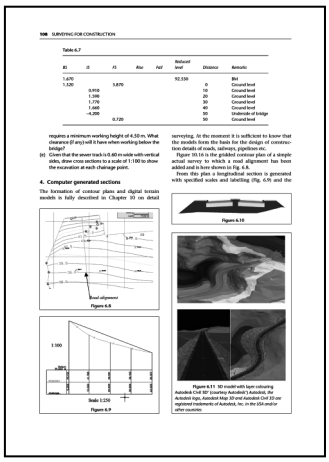

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Table 6.7

B1	*i1*	*F1*	*Rise*	*Fall*	*Reduced level*	*Distance*	*Remarks*
1.670					92.550		*Bm*
1.520		1.870				0	Ground level
	0.910					10	Ground level
	1.390					20	Ground level
	1.770					30	Ground level
	1.660					40	Ground level
	–4.200					50	Underside of bridge
		0.720				50	Ground level

requires a minimum working height of 4.50 m. What clearance (if any) will it have when working below the bridge?

(e) Given that the sewer track is 8.00 m wide with vertical sides, draw cross sections to a scale of 1:100 to show the excavation at each chainage point.

4. Computer generated sections

The formation of contour plans and digital terrain models is fully described in Chapter 10 on detail surveying. At the moment it is sufficient to know that the models form the basis for the design of construction details of roads, railways, pipelines etc.

Figure 10.16 is the gridded contour plan of a simple actual survey to which a road alignment has been added and is here shown in Fig. 6.8.

From this plan a longitudinal section is generated with specified scales and labelling (Fig. 6.9) and the

Figure 6.10

Figure 6.8

Figure 6.9

Figure 6.11 3D model with layer colouring Autodesk Civil 3D® (courtesy Autodesk). Autodesk, the Autodesk logo, Autodesk Map 3D and Autodesk Civil 3D are registered trademarks of Autodesk, Inc. in the USA and/or other countries

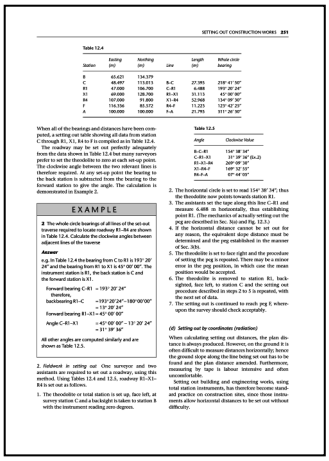

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Table 12.4

Station	*Easting (m)*	*Northing (m)*	*Line*	*Length (m)*	*Whole circle bearing*
B	45.421	134.379			
C	46.497	115.013	B–C	27.395	239° 41' 30"
R1	47.000	106.700	C–R1	6.088	195° 20' 24"
X1	49.000	126.700	R1–X1	31.113	45° 00' 00"
R4	102.000	81.000	X1–R4	72.929	129° 37' 30"
F	156.350	85.370	R4–F	71.225	127° 02' 37"
A	100.000	100.000	F–A	21.795	317° 20' 00"

When all of the bearings and distances have been computed, a setting out table showing all data from station to station (Table 12.4) is prepared for the site.

The roadway may be set out perfectly adequately from the data shown in Table 12.4 but many surveyors prefer to set the theodolite to zero at each set-up point. The clockwise angle between the two relevant lines is therefore required. At any set-up point the bearing to the back station is subtracted from the bearing to the forward station to give the angle. The calculation is demonstrated in Example 2.

EXAMPLE

2 The whole circle bearings of all lines of the set-out traverse required to locate roadway R1–R4 are shown in Table 12.4. Calculate the clockwise angles between adjacent lines of the traverse

Answer

e.g. in Table 12.4 the bearing from C to R1 is 195° 20' 24" and the bearing from R1 to X1 is 45° 00' 00". The instrument station is R1, the back station is C and the forward station is X1.

Forward bearing C–R1 = 195° 20' 24"
subtracting
backbearing R1–C = +195° 20' 24" – 180° 00' 00"
= 15° 20' 24"
Forward bearing R1–X1 = 45° 00' 00"
Angle C–R1–X1 = 45° 00' 00" – 15° 20' 24"
= 31° 39' 36"

All other angles are computed similarly and are shown as Table 12.5.

Table 12.5

Angle	*Clockwise Value*
B–C–R1	154° 38' 54"
C–R1–X1	31° 39' 36" (Ex.2)
R1–X1–R4	269° 09' 38"
X1–R4–F	52° 34' 07"
R4–F–A	189° 42' 23"

2. *Fieldwork in setting out* One surveyor and two assistants are required to set out a roadway, using this data (Table 12.4 and 12.5, roadway R1–X1–R4 is set out as follows:

1. The theodolite or total station is set up, face left, at survey station C and a backsight is taken to station B with the instrument reading zero degrees.
2. The horizontal circle is set to read 154° 38' 54"; then the theodolite now points towards station R1.
3. The assistants set the tape along this line C–R1 and measure 6.088 m horizontally, thus establishing point R1. (The mechanics of actually setting out the peg are described in Sec. 3(a) and Fig. 12.3.)
4. If the horizontal distance cannot be set out for any reason, the equivalent slope distance must be determined and the peg established in the manner of Sec. 3(b).
5. The theodolite is set to face right and the procedure of setting the peg is repeated. There may be a minor error in the peg position, in which case the mean position would be accepted.
6. The theodolite is removed to station R1, backsighted, face left, to station C and the setting out procedure described in steps 2 to 5 is repeated, with the next set of data.
7. The setting out is continued to reach peg F, whereupon the survey should check acceptably.

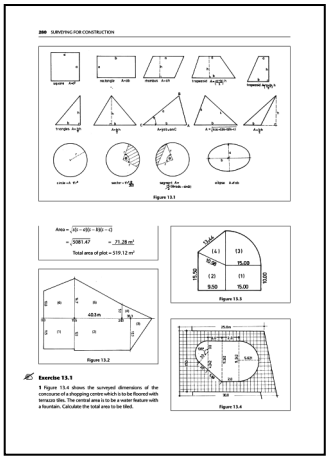
(ii) Setting-out by coordinates (radiation)

When calculating setting out distances, the plan distance is always produced. However, on the ground it is often difficult to measure distances horizontally; hence the ground slope along the line being set out has to be found and the plan distance amended. Furthermore, measuring by tape is labour intensive and often uncomfortable.

Setting out building and engineering works, using total station instruments, has therefore become standard practice on construction sites, since those instruments allow horizontal distances to be set out without difficulty.

Examples

Throughout the book these short examples give you opportunities to test your learning of the section material.

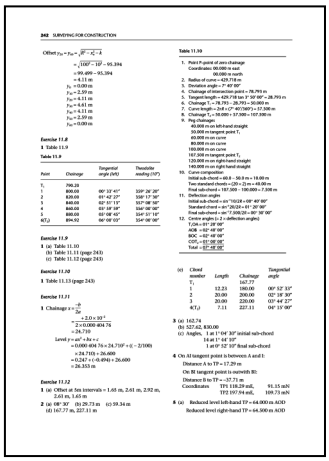


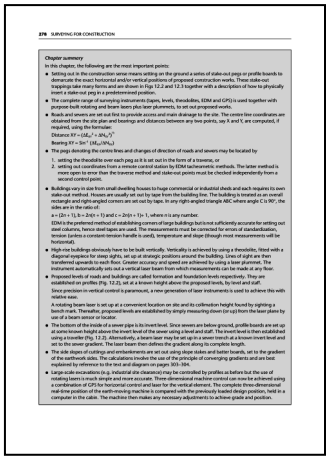
Exercises

The exercises interspersed throughout the chapter material provide a more in-depth chance to practice your understanding of surveying methodology and computation, and to understand real-world surveying practice.

Answers

The answers to the exercises are provided at the end of each chapter.





Chapter summary

This briefly reviews and reinforces the main topics you will have covered in each chapter to ensure you have acquired a solid understanding of the key topics.